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DAB
Disaster and Biodiversity

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Contents

Preface 2

Hiroyuki Takeda, IUBS President

1. Aims, Scopes and Results 3

Harufumi Nishida

The Influence of Disasters on Biodiversity

Chapter editors: Jun Yokoyama, Kaiyun Guan, Steven J. Wagstaff

2. Disaster and Biodiversity (DAB): Definition and Challenge 8

Kunio Iwatsuki

3. Natural disasters and biodiversity: a review of various types of disaster and their effects on biodiversity 17

Jun Yokoyama

4. Disaster and biodiversity in China 30

Kaiyun Guan

5. Disasters and biodiversity in the Ring of Fire of the Indonesian archipelago 39

Dedy Darnaedi and Iskandar Zulkarnaen

6. Disaster and biodiversity in New Zealand: review and considerations 46

Steven J. Wagstaff

7. Disaster-induced changes in coastal wetlands and soft-bottom habitats: an overview of the impacts of the 2011 tsunami and Great East Japan Earthquake 62

Gen Kanaya, Takao Suzuki, Kyoko Kinoshita, Masatoshi Matsumasa, Katsumasa Yamada, Koji Seike, Kenji Okoshi, Osamu Miura, Shizuko Nakai, Waka Sato-Okoeshi, and Eisuke Kikuchi

8. Impact of the 2011 Tohoku Earthquake Tsunami on marine and coastal organisms 81

Osamu Miura and Gen Kanaya

Natural history collections, their importance and conservation

Chapter Editors: Suzuki Mahoro, Masahiro Ohara, Paul Callomon

9. Museum specimens and their meanings 94

Paul Callomon

10. Why natural history specimens were ‘rescued’ 104

Makoto Manabe, Suzuki Mahoro, Martin J. Janal, and Masaru Kumagai

11. Salvage of natural history collections after natural disasters 108

Martin J. Janal
12. Salvage and restoration of natural history collections damaged by the 2011 tsunami in Japan
   *Suzuki Mahoro and Makoto Manabe*

13. How should we prepare for the next disaster? The present situation of Japanese biodiversity heritage in museums, with strategies for Conservation
   *Daisuke Sakuma*

14. Disaster preparedness and response: best practices, training, and networking to protect natural heritage collections in North America
   *Mariko Kageyama*

**Reconstruction Activity and Biodiversity**

*Chapter Editors: Satoquo Seino, Furuta Naoya*

15. Ecosystem-based disaster risk reduction: a review of recent progress and remaining gaps
   *Furuta Naoya*

16. “Living with the Sea” – The Folklore of Adaptive Reconstruction
   *Hajime Chiba*

17. Huge sea wall construction after the Great East Japan Earthquake and Tsunami: Conflicts and lessons learned (article in preparation)
   *Satoquo Seino*

**Appendix**

478 Days of Challenge – our proposal for a new Disaster Prevention Park in Gamou
*Yu Natori, and Susumu Ogawa*
Preface

Disaster and Biodiversity (DAB, 2013-2016) was one of six scientific programmes directly supported by IUBS, the International Union of Biological Sciences. IUBS is a non-governmental, non-profit organization, established in 1919, consisting of more than 30 countries and 80 academic societies all over the world. IUBS functions as an umbrella for biologists by promoting interdisciplinary cooperation and meetings on global issues such as the effect of global warming on biodiversity and ecology and also by assisting young scientist to attend related international meetings, particularly those who come from developing countries.

The 2011 Great East Japan Earthquake caused a tsunami and nuclear accident that heavily damaged local communities and the natural environment. The loss of biodiversity and precious biological records in nationally significant museums was also a matter of serious concern. DAB led by Prof. H. Nishida aimed at the establishment of international disciplines and protocols for monitoring and managing the influences of disaster on biodiversity and biological resources at the initial stage following a disaster, and organizing an effective collaborative system to cope with future events. This aim was well appreciated at the IUBS General Assembly in 2012, and the proposal was approved as a scientific programme from 2013 to 2015.

This special issue summarizes the results of three years’ discussions with internationally distinguished scientists in workshops and a symposium that was held in Sendai, a city damaged by the 2011 earthquake. I, as the President of IUBS, really hope that this issue will give all its readers direction on how to cope with future big disasters in terms of biodiversity and collection preservation. We should be prepared for disasters that undoubtedly will happen again somewhere in the near future.

Finally, I sincerely thank Prof. Nishida for his devotion to DAB and thank all participants (citizens, professionals and NGO members) who supported and got involved in the activity of DAB.

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Aims, Scopes and Results

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DAB background
The Great East Japan Earthquake that occurred on 11 March, 2011 followed by the collapse of the Fukushima Atomic Power Plant not only destroyed human life and property, but also seriously damaged biodiversity and primary industries of the area. Furthermore, many museums and biological specimens were also lost or damaged. The biodiversity and biological records are a part of the global biological resources that insure future sustainability, and should be inherited by the next generation in as good a condition as possible. Japan has paid considerable attention to biodiversity, e.g., renewing its National Biodiversity Strategy four times since 1995. However, the 3.11 disaster highlighted the lack of national academic and social systems that could continuously monitor local biodiversity and biological information to provide necessary data for urgent rescue activities of various aspects and fields. The 3.11 disaster also raised an urgent need to establish a protocol for precautionary measures in case of future disasters. Based on the experience in Japan the DAB project aims to accumulate similar cases worldwide in order to draw up standard measures and policies for various aspects of minimizing the influence of disasters.

The Japanese Tsunami and Earthquake disaster and subsequent collapse of the Fukushima Atomic Power Plant in March 2011 induced a national movement to monitor the loss and recovery of biodiversity and related biological resources in local affected environments (Iwatsuki and Domoto, 2012). The disaster also damaged many museums and preserved biological specimens, including type specimens (Saito et al., 2011, Nishida, 2011). Various natural disasters and related human-invoked chain disasters, such as the one in Fukushima and even wars, not only impact biodiversity and bio-resources but also damage biological records that should be kept safely for future generations. Various reconstruction activities after a disaster may also affect local ecosystems and even ecological physiognomy. Because human life and traditional culture are subtended by and based on local biodiversity and ecosystems, special care should also be taken to maintain historical landscapes as part of biodiversity. The biological communities have never taken international action to discuss the influence of such disasters on biodiversity with regard to factors such as recovery process, sustainable reconstruction strategies and future precautionary approaches.
At the IUBS General Assembly in 2012 in China, the DAB program was proposed with the goal of summarizing recent disaster-related biodiversity loss, the recovery processes, influence on local biota as well as primary production (agriculture, fishing, etc.), damage to biological information and records, their salvage process, and the influence of human reconstruction activities on local biodiversity. It is also aimed to provide an international protocol for effective logistics to minimize the influence of disasters based on precautionary risk management.

One of the most important features of the current moment in human and earth history is that human activities have reached such a scale that could cause disasters. Huge storms, rising sea levels, and other unpredictable climate fluctuations possibly originating from human activities have caused serious biodiversity loss, which is disadvantageous to both local and global environments and economies. Recent natural disasters have occurred worldwide, though unrelated, have induced secondary human-based second disasters such as the Fukushima atomic pollution. Disasters, whether natural or anthropogenic origin destroy local biodiversity, ecosystems that provide ecological services as well as human life and culture. The 3.11 earthquake and subsequent disasters in Japan in 2011 prompted us to think and act seriously and globally on this issue. Similar disasters have recently occurred in many countries. It is time that international academic societies deal with this issue cooperatively.

**Action plan for the IUBS triennium 2013-1015**

The IUBS Committee of the Science Council of Japan, 22nd Term, had its first meeting on April 22, 2012, where the first discussion on proposing the DAB program to IUBS was opened. The proposal was accepted by IUBS at its General Assembly in China in July, 2012. The DAB program was planned as below. The program for the first year of the triennium was to organize an international working group in 2013 to summarize recent worldwide information related to DAB in order to address the activities for the subsequent two years. Details of the project plan can also be referred to at the IUBS web site: http://www.iubs.org/prg/dab.html

Proposed Action Plan

2013: Start a DAB Working Group (WG) consisting of Japanese members and up to five selected international members. To start with, one workshop meeting will be held in Japan.

2014: Organize at least one workshop and one international symposium. The frequency of the workshops and the meeting places will be decided at the 2013 workshop. The symposium can be held either in Japan or in other countries depending on national fund-raising results and the amount of IUBS funding.

2015: At least one workshop for editing a publication of the results. The final goal of this triennium is to issue a publication on DAB at the end of 2015.

**Activities**

DAB 2013

DAB 2013 was planned to summarize various lesser known phenomena provoked by natural disasters worldwide, in order to prepare for a larger and more substantial international symposium which will be held in the autumn of 2014. The following two activities were carried out in cooperation with the Biodiversity Network, Japan.
1. The domestic workshop “Disaster and Biodiversity (DAB), IUBS Triennial Program 2013, Workshop 1”, summarizing biodiversity changes and recovery processes after the Tohoku 3.11 Earthquake and Tsunami was held at Chuo University, Korakuen Campus on 21 December, 2013. About 50 participants, including 4 invited speakers, citizens, professionals and NGO members who are interested in the DAB issue were gathered for preparatory work towards an international workshop scheduled for January of 2014. The cooperating NGO, BDNJ, is one of most active NGOs concerning biodiversity in Japan, as well as an IUCN NGO member. Good organizational and individual partnership were developed.

2. The international workshop “International Workshop on Disaster and Biodiversity, IUBS Triennial Program 2013, Workshop 2”, with three international and three domestic invited speakers was held at the Chuo University Korakuen Campus on 28 January, 2014. A number of international and domestic reports were presented and summarized in English abstracts. The content and logistics of the international symposium to be held in autumn 2014 were drawn up through brainstorming discussions. The meeting was followed by a field excursion to the Tohoku area on January 29-30 with 13 participants (three international guests, four invited guests, four BDNJ members, one interpreter and one student as supporting member).

DAB 2014
DAB 2014 was planned as the international symposium in Japan included in the goals of the DAB. The international symposium “Disaster and Biodiversity” opened on 6 September, 2914 at the Katahira Campus of Tohoku University and continued to 8 September, followed by a field excursion to Fukushima on 9 September. The symposium consisted of opening events on the first day, a one-day symposium open to the public and a one day round-table discussion featuring selected professionals, NGO members and others.

BDNJ supplied additional funds for inviting either international or domestic speakers, and for part of the logistics. The symposium program was advertised on BDNJ web site: http://www.bdnj.org/pdf/20140824.pdf
Symposium abstracts can be obtained as a pdf file from the BDNJ web site as indicated in the references section of this paper.

Ten foreign speakers were invited from Chile, New Zealand, PR China, Thailand, UK, USA (3), and Viet Nam, in addition to 22 Japanese specialists and 7 BDNJ members. The symposium and workshops were open to the public and more than 40 extra participants were counted.
The field excursion was a one-day bus tour to the coast between Sendai and northern Fukushima with 25 participants.

Organizations of varying fields have supported the symposium:
International Union for Conservation of Nature (IUCN)
Japan Association of Botanical Gardens (JABG)
Center for Ecological Adaptability, Tohoku University (CEATU)
Ministry of Environment of Japan
IUBS Committee of Science Council of Japan
The cooperative NGO, BDNJ, is one of most active NGOs concerning biodiversity in Japan, and also contributes as an NGO member of IUCN. Good organizational and individual partnerships have been established since the DAB 2013 workshops. The International symposium expanded the DAB project to a worldwide scope.

DAB is strongly related to the Disaster Risk Reduction (DRR) activities. Part of the results were reported by BDNJ members at the 3rd World Conference of Disaster Risk Reduction, which was held in Sendai from 14 to 18 March, 2015. Special attention has been paid to the recovery and conservation of natural history specimens, and to the importance of establishing academic networks between museums and other institutions functioning as specimen depositories (mainly discussed in WS2). Specialists at the Science Council of Japan and in scientific communities and museums have made two important proposals to the Government of Japan since 2014.

1) To enact a movement to establish new National Natural History Museum(s) in Japan.

2) To make a national law for the conservation of natural history heritage specimens. DAB activities contributed greatly to this new movement in Japan.

DAB 2015
In June 2015 an editorial board meeting was held at Chuo University, with Paul Callomon from the United States as the sole invitee. Other members gathered using their own funding or exchanged ideas using e-mail. During the DAB triennial program internal questions arose in IUBS regarding reorganization of the editorial board and logistics of the Biology International publication, mainly concerning a proposed shift of the journal from hard-copy distribution style to a pdf on-line version. The final decision was made at the 12th General Assembly of the International Union of Biological Sciences in 2015 in Berlin, where free pdf distribution from the IUBS website was agreed upon. Each special issue will be edited by a temporary editorial board. I was appointed as the editor-in-chief of the present issue at the same General Assembly.

Summary of the results
Not all of the symposia results could be presented in this volume as published pages, because the DAB project has been supported by mostly voluntary contributions from specialists in varying fields of science and citizens who might not have enough energy and time to spare for writing heavy articles. Nevertheless, 16 papers or reports are gathered here. The importance of the DAB issue is summarized and discussed with historical and future perspectives by Kunio Iwatsuki. The reports that could not be included here can be partly referred to at the BDNJ web sites whose links follow the references below. Since shortly after the 3.11 disaster, a large number of scientific activities have started. Referring to all these activities and reports would be beyond the scope of this special issue. It is hoped, however, that this volume can strengthen the importance of the DAB issue from different view points based on the goodwill of all the participants and contributors in varying fields of specialty. Although our activities did not produce any standard protocols as aimed at when DAB began, important words and future suggestions are expressed in each contributed report.

Natural disasters like Tsunamis can also cause broad dispersal of certain organisms. The evolutionary or phyllogeographical influence of such movements deserves further monitoring and analysis, although they are not discussed much in this issue.
DAB activities have greatly influenced this new movement in Japan. In 2016 certain numbers of scientific committees and sub-committees of the Science Council of Japan recommended establishing National Natural History Museums in Japan, and have started proposing construction plans for a new National Natural History Museum (SCJ Subcommittees, 2016). Certain serious obstacles will remain to be overcome before realizing this wish of various communities. Less for the sake of scientists or the present public, however, but for the future generations I strongly hope for the construction of these new natural history museums as scientific and educational centers, and as a symbol of Natural History studies, partly commemorating past disasters and the DAB activity.

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Special thanks are due to Tohoku University for providing us a nicely designed venue, and to Prof. Tohru Nakashizuka for his scientific and logistical support in realizing the international symposium at Katahira Campus of Tohoku University, in 2014. I cordially thank IUBS and the Japan Fund for Global Environment for financial support and collaboration. Deepest gratitude is extended to all the DAB supporters and contributors, and especially to Nathalie Fomproix of the IUBS office. Special thanks to Julien Legrand and Chizuru Nishida of Chuo University for their secretary jobs during 2014-2017.

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The Influence of Disasters on Biodiversity

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Disaster and Biodiversity (DAB): Definition and Challenge

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Introduction

We had fruitful discussion during the DAB Symposium successfully organized in Sendai during September 6-9th, 2014. Summarizing a variety of interesting discussions given there, I would have a comment on the topics of this Symposium, Disaster and Biodiversity, or simplified as DAB, which is a symbol word sounds comfortably and may be popular with this sound, irrespective of its severe subject.

This Symposium was performed at Sendai, one of the cities seriously impacted by the Great East Japan Earthquake on March 11th, 2011. The reconstruction project has been managed by great efforts of the government of Japan as well as of all the local governments concerned in addition to the activities of the local people themselves. We sincerely hope that the daily lives of the people in this area will become more comfortable day by day.

Beside the recovery of human lives in the damaged areas, the evolution of nature should also be watched carefully. As the nature on the earth is variously transformed by normal human activities nowadays, the evolution of nature is seriously under influence of a pressure by various human activities. The recovery from the great natural hazards by artificial efforts should carefully be designed with a deep consideration in this. It is regretful, however, in general the recovery from disasters is promoted urgently considering only the people living in the areas attacked, and natural evolution of earth surfaces after the hazards is usually set aside as another long-term event.

Such a long-term event is another severe problem, as the stability of natural environment is fundamental demand of the lives of people living there. And, it is inevitable to manage the artificially influenced natural environment by careful human activities, although it is usually postponed as one of the long-term, or non-urgent, matters, leaving everything to the nature itself. Moreover, we usually do not know, especially in connection with biodiversity, in which way it is damaged by the actual natural hazards and in which way we should be careful on the way of bringing the recovery projects.

In this article, it is expected to define the disaster and its influence to biodiversity. As this Sendai Symposium was organized under deep influence from the Great East Japan Earthquake attacked on March 11th, 2011, the actual materials for discussion were mostly from that disaster. It is also noted that an emergency Symposium was organized in Chiba entitled ‘Catastrophic Disaster and Biodiversity’ on July 10th, 2011, and a report was issued in Japanese as well as an English summary pamphlet. Some aspects of this article are taken from those noted in these occasions.
Challenges and long-term outlook

In his speech on Eco-DRR, Professor Naoya Furuta introduced the definition of the word ‘disaster’ by the United Nations International Strategy for Disaster Reduction as: a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources. Thus he concludes that disaster risk is considered to consist of three independent elements, namely hazards (hazardous events), exposures and vulnerabilities.

In this Symposium we had no specialists of disaster, and no discussion was extended on this definition. Most of the participants were interested in the dynamics of biodiversity in relation to disaster in this Symposium.

We do not know which is real hazard exactly, as the nature has more or less been influenced in these days by human activities. There must be some hazards, which were directly resulted from activities of the earth itself wholly independently from the influence of human activities. Some of the great hazards may, however, be induced under the influence of human activities, or so-called natural hazards include artificially induced ones. Or, the natural events may give a great disaster to the human beings introduced by the influence to the earth by the recent human activities.

This Symposium was organized in Sendai after the Great East Japan Earthquake, and during the Symposium we were always considering that earthquake in our discussion. We examined what effects this earthquake have on the Japanese people.

The ancestors of Japan lived in the Japanese Archipelago for some 40,000 years, mixing with other people who migrated thereafter independently from the Japanese at that time, and formulated the Japanese people, as we know today. The people in the Japanese Archipelago, while being blessed with a wealth of biodiversity, suffered countless disasters and overcame them. Towards the bottom of the Japanese culture we have inherited, we find our nature-views developed through the interaction our ancestors experienced in the Japanese Archipelago and we cannot ignore them. The word ‘disaster’ contains the meaning of artificial disaster as well as the meaning of natural disaster. We cannot overlook that ‘disaster’ includes a portion of those which may be called ‘accidents’. It also applies to the Great East Japan Earthquake. In addition, we should accurately understand that human activities have mitigated damages in some cases and unfortunately increased damages in other cases. Whatever the causes of damages, those with emergency nature should be dealt with immediately. The recovery from disaster requires accurate analyses on what really happened.

Naturally, emergency responses need to incorporate recovery perspectives on a long-term outlook. Otherwise we may face inconsistency in the following days. There are significant human interventions against the nature, so the fluctuation that occurred in the nature would have an impact on the current Japanese Archipelago with artificial structures instead of the one in a pristine state.

If we focus on the Great East Japan Earthquake and biodiversity, the following challenges seem to be raised specifically:
1) Major damages in the biodiversity-related facilities including the specimens and other materials in museums and the capacities in research and learning support for biodiversity.
2) Direct damages to animals and plants, such as destruction of vegetation, fluctuation in regional biota, and impacts on sustainable use of biodiversity; and
3) Potential effects of radiation on biodiversity caused by the nuclear accident.

It is natural that in our human society the lives of human beings should be considered primarily. Reconstruction of the human lives is the urgent and important task. At the same time, it is necessary to be alluded here that the nature on the earth is, at the moment, not natural at all.

Responses at disaster and their assessment

Just after the Great East Japan Earthquake, the Biodiversity Network Japan held a Symposium as an emergency session entitled ‘Catastrophic Disaster and Biodiversity’ on July 10, 2011 in Chiba. Based on the hot discussion there, the report including all the items discussed in this Symposium was issued on February 1st, 2012 in Japanese, and a pamphlet with English translation of some articles was followed.

Biodiversity under natural disasters was surveyed from various viewpoints, and a resolution of the Symposium to seriously consider the recovery of biodiversity on the way of general recovery project from the earthquake was proposed and handed actually to Mr. Satsuki Eda, the Minister of the Environment on July 13th, 2011. As we have as yet no full information on the biodiversity in relation to the natural disasters, it is a pity to note that the recovery of biodiversity is not very seriously considered even in the case of the recovery project from the Great East Japan Earthquake.

At that 2011 Symposium, I introduced some dangerous facts I actually met with at that time. Our museum held a press conference for the fifth year report of fossil excavation on March 15th and lifted the embargo of the information on March 30th. Some people criticized us, through telephone calls, claiming that we should not continue our ordinary operations and waste the precious press coverage in such a state of emergency.

We heard similar incidents in other places. I felt uneasy was that some people, including those in major mass media, claimed to leave behind biodiversity or global warming for a while and concentrate on emergency relief such as lifesaving. Of course, lifesaving is of utmost importance, but it does not imply that all Japanese should and could go to the devastated areas and be involved in relief activities. We have to review what happened after the disaster including those involved such irrationality.

It may not be necessary to note that our museum was involved in the Earthquake issue by our own way. After the disaster, our museum performed events for small kids in the areas impacted by the disaster, calling several other museums to collaborate with us in such a project. Actually, we succeeded to organize several museums to hold a series of events especially for kids. The people in the area concerned welcomed it. This is one of the ordinary activities of the museums and museums can help the people most efficiently in such a way, although our museum is prefectural and primarily expected to work in our prefecture. Ordinary activities as a museum should be supported even in such an emergency period.
And then after about one month later, the issues with pets and livestock began to surface on the media at last. While those evacuated from twisters in the US were holding their own pets in their arms while being interviewed by ABC or CNN. I am wondering if Japanese as a whole tend to collectively lose a sight of peripheral issues other than the central focus. That is why I think each of us should verify what happened in the various areas in responding the disaster.

Now, our understanding goes to the general information on the biodiversity in occasion of great natural hazards. And, we took a part of organization of this international symposium in co-operation with the International Union of the Biological Sciences.

As a subject of research, biodiversity as a whole is a huge target to be surveyed and there is an enormous amount of information to be analyzed. From a demand of our society who influenced strongly to the existence of biodiversity, it is an urgent task to analyze biodiversity from a viewpoint of natural science, though it is rather difficult to know whole the conspectus of biodiversity in relation to each disaster under consideration, as we are still suffering from basic information on biodiversity in general. Basic research on biodiversity in various levels is one of the urgent fundamental targets of science at the moment. It is critical to have more information on the biodiversity when a serious disaster occurs in any particular area on the earth.

To analyze the dynamics of biodiversity at present, it is convenient to take up the endangered species issue as a model of research on biodiversity in general, as we can express the dynamics of endangered species in some understandable figures to show general public. For more statistical analysis, GBIF, or Global Biodiversity Information Facility, expects to raise a world database of biodiversity in collaboration with various governmental and/or non-governmental organizations concerned, though the available digitalized data preserved in the GBIF database is still insufficient to treat with in constructing the recovery project in great disasters.

Even at the best of times more basic research on biodiversity is needed to inform better management. Why not when disaster gave influence to biodiversity in the particular area concerned? Actually, we know that the biodiversity at present is heavily endangered as is indicated clearly by the higher percentage of endangered species in existing biotas. And, the urgent estimation of the dynamics of biodiversity is better modeled by these endangered species.

There is one more thing I cannot help but think of. It is the expression that the scale of tsunami was ‘unexpected’. Surely, the disaster was beyond the imagination of the relevant parties. Even the research teams for earthquake prediction who are supposed to prepare carefully did not anticipate it, they say. But there is always a chance of new record in natural phenomenon, such as the heaviest rainfall in recorded history. Nobody can claim a certain scale of natural disaster would never happen because such thing did not happen in the past decades. One who does not expect it is cheating oneself and others because he thinks he will be screwed up if it happens. Those who may make excuses by saying an ‘unexpected’ thing has happened should not be involved in such operations that potentially put people at risk.

There is no such thing as one hundred percent safety in science and technology. The situation that responsible persons often claim ‘safety is secured’ in Japan seriously
reveals the lack of science literacy among some Japanese. What is required is to move the risk closer to zero and to make thorough preparation in responding once such a crisis unfolds.

**Specimens and biodiversity**
For the basic research on biodiversity, the natural history specimens reserved in the museums are fundamentally important materials for research work. Museums hold a vast numbers of valuable specimens and the data that support them. The hazards often damage the buildings of museums and specimens are destroyed and lost. In the case of the Great East Japan Earthquake, it was a pity to see that this actually happened and valuable specimens were destroyed in miserable way, particularly in the Rikuzentakata City Museum.

The damages to cultural properties have usually been accurately recorded and aggregated. It is very unfortunate that many were lost at the time of the Great East Japan Earthquake. At this point, we only expect to restore what were left and restore them to an original state as far as possible. The laws and regulations in Japan stipulate how to deal with cultural properties and budgetary steps have been actually taken.

As for specimens in natural history, there is no legal procedure to restore the damage induced by any hazards. In the case of that Earthquake, we were informed the conditions of natural history specimens only about one month after that disaster.

Several museums cooperated to restore the specimens and other materials of the Rikuzentakata City Museum. The activities at the Natural History Museum and Institute, Chiba and the Museum of Nature and Human Activities, Hyogo, and the outreach activities through them were reported separately in the forum in July, 2011 and the articles were published on this topic in addition to some report by newspaper articles as well as television videos. We must learn from these activities and how the museum network in Japan can function at emergency.

The specimens and other materials in natural history are not stipulated equivalent to cultural properties. It has been understood that they are accumulated under researchers' hands, with the historical background that the registry scheme of materials in natural history were not clearly stipulated. Though their registration as electronic data is in progress now, but they are yet to be recognized as cultural properties. The restoration of specimens would partly be covered with the government budget this time, but at the discretion of the officials in charge.

In order to make such arrangement permanent, we have responsibility to properly grasp the reality of low recognition among the general people and to salvage the situation. Although it is not widely recognized, natural history specimens are indispensable materials to enrich the information about the nature. Accumulation of such information is necessary to establish sound scientific base to face a variety of predicted natural hazards.

**Responses to humans and other lives**
Emergency responses include lifesaving, but the mental care is also indispensable. The Museum of Nature and Human Activities, Hyogo has conducted a traveling class for kids in a caravan in early July. We visited the children's houses in Rokugo and Shichigo in Wakabayashi Ward, Sendai City and were welcomed by children and the City Mayor.
It is our privilege to swiftly learn through the activities of museums. Such activities were continued to collaborate with the museums of the area concerned and contributed to the healing of younger people the aftermath of the disaster.

However, we took more than a month to pay attention to the lives other than humans. The livestock kept by the evacuees of the nuclear disaster have been left behind without care for a while. The wild lives were not even mentioned. They are almost completely ignored for many months. In some cases, it was rather difficult for the researchers to work on the basic scientific matters in the damaged areas, as there are humans who were suffered from the aftermath of the disaster.

In the case of the Great East Japan Earthquake, there were heavy damages by natural hazards and at the same time disasters induced by artificial structures. In addition to the information how natural disaster influence the transition of nature, we need down-to-earth researches how the radiation from the nuclear accident would cause effects on wild lives as well as the humans. This is a heavy topic and there are a number of trials and reports, and it is far beyond the area of this brief comment on the Symposium on ‘Disaster and Biodiversity’.

Recovery from disaster

It is reported that even the inland regions are not yet recovered from the Earthquake. Main transportation lines are reintegrated, logistics is secured, and the reconstruction seems to be ready. I wish the specific measures for reconstruction to be formulated and the ordinary lives to become normal again soon.

The tsunami left devastating damage that would require a wide variety of directly related recovery measures from the disaster, including the handling of wreckage. Unlike us who only accept the stories produced by the media, many people in disaster areas make their efforts to build up daily life in a proactive manner.

The industries in Tohoku region bear an important and cutting-edge role in the global supply chain, even impeding worldwide car production for a while after the disaster. I believe Tohoku will become an ever-more-vitalized region in the aftermath of the catastrophic disaster and its people will certainly pursue a way of life in which down-to-earth people are supported in a corner of the earth.

Meanwhile a remark that it would be better to temporarily leave behind measures such as for global warming at an emergency situation made me uneasy. A measure at emergency should not put another measure at risk. We have explored anew the meaning of sustainable use of biodiversity with a wide variety of people at COP10 held in 2010 in Nagoya. We have supposedly recognized the responsibility to seek sustainable use extensively in order to enjoy the benefits we have today in future. Then the unfortunate disaster has hit East Japan. However, this may be merely a temporary escape from the disaster, which ultimately may destroy the earth in future, is not an emergency escape at all. We would like to make sure that emergency responses that do not forget the abundance of the earth tomorrow is what we want.

And, actually there were a variety of disasters attacking the Japanese Archipelago every years, earthquakes, eruption of volcanoes, typhoons, floods and land slides caused by heavy rains, large amount of snowfalls, and others. They were smaller in scales than the Great East Japan Earthquake, though there were the dead people and many wounded in these disasters. Recovery from each disaster was conceived and performed urgently,
and normal lives of the people in the area concerned are retrieved in some time, though
the emotional scars remain long afterwards.

There is not enough room to go deeply into the nuclear plant issues caused by tsunami
in 2011. But let me raise an issue of conflicting interests in governing bodies. It was
criticized that the Nuclear and Industrial Safety Agency was set up under the Ministry
of Economy, Trade and Industry.

Now, a similar arrangement is proposed in transferring the conservation and
management functions of national parks to local governments to promote ‘eco-tours’. If
a governing body for development is given the authority in conservation that often puts
restriction on development, the check-and-balance function would be compromised in a
way or another. Sound reconstruction can only be achieved through taking advantage of
what we have learned from the disaster. That is an act of commemorating the people
who lost their lives at the disaster, in a true sense. To share our experiences we have
learned globally and make use of them should be the act we would carry out in addition
to recreating the past life in the Tohoku region.

Disasters and biodiversity
In the natural circumstance, the great disasters may have been overcome by the
diversity of organisms by themselves according to the situation given to them. The
evolutionary history shows us that at least five times in the past a great number of
species became extinct, but the biodiversity had the other prosperity after taking a very
long term for their further evolution.

The threat of biodiversity at the moment is greatly influenced by the human activities
in addition to the normal development of natural environment itself. Human beings
should have responsibility to their own activities, as the threat to the biodiversity is
directly the threat to the lives of the human beings themselves, an element of
biodiversity.

Natural disasters like the great earthquake are the natural events and we, the human
beings, cannot control them. Natural disasters usually influence to the evolution of
biodiversity in nature. At present, however, we should seriously recognize that the
natural disasters in the present ages give greater influences to the biodiversity by ever-
made pressures from the human activities in addition to the influence of natural
disasters themselves.

We should observe the facts how biodiversity is influenced by natural disasters: biodiversity on the earth has already been transformed to some extent by human
activities, and we cannot say that the present earth is not fully natural at all but
transformed greatly by artificial activities. And, we should not entrust all the recovery
of biodiversity by itself after any disaster, and have responsibility to help its recovery by
our own artificial contribution. The evolution of biodiversity, already wounded by
human activities, may need have artificial helps for its recovery from any damages by
natural disasters.

In the Sendai Symposium, it was designed that we should learn 1) the facts on
biodiversity how it was influenced by natural disasters, 2) restoration and management
of natural history specimens damaged by disasters, and 3) introduction of ever-made
successful examples of recovery of biodiversity from any damages by natural disasters.
I sincerely hope that we have had better exchange of information in this Symposium and the following events to enrich our knowledge on biodiversity in relation to natural disasters, especially concerning to the above items, and, based on rich information we have and will have, we would propose constructive ideas to recovery projects from any natural disasters, in the past and/or in future.

Conclusion
At the Chiba Forum, I had to apologize the situation after the great disaster as follows. ‘It is reported that we are regarded from overseas that, upon observing the disaster responses in Japan, the Japanese people are of first-rate, the Japanese economy is of second-rate, and the Japanese politics is of third-rate. Conceivably, those Japanese media that had repeated stereotyped reports may be of fourth-rate. It is increasingly apparent at this time four months after the disaster. It is also ridiculous to judge them collectively. During this period, a number of excellent programs were broadcasted. Sadly, many of them did not achieve high ratings. It is also frustrating to hear the contributed donations are yet to reach the hands of those suffered the disaster. However, it is same Japanese people who vote for politicians and watch the television’.

We have suffered massive misfortunes from the natural disaster. That's why we have to learn from our experiences and create a decent living in the Japanese Archipelago. To this end, we have a lot of things to learn. They should be reflected in the daily activities in the efforts to recover from the disaster. Even if those who are not in a directly affected area, they have a mountain of things to tackle.

An earthquake of magnitude 9 would seldom happen. Though another great earthquake may not happen soon in East Japan as it has released its energy, a Tonankai Earthquake is said to hit at any near future. We understand that highly reliable prediction is not available when such earthquake will actually strike. Then we should prepare to minimize the risk. Our ancestors in the Japanese Archipelago have been enjoyed the benefits of rich biodiversity by masterly staging the coexistence of human and nature, being backed up by their experiences with frequent disasters, at least before we took in the material/energy-oriented way of life from the West after the Meiji Restoration and especially after the defeat of World War II.

We agreed with the participants of COP10 in Nagoya in 2010 considering that the sustainable use of biodiversity is one of the major issues for the earth. We have proposed the ’Decade of Biodiversity’ after the meeting, and its activity has been put on the move mainly through the United Nations. Major disasters require a variety of emergency responses. At the same time we do not want to have another catastrophe from the mishandling of the emergency responses.

The Great East Japan Earthquake might be an occasion, which reminded us of the befitting life for the people in the Japanese Archipelago, getting back to the starting point once again. It is a chance for us to soundly reconstruct the Japanese Archipelago and the only earth for tomorrow if they are really of ’first-rate’.

Acknowledgement
I would show my hearty thanks to all the participants of the Symposium, especially to the contributors from abroad who joined us over long trips to Sendai. I would also thank to Professor Tohru Nakashizuka and all the Sendai colleagues for every kind of local
contribution, which made the Symposium enjoyable and most productive. We had financial support from ‘the Japan Fund for Global Environment’ and ‘the International Union of the Biological Sciences’, which made the Symposium actually open. I personally would also allude to the contribution made by the members of the Biodiversity Network Japan and all those who took parts of organizing this Symposium. All the contributions were made voluntarily to bring this Symposium to be actually performed. I hope all the participants of the successful four day-symposium enjoyed and learned a lot from this event, and will have further contribution to any issue on the disaster and biodiversity. This event has made an important first step in the promotion of the research on disaster and biodiversity and marks further development in this critical area.

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Natural disasters and biodiversity: a review of various types of disaster and their effects on biodiversity

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Abstract

Recently, severe natural disasters, including huge earthquakes, tsunamis caused by oceanic earthquakes, volcanic activity, and tropical storms, have received widespread media coverage. Different types of disaster affect particular ecosystems and the species that inhabit them. For example, tsunamis caused by oceanic earthquakes affect coastal ecosystems, inland earthquakes cause landslides in mountain areas, volcanic activity affects the adjacent ecosystems, and tropical storms often damage forests and coastal ecosystems. Most ecosystems have experienced disasters repeatedly over their long histories and have their own recovery mechanisms, such as primary succession after volcanic activity. However, these mechanisms are frequently disturbed by alien species. The destruction of ecosystems by natural disasters can also produce new habitats and has sometimes led to the evolution of species. We should consider both the short- and long-term effects of natural disasters on biodiversity.

Keywords: Biodiversity, Disaster, Disturbance, Earthquake, Eruption, Evolution, Tsunami, Tropical storm, Volcanic activity

1. Introduction

Japan has experienced several severe natural disasters in the last few years, including the Great East Japan Earthquake (GEJE) on March 11, 2011 (Mw=9.0). The GEJE and resulting tsunami destroyed much human infrastructure and affected the natural environments along the Pacific coast of Japan. Although such severe disasters are rare in the span of a lifetime, they occur frequently on evolutionary time scales, and the ancestors of extant organisms survived these historic events. The Pacific coast of the Tohoku district has been repeatedly struck by huge tsunamis (Abe et al. 1990; Sawai et al. 2006; Shishikura et al. 2007), and the species that live there have survived repeated
tsunamis. How then do such natural disasters affect the organisms that live in the potential areas of influence? Here, I briefly review the relationships between various natural disasters and species and their impacts on biodiversity.

2. Various types of natural disasters

The Japanese archipelago is often affected by various types of natural disaster because four tectonic plates meet there in a relatively small area. Consequently, volcanic activity is high, and earthquakes occur frequently. Additionally, the monsoon season can bring heavy rain, and several typhoons occur each summer. First, I briefly review each type of natural disaster and its influence on organisms.

(1) **Huge earthquakes and the resulting tsunamis**

Oceanic earthquakes that occur at the boundary of plates in subduction zones destroy landscapes directly, and the resulting tsunamis can have destructive effects on coastal areas. Studies of the effects of tsunamis on coastal ecosystems have focused on the GEJE and the Sumatra-Andaman Earthquake (SAE), which occurred on Dec. 26, 2004 (Mw=9.1 or 9.3).

Tsunamis caused by the SAE affected most of the coast of the Indian Ocean, and more than 200,000 people were killed. The tsunami also had strong effects on natural environments (United Nations Environmental Programme 2005), especially on the coastal vegetation (Hayasaka et al. 2012a; Porwal et al. 2012; Prabakaran and Paramasivam 2014) and seagrass communities (Nakaoka et al. 2007; Whanpetch et al. 2007, 2010) in various areas, although the effects of the tsunami on the latter differed with the area. On Andaman-Nicobar Island, which was quite close to the epicenter of the earthquake, the tsunami destroyed the coastal ecosystems, subduction led to the loss of mangal forests, and coral was damaged by uplift (Kayanne et al. 2007; Porwal et al. 2012). The tsunami also affected microbial communities in Thailand (Somboonna et al. 2014). The GEJE had similar effects on the Pacific coastal ecosystems in the Tohoku district, northern Japan (Hayasaka et al. 2012b; Urabe et al. 2013). Similar earthquakes and tsunamis have occurred at intervals of several 100 to 1000 years (Jankaew et al. 2008; Monecke et al. 2008).

Unlike the effects of coastal earthquakes, the effects of inland earthquakes on organisms have not been characterized as well. The Wenchuan earthquake, which occurred in China on May 12, 2008 (Mw=7.9), was estimated to have destroyed more than 1,000 square kilometers of natural ecosystems (Ouyang et al. 2008). Remote sensing revealed ~10% forest loss caused by the earthquake, and many small landslides that cannot be detected by remote sensing were reported in the Wolong Natural Reserve, the famous habitat of the giant panda (*Ailuropoda melanoleuca*) (Zhang et al. 2011; Kou et al. 2014, but also see Zheng et al. 2012 for the effect of habitat loss on the giant panda). More than 2,700 landslides, with a total area exceeding 38 square kilometers, occurred in the Nepal earthquake of April 25, 2015 (Mw=7.8) (Ministry of Science, Technology & Environment, Government of Nepal 2015). This earthquake might have had large effects on various species, but the details are still unknown (Ministry of Science, Technology & Environment of Nepal 2015).

(2) **Volcanic activities**

In Japan, there are 110 active volcanos (*i.e.*, those that have erupted within ca. 10,000 years; Japan Meteorological Agency). This is ca. 7% of the active volcanos worldwide.
The activity of these volcanoes is strongly correlated with plate tectonic activity. In Japan, the recent eruption of Mt. Ontake (2014) was notable because it killed many hikers. Additionally, the relatively recent eruptions of Mt. Usu (1977–1978) (National Research Center for Disaster Prevention 1978; Tsuyuzaki 1987) and Mt. Odake (Miyake Island, Izu Islands, 2000) (Kamijo et al. 2002; Tokyo Metropolitan Government 2007) affected natural ecosystems. Volcanic activity involving rock flows, pyroclastic flows, lava flows, and/or falling volcanic ash markedly affects terrestrial ecosystems and the recovery processes. On volcanic islands, volcanic tsunami sometimes occurs with eruptions (Paris et al. 2014). From the perspective of vegetation, the recovery from volcanic activity is a good example of succession (del Moral and Grishin 1999; for a review, see Tsuyuzaki 2001, 2009). Volcanic activity also affects oceanic ecosystems via chemical inputs by ash or rocks (Duggen et al. 2007; Schils 2012; Chikamoto et al. 2016).

Whereas small eruptions affect the ecosystem surrounding the volcano, huge eruptions (Volcanic Explosivity Index (VEI) > 6) destroy large areas and can affect the global climate (Golovanova et al. 2010; Costa et al. 2012). One well-documented huge eruption that affected ecosystems was the Krakatau eruption (August, 1883, VEI=6). Approximately half of the island vanished in the eruption, and more than 30,000 people were killed. Early biologists focused on the event to follow the sequence of ecosystem reconstruction in nature, and detailed investigations, especially of the land ecosystems (Tagawa et al. 1985, 1986; Thornton et al. 1988; Thornton and Walsh 1992; Whittaker et al. 1989, 2000; Whittaker and Jones 1994; Partomihardjo 2003; Yamane 2006; New 2008, 2015; also see the review by Darnaedi and Zulkarnaen in this volume), and, to a lesser extent, of below-water ecosystems (Barber et al. 2002; Starger et al. 2010), have continued from the end of the catastrophic eruption to the present. The most recent eruption to reach VEI=6 was that of Mt. Pinatubo in the Philippines in June 1991 (Global Volcanism Program 1991a, 1991b). Studies are examining the recovery of vegetation around Mt. Pinatubo (Marler and del Moral 2011).

Although there are no exact records, there have been even more catastrophic eruptions geologically (ultra-Plinian eruptions), including Yellowstone, USA (ca. 640 kya) and Toba, Indonesia (ca. 75,000 ya); both eruptions were categorized VEI=8. The latter is postulated to be the cause of a dramatic decrease in the human population due to cold weather (volcanic winter) caused by the eruption (Ambrose 1998; but also see Petraglia et al. 2007). Similar smaller eruptions have also been recorded in Japan, including Aso (the most recent eruption was ca. 85,000–90,000 ya), Hakone (ca. 53,000 ya), and Kikai (ca. 7,300 ya); all three eruptions were categorized as VEI=7 (Maeno 2014).

(3) Tropical storms

Tropical storms (called hurricanes in the north–eastern Pacific and Atlantic including the Caribbean Sea; typhoons in the north–western Pacific; cyclones in the Indian Ocean; and willy-willies in the south–western Pacific) regularly arise in tropical and subtropical oceanic regions and frequently reach low-altitude land areas. They produce strong winds and heavy rainfall, and the winds greatly affect terrestrial ecosystems (e.g., Vandermeer and de la Cerda 2004; Mascaro et al. 2005; Xi et al. 2008; Schnitzer et al. 2012; epiphytic plants: Vale et al. 2013; Wiegand et al., 2013). The strong waves
produced by storms also affect coastal and along-the-coast terrestrial ecosystems (e.g., Piou et al. 2006; Walker et al. 2008; Middleton 2016).

Tropical storms are relative frequent natural disasters and are agents of periodic disturbance in regions frequently struck by the storms (Uriarte et al. 2009; Urquhart 2009).

(4) Other types of disasters

Local-scale disasters, such as landslides and floods caused by heavy rains, are relatively frequent in various regions and affect ecosystems (Wright et al. 2017). Drought also affects terrestrial ecosystems (Liu et al. 2015). The recent increase in these water-related disasters is related to global climate change and consequent changes in the global hydrological cycle (Huntington 2006; Trenberth 2011). Landslides occurred in areas with permafrost release ‘greenhouse gases’ (e.g. methane) and may accelerate global climate change (Huscroft et al. 2004; Chen et al. 2016; Mu et al. 2016).

Wildfires sometimes burn out large areas of vegetation and are very destructive to terrestrial ecosystems (Dawson 2001; Reich et al. 2001; Burrows 2009; Bowman et al. 2009; Bowman and Murphy 2010). The frequency of wildfires differs among ecosystems and depends on various factors, such as climate conditions, vegetation types, and human activities (Blarquez et al. 2015; Jolly et al. 2015; Coates et al. 2016; Bowman et al. 2017).

Meteorite impacts are rare but catastrophic events if the meteorites are huge (Chapman and Morrison 1994; Cockell and Lee 2002). The Chixulub asteroid impact occurred ca. 65.5 Mya and caused mass extinction at the Cretaceous–Paleogene boundary (Schulte et al. 2010; Renne et al. 2013; Tyrrell et al. 2015). However, due to the lack of sufficient information, the effects of meteorite impacts on ecosystems are largely unknown (Cockell and Lee 2002). Much rarer astronomical events than meteorite impacts, such as strong radiation bursts, may bring catastrophic consequences both the earth and lives on it (Melott and Thomas 2009, 2011), but details are still unknown.

3. Effects of natural disasters on biodiversity

As mentioned above, natural disasters have occurred repeatedly in the long history of organismal evolution. Most extant ecosystems persist after being subject to various natural disasters. The observation that natural vegetation decreases the impact of tsunamis, such as after the SAE and GEJE, is the result of the evolution of vegetation over a long history of tsunami impacts (Danielsen et al. 2005; Tanaka et al. 2007; Kaplan et al. 2009; Laso Bayas et al. 2011).

The extent of the destruction of a natural ecosystem and rate of its recovery from the destruction depends on the impact level. Several factors should be considered when evaluating the impact level of a given natural disaster. First, we should determine the dimensions of the natural disaster. When a given disaster has catastrophic effects that cause to loss of most of the elements required to maintain a particular ecosystem in a given area, the natural recovery process will be prolonged. The vulnerability of ecosystems themselves and their elements (i.e., species) also affects the recovery process. If a given disaster destroys the habitat of vulnerable species, the impact on biodiversity will likely be strong, and it may not recover. That risk is enhanced when volcanic activity affects mountains or islands that have many endemic species.
Disturbances caused by disasters sometimes change species interactions (Roznik et al. 2015). Consequently, the natural recovery processes are sensitive to the members and sequences of species in disturbed areas (Tsuyuzaki 2009). In the recovery process, additional human-caused disturbances have strong negative effects. Ongoing disturbances resulting from human activities have destroyed natural ecosystems and decreased the source species that would enable the recovery of adjacent areas from natural disasters. In addition to such quantitative effects, the recovery process can also suffer qualitatively from the appearance of alien species. For example, Hayasaka et al. (2102) reported differences in the recovery of vegetation from the tsunami between places influenced and not influenced by human activities. The composition of the natural coastal plant communities changed after the SAE tsunami, but it returned to near-normal within 7 years. By contrast, the vegetation of resort beaches had not returned to their original compositions due to the many alien species. There are various examples of alien species altering the recovery process after a volcano has destroyed the vegetation. For example, in Hawaii, an exotic plant with actinorhizal symbiosis, Myrica faya (Myricaceae) and Falcatafia moluccana (=Albizia falcataria, Fabaceae), fertilizes the sites it invades by fixing nitrogen and altering the succession process (Vitousek et al. 1987; Hughes and Denslow 2005). Kondo and Tsuyuzaki (1999) reported the invasion of the area by alien larch, Larix kaempferi (Pinaceae), from plantations affected the 1929 eruption of Mt. Koma, Hokkaido. After the catastrophic eruption of Mt. Pinatubo, most of the plants (34/58 spp.) growing in disturbed areas were alien species, and the invasive Pennisetum setaceum (Poaceae) and Chromolaena odorata (Asteraceae) were especially widespread (Marler and del Moral 2011). Fattorini and Borges (2012) reported the recovery of arthropods after the eruption of the Capelinhos Volcano, Faial Island, Portugal, in 1957. After the eruption, there were significantly more alien arthropods in the disturbed area than in the moderately disturbed or undisturbed areas. These studies indicate that introduced organisms have conspicuous effects on the recovery from natural disasters, and we need to consider the combined effects of human activities on the recovery processes.

We tend to consider only the negative impacts of disasters on biodiversity. However, disasters are natural phenomena that are simply extreme disturbances (Tsuyuzaki 2001, 2009). Such disturbances have provided large new habitats for the species that depend on disturbances. Some natural disasters also create new empty habitats that can become the evolutionary basis of new taxa. For example, off-shore volcanic activity sometimes creates islands (Fridrikksson and Magnússon 1992; Abe 2006; Ingimundardóttir et al. 2014), and many oceanic islands are “experimental fields of organismal evolution” with many endemic species (Wagner and Funk 1995; Grant 1998; Stuessy and Ono 1998; Caujapé-Castells et al. 2010; Losos and Ricklefs 2010). Volcanic activity can also produce new, isolated mountain habitats, which tend to have endemic species (Japan: Tagawa 1939; Chile: López et al. 2010; Green et al. 2012). The ash and pumice produced by volcanic activity sometimes has positive effects on ecosystems and biodiversity. Volcanic ash provides nutrients and affects the productivity of ecosystems (Duggen et al. 2007), whereas pumices act as dispersal agents for the long-distance movements of marine invertebrates, macroalgae, and bacteria (Bryan et al. 2012). Wildfires place strong selective pressures on various species, especially land plants, and may lead to extremely high endemism in some biodiversity hot spots (Wells 1969;
Huge earthquakes sometimes create lakes or ponds by damming rivers or causing uplift along the coast. Lescak et al. (2015) reported rapid phenotypic divergence in freshwater pond populations of sticklebacks over the past 50 years. The freshwater habitats were created by island uplift in the Gulf of Alaska in the Great Alaska Earthquake (March 27, 1964; Mw=9.2). Although we tend to focus on the short-term consequences of ecosystem functions and their recovery to previous conditions, we should also consider the long-term consequences of natural disasters on biodiversity resulting in the evolution of new traits or new species.

4. Conclusion
Information on the effects of natural disasters on biodiversity is difficult to collect, especially in the cases of catastrophic disasters because of their rarity. We should continue to evaluate the effects of natural disasters on biodiversity. As we cannot have advance knowledge of when and where such disasters will occur, it is necessary to collect data on the ecosystem conditions and biodiversity in various potential disaster areas (Titus et al. 1998; Tsuyuzaki 2001). This information can serve as the “baseline conditions” when evaluating the effects of natural disasters. Unfortunately, in the case of the GEJE, we did not have enough baseline information about the ecosystems and biodiversity in the affected areas. We should use this case as a warning when considering the relationships between natural disasters and biodiversity.

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Disaster and Biodiversity in China

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Abstract

Natural disasters occur frequently in China, causing the loss of human life and property as well as devastation to the environment. However, little scientific research has been conducted on the impact of natural disasters on biodiversity in China. Very few studies of disasters and biodiversity (DAB) have been published in Chinese. We summarize and discuss recent natural disasters in China and their possible effects on biodiversity, and suggest avenues for future research on this topic.

Keywords: Biodiversity, China, Disaster, Drought, Earthquake, Endemic species, Flood, Typhoon

1. Introduction

China experiences natural disasters more frequently than most nations of the world. Natural disasters such as earthquake, drought, inundation, desertification, mud-rock flows, forest fires, hailstones, sand and dust storms, freezing rain, or extremely cold weather have occurred very frequently over the past 60 years (Fig. 1). Natural disasters can cause the loss of human life and property as well as devastation to the ecological environment, threatening local biodiversity. Research on natural disasters has focused mainly on economic and human losses, and the causes, forecasting, and prevention of natural disasters. As a research topic, disasters and biodiversity (DAB) is rather new in China. Very few studies of the effects of natural disasters on biodiversity have been conducted in China; of these, almost none have been published in Chinese. We summarize and discuss the natural disasters that have occurred in China over the past 60 years and their possible influences on biodiversity.

2. Major disasters in China since 1950

Top 10 natural disasters in China (1950–1985)

Of the top 10 disasters in China between 1950 and 1985, five were floods, three were earthquakes, and two were droughts.
Fig. 1. Examples of major disasters in China, a: landslide, b: flood, c: forest fire, d: drought.

1. The Huaihe River Flood (Zhou et al., 2002). The flood occurred in Henan province and the northern part of Anhui province, in July, 1950. Over 2.3 million ha of land were flooded and 13 million people were affected.
2. The Changjiang (Yangtze) River and Huaihe River Flood (Yin and Li, 2001; Zhou et al., 2002; Shankman et al., 2012). The flood occurred in July, 1954. Over 3.17 million ha of land were flooded and ca. 19 million people were affected.
3. Three Years of Natural Disasters. From 1959 to 1961, most of China experienced continuous drought and late spring cold (Zou et al., 2005; Xiao et al., 2009; Zhai et al., 2017). Agricultural and industrial production was greatly affected and people endured serious food shortages (Lin and Yang, 2000). The Chinese population decreased by 10 million people within 1960 alone.
4. The Haihe River Flood (Luo et al., 2014; Wang and Xu, 2015). Hubei province experienced five torrential rains in August, 1963. The total rainfall exceeded 2,000 mm within seven days in some areas. Over 104 counties and 22 million people were affected.
5. The Xingtai Earthquake (M6.8). The earthquake occurred in Xingtai, Hebei province (Wang et al., 1997), on March 8, 1966. A total of 8,182 people died; 51,395 people were injured, and more than 5 million buildings collapsed.
6. The Tonghai Earthquake (M7.1). The earthquake occurred in Tonghai, Yunnan province, on January 5, 1970. A total of 15,621 people died; 26,783 people were injured, and 338,456 buildings collapsed (Zhou et al., 1983).
7. The Henan Flood. Between August 5–7, 1975, Henan received a total rainfall of 1,605 mm within 20 hours from super-typhoon Nina (Hurricanes Science and Society Team, http://www.hurricanescience.org/history/storms/1970s/typhoonnina/; Yang et al., 2017). The heavy rains caused dike breaching in three rivers and dam breaching in three reservoirs (including the world’s worst dam failure, at the Banqiao Dam; Xie, 2012). This was a serious disaster; the direct economic losses exceeded 10 billion Yuan.
8. The Tangshan Earthquake (M7.8). The earthquake occurred in Tangshan, Hebei province, on July 28, 1976. A total of 242,769 people died; 435,556 people were injured, and 5.3 million buildings collapsed. This earthquake caused more human damage than any other earthquake in the 20th century (Chen et al., 1988; Liu and Wang, 2012).
9. The North China Drought. From 1978 to 1983, the northern, northeastern, and northwestern regions of China experienced continuous drought (Xiao et al., 2009). In 1981 alone, 26 million ha of farmland were affected by the drought, and more than 12 million ha of farmland produced no harvest. Nearly 23 million people experienced a water shortage.
10. The Liaohe River Flood. Heavy rainfall caused the breach of more than 4,000 dikes in August, 1985. The flood affected 60 counties, 12 million people, and 4 million ha of farmland.

Top 10 natural disasters in China (2008–2013)
Among the top 10 natural disasters in each year between 2008 and 2013, 14 were floods, 10 were earthquakes or droughts, 7 were typhoons, 6 were storms or hail storms, 4 were mud-rock flows, 3 were landslides, 3 were blizzards or heavy snowfalls, 2 were extreme low temperatures or freezing rain, and 1 was a sea ice disaster.

2008: 1. The Wenchuan Earthquake (M8.0) occurred in Sichuan on May 12; 69,227 people died, 374,643 people were injured, and 17,923 people were missing (Chen and Booth, 2011); 2. Extremely low temperature and large amounts of frost, rain, and snow affected 21 provinces in early 2008; 3. Severe Tropical Storm Hagupit affected Guangdong and Guangxi (Li et al., 2013a, b); 4. A serious flood occurred in south central China in June; 5. The second most serious drought in the history of Xinjiang occurred (Cao et al., 2015); 6. Autumn flooding along the Changjiang River; 7. The Panzhihua-Huili Earthquake occurred in Sichuan (M6.1, Wang et al., 2011); 8. Sichuan was badly flooded in late September; 9. A serious drought occurred in Ningxia; and 10: Heavy snow occurred in Xizang, affecting 100,000 people.

2010: 1. The Yushu Earthquake occurred in Qinghai on April 14 (M7.1: Li et al., 2011); 2. An extremely large mountain flood and mud-rock flow occurred in Zhouqu, Gansu, on August 8 (Chen, 2010); 3. Southwest China experienced extreme drought from autumn to winter (Qiu, 2010); 4. Torrential rains and flooding occurred from May to July along the mid and lower reaches of the Changjiang River; 5. Northeast China experienced flooding in late July; 6. A mountain flood and mud-rock flow occurred in Ankang, Shanxi; 7. In Guanlingshan, Guizhou, a large landslide occurred on June 28; 8. Typhoon Fanapi affected southeastern China (Ko et al., 2016); 9. Blizzard occurred in the northern part of Xinjiang in early 2010; and 10. A sea ice disaster occurred in the Bohai and Huanghai Seas early in the year (Shi and Wang, 2012a, b).

2011: 1. A storm occurred in western China in autumn; 2. Southwest China experienced drought from summer to autumn (Wang et al., 2015); 3. The Yingjiang Earthquake occurred in Yunnan (M5.8: Lei et al., 2012); 4. Continuous drought occurred from summer to autumn along the mid and lower reaches of the Changjiang River; 5. South China experienced flooding in June; 6. Drought occurred from winter to spring in the winter wheat cultivation area; 7. Typhoon Muifa affected mainland China (Liu et al., 2015); 8. Typhoon Nesat greatly affected southwestern China (Yang and Hou, 2014); 9. South China experienced a freezing rain and snow disaster; and 10. The Xizang Earthquake occurred on September 18 (M6.8: Prajapati et al., 2013).

2012: 1. Floods, storms, and hail storms occurred in northern China in July; 2. The Yiliang Earthquake occurred in Yunnan on September 7 (M5.7: Lim et al., 2014); 3. Extremely large mountain torrents, hail, and mud-rock flow occurred in Minxian, Gansu on May 10; 4. Typhoons Saola and Damrey occurred in August (Chen et al., 2015); 5. Floods, storms, and hail storms occurred in June; 6. A drought occurred in Yunnan from the winter of 2011 to the spring of 2012; 7. Sichuan and central China were affected by flooding in July; 8. Sichuan and Chongqing experienced torrential rain and flooding in August; 9. Flooding occurred in southern China in July; and 10. Hunan experienced torrential rain and flooding in June.

2013: 1. The Lushan Earthquake occurred in Sichuan (M7.0: Liu et al., 2014); 2. Flooding, storms, and hail storms occurred in northeastern China in August; 3. Sichuan, northwestern, and northern China experienced flooding in July; 4. The Minxian Earthquake occurred in Gansu (M6.6: Xu et al., 2014); 5. Extreme heat and drought occurred in southern China from July to August; 6. Typhoon Utor affected large areas of China (Meng and Wang, 2016a, b); 7. In Mozhugongka, Xizang, a large landslide occurred in March; 8. Typhoon Fitow severely affected mainland China (Xu et al., 2016); 9. Storms, hail, and flooding affected Sichuan and central China; and 10. The Songyuan Earthquake occurred in Jilin (M5.5).

3. Other recent disasters in China

(1) Forest fires
Forest fires occur almost yearly in China. In May 1987, Heilongjiang experienced a serious fire, with a burned area greater than 1,000,000 ha, with 70% of the burned area being forest (Shu et al., 2003). Between 2010 and 2012, 7,723 forest fires occurred, burning a total area of 1.16 million ha. In 2013, 3,626 forest fires occurred and 12,400 ha of forest were burned.

(2) Desertification
The total area of desert in China is 1,739,700 km², occupying 18% of the total Chinese land area. Desert lands enlarge at a rate of 1,560 km² per year in the 1950s. However, the rate of expansion increased to 2,460 km² per year in the 1990s. It is said that the rate will continue to increase if no remedy measures are enforced. Desertification is a significant factor leading to the deterioration of western China’s environment, manifesting in the loss of stabilizing vegetation cover and nutrients, and the destruction of soil structure and moisture-holding capacity. China’s annual soil loss due to desertification is estimated at 5 billion tons, according to a recent report released by the Asian Development Bank (Berry, 2003).

(3) Fog and haze
Eleven fog and haze events occurred at the beginning of 2013, affecting 1.3 million km² and 6 hundred million people (Che et al., 2014).

(4) Sand and dust storms
Eight sand and dust storms occurred in the 1960s, 13 in the 1970s, 14 in the 1980s, and 20 in the 1990s. One severe sand and dust storm occurred in 2002, which lasted 49 hours and affected a total area of 1.4 million km² and 1.3 hundred million people (Lu and Wang, 2003).

4. Biodiversity in China
China is the richest source of biodiversity in the Northern Hemisphere and is considered a megadiverse country. China has over 30,000 species of higher plants, placing it third in the world (Wu et al., 1994). Among these plants, 2,200 species are mosses (9.7% of the world total, 106 families which represent 70% of the world total); 52 families and 2,200–2,600 species are ferns (80 and 22% of the world totals, respectively); 250 species in 10 families are gymnosperms; approximately 30,000 species in 3,123 genera; and 328 families are angiosperms (approximately 75 and 10% of the world total of families and species, respectively). China is also rich in animals. There are 6,347 species of vertebrates (13.97% of the world total); 1,244 species of birds (13.1% of the world total); and 3,862 species of fish (20.3% of the world total). Most invertebrate species, including insects, lower plants, fungi, bacteria, and actinomycetes have not yet been identified. Many organisms in China are endemic, such as the giant panda (Ailuropoda melanoleuca), white-flag dolphin (Lipotes vexillifer), Metasequoia glyptostroboides, Davidia involucrata, Cathaya argyroa, Cathaya argyrophylla, and Cycas panzhihuaensis. Among the 30,000 species of higher plants, approximately 17,300 species are endemic to China, representing 57% of the total number of higher plants in China (Wu et al., 1994).

China has a history of over 7,000 years of farming and domestication, with abundant germplasm resources of cultivated plants and domesticated animals. Many plants and animals upon which human beings rely, and their kindred species, originate or are kept in China. According to recent reports, China has 1,938 cultivars or types of domesticated animals and insects, over 1,000 economic plant species, approximately 11,000 medicinal plant species, 4,215 forage plant species, and 2,238 ornamental plant species (Zheng et al., 2012). China is one of the countries of origin for rice (Oryza sativa) and the country of origin for soybean (Glycine max), with 50,000 local rice cultivars and 20,000 soybean cultivars (Zuo, 2001).
5. Possible influence of disasters on biodiversity in China

The types of disasters that occur most frequently in China are floods, earthquakes, droughts, typhoons, storms, and hail. These disasters might directly influence or harm biodiversity or they may have more significant secondary effects on biodiversity. Earthquakes can cause landslides and create barrier lakes. Species from earthquake-affected areas may be destroyed directly or affected by the loss of habitat or food sources. One example from China is the migration of giant pandas due to the 2008 earthquake in Wenchuan, Sichuan. Flooding can directly impact many species, especially domestic animals and cultivated plants. Most species in remote areas of China are important genetic resources for breeding purposes; these cannot be recovered once lost. Drought can lead to the death of many plants and animals, and occur frequently in China; however, the exact influence of drought on biodiversity in China remains unknown. The destruction of biodiversity by mud-rock flows and landslides depends on the scale of the disaster. However, some species would become locally extinct if such a disaster were to occur in a habitat with an extremely small population. Extremely low temperatures and freezing rain have occurred regularly in China in recent years. These disasters could lead directly to the destruction of many species, particularly in the subtropical and tropical climates of southern China. Forest fires may be one of the most critical disasters causing a decline in biodiversity. Major forest fires occur yearly in China. However, very few studies have been conducted on the number of species destroyed, threatened, or newly appeared following forest fire. Desertification is a significant factor leading to the deterioration of the environment, particularly in western China. All of these changes can directly influence the present status of biodiversity in China. One severe sand and dust storm occurred in 2002; however, the extent of the influence of such disasters on biodiversity is unknown.

6. Conclusion

It is certain that disasters not only destroy human life and property but also greatly influence biodiversity. However, very few studies on the influence of natural disasters on biodiversity have been conducted in China or globally. It is time for us to take international action to discuss the influence of disasters and to establish an international protocol for future precautionary approaches to minimize the influence of natural disasters on biodiversity.

We suggest that the following points should be the focus of future research on DAB: 1. Understanding the importance of DAB; 2. The collection and accumulation of basic data or information; 3. Long-term monitoring; 4. The development of methodology for DAB research; 5. The establishment of stable and long-term funds to support DAB research; 6. Personnel training; 7. International cooperation and exchange; and 8. Governmental support.

References


Disasters and biodiversity in the Ring of Fire of the Indonesian archipelago

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Abstract

Indonesia is situated in the so-called “Ring of Fire,” one of the most active natural disaster regions in the world, highlighting its need to pay serious attention to the impacts of disasters. More than 20 major earthquakes in the last 60 years have been recorded along the Indonesian archipelago, and more than 127 volcanic mountains, including Krakatau, Tambora, and Gamalama, are known in Indonesia. Natural disasters may significantly affect the ecosystems of Indonesia, which has one of the highest levels of biodiversity and species endemism in the world. Although the details of these effects remain poorly understood in Indonesia, there have been some studies on biological recovery after disasters and the importance of natural ecosystems, such as mangroves and beach vegetation, for reducing disaster impacts. Among biodiversity surveys related to natural disasters in Indonesia, the best-documented case is the post-eruption recovery process following the catastrophic eruption of Krakatau in 1883. For more than 100 years, monitoring has continued to reveal the recovery process on a tropical island ecosystem. Collaborations among hundreds of scientists from numerous countries have detailed many post-eruption geological and biological phenomena. The Indonesian government and public have paid considerable attention to risk management and natural disaster impact reduction, especially after the catastrophic destruction caused by the Aceh tsunami in 2004. The government of Indonesia officially established a special board (BNPB) to manage disasters at the national, provincial, district, and local level. The board is also responsible for promoting public awareness, establishing early warning systems, and holding various training activities. The budget allocation for disaster management is also increasing annually, although it remains very small relative to the area to be covered. Unfortunately, the impacts of disasters on biodiversity loss are not well documented and only sporadically reported for different sites, in the absence of a national agenda. International collaborations for managing natural disasters, by sharing experiences and establishing standard regulations for the region, are strongly recommended.
Keywords: Biodiversity, BNPB, Disaster, Indonesia, Krakatau, Local knowledge, Tsunami, Volcanic eruption

1. Introduction

Natural disasters can have significant impacts on humans, infrastructure, public facilities, industries, biodiversity, and natural environments. Humans and their supporting infrastructure usually receive the most immediate attention following a natural disaster, while impacts on biodiversity and other important facets of the environment are given the lowest priority or, in places like Indonesia, are simply ignored. Natural disasters, such as earthquakes, volcanic eruptions, and tsunamis, are much more challenging than anthropogenic disasters because they are difficult to predict and avoid using current technologies. The best available solution is to minimize the risks and impacts of any disaster to humans and their supporting infrastructure.

The Indonesian archipelago, comprising ca. 17,000 islands, is part of a subduction zone known as the “Ring of Fire,” along with the Philippines, Japan, Canada, Central America, and Peru–Chile (South America). Geographically, the Indonesian archipelago is part of the Eurasian and Australian continents. These two continents are still moving actively along the western part of Sumatra, the southern part of Java, the Lesser Sunda Islands, Moluccas, and the Philippines, as well as the western part of Papua. Indonesia is thus situated in one of the most geologically and climatologically active regions in the world, where various types of natural disaster occur frequently, including earthquakes, volcanic eruptions, tsunamis, landslides, floods, tropical cyclones, droughts, and forest fires. In the last 60 years, more than 20 major earthquakes have been recorded along the subduction zone of Indonesia. Indonesia also has more than 127 high volcanic mountains; some of these are still active, while others are in either in temporary or long-term dormancy. The active volcanoes are scattered across the country, and include mountains on small islands, such as Krakatau, Mt. Tambora on Sumbawa Island, and Mt. Gamalama on Ternate Island. Volcanic eruptions and earthquakes on small islands are usually followed by tsunamis. The largest tsunami in Indonesia in the last 15 years was the Aceh tsunami in December 2004, which killed nearly 230,000 people both during and after the wave impact. This event forced the government and public in Indonesia to confront the fact that a country with millions of people along the Ring of Fire is at high risk for many natural disasters.

During the six decades since its independence, the Indonesian government has focused on developing its rich natural resources, including petroleum, gas, minerals, as well as forest-based materials, like timber, and other bio-resources. In many cases, economic growth has been driven only by raw materials (without any technological inputs), often through environmentally unsustainable practices. Consequently, Indonesia is faced with many environmental problems, including land degradation, agricultural contamination, significant losses of various types of vegetation, species extinctions, and genetic erosion. Such problems have negatively impacted public health via water and air pollution. In 2015, Indonesia struggled with an extended dry season and, in many regions, subsistence farmers could not cultivate plants for food. For a developing agricultural country like Indonesia, drought and lack of clean water are serious problems. Studies have suggested that recovering from environment destruction and
biodiversity loss is much more expensive than neglecting economic growth. This means that maintaining environmental health, biodiversity, and habitats is much more important than the immediate benefits of economic growth. The World Bank estimates show that, over the last 10 years, the annual economic impact of natural disasters has corresponded to 0.3% of Indonesia’s GDP, or about US $1.5 billion (Gunawan and Mahul 2011). Major earthquakes (occurring once every 250 years) may also cause losses in excess of 3% of national GDP (Gunawan and Mahul 2011).

2. Impact of disasters on biodiversity

Indonesia has one of the highest levels of biodiversity in the world, with numerous vegetation types and high species richness and endemism (Myers et al. 2000; Murray et al. 2015). Although the biodiversity of Indonesia is under active study, the exact number of species (and their genetic diversity) remains unknown. During the last few decades of economic development, Indonesia has intensively explored its natural resource options, including conversion of forests for various activities. Rates of vegetation change and biodiversity loss are presumed to be very high, including those due to natural disasters; however, the specifics of these losses remain poorly studied and are generally reported only sporadically, without any national-level guidelines.

2.1. Bird populations after volcanic eruptions

As mentioned above, Indonesia is situated in one of the world’s principal areas of active volcanism. In many regions, no information is available on biodiversity before volcanic eruptions, so the direct influence of these disasters on biological losses or the extinction of local species remains unknown. A 10-day survey of avifauna during June–July 2000 on Gunung Tambora (2,850 m), Sumbawa Island, which was the site of the greatest volcanic eruption in recorded history in 1815, revealed that bird diversity around the volcano was significantly lower than that typically found on the rest of the island (Trainor 2002). Only 11 of 19 range-restricted bird species known in Sumbawa were recorded, with speculation that several absences were due to the eruption. All 11 range-restricted species were observed at 1,200–1,600 m, and 10 were found above 1,600 m, highlighting the conservational significance of hill and montane habitats (Trainor 2002; see also Johnstone et al. 1996).

2.2. Influences of invasive alien species on natural habitats

Invasive alien species (IAS) are aggressive species that influence the populations of local species and natural ecosystems, including protected areas. IAS have become a global issue and are identified as a priority in Aichi Biodiversity Targets (https://www.cbd.int/sp/targets/). Indonesia has responded to this issue, and biologists are actively preparing a national check-list of invasive plants and animals. Eighteen months after an eruption, 10 species of exotic plants were identified in Mt. Merapi National Park, Central Java, namely *Acacia decurrens*, *Calliandra calothyrsus*, *Leucaena leucocephala*, *Dalbergia latifolia*, *Pinus merkusii*, *Sesbania grandiflora*, *Mangifera indica*, *Artocarpus heterophyllus*, *Tectona grandis*, and *Psidium guajava*. *Acacia decurrens*, which is considered an invasive species (Gunawan et al, 2013), grows rapidly and aggressively, covering most types of vegetation due to its intensive seed dispersal. In the park, it had a population density of 2,697 individuals/ha, which was greater than that of many local species, such as *Schima walichii*, which had a population density of 2,632 individuals/ha. Local pioneer species identified in Mt. Merapi National Park included *Ficus fistulosa*,
Macaranga triloba, Paraserianthes lopanth, Schima wallichii, and Trema orientalis. These species are critical to the recovery of natural vegetation; their protection, along with control measures for Acacia decurrens, should be prioritized in restoration programs conducted at the park (Gunawan et al., 2013).

2.3. Post-eruption species dynamics—Mt. Merapi is an active volcano in Central Java (Gertisser et al., 2011). The last eruption, in 2006, caused a fast-moving gas cloud to travel 7 km down the southern slope of the mountain along the Gendol River (Charbonnier & Gertisser, 2008, 2009; Gertisser et al., 2011). This event had significant impacts on the local human population, agriculture, and biodiversity. Two years after the eruption, an international collaborative research project monitored five plots (50 × 20 m) for 18 months to elucidate the succession processes of species in the area. The initial results of this study can be used as a basic reference for post-eruption forest rehabilitation strategies and supporting management programs in Gunung Merapi National Park (GMNP).

2.4. Geological and biological studies after volcanic eruptions—The first documented geo-biological study after a disaster was that following the eruption on Krakatau Island on 27 August 1883. Krakatau, or Rakata, is a small island lying between the islands of Java and Sumatera. The eruption was at level 6 on the volcanic explosivity index (VEI). This is only slightly lower than the eruptions of Mt. Tambora on Sumbawa Island in 1815 (level 7 VEI) and Lake Toba in Sumatra (level 8 VEI) 74,000 year ago. The eruption of Mt. Krakatau was about 21,574 times stronger than the Hiroshima atomic bomb explosion (De Neve, 1984). It killed ca. 36,000 people, with the resulting tsunami reaching India and Africa. The eruption also had significant impacts on the agriculture, infrastructure, and biodiversity of the islands around Krakatau, the western part of Java, and the southeastern part of Sumatra.

The catastrophic eruption on Krakatau not only demonstrated the potential significance of impacts on people, infrastructure, and biodiversity, but also provided an opportunity to learn how barren lands or islands can recover naturally. The island was destroyed and no organisms remained alive after the eruption (Treub, 1888). In June 1927, a sandy mound, 10 m long and 8.93 m high, appeared in the ocean following a small eruption. This was a new volcano, later named Anak Krakatau, which grew gradually via repeated eruptions and flowing lava streams (Global Volcanism Program, 2013). In 2006, the height of Anak Krakatau had reached 315 m above sea level (Hoffmann-Rothe et al., 2006).

2.5. Biological recovery after a disaster—The influence of disasters on regional biodiversity can be estimated indirectly by studying recovery and re-vegetation processes in any disturbed forest. Plant species in nearby areas are the main sources for re-vegetation. Natural recovery processes after eruptions are critical for understanding the re-vegetation process. Small barren islands can be treated as natural laboratories allowing evaluation of primary succession processes. In the case of the 1883 Krakatau eruption, hundreds of scientists gathered to discuss various issues related to geology, biology, and society. Botanical surveys of the island after the eruption were conducted by Treub in 1883, 1886, and 1897 (see Treub, 1888), Ernst in 1908 (see Ernst, 1908), Backer in 1908 (see Backer 1909), and Docters van Leeuwen from 1911 to 1932 (see Docters van Leeuwen, 1936). Tagawa et al. (1985) reported that the first dominant species on Rakata Besar was Casuarina equisetifolia in 1897, followed by Terminalia
catappa in 1897, Neonauclea calycina in 1905, Timonius compressicaulis in 1928, Dysoxylum caulostachyum in 1931, and Schefflera polybotrya in 1951. On Rakata Kecil, the first three dominant species were C. equisetifolia, Terminalia catappa, and Timonius compressicaulis in 1896, followed by N. calycina and D. caulostachyum. On Sertung island, the succession process was nearly identical to that of Rakata Besar, although T. compressicaulis, D. caulostachyum, and S. polybotrya were not recorded.

2.6. Maintaining natural barriers—The Aceh tsunami destroyed nearly everything in North Sumatera except for some mangrove vegetation, dense coconut plantations, and small hills along beaches. Based on preliminary surveys, mangroves and beach vegetation along coastal areas protected local communities from the wave. Beach vegetation and dense coconut plantations also helped reduce the strength of the wave and provided a buffer against coastal erosion. These features act as natural barriers, protecting lowland areas from tsunamis. Coral reefs act as natural breakwaters, which also reduce the strength of waves before they reach the shore. Rehabilitation of mangrove ecosystems using local species was strongly recommended by Indonesian scientists following the Aceh tsunami (Laso Bayas et al., 2011). Due to the small number of mangrove species that survived the Aceh Tsunami, rehabilitation was conducted using different plant species from the other side of Aceh (Universitas Syiah Kuala, Banda Aceh, pers. comm.).

3. Government policy, public awareness, and local knowledge
The unexpected disaster of the Aceh tsunami forced the government and public in Indonesia to confront the fact that a country with millions of people living along the Ring of Fire is at high risk for many natural disasters. Human coastal populations are threatened by tsunamis, while those who live at higher elevations near active volcanoes, particularly farmers, are faced with volcanic eruptions, which can be followed by hot lava, cool lava flows with flooding, and poisonous gases.

3.1. Indonesian National Board for Disaster Management—The Indonesian National Board for Disaster Management, or Badan Nasional Penanggulangan Bencana (BNPB), was established in 2008 to replace the National Disaster Management Coordinating Board (the advisory board for natural disasters), which was established in 1979. The BNPB reports directly to the president, who also appoints the chairman. Politically, the BNPB holds a very strong position within the government. The implementation mechanism of the BNPB is supported by coordinating boards in provinces, which are chaired by governors, and by district-level boards, which are chaired by mayors of districts or cities. This structure allows direct, central instruction and control of disasters, to organize local resources, support facilities, and preliminary recovery efforts. The BNPB, in collaboration with the Centre for Volcanology and Disaster Hazard Mitigation, issues regular information bulletins about the status of alerts for certain Indonesian volcanoes, to warn residents of likely threats and help plan emergency response activities. The alerts are also useful for visitors who may be planning trips to various sites in Indonesia.

Unfortunately, due to national financial limitations, the board has noted that support for disaster responses in Indonesia remains limited. Only Rp 4 trillion (around US $470 million) was allocated to disaster relief efforts in Indonesia during 2010–2011. Although this represents a 30% increase from 2009, it still may be insufficient to deal
with a major catastrophe, or a series of moderate to severe disasters, in a given fiscal year. More importantly, budget re-appropriation is required after almost every disaster. One study estimated that the immediate liquidity required for public post-disaster recovery could exceed US $2 billion for major disasters (Gunawan and Mahul 2011). The fund is still very limited given the huge area that needs to be covered, in which a high number of disasters of varying degrees of severity could occur. Thus, Indonesia still requires more disaster funds (The Jakarta Post, 23 July 2011).

3.2. Never forget—Early warning systems for disasters have been established in many parts of Java and Sumatera. Recently, warning systems for landslides were also established in two high-risk regions, Cilacap and Banyumas (both Central Java) (Kompas 3 September 2015). This system can be integrated with any other system, which helps local people respond to risks as early as possible. However, early warnings may not always help local people, due to indifference in those in danger of being affected by disasters. Additionally, some facilities to monitor mountain and ocean earthquakes do not work properly. The purpose of recently established evacuation points in many open areas is also not well understood by local people, who often use these areas simply as daily meeting points without understanding their function during a disaster.

More than 10 years after the Aceh tsunami, many people have forgotten, or are unaware of, the dangers of tsunamis and earthquakes. This is true not only of people in general, but also of communities living in and around these dangerous environments. Local farmers near active volcanoes, such as Gunung Merapi in Central Java and Gunung Gamalama on Ternate Island, simply enjoy their daily lives, despite early warning systems reminding them of the need to relocate.

Currently, the government of Indonesia is promoting public awareness of dangerous situations. This promotion is called melawan lupa, which means “against forgetting.” There are regular discussions, promotions, and advertisements informing the public that they live in a region at high risk of volcanic eruptions, landslides, earthquakes, and tsunamis. The most important consideration is to encourage local people to participate actively and to inform them of what to do when disasters strike.

3.3. Indigenous and local knowledge systems—The collective memories of local communities, as well as indigenous knowledge, e.g., among the Simeuleu people from a small island close to the Aceh earthquake epicenter, should also be considered. In the time leading up to the tsunami impact, all of the residents on the island reportedly ran toward the hills when the sea level dropped. Only 7 of 78,128 people living on the island were killed by the tsunami. They learned from their ancestors that tsunamis follow shortly after drops in sea level and, in this situation, they ran for high ground without looking back. The memory of the local community stems from “Smong 07,” a large tsunami in 1907. The Simeuleu people traditionally tell new generations about this episode to keep the memory of the danger alive. This is the best way to pass such information from one to generation to the next. The contributions of indigenous and local knowledge of dangerous tsunamis in these communities should be recognized and respected. This is consistent with the Busan Outcome (United Nations Environment Programme, 2010), which includes the following Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) principle: recognize and respect the contribution of indigenous and local knowledge to the conservation and
sustainable use of biodiversity and ecosystems (IPBES Operating Principles 4; http://www.ipbes.net/about-us).

4. Conclusion
Indonesia is situated in one of the most active natural disaster regions in the world, where earthquakes, volcanic eruptions, tsunamis, landslides, floods, droughts, and forest fires frequently occur. Government and public attention regarding such disasters is mainly focused on the impacts on humans and infrastructure. Impacts on biodiversity and other important facets of the environment are given the lowest priority, and are outright ignored in some provinces in Indonesia. The government and politicians in Indonesia have paid serious attention to natural disasters for a long time, establishing the BNPB and allocating an annually increasing proportion of the budget to disaster management. However, the funds are still quite low relative to the huge area that needs to be covered. Public awareness is an important issue and the active participation of local people needs to be encouraged to reduce the impacts of future natural disasters.

Studies of the impacts of natural disasters on biodiversity have focused on locations featuring active volcanoes, where significant degradation of bird populations may be observed after eruptions. Issues such as IAS entering protected areas, re-vegetation processes on small islands after eruptions, and the importance of mangrove vegetation for reducing the impacts of tsunamis have also received considerable attention. A national agenda for evaluating and documenting the impacts of natural disasters on biodiversity, and the loss of important environmental features, is critical, as is strengthening regional and international research collaborations related to the impacts of natural disasters.

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Disaster and Biodiversity in New Zealand: Review and considerations

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Abstract

New Zealanders are exposed to a host of natural hazards, which can trigger an environmental cascade with disastrous effects. Disasters are a significant and rising cost to communities. The impacts are generally measured in terms of human hardship, property damage and loss of life. The severity of a disaster depends on the affected people’s resilience and their ability to recover. In many cases the impacts will be further exacerbated by climate change. Recovery efforts following a disaster are largely driven by socio-economic and political considerations; preserving biodiversity generally gets a lower priority. Annually billions of dollars are invested, but reconstruction efforts often are hastily conceived without adequate local community engagement or scientific input. Recent evidence suggests our best intentions may actually contribute to an even greater loss of biodiversity in the aftermath of a disaster and could prolong or alter the successional changes occurring in natural communities. We must assist the victims of disasters with urgency and compassion, but at the same time disaster recovery should be accomplished in an environmentally sensitive and sustainable manner that balances environmental quality with sustainable economic aspirations.

Keywords: Biodiversity, Environmental cascade, Climate change, Disaster risk reduction and recovery, Ecosystem function, Feedback loops, Interdependent networks, Wellbeing

1. Introduction

Our world is rapidly changing (McKibben, 2010). Average global temperatures are increasing. Sea levels are rising, inundating many low-lying coastal areas putting them at greater risk to typhoons and tsunami. The oceans are getting warmer and increasing in acidity, and the altered pH is changing phytoplankton communities, dramatically altering primary food webs. The polar ice caps are melting at an alarming rate decreasing the reflection of the sun's rays back into the atmosphere and increasing the amount of solar radiation absorbed by the deep blue oceanic waters. The Arctic
permafrost is melting, releasing methane, a potent greenhouse gas. Tropical rain forests are being cleared for agriculture at an alarming rate often by illegal slash and burn activities with a tragic loss of biodiversity. Wildfires are increasing in frequency, size and intensity releasing more carbon into the atmosphere and removing a natural carbon sink. Tropical climatic zones are expanding triggering tropical storms at higher latitudes with increased severity. Warm air holds more moisture; the increased rainfall in some regions is causing disastrous flooding while dry westerly air cells are being pushed to higher latitudes resulting in severe droughts in other regions. Glaciers that gradually store and release water throughout the growing season are rapidly declining. Ecosystems and the services they provide are being degraded, and the biodiversity upon which they depend is increasingly threatened. McGuire (2013) examined the occurrence of natural catastrophes at the end of the last ice age and predicts that the disasters caused by earthquakes, tsunamis and volcanic eruptions will occur more frequently as a result of climate change. These global changes will have a profound impact upon the well being of New Zealanders, the resilience of our communities and our ability to recover from the impacts of disasters.

The Convention on Biological Diversity’s (CBD’s) Strategic Plan for Biodiversity 2011–2020 envisages that “by 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people.” The strategic plan has five immediate goals: (A) to address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society; (B) to reduce direct pressures and promote sustainable use of biodiversity; (C) to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity; (D) to enhance the benefits to all from biodiversity and ecosystem services; (E) and finally to enhance implementation through participatory planning, knowledge management and capacity building (Díaz, et al., 2015). New Zealand is a signatory of the CBD and has developed a strategy to inventory the current status of biodiversity and to take actions to halt its decline.

2. General Features Of New Zealand

New Zealand is an isolated island archipelago located in the pacific ring of fire (Ministry for the Environment & Statistics New Zealand, 2015; Te Ara – The Encyclopedia of New Zealand, 2015). It has one of the longest coastlines of any nation in the world and is comprised of two large islands, the North and the South Island and numerous smaller offshore islands. New Zealand lies on both the Pacific and Australian continental plates and is tectonically active. Steep mountain ranges dominate the South Island and extend to the southern two thirds of the North Island. Several active volcanos are found on the North Island. New Zealand lies in latitudinal zones ranging from the subantarctic to the subtropics and experiences rapidly changing unpredictable weather patterns. The complex climatic gradients support diverse vegetation, which ranges from subantarctic cushion plant communities to subtropical rainforests. The soils in New Zealand are derived from diverse parent materials, but are generally low in nutrients. Because of its isolation, environmental heterogeneity and unique plants and animals, New Zealand is internationally recognized as a hotspot of biodiversity.

New Zealand was first colonized by Polynesians about 900 years ago, but the land was claimed by British explorers nearly 700 hundred years later (Te Ara – The
Representatives of the British crown and 40 Māori chiefs signed the Treaty of Waitangi on 6 February 1840. The treaty is a broad statement of governing principles and is the founding document of New Zealand. However Māori understanding of the original spirit of the treaty is at odds with those negotiating for the Crown, and contentious debate still remains about treaty violations in particular to rights in respect to protection, guardianship, stewardship and customary use of the natural, physical and spiritual resources of Aotearoa — New Zealand. Māori have a deep spiritual connection with the land, developed through their observations of the natural world of Aotearoa, and incorporating Māori views into environmental policy adds value to New Zealand’s resource management vision.

According to the most recent census there are about 5 million people currently living in New Zealand, but the population density is low (Statistics New Zealand Tatauranga Aotearoa, 2013). Most New Zealanders live in the five population centres, Auckland, Hamilton, Wellington, Christchurch and Dunedin. The primary industries—dairy, wool, timber, and fishing—are resource based, and most of these commodities are exported. New Zealand has recently negotiated the Trans Pacific Partner Agreement (TPPA) with 12 Asian and Pacific-rim nations. The TPPA attempts to address trade issues and liberalize trade and investment. It is significant agreement that encompasses about 40% of global GDP. However many New Zealander’s have voiced concerns about the lack of government consultation and that the full implications of the trade agreement have yet to be realized (Wise Response: http://wiseresponse.org.nz). Opponents fear that global trade agreements could erode hard fought legislation that protects the environment of New Zealand.

New Zealand has a constitutional monarchy with a democratically elected government and a Westminster-style of parliament (Te Ara – The Encyclopedia of New Zealand, 2015). The head of state is a sovereign, currently Queen Elizabeth II. The present Governor-General of New Zealand, Sir Jerry Mateparae, represents the Queen. New Zealand uses a mixed member parliamentary (MMP) system. It is unlikely that one party will win a majority of the seats in the house, so the leading party is then obliged to negotiate an agreement or coalition with minor parties in order to form a majority government to gain the confidence of the house. Bill English, leader of the National Party is the current Prime Minister. There are three branches of central government: legislative (parliament), executive and judiciary (law). The local governments in New Zealand are separated into two tiers consisting of City/District Councils and Regional Councils. They are charged with 1) Enabling local decision-making and acting on behalf of local communities and 2) Promoting the social, economic, environmental and cultural wellbeing of communities in the present and for the future. The City/District Councils perform a variety of services such as roads maintenance, stormwater drainage, community housing and health, while the Regional Councils are responsible for the air, water and soils. Despite a broad consensus about the benefits of public participation in disaster recovery, appropriate local community involvement is complex and difficult to achieve (Vallance 2015). The effected communities have a vital role to play in disaster recovery. Participating in the recovery process provides victims with a sense of control and ownership, which aids their recovery. Additional benefits include cost effectiveness, more efficient delegation of duties, promoting environmental sustainability and community participation and building trust. According to Shaw...
(2014) when autocratic government agencies constrain community participation, they limit the abilities to communities to organize, learn, adapt and ultimately recover from disasters.

2.1 State of the New Zealand environment

New Zealand was among the last places on Earth to be settled by humans, but has one of the worst records of indigenous biodiversity loss (Ministry for the Environment & Statistics New Zealand, 2015). Throughout most of its history the biota of New Zealand has evolved in isolation. However the land was dramatically altered shortly after the arrival of the first humans, and almost all of the productive land has since been cleared for agriculture or urban development. The indigenous taxa of New Zealand and the ecosystems in which they live are under immense pressure from human-induced changes, predators, invasive species, urban development and the intensification of farming. Nearly 80% of the native land birds, 90% of the lizard species, and 40% of the vascular plants of New Zealand are threatened with extinction. The environmental quality of freshwater ecosystems is declining. Large increases in the application of fertilizers to support intensive farming, especially dairy, have lead to increased nutrient levels and algal blooms in once pristine rivers and lakes. The intensification of farming and urban development has lead to an increase in the emission of greenhouse gases. The Environment Aotearoa 2015 (Statistics New Zealand Tatauranga Aotearoa 2015) report highlights the failure of local and central government to enforce existing legislation to adequately protect the environment.

2.2. Environmental legislation in New Zealand

The Resource Management Act 1991 and the Conservation Act 1987 are the primary legislation enacted to protect the environment of New Zealand. The purpose of the RMA is sustainable management of the natural and physical resources of New Zealand. Provisions within the RMA regulate virtually all of the significant uses of land, air, coastal, or water-related resources. Critics argue the RMA is a barrier to investment. The New Zealand Business Roundtable has long expressed concerns that the act is a cumbersome, time-consuming and costly piece of legislation that adds considerable uncertainty to business decision-making and is a major impediment to the country's economic growth. However Wheen (1997, 2002) notes that a broad interpretation of the RMA reduces sustainable management to a balancing act that is biased towards tangible economic benefits over intangible environmental concerns. The Royal Forest and Bird Protection Society of New Zealand notes that public participation in the RMA is minimised because 95% of resource consents are granted without public notification and less than 1% of applications for consents are declined (MfE 1999–2000 survey). Businesses equate public participation with added costs, but the OECD considers New Zealand to have low environmental compliance costs. At best the consent process is an uneven playing field, as developers usually have better access to legal, planning, scientific experts than the general public. The absence of national environmental standards and policy statements has also led to inconsistency between regional councils in New Zealand.
Fig. 1. The biosphere is comprised of an intricate web of tightly linked interacting systems.

The Conservation Act 1987 is the principal legislation governing the conservation of indigenous biodiversity in New Zealand. The Act established the Department of Conservation (which is responsible for administering the Act) and the Department of Fish and Game. The Conservation Act complements the National Parks Act 1980 and the Reserves Act 1977. The Conservation Act and the management strategies and plans that are created under it have the overriding principle of providing protection for the environment. The Conservation Act also sets out a number of specially protected areas. This is contrasted with the overriding principle of New Zealand's most important planning statute, the Resource Management Act 1991, which is sustainable management. While there is often overlap between the RMA and the Conservation Act, the principle of protection has primacy over sustainable management. An important role in conservation advocacy in New Zealand is ensuring that separation of these visions is maintained, rather than blurred.

3. Natural disasters in New Zealand
The biosphere is an intricate web of interacting systems (Fig. 1). A disaster disrupts these intricate networks in ways that are complex, and we do not fully understand. A disaster is an environmental cascade set in motion by a single event. For example an earthquake could trigger a tsunami, landslides, floods, fires, the release of toxic chemicals, destroying urban infrastructure. This cascading effect makes it virtually impossible to predict the location, timing or full extent of a natural disaster, and this hampers our ability to mend these networks. Disasters vary widely in scale from small weather-related landslides, to large earthquakes, tsunamis, tropical cyclones and volcanic eruptions, which have regional impacts. The extinction of local populations following a natural disaster affects the structure of communities and consequently the functioning of ecosystems.

New Zealand’s are exposed to a host of natural hazards (Hicks and Campbell 1998). Historic records from 1840 onwards suggest New Zealand will experience magnitude 6 earthquakes annually, a magnitude 7 earthquake every 10 years and a magnitude 8 earthquake every century. Every year nearly 15,000 minor earthquakes are detected. Most of these occur along the main mountain ranges trending from Fiordland to the North Cape. The large cities of Wellington, New Hastings and Napier lie along these faults, and have experienced damaging earthquakes. The most severe earthquake magnitude 8.5 occurred in Wairarapa in 1855. About 5500 m² of land was vertically displaced with the maximum uplift of 6.4 m near Turakirae Head. The maximum horizontal displacement was 18 m. The magnitude 7.8 Hawke’s Bay earthquake crippled both Napier and New Hastings and was New Zealand’s deadliest (Fig. 2); 256 people were killed (McSaveney 2016).

Tsunamis with tidal surges greater than 1 m or more have historically occurred about once in every ten years in New Zealand (Power 2013). This is about the same frequency as Indonesia and Hawaii, but about one third of that experienced in Japan. Since 1835 New Zealand has been affected by at least 80 tsunamis; ten of these were higher than 5 m. Most New Zealand tsunamis were generated by seafloor quakes near the New Zealand coast, but a few had distant origins. A meteo-tsunami was caused by air pressure disturbances caused by the blast from the Krakatau eruption in 1883. While there is more warning for distant tsunamis, a tsunami originating near the coast could arrive within minutes. The Puysegur trench, southwest of New Zealand and the Tonga Kermadec trench, northeast of New Zealand are the source of most of the regional tsunamis. The M_w 8.2 Wairarapa earthquake in 1855, the M_w 7.1 earthquake, which occurred 50 km offshore from Gisborne in March 1947 and distant earthquakes in South America in 1868, 1877 and 1960, generated the five most severe tsunamis in New Zealand. Unlike earthquakes, tsunamis impact large areas of coastline and can extend inland up to several kilometres. Depending upon the coastal geomorphology and topography, the inundation depth, run-up and damage can vary significantly over short distances. Bays, sounds, inlets, rivers, streams, islands or artificial channels can amplify the wave height and increase the impact of a tsunami.

The most destructive volcanic eruptions in New Zealand come from rhyolitic volcanos that form super craters called caldera (McSaveney, Stewart and Leonard 2006). Lake Taupo fills a caldera that last erupted about 1800 years ago nearly 1000 years before the first Polynesians colonized New Zealand. During the main eruption the volcano spewed a plume of dust and ash high into the atmosphere spreading pumice and
ash across most of New Zealand, and hot ground-hugging pyrocastic flows incinerated thousands of kilometres of the forested landscape. Before the arrival of European colonists Māori witnessed the eruptions of Tarawera, Rangitoto, Taranaki (Mt. Egmont), Tongariro, Ngāuruhoe, Ruapehu and Whakaari (White Island). Over 70 ash eruptions have occurred between 1839 and 1975, on average about six years apart. Eruptions of lava are less common; they have been witnessed only in 1870, 1949 and 1954.

The weather patterns in New Zealand are complex, rapidly changing and difficult to predict. The prevailing frontal systems are extra tropical cyclones, North Tasman lows, depressions from the south, and Antarctic cold fronts. These systems harbor strong winds caused by large pressure gradients near the centre of low pressure. Extreme winds can also be caused by tornadoes and convective downbursts from isolated thunderstorms that are not associated with a large storm system. Heavy rainfall (more than 100 mm in 24 hours) is one of the most frequent and severe weather hazards to impact New Zealand. Heavy rainfall can trigger flooding and landslips. River floods are the cause of some of New Zealand's costliest disasters (Smart and McKerchar 2010). Between 1999 and 2011 there were 29 flood-related events, 21 of which caused insurance damages exceeding one million dollars.

3.1. The Christchurch Earthquake

Christchurch, the second most populated city in New Zealand, experienced a $M_w$ 6.3 earthquake on 22 February 2011. The earthquake was centred about 2.1 kilometers west of the port of Lyttelton and about 10 kilometers southwest of the city centre. The initial quake only lasted about 10 seconds, but because of its shallowness and proximity to the city the central city and eastern suburbs were badly damaged. The peak ground acceleration was extremely high, and the simultaneous vertical and ground movement made it almost impossible for many buildings to survive intact. Over 10,000 homes required demolition and 100,000 were damaged. One hundred and eighty-five people were killed. Significant liquefaction caused an upwelling of about 200,000 tons of silt. Eighty percent of the residents were without power, and the water and sewage systems were severely damaged. More than 361 aftershocks were recorded in the week following the earthquake.

Fig. 2. Historical records show that New Zealanders are at risk of range of natural hazards. A. Fires along Emerson Street in Napier in the aftermath of the 1931 earthquake B. Damage to Napier caused by 1931 earthquake C. On June 1886, a fissure through the Ruawāhia Dome on Mt Tarawera erupted. The landscape around Rotomahana and Tarawera was stripped of vegetation, thick mud and ash blanketed hundreds of square kilometres of land, and large cracks criss-crossed the region. D. View from Te Wairoa village, about 7.5 kilometres from the terraces. The official death toll was put at around 150, but it is likely more lives were lost. E. On December 1953, the North Island main trunk express plunged off the Tangiwai Bridge into the Whangaehu River. The bridge had been fatally weakened by a lahar from Mt Ruapehu’s crater lake. One hundred and fifty-one lives were lost when the train filled with holiday passengers piled into the swollen river. F. The rain that fell on west Otago on January 16 and 17, 1980 burst the banks of the nearby Pomahaka River and submerged the town of Kelso. G. City center of Queenstown in flood. H. Damage caused by the Franklin tornado of 1948.
A state of national emergency was declared the following day, and a regional command centre was established in the Christchurch Art gallery to coordinate relief efforts. The central city was established as an exclusion zone and cordoned off. The Christchurch police received assistance and resources from throughout the country and were supported by a contingent of police officers from Australia. The New Zealand Fire service coordinated search and rescue services with support from experts from Australia, United Kingdom, United States, Japan, Taiwan, China and Singapore. The New Zealand Defence Force assisted the police providing logistics, supplies, transport, equipment, and evacuations. The New Zealand Red Cross launched an appeal for donations to support the victims, and thousands of volunteers helped with the clean-up efforts.

On 29 March 2011, Prime Minister John Key and Christchurch Mayor Bob Parker announced the creation of the Canterbury Earthquake Recovery Authority (CERA) (2013) to manage the earthquake recovery. Within CERA the Natural Environment Recovery Programme (NERP) was established to “restore healthy and functioning ecosystems, to support biodiversity and economic growth, and enable safe opportunities for outdoor recreation, social and cultural activities”.

Recovery efforts encompass both restoring the damage caused by the earthquake and enhancing the region in the process (Christchurch City Council 2012). NERP was created to identify ways to make improvements to the pre-earthquake state of the environment. The Christchurch earthquakes have raised awareness of the importance of the natural environment to our wellbeing. Having healthy rivers, open spaces and recreational facilities close to home, and reducing and managing our waste, have become more important for people. We now have the chance not only to repair the damage where necessary, but also to use more environmentally sustainable methods to protect and improve the quality and health of our land and waterways (Environment Canterbury 2013).

3.2. Cyclone Ita
On 1 April 2014 a broad poorly defined area of low pressure consolidated over the Solomon Islands. A large dense overcast blossomed over the low on 3 April prompting the Joint Typhoon Warning Centre to issue a Tropical Cyclone Formation Alert. After moving away from Papua New Guinea the storm intensified. It attained peak intensity as a Category 5 severe tropical cyclone on 11 April with wind speeds estimated at 215 km/hour. The storm weakened as it approached landfall in Australia, but the severe gale force winds and heavy rainfall and flooding devastated many communities. The total economic damage cased by Cyclone Ita was estimated at over US$1 billion dollars, and twenty-two people were killed in the Solomon Islands.

When Cyclone Ita struck the West Coast of New Zealand thousands of native trees were toppled in an area that was estimated at more than 20,000 hectares (Brooks, 2015). An estimated several million cubic metres of native trees (Nothofagus spp. Dacrydium cupressinum, Dacrycarpus dacrydioides, Podocarpus totara, Prumnopitys taxifolia, Prumnopitys ferruginea) were blown over during the cyclone. Timber companies, politicians and others promptly called for the trees to be salvaged despite advice from
ecologists about the importance of wind blown trees to the forest ecosystem. Severe storms frequently occur on the West Coast, and the slow decay of windblown trees is a natural cycle in forest succession. Dead and decaying trees slowly release nutrients over time and provide critical habitat to a host of forest organisms. Mining and forestry are important to the economy of the West Coast, but logging of indigenous forests in New Zealand was banned by legislation enacted in 1987. On June 2014 special legislation that overturned protection for windblown trees on the conservation estate was rushed through parliament under urgency with no opportunity for comment from experts or the general public. The West Coast Windblown Timber (Conservation Lands) Bill allows recovery of useable wood in the areas affected by Cyclone Ita, but excludes timber removal from World Heritage areas, national parks, ecological areas and the white heron (*Ardea modesta*) sanctuary reserve at Whataroa. Permission to take the timber is at the discretion of the Department of Conservation (DOC), where the proposed method is safe for workers and the public and has minimal environmental impacts. Logging of the windblown trees began in late 2014. In some areas the fallen trees can be harvested by helicopters, but where the fallen trees are near roads, they are dragged through the forest to portable sawmills. The recovery of the timber will end on July 1, 2019 when the bill expires, and all revenue from royalties will go to DOC. The Department of Conservation will be commissioning research on the effects on forest regrowth and ecology by comparing similar wind-blown areas where timber has and has not been recovered to help make a long-term policy decision on this issue.

4. Reducing the risks of disaster in New Zealand

Disasters are environmental cascades that can be either anthropogenic or natural in origin or can be triggered by a combination of these factors. Disasters brought about by humans result from conflicts or environmental pollution, while natural disasters can be geophysical (e.g. earthquakes, tsunamis, landslides), climatic (e.g. cyclones, floods, droughts) or biological (e.g. epidemics, pest infestations). Small and mid-sized disasters are occurring more frequently and increasing urbanization is placing more focus on the social, economic, and environmental impacts of disasters. According to the World Economic Forum (2015) three of the top disaster risks in the next ten years are environmental risks—water crises, failure to adapt to climate change and the loss of biodiversity.

Reducing the risks of natural disasters in New Zealand is about making wise choices. Each decision and action we take can make us more vulnerable - or more resilient. The severity of a disaster is in part dependent on the choices we make for our lives and for our environment. These choices relate to where and how we build our homes, how we grow our food, what kind of government we have, how our financial system works and even what we teach in schools. Reducing our exposure to natural hazards, lessening vulnerability of people and property, wise management of land and the environment, and improving preparedness and early warning for adverse events are all a part of disaster risk reduction (Yodmani 2001).

Natural communities in New Zealand are remarkably resilient in the event of a natural disaster, and over time recover with little or no human intervention. In fact human intervention during the recovery process can hinder or prolong the processes of ecological succession or completely alter it. Some engineering solutions may have a
greater impact on biodiversity than the disaster itself. When ecosystems are degraded, they are not as resilient in the face of natural or anthropogenic disasters. Biodiversity and ecosystem conservation and restoration play important roles in reducing the long-term risks of disasters and may influence the degree or need for human intervention in mediating the effects of disasters on natural systems (Kusch et al. 2016).

5. Biodiversity, ecosystem function and the wellbeing of New Zealanders
The services delivered by indigenous biodiversity and natural ecosystems contribute in many ways to health and wellbeing (World Health Organization and Secretariat of the Convention on Biological Diversity, 2015). According to Max-Neef’s (1991) theory of Human Scale Development all humans have the same nine fundamental needs—subsistence, protection, affection, understanding, participation, leisure, creation, identity and freedom (Cruz et. al. 2009, Max-Neef 1991). Roberts et al. (2015) examined each of Max-Neef’s fundamental needs and considered how ecosystem services contributed to the satisfaction of these needs, enhancing the wellbeing of New Zealanders. The very essentials for our subsistence—fresh air to breathe, clean water to drink, food to eat, shelter and clothing—come from nature. In New Zealand, the food species we farm and hunt are nearly all imported. By contrast, food from the sea almost entirely consists of species whose natural habitat is in the South Pacific, and whose continued existence depends on intact functioning ecosystems. For Māori, the importance of gathering food from their tribal lands and waters is increasingly reasserted in the post-Treaty settlement era. Nutritious food obtained from healthy ecosystems, and the opportunities to spend time in, recreate in and to be inspired by green and blue spaces contribute to our physical and psychological health. The forests that produce timber and wood fiber for our housing, furniture, paper and a source of heat for many homes in New Zealand are reliant upon a suite of ecosystem services. Although most clothing fiber production in New Zealand uses imported species and materials, the merino sheep and possums that produce the fiber for warm elegant fabrics graze on native tussocks and forests. The energy to power our lives also comes from nature. Fossil fuels are stores of energy that were originally trapped by plants living millions of years ago, while biofuels contain energy that has more recently been trapped by plants. Furthermore hydroelectricity, wind, geothermal and tidal power are all derived from natural systems (Roberts et al., 2015).

While Max-Neef did not consider material wealth as a fundamental need, natural environments nonetheless make a significant contribution to the wealth of New Zealanders. In 2012, 13 of our top 20 commodity exports (accounting for 77.4% of income) came from biologically based sectors (dairy, meat, timber, fruit, seafood, wine, wool, etc.), which depend heavily on intact functioning ecosystems. Tourism generates similar earnings, and again our natural landscapes and unique flora and fauna are key tourism attractions. Further, in 2011, 76.7% of our electricity and 39% of our total energy supply came from renewable energy sources (principally hydro, geothermal, biogas, wood and wind) (Roberts et al., 2015).
6. Summary and considerations
As a society, New Zealanders are using the goods and services provided by nature in an unsustainable manner so are increasingly at risk to the impacts of natural disasters. Indigenous biodiversity helps to protect us from floods, droughts and disease. Forest, tussocks and mosses capture and hold water, reducing the risk of landslides and floods, while wetlands and swamps play a critical role in absorbing floodwaters and purifying our waters. Plants and microorganisms form the basis of nutrient cycles critical for functioning ecosystems and agriculture. There is an increasing need in New Zealand and internationally for public decision making to more effectively take into account the roles played by biodiversity and the provision of ecosystem services on social wellbeing (Roberts et al., 2015). Díaz et. al., (2015) proposed a simplified model illustrating the interrelationships between nature and people (Fig. 3).
There are several key points to consider:

- We must advocate for the victims or natural disaster with urgency and compassion. Involve local communities in the recovery process; learn from them; respect their spiritual connections to the land and the uncertainty and fear that come from surviving a disaster.

- Seek a greater understanding of biodiversity by undertaking fundamental scientific research on the processes that produce and influence biodiversity, the functional ecology of natural ecosystems and their relationship to human based ecosystems and the changes to natural systems that follow a disaster.

- Present a strong unified vision to policy makers and government bodies about the importance of biodiversity and functioning ecosystems to our societal wellbeing. This involves mentoring young scientists, promoting public education of the relationships between society and the natural world, and working to preserve our museum collections, botanical gardens and nature preserves; they hold priceless treasures. We should seek international consensus to strengthen this vision.

- Embrace “soft green” technological approaches to the recovery from disasters that are in harmony with nature and informed by sound science, while acknowledging the necessity of “hard grey” approaches to infrastructure repair and the need for socioeconomic tradeoffs.

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Disaster-induced Changes in Coastal Wetlands and Soft-Bottom Habitats: An Overview of the Impacts of the 2011 Tsunami and Great East Japan Earthquake

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Abstract

We provide a summary of the changes in coastal wetlands and soft-bottom habitats along the northeastern Japanese coast induced by the 2011 Great East Japan Earthquake. Habitat structures were altered through changes in topography, bottom elevation, sediment characteristics, and vegetation, which induced drastic changes in associated biotic communities. Around the Oshika Peninsula (close to the epicenter), most of the intertidal zone was submerged due to the massive scouring effects of the tsunami (max. inundation depth >20 m) and seismic subsidence (max.: 1.2 m). In the brackish lagoons of the Sendai alluvial plain, most reed marshes and tidal flats were washed away, and a huge volume of drifting sand was deposited. Tsunami currents also disturbed the
subtidal soft-bottom community of the Sanriku Ria Coast. We observed the creation of “new tidal flats” following land subsidence, disappearance of vegetation, and/or sediment deposition, which provided benthic invertebrates, birds, and wetland vegetation with new habitats. The tsunami height in Tokyo Bay was <3 m, and the wave impact was minimal. However, massive liquefaction caused mud boiling, the destruction of coastal structures, and lateral flow in the coastal zone. The biotic community in the disturbed area has gradually recovered in the 5 years since the earthquake, but ongoing restoration works, such as land reclamation and construction of seawalls, are potential threats for coastal ecosystems.

**Keywords:** Community structure, Earthquake, Liquefaction, Macrozoobenthos, Soft-bottom habitats, Subsidence, Tsunami

1. **Introduction**

Extraordinarily large physical impacts created by massive tsunamis, such as scouring, deposition of debris, and destruction of coastal structures, can modify coastal habitat structures over broad spatial scales (Jaramillo et al. 2012; Okada et al. 2011). However, understanding of the ecological consequences of huge tsunamis remains limited.

On 11 March 2011, the Pacific coast of northeastern Japan was struck by huge tsunamis (inundation depth: up to 20 m) generated by the M9.0 Great East Japan Earthquake (Okada et al. 2011; Sawai et al. 2012). The earthquake also induced seismotic subsidence (up to 1.2 m near the epicenter) along this coastline (Imakire and Kobayashi 2011). These events caused extraordinary physical disturbance in tidal flats, salt marshes, and sandy shores of the region (Suzuki 2011, Kanaya et al. 2012; Richmond et al. 2012; Szczuciński et al. 2012; Okoshi 2015). Tsunami currents, for example, intensively scoured the sediment of tidal flats, sand dunes, and salt-marshes (Hayasaka et al. 2012; Kanaya et al. 2012; Richmond et al. 2012; Ishida et al. 2015). The moving waters transported huge amounts of allochthonous sediments and debris (i.e., tsunami deposits) and deposited them in the coastal zones (Richmond et al. 2012; Szczuciński et al. 2012; Haraguchi et al. 2013; Seike et al. 2016). Seismotic subsidence and sediment liquefaction also induced changes in the topography and bottom characteristics of the intertidal zone (Suzuki 2011; Kanaya et al. 2015a; Okoshi 2015). In some cases, new intertidal zones were formed due to land subsidence and washout of vegetation (Kanaya et al. 2012; Okoshi 2015; Matsumasa and Kinoshita 2016). These events may have altered habitat structures and their associated biotic communities to different extents depending on the intensity of disturbance across large spatial scales.

Here, we provide an overview of the impacts of the tsunamis and the megathrust earthquake along the northeastern Japanese coast based on our field observations conducted after the 2011 earthquake and available published works. We classified the types of habitat alterations caused by the 2011 earthquake and tsunami across an area extending from Mutsu Bay to Tokyo Bay (Fig. 1). We also reviewed the impacts of the disaster on biotic communities associated with the coastal habitats. Finally, we discuss the potential threats to habitat structures and associated biotas due to ongoing restoration works in the region.
2. Historical records of earthquakes and tsunamis in northeastern Japan
The coastal habitats along the northeastern Japanese coast have been disturbed by tsunamis generated by megathrust earthquakes over the past 1200 years (Table 1). These events have caused severe damage to human populations and their infrastructures and to the structure of estuarine coastal habitats. The 2011 tsunami and the AD 869 Jogan tsunami were among the largest recorded in the Tohoku Region (Sawai et al. 2006; 2012). Sawai et al. (2012) examined the paleontological records of tsunami deposits in Miyagi and Fukushima Prefectures; they found that a tsunami deposit associated with the Jogan earthquake had traveled inland for at least 1.5 km across the coastal lowlands. Deposits were moved similar distances during the 2011 tsunami. Sawai et al. (2012) also indicated that the recurrence intervals of huge tsunamis in the Tohoku Region have been in the range of 500–800 years. Historical records show that smaller tsunamis have occurred more frequently, often several per century (Sawai et al. 2006). Thus, coastal habitats in the Tohoku Region have been disturbed repeatedly by massive tsunamis in the past.

3. The 2011 tsunami disaster
On 11 March 2011, a M 9.0 megathrust earthquake (Great East Japan Earthquake) occurred in the western Pacific (38.322°N and 142.369°E, Fig. 1), ca. 130 km east of Sendai City, Miyagi Prefecture. It generated huge tsunamis with maximum inundation depths of >20 m that impacted broad areas of the eastern Japanese coast (Haraguchi and Iwamatsu 2011, see Table 2). These massive tsunami waves caused radical erosion and deposition of seafloor materials, thereby creating widespread devastation in shallow-marine benthic ecosystems. Infrastructures near the coastline, such as airports, railways, ports, sewage treatment plants, and oil storage tanks were severely damaged (Okada et al. 2011). In many cities along the coastlines of Sendai Bay and Sanriku, oils, automobiles, and houses were burnt in large conflagrations. Seismotic subsidence occurred in eastern Japan; the displacement was greatest (up to 120 cm; Imakiire and Kobayashi 2011) near the Oshika Peninsula.

4. Sediment scouring and deposition
The sediment granulometries of sandy shores, seagrass beds, shallow coastal zones, and continental slopes can often change over vast areas after tsunami events (Narayana et al. 2007; Noda et al. 2007; Whanpetch et al. 2010; Lomovasky et al. 2011). During the 2011 disaster, tsunami intensively scoured the sediments of tidal flats, salt marshes, and subtidal soft-bottoms in the Tohoku region, and deposited huge amounts of allochthonous sediment.
For example, the coastal sediment in the Sendai alluvial plain was washed away and replaced with tsunami deposits consisting of drifting sea sand (Richmond et al. 2012; Szczuciński et al. 2012). Kanaya et al. (2015b) reported that the sediment in Gamo Lagoon became much coarser, organically poorer, and more oxidized after the tsunami; silt-clay and total organic carbon sharply declined, while the redox potential values increased (Fig. 2).
Haraguchi et al. (2013) reported that the sea bottom sediments at water depths of 10–15 m in Kesennuma Bay were largely reworked to a depth of several meters by the 2011
Fig. 1. Tidal flats in northeastern Japan (selected). Code numbers (1–53) match those in Table 2.
tsunami. The mud contents in the subtidal zones of Funakoshi and Otsuchi Bays (water depths: 1.8–20.6 m) on the northern Sanriku Ria Coast (close to site No. 7 in Fig. 1) decreased after this event due to the washout of mud and deposition of coarser sediment particles by the tsunami currents (Seike et al. 2013). These indicate that the sediment environment in the Tohoku Region had been altered substantially.

Fig. 2. Changes in sediment characteristics in Gamo Lagoon in Sendai Bay following the 2011 tsunami. (a) Silt-clay, (b) total organic carbon (TOC), and (c) redox potential (Eh). Modified from Kanaya et al. (2015b) doi:10.1371/journal.pone.0135125.g002.

5. Impacts of sediment disturbance on the macrozoobenthos

Intensive sediment disturbance resulted in losses in the diversity, abundance, and biomass of macrozoobenthos (Kanaya et al. 2012; Miura et al. 2012; Seike et al. 2013; Urabe et al. 2013). Seike et al. (2013) conducted SCUBA surveys of the seafloor structure and the distributions of large benthic animals in subtidal soft-bottom habitats of Otsuchi and Funakoshi Bays (close to site No. 7 in Fig. 1). They showed that patterns of succession and distribution following the tsunami varied markedly among megabenthic taxa, indicating that the impacts of the tsunami were taxon-specific. In Otsuchi Bay, the bivalve *Yoldia notabilis* disappeared after the event, whereas the bivalve *Gomphina melanaegis* was not affected much.

The impacts of the tsunami on intertidal macrozoobenthos were also taxon-specific (Urabe et al. 2013; Kanaya et al. 2014; 2015b). In Gamo Lagoon, for example, opportunistic taxa, such as polychaetes and amphipods, recovered their population sizes within 5 months of the tsunami, but long-lived bivalves and decapods recovered much more slowly (Kanaya et al. 2015b). Thus, the sensitivity and recovery potential of macrozoobenthos are closely linked to ecological characteristics, such as the tolerance of physical disturbance, life-history traits, and life forms.
6. Loss of coastal vegetation
The tsunami extirpated the coastal vegetation of Tohoku Region over broad spatial scales (see Table 2). Hayasaka et al. (2012) reported the washout of sand dune vegetation and the loss of species diversity along the northern Sanriku Ria Coast. Kanaya et al. (2012) also reported sharp reductions in the areas of reed marsh (7.8 → 1.2 ha), sand dune vegetation (8.6 → 0.1 ha), pine forest (4.2 → 2.0 ha), and macroalgal patches (7.8 → 1.8 ha) in Gamo Lagoon, Sendai Bay. As shown in Fig. 3, intensive tsunami currents washed away most of the reed marsh and sand dune vegetation in Gamo Lagoon, creating large unvegetated areas.

![Fig. 3. Disappearance of (a) reed marsh and (b) sand dune vegetation in Gamo Lagoon. Images were captured in (a) June 2004 and June 2014 and in (b) August 2009 and June 2012 by G. Kanaya. Image in the upper-left panel was from Kanaya et al. (2014).](image)

The loss of reed marshes eliminated the habitats of marsh-associated biota (Warren et al. 2002). For example, the marsh-associated gastropod *Cerithidea rhizophorarum* in Gamo Lagoon was close to extinct after the tsunami (Kanaya et al. 2012). The reed marsh in the lagoon had barely recovered 4 years after the event, while the opportunistic annual halophyte *Suaeda maritima* proliferated in the new barren high tide zone (Kanaya et al. 2016). Furthermore, the invasive plant species *Cakile edentula*, which was not seen before the tsunami, increased its population size over the devegetated sand dune in 2013.
Proliferation of non-indigenous plants also occurred on other sandy shores along the Sanriku Ria Coast (Hayasaka et al. 2012). These observations indicate that the coastal vegetation of tsunami-impacted areas is still at an early succession stage. It will take much longer (i.e., several decades) for complete recovery of coastal vegetation (including reed marshes), as reported for other estuarine systems (Warren et al. 2002; Borja et al. 2010).

Fig. 4. Disappearance of intertidal flats in (a) Hoso-ura and (b) Sawada due to seismic subsidence and scouring. Images were captured in (a) May 2010 and July 2011 by T. Suzuki, (b) May 2009 by T. Suzuki, and May 2015 by G. Kanaya.

7. Changes in the intertidal zone: disappearance and creation of tidal flats
Massive sediment scouring and seismic land subsidence have resulted in the disappearance of intertidal flats in the Tohoku Region, especially on the southern Sanriku Ria Coast (Nos. 6–16, Table 2), where the forces of the tsunami and land subsidence were intense. Intertidal sediment in the area was largely washed away, leading to the complete disappearance of intertidal flats (Suzuki 2011). Thus, the sandy intertidal zones of the Orikasa and Unosumai Rivers were mostly submerged after the tsunami. Most of the sandy intertidal flats at Hoso-ura on Shizugawa Bay also disappeared (Fig. 4a). Though the tsunami height was low (< 3 m), the intertidal zone of Mangoku-ura (Ohama, Inodoshi, and Sawada) was submerged due to intense seismic subsidence (>80 cm, Fig. 4b). Changes in bottom elevation affect the spatial distribution of macrozoobenthos, because the species are clearly zoned in relation to tidal level (Wada and Tsuchiya 1975; Miura et al. 2006; Jaramillo et al. 2012).
In northeastern Japan, in some cases, land subsidence formed a “new intertidal zone” in lands behind the shore (see Okoshi 2015). The washout of reed marshes, coastal structures, and houses also contributed to the creation of bare intertidal zones. For example, new tidal flats were created in residential areas (Nagatsura-ura), parking spaces (Ohama and Moune), farm lands (Unosumai, Moune, Koizumi, and Otomo-ura), and reed marshes (Kitakami River, Gamo, Idoura, and Higashi-yachi) in the Tohoku region (Matsumasa and Kinoshita 2016, Authors’ pers. obs.). In Nagatsura-ura, the destruction of houses and coastal structures created a bare intertidal zone near the lagoon edge (Fig. 5a). In Idoura Lagoon, reed marshes and forests behind the shore were mostly washed away by the tsunami, followed by drifting sea sand accumulation in the area, creating a bare tidal flat at Higashi-yachi (Fig. 5b).

The tidal flats created in this manner should function as habitats for intertidal macrozoobenthos, birds, and wetland vegetation. Several macrobenthic taxa immigrated to the new intertidal zones in these areas within 1–2 years of the tsunami (Okoshi 2015; Matsumasa and Kinoshita 2016). In Moune Bay, the manila clam *Ruditapes philippinarum* densely colonized the newly created intertidal zones (Authors’ pers. obs.). A re-established population of the gastropod *Batillaria attramentaria* was also found on the new tidal flats at Otomo-ura, Moune, Ohama, Koizumi, Nagatsura-ura, and Idoura (Matsumasa and Kinoshita 2016; Authors’ pers. obs.). Reclamation of some of the
newly created flats has begun (Okoshi 2015); others remain as nursery grounds for associated biota.

Fig. 6. Impacts of liquefaction in inner Tokyo Bay: (a, b) Sanbanze, (c) Shinhamako, and (d) Oi. Images were captured in (a, b) March 2011 by Takeshi Fukuda, (c) May 2013 by Takeshi Yuhara, and (d) March 2011 by G. Kanaya.

Rebound uplift of land is also ongoing in the area. Around the Oshika Peninsula, the ground level became higher in about 30cm during 4 years after the earthquake (http://www.gsi.go.jp/kanshi/h23touhoku_4years.html). This indicates that the tidal zonation patterns of macrozoobenthos would be changed in future, related to changes in tidal levels.

8. Habitat alteration in the Kanto Region resulting from sediment liquefaction

During the 2011 earthquake, massive sediment liquefaction occurred widely in Tokyo Bay across areas that included reclaimed lands, shorefronts, and tidal flats (Yasuda et al. 2012; Kanaya et al. 2015a; Okoshi 2015). At Sanbanze, which is located in the innermost part of Tokyo Bay, tsunami-induced disturbance was minimal (indicated by the sloping, yet still surviving, nori-culture poles in Fig. 6a). However, coastal structures suffered massive destruction (Fig. 6b) that was attributed to massive sediment liquefaction (Okoshi 2015). In Urayasu City, near Sanbanze, 3680 houses were partially destroyed, sewage pipes were lifted up or broken, and many manholes were horizontally sheared during the 2011 earthquake (Yasuda et al. 2012). On the Yatsu tidal flats and surrounding areas, liquefaction occurred immediately after the earthquake and before
the tsunami arrived (Okoshi 2015). In the intertidal zone of Shinhamako, liquefaction induced a massive lateral flow that caused a large subsidence in the tidal flat (ca. 70–80 cm, T. Yuhara pers. comm., Fig. 6c). After the event, the largest part of the Shinhamako tidal flat was submerged.

Mud boiling occurred in the mid to low tide zones of the Oi tidal flat, and the sediment surface became covered by a 20 cm thick layer of mud (Fig. 6d). As shown in Fig. 7, the silt-clay (fine sediment fraction; <0.063 mm mesh) content in the intertidal zone increased markedly (up to 80%); the water content also increased (see Kanaya et al. 2015a). Although changes in sediment granulometry on the tidal flat were distinct, the macrozoobenthic community structure barely shifted after the earthquake (Kanaya et al. 2015a). The silt-clay content of the Oi tidal flat gradually recovered by 5 months, possibly due to vertical mixing and horizontal dispersal of sediments by waves and tidal currents. Liquefaction was also expected in the Tohoku region (Okoshi 2015), but the tsunami waves masked all traces of the process in this area.
Fig. 8. Disturbance caused by restoration works in (a) the Same River (b) Matsukawa-ura, and (c) Matsushima Bay. Satellite images in (a) (March 2014) and (c) (April 2012) are from Google Earth™. Images were captured by G. Kanaya in May 2014 (upper-central panel) and in May 2015 (lower panels).

9. Impacts of restoration works

Anthropogenic disturbances caused by ongoing disaster restoration works along the northeastern Japanese coast are of increasing concern. For example, the construction of huge sea walls from Osawa to Kuranai on the Motoyoshi shores of the Sanriku Ria Coast (14.7 m high; http://www.kesennuma.miyagi.jp/sec/s019/010/010/020/026/261111/3100261111iinkai_08.pdf) and in Sendai Bay (7.2 m high; http://www.thr.mlit.go.jp/Sendai/kasen Kaigan/fukkou/kouzou.html) is a potential threat to the coastal biotic community (Kanaya et al. 2014).

Fig. 8a shows the reconstruction of a levee in the reed marsh of the Same River Estuary, Fukushima Prefecture. Initially, the administration office planned to construct a strip road on the bank. Since the bank provided a habitat for the endangered burrowing crab *Chasmagnathus convexus*, the road was moved seaward to avoid direct disturbance of the zone of colonization. Though the crabs still colonized the habitats (Authors' pers. obs. in August 2015), impacts of the anthropogenic habitat alteration should carefully be monitored in future. In Matsukawa-ura, reconstruction of flood wall also devastated the local population of the batillarid snails *Batillaria attramentaria* and *B. multiformis* on the landward edge of tidalflat (Fig. 8b). However, mitigation of the tidalflats was done after the bank revetment. In such cases, macrozoobenthos would recolonize the habitat after a certain period of time.

Reclamation is also proceeding in other areas of Tohoku Region, which will disturb or completely burry intertidal flats and salt marshes in the area. Some areas of newly created tidal flats have been reclaimed (e.g., Unosumai, Otomo-ura, and Koizumi; Authors' pers. obs.). Fig. 8c shows the reclamation of a tidal flat in Matsushima Bay.
(Ohtaka-mori) as part of the restoration works. This site provided a habitat for the endangered intertidal limpet *Patelloida pygmaea* (Nakai et al. 2006), but the local population was extirpated during the reclamation works. In Mangoku-ura, almost all tidal flats were lost as a result of subsidence after the earthquake. Sediment excavated from mountain slopes has been transferred to the ocean floor in the region to provide artificial tidal flats for clam aquaculture. It induced highly turbid water in the lagoon and a deposition of fine silt on the sediment surface. The effects of man-made structures on the recruitment of juveniles and the persistence of marine life certainly warrant further investigation (Okoshi 2015).

10. Conclusion
In this review, we provide a summary of the disaster-linked changes in coastal habitats along the northeastern Japanese coast (listed in Table 3). A huge tsunami caused (1) sediment scouring, (2) sediment deposition, (3) vegetation losses, and (4) destruction of coastal structures. Seismic subsidence eliminated some tidal flats but created new intertidal zones in other areas. Liquefaction in Tokyo Bay altered habitats through (1) changes in sediment composition caused by sand/mud boiling, (2) lateral flow and subsidence of tidal flats, and (3) destruction of coastal structures.

Current restoration works also threaten estuarine coastal ecosystems. Restoration projects should avoid the destruction of reed marshes, sand dune vegetation, and tidal flats, especially those that provide habitats for endangered species. The time frame for the recovery of ecological equilibrium in the biotic communities after a massive disturbance event is generally protracted (Borja et al. 2010). Appropriate assessment and adaptive management (see Keith et al. 2011) are required for the conservation of biodiversity in estuarine coastal habitats along the northeastern Japanese coast.

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Table 1. Major tsunamis in Sendai Bay and the Sanriku region since the Jogan Tsunami in AD 869 (selected).

<table>
<thead>
<tr>
<th>Year</th>
<th>M</th>
<th>Tsunami height (m)</th>
<th>Name of earthquake</th>
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<td>?</td>
<td>Jogan</td>
</tr>
<tr>
<td>1454</td>
<td>?</td>
<td>?</td>
<td>Kyotoku</td>
</tr>
<tr>
<td>1611</td>
<td>8.1</td>
<td>3</td>
<td>Keicyo</td>
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<tr>
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<td>Enpoh</td>
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<td>7.5</td>
<td>1</td>
<td>Kyoho</td>
</tr>
<tr>
<td>1763</td>
<td>8.0</td>
<td>1</td>
<td>Houreki</td>
</tr>
<tr>
<td>1793</td>
<td>8.2</td>
<td>2</td>
<td>Kansei</td>
</tr>
<tr>
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<td>7.4</td>
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<td>Sendai</td>
</tr>
<tr>
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<td>8.4</td>
<td>2</td>
<td>Tenpo Tokachi-oki</td>
</tr>
<tr>
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<td>8</td>
<td>2</td>
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<td>1</td>
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</tr>
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<td>2</td>
<td>Nemuro-oki</td>
</tr>
<tr>
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<td>6.9</td>
<td>4</td>
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</table>

Data from Sawai et al. (2006) and Okada et al. (2011).
Table 2 Tsunami heights (maximum inundation depth; m) and land subsidence (cm) in
the tidal flats (selected) of northeastern Japan. Impact types are categories developed
from our field observations.

<table>
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<tr>
<th>No.</th>
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<th>Subsidence (cm)</th>
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<td>−28</td>
<td>Sco, Dp, Vg</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Torinoumi Lagoon</td>
<td></td>
<td>7.9</td>
<td>−23</td>
<td>Sco, Dp, Vg</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Ushibashi Lagoon</td>
<td></td>
<td>10.8</td>
<td>−23</td>
<td>Sco, Vg</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Fukushima Matsukawa-ura</td>
<td>Unoo</td>
<td>9.4</td>
<td>−32</td>
<td>Sco, Dp, Vg</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Uda R.</td>
<td></td>
<td>5.3</td>
<td>−32</td>
<td>Sco, Dp, Vg</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Isobe</td>
<td></td>
<td>7.1</td>
<td>−32</td>
<td>Sco, Dp, Vg</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Pacific coast</td>
<td>Same R.</td>
<td>6.7</td>
<td>−37</td>
<td>Dp, Vg</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>Ibaraki</td>
<td>Naka River</td>
<td>1.9</td>
<td>−24</td>
<td>Sco, Lq, Vg</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Chiba</td>
<td>Pacific coast</td>
<td>Ichinomiya R.</td>
<td>−7</td>
<td>Sco, Lq, Vg</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td></td>
<td>Isumi R.</td>
<td>4.0</td>
<td>−7</td>
<td>Lq, Dp, Vg</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Tokyo Bay</td>
<td>Banzu</td>
<td>2.5</td>
<td>−5</td>
<td>n.i.</td>
<td></td>
</tr>
<tr>
<td>43</td>
<td></td>
<td>Futatsu</td>
<td>2.0</td>
<td>−5</td>
<td>n.i.</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>Yatsu</td>
<td>2.8</td>
<td>−9</td>
<td>Lq, Sb</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>Sanbanze</td>
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<td>−7</td>
<td>Lq, Sb</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>Shindahamako</td>
<td>0.0</td>
<td>−7</td>
<td>Lq, Sb</td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Tokyo Bay</td>
<td>Kasai</td>
<td>2.8</td>
<td>−3</td>
<td>n.i.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td>Run up</td>
<td>Subsidence</td>
<td>Scouring</td>
<td>Vegetation Loss</td>
<td>New Intertidal Zone</td>
</tr>
<tr>
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</tr>
<tr>
<td>48</td>
<td>Oi</td>
<td>1.5</td>
<td>-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Tokyo Port Wild Bird Park</td>
<td>1.5</td>
<td>-3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Tama R.</td>
<td>1.6</td>
<td>-4</td>
<td></td>
<td></td>
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</tr>
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<td>51</td>
<td>Kanagawa Tokyo Bay</td>
<td>Nojima</td>
<td>1.6</td>
<td>-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Ena Bay</td>
<td>2.0</td>
<td>-6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Sagami Bay</td>
<td>Koaijo Bay</td>
<td>2.0</td>
<td>-6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Data from Haraguchi and Iwamatsu (2011). For Tokyo and Kanagawa Prefectures, we used run up heights provided by “The 2011 Tohoku Earthquake Tsunami Joint Survey (TTJS) Group”. Data for Hinuma are from http://www.maebashiit.ac.jp/~tsuchiya/pdf/naka.pdf. b Data from GSI, Japan. n.i., no impact; n.d., no data; Dp, sediment deposition; Sb, subsidence; Sco, scouring; Vg, vegetation loss; New, new intertidal zone; Lq, liquefaction.*
Table 3. Classification of habitat alterations induced by the 2011 earthquake and subsequent tsunamis in the estuarine coastal habitats along the eastern Japanese coast.

<table>
<thead>
<tr>
<th>Cause</th>
<th>Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunami</td>
<td>1. Sediment scouring</td>
</tr>
<tr>
<td></td>
<td>&gt; Disappearance of tidalflat</td>
</tr>
<tr>
<td></td>
<td>2. Sediment deposition</td>
</tr>
<tr>
<td></td>
<td>&gt; Creation of new tidalflat</td>
</tr>
<tr>
<td></td>
<td>3. Vegetation loss</td>
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<tr>
<td></td>
<td>&gt; Salt-marsh</td>
</tr>
<tr>
<td></td>
<td>&gt; Sand dune vegetation</td>
</tr>
<tr>
<td></td>
<td>&gt; Macroalgae</td>
</tr>
<tr>
<td></td>
<td>&gt; Seagrass</td>
</tr>
<tr>
<td></td>
<td>&gt; Coastal forest</td>
</tr>
<tr>
<td></td>
<td>4. Destruction of coastal structures</td>
</tr>
<tr>
<td>Seismic subsidence</td>
<td>1. Disappearance of tidalflat</td>
</tr>
<tr>
<td></td>
<td>2. Creation of new tidalflat</td>
</tr>
<tr>
<td>Liquefaction</td>
<td>1. Sand/mud boiling</td>
</tr>
<tr>
<td></td>
<td>&gt; Changes in sediment type</td>
</tr>
<tr>
<td></td>
<td>2. Lateral flow</td>
</tr>
<tr>
<td></td>
<td>&gt; Disappearance of tidalflat</td>
</tr>
<tr>
<td></td>
<td>&gt; Creation of new tidalflat</td>
</tr>
<tr>
<td></td>
<td>3. Destruction of coastal structures</td>
</tr>
</tbody>
</table>
Impact of the 2011 Tohoku Earthquake Tsunami on Marine and Coastal Organisms

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Abstract

The 2011 Tohoku Earthquake Tsunami damaged the organisms in marine and coastal areas. We reviewed the researches which investigated the effects of the tsunami on the organisms in various habitats including intertidal, subtidal, deep sea and inundated terrestrial areas. Our review demonstrated that the organisms in shallower habitats were more influenced by the tsunami compared to those in deeper habitats. Further, we found that the organisms with shorter lifespan and ones with high dispersal ability were more resilient to the damage associated with the tsunami. There are trends of recovery in many organisms within four years after the tsunami. It will, however, take more time to fully recover their populations. Further research on their recovery process is necessary to thoroughly understand not only the short-term but also the long-term impact of the tsunami on the marine and coastal organisms.

Keywords: Tsunami; Disturbance; Recovery process

Introduction

On 11 March 2011, an earthquake off the coast of the Tohoku region created tsunami waves that struck the Pacific coast of northeastern Japan. The tsunamis with more than ten meters high were recorded at many bays, beaches and rocky shores along the coasts in Iwate, Miyagi and Fukushima Prefectures (Mori et al. 2011). These tsunamis devastated the coastal area and imposed the strong impact on marine and coastal organisms.

Several researches have been conducted to understand the impact of the tsunami on marine and coastal organisms (Table 1). Tsunami is unpredictable event and thus it is not possible to make a research plan in advance to evaluate the ecological impact of tsunami. Therefore, ecological studies associated with tsunami are essentially posteriori survey. However, there are sometimes pre-tsunami ecological dataset being available in tsunami affected sites, the dataset which are usually collected for other research
purposes. These pre-tsunami dataset provide great opportunities to directly compare the population densities and species diversities before and after the tsunami (e.g., Kanaya et al. 2012, Miura et al. 2012, Urabe et al. 2013). Although it is ideal if there are pre-tsunami dataset, there are several ways to estimate the impact of the tsunami without the pre-tsunami dataset. The ecological comparison between tsunami affected area and unaffected area is one way to evaluate the impact of the tsunami (Mukai et al. 2014). Further, researchers can assume that the ecological condition before the tsunami were similar to the conditions which reported in other regions and they can evaluate whether the conditions after the tsunami is significantly deviated from those “regular” conditions (e.g., Grzelak et al. 2014, Toyofuku et al. 2014). Some studies analyzed the sequential dataset after the tsunami to look at the recovery process in the biotic community (Kanaya et al. 2014, Ishida et al. 2015, Seike et al. 2016). Difference of ecological parameters between immediately after the tsunami and after a certain amount of recovery time can be useful to infer the damages caused by the tsunami.

Ecological impact of the tsunami can be different among organisms with different sizes, habitat types and lifestyles. Therefore, in this review, we classify the studies into six categories (macrobenthos, meiobenthos, planktons, nektons, coastal vegetation and terrestrial and freshwater organisms, see Table 1) based on ecology of the focal organisms and discuss immediate damages and recovery process of the organisms in each ecological category. The studies conducted in various organisms in diverse habitats demonstrate that ecological traits and habitat depth are important factors to determine the ecological impact of the tsunami.

**Macrobenthos**

One group of researchers saw the earthquake when they conducted an ecological investigation on macrobenthos at a tide flat in Tokyo Bay. Okoshi (2015) reported how tide flat changed during the earthquake. He described “During the earthquake, wavelike movement observed on the surface of the tide flats. Liquefaction occurred just after the earthquake before the tsunami.” and he further described the detail of liquefaction as follow “There were many sand boils that erupted in tide flats during the earthquake”. Liquefaction pushed many organisms inside the substratum up on the surface of the tide flats (Okoshi 2015). About an hour later from the earthquake, the tsunami hit the Pacific coast of Japan.

The mud snail, *Batillaria attramentaria* was one of the major macrobenthos in tide flats in Tohoku region. Miura et al. (2012) reported that the populations of *B. attramentaria* were severely damaged by the tsunami and they nearly disappeared at some sites despite their density often exceeded a hundred individuals m$^{-2}$ before the tsunami. Similar population destruction occurred in the mud snail *Cerithidea rhizophorarum*. Using the density and distribution data obtained before and after the tsunami, Kanaya et al. (2012) estimated that 99.9% of *C. rhizophorarum* individuals were lost from Gamo Lagoon in Miyagi Prefecture due to the tsunami. In addition, sandhoppers (*Trinorchestia* spp.) which live on the beach also damaged due to the tsunami, though subsequent monitoring showed that they were rapidly recolonized by the individuals recruited form survivors and immigrants within a few years from the event (Ishida et al. 2015).
Kanaya et al. (2012) investigated all kind of macrobenthos in Gamo Lagoon and compared the dataset obtained before the tsunami. Of 79 species recorded before the tsunami, only about a half (47 species) was found a few months after the tsunami. Further 17 observed species were nearly extinct. On the other hand, some group of organisms increased their abundance after the tsunami. In particular, some polychaete and amphipods increased their population size several-fold compared to those before the tsunami (Kanaya et al. 2015a). They are opportunistic species and their high population turnover might facilitate the rapid population expansion at the nearly empty niche after the tsunami (Kanaya et al. 2012). Nine species that disappeared after the tsunami recolonized and recovered their populations by 2013 (Kanaya et al. 2014). Although these results show that the macrobenthos in the lagoon gradually recovered in a few years after the tsunami, about 20 species were still missing in this lagoon, suggesting that it would take more time for the benthic community of the lagoon to recover.

Urabe et al. (2013) conducted the ecological surveys at nine tide flats around Sendai Bay in Miyagi Prefecture. They reported 30 – 80% of the macrobenthos in the tidal flats disappeared after the tsunami. Interestingly, the impact of the tsunami was different among the organisms with distinct life histories. The tsunami imposed greater damages on endobenthic and sessile epibenthic organisms than mobile epibenthic organisms, suggesting that the ecological traits are tightly associated with the impact of the tsunami. In particular, dispersal ability is an important factor to persist against the tsunami or return to the original habitat after the tsunami (Urabe et al. 2013). Further, they found that the changes in community composition were greater for the sites hit by larger tsunamis. This result demonstrated that the ecological impact of the tsunami was correlated with the height and physical energy of the tsunami (Urabe et al. 2013).

The macrobenthic organisms on rocky shore were also disturbed by the tsunami. Takami et al. (2013) reported that more than 50% of adult and 86% of juvenile abalones (*Haliotis discus*) were disappeared after the tsunami at Tomarihama in Miyagi Prefecture. There were strong reductions on the number of juvenile abalones compared to adults, perhaps because the habitat preferred by juvenile abalones were more severely disturbed by the tsunami and many dislodged abalones were transported to unsuitable off-shore or on-shore habitats. The density of the abalone has not recovered even two years after the tsunami at Tomarihama (Kawamura et al. 2014). Sea urchin (*Strongylocentrotus nudus*) which lives at similar habitat as abalone was also severely affected by the tsunami. Ninety-five percent of sea urchin individuals were disappeared after the tsunami at Tomarihama. The adhesive ability of sea urchin is not strong as abalone and thus most of them were dislodged and swept away by the tsunami. The population of sea urchin at Tomarihama was greatly damaged and, as with the case with the abalones, there were no trends of recovery yet at the observations conducted between 2011 and 2013 (Takami et al. 2013, Kawamura et al. 2014). Interestingly, loss of sea urchin and abalone changed the landscape of rocky shore. Several macroalgae were released from grazing pressure by sea urchin and abalone and grew abundantly at the disturbed rocky shore (Takami et al. 2013, Kawamura et al. 2014).

Komatsu et al. (2015) investigated seaweed (*Sargassum* spp.) and seagrass (*Zostera caulescens*) on subtidal area in Otsuchi Bay in Iwate Prefecture. While seaweed on hard substrate located near the mouth and middle of the bay did not significantly affected by the tsunami, the seagrass on the sandy floor at the closed-off section of the bay were
substantially damaged by the tsunami. The physical impact of the tsunami could be larger at the head of the bay since waves generally increase in height as they approach the shore. Further, the hard substrate (rocks) may be heavy enough to remain unmoved during the tsunami, which might protect the seaweed population from the tsunami disturbance (Komatsu et al. 2015).

Tsunami also disturbed benthic community in deeper shore. Seike et al. (2013) compared the macrobenthos assemblages at subtidal soft-bottoms (2.5 – 20 m depth) before and after the tsunami at Otsuchi and Funakoshi Bay in Iwate Prefecture. They found that some benthic animals such as a snail (*Umbonium costatum*), bivalves (*Yoldia notabilis*), *Felaniella usta*), and a sea urchin (*Echinocardium cordatum*) temporally disappeared from at least one of the sampling sites. They might be killed by the tsunami or be temporally moved from their original habitats due to the tsunami (Seike et al. 2013). Further, Seike et al. (2016) investigated sediment cores from 38m below the sea surface to see the presence and vertical distribution of burrows produced by macrobenthos at Onagawa Bay in Miyagi Prefecture. While bioturbation was only found near the surface of the cores in 2012 and 2013, there were clear evidences of biogenic sedimentary structures in the lower part of the cores in 2014, suggesting macrobenthos which once disappeared from this area recolonized within three years after the tsunami event.

**Meiobenthos**

Beaches in Tohoku region was covered by the tsunami and the strong current of the tsunami scoured the sediment (Kanaya et al. 2015b). There were significant coastal erosion at beaches but some of them were filled with sand shortly after the tsunami (Goto et al. 2012). Grzelak et al. (2014) investigated the meiobenthos community in five beaches along the Sendai Bay. They found rich meiobenthos assemblage in the study sites about two months after the tsunami. This indicates that the meiobenthos community rapidly recovered after the tsunami disturbance. Indeed, several studies demonstrated that the resilience of meiobenthos is extremely high and meiobenthos community can often recover to typical condition within one week after the disturbance (Kotwicki and Szczucinski 2006, Schratzberger et al. 2006).

The earthquake and tsunami also affected deep sea floors. Meiobenthos assemblages were investigated using sediment cores at the deep-sea stations located 120 – 5600m water depth (Kitahashi et al. 2014, Nomaki et al. 2015). Kitahashi et al. (2014) reported that the meiobenthos densities after the tsunami were not significantly different from those before the tsunami. Consistent with Grzelak et al. (2014), this result also supported that the meiobenthos community is highly resilient. However, there were evidences that the deep sea meiobenthos communities were once strongly affected by the tsunami since there were the significant changes in their vertical profile after the tsunami. Kitahashi et al. (2014) documented the unusual distribution of meiobenthos along the vertical profile of the sediment cores. Although meiobenthos are generally abundant at the topmost part of the sediments, they were abundant at deeper subsurface sediment after the tsunami. Nomaki et al. (2015) also reported that the higher density of nematodes and prokaryotic cells at the subsurface compared to the topmost part at two study stations. These unusual distribution patterns can be explained by the deposition of thick turbidite layer on the sediment (Nomaki et al. 2015) or by the decline in organic
contents in the topmost part of the sediment due to the turbidity current associated with the tsunami (Kitahashi et al. 2014).

Toyofuku et al. (2014) reported the distribution and diversity of foraminifera in deeper shore between 55 and 211m depth shortly after the tsunami. Diverse foraminifera species were found at the study sites between 55 and 105m but foraminifera community at 211m depth was dominated by a single opportunistic species which generally colonizes after major physical disturbance, suggesting the effect of the tsunami disturbance was larger at 211m depth compared to the shallower sites (Toyofuku et al. 2014). Since the deep site was located just beyond the shelf break while the other sites (55 – 105m depth) was located on the continental shelf, the specific topography of the deep site might create the turbidity current associated with the tsunami and damaged foraminifera community.

**Planktons**

The density and diversity of phytoplankton were investigated before and after the tsunami in Kesennuma Bay in Miyagi Prefecture and Ofunato Bay in Iwate Prefecture (Okumura et al. 2015). Significant changes in phytoplankton communities were observed in Ofunato Bay. The analysis of Chl $a$ concentration suggested that phytoplankton quantities increased after the tsunami. In addition, the species composition of phytoplankton was also changed after the tsunami. These changes in quantities and diversity of phytoplankton community were perhaps caused by accidental addition of nitrogen and phosphate leaked from broken sewage disposal plants (Okumura et al. 2015). In contrast, there were no major changes in quantity and diversity of phytoplanktons before and after the tsunami in Kesennuma Bay. The study site in Kesennuma Bay was faced to the Pacific and not in the inner part of the bay. So that eutrophied costal water may not strongly affected phytoplankton community in this site (Okumura et al. 2015).

Above results suggest that the planktonic community in the closed environments is more susceptible to the tsunami. Consistent with this, Kayana et al. (2014) observed the strong impact of the tsunami on phytoplankton community in a semi-closed lagoon. Kanaya et al. (2014) examined Chl $a$ concentration in Gamo Lagoon. This was an eutrophic lagoon and a very high concentration of Chl $a$ was observed before the tsunami in the lagoon (> 100 ug L\(^{-1}\)). However, the Chl $a$ concentration became much lower after the tsunami (11.5 – 25.9 ug L\(^{-1}\)), demonstrating that the amount of phytoplankton in the lagoon was greatly reduced, probably because of the runoff of organic nitrogen and phosphorus stocks in the lagoon sediment by the tsunami.

**Nektons**

The distribution pattern and growth rate of the Pacific cod (*Gadus macrocephalus*) were investigated off coast of Sendai city in Miyagi Prefecture (Narimatsu et al. 2015). The study demonstrated that the distribution pattern of the juvenile cod was changed after the tsunami. Whereas the smaller cods were primarily distributed in shallower water before the tsunami, most of them were disappeared after the tsunami and the density distribution peak shifted to deeper area. Higher mortality of the juvenile cods in shallower area due to the tsunami event may explain this unusual distribution pattern. Further, the survived juvenile cods exhibited lower growth rate compared to those
before the tsunami. Although it is unclear what factors reduced the growth rate of the juvenile cods, the alteration in the prey organisms may be one of the possible reasons since the tsunami altered abundance and species composition of benthic and planktonic organisms as shown in the above sections.

**Coastal vegetation**

Several researchers investigated damages and recovery processes of coastal vegetation after the tsunami. Kanaya et al. (2012) examined the distribution of plants in and around Gamo Lagoon and they exhibited that approximately 99% of beach vegetation was lost due to the tsunami. In addition, About 52% of pine forest and 84% of reed marsh were also lost (Kanaya et al. 2012). The follow-up survey conducted in 2013 showed that marsh and beach vegetation have not recovered yet, probably because of substantial changes in the saline regime after the tsunami (Kanaya et al. 2014). Rare plant species were also damaged by the tsunami. Based on the survey conducted on the coastal plants in Iwate Prefecture, 53% of the habitats where the rare plant species were observed were devastated by the tsunami (Oyamada et al. 2012).

Hayasaka et al. (2012) compared pre-tsunami and post-tsunami dataset and evaluated the impact of the tsunami on coastal vegetation. Although the number of overall vascular plant species and that of non-beach species were not greatly changed, the number of typical beach species was significantly decreased after the tsunami. Further, the calculated evenness and diversity indices were both decreased after the tsunami (Hayasaka et al. 2012). They found that non-beach species rapidly grew on disturbed beach habitat probably because the deposition of inland sediment that contains seeds of these plants.

Although natural disturbance reduces plant diversity at a small scale, the diversity at a larger scale may increase by increasing the environmental heterogeneity due to the disturbance events (Elliott et al. 2002). Indeed, while Hayasaka et al. (2012) demonstrated the reduction of plant diversity at a local scale, Onza et al. (2014) recorded a higher beta diversity at a larger scale including disturbed and undisturbed areas at a coast in Sendai Bay after the tsunami. The environmental heterogeneity between disturbed and undisturbed area created distinct plant communities, which increased beta diversity of the plant species after the tsunami.

There is a large concern about the recovery process of the coastal vegetation. After the tsunami disturbance, invasive plant species such as *Phytolacca americana* and *Oenothera laciniata* dominated in the disturbed area. In addition, invasive tree species *Robinia pseudoacacia* rapidly increased in the disturbed forest (Kanno et al. 2014, Oka and Hirabuki 2014). These invasive species are highly competitive and are tolerant to environmental stress, and thus, they may interrupt the recovery of native plants (Kanno et al. 2014).

**Terrestrial and freshwater organisms**

Several studies reported the outbreak of flies and mosquitoes in the inundated terrestrial area (Hashimoto et al. 2012, Hayashi et al. 2012, Kasai and Kobayashi 2012, Kobayashi et al. 2012). Massive flies (e.g., *Calliphora nigrabarbis*, *Aldrichina graham*, *Phormia regina*, *Musca domestica*) were observed in spring and summer 2011 in the area where temporally covered by the tsunami. The flies perhaps emerged from rotten fishes, rice
and other organic materials which were spread from storages due to the tsunami (Kasai and Kobayashi 2012). As well as flies, a large number of mosquito larvae (*Aedes* spp., *Culex* spp. and *Armigeres subalbatus*) were found in summer 2011 in the opened septic chambers and the tanks for the sewage disposal system (Kobayashi et al. 2012) and also found in ground pools that has been utilized for rice cultivation before the tsunami (Tsuda and Kim 2013).

In contrast, rats (*Rattus* spp.) were not observed in the inundated area after the tsunami. Yabe et al. (2012) investigated rat populations at the inundated sites in Miyagi Prefecture in the early November 2011 and they found no rats in the traps they set in storehouse for marine products, rice storehouse, temporarily dump for debris and a fish market. This result indicates that the tsunami swept away most of the rats in these area (Yabe et al. 2012).

Above studies suggested the tsunami changed the demography of the organisms which live near the coast. However, this is unfortunate that the lack of pre-tsunami dataset for these organisms prevent us to fully understand the impact of the tsunami on terrestrial communities. To construct decent discussion without pre-tsunami dataset, Mukai et al. (2014) utilized unaffected areas as references and evaluated the impact of the tsunami on freshwater animals in rice paddies. They investigated a total of one hundred taxa and classified them into four categories based on their ecology (flight dispersers, walk dispersers, obligatory aquatic animals without resting stages, and obligatory aquatic animals with resting stages). They compared taxonomic richness separately for each category and between tsunami affected and unaffected areas to evaluate the impact of tsunami on terrestrial animals with different ecologies. Interestingly, while the tsunami imposed significant damages on walk dispersers and obligatory aquatic animals without resting stages, there were no notable damages detected on flight dispersers and obligatory aquatic animals with resting stages. Their results demonstrated that ecological traits such as dispersal ability and resting stage are important factors for recolonization of aquatic animals. This conclusion may be applicable for the terrestrial organisms shown above. The highly dispersive flies and mosquitoes rapidly colonized after the tsunami (Hashimoto et al. 2012, Hayashi et al. 2012, Kobayashi et al. 2012), while the rats as a walk disperser disappeared in the tsunami damaged area (Yabe et al. 2012).

**General patterns of tsunami-impacts and community recovery**

The accumulation of ecological studies conducted for various organisms after the tsunami (Table 1) suggests that the damages due to the tsunami varied among organisms and locations. In general, the organisms in the intertidal and beach areas were more influenced by the tsunami compared to those in subtidal and deep sea areas. This is probably because the height and physical energy of the tsunami increase as it approaches to the shore. The community level study conducted at the tide flat in Miyagi Prefecture explicitly demonstrated the destructive conditions of coastal ecosystems after the tsunami (Kanaya et al. 2012, Urabe et al. 2013). In the extreme case, 80% of organisms in a community were disappeared from the study area (Urabe et al. 2013). In contrast, there were often limited damages on the organisms in the subtidal and deep sea areas (Kitahashi et al. 2014, Toyofuku et al. 2014, Komatsu et al. 2015, Okumura et al. 2015). However, this pattern is not always true. Even at deep habitats, several
organisms were greatly damaged due to turbidity current associated with the tsunami (Seike et al. 2013, Takami et al. 2013, Seike et al. 2016). In the subtidal and deep sea areas, the topography of the study sites can be one of the important factors to determine the impact of the tsunami. For example, Komatsu et al. (2015) demonstrated that the effect of the tsunami was greater at the head of the bay than the mouth/middle of the bay, even at the similar habitat depths. Further, Toyofuku et al. (2014) showed that the foraminifera community at the deeper site just beyond the shelf break were more influenced by the tsunami than those located on shallower continental shelf.

The life history of the organisms can be one of the important factors for recovery process. The organisms with shorter lifespan can be easily recover after the disturbance while it may take a long time to recover for the organisms with longer lifespan. The studies on meio-benthos, which generally have very short lifespan, explicitly demonstrated that short-lived organisms recover rapidly after the tsunami event (Grzelak et al. 2014, Kitahashi et al. 2014, Nomaki et al. 2015). In contrast, many coastal macrobenthic animals, which generally live for years, have been disappeared after the disturbance and some of those have not yet recolonized (Kanaya et al. 2012). Further, the coastal trees, which can live for hundreds of years, have not recovered yet, though the seedlings were observed within three years from the tsunami event (Kanno et al. 2014). In addition, the studies show that the dispersal ability of the organisms can also be important for the recovery process. The studies on macrobenthos and freshwater animals consistently demonstrated that the damage caused by the tsunami was minimal for highly mobile organisms (Urabe et al. 2013, Mukai et al. 2014). The organisms with high dispersal ability may be able to easily and rapidly recolonize in the disturbed area after the tsunami.

Conclusions

About four years passed after the 2011 Tohoku Earthquake Tsunami and there are accumulations of the studies on the ecological damages caused by the tsunami. Although some organisms rapidly recovered their population, there were still a lot of organisms which have been in low density after the tsunami, and ones which have disappeared from the local sites after the tsunami. The ecological monitoring on the recovery process from the tsunami disturbance should be conducted and continued, which would provide a great insight into the recovery process of costal organisms and promote our understanding of the long term ecological impact of the tsunami.

Acknowledgements

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Table 1. The list of the studies which investigated the ecological impact of the tsunami. The data collection (before and after the tsunami / after the tsunami), data type (species base / community base) and locality of each study were shown.

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<thead>
<tr>
<th>Categories</th>
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Natural Historical Record, its importance and conservation

Chapter editors:
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*Masahiro Ohara*
*Paul Callomon*
Museum Specimens and their Meanings

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Introduction
There are many different kinds of museum, but all share a basic mission to preserve and display artifacts and natural specimens. Among the larger such institutions are a number of traditional research museums, which augment public exhibits with programs of scientific investigation and publication. Most research museums focus on natural history and the related fields of anthropology and archaeology, though many libraries and art museums also conduct formal studies in social and cultural history.

Victorian natural science was based on collecting, and by the late nineteenth century every major Western country had a national museum of natural history1. In what was still an age of exploration, these institutions launched collecting expeditions to the jungles and shores of far-flung lands, returning with specimens that formed the core of vast collections often housed in elaborate and expensive buildings. At the same time, dedicated amateur collectors worked in association with the museums, building up specialized private collections that eventually would form part of the institution’s holdings.

Though most of the great national museums remain open today, their research focus has gradually shifted from cataloging the fruits of voyages of discovery to new work in systematics, conservation and environmental science. Their original collections nevertheless remain largely intact and are providing fertile ground for new forms of investigation2. Many are affiliated with universities, and their curators also teach the principles and methods of natural history research at all levels.

By comparison with the discover-and-describe enterprise of a century ago, natural science in the 21st century is becoming increasingly holistic as the pan-global issues of climate change and habitat destruction call on everyone - scientists and citizens alike - to participate in collecting, collating and analyzing data3. Without a detailed understanding of the local effects of global change, it becomes harder to create and implement workable solutions.

Specimens and their data

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1 See e. g. Fortey, 2009; Peck & Stroud, 2012; Aso, 2013.
2 See e. g. Miller (Ed.), 1985; Nudds & Pettitt (Eds.), 1986; Suarez & Tsutsui, 2004.
3 See e. g. Dickinson & Bonney, 2012.
The specimens in natural history collections embody many different kinds of information (Fig. 1). Basic collecting data – place, date and person – are only a small part of the total body of knowledge that a well-organized collection represents. The recording, organization and preservation of broader classes of data further enhance the value of an institution’s entire collections and archives⁴.

Fig. 1. The heteropod snail *Atlanta* lives in all the world’s oceans and spends its entire life swimming among the plankton. Its calcitic shell is extremely thin, and even slight acidification of the sea water is likely to affect the animal’s ability to produce it. This remarkable picture was taken by Robert Robertson in 1970, and is clear enough to estimate the thickness of the shell.

⁴Duckworth et al., 1993.
Increasingly, this data is being incorporated into international trans-institutional resources such as GBIF, Tree of Life, WoRMS and iDigBio. In this way, specimens that were collected around a certain place or time but are now in different museums can “find” each other again, bringing new levels of detail to larger pictures of species distribution and ecology.

Collections databases often also form part of “thematic” networks that concentrate and collate data on particular groups of organisms. Examples include VertNet, itself a collation of four smaller networks\(^5\) of vertebrate groups, and the Global Plants Initiative\(^6\).

At the same time, technologies such as barcoding and high-resolution digital imaging are making it easier to present images of specimens with their data in a single online interface, bringing the contents of millions of drawers to any computer desktop in the world.

Even as new molecular techniques are giving scientists a clearer understanding of the pace of evolutionary processes, the number of trained taxonomists worldwide is declining\(^7\). Those who still choose the field, however, can access a gigantic and fast-growing data set thanks to the digitization of museum collections\(^8\) (Fig. 2).

### Reporting on the past

Museum specimens differ in one major aspect from material collected by contemporary field surveys in that they embody the environmental conditions of the past (Fig. 3). The older the specimen, therefore, the more valuable its contribution will be to reconstructing the ecological history of a given place. Time scales in this regard can be remarkably short, as a few examples show:

- From the 1930s to the 1960s, large collections of the common *Partula* snail were made in Tahiti and its surrounding islands by scientists investigating population dynamics and speciation. Sadly, by the 1990s these once vastly abundant snails had become extinct throughout Polynesia, eradicated mostly by introduced invertebrate species. In keeping with their mission of preservation, however, several museums had retained the earlier samples, comprising thousands of preserved bodies and shells. So it is that material collected as vouchers for one kind of study is now also critically important to another - conservation and restoration\(^9\).

- Starting in the 1870s, the first Western travelers in Meiji-era Japan eagerly collected plants and animals from localities that no outsider had ever visited. Though often placed in collections for their curiosity value, these specimens are nowadays seen as important relics of the countryside before artificial fertilizers, pesticides and industrial pollution\(^10\).

- Oyster specimens in museum collections are increasingly being used to assess baseline levels of marine water pollutants such as oil and industrial chemicals. Their

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\(^5\) HerpNet (Herpetology), ORNIS (Ornithology), FishNet (Ichthyology) and MaNIS (Mammalogy). See vertnet.org.
\(^6\) See e.g. Mitrow & Catling, 2012.
\(^7\) Drew, 2011.
\(^10\) See e.g. Barnes, 2001
shells yield rich samples that can span many years of growth, and their collection dates provide the key to exact measurement\textsuperscript{11}.

Fig. 2. *Atlanta* shells from a museum collection. These specimens are over a hundred years old, and will prove invaluable in assessing changes in shell growth rates through comparison with present-day examples.

\textsuperscript{11} See e.g. Alzieu, 1998; Ferrell \textit{et al}., 1973.
A unique form of contagious cancer has been identified in the Tasmanian Devil, an endangered Australian marsupial. In a recent study that concluded that low genetic diversity was a major factor, DNA was taken from both living and museum specimens to establish the baselines for original diversity\textsuperscript{12}.

![Preserved birds in a museum collection. Specimens such as these allow the reconstruction of vanished habitats and the former distribution patterns of species whose numbers have rapidly declined in modern times. Scientists can retrieve DNA from preserved specimens that reveals evolutionary patterns and relationships among even extinct species.](image)

**Contemporary issues**

The most important relationship humans have is not with each other but with the biosphere. No change we make to the environment is without consequences, but their signs can be very subtle at first. For example: many of the microscopic animals that live among marine plankton have thin, delicate shells made of calcium. Even a slight change in the acidity of surface waters will affect their ability to make their shells, though in what way is difficult to predict. However, we do know that zooplankton form a vital and irreplaceable link in the marine food chain; if they decline, their places will be taken by other organisms whose sudden expansion may be a serious problem. Any threat to the zooplankton is thus of major importance. Historic specimens in museum collections (for

\textsuperscript{12} Miller \textit{et al}., 2011.
no private collector is interested in nektonic micro-organisms) will tell us what those shells were like before the elevated carbon dioxide levels of our industrial age began to acidify the oceans, and thus how far the underlying problem has developed. This is just one example of the enormous body of evidence for climate change that natural history collections represent.

In terms of planning post-disaster remediation and conservation, nothing is more important than museum collections. Aside from the specimens themselves, the information in photographs, maps and field books allows realistic targets to be set for reconstruction and restoration. A natural or man-made disaster can inspire the reassessment of decades of previous development and change, and bring about new social and infrastructure schemes that more closely embody what history tells us was once sustainable.

Some of the most urgent conservation challenges are in parts of the world where economic development has already led to widespread environmental degradation and the extinction of species. In many such cases, museum collections in other countries can provide priceless evidence of former conditions. Invasive plant and animal species can disrupt ecosystems in very short time frames, and their original introduction points and rates of spread can often best be assessed from preserved specimens and records.

In an increasingly networked and globalized world, the value of communities and their local knowledge is becoming clearer. As major current events take place on an ever-widening stage, historians and social scientists are concentrating on studies at smaller scales that reveal new patterns of interaction and interchange. Properly articulated, these can inform policy at the highest level through transformative initiatives such as micro-finance and community-based citizen science. Rich material for building community histories lies in museums and archives, and natural history collections are a priceless source of basic information on human activities in former times.

Collections are also vital resources for studies in the Humanities. For example: ornithology field collecting books from the American West in the early nineteenth century contain vital observations about plants, weather and the local inhabitants, even though their authors were collectors looking for birds. The means they chose to send their specimens back to the East Coast, and how much they paid for that; what they ate, and how they carried it; what they believed they would encounter before they left on their expeditions - all of this is valuable historic information that resides mainly in museum archives.

To make them as useful as possible, however, specimen data and related information must be organized to allow the widest possible access via open forums such as the Internet. Within the institution, regular offsite backups are an essential safety measure that requires relatively little investment. A solid data management plan acknowledges the importance of an institution’s collections as global cultural assets. Looking ahead,

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13 See e.g. Orr et al., 2005; Roger et al., 2012.
14 See e.g. Akanuma & Suzuki, 2014
15 See e.g. Shaffer et al., 1998.
16 See e.g. Cato, 1991.
17 See e.g. Delisle et al., 2003.
the increased adoption of common file formats across all platforms is enhancing collaborations between and among projects in different institutions.

**Educating for the future**
Museum collections have myriad uses in education, from kindergarten encounter sessions with live animals and touchable specimens to science projects for students in high school and beyond\(^\text{18}\) (Figs. 4-6). Even with all the technologies deployed in the modern classroom, there is still no substitute for the real thing - authentic objects and specimens that embody stories of discovery, collection and scholarship. Skilled educational staff can build exciting lesson plans around groups of specimens that link diverse fields such as history, ecology and conservation. These in turn often have a positive influence on students’ perception of the natural sciences as a career and field of interest.\(^\text{19}\)

Fig. 4. Museum collections are an ideal environment for hands-on teaching at all levels.

**Summary**
Transformations in the natural world can take the form of sudden events, like earthquakes and volcanic eruptions, or gradual shifts such as climate change. Natural disasters are often followed by detailed surveys that assess damage to communities, infrastructure and - to a far lesser extent - the natural environment. It is usually relatively easy to understand what has happened to the artificial environment, but far harder to tell what the natural surroundings were like beforehand. Whether a change occurs in a day or over a century, however, museum specimens are often the best and most reliable source of data on the situation prior. Increasingly sophisticated techniques


\(^{19}\) Melber, 2003.
for recovery and amplification of ancient DNA as well as for the measurement of toxins, metals and other significant elements are constantly expanding the range of knowledge that can be gained from even the most unpromising material.

Fig. 5. Museum staffs also travel to schools, colleges and other institutions to teach specimen-based lessons.

The key factor is that these specimens are preserved, together with their associated data, and made accessible to researchers. This is the role of natural history museums; not just to educate and fascinate the public, but to house the archives of the entire planet in perpetuity.
Fig. 6. People of all ages can engage with the study of nature through museum programs and visits.

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Institute for the Conservation of Cultural Property.
Why Natural History Specimens were ‘Rescued’

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Abstract

The ‘rescue’ activities in Rikuzentakata museums turned out not only to restore what they had before the tsunami on 11 March 2011. Through ‘rescue’ activities participating scientists came to learn about the importance of the collections at the two local museums in Rikuzentakata. Many of the specimens are not mere ‘duplicates’, and some have significance beyond the region. A local museum is not only preserving the past but also making us aware of the present and the future. A museum is our commitment to the present and future generations.

Background

Natural history collections have long been indispensable resources for studies of Earth’s biodiversity, and the need to maintain them has recently taken on greater urgency (Ponder et al., 2001). Museums offer a unique perspective, providing data over a vast time span ranging from millions of years ago (paleontological collections) to the present. Three broad areas of study related to species decline and the loss of biodiversity have become crisis disciplines and depend heavily on the baseline information that museum collections offer: species’ response to habitat loss and fragmentation, biological invasions, and the consequences of global climate change (Suarez and Tsutsui, 2004).

The earthquake and subsequent tsunami in March 2011, caused significant changes along the coast of northeastern Honshu. The local fauna and flora received a lot of attention after the incident. There had not been many studies on the local fauna and flora of the area before the incident, in the 'normal' time. The specimens in the local museums had been collected, in many cases, through such local activities as the efforts of amateur collectors and student projects. In the case of the two Rikuzentakata museums, one had to 'rescue' these precious specimens from the debris. Otherwise, the information gathered before the incident must have been lost forever.

Are the specimens in local museums of mere regional importance?
The trend in natural history has been to reject a typological concept of species in favor of one which takes into account the range of diversity within species (Mayr, 1982). Thus, increasing the number of specimens of any given species or community is objectively important in order to understand the biodiversity around us. One representative specimen or type for each species is not sufficient or desirable. This is not only the case in regard to statistical analyses. There are potentially variations in each species in gender, age, and size, and also in shape, behavior, and physiology. More specimens will also help us to understand variations within species, the source of evolution. Thus, the idea that some specimens, especially those in smaller museums, are mere "duplicates" is a mistaken one. Regional museums that house such "duplicates" are actually storehouses of valuable information.

After salvaging and restoring plant and shell specimens of museums in Rikuzentakata City, researchers found a lot of paratypes and syntypes previously overlooked from the collections. Furthermore, they found that the old local collections contained some taxa with invalid names that were worth studying taxonomically even today.

In the plant specimen collection salvaged from the Rikuzentakata City Museum, there was a sheet of an orchid, Liparis kumokiri, that grows in the mature mountain forest. One hundred and ten years ago, a school teacher in the city collected the specimen from the coastal windbreak of pine trees, known to have been planted in the 18th century. The orchid specimen is ecological evidence that shows the pine forest to be fully matured at that time. Thus, local specimen collections can offer vast amounts of ecological and historical information of the area. A partial list of the rescued plant specimens made by Takashi Akihiro of Shimane University* is now available online.

Entomological specimens rescued from Rikuzentakata City Museum are being put together for an online database created by the Entomology Database Project led by Osamu Tadauchi of Kyushu University (Tadauchi et al., 2012).** Kazunori Hasegawa of the National Museum of Nature and Science, Japan, is planning to publish an online database of nearly 40 primary type specimens from among the mollusc specimens that survived the tsunami.

More than 1400 geological and paleontological specimens such as rocks and fossils were salvaged from the debris in the Rikuzentakata City Museum after the tsunami in 2011. Brachiopod fossils salvaged from the tsunami have been studied by Jun-ichi Tazawa, Professor Emeritus of Niigata University with financial support from the Palaeontological Society of Japan. Tazawa published a paper based on the salvaged specimens from a famous Permian invertebrate fossil locality in Imo, Rikuzentakata (Shen and Tazawa, 2014). In his paper, he reported six specimens of Dicystoconcha lapparenti previously described only from Afghanistan. Tazawa’s paper is one of the first scientific publications based on salvaged natural history specimens.

There are about 200 fish fossils in Rikuzentakata City Museum. The catalogue was lost in the tsunami in 2011, and there were only a few pieces of paper stating the name of the donor. The donor was Jiro Sato, a former high school teacher in Iwate Prefecture who studied on his own Miocene fish fossils from Gunma Prefecture. Most of his collection is housed at the Gunma Prefectural Museum of Natural History and Tohoku University. He also donated some of the fish fossils to Rikuzentakata City Museum before he passed away. The collection at Rikuzentakata was not known to fossil fish workers such as Yoshitaka Yabumoto of the Kitakyushu Museum of Natural History.
and Human History. Yabumoto went through the collection and found potentially important specimens and he is currently studying them. Yabumoto gave a poster presentation informing the community of the collection at a Palaeontological Society of Japan meeting (Yabumoto et al., 2013). Thus, ‘rescue’ activities have definitely shed light on forgotten specimens stored in the Rikuzentakata City Museum.

**Importance of local museums**

Most of the collections at Rikuzentakata City Museum came from donations from citizens over many generations. The museum therefore included many common things of the area in their times. These common things are easily forgotten and knowledge of their use and importance is hard to pass down to future generations, as they are often given low priority. These common things are actually more difficult to find in other museums.

Maintaining a public museum requires a financial commitment for the local authorities. Such museums are usually not highly valued because it is expensive to keep them running even if there are not so many museum visitors. The sea off the coast of the area heavily hit by the earthquake and tsunami in March 2011 is traditionally known for the wealth of seafood it provides and therefore for the seafood-related industries it generates. Cold and warm currents meet in the area, and the mixture has produced its rich marine biodiversity. Archaeological data suggest that the people in the region have taken advantage of the sea's resources at least from the Jomon Period, that is, for more than 15,000 years. Fishing tools developed in the area are internationally known for their elaborateness and uniqueness. Many local traditions and rituals are derived from the bounty of the sea. Modern citizens may not be fully aware of these influences, but some part of their identities is shaped by the richness of nature and the human activities based on it. What we have learned from the tragic experience of the tsunami and earthquake since March 2011 is that cultural history and natural history are intertwined, and both are important elements for local identity. Unless there is a local museum with such collections, people do not know where to go to save and retrieve the items and records important for the local community at times of emergency.

In the sphere of cultural history, we have customarily dealt with the cultural activities of only one species, *Homo sapiens*, for the last 40,000 years or so. Now, however, we recognize that we are a part of the global ecosystem, with more than 1.5 million species known to science (Costello et al., 2013). Some studies suggest that there are approximately 8.7 billion species (Mora et al., 2011) around us not counting all the extinct species that lived before us in the Earth’s 4.6 billion years of existence. Recent studies suggest that the global ecosystem we are living in is entering the age of the sixth mass extinction (e.g. Ceballos et al., 2015). Unless we pay more attention to the natural world silently changing around us, we will be on the list of endangered species if not extinct species. A local museum is not only preserving the past but also making us aware of the present and the future. A museum is our commitment to the present and future generations.

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Salvage of Natural-historical Collections after Natural Disasters

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Abstract

The particular problems of salvage of natural-historical collections after natural disasters are examined from an historical and taxonomic perspective. Destruction of collections is a consequence of their concentration in institutions that have the financial and technical capacity to collect and store the materials. Since the growth of large museums and state collections, driven to some extent by political factors, many collections have been lost to natural and man-made disasters. Small museums can act as preservers of local culture and natural history and backup resources for national collections. Older museum collections have become new sources of information as potential sources of historical DNA. Criteria for evaluating specimens for potential emergency situations are discussed. A system for prioritizing salvage of affected material should be in place for every institution.

Background

This article addresses urgent questions that the museum and scientific communities should consider in the face of rapid changes in global, regional, and local environments. Museum collections now in many ways represent a past state of things that cannot easily or even at all, be reconstructed.

In the aftermath of natural and man-made disasters attention is often focused on the saving, salvage, and restoration of art works. However, natural historical collections are subject to the same forces. The 2011 Tohoku Earthquake and the tsunami it generated had a devastating impact on Pacific coastal areas of Japan. Entire towns were leveled by the tidal wave, and in the hardest hit localities no buildings, including civic and governmental centers, survived unscathed. Rikuzentakata, a fishing town adjacent to a beauty spot known for its many thousands of pine trees, was particularly hard hit. The local museum was inundated and the curatorial personnel, with one exception, perished. The task of restoring the museum collections at Rikuzentakata and elsewhere in the earthquake-afflicted region attracted volunteers from the museum field, among them Drs. Makoto Manabe of the National Museum of Nature and Science and Yoshitaka Yabumoto of the Kitakyushu Museum of Natural History (for a review of these activities see the journal Kaseki (Fossils), 2013, no. 93, passim: Nemoto et al., 2013; Manabe, 2013; Oishi et al., 2013; and others). A debate arose concerning the scientific
value of the restoration work, given more pressing humanitarian issues and the finiteness of resources. Importantly, also, the wishes of the local population had to be considered. The decision was made to restore as far as possible all the museum collections. These included, besides natural-historical objects, including a substantial conchological collection, irreplaceable books and manuscripts of historical interest and cultural artifacts representing the agricultural and maritime traditions of the region. As part of this effort, oral histories concerning the artifacts were also collected. This effort has already consumed as of the time of writing many tens of thousands of labor hours. Such situations may become more frequent as climate change brings about peculiar weather patterns and coastal flooding. For example, in 2012, the New York Aquarium, located in Coney Island, had to be shut down for an extended period due to storm damage from Hurricane Sandy. It therefore seems timely to develop curatorial parameters for dealing with such disasters. Such questions lie beyond the scope of purely technical protocols (e.g. Galban, 2003). As a starting premise in considering the utility of salvaging distressed collections, we argue that all museum specimens are unique documents. Biological specimens including fossils, insofar as they represent individual organisms, are self-evidently unique, but rock and mineral specimens are likewise potentially unique, since the chemical composition of rocks and minerals of the same name can vary within definitional limits. The following discussion concerns biological specimens.

Evidence indicates that natural-historical "collections" are nearly as old as sentient man. Marine shells and amber were traded far from their points of origin in Neolithic times. In ancient and medieval Europe menageries of exotic live animals, sometimes obtained as gifts between rulers, existed, but were not maintained for any scientific purpose. Chinese sources of the Tang Dynasty reveal a fascination with the unfamiliar plants and animals of distant lands enveloped by its expanding imperial sphere of influence (Schafer, 1963, 1967). Centuries later, prompted by a similar expansion of the known world, the Renaissance saw a growing scholarly appreciation of exotica, organized, or, from the modern perspective, disorganized in cabinets of curiosities, rooms that included both exotic art objects and natural-historical rarities such as shells and other portable botanical and zoological remains. Basilius Besler (1561-1629), compiler of the sumptuously illustrated florilegium Hortus Eystettensis, maintained a cabinet that was passed down to his nephew, Michael Rupert Basler, who augmented it and published its contents (Besler, 1642) arranged according to the three kingdoms of animal, vegetable, and mineral, the latter also comprising fossils. The Beslers, botanists and apothecaries, were on surer ground with plants; their zoological possessions included a bird of paradise, a Russian desman (Desmana moschata Linn.) and bits and pieces such as a rhinoceros horn, swan and wolf skulls, and a narwhal tusk, taken to be the horn of a unicorn. Alongside these natural specimens were altered objects, including a carved nautilus shell and a girdle woven by Brazilian Indians hung with the poisonous nuts of the ahovai (Cerbera thevetii, Linn.). Even this partial list thus includes objects from nearly every part of the world. Such collections were seen as not only prestigious but also valuable. An especially famous one was formed along encyclopedic lines by Emperor Rudolph II (1552-1612) of Bohemia, who showed a deep interest in protoscientific subjects. In 1648 a Swedish army deliberately targeted the portions of his collection still in Prague and carried it away as war booty. The deliberate theft of
important collections, including famous fossils (Buffetaut, 1987), continued as the revolutionary armies of the French Republic remade the political map of Europe.

With the growth of nation states and the accompanying absorption into various centers of the products of exploration, imperialism, and frontier expansion, the formation of natural-historical collections shifted from private ventures to institutional collecting. To cite a few examples, the British Museum, based on the personal collection of Sir Hans Sloane, was founded in 1753. In 1784 Sir James Edward Smith purchased the private herbarium and library of Linnaeus and in 1788 founded the Linnaean Society of London to house it; after his death in 1826 the Society acquired it, along with Smith's own considerable botanical collection. The Muséum Nationale d'Histoire Naturelle became a Republican establishment in 1793, built on the revolutionary confiscation of the Jardin du Roi. The United States Congress established the Smithsonian Institution in 1846, and the American Museum of Natural History was incorporated in 1869. National museums were founded in Russia in the early nineteenth century based on division of the collection of Peter the Great (reigned 1682-1725), with the zoological portion becoming the Zoological Museum of the Russian Academy of Sciences. In Japan the Meiji Restoration's modernization policies led to the founding of the Tokyo National Museum in 1872. Classification of biological holdings according to the Linnaean system provided a framework and an internationally recognized common language for the organization of collections; similarly, schemes for rock and mineral classifications, such as Dana's *System of Mineralogy* (1837) were likewise promulgated. Such institutions conveyed the powerful status of their host countries and were intended to have worldwide influence and a long grasp in collecting. Expeditions, partly scientific, partly exploratory, partly economically and politically motivated, poured specimens into these metropolitan centers.

In contrast to the millennia-long interest in exotica, with the advent of widespread education, environmental consciousness, and nostalgia for vanishing landscapes and ways of life, numerous local scientific societies and museums came into existence, which, rather than competing in collecting "museum-quality" specimens, emphasized the documentation of the local culture and natural environment. The course followed by the Portland Society of Natural History, of Portland, Maine, USA, founded in 1843, illustrates these local and international trends. Although culturally a peripheral city compared to older centers like New York and Philadelphia, Portland grew in importance as a world port when it became the Atlantic terminus of the Grand Trunk Railway of Canada in 1853. In 1864 the Society began publishing a journal; the lead article in the first number was by Edward S. Morse, later to become the first Professor of Zoology at Tokyo Imperial University. Fires twice destroyed the Society's collections, in 1854 and again in 1866. Undeterred, it rebuilt its collections and exhibition rooms a third time. While devoted to documenting the natural history of Maine, it looked beyond as well. In 1881 it produced a publication (Wood, 1881) soliciting the assistance of mariners in procuring materials for it from distant places. The pamphlet, given out along the waterfront, offered the following advice: "The idea that [the common objects of foreign places] can possibly be of value and worth the trouble of gathering becomes lost in a vain attempt to find something of greater interest and 'worth bringing home.'" Rather, "the most common things of those regions, and which are to be had without money or price, except the trouble of collecting and preserving them, are the most desirable
things." Even samples of mud scraped from anchors with the location recorded were welcome for the marine organisms they might contain. These contributions, when eventually displayed in its cabinets, would "throw light and greater interest upon the animate or inanimate objects that we gather from every part of our State." When the Society finally dissolved in 1972, its holdings were dispersed.

Concentrations of valuable specimens in large institutions created new vulnerabilities. The mineral collection of James Smithson, which came to the United States as part of the Smithsonian bequest, was destroyed by fire in 1865. The entire collection of the California Academy of Sciences, with scattered exceptions, was incinerated in the San Francisco Earthquake of 1906. In the aftermath of the Great Kanto Earthquake of 1924, the natural-history collections were separated from the damaged Tokyo National Museum, becoming the nucleus of the National Science Museum. Man-made disasters also affected museum collections. Aerial warfare became a feature of twentieth-century life, forcing the evacuation of collections away from city centers, as the British Museum (Natural History) did during World War II (Wheeler, 2000), while others in Germany, Great Britain, and elsewhere, were destroyed or damaged (see palaeos.com/vertebrates/sauropotrygia/pachypleurosauridae2.html for some bibliographical citations). For example, the holotype of *Spinosaurus aegyptiacus* Stromer, 1915, was destroyed along with much of Stromer’s other material during a bombing raid on Munich in 1944. The notorious composite fossils assembled and displayed as "sea serpents" by Albert Koch in the 1840s, in actuality the bones of various individuals of the archaeocete *Basilosaurus cetoides*, suffered destruction twice: one set of materials that had done further service as a commercial museum attraction was destroyed in the Great Chicago Fire of 1871, while the specimen sold by Koch to the King of Prussia was destroyed in Word War II. On the other hand - Koch was a serial faker – the composite mastodon skeleton he created and called *Missourium* still stands, remounted correctly, in the Natural History Museum (London).

While all museum specimens, in particular biological specimens, can be regarded as unique documents, it is obvious that some specimens are scientifically more valuable than others. At the bottom rung of the ladder, specimens without collecting information likely never will be worth the effort of reexamination. At the other extreme, long-established collections acquire a historic and comparative importance beyond that of their mere contents. This was true even in the early days of scientific taxonomy.

A notorious example is the Homo diluvii testis, first published in 1726 by the Swiss naturalist Johann Jakob Scheuchzer in his *Lithographia Helvetica* as the supposed remains of a human child who died in the biblical Deluge, and cited numerous times thereafter, although skeptically, under that name. That specimen was acquired by the Teyler Museum in Haarlem, Netherlands, and so survived to be reexamined by later investigators and finally identified as a fossil salamander by Cuvier in 1811 during a visit to Haarlem. Had no museum existed to acquire and preserve it, it might have remained somewhat enigmatic, as the skeleton was partly obscured by matrix when originally illustrated. Ending this oft-told story thus, it might be left as an amusing example of the mistakes made in the dawn days of paleontology, although the context is usually omitted: Cuvier (1812, p. 83 ff.) was disproving evidence of fossil humans. To carry the story further, however, in 1837 the fossil received its present binomial of *Andrias scheuchzeri* in a paper by Tschudi (1837), who had the opportunity to examine
it in Haarlem. Tschudi stated that Cuvier's illustration was inaccurate, that he had just seen in Leyden the skeleton of a Japanese giant salamander brought thence by Philipp Franz von Siebold, and that he instantly saw the resemblance between the two. Thus, this specimen actually brings to mind a host of scientific and cultural connections between Japan and Europe. The disjunct distribution of *A. scheuchzeri* and the only other known species of the genus, both East Asian, *A. davidianus*, the Chinese giant salamander, and *A. japonicus* raises further interesting questions, and, so far as can be gathered from the literature, the paleoenvironmental context of *A. scheuchzeri* has not been fully investigated. Therefore it seems that the Haarlem specimen, after more than two hundred years, still has potential interest for science.

The vast majority of specimens lie between these two extremes. The question then to be asked is whether the specimen or the circumstances under which the specimen was collected are reproducible. Various factors can come into play. In the first place, does the collecting site still exist? Outcrops and quarries can both disappear in the normal course of events and can also, if they secondarily prove to be interesting to collectors, be mined for minerals and fossils to the point of barrenness. An extreme case in point is the Burgess Shale Lagerstätte, which has been entirely removed for study. If the site no longer exists, are there similar sites? Then it must be asked whether the given specimen is unique or has a typological status, i.e., is the type of a species or subspecies. If not unique and already known to science, is the specimen one of a species rare in the particular locale, or rare in general? Is its rarity real or apparent? Could its loss be readily remedied?

As an example, consider the case of *Archaeopteryx*. *Archeopteryx* was discovered at a critical time for evolutionary theory. To naturalists of the time, as a bird with reptile-like features, or a reptile with bird-like features, it not only displayed transitional features between the two groups, but more importantly meant that reptiles and birds were not "natural" groups based on entirely distinct archetypes. The first known skeletal specimen of *Archaeopteryx* was sold in 1863 for £700 to the British Museum, and the first few specimens found thereafter also fetched considerable sums. Therefore, there was and is a strong financial incentive to look for further specimens of *Archeopteryx*. Yet, in the century and a half since its first description, only ten or eleven specimens, not all of the same species, have come to light. One of those specimens was reclassified by Ostrom (1970) from a specimen again in the trove of the Teyler Museum previously described as a pterodactyl. It is therefore genuinely rare. Similar financial rewards for Chinese feathered dinosaurs in the 1990s led to chimerization of fossils.

Rarity can be due to ecological, geological, biological, and man-made circumstances, or a combination of those factors. We know that Cretaceous bird fossils are, for various reasons, rare. Indeed, bird fossils are in general rare or at least uncommon compared to other vertebrate groups. Nevertheless, rarity is not an absolute, fixed quantity that can be always attached to a particular taxon. We illustrate this with a couple of examples. The first example is from the area of conchology. The conid *Conus gloriamaris* Chemnitz, 1777 was at one time, and for a long time, the most valuable shell in the world (Dance, 1966, p. 238-244). It was prized for its beautiful markings, but also because only a handful of specimens had ever been found. In the 1960s, nearly two centuries after its first description, its habitat was located in shallow seas of the western Pacific. Now it can be readily obtained from shell dealers and is no longer rare. An
opposite case has to do with the collecting of bird's eggs and skins. The nineteenth
century saw many natural-historical collecting crazes, notably for ferns and bird's eggs
(Barber, 1980). Eggs were removed from bird's nests by collectors, traded, and
purchased from specialized supply houses. As certain species declined, so the hunt for
the last specimens intensified, making matters worse. The taking of eggs of wild birds
en masse, augmented by collection building by museums, led some species to the brink
of extinction and over it. The enormous numbers of eggs in some collections, upwards
of 100,000, attest to the subtraction of those eggs from breeding populations. Thus, eggs
and skins can be common in institutional collections, while the organisms, the birds,
themselves are rare or extinct. A similar phenomenon occurred with the overcollection
of ferns and also of orchids, another mania of the era (Mabey, 2005, p. 146).
Representation of species in museum collections that have become recently extinct
can also depend on subjective and coincidental factors. The one specimen spared from
the 1854 fire which destroyed the Portland Society of Natural History was a stuffed
passenger pigeon out on loan to a painter; it pained the Society's director that out of all
their collections so worthless an object had alone survived. Sixty years later the
superabundant passenger pigeon was extinct. Nevertheless, its sheer commonness
unintentionally ensured that it is well represented in museum collections. The only types
rescued from the incineration of the Ornithology and Mammalogy collection of the
California Academy of Sciences were two specimens of the Guadalupe storm petrel,
Oceanodroma macrodactyla Bryant (1887, p. 450, 451), which at the time of the fire
had a seemingly reasonable-sized population of a few thousand on Guadalupe Island,
Baja California, its only nesting ground, but which within a decade was in all likelihood
extinct. The last specimens scientifically taken were two collected by the Albatross
Expedition in 1911 (Townsend, 1923, p. 6). These are probably the only extant museum
specimens.
Proceeding further, is the specimen, in the case of Recent or sub-Recent material, still
extant, if so, extant in the area of collection and/or or extant elsewhere? Natural
climatic shifts such as have marked the Pleistocene and Recent certainly play a role in
ecological succession and back-and-forth distributions of plants and animals. Likewise,
and increasingly so, human activities, including anthropogenically induced global
warming trends, the disappearance of ecotypes such as wetlands, and introduction of
new food crops, can affect floral and faunal suites within a small time frame. Green
markets in the United States abound now, not only with novel foods, but with so-called
heirloom varieties of apples (of Central Asian origin), potatoes (of South American
origin), tomatoes (of Mesoamerican origin), and even heirloom breeds of livestock
ultimately of European origin. The faunal and floral record of North America, indeed of
the Earth, to a future science, would look like a huge geodispersal event, not the least
evidence of which would be the explosive spread of our species. Coupled with this, that
future science would see evidence of an ongoing mass extinction event: the
disappearance of most terrestrial herbivorous megafauna, of large predators, of many
endemic birds, of fishes, perhaps of corals and much of ocean life.
Consequently, type material of Recent and sub-Recent subspecies and varietal and
other forms of unofficial nomenclatural standing may be of high future scientific value;
approximately one-quarter of the taxa protected by the Endangered Species Act in the
United States are subspecies. Such materials, often within the purview of museums of local natural history, can be used in investigating such questions as geographic isolation, hybridization under stress, genetic drift and bottlenecks, and speciation, and also for determining conservation policies and even scenarios for reviving extinct species by backbreeding. The category of subspecies, in itself, can be fluid and subject to taxonomic fashion and the individual preferences of investigators. *Oceanodroma macrodactyla* was originally described as a subspecies, *Oceanodroma leucorhea macrodactyla*, then elevated to species status. As a species, nearly a century after its apparent extinction, survivors were still being sought (BirdLife International, 2013); as a sympatric subspecies, its unfortunate loss might have been written off more casually.

A further reason for valuing local collections is the widespread introduction of genetically modified organisms. Despite manufacturers’ representations that genetically modified organisms would be confined to controlled agricultural settings, transgenes rapidly leaped into wild stocks when conditions favored the process. Consequently, museum specimens collected prior to the introduction of transgenic stocks can become important comparative records of the prior genetic states of local populations of the wild plants. Food plants that have wild relatives are most likely native or very well established species to begin with. Future collecting strategy also might take into consideration documentation of wild plants threatened or likely to be encroached upon by genetically modified organisms.

Museum specimens can now also be evaluated as resources for historical DNA recovery, particularly those of recently extinct species, where degradation is not advanced. While newly collected specimens considered candidates for nuclear and mitochondrial DNA extraction are now handled to prevent contamination, the technique has proven practical with older museum materials (Pääbo *et al.*, 2004; Rizzi *et al.*, 2012); on the use of avian skins see Payne and Sorenson, 2003 and Iresedt *et al.* 2006). The first successful extractions of DNA from museum specimens were carried out on the hide of a quagga, which became extinct in 1888 (Higuchi *et al.*, 1984; cf. Leonard *et al.*, 2005), and on human mummies (Pääbo, 1985); it is interesting to note that Cuvier also utilized mummies, in his case of ibises and cats, to demonstrate supposed species invariance over several thousand years. Since these early studies, many others have employed already curated museum materials both primarily, to determine the taxonomic standing and relationships of the specimen itself, and secondarily, to determine the history and mode of transmission of hitchhikers such as pathogens (Ristaino, 1998; Suarez and Tsutsui, 2004). The phylogenetic relationship to other columbids of the passenger pigeon, an obvious research target as an icon of species destruction and for which a plentiful supply of museum specimens existed for DNA sampling, has been reconstructed (Johnson *et al.*, 2010). Barnett *et al.* (2007) noted that many poorly provenanced lion specimens found their way to European museums after having been displayed in zoos and menageries; using mitochondrial DNA recovered from a two-hundred-year-old lion skeleton in the Zoological Museum, Amsterdam, they determined that it was not, as previously thought, an example of the extinct Cape lion, *Panthera leo melanochaitus*, but was instead an individual of the extant Asiatic subspecies *P. leo persica*. Beyond the results of the DNA analysis, the study delved into the history of the animal trade to determine how the specimen might have arrived in Holland. Unlike the last two examples, reflecting their small population sizes there is a relative paucity of
older material of early hominins, and consequently museums were reluctant to have such specimens consumed for DNA analysis; nevertheless, in a pioneering study, Krings et al. (1997) extracted mitochondrial Neanderthal DNA from a femur of the type specimen of *Homo neanderthalensis*, discovered in 1856, in the possession of the Rheinisches Landesmuseum, Bonn, Germany. Artifacts likewise proved amenable to DNA sampling. Woodward et al. (1996) analyzed parchment documents written ca. two thousand years ago to determine the species that furnished the parchment, to identify individual animals or herds whose hides were joined compositely in a single scroll, and to combine fragments of common origin. Pichler et al. (2001) nondestructively analyzed the DNA of sperm whale teeth and a piece of scrimshaw. DNA recovery is no longer controversial and other examples are too numerous to cite.

The preceding discussion has explored some historical aspects of older museum collections, the problems and contradictions they can present as representations of the outside world, and the uses to which they can be put. As a plan for future action, we suggest that, firstly, it is of the utmost importance that collecting information be preserved. As old hand- and typewritten museum records are digitized it may be that valuable notations, remarks and contexts are not transferred to the new format. Therefore, it is desirable that photographic images of card files and ledgers be kept along with the converted records if the original records cannot be kept. Secondly, specimens should be evaluated before disasters occur in terms of their importance and this should be part of their registry information. Objectively, unique specimens and type specimens are obvious choices in terms of rescue and salvage. Paradoxically, however, the better a type specimen has been described, the more easily its loss could be remedied. For example, although the sole definitive specimen of *Spinosaurus aegyptiacus* is not extant, Stromer's published descriptions and drawings, corroborated by more recently discovered photographs of the specimen, provided the basis for further scientific evaluation (Smith et al., 2006, q.v. for original references). With the discovery of new material, the revelation that *Spinosaurus* was adapted to a semiaquatic lifestyle (Ibrahim et al., 2014) has become one of the most fascinating dinosaur discoveries of recent times; a reconstruction of its skeleton was the star attraction of Dinosaur Expo 2016 at the National Museum of Nature and Science (Ueno, Tokyo). A further example is the original material of Peking Man, *Homo erectus pekinensis*, all of which still in Chinese hands disappeared in the chaos of World War II China, but which is sufficiently well documented via descriptions and casts. In that case, however, DNA recovery might have been possible if the originals had survived. The selling of casts of museum favorites such as *Tyrannosaurus rex* also incidentally provides some protection against loss of the original. Furthermore, the use of 3-D printing to create duplicates, the templates for which can be electronically stored, provides additional backup, at least for external parameters. Therefore, the mere fact of a specimen being a name carrier is not in itself a mark of high value in an emergency situation, especially considering the high percentage of synonyms for many groups. As the oldest name generally has priority, it follows that the earliest validly named specimens are more likely to be senior synonyms in their particular group, so that the date of description provides a further objective criterion for preference.

It could be argued that these procedures overvalue a typological approach which has been criticized, most prominently by Ernst Mayr, and which is to some extent being
bypassed by cladistics, which is operating as a kind of shadow cabinet in relation to conventional taxonomy. Nevertheless, the entire historical structure of taxonomy for the last two hundred and fifty years rests on the identification of specimens by means of Linnaean nomenclature. Mayr himself, the great opponent of typology, named 26 new species and 445 new subspecies between 1926 and 1960 (Haffer, 2007, p. 161). Whatever alternatives may arise in the future, this is the reality, so far as museum collections are concerned. It may be noted that mineral classification has more recently adopted a typological approach modeled on the biological one, so that the loss of a mineral holotype is as consequential as the loss of one of an organism.

Realistically, cost factors and limitations in skilled personnel come into play in planning for recovery from disasters. The first thing, clearly, is to have a plan in place. Anticipation can be based on history and local circumstances. In Japan damage from earthquakes and tsunamis is to be expected; in Australia, on the other hand, exterior fire is the main danger; elsewhere, floods. In my view, conserving records is primary, and this can be done in advance. In larger institutions, curators should be cognizant of what they regard as the most important specimens in their particular areas of responsibility. Knowledge of what to do in the face of disasters should be institutional, rather than individual, in other words, should not necessarily be dependent on the continued presence of the person or persons who made the preparations and selections. In smaller institutions, focus should be on saving locally unique and irreplaceable specimen material, and, with an eye to the future, on documenting genetically threatened species. The importance of this is highlighted by the fact that the New York Botanical Garden and the Brooklyn Botanical Garden, both venerable institutions with important collections of worldwide scope, have recently instituted programs to document local floras more fully.

Acknowledgements
Following the 2011 Tohoku Earthquake and Tsunami, I visited the affected areas in two successive years (2013 and 2014), observed the hard work and resilience of the inhabitants and especially of the museum personnel, and visited the facility where restoration work on the Rikuzentakata museum collections is being carried on. I was also able to attend two successive annual meetings of the curators’ group of Tohoku, which saw the need for regional coordination among museums after the disaster, and visited many museums in the area as part of the program of the meetings. I particularly thank Makoto Manabe (National Museum of Natural History, Tokyo, Japan) for his companionship and invaluable assistance, and Masaru Kumagai and family of Rikuzentakata for their hospitality. I also thank Suzuki Mahoro (Iwate Prefectural Museum, Morioka, Japan) for her help during my visits, and for taking on the task of preparing this volume.

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Salvage and Restoration of Natural History Collections
Damaged by the 2011 Tsunami in Japan

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Abstract

The tsunami of 11 March 2011 destroyed museums on the coasts of Iwate and Miyagi Prefectures in northern Japan. Thousands of natural specimens stored in the museums were severely damaged by the tsunami and had to be salvaged by museum staff. Nationwide networks of curators, researchers and volunteers have been involved in cleaning and restoring the specimens. This paper describes the procedures used in the salvage and restoration of the collections, and discusses emergency response and disaster preparedness in museums.

1. Natural history collections damaged by the 2011 tsunami.
On the coast of the Tohoku region of Japan, which was hit by the Great Eastern Japan Earthquake and subsequent tsunami on March 11, 2011, many cultural institutions including museums, libraries and archives were severely damaged.

Table 1 shows museums that housed natural history collections and that were damaged by the tsunami. All were on the Sanriku Coast. Other museums in the tsunami-inundated area were also damaged, but they had few natural specimens.

Table 2 shows the natural history collections of the tsunami-damaged museums in Iwate Prefecture. 84% of over 80 thousand marine algae sheets in the Yamada Town Whale and Sea Research Center were lost. 27% of 130 thousand shell specimens in the Rikuzentakata Sea and Shell Museum were lost. The Rikuzentakata City Museum housed biological and geological specimens representing various taxa and most of them were salvaged. Besides these, tens of thousands of specimens in personal collections are believed to have been lost.

In Miyagi Prefecture, the number of natural history specimens lost was much smaller than in Iwate Prefecture. Kawase (2011), Nagatomo (2011) and Sasaki et al. (2013) reported in detail on tsunami-damaged specimens and museums in Miyagi Prefecture.
2. Tsunami-damaged museums in Iwate and the "collection rescue" operation

The Whale and Sea Research Center in Yamada Town collected whale specimens as well as whaling and fishing tools. It also housed a collection of about 82,500 marine algae specimens collected by the late Dr. M. Yoshikawa.

Photo 1 was taken on 24 May 2011, 74 days after the tsunami. It shows the exhibition of algae on the third floor of the building. There was a line on the wall that showed that the sea water actually came up to this level.

Photo 2 shows a storage room on the first floor of the building. Sea water and mud rushed into the room, and the marine algal specimen bottles were buried. The bottles were salvaged by museum staff and volunteer workers.

Photo 3 shows the site of the lost storehouse that contained the marine algae specimens. 70,000 specimen sheets were washed away and the remainder were buried under the rubble. The latter were also salvaged by museum staff.

Photo 4 shows a whale skeleton exhibited in the damaged museum. Nakamura (2011) described the cleaning and restoration of this specimen.

The Rikuzentakata Sea and Shell Museum housed over 130,000 shell specimens, including the types of many marine snails.

Photo 5 was taken four weeks after the tsunami, when one of the authors (Mahoro S.) firstly visited the tsunami-damaged area. It shows that large pieces of debris from houses flowed into the entrance hall of the museum with the receding water. All the windows on the first and second floors were broken, and most of the exhibited specimens were washed away by the tsunami.

There was a windowless storage room on the second floor and all the specimens in it remained, whereas most of those in another storage room that had a window were carried away by the tsunami through the window (Photo 6).

The museum staff began salvaging specimens on 4 April 2011, about one month after the tsunami. The staff of the Iwate Prefectural Museum in Morioka City, 110 km from Rikuzentakata, came to help them. All the salvaged specimens were wet and covered with sand (Photo 7). The museum staff transported them to safe inland places in Rikuzentakata City and Morioka City.

The Rikuzentakata City Museum was established in 1959, and is the oldest museum in Iwate Prefecture. It had 150,000 items chronicling the historical and natural heritage of the city.

Photo 8 was taken 12 days after the tsunami. At this time, no-one could approach or enter the building because the rubble blocked the entrance.

Photo 9 was taken one month after the tsunami, in which the entire museum staff perished. The collection rescue operation started one month after the tsunami, in parallel with that at the Sea and Shell Museum. The staff of the Sea and Shell Museum and their colleagues from Iwate Prefecture removed rubble and waste from the building, and salvaged the collections.

Rubble and waste were packed into the storage room on the ground floor (Photo 10). Specimens were stored at the farther end of the room.

Two weeks later, we began to receive support from the Japan Self-Defense Forces (Photo 11). That made it possible to salvage all the collections of the museum.
In summary, the collection rescue operation started one month after the tsunami, and it took about 2 weeks. We were eventually able to transport the natural history collections to safe places.

Guidelines for disaster preparedness in museums often say that “the response during the first 48 hours after disaster strikes is critical.” In our case, it took 48 days to salvage the collections.

One of the reasons why it took so long is that the scale of human loss was so huge. In Rikuzentakata City, 7% of the population, including two thirds of museum staff, were lost in the tsunami.

Secondly, it took two weeks to restore transportation and communication systems in Iwate, especially in the tsunami-damaged area. We could not get gas to go there by car nor even telephone the people in the damaged area for two weeks after the tsunami.

Finally, museums in Japan were poorly prepared and had little strategy for such huge disasters. We have to establish or improve local and nationwide museum networks and prepare them for emergencies and disasters. As the first step, the local museum associations in Japan will draw up rules for disaster response over the coming years. We also need these rules at the national level. If we can achieve this goal we will be able to cope more efficiently with future large scale disasters like the one in 2011.

3. Restoration project for tsunami-damaged collections of Rikuzentakata City Museum.

1) Biological specimens

15,000 sheets of vascular plant specimens were salvaged from Rikuzentakata City Museum. We transported them by car to the garage of the Iwate Prefectural Museum in Morioka City (Photo 12).

Fortunately, each sheet had been housed in a plastic bag. Half of them were therefore safe and clean, but the other half were wet, muddy and partly moldy.

Photo 13 shows salvaged insect boxes. We transported 240 boxes to Morioka. Their glass covers were broken and specimens inside were covered in mud.

Animal taxidermy specimens were also salvaged from Rikuzentakata City Museum, though they were moldy and half-rotten (Photo 14).

In this way we salvaged biological specimens 48 days after the tsunami. They included many types and historic specimens that are invaluable to academics, as well as important natural records of the flora and fauna of the Sanriku coast. They were wet and dirty, moldy and half-rotten. They needed to be washed, dried, and sterilized.

The project to restore the damaged specimens started seven weeks after the tsunami. We drew up cleaning and restoration protocols for plant, insect and shell specimens. Then we sent e-mails to other museums all over Japan and asked them to join the restoration project. At this time, we had no public financial support, so this project was a voluntary effort. However, the museum and curators' networks supported us, and we had enough offers of help within a few days. We packed the damaged specimens in cardboard boxes and sent them to about 50 museums and research institutes all over Japan by private delivery service. At the museums and institutes, staff and volunteers washed the specimens. The curators discussed and improved the protocols via e-mail.

Damaged specimens were contaminated with sea water and mud that contained a considerable amount of sea salt. We thought that the salt would attract moisture and
mold, so we placed emphasis on desalting specimens in the protocols. The methods to clean and desalt damaged specimens have been published on the web (Mahoro 2015a; Mahoro 2015b; Mahoro and Kumagai 2015; Tomioka 2015; Iwami 2015; Yamada and Tajima 2015).

We have finished cleaning most of the specimens according to the protocols and are testing their scientific adequacy. We also need to monitor the state of these specimens for long-term preservation. We are creating databases and images of the collections and are going to publish them on the internet. By sharing the databases, we can let people know the value of the salvaged specimens.

2) Geological and paleontological specimens

More than 1400 geological and paleontological specimens, such as rocks and fossils, were salvaged from the Rikuzentakata City Museum. These specimens were too heavy to be sent out to volunteers, who instead were asked to come to Rikuzentakata City to “rescue” the specimens (Oishi et al. 2013) (Photo 15, 16). These group activities were organized by Dr. Masayuki Oishi of Iwate Prefectural Museum, and have been partly funded by the Geological Society of Japan and the Paleontological Society of Japan. Additional funding was provided by the National Museum of Nature & Science, Japan, the Paleontological Society of Japan, and the Tokyo Geographical Society in order to send experts from various parts of Japan to Rikuzentakata to study geological specimens. Okumura et al. (2013) and Oishi (2015) described in detail the methods for cleaning with hypochlorous acid, identifying, classifying and re-cataloguing the specimens.

The restoration projects for tsunami-damaged collections of the Rikuzentakata City Museum were accomplished by wide-area networks of museums and curators in Japan. They included short-term trials and voluntary activities. In preparation for future disasters, museums need a permanent nationwide framework that can provide rapid and systematic aid and financial support to “collection rescue” projects.

Acknowledgements

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References


Mahoro, S. 2015b. Stabilization and restoration of insect specimens. In: Multi-Organizational Co-Operative Project for Preserving and Restoring Cultural Assets


Photos and Tables


Photo 2. A storage room on the first floor of the Whale and Sea Research Center in Yamada Town.
Photo 3. The site of the lost storehouse that contained the marine algae specimens in Yamada Town. Photograph taken by Dr. T. Kitayama (National Museum of Nature and Science, Japan).

Photo 4. A whale skeleton exhibited in the Whale and Sea Research Center in Yamada Town.
Photo 5. The entrance hall of the Rikuzentakata Sea and Shell Museum. Photograph taken on 7 April 2011.

Photo 6. A storage room on the second floor of the Rikuzentakata Sea and Shell Museum. Most of the specimens were carried away by the tsunami through the window.
Photo 7. The salvaged specimens of the Rikuzentakata Sea and Shell Museum.

Photo 8. The Rikuzentakata City Museum. Photograph taken 12 days after the tsunami.

Photo 10. The storage room on the ground floor of the Rikuzentakata City Museum.
Photo 11. Support from the Japan Self-Defense Forces to the collection rescue operation.

Photo 12. 15,000 sheets of vascular plant specimens salvaged from Rikuzentakata City Museum.
Photo 13. Insect boxes salvaged from Rikuzentakata City Museum.

Photo 15. Washing geological specimens salvaged from Rikuzentakata City Museum.

Photo 16. Attaching labels to the geological specimen.
Table 1. Museums that housed natural history collections in the tsunami-damaged Area.

<table>
<thead>
<tr>
<th>Prefecture</th>
<th>Museum Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iwate Prefecture</td>
<td>Yamada Town Whale and Sea Research Center</td>
</tr>
<tr>
<td></td>
<td>Rikuzentakata Sea and Shell Museum</td>
</tr>
<tr>
<td></td>
<td>Rikuzentakata City Museum</td>
</tr>
<tr>
<td>Miyagi Prefecture</td>
<td>Utatsu Ichthyosaur Museum</td>
</tr>
<tr>
<td></td>
<td>Oshika Whale Land</td>
</tr>
<tr>
<td></td>
<td>Minami-sanriku Nature Center</td>
</tr>
</tbody>
</table>

Table 2. Natural History Collections of Tsunami-Damaged Museums in Iwate.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Number of stored specimens</th>
<th>Number of salvaged specimens</th>
<th>Museum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological specimens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular Plants</td>
<td>16,000</td>
<td>16,000</td>
<td>Rikuzentakata CM*</td>
</tr>
<tr>
<td>Mosses</td>
<td>500</td>
<td>500</td>
<td>&quot;</td>
</tr>
<tr>
<td>Lichens</td>
<td>200</td>
<td>200</td>
<td>&quot;</td>
</tr>
<tr>
<td>Fungi</td>
<td>170</td>
<td>155</td>
<td>&quot;</td>
</tr>
<tr>
<td>Insects</td>
<td>27,000</td>
<td>24,000</td>
<td>&quot;</td>
</tr>
<tr>
<td>Marine Animals</td>
<td>150</td>
<td>134</td>
<td>&quot;</td>
</tr>
<tr>
<td>Vertebrates</td>
<td>500</td>
<td>500</td>
<td>&quot;</td>
</tr>
<tr>
<td>Shells</td>
<td>130,000</td>
<td>96,000</td>
<td>RSSM**</td>
</tr>
<tr>
<td>Marine Algae</td>
<td>82,500</td>
<td>13,500</td>
<td>Yamada Whale RC†</td>
</tr>
<tr>
<td>Total</td>
<td>269,020</td>
<td>149,989</td>
<td></td>
</tr>
<tr>
<td>Geological specimens</td>
<td>3,300?</td>
<td>3,300</td>
<td>Rikuzentakata CM*</td>
</tr>
</tbody>
</table>

* Rikuzentakata City Museum
**Rikuzentakata Sea and Shell Museum
+ Yamada Town Whale and Sea Research Center
How Should we Prepare for the Next Disaster?  
The Present Situation of Japanese Biodiversity Heritage in Museums, with Strategies for Conservation  
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Keywords: cultural properties, digitization, museum networks, natural history, preservation  

Preface  
In 2011, Japanese society faced gigantic disasters. Following the Tōhoku earthquake and tsunami, fire and nuclear accidents made the situation even more complicated. Museums and cultural properties scattered along 500 kilometers of Japan’s Pacific coast suffered heavily. This was a disaster on a scale that Japanese museums had never experienced before, not only in the size of the affected area but also in the variety of cultural properties in need of rescue.  

Natural history collections were among those affected. Many Japanese natural history museums joined in the restoration of entomological and botanical specimens, shells, bones, stuffed animals, and geological specimens including fossils. The disaster happened at the beginning of spring, so quick treatment was needed to avoid further damage to specimens and labels through bacterial and fungal action.  

Salvage and stabilization activities have been well documented by Mahoro and Manabe (2016). In this chapter, we focus on the social and legal aspects of the conservation and preservation of natural history collections.  

The overall situation of natural history collections in Japanese museums  
According to the Social Education Survey (2013), museums in Japan (including botanical gardens, zoos and aquariums) house 53,285,808 zoological, botanical and geological specimens. This considerable total is comparable to that for archeological and historic artifacts (Table 1).  

The number of natural history specimens in museums has grown rapidly during the last 30 years (Fig. 1). In the 1980s there were 27,713,856 such items in university collections (Research Group for Natural History Specimens owned by Universities 1981) but only 2,337,786 in public museums. Universities have traditionally stored many specimens of high academic and historic value, but some have been lost or transferred to local and national museums as professors have retired. Recently some
universities have set up their own museums to house important specimens, but there have been problems with facilities, staff and operating budgets. Meanwhile, local natural history museums were founded in the 1980s and 1990s, as environmental issues became more important. These institutions vary in size according to mission, budget and the requirements of local governments. Some smaller museums experience conflicts between the conservation of specimens and other work. Nevertheless, local museums have come to be an important component in the nationwide conservation of natural history specimens alongside national museums and universities.

**Japanese natural history specimens in the legislative system**

The Japanese Cultural Property Law has its roots in pre-WWII regulations governing the conservation of fine art and national treasures, and it thus does not specifically cover natural history collections. It is possible to register certain antique natural history specimens as items of cultural heritage, but most are not governed either by the Agency for Cultural Affairs or the cultural departments of local governments and therefore have no legal standing. On the other hand, the Museum Act defines museum as “organizations with the purpose of collecting and preserving (including nurturing) materials related to history, the arts, folk customs, industry, natural science, etc., exhibiting them, providing them for use by the general public on the basis of educational considerations, conducting necessary work in order to contribute to education, research, recreation, etc., and in addition undertaking surveys and research relating to these materials.” Natural history collections in museums are therefore considered museum property under the law.

The Museum Act sets certain standards for Japanese museums, including registration, curator certification etc., but national regulations regarding museum governance and policy are limited. Collections, including specimens and related documents, antiques, art etc., are protected under the policies of each museum and not by national standards or restrictions. Historic or artistic items, however, are covered by the Cultural Property Act. As the governing body under the Act, the Agency for Cultural Affairs supervises and sets standards for conservation practices, but as mentioned above natural history collections do not fall under its purview.

In 2011, salvage activities were conducted using an expanded definition of “cultural properties” to classify items of many kinds as “unregistered cultural properties” under the Cultural Property Act. United as the “Committee for salvaging cultural properties affected by the 2011 earthquake off the Pacific Coast of Tōhoku and related disasters”, museums and academics of many kinds cooperated widely. The salvage of natural history specimens was also overseen by this committee.

As a result of the committee’s activities from 2011 to 2013, this expanded concept of “cultural properties” has become a de facto standard. The National Task Force for the Japanese Cultural Heritage Disaster Risk Mitigation Network (http://ch-drm.nich.go.jp/eng/) set up in 2014, includes the National Museum of Nature and Science in Tokyo, the Japanese Council of Science Museums and the Natural History Museum Network of Western Japan among a variety of other cultural and museum-related organizations. The expansion of conservation and salvage strategies is reflected in local networks for cultural property conservation following disasters. Although local government activities used to be limited to those required by the Cultural Property Act,
the need for conservation and salvage of natural history collections has gradually become accepted by cultural professionals. However, there remains a gap in the legislative system. The CH-DRMN is not a permanent organization and has only temporary funding. There is currently a need to further discuss the value and conservation needs of natural history collections with a wide range of cultural professionals in order to establish a more concrete system for conserving them with a legislative foundation.

**The role of museum professionals in setting standards**

The legislative process requires both evidence of social needs and standard models for practice. To achieve legal protection for natural history collections, we have to model conservation practices not just within the museum but also at the social level. Today, “public participation” is a key concept even in museum specimen conservation (Shirk et al. 2012). Many volunteers participate in the conservation process at various museums, but these activities are solely under the direction of the institution’s curators. However, many small museums in the countryside lack professional curators and there is a risk of misdirection or inappropriate treatment of specimens. In promoting public participation, therefore, appropriate direction by museum curators and the use of standard procedures are important. Standards should include a written code of ethics, textbooks and operating manuals, and discussion bodies should be set up to develop consensus among museum professionals.

The Code of Ethics & Museum Principles of the Japanese Association of Museums was adopted in 2012. In addition, the ICOM Code of Ethics for Natural History Museums has been translated into Japanese (Sakuma 2014). There are also some textbooks for natural history collection management (Matsuura 2014, Osaka Museum of Natural History and Osaka Natural History Center 2007). Discussion bodies for museum professionals should be a key factor in bringing these standards and manuals into practice, but are still under development in relation to natural history museums in Japan.

There are several activities at different levels, and we should coordinate these activities to make better discussion bodies.

**Level 1. General national bodies for museums**

The Japanese Association of Museums and The Museological Society of Japan are national discussion bodies encompassing museums of all kinds, though as natural history museums are in the minority it can seem difficult to focus discussion on their collections. On the other hand, these bodies host inter-disciplinary discussions among many kinds of museums.

**Level 2. National bodies for natural history museums**

The Global Biodiversity Information Facility (GBIF), which aggregates natural history specimen data, has Japanese node in the National Museum of Nature and Science and a nationwide network of curators. It arranges meetings to improve data quality and the protection of collections and to foster mutual understanding among natural history museums. This can be a forum for discussion of preservation and conservation issues, even though it is outside the scope of the present project. The Japanese Council of Science Museums is another nationwide association that includes natural history museums. Its annual meeting features symposia and research
presentations but attendees tend to be mostly directors and curators from larger museums.

Level 3. Local museums

The Hokkaido Natural History Research Society and the Natural History Museum Network of Western Japan are active local groups of natural history museums. Together with the personal network of curators in the GBIF project they were the main participants in the salvage activities of 2011.

In creating a forum for discussion among natural history professionals, a mixture of levels 2 and 3 would be most effective. Their proposals could then be discussed at level 1 to broaden understanding among museums of all kinds. The Science Council of Japan, which set up a “Sub-committee for the treatment of natural history collections as cultural heritage” in its basic biological science committee in 2012, is another target for efforts to promote mutual understanding. Their discussions (Nishida 2015) have included steps towards greater evaluation of natural history specimens. Some curators have also held a series of meetings with The Ecological Society of Japan to expand the possible utilization of specimens (eg. Mitsuhashi 2005, Sakuma 2011). Academic support of all kinds is important, especially in the legislative process.

Next steps in improving the protection of Japanese natural history collections

We have to prepare for future disasters and such preparations should not inhibit the activities of museums, but rather should enhance them. We present here a tentative menu for Japanese natural history museums over the next 5 to10 years.

1. Summarize the technical manuals developed for the salvage projects of 2011
This has already been almost completed through the efforts of Akanuma and Suzuki, who wrote detailed accounts in “Stabilization processing” (“Multi-Organizational Co-Operative Project for Preserving and Restoring Cultural Assets Damaged by Tsunami on March 11th, 2011” 2014). We also have some plans for manuals in Japanese, and these will be useful for volunteer work following future disasters.

2. Promote discussions among natural history professionals
Discussions should not only be among professionals in museums, but should also involve taxonomists, ecologists, geologists, paleontologists, etc. in universities and at citizen level. It is important to have helpers working pro bono outside the museums. To achieve that we should learn from the US-based Society for the Preservation of Natural History Collections (SPNHC), whose members offer broad experience in cooperation between museums and university collections and in citizen participation. The discussion should be accompanied by action, such as workshops, the development of toolkits and training programs. Again, there are many model cases overseas (Kageyama 2017).

3. Create an academic medium for Japanese Natural History Preservation
For most natural history curators, conservation work has no benefit in terms of academic output, simply because there is no suitable medium for it. International journals such as “Curator” are thought to be inappropriate for short papers on local matters. We should instead create domestic journals to share our knowledge and
experiences. We are currently considering establishing a web-based journal starting around 2017.

4. Better digitization of museum data
Natural history specimens should be more fully digitized for enhanced utilization and safer storage. Data from natural history specimens have potential uses in broader scientific study, in environmental policy-making and in “Linked Open Data” platforms such as Wikispecies. As national and local biodiversity conservation strategies increase in importance, so museum data is becoming more valuable.

Digital data enable museums to have remote backups. In the case of the Rikuzentakata Sea and Shell Museum, the specimen data stored in the museum was lost. Luckily, old backups were found at another site and these were helpful in the salvage process. However, most local museums in Japan currently have no official backup system. For the future salvage of museums following disasters, nationwide backup systems are very important.

Because GBIF only gathers “published data” without personally identifiable information and “unpublished data” such as records of endangered species, uncertain information and so on, it cannot be a full backup system. At present, the Japanese GBIF system has a double layer of “GBIF data” and “data in Japanese” for each specimen record. If we made this into a 3-layered system of “published GBIF data”, “published data in Japanese”, and “unpublished data”, that could serve as a full backup system for local museums. Possibilities therefore do exist.

The digitization of local museum specimens should be part of national policy. In 2015, the Japanese government launched its ”Basic Plan for Cultural Programs in the 2020 Olympic Games”. The information stored in museum collections represents vast, unique, and diverse cultural properties and the same is true for natural history specimens. We have to connect these immense resources of local cultural and environmental content to web-based media to utilize them as “collective knowledge” of our society. The National government set out a “Strategic Program on the Creation, Protection and Exploitation of Intellectual Property” in 2016. Museum digitization and conservation enforcement ought to be important parts of this program. We have to actively promote the value of museum specimens in the social, academic, and government spheres until it becomes generally accepted.

Acknowledgement
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References
Matsuura, K. 2014. Collection building and management for natural history (2nd ed.)


Table 1. Number of museum stored specimens in Japan

<table>
<thead>
<tr>
<th>Type of the specimens</th>
<th>Natural History</th>
<th>Archeology</th>
<th>Folklore</th>
<th>History</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>53,285,808</td>
<td>44,892,946</td>
<td>6,662,292</td>
<td>1,804,222</td>
</tr>
</tbody>
</table>

According to Social Education Survey (Ministry of Education, Japan 2013). The number of the specimens are accumulated all types of the museum in Japan, including botanical gardens, zoos and aquarium. Specimens of Research institutions are not included.

Fig. 1. Number of museum stored natural history specimens in time.

Data is taken from “Social Education Survey”, held in every 3 years. In 2008, it seems that some of the museum did not respond.
Disaster Preparedness and Response: Best Practices, Training, and Networking to Protect Natural Heritage Collections in North America

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Keywords: emergency management, museum, natural history, preservation

Abstract

The purpose of this paper is to alert biodiversity researchers, especially natural history collection administrators and affiliated professionals to the risk of disasters and their potential catastrophic impact on irreplaceable scientific specimens. First, the paper puts emphasis on the importance of identifying risk that can lead to different emergency scenarios. Next, it focuses on the importance of developing a disaster response plan during a non-emergency time to minimize damage to collections. Finally, the paper discusses the benefit of building partnerships and networks in emergency preparedness and response activities.

Introduction

The author wishes to contribute to the theme of Disaster and Biodiversity by introducing various approaches and solutions to emergency planning for collections that have been adopted in North America, so that these examples may possibly serve as best practices that can be modeled after in other regions of the world. Stakeholders such as museum administrators, directors, curators, and collection-based scientists are particularly encouraged to reach out and start dialogues even beyond the bounds of their own institution and academic discipline to tackle this common challenge, with the shared goal of safeguarding invaluable collections of natural and cultural heritage.

Need for Emergency Planning

Today, emergency preparedness and response planning has become an important part of museum operations in the United States, in keeping with the trend over the last century towards actively building and appreciating heritage collections. Heritage collections, including natural history collections, are held in trust for the public. From a legal point of view, heritage organizations assume a duty of care for collections entrusted to them
Museums are responsible for minimizing foreseeable risks to these cultural and scientific assets. Indeed, the American Alliance of Museums (AAM), which sets national industry standards as the largest museum professional organization in the country (Merritt 2008), treats a disaster preparedness and response plan as one of the five core documents required for a museum to achieve the Alliance’s prestigious "accredited" status (AAM 2012a, 2012b, 2012c). Yet not until recently had the practices of disaster planning gained broader support in the collection preservation field. This worrisome situation was highlighted by a nationwide survey conducted by Heritage Preservation in 2004, which revealed that as many as 80% of collection-holding institutions in the U.S. were at serious risk as they lacked a disaster plan for safeguarding their collections and staff trained to carry it out in an emergency (Heritage Preservation 2005). Natural history museums and related scientific institutions are no exceptions, but it is also worthy of note that natural history museums are a clear minority in the U.S. museum sector, accounting for only about 1% of 35,000 non-profit organizations categorized as museums in the nation, compared to cultural organizations such as historical societies and art museums, which account for over half (Grimes et al. 2014). The library and archive community is even larger, with about 120,000 libraries known in the nation according to the American Library Association (2016). This means that rather than reinventing the wheel with limited resources by themselves, those who are committed to protecting biodiversity collections from disasters are able to learn a great deal from similar projects spearheaded by cultural property professionals.

An increasing number of natural and man-made disasters have alerted not only collection caretakers but also institutional administrators to the urgent need for emergency planning. Fortunately, relatively abundant literature, free online resources (e.g., Foundation of the American Institute for Conservation (FAIC) 2014; Smithsonian Institution Cultural Rescue Initiative 2016), and training opportunities are available to museum and archive personnel in the forms of staff education, table top exercises, and community forums with a primary focus on emergency planning. Not surprisingly, advocacy for emergency preparedness has been all the more prominent in geographic regions frequently hit by large-scale natural disasters. Numerous institutions in these areas have had to learn painful lessons from loss and damage caused by major disasters like hurricanes on the Gulf and East coasts, tornados in the Plains, and wildfires in the Southwest. As another example, in earthquake-prone California, the Getty Conservation Institute affiliated with the J. Paul Getty Museum in Los Angeles is recognized as having exhibited strong leadership in emergency preparedness against seismic activities (Dorge 1999; Podany 2008).

Generally, disaster planning can be viewed as a circular continuum of several major phases of actions encompassing mitigation, preparedness, response and recovery (Figure 1) (Baird 2010; National Governors’ Association Center for Policy Research 1979; Untch 2011). During a non-emergency time, which corresponds to the mitigation and preparedness phases, institutions are encouraged to assess risk, write a plan and test it, take mitigating and preventive measures, build and train a team, and develop good relationships and communication mechanisms with local emergency response partners. Without maintaining an institutional emergency plan as a living document or regularly testing and exercising it as a whole team, disaster planning will remain incomplete and ineffective, which in turn renders such institutions vulnerable in any future crisis.
Conversely, if an organization truly commits to planning, improving, training and networking, diligence will pay off and its long-term mission of prolonging the value of its natural history collections will be fulfilled.

**Risk Assessment**

Anyone can get involved with emergency preparedness activities by first identifying risk factors present in a particular geographic location, building facility, and collection storage space (Canadian Conservation Institute (CCI) 2014). This initial step makes it possible to address in emergency planning the specific threats posed to collections. With respect to risk assessment, the material compositions and physical properties of preserved objects also matter. Biological specimens are predominantly composed of organic materials, which are highly susceptible to environmental factors. However, the material basis of preserved specimens can also be a composite of inorganic and organic (e.g., organisms preserved in ethanol solution in a silica glass container; insects with pins made of steel or unknown metal). Furthermore, cryogenic collections such as frozen animal tissue samples may be highly vulnerable to power outages (Simeon-Dubach et al. 2013). Obviously, each different type of material interacts differently with various risk factors, and knowledge of potential health hazards while handling objects is also essential (Hawks et al. 2011; Kageyama 2013).

In the museum conservation field, a theoretical framework for preserving heritage collections has been well established around nine agents of deterioration (CCI 2014), specifically:

1. direct physical forces (vibration, etc.)
2. thieves, vandals, and displacers
3. fire
4. water
5. pests
6. contaminants
7. radiation (natural light, UV, etc.)
8. incorrect temperature including fluctuation
9. incorrect relative humidity including fluctuation

Often “custodial neglect” is added as a tenth agent of deterioration (Waller 1995). Deterioration of objects triggered by these agents can be either cumulative or catastrophic. With an understanding of these known agents of deterioration, it is useful to assess and analyze the vulnerability of collections to identified risk factors in an objective, comparable manner. For instance, the Cultural Property Risk Analysis Model (CPRAM) has proven to be an effective quantitative tool to assess risk not only in cultural property collections but also in natural history collections (Elkin et al. 2013; Southward et al. 2013). According to CPRAM, the Magnitude of Risk (MR) is the fraction of collection value expected to be lost given 100-year exposure to current conditions. MR is the simple product of four variables (Fraction Susceptible [FS], Loss in Value [LV], Probability [P], and Extent [E]) that are multiplied as follows: $MR = FS \times LV \times P \times E$ (Waller 2003).
Preparedness and Mitigation

Writing a comprehensive disaster plan based on risk assessment can be daunting. However, it can start small and expand to a full-scale version over time. For example, Pocket Response Plan™, which is a simple template printed on both sides of a sheet of paper and folded into a wallet size, is intended to be carried by staff at all times (Figure 2). The Pocket Response Plan’s content can be customized to each collection’s need to facilitate prompt access to the museum’s emergency phone tree and other critical contact information such as first responders, local partners, a 24-hour hotline to emergency response networks, and commercial vendors including freezer trucks and an insurance company. It can also include a step-by-step checklist, such as (1) channels of communication – immediate notification, and of whom; (2) how to assess collection damage; (3) collection salvage priorities; and (4) how to handle water damage to objects (Council of State Archivists 2006).

Even with limited time and efforts, at least the most important items within each collection should be accounted for and their condition monitored on a regular basis. First priority should be given to irreplaceable items, such as type specimens, specimens on loan from other institutions, those of extinct and endangered species, rare research materials, and original catalogue ledgers. Their inventory information can be readily incorporated into an emergency evacuation and salvage plan document. Their storage locations can be highlighted on a building floor plan to facilitate timely access while ensuring their security. Similarly, colorful graphic signage and visual aids such as flow charts, color-coded loose leaf binders, floor plans and maps may work as effective communication tools to inform people of what to look for and what to do in an emergency (e.g., Preservation Directorate 2009). An Emergency Response and Salvage Wheel™ (Figure 3) and its corresponding mobile App are popular tools for quick easy access to necessary information to respond to different major types of disasters and to treat various groups of collection objects (Heritage Emergency National Task Force 1997; National Park Service National Center for Preservation Technology and Training 2013). Another recommended preparedness activity is to create moveable storage bins and emergency kits to keep disposable salvage supplies, Personal Protective Equipment (PPE), and other useful items (e.g., gloves, masks, boots, helmets, towels, first-aid supplies, flash lights, cameras) in one place near the collection space that are immediately accessible by staff members. Additionally, facility management such as routine inspections of heating, ventilation and air conditioning (HVAC) and the fire suppression system is an extremely important step toward disaster mitigation.

Response and Recovery

In principle, disaster response must be swiftly initiated with life safety the first priority, followed by stabilization of the incident scene and affected infrastructure, usually led by first responders like fire fighters, police, and rescue professionals dispatched from local stations. If an event is area-wide, an Incident Command System (ICS) may have been established by the municipality (Carmicheal 2010; Emergency Management Institute 2013; Heritage Preservation 2006). Once a site inspection is conducted and safe access to the premises and collection storage facilities is approved, it is time to mobilize a trained emergency response team of dedicated museum professionals to carry out a series of property recovery actions (American Institute for Conservation of Historic and
Artistic Works (AIC) 2015; Heritage Preservation 2006). An emergency response team’s activities include assessment, documentation, stabilization, and salvage of both undamaged and damaged specimens and artifacts according to pre-planned response procedures and salvage priorities (AIC 2015; Heritage Preservation 2006). At the same time, the response team is expected to follow directions from the Incident Command System, which is still in charge of the overall situation in the area and the buildings immediately following an incident (Carmicheal 2010; Emergency Management Institute 2013).

The aim of the emergency response and recovery phases is to secure visitors and staff safety first and then to get back to normal operation as soon as possible, while minimizing loss and damage to treasured collections. 48-72 hours is viewed as the most effective and desirable response time for stabilizing damaged specimens and artifacts from a standpoint of object conservation best practices (AIC 2015; CCI 2014; Heritage Emergency National Task Force 1997; Heritage Preservation 2006). In reality, each incident can involve a new and different scenario, posing a unique set of challenges for which one may not be fully prepared. However, as long as disaster planning is in place and regular testing has been done beforehand, decision-making processes and appropriate actions will be executed promptly and smoothly, enabling the institutions to get back to their normal essential operations in the shortest time possible (FAIC 2014).

Pertaining to resources specifically designed for biodiversity collections, knowledge base for handling, stabilizing, salvaging and restoring damaged natural history specimens are quite limited on the publication or even anecdotal level (but see Galban (2003) as one of the few papers discussing natural history collections). Justification behind the recommended techniques and procedures in the collection object recovery methods (e.g., Heritage Emergency National Task Force 1997), such as putting water-damaged organic objects into a freezer to deter mold infection and "buy time," has been largely informed from the cultural property sector, especially paper conservators. The information is indeed versatile and applicable to diverse collection types. Nevertheless, from a more practical standpoint, scientific research materials do not always fit that general category. This situation can be viewed more positively as a great opportunity for future preservation scientific study. It seems all the more important today to document past incidents, accumulate empirical data, and establish and share best practices in emergency salvage procedures optimized for natural science materials. Such information must be highly useful during the response-recovery phases of the disaster preparedness cycle.

Training and Networking
Over the years, regional and local networking and collaborative training across institutions of different collection types has proven to be a key to success in raising community awareness and support. The most notable among such programs in North America with demonstrated success are those developed by Heritage Preservation, a non-profit organization founded in 1973 (but all of whose programs were merged into FAIC in 2015). Nationwide initiatives that have been promoted by Heritage Preservation include the Heritage Emergency National Task Force (e.g., Heritage Emergency National Task Force 1997; Heritage Preservation 2006), the Alliance for
Response (FAIC 2003), and the "MayDay" annual initiative (Society of American Archivists 2006).

On top of these, the American Institute for Conservation’s National Heritage Responders (AIC-NHR, formerly Collections Emergency Response Team: AIC-CERT) and the Western States and Territories Preservation Assistance Service (WESTPAS) are among bodies recognized as reliable non-commercial disaster assistance services with a 24/7 helpline (AIC 2015; WESTPAS 2013). The author participated in several of the WESTPAS emergency preparedness workshops together with a few dozen collection professionals representing various cultural institutions in Colorado, and found the intensive group training highly effective. These service organizations receive funding support and grants from federal agencies such as the Institute of Museum and Library Services (IMLS) and the Federal Emergency Management Agency (FEMA) to sustain their operations. On a much smaller scale, some major universities have formed cross-campus coalitions of libraries, museums, archives, galleries, and academic departments holding special collections and high-value resources located on the same campus for the purpose of sharing knowledge and resources (e.g., University of Illinois at Urbana-Champaign 2016). Finally, the Society for the Preservation of Natural History Collections (SPNHC) has also played a significant part in advancing the field, creating opportunities for networking among biodiversity collection stakeholders, and developing health and safety best practices for collection care professionals (Hawks et al. 2011).

Funding
Conventionally, U.S. federal agencies have provided major funding to promote disaster planning campaigns for non-profit organizations in the country. The IMLS, for example, has administered Museum for America grants and National Leadership grants with the goal of supporting exemplary leadership and stewardship of heritage collections (IMLS 2016a). Past funded projects conducted by organizations of all sizes and types include building a new regional support network to increase emergency response capability as well as a facility upgrade, such as a fire suppression system and indoor climate monitoring devices to address existing challenges in collection preservation (IMLS 2016b).

Turning specifically to natural history collections, the National Science Foundation (NSF), another federal agency that provides a funding for scientific research, has played a considerable role in emergency preparedness. The NSF does not directly fund disaster training or assistance programs for collections in a way FEMA or IMLS does as mentioned earlier. However, in line with one of its objectives of promoting biodiversity research, the NSF rather indirectly supports the initiative at the disaster mitigation phase, which is still significant in economic terms. The NSF has administered the Collections in Support of Biological Research (CSBR) Program, which provides funds for, amongst other criteria, improvements to secure and organize collections that are significant to the NSF-funded research community (NSF 2016a). Some of the past CSBR awards have been granted to projects that aim at improving the collection facility design in a way that make the scientific collections more risk-averse. For example, in recent years, at least several institutions holding major genetic resources collections have been awarded CSBR grants to upgrade their existing electrical freezers to a liquid
nitrogen system, which can achieve not only improving preservation quality of cryogenic samples but also providing better security from catastrophic interruption of power or other emergency, while reducing energy consumption (NSF 2016b, see e.g., NSF Award Numbers: 1458334, 1451925, 1561342).

Discussion
The foregoing review illustrates approaches generally accepted in the North American collection preservation community. However, the author does not intend to propose that these are one-size-fits-all solutions for protecting biodiversity research collections deposited in other countries. Administration of scientific collections takes many different forms and also comes with budgetary constraints. Yet it is the author’s hope that some solutions presented herein will inspire natural history institutions and biodiversity researchers to start a conversation on this very topic.

A few characteristics peculiar to the American model are worth special consideration. First, many of the endeavors are decentralized programs, coordinated not by the central government authority but by stakeholders and not-for-profit organizations representing public and community interests. The government only influences collections-focused emergency preparedness activities through grant funding. Accordingly, emergency response often takes a bottom-up approach. Executive decisions are usually made on site instead of orders coming down from a headquarters far away from the disaster scene. This is attributable partly to the government policy and legal system that permit semi-independent local decision making by nonprofit entities, but it is also driven by a strong sense of volunteerism and mutual trust rooted in the heritage collections community.

Secondly and related to the first point, no matter what types of heritage collections are to be protected from catastrophic events, the main emphasis is placed on taking prompt action in each unique disaster scenario as best as one can under the circumstances. Cross-institutional activities tend to be more locally focused, partnering with cultural organizations located in the same geographic area rather than seeking help from academic societies and scientific experts located elsewhere. Note that recovery team members may not be necessarily trained with natural history specimens, but that does not itself disqualify them from coming to provide assistance. They are still capable of methodically executing a disaster plan step by step even under highly stressful conditions. Given the country’s enormous geographic area, this approach makes sense.

For example, WESTPAS has a mission to serve and provides local training workshops in such remote regions as Alaska, American Samoa, Guam and Hawaii (WESTPAS 2013). The Alliance for Response program has contributed to launching decentralized cooperative disaster networks in 25 different geographic regions including suburban areas throughout the country (FAIC 2003). Swift mobilization of such existing support networks allows for timely recruitment and dispatch of a collection recovery team if one is requested.

As a thought-provoking story, a joint team of the AIC-CERT, the US Committee of the Blue Shield, and the Smithsonian responded in a timely way to the 2010 earthquake in Haiti (AIC 2015). The same organizations were also on alert in case they received an official request from the Japanese government to send a team of consultants to Eastern Japan in the aftermath of the 2011 Tōhoku earthquake and tsunami (Kageyama personal
communication). What if a Japanese counterpart, whether a government authority or a professional organization, had consulted the AIC-CERT/Blue Shield/Smithsonian immediately after the 3-11 disaster? This is the author’s mere afterthought, but the collection recovery program in Tōhoku upon receiving technical advice and logistical support from these outside experts might have operated quite differently.

Third, human resources that have traditionally supported collection operations might have lowered psychological hurdles to disaster planning work. The U.S. heritage collection sector recognizes and often employs specialist positions such as object conservators, collection managers, registrars, archivists, and facility managers separately from administrators, curators, and researchers. It is likely these professionals are willing to allocate more time and resources to disaster planning at their discretion as a part of their regular duties. The author’s further observation is that irrespective of collection types, cross-institutional cooperation and aid agreements tend to materialize more often among smaller organizations with limited resources yet having at least one dedicated collection care specialists on staff taking a lead in the collaborative planning process.

In summary, it is commonly recognized among many North American practitioners that disaster preparedness and response planning for museum collections, including natural heritage collections, is a major undertaking. It cannot be accomplished by a single person or in a day. It involves face-to-face dialogues with a number of colleagues, local partners, and outside experts. It emphasizes careful risk assessment, collaborative planning, drilling, and resource sharing. Most importantly, all these activities must happen and be ongoing during a non-emergency time period.

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Fig. 1. Four phases of the emergency preparedness cycle (adapted from Baird 2010).
Fig. 3. Emergency Response and Salvage Wheel™ (Heritage Emergency National Task Force 1997). Above: front side; below: back side.
Reconstruction Activity and Biodiversity

Chapter editors:

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Ecosystem-based Disaster Risk Reduction: A Review of Recent Progress and Remaining Gaps

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Abstract

Since the Indian Ocean Tsunami in 2004, there has been a growing interest and recognition of the role that ecosystems play in disaster risk reduction and ecosystem-based disaster risk reduction (Eco-DRR) approaches globally. This trend was further accelerated after the Great East Japan Earthquake in 2011 and has Eco-DRR now become widely recognized in various global policy frameworks. Despite this recent significant progress, Eco-DRR still faces some gaps and challenges. One gap is the scientific knowledge and evidence on the relationship between species, genetic diversity and DRR. Recently several research efforts have started to fill this gap and deepen our understanding how biodiversity conservation and Eco-DRR can interact.

What is Eco-DRR?
The Great East Japan Earthquake in March 2011 created a huge shock to all aspects of Japanese society. Ever since, we are continuously seeing and hearing many news stories about different types of natural hazards throughout the world such as flooding, landslides, avalanches, volcanic eruptions etc. Indeed, in the past few decades, the number of disasters caused by natural hazards has been increasing steadily, particularly those related to meteorological events (i.e. storms), hydrological events (i.e. floods) and climatological events (i.e. extreme temperatures, droughts and forest fires) (Monty et.al. 2016). Although the number of people killed by these disasters has been decreasing over the long term due to major advancements in non-structural mitigation measures such as early warning systems, evacuations, and risk communications, the amount of economic losses continue to increase exponentially (Renaud et.al. 2013).

While disaster is defined as “A serious disruption of the function of a community or a society involving widespread human, material, economic or environmental losses and
impacts which exceeds the ability of the affected community of society to cope using its own resources” (UNISDR 2009) disaster risk is defined as “The potential disaster losses – in lives, assets, livelihoods, etc. – which could occur to a particular community or society over some specified future time period” (UNISDR 2009). Disaster risk is determined by a combination of three main factors, namely i) hazards, ii) exposure and iii) vulnerability (Figure 1). Hazards are natural phenomena such as volcanic eruptions or avalanches. If such an event takes place in remote places far from human activities, it does not become a disaster. It is only when a hazard occurs in places where people or assets exist (exposure) and they cannot withstand shocks from the hazard (vulnerability), does it become a disaster.

Recently, reducing disaster risk became a major strategy at the global disaster management policy. Hyogo Framework of Action (HFA) 2005-2015 adopted at the Second World Conference on Risk Reduction in Kobe, Japan 2005 was the first global policy framework which featured DRR as its core element (UNISDR 2005).

Healthy ecosystems contribute to disaster risk reduction (DRR) through the three abovementioned elements of disaster risk. For instance, well established and managed forests could reduce the occurrence of natural hazards such as landslides. Healthy ecosystems could also strengthen the vulnerability by their ability to provide clean water or fuel in the aftermath of disasters. If hazard-prone areas are designated as protected areas, it could reduce the exposure through avoiding development activities that would have occurred otherwise in that area. In this way, maintaining healthy ecosystems reduces disaster risks.

An approach aiming at reducing disaster risk through “sustainable management, conservation, and restoration of ecosystems with the aim of achieving sustainable and resilient development” is called Ecosystem-based Disaster Risk Reduction (Eco-DRR) (Estrella and Saalismaa 2013) and has been recognized particularly since the Indian Ocean Tsunami in 2004 (Sudmeier-Rieux et.al. 2006). Around that time, the Millennium Ecosystem Assessment clearly provided evidence how various types of ecosystems such as forests, coral reefs and wetlands mitigate natural hazards through their regulation of ecosystem services (Millennium Ecosystem Assessment 2005).

**Eco-DRR: gaining momentum in the global policy**
Recently there was a substantial progress on integrating Eco-DRR into nature conservation and disaster management policy at the global level. For example, at the 12th Conference of Parties (COP) of the Convention on Biological Diversity (CBD) held in Korea in October 2014, the importance of Eco-DRR was recognized for the first time by parties by the adoption of decision XII/20 Biodiversity and Climate Change and Disaster Risk Reduction that also gives a strong mandate to the CBD secretariat to start working on this issue. This was followed by another decision XIII/4 Biodiversity and Climate Change at COP13 in Cancun, Mexico in December 2016 that encourages parties, other Governments and relevant organizations to integrate ecosystem-based approaches climate change adaptation and mitigation, and disaster risk reduction into their strategic planning across sectors. In June 2015, the Ramsar Convention COP12 in Uruguay also recognized the importance of Eco-DRR by adopting decision XII.13 on Wetlands and Disaster Risk Reduction which was proposed by the government of Philippines. They recognized the mitigation function of coastal mangrove forests played during the Hurricane Haiyan in 2013 and tried to raise awareness about the positive role of wetlands for DRR at the global level.

The Third UN World Conference on Disaster Risk Reduction (WCDRR) held in March 2015, Sendai, Japan adopted the Sendai Framework for Disaster Risk Reduction 2015-2030, which recognized the positive role of ecosystems for DRR (UNISDR 2015). At the same time, there is also a growing interest in ecosystem-based approaches for climate change adaptation (CCA), or Ecosystem-based Adaptation (EbA). EbA is defined as “the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change” (CBD 2009).

The fifth IPCC report on impacts, adaptation, and vulnerability by the WGII noted the rising risks of heat waves, heavy rains, floods, landslides, droughts etc. and also growing recognition of the value of EbA in addition to the conventional engineering and technological measures to address climate change impacts (IPCC 2014). The Paris Agreement on Climate Change adapted at the UNFCCC COP21 in Paris 2015 also recognized the importance of ecosystem-based approaches for both adaptation and mitigation. Although Eco-DRR covers non-climate related hazards such as earthquakes or volcanic eruptions, there is a substantial overlap between Eco-DRR and EbA as majority of disasters are caused by climatological, hydrological or metrological events (Lo 2016). The number of such disasters is expected to increase in the future as climate change accelerates. Thus many Eco-DRR measures are also expected to contribute to climate change adaptation in the long run.

Advantages of Eco-DRR and growing project implementation
At the field level, projects involving some form of Eco-DRR or EbA or both are being undertaken around the world, largely involving some type of ecosystem restoration, ecosystem management for improving livelihoods while reducing the impacts of hazard events (Doswald et al., forthcoming). Eco-DRR projects can also involve institution-building, such as establishing integrated watershed management coordination bodies for managing both natural resources and disaster risk.

In fact, Eco-DRR has become a bridge between two quite separate fields: ecosystem/natural resources management and DRR, in practice involving aspects of both.
Examples include IUCN’s Ecosystems Protecting Infrastructure and Communities (EPIC) project; UNEP’s Environment and Natural Resources Thematic Programme; or the Partners for Resilience project. Funded by the International Climate Initiative, EPIC operates in six different countries: Thailand, Senegal, Burkina Faso, Nepal, Chile and China, and combines various aspects of community-based ecosystem restoration with institution strengthening and global policy advocacy.

![Figure 2. Overlap between ecosystem-based adaptation (EbA) and ecosystem-based disaster risk reduction (Eco-DRR) (Source: Lo, 2016)](image)

The reason for this growing interest in Eco-DRR can be attributed to various advantages that Eco-DRR approaches have as compared to other conventional approaches that depend on structural measures (Sutton-Grier, 2015). Such advantages include lower construction and maintenance costs for Eco-DRR. Eco-DRR options could also provide various benefits thorough its ecosystem-services to local livelihoods and society during times when there are no disasters.

These advantages are making Eco-DRR popular in various parts of the world and traditional DRR practices that align with Eco-DRR ways of thinking are also being re-discovered (Ministry of the Environment of Japan 2016). For example, in Japan, people have been traditionally using forest management for many years to mitigate landslides, reduce wind-borne sand in coastal areas, floods in river basins and protect from other wind related hazards. Until recently, many civil work projects applied Eco-DRR concepts such as quasi-natural river restoration or flood control management using rice paddies and wetlands (Furuta 2015, 2016a, 2016b).

Similar movements can also be observed outside of Japan. For example, starting in 1996, a 20 year comprehensive national river work program, “Room for the River” has been undertaken in the Netherlands. Project activities included widening rivers, ecosystem restoration, and local economic revitalization. The Room for the River program was triggered by high water levels of the Rhine delta that led to the evacuation
of 200,000 people in the vicinity. One of the reasons for this high water level was the water flow increase due to climate change, in addition to urbanization and the channelization of rivers which increased water velocities, leading to a transfer of flood risk further downstream. In order to address this challenge, the Room for the River program used unconventional approaches such as widening rivers, creating new canals, restoring wetlands rather than increasing the levee heights (Furuta 2016c).

In the U.S., green options or approaches were incorporated in several recommendations in the Hurricane Sandy Rebuilding Strategy (Hurricane Sandy Rebuilding Task Force 2013) and an international competition to select Sandy recovery plans was organized under these recommendations (Table 1). In addition, the National Science and Technology Council published a report identifying research needs for coastal green infrastructure in August 2015 (CGIES Task Force. 2015). Following this report, the White House issued a memorandum to federal government agencies for requesting to incorporate ecosystem services into future decision making (Executive Office of the President of the United States 2015).

Table 1 Hurricane Sandy Rebuilding Strategy (2013) Recommendations on Ecosystem Services

<table>
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<tr>
<th>Recommendation</th>
<th>Description</th>
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<tbody>
<tr>
<td>19</td>
<td>Consider green options in all Sandy infrastructure investments.</td>
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<tr>
<td>20</td>
<td>Improve the understanding and decision-making tools for green infrastructure through projects funded by the Sandy Supplemental.</td>
</tr>
<tr>
<td>21</td>
<td>Create opportunities for innovations in green infrastructure technology and design using Sandy funding, particularly in vulnerable communities.</td>
</tr>
<tr>
<td>22</td>
<td>Develop a consistent approach to valuing the benefits of green approaches to infrastructure development and develop tools, data, and best practices to advance the broad integration of green infrastructure.</td>
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</table>

Source: Hurricane Sandy Rebuilding Task Force 2013

In the meantime, many other projects have been implemented in developing countries such as restoring mangrove forests in coastal areas to mitigate damages by tsunamis and high tides. In addition to the IUCN’s EPIC and UNEP’s Environment and Natural Resources Thematic Programme; or the Partners for Resilience project, a project called Mangrove for the Future (MFF) that started after the Indian Ocean Tsunami in 2004 is such an example and is implemented by the International Union for Conservation of Nature (IUCN) and the United Nations Development Programme (UNDP) (Mangrove for the Future 2017). Wetlands International is also implementing a mangrove restoration project in northern Java where serious coastal erosion is occurring (Furuta 2016d).

Available guidelines and tools on Eco-DRR

In order to meet the growing awareness and interest in Eco-DRR, various guidelines and tools that explain basic concepts and examples have recently become available. For example, at the World Parks Congress in Sydney 2014, a compilation of case studies on protected areas and DRR was launched (Murty and Buyck 2014) and guidelines for protected areas management for DRR was launched at the Third UN World Conference on Disaster Risk Reduction (Dudley et.al. 2015).
The Partnership for Environment and Disaster Risk Reduction (PEDRR) was established by more than 10 international agencies and NGOs including IUCN and the United Nations Environment Programme (UNEP) in 2008 has been providing training courses in various parts of the world and also providing MSc course and on-line course on Eco-DRR. Particularly, a Massive Open Online Course (MOOC) started 2015 attracted more than 10,000 subscribers from all over the world (Sudmeier-Rieux 2015). PEDRR also organized three international science and policy workshops on Eco-DRR that resulted in two books (Fabrice et.al. 2013 and 2016).

The Ministry of the Environment of Japan has been promoting Eco-DRR since the Great East Japan Earthquake in 2011. MOEJ has established a new national park called “Sanriku Fukko (reconstruction) National Park” in the coastal zone affected by Great East Japan Earthquake through integrating and upgrading existing various types of protected areas into one large national park and also by developing a long natural trail called “Michinoku Shiokaze Trail” in order to utilize natural resources to positively contribute to the reconstruction of neighboring communities (Kumagai et.al. 2013). MOEJ also produced a hand book to support implementing Eco-DRR projects by compiling basic information about Eco-DRR (Ministry of the Environment of Japan 2016). The Japan International Cooperation Agency (JICA) also published a flyer highlighting their own experiences on Eco-DRR projects in developing counties at the Third UN World Conference on Disaster Risk Reduction in March 2015 (Japan International Cooperation Agency 2015).

There is also a growing interest in Eco-DRR by the private sector. For example, a business association called WBSCD (World Business Council on Sustainable Development) headquartered in Switzerland has developed a training materials and started implementing training workshops on Natural Infrastructure that incorporate Eco-DRR as part of its concept (Natural Infrastructure for Business 2017). “Building with Nature” and the Ecoshape consortium are also working on several coastal protection sites around the world, while defining ecological engineering standards in partnership with the private sector (Furuta 2016d). Tokio Marine, a Japanese insurance company group that started mangrove reforestation in developing countries 1999 is actively communicating the economic value of their mangrove reforestation including those values related to coastline stabilization and erosion prevention, coastal hazard mitigation as well as other benefits to the local livelihood (Tokio Marine 2016).

**Challenges: the role of biodiversity for Eco-DRR**

As mentioned above, there has been significant progress in advancing Eco-DRR in the past years. However, there still exist many gaps that need to be addressed such as policy implementation (Furuta and Seino 2016) and scientific knowledge (Sutton-Grier et.al. 2015) etc. One of such gaps is the linkages between biodiversity conservation and Eco-DRR. There is a relatively good understanding of the role that different types of ecosystems could play for DRR but very little is known or documented about how biodiversity (i.e. species and genetic level of diversity) can mitigate disaster risk (Monty et.al. 2016).

The RELIEF kit project is contributing to deepening the understanding about the relationship between biodiversity conservation and DRR by consolidating existing knowledge and streamlining conceptual relationships between species and genetic
diversity and DRR. The RELIEF kit project identified three areas where species and genetic diversity can contribute to disaster risk reduction: 1) by contributing to the resilience of ecosystems to disturbances (i.e. species diversity contributes to complexity of ecosystems and can influence ecosystem functioning and services thus can enhance resilience), 2) by enhancing the protective functions of ecosystems (i.e. higher species diversity in an ecosystem is equivalent to more diversity in both physical and biological traits that can potentially strengthen the protective function), and 3) contributing to social resilience (i.e. maintenance of genetic diversity in food crops provides important long-term adaptivity and can contribute to food security) (Figure 3).

Although these three areas were underpinned by exiting scientific studies, one of the study’s conclusions is a general lack of scientific literature and quantitative evidence on this emerging topic (Monty et.al. 2016).

The relationship between biodiversity conservation and Eco-DRR and how to synergize these two efforts also needs to be explored further. There is no straightforward relationship between Eco-DRR activities and biodiversity conservation and vice versa. For example, a recent study suggested that coastal forest plantation for mitigating coastal hazards after the GEJE negatively impacted biodiversity in the area (Onza et al. 2015). This example shows that biodiversity conservation and Eco-DRR have their own objectives and they may contradict each other under certain conditions. At the same time, there are ways to enhance synergies of these two objectives and co-benefits. Therefore, we need to explore opportunities by applying best scientific knowledge and lessons from such experiences (Monty et.al. 2016).

Conclusions
We live in a world where climate change is accelerating and vulnerability is becoming more intense, thus disasters are expected to increase and become more unpredictable. In
such circumstances, Eco-DRR has a huge potential to reduce disaster risks with a reasonable cost, while conserving natural environments and enhancing people’s livelihoods at the same time. This is why the global community has become interested in Eco-DRR and has been integrating it into various policy frameworks in the past years. Gaps still exist for effective implementation of Eco-DRR, such as more robust scientific knowledge and in-depth understandings about the role different levels of biodiversity could play role for DRR. But we also have enough knowledge and experience to implement this option on the ground. In addition, we now have a suite of strong global policy frameworks to promote Eco-DRR such as the SFDRR 2015-2030 and the CBD decisions. So now is the right time for us to start implementing Eco-DRR on the ground and accumulate more experiences and scientific knowledge through these activities.

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“Living with the Sea” – The Folklore of Adaptive Reconstruction

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In the days when Owami (1) fishing was very productive, at the end of the year one yellowtail tuna was distributed to each household as the appropriate fish for the New Year’s holiday celebrations. It was considered a time when all could share in the power-generating spirit renewal that was granted to us from the far reaches of the sea. Owami fishing also played a part in symbiotic social development. In years of abundant catches, large amounts of money were donated to improve educational facilities at Ohya elementary and middle schools. When the Sanriku Tsunami disaster of 1933 struck, significant disaster relief donations were raised, and abundant Owami catches also contributed to this fund. The money was used to build a very large wooden structure – the “Reconstruction Memorial Hall,” one of the few showpiece public works structures that actually proved useful. Thanks to abundant yellowtail catches, the Ohya Middle School building had also been rebuilt, and was nicknamed “Yellowtail School.” My mother, my younger brother and I were all educated at this school. The Memorial Hall and Yellowtail School have now completely disappeared. However, the memory of having been brought up thanks to the Owami fishery still remains strong.

My maternal grandfather Miyoji Hatakeyama and my great-grandfather Naosaku Hatakeyama served as “Daiboh” - head of the Owami fishery - for long periods of time. Even after Naosaku retired from active duty, he would go out every morning to take a look at the sea, watching for the “Kashima Current” (a local name for the warm Kuroshio Current), noting the color of the leaves of the big zelkova tree at Kumano Shrine at the edge of the sea in an attempt to predict the advent of a big catch of bluefin tuna. Even now I can recall with inexplicable vividness the image of my grandfather watching calmly over me when he was 80 years old, looking lonely, wearing a kimono and sitting in a pool of sunlight on the narrow wooden veranda – a virtual incarnation of “the legends of the sea” that we should recognize and hand down. Foolishly, I have only now realized this.

To listen carefully to the voices of nature and the sea, that unscientific technique. With the hypertrophy of technology designed to conquer nature, we have easily driven those who came to embody a non-autonomic (lemma), anthropomorphic way of life away toward the distant realm of memory. However, that former way of life was an excellent one, well adapted to nature and the local ecosystem.
The women would go around to the many local Shinto shrines large and small on the first and 15th days of the month to pray for the safety of the fishery and for abundant catches. “Only a single plank separates the fisherman from the hell of the deep.” That is, they offered these prayers for their husbands, sons and relatives engaged in this very dangerous work on the sea. Formerly it was considered taboo for the men to go out fishing on these two days. The fishing was thought to be better on days of the full moon and new moon than on other days, and so these were designated as sacred holidays – the reasonableness of this tradition continues to surprise us even today. The women would also go up to the mountains at the edge of Hitakami Highlands overlooking the village, and take a masu trout or other fish caught during the Owami fishery’s first catch of the year up to the Hitakami foothills overlooking the village as an offering to the mountain. They made a long trek, from Mt. Sannohsan (lit. “Mountain King Mountain”) to Mt. Tenagasan (lit. “Long-arm Mountain,” a “Daidarabocchi” mythical giant that thrusts out his great arm into the sea from behind the mountains to dredge and sift out fish and other seafood to eat, and further to Iwakura Shrine, a small grotto in a huge rock that is the most sacred spot to local people. They did this even when catches continued to be poor. So that Long-arm Mountain would reach out his hand to dredge out the nearby sea, the people would take abalone and other seafood delicacies as “the mountain’s share” up to the summit and quietly leave the offering as a way of placating the giant of Tenagasan. This was equal to the ceremony of sending back the spirits to their origin. Also, an offering of a bluefin tuna would be carried to Iwakura Shrine and donated by the Owami. A world such as the one described in Miyazawa Kenji’s “Wolf Forest, Bamboo Basket Forest, Thief Forest” (2) unfolded in the reality of our everyday world of living with the sea through “the ritual ascent of mountains by women” described above. I think that is where we can find the things we have forgotten – an ethical relationship with nature and a life in which we can converse with the forest.

When the Owami fishing was slow, my maternal grandmother Kiyoyi Hatakeyama would pay a visit to a certain elderly blind lady whom everyone called “Ogami-sama,” (“The Shaman”) to hear her predictions for the future and suggested strategies for the present. I was also told that my grandmother would fill a large bamboo basket with fish, which she would hoist up and carry here and there to sell. In the past, the women would take fish and other gifts of the sea that the men caught just offshore and carry them to the hinterland to exchange for rice and other goods. On the beach, the women worked equally hard as the men. They wandered up and down peddling – one kind of meeting, with strangers – which was made possible by another kind of meeting – a transitional one between land and sea. The labor of fishing is always shadowed by the gamble of being entrusted with the fruits of divine providence. Still, that insecure occupation carried out perched atop the death-dealing deep was always being securely supported by the women on shore.

I was still in elementary school when I went out on my first job with my father and grandfather on the opening day of the abalone fishing season. When we finished our fishing and headed for shore, I could see my mother and grandmother waiting anxiously for us down on the beach. I felt the chilly air warm up a little. As is customary, they were out meeting the boat carrying their family home from the sea. This may have been a perfectly commonplace scene with nothing out of the ordinary. However, for me now it draws forth a deeply heart-felt confirmation of the support that our lives and safety on
the sea received from the strong prayers offered by our womenfolk on their ritual ascent to the mountains. Latent on a deeper level is something similar to the concept of the “wandering Mountain God,” in which the god of the mountain becomes the god of the fields and protects the rice crop. The meeting that is the beach and the rocky shoreline is the rightful domain of the mothers who perform the ritual ascent of the mountains and act as mediums who protect the fishery.

Women help support their families through gathering-type harvests of seafood. The fragrance of an Austric style of marine coastal culture emanated from the women of the Sanriku region. The fact that only women and children were allowed to gather “hunori” (glue plant) represented a fading ember of that cultural continuity. The foods collected by children as they played along the rocky seashore usually ended up on the dinner table. Compared to the gamble taken by the men fishing offshore, the fertile rocky seashore plied by the robust and ebullient women and children functioned to guaranteed food security, or we might even say the right to life.

We must not forget that the seaweed beds and rocky seashore that supported the seaside gathering economy at the same time harbor the living resources that support the coastal/nearshore fisheries. Seaweed beds and rocky coastline are habitats where fish and shellfish lay their eggs, and provide cover for hatchlings and juveniles. For example, little flatfish no bigger than a flat Japanese-style “ohajiki” marble hide themselves by blending in perfectly with the shallow rocky shore background. As they reach maturity these fish move offshore. These precious lures for the large migratory fish that support the Owami fishery lived in these habitats right at our feet. These fertile rocky shorelines were tied to the survival of the fisherfolk, while serving the sea as a nursery for birthing and nurturing new life, and as such were the natural territory of the women, who were expected to keep the house and raise the young in their own families as well. A mystical unconscious that considers the tidal flat/ rocky shore/ seaweed bed environments to be the same as the mothers and other womenfolk, or a disposition towards awareness of folklore that repeats legendary/mythical archetypes sustained the practice of this kind of marine-based way of life.

The wild camellia forests that covered the cliffs rising up from these rocky shorelines create a landscape symbolic of my birthplace, Maehama. From ancient times people have extracted wild camellia (tsubaki) oil and used it to dress their hair, prevent rust on blades as well as in cooking. Wild camellia trees are also planted on banks to retain earth. In particular, plenty of tsubaki oil was used to prepare a ritualistic food - deep-fried vegetable soup (“kenchin-jiru”) - served after Buddhist lecture meetings. Wild camellia forests were a precious gift and served as an important plant resource which helped create and maintain the network of ties among the people.

“The legend of Tsubakiyama” from the Natsudomari Peninsula in Aomori prefecture tells how a wild camellia forest grew from a single seed planted by a sailor beside the grave of his beloved. The “Yaobikuni” legend handed down over the ages tells of a Buddhist nun who ate the flesh of a strange fish (or mermaid) and became ageless and deathless, but had to witness innumerable deaths. A cane of camellia wood she carried on her long pilgrimages budded and soon became a camellia forest. For us, wild camellia constitutes background scenery to the ocean, fishing villages and fishermen. And, at the same time, it is also a background to the problem of death. Wild camellia forests are symbolically thought of as kindly embracing the dead and leading them to
that peaceful land far away (ethnic origin). Small forests of wild camellia where the old
dead are sleeping quietly in fields were a familiar part of our hometown scenery. This
may have reflected people’s sense that the realm of the dead lay in the distance of the
sea (an imitative recurrence of ethnic origin).

In the morning every August 16th, the day after the Obon (the festival of the return of
the souls of the dead) my father and I would make tiny boats out of barley straw. We
would place offerings in these boats and send the souls of our ancestors off toward the
horizon. Every person living on the Sanriku coast would feel the painful memories in
their hearts thinking about the distance of the sea, while also feeling the mournful hope
that their missing fathers, brothers, sons, friends and other victims were living together
with the sea god of “Wadatsumi” somewhere out in the boundless sea. We make these
little Obon boats thinking of the precious sea and of our departed loved ones and send
them off from the edge of the water, murmuring “Please come back next year…” as
they float away. We are being given life by that sacred sea. The Bluefin and Skipjack
(bonito) migrating from southern seas are gifts we receive every year from the dear
departed living out over the sea.

I think that there is a story that tells of a “metamorphosis of mortal remains” in which
our dear departed embraced by the wild camellia forests undergo changes into the gifts
of the sea. We might consider the forests of wild camellia as sacred fish-inviting groves
symbolizing the return current of souls. The wild camellia’s roots are straight and grow
deep and its leaves have a thick cuticle layer; these may be important qualities in its
ability to form a forest buffer against wind and incursions by the sea. However, to
prevent or reduce disaster damage, I think we need to place importance on a way of life
lived in a world of faith, tradition and the natural environment. In other words, we need
to recognize and respect the feeling that the dwellers of that kind of world are important.

In a manner that we might describe as a “myth of fishery metamorphosis,” we are
given supernatural power in exchange for the death of our ancestors and the men who
have been shipwrecked or died in disasters. This life principle revived the fishery and
gave us new life – a profession of circulating souls. Forming a counterpart to the death
of men or the circulation of souls was the “wandering mountain god protecting the
seashore” embodied through the women’s prayers supporting that occupation. Also
between these two traditional concepts, coming down from the upper watershed of the
forest bringing good fortune to the village were the child-like “fairy infants meeting in
the shallows,” that nursery-like, motherly environment, territory of the women, or, we
might say “future of the occupation as life”. “Stay with the Ocean” is Kesennuma City’s
motto for its recovery program from the 3.11 Tsunami disaster of 2011, but if we want
to do that properly, we must re-familiarize ourselves with the reasons for the traditional
view of interaction/ cooperation between the sea and the mountains, anthropomorphized
as men and women. In other words, to deny the “meeting” of land and sea, and the
fertility that implies, should be simply unimaginable.

Given life by the sea, living with our dear departed, protected by our women - those
helping hands, the look in the eyes of our protectors - I recollect these things as being in
the “meeting of land and sea.” It has seemed to me that we should attempt coastal
reconstruction based on cognitive work about this dynamic or harmony between
folklore and nature. The issue of what to do about the beaches and rocky shoreline
where seawalls are being built is about ecosystem services, which simultaneously
involves the maternal function symbolized by these places’ nurturing ability. Speaking very personally, I cannot divorce this conviction from my personal feelings of affection for my own mother and grandmother who remained standing filled with anxiety about their family on the beach in the cold of winter. I would like it to be understood that I am speaking as a private individual here. I never shall be able to agree to construction of a giant revetment that will trample and crush the beach where my mother and grandmother stood praying for my safety. Also, “concrete-first” government administration and coastal management that pays no heed to the voices of the sea and of nature will always and completely clash with the lives led by my grandfather and great-grandfather devoted to their work on the sea as Daiboh (head of Owami fishery). Mr. Sugawara, Mayor of Kesennuma City, has directly confronted me, saying “When we are considering safety, to argue about whether or not the revetment will block our view of the sea is utter nonsense.” Surely he has not lived with the sea. Still, I hope to stick to whatever will let us see the sea. This is because I keep inside me the lives of my late grandfather and great-grandfather. I will stick to standing on the beach and looking out to sea. Like my mother’s and grandmother’s prayers.

References


Annotations

1) “Owami” is a popular name for “Daibouamia” a type of fishery using large fixed shore nets; this term includes the organization and groups of fishers implementing the work. The net used is a kind of fence net designed so that fish entering the net cannot normally escape, and is set up in the middle of routes where schools of tuna or other fish are expected to pass.

Synopsis: Farmers wishing to develop a new village go to the forests to ask for their consent. The forests give agreement and materials for their needs. But after this, several things disappear – children, farming tools and harvested grain of foxtail millet. These happenings were acts of the Wolf, Bamboo Basket and Thief Forests. These disappearances all are recovered as a result of the farmers’ entreaties. The farmers put millet (粟) cakes in these forests to give thanks. Then the forests make friends with the farmers, and come to get millet cakes every year at the beginning of winter.
Chiba Hajime comments: “In contrast to taming nature with modern machinery, these stories repeat a theme of reconciliation and communication with the forest and nature.”
Huge Sea Wall Construction after the Great East Japan Earthquake and Tsunami:
Conflicts and Lessons Learned

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The article is in preparation waiting for the author’s health recovery.
Appendix

478 Days of Challenge – Our Proposal of a New Disaster Prevention Park in Gamou

The Association for the Consideration of Seawalls by High School Students in Sendai

Summarized by Yu Natori¹, and Susumu Ogawa²)

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Activities

The Beginning
We, high school students, carried out learning activities for 3 years to “see and think for oneself” about our local seawalls. We would explain how the activities
had started. This is a report summarizing activities of students by the authors who organized a local study group in Sendai. The advisor of the program is Mr. Ogawa, who suffered from the 2011 Great East Japan Earthquake when he was working at Shiogama High School. He still lives at the temporary housing as of February 2017. Based on his own experience, he had been thinking about the best way for his students to think continuously about these events from now on. Then he came up with the idea of activities to survey the tsunami-affected areas and to set up signs. However unexpectedly, he was transferred to Tagajo High School in March, 2012. At Tagajo HS, there was no school designated courses. Mr. Ogawa used his physics period to invite interested students to make up a team. When the student’s grade participated in 2013, the program was already into its 2\textsuperscript{nd} year. Most buildings in Shiogama and Tagajo were standing still and the damages of the earthquake were left in them. The damages were only left at certain spots like windowpanes and the back of signboards. We scattered ourselves to look for them, and then measured the height to the utility pole using a level. We did this the entire summer, and formed a recognition that the activities were just like any other club activities.

\textbf{1. Explaining in Gamou; Dec. 28, 2013}

Our survey team also had members from a Junior High School in Shichigahama and Takasago Junior High School in Sendai. When we learned that there was a seawall construction plan near Takasago Jr. HS at Gamou, we wanted to know more about it.

On Dec. 28, people from the environmental group and residents in Gamou talked about the plan to build a seawall at the Gamou Tidal Flat. For Natori, as a graduate
from the Takasu Jr. HS who used to do clam digging at there, it was shocking to learn about their plan.

2. Forests that protect lives; Jan. 13, 2014
In January Ogawa told the students, “There is a study session about Forests That Protect Lives.” And so, some of us decided to participate in it. The most interesting thing about it was that in addition to covering the earth embankment with concrete to stabilize it against tsunamis, there was another way to stabilize it with densely planted trees. We learned that even non-professional builders could plan a seawall using trees instead of concrete.

A few days later, we told the members who couldn’t come to the session about Forests That Protect Lives. Their opinions varied. “Think about a seawall which can be a playground for kids,” said the teacher, and certain number of students remembered vividly how they used to play at the playground at Arahama, Sendai when they were younger. Everyone was encouraged by the teacher’s words by now.

3. The 1st Draft: Fun Seawall; Feb. 8, 2014
We first gathered opinions from other HS students and friends, and then planned a seawall as a playground for children. It was later expressed as an illustration. We presented this “Fun Seawall” at the citizen meeting in Gamou. This is our 1st draft. We now think that this plan is mainly focused on the seawall’s function as a playground. After our presentation, the elders said, “The area where a seawall would be put up used to have a canal for boats and we used to play there.” Our plan suggested a seawall to be built on top of the ancient canal. We realized that the history of the area need to be acknowledged as well.

4. The 2nd Draft: Green Seawall and History & Adventure Land; March 16, 2014
Later, we read the local history of Gamou and learned that Gamou has its peculiar history within the Sendai domain. We carefully decided the location of the seawall so as to protect the familiar Jizo Bodhisattva statue on the levee at Nanakitagawa River. This plan allows us to have a large park on the seaside of the seawall. Based on the questionnaire, we allotted the playground equipment on it. There it is, the beach park with its separate adventure area and nature observatory area was designed. The members agreed upon seeing the plan that it will attract a number of people.
5. The 2nd Draft: Presentation and Afterwards
The local residents and people from the environmental group were the audience for our presentation of the 2nd draft of the park/seawall plan. But since we worked on this over and over, this time we were able to deliver it more confidently.

The presentation was given at the Japanese-style room on the 2nd Fl. of the Takasago Civic Center to the local people. The Jr. HS students who answered the questionnaire came to participate in this event which was received well. Even after the presentation, we gathered around the illustrated map, talking with the students about a new park which will be no less than the adventure playground in Arahama.

6. Interviews during Summer Vacation and Self-Learning
There is a limit to distribute our idea by oral presentation alone, so we produced 20,000 brochures featuring both illustrations and manuscript and delivered them to the people at the temporary housing. We visited the temporary housing in Gamou with the brochures. Some people were encouraging, while the others even refused to receive the brochure. The interest level towards our plan in these people varied, but overall, it seemed low. At that time, they just have lost their housing and maybe they didn’t have enough time to think about anything else.

We did other learning activities in addition to our presentation. We all agreed what our advisor said; “It’s irresponsible just to give an advice only. When you give an advice, you follow it with your effort to make it happen.”

So we planned our activities for the month of June. They are: 1) interview teachers about their schools at the time of the earthquake; 2) interview people at
the temporary housing about Gamou; 3) investigate the direction from which the
tsunamis came to hit Gamou; and 4) interview a jury from the Protection of
Cultural Properties about the historical heritage in Gamou.

7. Presentation at the Reconstruction Committee; Sept. 7, 2014
After our summer vacation, we presented at the Reconstruction Committee on
Sept. 7. It became an unforgettable event. The Reconstruction Committee was
organized by 4 ward mayors and 7 town chairs within Gamou. It acts as a
committee to have a briefing from the administration about the reconstruction and
land reallocation, and in return, the administration receives the local opinions
from the committee.

On April 8, when we presented to the local residents, we also planned to present
to the committee, but it never happened. Because the Reconstruction Committee
handles the sales of real estate, thus financially involved, the meeting had a heavy
atmosphere. We were told to “Hurry up, since we are busy” upon our arrival at the
room. But once we did our best to appeal to the audience, everyone applauded our
presentation. That was an unexpected reaction.

8. Application for World Conference on Disaster Reduction and Disaster
Prevention; Sept. 12, 2014
People suggested us to participate in the World Conference on Disaster Reduction
in March, 2015. Ogawa went to consult with its secretariat before the deadline for
the application. The person in charge of it used to work at the Miyaginoku Ward
Office when the earthquake hit, and she was supportive of our activities. However,
she told Ogawa that “the plan your students have is wonderful, but you cannot
participate in the conference because there is no proposal to prevent disasters.”
Indeed, the only prevention we thought was to evacuate on top of the hill at the
park.

We decided to visit Kasai Rinkai Park in Tokyo after what the secretariat told us. In preparation, we studied the definition of disaster prevention park, its 5 categories, and their strategy against high tides in Edogawa Ward. Our visit to the park was received by the former park’s director, Mr. Sakamoto. We realized when we were studying that the disaster prevention park is only confined to the landward side of the seawall. We asked Mr. Sakamoto about this. He pointed to the road where people were jogging. He said that the seawall is buried underneath it. In Kasai, from this seawall to the landside is the disaster prevention park, and towards the sea is designated as the coastal protection zone. We thought we could use the same design in Gamou. Additionally, we noticed that people here can go around by water taxi and ferries around Tokyo Bay area. We were happy to see the possibility to do the same in Gamou by using the Teizan Canal. We then oversaw the entire ocean view from the observatory deck at the Crystal View and saw people flocking in the park. We couldn’t help thinking that once again in Gamou, people who had to evacuate will return to enjoy the seaside area like they used to do.

At the Crystal View, there was a photo exhibit of the 7.8m seawall which existed in Edogawa Ward 30 years ago. Tokyo at that time learned that the seawall could divide up the land and sea, so they created many water front parks like Kasai Rinkai Park. However, the areas that suffered from the earthquake are going
backward to the old way. While we feel disappointed by their plan, we sensed the urge to make changes on our own.

10. Starting Up The 3rd Draft
After what we learned at Kasai Rinkai Park, we started to revise our own plan for the seawall park.
<Temporary evacuation centers>
When the tsunamis came, about 600 people evacuated to the Nakano Elementary School which was the closest to the Gamou Tidal Flat. In addition, Okada Elementary School and Takasago Civic Center were also turned into an evacuation area. The city was planning to set up 11 evacuation towers along the coastline, but there was none planned near the ruin of Nakano Elementary School. The city estimates the population in Gamou during the daytime as 3,300 and there is not enough evacuation centers to accommodate these people. Moreover, it’s easier for older people to evacuate by car, we figured that a high evacuation ground is necessary at the Nakano Elementary School ruin.
<Setup of an evacuation route>
The Surfer Parking Lot had 60 evacuees when the tsunami hit, but then it became isolated. We need an evacuation route. We considered an evacuation route which can also be a seawall between 2 areas: the Surfer Parking Lot and the higher ground at the Nakano Elementary School ruin. Now we completed the layout of the disaster prevention park with two evacuation spots and an evacuation route connecting these areas.
<Utilization of the coastal protection zone>
Just like Kasai Rinkai Park, the seaward area of the disaster prevention park in Gamou will be designated as a vast coastal protection zone. Based on what we saw at Kasai, we understand that various facilities can be built on this zone, and we will consider it as a regular park.

11. Symposium: “Gamou Tidal Flat and the Seawall”; Nov. 9, 2014
The 3rd draft was completed based on our visit to Kasai Rinkai Park, and was presented at a symposium “Gamou Tidal Flat and the Seawall” on November 9. The Group of High School Students was given 25 minutes to explain 5 different
themes for the presentation. There were other presentations, but ours was received favorably because we gave some constructive plans. However, people shifted their attention on gathering petitions to submit to the Ministry of the Environment, and we became forgotten. Since this time around, we started to feel that we were going into a different path from the other organizations.

12. Suggestion to Matsushima Aquarium; December 14, 2014
We started to act rather independently in order to carry out our 3rd draft. We first visited the Matsushima Aquarium. This institution will be moved into the Sendai City Aquarium. Our idea in the 3rd draft is to create an aquarium standing behind the Gamou Tidal Flat, just like it was at Kasai Rinkai Park. However, the construction of the seawall had already started, we revised our idea to connect it with the tidal flat by bus and to set up a tour facility at the site. The aquarium curator kindly listened to us, however, we were told that the business of the new aquarium would be managed by an operation company. We took a look around at the aquarium afterwards and noticed that a number of families with children were visiting the facility. We were hopeful that if our plan works out, Gamou will be filled with happy smiles from people like them.

13. Gamou Civic Briefing Session 1; December 20, 2014
If things were getting into a wrong direction, the construction of the seawall would have been decided at this meeting. Based on our previous experience at Shichigahama, we felt a tension in the room. The meeting was peculiar as the Chief Civil Engineering Division opened the it with an apology. Because his office
forgot to explain to the attendees what they talked to the Council involved about the change in their plan to move the seawall into landward. At the Q & A session after the explanation of the plan by prefectural staff, an attendee from Gamou, in an furiously excited state, said, “I will never sell out my own land.” He was especially emotional because he just lost his two sons and was very frustrated at the seawall. The meeting was closing with a number of opposed opinions against the changed plan. The moderator was summing it up, saying, “the closing time is coming and now I would ask if we finish the meeting with all of you agree with the plan.” Now everyone was shouting and jeering. Finally, it was over with another meeting planned for January.

We were stunned by the scene. However, we came to understand why the administrations wanted to get an agreement 2 years later, in the summer of 2016. At this point, the prefectural Civil Engineering Division had arranged a construction of the seawall. As it turns out, no matter how many people disagree with the plan, they had to make it as all agreed upon.

14. Submission of the 3rd Draft to Sendai and Miyagi Prefecture; December 26, 2014

Before the end of the year, we decided to submit our draft to the administration. In Sendai we went to the Restoration Works Department and Cultural Properties Division, and received their feedback. However, their response was pretty negative, saying that our plan would interfere with the Land Reallocation Works and the ruins could be recorded in photographs. Additionally, Chief of the Restoration Works Department told us that “there won’t be any tax revenue,”
pointing out the profit concern. To this the high school association replied, “Money is important, but if we just focus on it, we will lose our nature and history as well from Japan.” We believed that there are more important things to keep than money.

15. Visiting the Seawall within the Matsushima Bay; January 11-12, 2015
Into the new year, while worrying about the profitability of our plan, we went to visit the other seawalls to study and prepare for the United Nations World Conference on Disaster Reduction and Disaster Prevention in March. On January 11, we visited the seawall in Miyado-jima and next day in Nono-shima and Katsura-shima. The conditions at each location were different, however, we wondered why all of them had the same seawalls.

16. Gamou Civic Briefing Session 2; January 17, 2015
Following the last meeting, we had the second Gamou Civic Briefing Session. However, this time we didn’t feel the energy from the people who attended. Their opinions were unclear as to whether they agreed or opposed the administration’s plan. The administrations concluded that the people agreed with their plan, but this time everyone was quiet. We were stunned at this scene.

After the session, we discussed further at the Civic Center. Our plan got rejected after they have decided to build a seawall. This prevents us to present at the UN conference, or we will present a plan that is not going into effect. In the newspaper next day, the headline read, “Certain Understanding from Residents,” “Residents in Favor of the Plan.” In reality, it wasn’t like that at the meeting.
17. The Profitability of the Park and Our 4th Draft

Our idea to preserve Gamou for the future generation had vanished into the air. There is no way to make it come true. Now we were pressed to decide whether to attend at the UN conference. During such a tense period, a high school student from Yokohama (a representative of a company, GLOPATH) contacted Ogawa. She wanted us to participate in the Junior Disaster Prevention Meeting on March 16 which they were organizing. They came to visit us even after we declined their offer. The second time when they came to meet us, they suggested us 4 ideas: 1) the park behind the seawall will be up for sale by a firm; 2) in order to secure a profit, build a movie theater with a projector screen; 3) build a movie theater by a French filmmaker; 4) on top of the facility, build an ice skate link.

They came up with these constructive ideas just during one week of their stay, and we were hopeful again that we could carry out these plans. In addition to our 3rd draft, ideas from GLOPATH, together with the images of Kasai Rinkai Park we formed our 4th draft.

18. Japan Nature Conservation Award; March 8, 2015

It was March 8th, right before the United Nations World Conference on Disaster Reduction and Disaster Prevention. We were in Tokyo to attend at the Japan Nature Conservation Award. A total of 7 awardees were either individuals or groups, and our group was one of them. The presentations after the awarding ceremony highlighted achievements each of them has attained after years of work.
Compared to them, our activities are just over one year. But we felt like our efforts were finally accepted, and the whole experience was refreshing.

19. United Nations World Conference on Disaster Reduction and Disaster Prevention, March 17, 2015
The 4th draft was about our plan of a park for a corporate acquisition, so we presented it to 105 firms that use the Sendai Port. If some firms show an interest, there remains a possibility to build a park. There were other high school students participating at the conference, but it seemed rather peculiar for high school
students to host a public forum and there were reporters from newspapers and local TV stations covering it.

It was a regular school day, but our members got a special permission to come to the conference. The room had about 100 seats that were all occupied, however, only 3 corporations came to the forum. Some of the large corporations such as one of major beer companies in Japan told us that they would consider our proposal, but they never showed up. There was a pretty good Q & A session following our presentation, but our goal for a corporate buyout of a park failed. We lost our chance to make our 4th draft come true.

20. Our Last Proposal; April 20, 2015
As we get more and more obstacles, we are getting conflicts among ourselves and we often clash with opposing opinions and ideas. Everyone is now more seriously thinking about the future of our Gamou. We collected each opinion from everyone. As a result, we will think again what we can suggest to do while they push forward the construction of a seawall as the prefecture planned out. We got rid of the concept of the “park” and started to feel what we want to “protect.”

We submitted our proposal to the city of Sendai and Miyagi Prefecture on April 20, 2015. Its contents are: 1) apply the style of seawall built at Hamamatsu; 2) set up the Warehouse statue at the same location even after the river levee is fixed; 3) move the playground area at the ruin of Nakano Elementary School to where the
store house and boat area are located as to conserve the ruin; and 4) set up a water gate at the fish farm. Other than the ideas of the Warehouse statue and water gate, no favorable reactions were gained. This day marked the end of the activities as the Association for the Consideration of Seawalls by High School Students in Sendai. It lasted for 478 days since December 28, 2013.

21. Afterthoughts (by Yu Natori)
With this project in our minds, we started to prepare for the university exams. When we reflect our activities now, most of the 478 days were of struggles. The administrations that don’t work to make a better project, but give out impossible orders. The grown-ups who only praise and do nothing else. “It's nice if this dream-like proposal can come true,” said someone. We wanted to say, “It’s not a dream.” However, at the end, we failed to protect what we wanted to preserve. Still, there are people who see a ray of hope in Gamou and are actively working for it. Our duty now is to watch them over. We will continue to watch how Gamou will change from once it was

Considerations and Future Challenge (by Susumu Ogawa)

Introduction
It’s January, 2017. The local people feel disappointed by the loss of the coastline due to a seawall construction after the Great East Japan Earthquake. The 2011 tsunami was a natural disaster, but the environmental destruction by a seawall construction is man-made and this was even more shocking to everyone. To this point, many symposia were held between 2013 and 2014. Nonetheless, the decision to build a seawall didn't change. At these symposia, only concerns and issues were raised, but no plan to solve them was offered.

Most of the presenters were researchers at universities. As if they say, “We are researchers, not activists,” “concerned citizens should become activists.” For the local people who will lose the coastline, the purpose of their studies seems self-served.

1. Construction of a Seawall and Establishment of the Area to Be Evacuated
The record of the 3rd meeting on the central disaster prevention in June, 2011 states, “The standard response to the tsunamis that come once in 50 to 100 years would be a solid object. For the tsunamis that come once in 500 to 1000 years, escaping from them would be more important than protecting the area, and therefore city planning must play a role to protect the residents from disasters.” This means that against a tsunami which comes once in 100 years, a protection from it is considered, so that once a seawall is built, the housing behind it would be safe. However, the administrations designated most of the areas behind a seawall to be evacuated. If a seawall would be built, the area behind it would be safe; and if a seawall would be built, the area behind it should be evacuated. This logic doesn’t make sense at all. Since the people had to evacuate from the areas they were living, the coastline lost its protectors. Even now when the environmental groups
or researchers try to raise their voices, since they are just outsiders, the local administrations won’t listen to them.

2. Environmental Assessment and Restoration Construction
A seawall construction is planned as a restoration work. It is understandable to repair and restore the bridges and roads that were destroyed and washed away without any environmental assessment. The definition of a restoration is to “restore what has been damaged or destroyed” and repair them to the state where they had been. However, the administrations took an advantage and try to construct a massive seawall like the one in Koizumi, Kesennuma. But the opposition party didn’t push it on a legal ground as much as they should have.

At a symposium, it cannot reach an effective solution if an environmental safety cannot be legally guaranteed. The administrations work around the law. If we want to oppose what they do, we need an attorney specializing in the case. The voices of residents or environmental groups alone would not help when a legality issue is involved.

3. Asking Environmental Researchers to be at Civic Briefing Sessions
I myself went to such civic briefing sessions about the construction of seawalls in Shichigahama, Gamou, and Koizumi. At each briefing, the administrations were very polite, but had no time to listen to the residents. It was about creating the record that they held such a meeting.

The administration was carrying out the law-abiding plan, and the demands from the residents were rejected by law. It seems as if the laws were not created for the residents.

In addition, there are no scholars and researchers specializing in environmental issues attending at the briefings. They only give advice from afar and this is very irresponsible of them. It is as if making the civilians carry a stick against a fully armed soldiers. If they must, must the citizens carry a weapon? Rather an appropriate legal backup – this is the way it should be.

4. The Council
- City Planning Council
We went to hear the City Planning Council of Sendai in 2015. This was a meeting where opinions of the people in Shichigahama and Gamou about the seawall were discussed. At the meeting, all the opinions were put on a paper, and the administration was answering the questions from the staff of the council. The council member asked, “Did the residents understand and agree?” to which the administration answered, “We try to convince them.” If the council member had some doubts about such a reply, he or she won’t be elected as a council member the next time. The scene was rather comical.

- Gamou Tidal Flat Nature Restoration Council
Gamou Tidal Flat has “Gamou Tidal Flat Nature Restoration Council” which is based on the “Law for the Promotion of Nature Restoration” set up by the Ministry of the Environmental system. However, after the earthquake, “The tidal flat had disappeared by the tsunami and now the council has no subject.” For this reason,
only irregular exchange of opinions was resumed. Even after the tidal flat was almost restored, there is only this exchange of opinions and nothing else. To the demand to officially reopen the dialogue from the environmental groups, the nation, prefecture, and the city avoid it by sabotaging the meeting. There is no regulation to correct this situation and the environmental groups cannot go forward.

5. Tsunami Simulation
In 2014, the Miyagi Prefecture presented a movie of a simulated tsunami by the residents at a civic briefing session in Koizumi. The movie was against the suggestion to elevate the Route 45 and make it a seawall. It showed that the raised Route 45 would cause a reflected wave gushing into the Koizumi Elementary School which sits at a higher ground. If the levee is set back away from the water, the power of tsunamis would be reduced, but they showed another simulation that the devastation would be larger and rejected the residents.

Two years later, some people started to whisper, “That simulation was showing the seawall not as a slope, but as vertical and so that the reflected wave was strong.” This was an excuse from the administration. It must be that the residents had to submit a simulation upon giving out their suggestion. From this experience, the residents created a better simulation against the seawall issues in Urato Islands in 2016. They have been successful making seawalls withdrawn.

This example shows that when the officials give a simulation, the residents also need to give a simulation. Like so, if they use the law, the residents need to use the law as well.

6. Range of Possible Change in the Seawall Plan
The results show the lawfully possible choices that are given below:
1) a seawall created by CSG explain what is CSG
2) a correction of a seawall construction plan with nothing to protect

Was there even necessary to work to lawfully correct these?

While agreeing the fact that the set back of a levee into landward must be the best solution for the environmental protection, placing of a new seawall won’t be a restoration. For this reason, the administration might not accept it. They put an emphasis on the restoration, because restorative work doesn’t require an environmental assessment.

7. Final Thoughts
The restoration plan to rebuild the seawall is abiding the law. If we want to change it, we must do it so by abiding the law. Even so, there are multiple steps to obtain permission, and it is difficult to complete each one without the assistance of a legal specialist.

However regretfully, there was only one symposium by the Bar Association in Miyagi, and they offered no help, probably because the case involved in the seawall was not profitable. The remaining law-makers and specialists are from the universities, and it can be easier for the environmental scholar to have a contact with them. But it seems they have never attended at the symposium.
The environmental groups and scholars only insist the importance of conservation, which by itself is not realistic. I hope that people who would be leading the residents could learn the lesson from this experience. Afterall, isn’t it the duty of the environmental scholars and researchers to understand the legal system when they ought to handle cases that involve administrative bodies?

Summarizers Profiles
Yu Natori
Currently living in Rifu-cho. A graduate at Miyagi First Senior High School. She used to spend summer at her mother’s home in Shichigahama, but it was washed away by the tsunami. The place where the house once stood became designated as a location of a seawall and because of this experience, she joined the survey activities of tsunami-damaged ruins and the Association for the Consideration of Seawalls by High School Students in Sendai. She continues to watch over the activities.

Susumu Ogawa
CEO, Sendai Educational Technology Laboratory; Advisor, Association for the Consideration of Seawalls by High School Students in Sendai; Former Science Teacher at Miyagi High School. He instituted activities “learning about local matters from local material” during his teaching, and held a course in Shiogama Study, and the Study of Cherries in Shiogama, which won an award in 2011 from Miyagi University of Education and in 2013 from the National Science Museum. He also held “Study of Land and Water in Shiogama, which won an award in 2011 from the National Science Museum. From 2003 to 2010, he held an excursion to Urado for freshman at Shiogama High School.

Related maps and QRcode for Association for the Consideration of Seawalls by High School Students in Sendai