Impact of the Great East Japan Earthquake on the Natural Environment in Tohoku Coastal Regions

Sanriku Fukko (reconstruction) National Park/Green Reconstruction Project

The Ministry of the Environment is working on many programs in “Green Reconstruction Project through Establishment of Sanriku Fukko (reconstruction) National Park” aims at the reconstruction of the pacific coastal regions in Tohoku. The national park, the axis of the project, was established in May 2013, for the purpose of contributing to the reconstruction of the areas damaged by the Great East Japan Earthquake.

The park stretches about 220 km from north to south, with magnificent cliffs known as the “Marine Alps” in the north and elegant Rias coasts with intricate geographical features extending towards the south. There are seabird breeding sites such as the Black-tailed gull and streaked shearwater along the coast where people can observe wildlife in close proximity. It also boasts of several leading fishing ports in Japan such as Hachinohe, Miyako, Kamaishi, Ofunato, Kesennuma etc. where people can enjoy fresh seafood. In addition, many people from all around the nation visit the area for eco-tourism.

The pacific coastal regions in Tohoku are now on the road to recovery and the tourism industry has also resumed. “Michinoku Coastal Trail,” which connects the nature and life, traces of the earthquake, visitors and local people in the regions, is available. Do come and visit Sanriku Fukko (reconstruction) National Park to experience culture, life and the natural blessings!!

Green Reconstruction [http://www.env.go.jp/jishin/park-sanriku/]
Michinoku Coastal Trail [http://www.tohoku-trail.go.jp/]

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On March 11, 2011 at 2:46 p.m., a great earthquake of magnitude 9.0 occurred offshore in Sanriku. In Miyako City, Iwate Prefecture, tsunami waves measuring 40.5 meters high were recorded. The wide area along the Pacific Coast in the Tohoku region were assaulted by the tsunami, causing an unprecedented disaster which is said to occur only once in a thousand years.

In 2011, the Ministry of the Environment started monitoring the coastal regions along the Pacific Coast from Aomori Prefecture to Chiba Prefecture where the natural environment has changed drastically.

Vegetation Changes
The vegetation changes before and after the earthquake disaster were reported by creating and overlaying the vegetation maps in areas submerged by the tsunami before and after the earthquake disaster.

Sandy Beach Changes
The sandy and muddy beaches within a range of about 100-500 meters inland from the coastline in three different periods — the 1970s, before the earthquake (2000s), and after the earthquake—were interpreted to analyze the changes in the beaches.

Change in the last Hundred Years
"Rivers", "lakes and marshes", "wetlands", "sand dunes", etc. were interpreted the Old Edition from maps of the late Meiji Period (1903) to the early Taisho Period (1918). We used these information to identify the factors of the flooding and to plan the future land use.

Ecosystem Monitoring
Post-disaster surveys were carried out in 16 tidal flats, 6 Zostera beds, 5 seaweed beds and 4 seabird breeding sites which were surveyed previously before the earthquake to compare with the situation before the earthquake.
Changes in Gamo, Sendai City

In Gamo, Sendai City, Miyagi Prefecture, there is a lagoon consisting of a mixture of fresh and sea water which extends inland towards the sand dunes. At low tides, a mud flat appears as an extension of the surrounding wetlands where many plants and animals live and breed. However, that aspect has changed vastly due to the strong impact of the tsunami.

Changes in the last hundred years

- **1907**
  - Wetlands used to extend inland along the Nanakita River which meanders in the northeast.
  - Part of the wetlands was removed but most changed into fishery and Black pine plantations. White part of the sand dunes was planted with Black pine.

- **2000s before the earthquake**
  - Sand dune vegetation, reed in the tidal flats and salt marsh vegetation used to grow along the sandy beaches.
  - Most of the Black pine have either fallen or withered away and Black pine in areas that were once wetlands have been washed away.

- **2011 after the earthquake**
  - Vegetation Changes


Changes in the invertebrate habitats before & after the earthquake

- **Scaphirella gilvaea**
  - Not seen before the earthquake. They have only recently appeared in the sand brought in by the tsunami.

- **Nuttalia japonica**
  - The bladders known as Kuruwa amami and footsteps pl Bluister were seen before the earthquake. After the earthquake, a significant number of them remained.

- **Gracillidastella japonica**
  - Several species of Gracillaria that were not seen before the earthquake disaster were observed and their population also increased.

Vegetation Changes before & after the earthquake

- **2000s (before the earthquake)**
  - Vegetation Changes

- **2011 (after the earthquake)**
  - Vegetation Changes

Sandy Beach Changes before & after the earthquake

- **Before the earthquake (2003.9)**

- **After the earthquake (2011.5)**

From the changes in the areas shown within the red frames in the diagram above, it can be seen that Reed (Phragmites) (blue) and Black pine (Pinus thunbergii) vegetation (green) have decreased while natural bare land (light yellow) and weed community in vacant site (orange) have increased.

The shoreline has receded a maximum of 200 meters inland within the range shown in the red frames in the diagram above. The sandy beaches have vastly changed their shapes and most of the coastal forests have been washed away.
Vegetation Changes

In order to understand the changes in the vegetation in areas submerged by the tsunami along the Pacific coastline from Aomori Prefecture to Chiba Prefecture (about 576 km²), we created vegetation maps before and after the earthquake (November 2012) and then overlaid them to compare the changes before and after the earthquake. A scale of 1/10,000 was assumed for the plot accuracy up to a distance of about 500 meters inland. Thereafter, a scale of 1/25,000 was used further inland.

Before the earthquake, sandy beach, sand dune vegetation and Black pine plantation could be seen along the shoreline while paddy fields and farmlands extended inland. After the earthquake, the sandy beaches, sand dune vegetation and coastal forests disappeared and the shoreline receded. In addition, the paddy fields and farmlands became vacant site covered in weeds, uncultivated field areas and debris storage site. After classifying the change patterns and vegetation damage status based on the maps before and after the earthquake, we found that many of the coastal and river bank areas have been submerged or washed away, while many inland areas have become barren lands or have been transformed for artificial uses.

Pattern of change due to the tsunami

Legend
- Remained Forest (50% or more remained)
- Lodging / Die back (less than 50% remained)
- Covered by invasive alien tree species
- Changed from natural and secondary vegetation to other natural vegetation
- Revegetated (Natural vegetation)
- Changed from unvegetated area to natural vegetation
- Change to barren land
- Changed to natural bare land
- Changed for artificial use
- Flowed out / Sink
- Change to Secondary grass field

*Geographical map: 1/25,000 map of Geospatial Information Authority of Japan

Changes in the Vegetation

Although the majority or about 60% of the areas showed “No change”, “Remained Forest” areas also accounted for about 15% of the area.

“Changed to barren land” areas occupied about 40%, “Flowed out/Sink” areas were also seen in about 5% of the land.

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Based on all the areas in the six prefectures, “Changed to barren land” areas (where weeds grow abundantly in areas damaged by the tsunami) occupy the greatest share at 30% of the total area. This is followed by “Changed for artificial use” (e.g. developed lands and debris storage areas etc.) which occupies 10% of the overall area. Due to the concern over the potential invasion by invasive alien species in these areas, monitoring of the trends is thus required in future.

Example ① Remained Forest (50% or more remained)
Before the earthquake (October 2006)
After the earthquake (May 2011)

Example ⑧ Changed to barren land
Before the earthquake (October 2006)
After the earthquake (May 2011)

Example ⑨ Flowed out / Sink
Before the earthquake (October 2006)
After the earthquake (May 2011)

Example ⑩ Natural bare land
Before the earthquake (October 2006)
After the earthquake (May 2011)

Example ⑪ Secondary grass field
Before the earthquake (October 2006)
After the earthquake (May 2011)

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- Remained Forest
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Aerial Photos: Taken by Geospatial Information Authority of Japan
Sandy Beach Changes

In order to understand the changes in the sandy and muddy beaches along the Pacific coastline from Aomori Prefecture to Chiba Prefecture (about 680 km in total length) due to the tsunami, we compared the changes in the three periods using aerial and satellite photos taken in the 1970s, before (2000s) and after the earthquake disaster. A scale of 1/10,000 was assumed for the plot accuracy and the survey range covered a width of 300-500 meters for areas with wide sandy beaches and 100 meters for areas with narrow beaches.

Area change in from the 1970s until the earthquake

“Coastal structures” such as harbours and fishing facilities increased in all survey regions. Although the “sandy beach” area shrank in Aomori Prefecture, the “coastal forest” area increased.

In Ibaraki and Miyagi Prefectures, “sand dune vegetation area” decreased. In Chiba Prefecture, “sand dune vegetation” and “coastal forest” in Miyagi Prefecture, “sand dune vegetation area” decreased.

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Area change before and after the earthquake

“Sand dune vegetation” and “coastal forest” were vastly reduced in all survey regions, and most were transformed through man-made developments or changed into barren lands (included under “Others”). “Sand dune vegetation” in Aomori Prefecture, “sand dune vegetation” and “coastal forest” in Miyagi Prefecture, and “coastal forest” in Chiba Prefecture were changed to “Others” by almost the same extent in terms of the area.

Nehama, Kamaishi City, Iwate Prefecture

- 1970s until before the earthquake disaster
  Sand dune vegetation grew in sandbars with a width of about 50 meters while coastal forest extended towards the south. The estuary of the Unosumai River moved towards the north comparing the changes of the two periods.

- Before the earthquake disaster – After the earthquake disaster
  The sandbar extending from the right bank disappeared due to the tsunami. A V-shaped gulf section was formed and the shoreline receded by a maximum of about 400 meters.

Changes in the last hundred years

From the Old Edition map of the Geospatial Information Authority of Japan which was surveyed about a hundred years ago from 1903 to 1917, “old river channels,” “rivers,” “lakes and marshes,” “wetlands,” “sand dunes,” “sandy beaches” were identified and converted to GIS. As shown in the following examples, the state that the land used to be is presumed to be reflected after the earthquake.

**Idagawaura (Minamisoma City, Fukushima Prefecture)**

- Before the earthquake
  The land reclaimed in 1929, was used as a reclaimed paddy field.

- After the earthquake
  Due to the impact of the tsunami, it returned to the water region and wetlands that it used to be after the earthquake.

**Torinoumi (Watari Town, Miyagi Prefecture)**

- Before the earthquake
  A series of sand dunes (orange) used to extend parallel to the coastline with the areas in-between being wetlands (yellow-green).

- After the earthquake
  Areas which used to be sand dunes were turned into fields while areas which used to be wetlands were turned into paddy fields.

August 2012

Idagawaura, which was drained and turned into paddy-field, was still submerged even one year after the earthquake.

May 2011

Ground of inland coastal forests which used to be wetlands was lowered and submerged.
Ecosystem Monitoring

We monitored the seaweed habitat, Zoster beds, seabird breeding sites and benthos living landscape in tidal flats along the Pacific coastal regions from Aomori Prefecture to Chiba Prefecture which are thought to be affected by the earthquake especially.

### Benthos in tidal flats

There are various types of tidal flats depending on the sites and geographical locations and the level of impact differs for each area.

- **Sanriku Coast**
  - The disturbance was on a relatively large scale and the benthos landscape has changed vastly together with changes in the shape and submergence of the tidal flats.
- **Sendai Bay**
  - Although the disturbance was on a relatively moderate scale, the benthos landscape has changed together with the disappearance and slighting of Phragmites and deposit of sand on the sea bottom.
- **Matsushima Bay**
  - The disturbance at the entrance of the bay was on a relatively moderate scale and the benthos landscape had changed. In the inner bay, the disturbance was on a relatively small scale and the benthos landscape hadn't changed so much.

### Seabird breeding sites

Although there was no direct impact on migratory seabirds since the earthquake occurred before they flew here to breed, the land was stripped of its vegetation and litter floated out into the area together with the flooding caused by the tsunami.

- **Hachinohe City, Aomori Prefecture**
  - The impact on the land slipping due to the tsunami was minor and the proportion of vegetation such as Dactylis glomerata, Poa annua and Brassica napus increased.
- **Miyako City, Iwate Prefecture**
  - Although the area was flooded up to a height of 20-40 meters, no soil runoff due to the tsunami or impact caused by the land stripping were observed.

### Seaweed beds

Seaweed beds are mainly located at the mouth of the bay facing the open sea. While there has been some impact due to the sinking of the ground caused by the tsunami, no large changes in the population landscape were observed. Also as this area is mainly used for growing young algae such as Undaria pinnatifida and Laminariaeaceae, the impact on the population was thus thought to be relatively minor.

- **Matsushima Bay**
  - Before the earthquake, the largest Zostera forest in the Sanriku area was formed here. There was a clear demarcation between Zostera marina in the shallow areas and Zostera caulescens in the deeper areas. However, the ground subsided by about 60-80 cm after the earthquake and the distribution border became indistinguishable.
- **Mangokuura**
  - Zostera was seen from the west coast of Kuroshima Island to about 100 meters out at sea before the earthquake disaster. After the earthquake, the ground subsided by about 90 cm, wiping out large areas of the Zostera population.
- **Hirota Bay**
  - Before the earthquake, it was a Zostera marina bed mainly consisted of Laminaria japonica Areschoug and Costaria costata. After the earthquake, Laminaria japonica Areschoug was seen.
- **Shizugawa Bay**
  - Before the earthquake, it was a Laminariaceae bed mainly consisted of Undaria pinnatifida and Sargassum beds. After the earthquake, Sargassum beds were seen in the shallow areas while Undaria pinnatifida and Sargassum beds moved in the deeper areas.
- **Kitaibaraki City area**
  - Before the earthquake, it was mainly Undaria pinnatifida and Sargassum beds. After the earthquake, it became a mixture of Undaria pinnatifida and Sargassum.