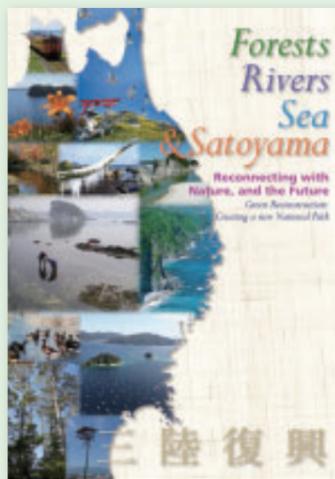




Fallen trees in the coastal forest immediately after the earthquake disaster
Arahama, Watari Town, Miyagi Prefecture April 2011

 The information gathered in this survey is published on the Ministry of the Environment, Biodiversity Center of Japan's website "Shiokaze Natural Environment Log"
URL <http://www.shiokaze.biodic.go.jp>

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, Kesenuma 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 **URL** <http://www.env.go.jp/jishin/park-sanriku/>
Michinoku Coastal Trail **URL** <http://www.tohoku-trail.go.jp/>

Issued by  Nature Conservation Bureau, Ministry of the Environment
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Edited by | Asia Air Survey Co., Ltd.
Published in November 2013



Larus crassirostris (Matsushima Bay)



Bulrush (*Typha orientalis*)



Clam • Japanese littleneck clam (*Ruditapes philippinarum*)



Pickerel weed (*Pontederia*)



Crab (*Helice tridens*)



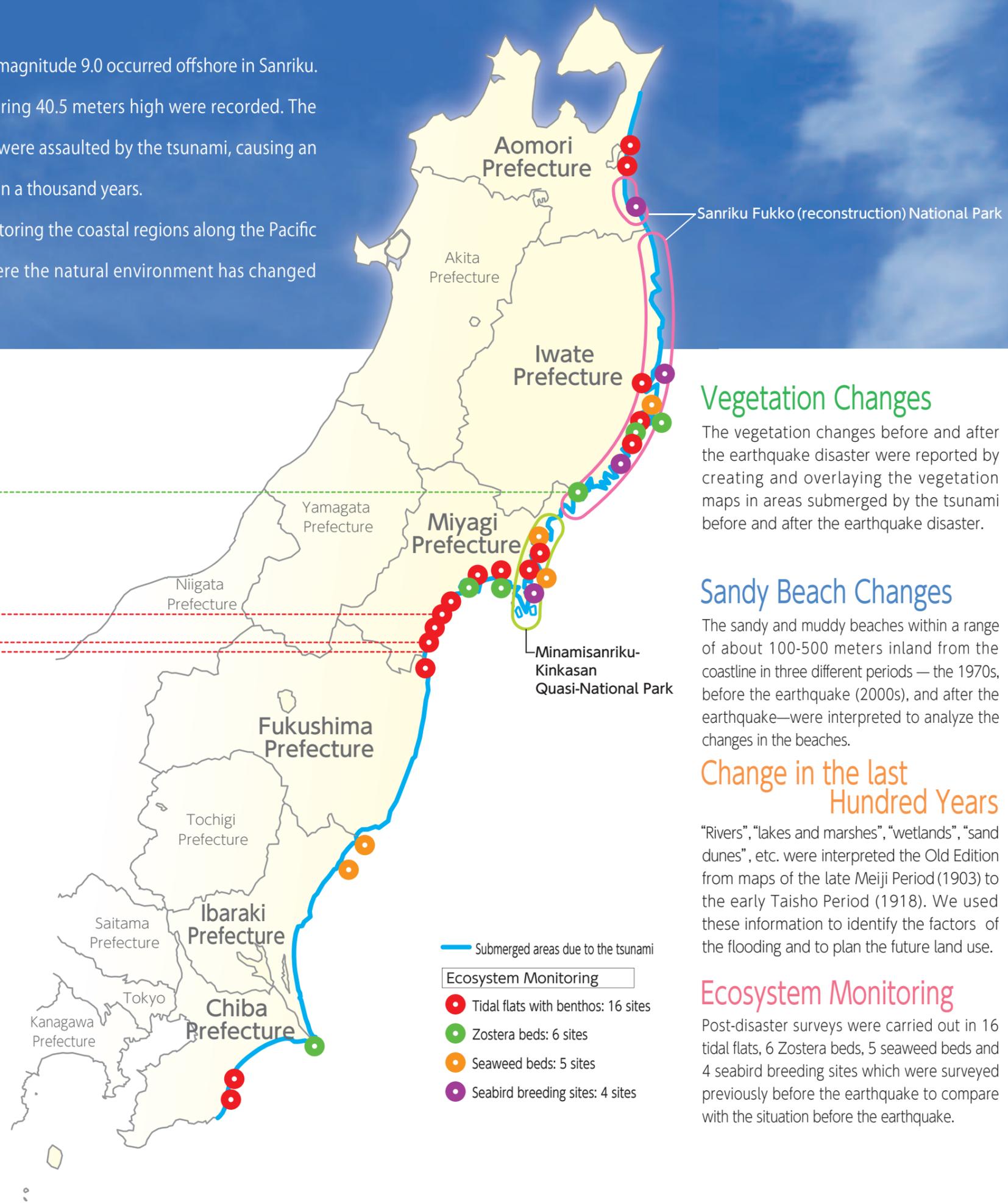
Bar-tailed Godwit (*Limosa lapponica*)

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

 Nature Conservation Bureau, Ministry of the Environment
Biodiversity Center of Japan

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.



Aerial photo: Taken by Asia Air Survey Co., Ltd. (March 2011)

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.



Idoura, August 2012

Sandy Beach Changes

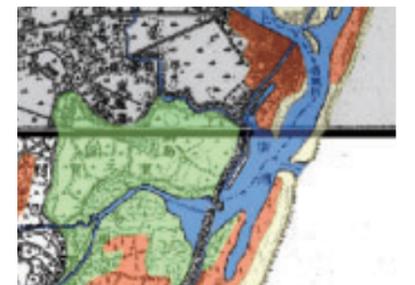
The sandy and muddy beaches within a range of about 100-500 meters inland from the coastline in three different periods — the 1970s, before the earthquake (2000s), and after the earthquake—were interpreted to analyze the changes in the beaches.



Nakahama, Yamamoto town, May 2011

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.



Hiroura, Natori City, 1907

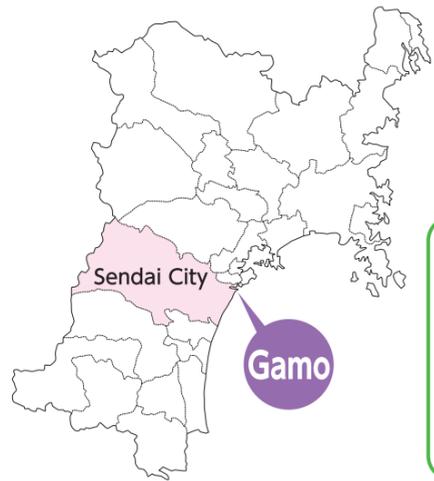
Ecosystem Monitoring

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.



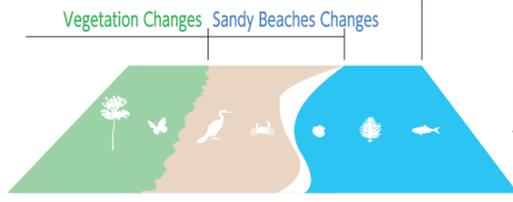
Yamada Bay, October 2012

Changes in Gamo, Sendai City



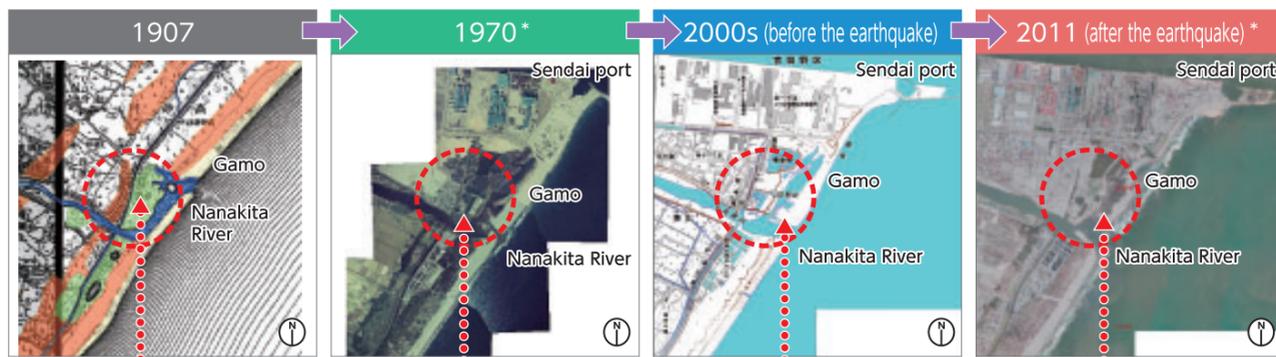
In Gamo, Sendai City, Miyagi Prefecture, there is a lagoon consisting of a mixture of fresh and sea water which extends inland towards to the sand dunes. At low tides, a mud flat appears as an extension of the surrounding wetlands where many plants and animals live and breed. However, that aspect has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

Ecosystem Monitoring, Changes in the last one hundred years



By comparing the coast and vegetation before and after the earthquake disaster by using past images such as the Old Edition maps and aerial photos taken in the 1970s, we identified 'what' and 'how much' changes occurred.

Changes in the last hundred years



1907
Wetlands used to extend inland along the Nanakita River which meanders in the northeast.

1970*
Part of the wetlands was remained but most changed into fishery and Black pine plantation. While a 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.

2011 (after the earthquake)*
Most of the Black pine have either fallen or withered away and black pine in areas that were once wetlands have been washed away.

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

*Aerial Photos: Taken by Geospatial Information Authority of Japan

Changes in the invertebrate habitats before & after the earthquake



Scopimera globosa

Not seen before the earthquake, they have only recently appeared in the sand brought in by the tsunami.



Nuttallia japonica

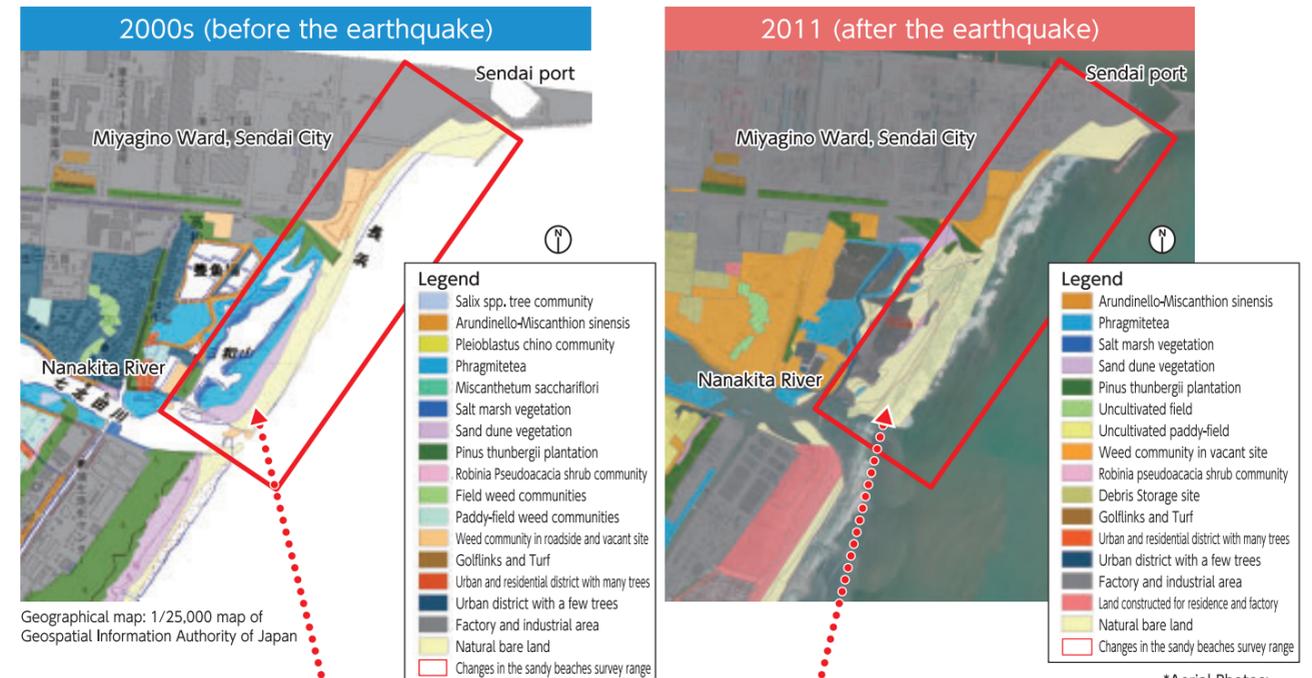
The bivalves known as *Nuttallia japonica* and *Ruditapes philippinarum* were seen before the earthquake. After the earthquake, a significant number of them remained.



Grandidierella japonica

Several species of *Gammarus* which were not seen before the earthquake disaster were observed and their population was also increased.

Vegetation Changes before and after the earthquake

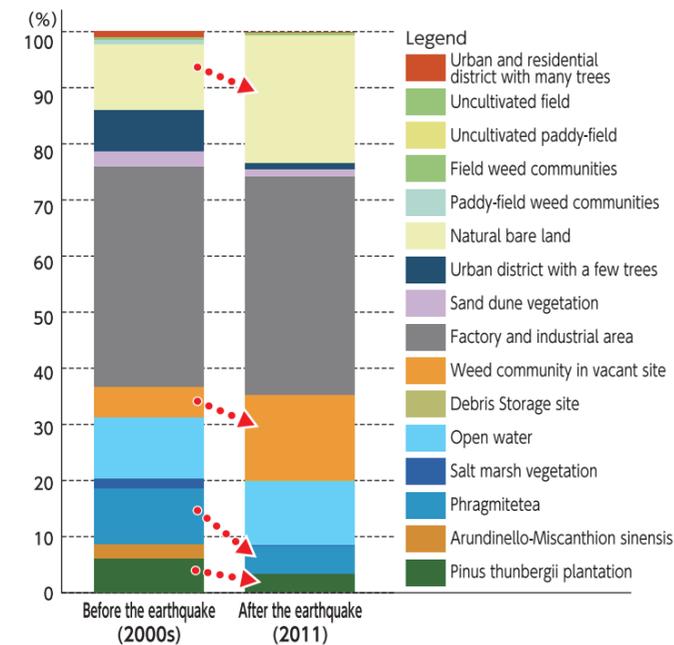


Geographical map: 1/25,000 map of Geospatial Information Authority of Japan

*Aerial Photos: Taken by Geospatial Information Authority of Japan

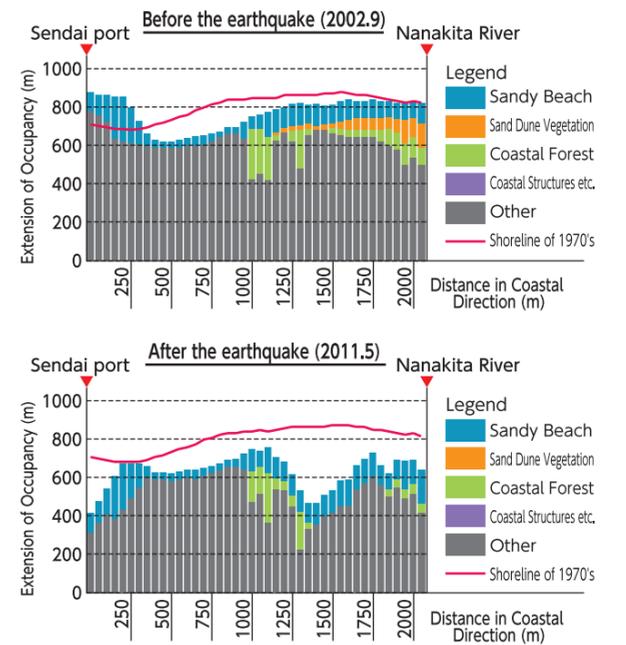
Large parts of the vegetation in the sand dunes (purple), Phragmitetea in the tidal flats (light blue) and Salt marsh vegetation (blue) growing along the sandy beaches were washed away.

Vegetation Changes area before & after the earthquake



From the changes in the areas shown within the red frames in the diagram above, it can be seen that Reed (Phragmitetea) (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.

Sandy Beach Changes before & after the earthquake



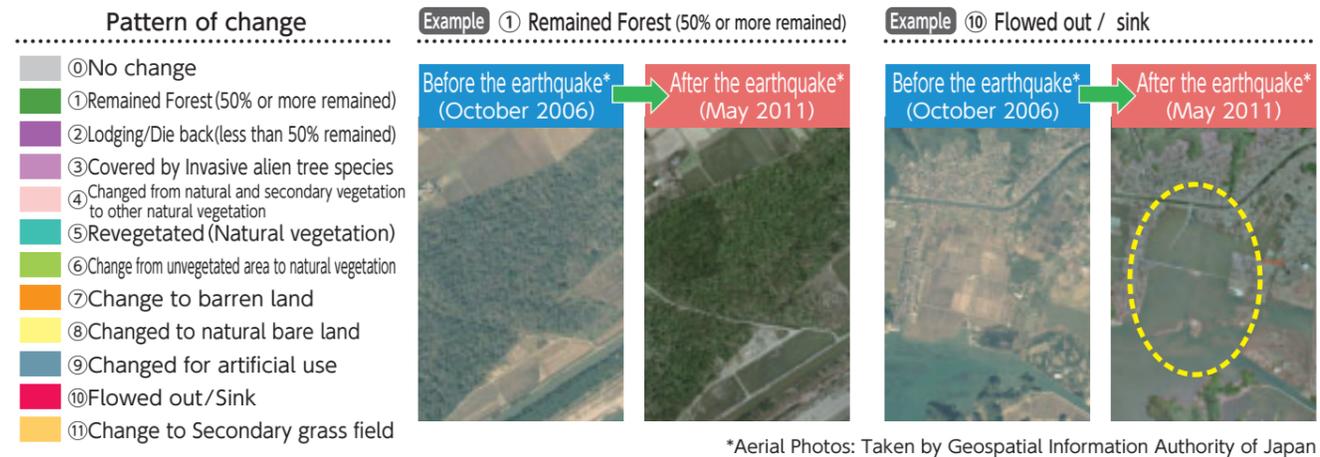
The shoreline has receded a maximum of 200 meters inland within the range shown in the red frames in the diagram above. The sandy beaches have vastly changed their shapes and most of the coastal forests have been washed away.

Vegetation Changes

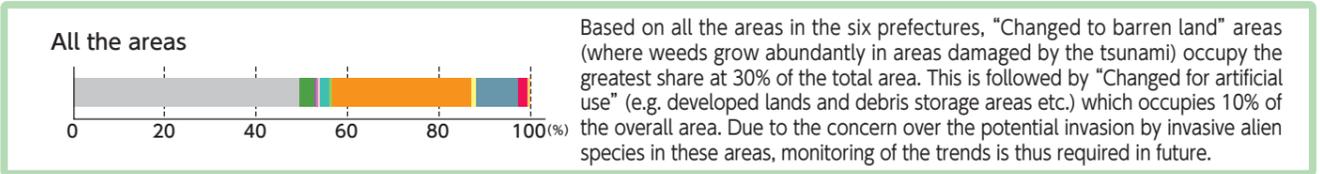
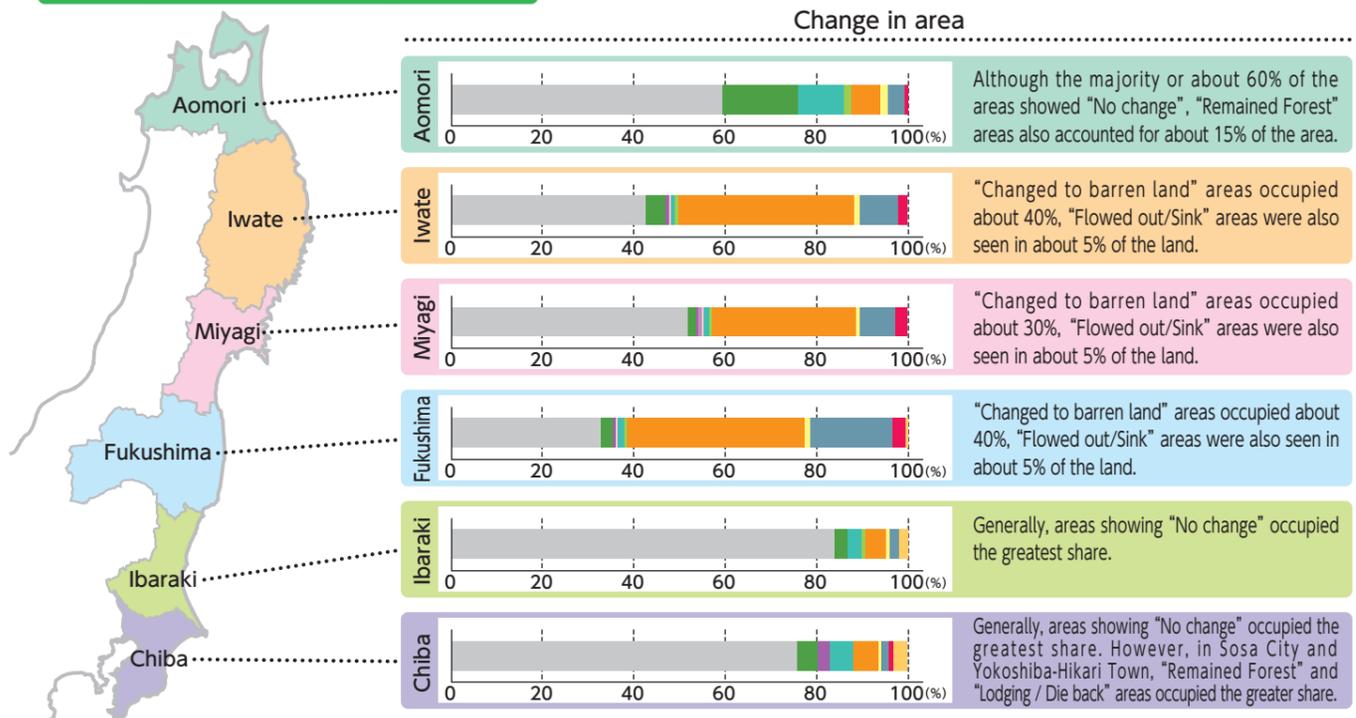
In order to understand the changes in the vegetation in areas submerged by the tsunami along the Pacific coastline from Aomori Prefecture to Chiba Prefecture (about 576 km²), we created vegetation maps before and after the earthquake (November 2012) and then overlaid them to compare the changes before 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.

Pattern of change due to the tsunami



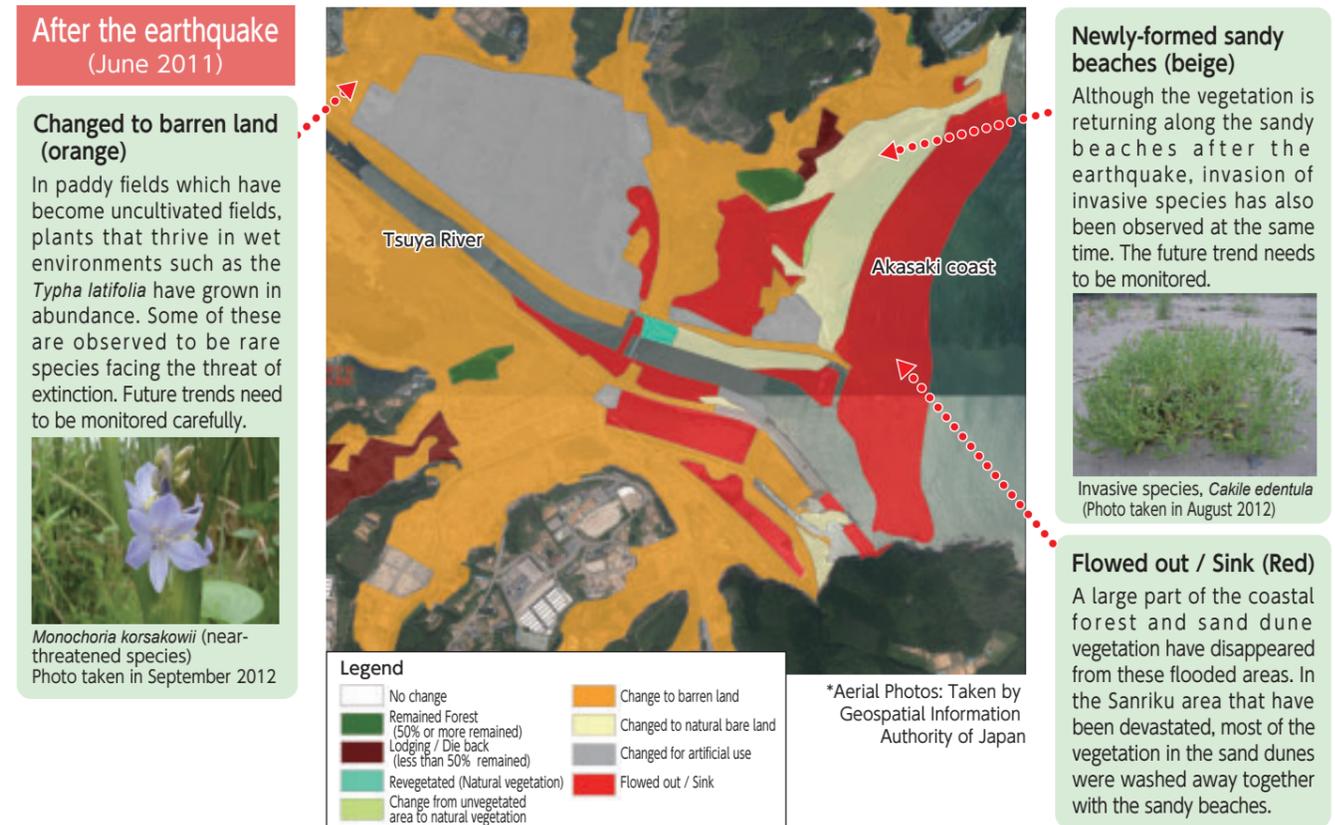
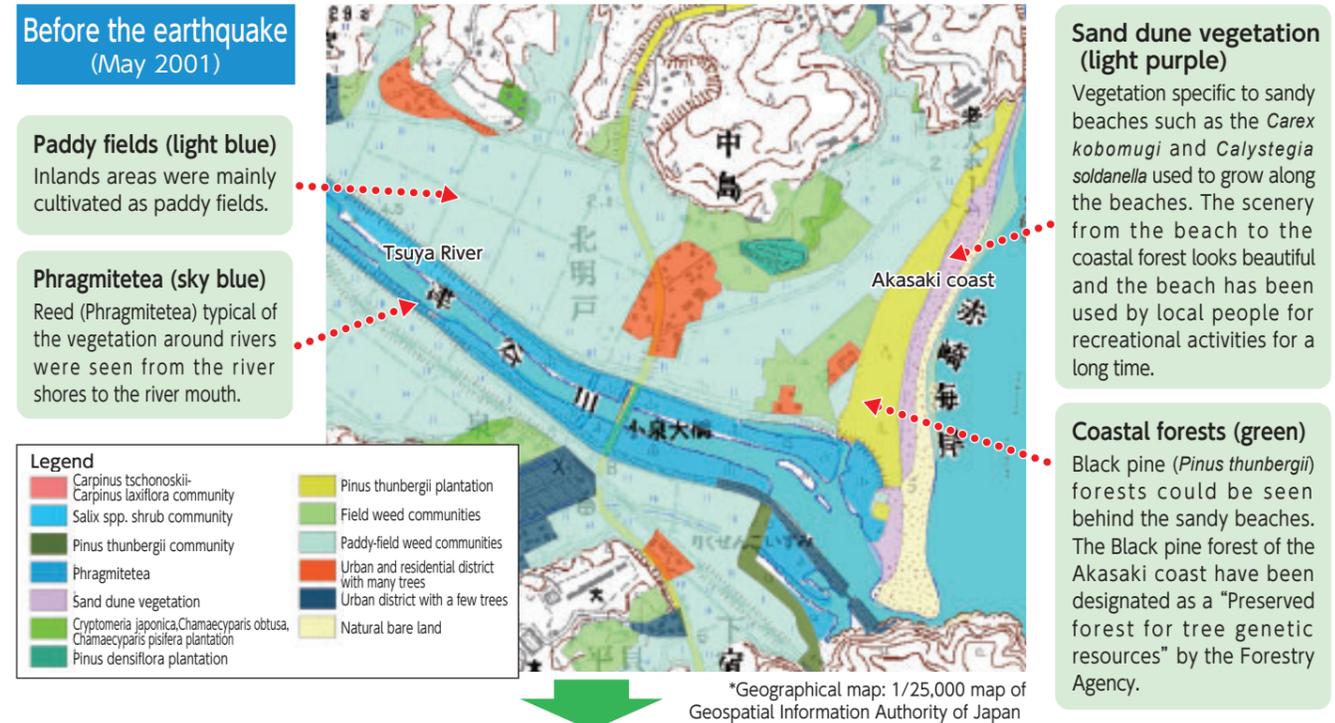
Changes in the Vegetation



e.g. Akasaki coast (Kesenuma City, Miyagi Prefecture)

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.



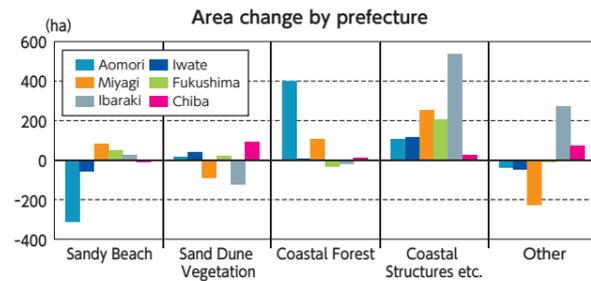
Sandy Beach Changes

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.

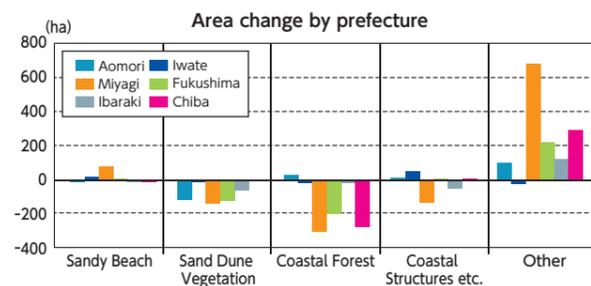
Area change in from the 1970s until the earthquake

“Coastal structures” such as harbours and fishing facilities increased in all survey regions. Although the “sandy beach” area shrunk in Aomori Prefecture, the “coastal forest” area increased. In Ibaraki and Miyagi Prefectures, “sand dune vegetation area” was decreased.



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.



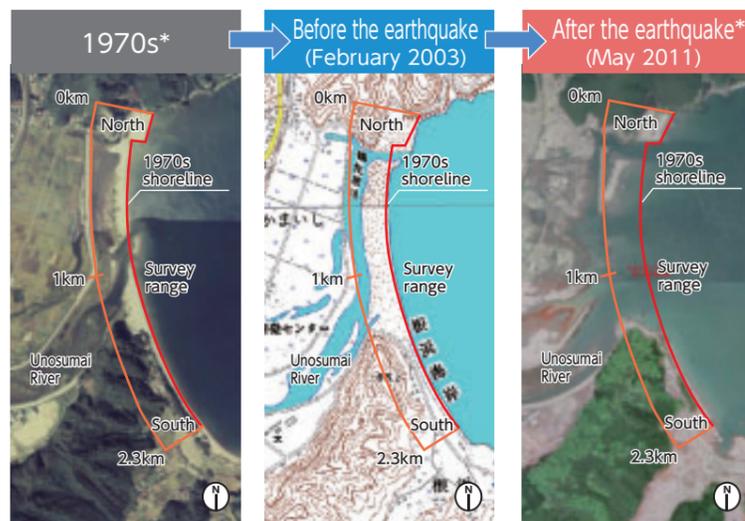
e.g. Nehama, Kamaishi City, Iwate Prefecture

1970s until before the earthquake disaster

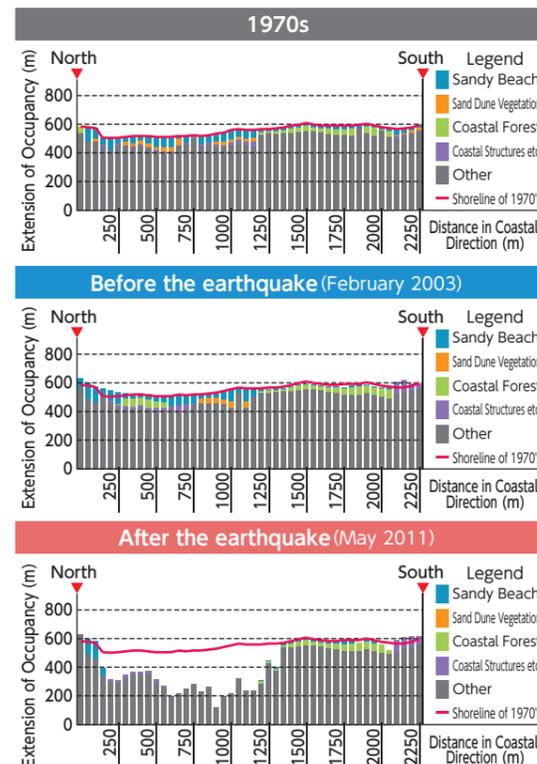
Sand dune vegetation grew in sandbars with a width of about 50 meters while coastal forest extended towards the south. The estuary of the Unosumai River moved towards the north comparing the changes of the two periods.

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.



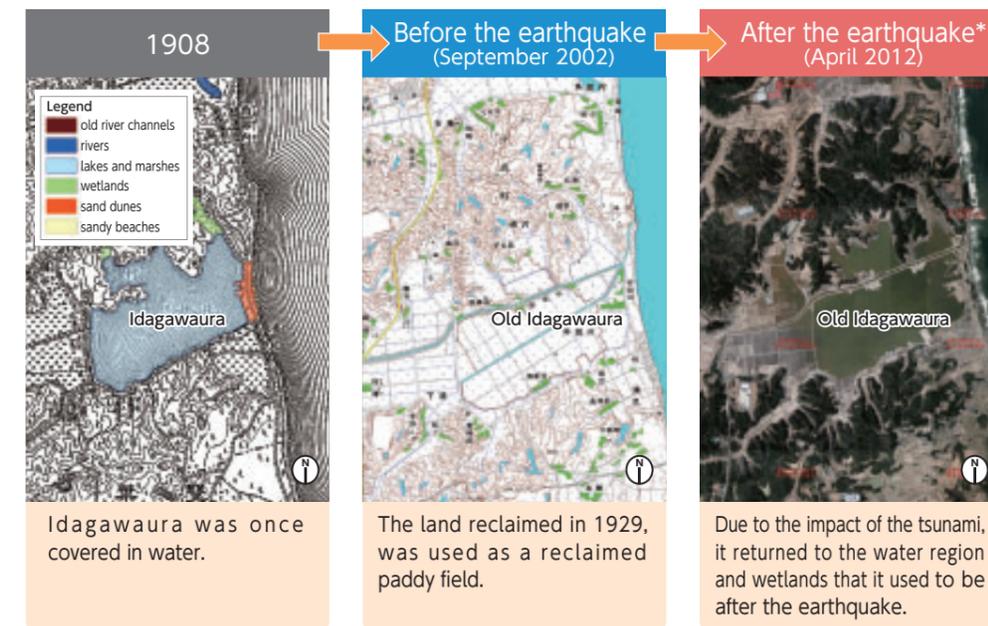
Geographical map: 1/25,000 map of Geospatial Information Authority of Japan *Aerial Photos: Taken by Geospatial Information Authority of Japan



Changes in the last hundred years

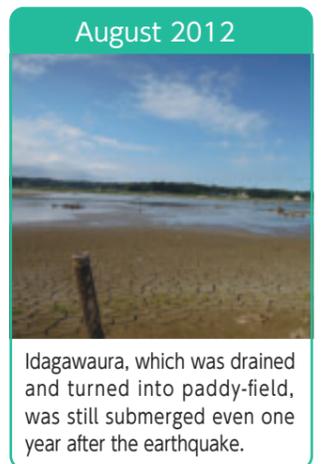
From the Old Edition map of the Geospatial Information Authority of Japan which was surveyed about a hundred years ago from 1903 to 1917, “old river channels”, “rivers”, “lakes and marshes”, “wetlands”, “sand dunes”, “sandy beaches” were identified and converted to GIS. As shown in the following examples,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

e.g. Idagawaura (Minamisoma City, Fukushima Prefecture)



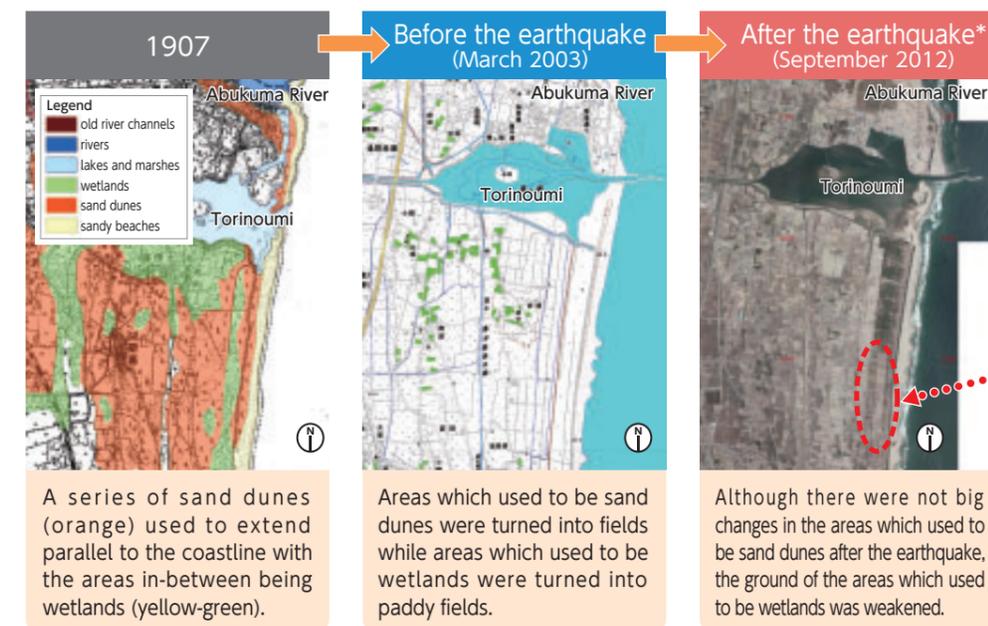
Geographical map: 1/25,000 map of Geospatial Information Authority of Japan

*Aerial Photos: Taken by Geospatial Information Authority of Japan



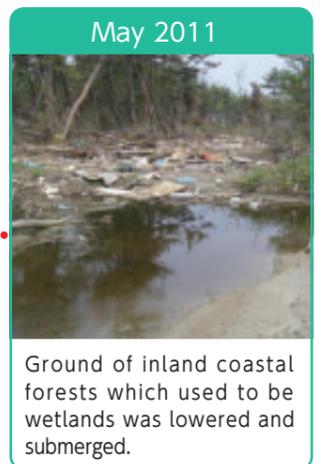
Idagawaura, which was drained and turned into paddy-field, was still submerged even one year after the earthquake.

e.g. Torinoumi (Watari Town, Miyagi Prefecture)



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

*Aerial Photos: Taken by Geospatial Information Authority of Japan



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

Ecosystem Monitoring

We monitored the seaweed beds, Zostera 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.



Many-formed cerith (Matsushima Bay)

Aomori coast

The disturbance was on a relatively small scale and no changes in the sea-bottom living landscape were observed.

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 withering of *Phragmites* and deposition 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.

Mangokuura

Although the impact of the tsunami was small, the disturbance was on a relatively moderate scale; the previous appearance of the tidal flat at a low tide was lost due to approximately 80 cm land subsidence. The benthos landscape changed with that.

The east coast of the Boso peninsula

Although the disturbance was on a relatively moderate scale, the benthos landscape changed together with changes in the sea bottom.

e.g. The estuary of Unosumi River, Kamaishi City, Iwate Prefecture (Sanriku coast)

Before the earthquake

In tidal flat areas with brackish water and relatively low salt content, many polychaete such as *Tylorrhynchus heterochaetus* and crustacean such as *Deiratonotus cristatus* were observed.

After the earthquake

Due to the tsunami, the sandbar disappeared and the estuary opened up directly into the sea with the agricultural land on the left bank being turned into a tidal flat. As a result, organisms that live in brackish waters with relatively higher salt content such as *Nuttallia japonica*, *Laternula marilina*, *Ruditapes philippinarum* and *Mya arenaria oonogai* moved in, resulting in changes to the ecosystem.



Left bank of estuary of Unosumi River that has been turned into a new tidal flat

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 flowed out into the area together with the flooding caused by the tsunami.



Calonectris leucomelas (Hide Island)

Kabu Island (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.

Hide Island (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.

Sangan Island (Kamaishi City, Iwate Prefecture)

The area was flooded up to a height of about 20 meters and landslides shrunk the area where storm petrels could build their nests.

Ashi Island (Onagawa Town, Miyagi Prefecture)

The impact of soil runoff due to the tsunami was minor and most of the vegetation and land within the nesting range remained intact.



Nest area of the *Larus crassirostris* at the northern end of Ashi Island

e.g. Ashi Island, Onagawa Town, Miyagi Prefecture

Before the earthquake

Ashi Island is the southern tip of the breeding grounds for *Cerorhinca monocerata*, and *Calonectris leucomelas* also used to build their nests in the same area.

After the earthquake

The tsunami was thought to have reached a height of about 15 meters as it exceeded the height of the saddle in the center of the island (height about 15 meters). However, the land and vegetation remained in most areas and thus the impact on the nest density of the *Cerorhinca monocerata* was thought to be minor.

Zostera beds

As Zostera forest are mainly located in the inner bay areas where the force of the tsunami is concentrated, the great disturbance such as disappearance of the sea bed caused by the tsunami was observed.



Phyllospadix iwatensis (Inubosaki)

Yamada Bay

There was a large population of mixed *Zostera caespitosa* and *Zostera marina* before the earthquake. After the earthquake, the northern and central areas of the bay were observed to be just as dense even though the ground subsided by about 40 cm.

Hirota 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 caespitosa* 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.

Matsushima Bay (Sabusawa Island)

One species of *Zostera marina* used to grow here before the earthquake disaster. After the earthquake, the ground subsided by about 1 meter, and only a small number at the mouth of the bay remained intact.

Inubosaki

Before the earthquake, cold and warm temperate and cold current algae and seaweed used to grow in this area and no significant changes were seen after the earthquake.

Otsuchi

Small-scale Zostera beds used to dot the area before the earthquake. After the earthquake, most of it disappeared together with the seabed. Although some Zostera was seen, the coverage was almost 0%.

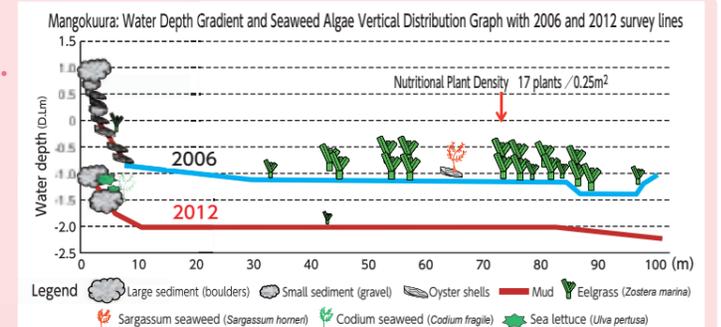
e.g. Mangokuura, Ishinomaki City, Iwate Prefecture (lagoon)

Before the earthquake

According to a survey of the west coast of Kuroshima Island carried out near the center of the lagoon in Dec 2006, Zostera was observed to be growing from the coast up to about 100 meters out at sea.

After the earthquake

The ground was seen to have subsided by about 0.9 meters, becoming muddy as sludge accumulated. The distribution area of the Zostera was drastically reduced. Zostera population reported in the survey in 2006 was exterminated.



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 Laminariaceae bory, the impact on the population was thus thought to be relatively minor.



Japanese kelp (Yamada Bay)

Yamada Bay

Before the earthquake, it was a Laminariaceae bed mainly consisted of *Laminaria japonica* Areschoug and *Costaria costata*. After the earthquake, *Laminaria japonica* Areschoug was seen.

Shizugawa Bay

Before the earthquake, the main population seen was *Eisenia bicyclis*. No major changes in the population landscape were seen immediately after the earthquake but significant growth of *Undaria pinnatifida* was seen in 2012.

Onagawa Bay

Before the earthquake, there were almost no large algae species and several varieties of small red algae were seen mostly. After the earthquake, *Schizymenia dubyi* and *Laminaria religiosa* were seen mainly in the shallow areas while *Undaria pinnatifida* and *Sargassum homeri* were seen mainly 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 *Eisenia bicyclis*, *Undaria pinnatifida* and *Sargassum*.

e.g. Onagawa Bay, Onagawa Town, Miyagi Prefecture (Minamisanriku)

Before the earthquake

Originally, the bed consisted of *Undaria pinnatifida* and *Sargassum* but is now dominated by several varieties of small red algae dotted with *Dictyota dichotoma*, a large brown algae (March 2007 survey).

After the earthquake

In the shallow areas, a red algae *Schizymenia dubyi* grows in abundance mixed with a large brown algae, *Laminaria religiosa*. In the deeper areas, it is mainly dominated by *Sargassum homeri* and *Undaria pinnatifida* (August 2012 survey).



*Aerial Photos: Taken by Geospatial Information Authority of Japan