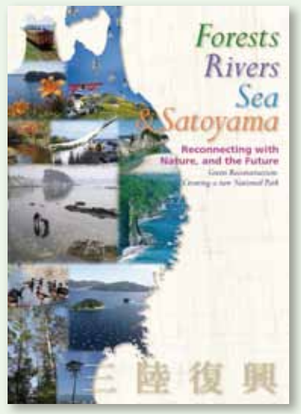
Fallen trees in the coastal forest immediately after the earthquake disaster
Arahama, Watari Town, Miyagi Prefecture April 2011

WEB 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 Reconstrustion Project



The Ministry of the Environment is working on many programs in "Green Reconstruction Project through Establishment of Sanriku Fukko (reconstruciton) 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 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
Biodiversity Center of Japan
5597-1, Kenmarubi, Kamiyoshida, Fujiyoshida-shi, Yamanashi 403-0005
TEL : +81-555-72-6033 FAX : +81-555-72-6035

Edited by | Asia Air Survey Co., Ltd.
Published in November 2013

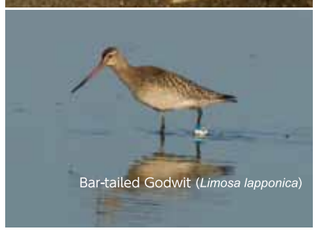

Larus crassirostris (Matsushima Bay)

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.

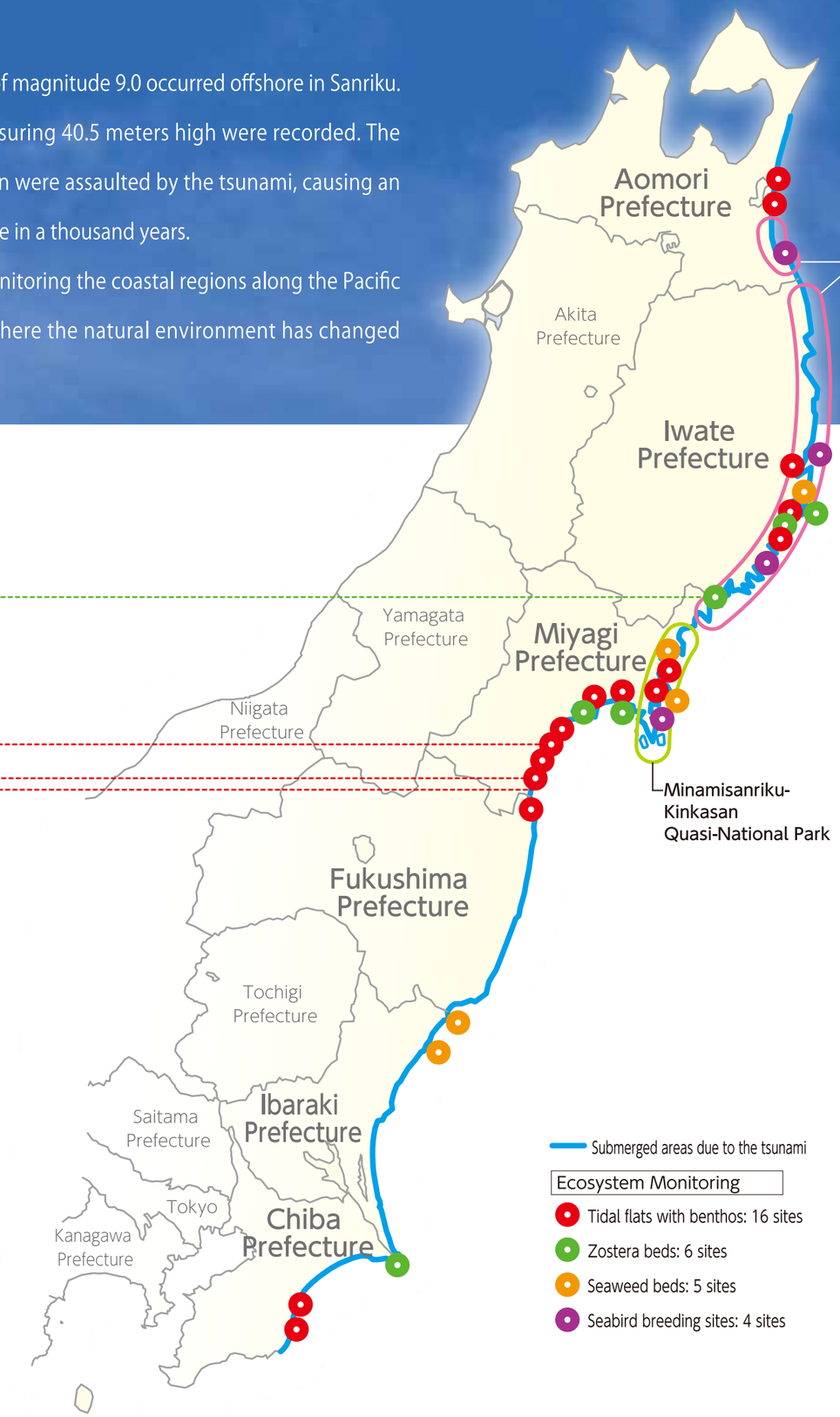

Takatamatsubara, Rikuzentakata City, Iwate Prefecture


Arahama, Sendai City, Miyagi Prefecture


Torinoumi, Watari Town, Miyagi Prefecture


Nakahama, Yamamoto Town, Miyagi Prefecture

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

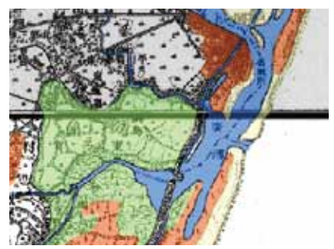
Sandy Beach Changes

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.

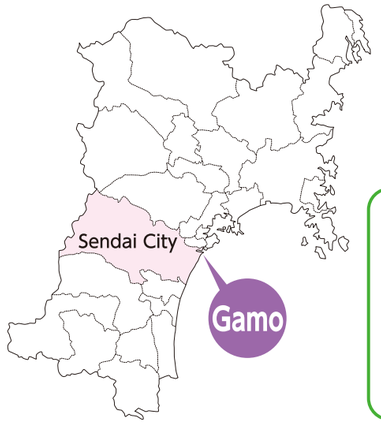

Hiroura, Natori City, 1907

Ecosystem Monitoring

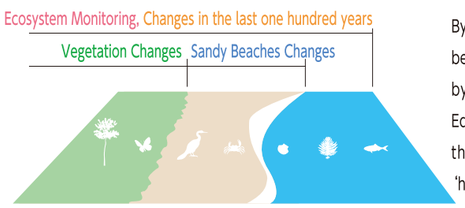
Post-disaster surveys were carried out in 16 tidal flats, 6 Zostera beds, 5 seaweed beds and 4 seabird breeding sites which were surveyed previously before the earthquake to compare with the situation before the earthquake.


Yamada Bay, October 2012

Changes in Gamo, Sendai City

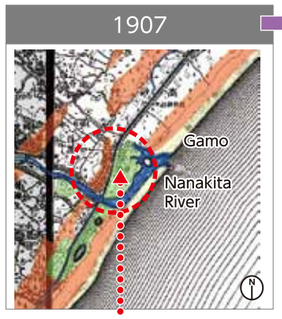


In Gamo, Sendai City, Miyagi Prefecture, there is a lagoon consisting of a mixture of fresh and sea water which extends inland towards to the sand dunes. At low tides, a mud flat appears as an extension of the surrounding wetlands where many plants and animals live and breed. However, that aspect has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

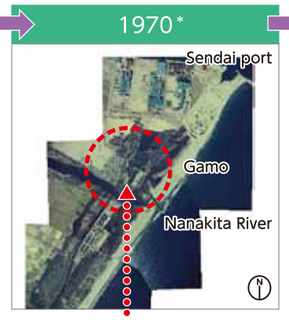


By comparing the coast and vegetation before and after the earthquake disaster by using past images such as the Old Edition maps and aerial photos taken in the 1970s, we identified 'what' and 'how much' changes occurred.

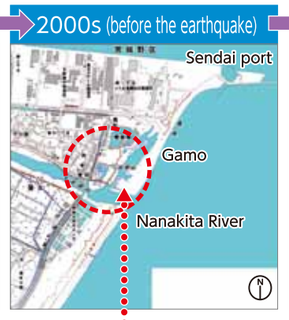
Changes in the last hundred years



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



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.



Sand dune vegetation, reed in the tidal flats and salt marsh vegetation used to grow along the sandy beaches.

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

Most of the Black pine have either fallen or withered away and black pine in areas that were once wetlands have been washed away.

*Aerial Photos: Taken by Geospatial Information Authority of Japan

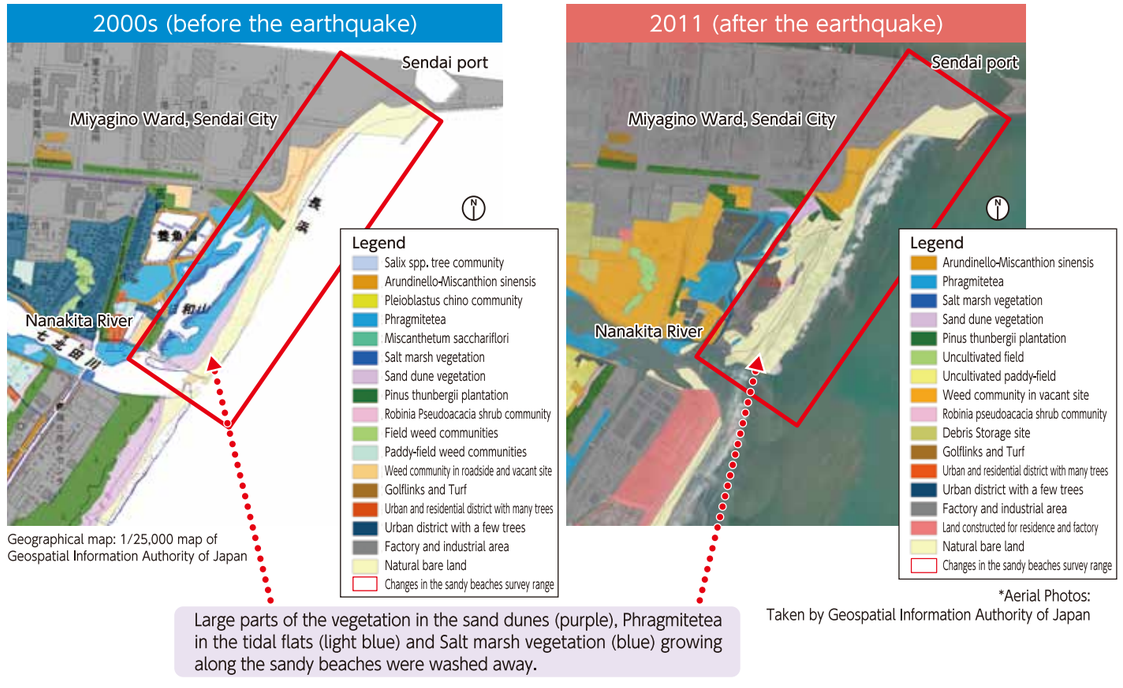
Changes in the invertebrate habitats before & after the earthquake

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

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

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

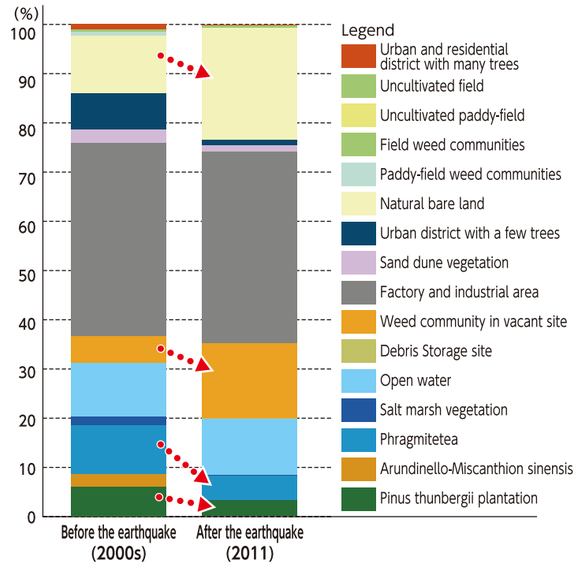


Geographical map: 1/25,000 map of Geospatial Information Authority of Japan

*Aerial Photos: Taken by Geospatial Information Authority of Japan

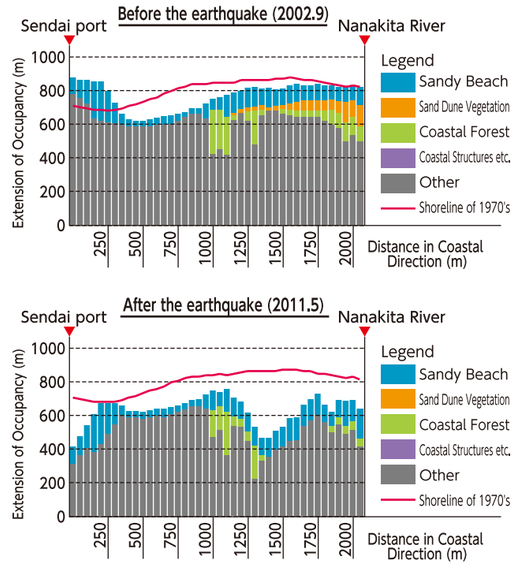
Large parts of the vegetation in the sand dunes (purple), Phragmitetea in the tidal flats (light blue) and Salt marsh vegetation (blue) growing along the sandy beaches were washed away.

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 km^2), we created vegetation maps before and after the earthquake (November 2012) and then overlayed them to compare the changes before and after the earthquake.

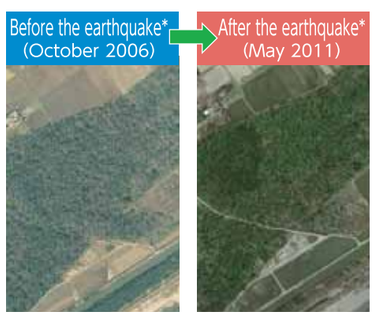
A scale of 1/10,000 was assumed for the plot accuracy up to a distance of about 500 meters inland. Thereafter, a scale of 1/25,000 was used further inland.

Pattern of change due to the tsunami

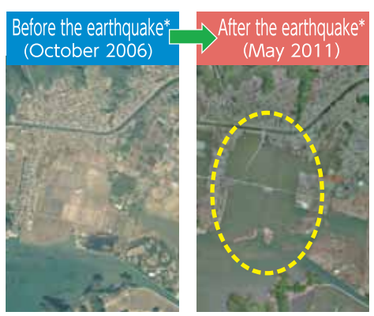
Pattern of change

- ⓪No change
- ①Remained Forest (50% or more remained)
- ②Lodging/Die back (less than 50% remained)
- ③Covered by Invasive alien tree species
- ④Changed from natural and secondary vegetation to other natural vegetation
- ⑤Revegetated (Natural vegetation)
- ⑥Change from unvegetated area to natural vegetation
- ⑦Change to barren land
- ⑧Changed to natural bare land
- ⑨Changed for artificial use
- ⑩Flowed out/Sink
- ⑪Change to Secondary grass field

Example ① Remained Forest (50% or more remained)

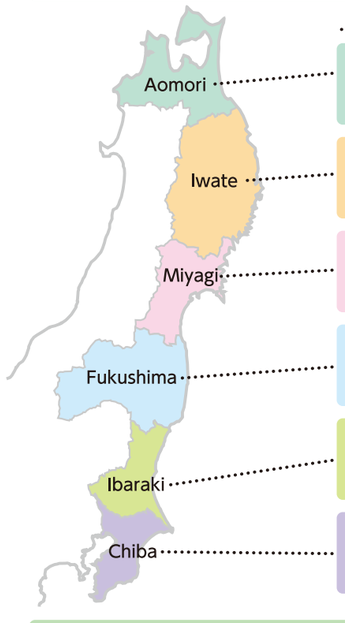


Example ⑩ Flowed out / sink

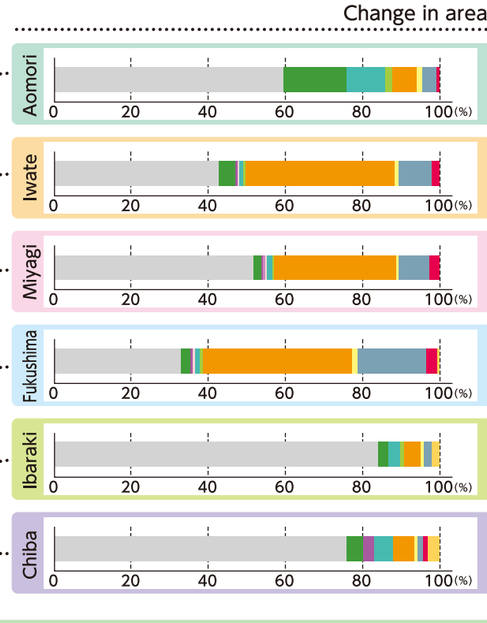


*Aerial Photos: Taken by Geospatial Information Authority of Japan

Changes in the Vegetation



Change in area



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.

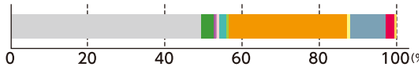
"Changed to barren land" areas occupied about 30%, "Flowed out/Sink" areas were also seen in about 5% of the land.

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

Generally, areas showing "No change" occupied the greatest share.

Generally, areas showing "No change" occupied the greatest share. However, in Sosa City and Yokoshiba-Hikari Town, "Remained Forest" and "Lodging / Die back" areas occupied the greater share.

All the areas



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.

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

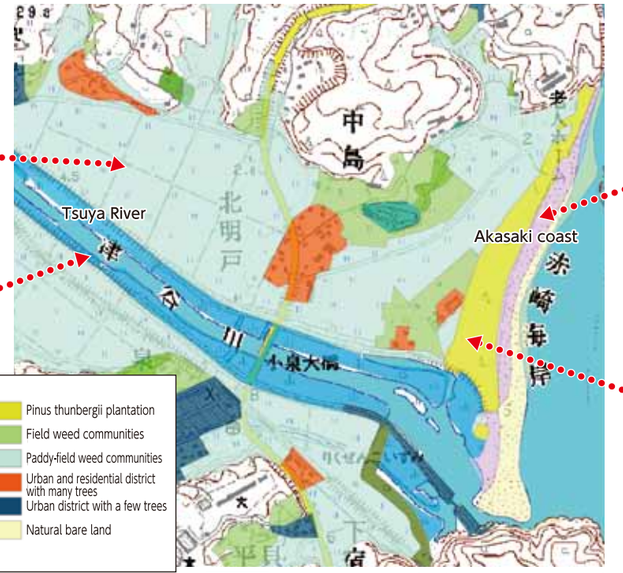
Before the earthquake, sandy beach, sand dune vegetation and Black pine plantation could be seen along the shoreline while paddy fields and farmlands extended inland. After the earthquake, the sandy beaches, sand dune vegetation and coastal forests disappeared and the shoreline receded. In addition, 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.

Before the earthquake (May 2001)

Paddy fields (light blue)
Inlands areas were mainly cultivated as paddy fields.

Phragmitetea (sky blue)
Reed (Phragmitetea) typical of the vegetation around rivers were seen from the river shores to the river mouth.



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

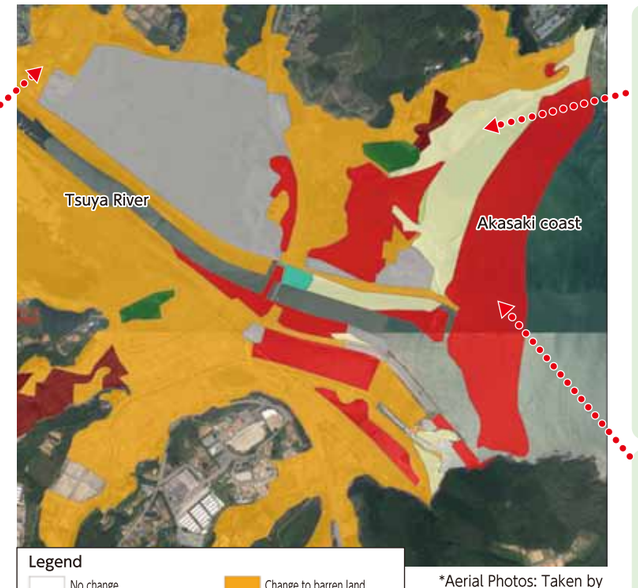
Sand dune vegetation (light purple)
Vegetation specific to sandy beaches such as the *Carex kobomugi* and *Calystegia soldanella* used to grow along the beaches. The scenery from the beach to the coastal forest looks beautiful and the beach has been used by local people for recreational activities for a long time.

Coastal forests (green)
Black pine (*Pinus thunbergii*) forests could be seen behind the sandy beaches. The Black pine forest of the Akasaki coast have been designated as a "Preserved forest for tree genetic resources" by the Forestry Agency.

After the earthquake (June 2011)

Changed to barren land (orange)
In paddy fields which have become uncultivated fields, plants that thrive in wet environments such as the *Typha latifolia* have grown in abundance. Some of these are observed to be rare species facing the threat of extinction. Future trends need to be monitored carefully.

Monochoria korsakowii (near-threatened species)
Photo taken in September 2012



*Aerial Photos: Taken by Geospatial Information Authority of Japan

Newly-formed sandy beaches (beige)
Although the vegetation is returning along the sandy beaches after the earthquake, invasion of invasive species has also been observed at the same time. The future trend needs to be monitored.

Invasive species, *Cakile edentula* (Photo taken in August 2012)

Flowed out / Sink (Red)
A large part of the coastal forest and sand dune vegetation have disappeared from these flooded areas. In the Sanriku area that have been devastated, most of the vegetation in the sand dunes were washed away together with the sandy beaches.

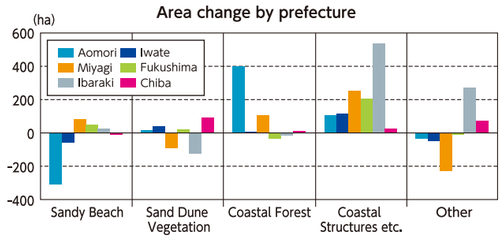
Sandy Beach Changes

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.

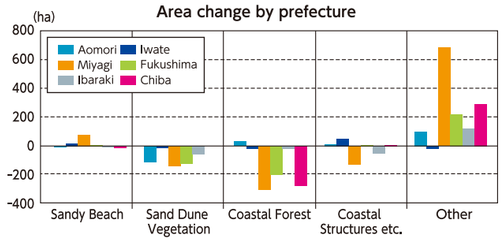
Area change in from the 1970s until the earthquake

"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.



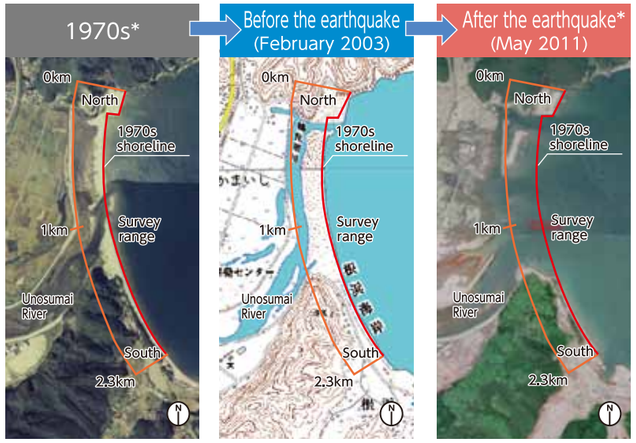
e.g. Nehama, Kamaishi City, Iwate Prefecture

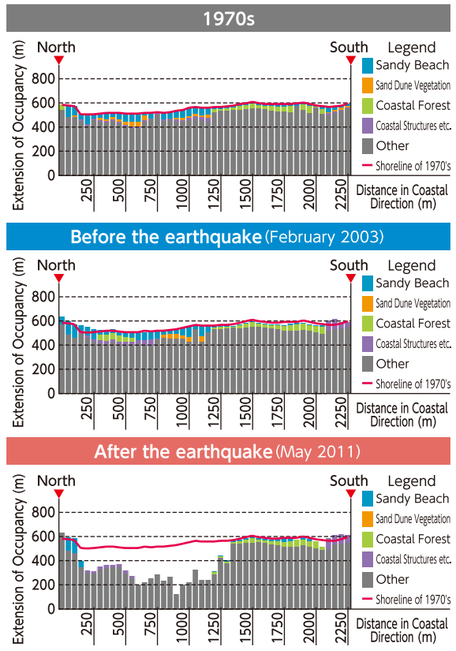
1970s until before the earthquake disaster

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.



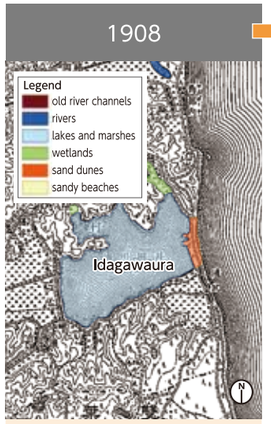


Geographical map: 1/25,000 map of Geospatial Information Authority of Japan
*Aerial Photos: Taken by Geospatial Information Authority of Japan

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)



Idagawaura was once covered in water.

The land reclaimed in 1929, was used as a reclaimed paddy field.

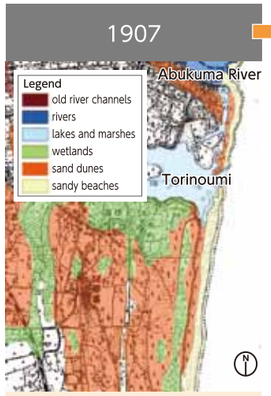
Due to the impact of the tsunami, it returned to the water region and wetlands that it used to be after the earthquake.

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

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

*Aerial Photos: Taken by Geospatial Information Authority of Japan

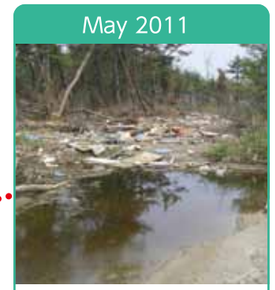
e.g. Torinoumi (Watari Town, Miyagi Prefecture)



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

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

Although there were not big changes in the areas which used to be sand dunes after the earthquake, the ground of the areas which used to be wetlands was weakened.



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

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

*Aerial Photos: Taken by Geospatial Information Authority of Japan

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 Phragmitetea 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 Unosumai 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 Unosumai 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.

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.

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

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 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.

●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.

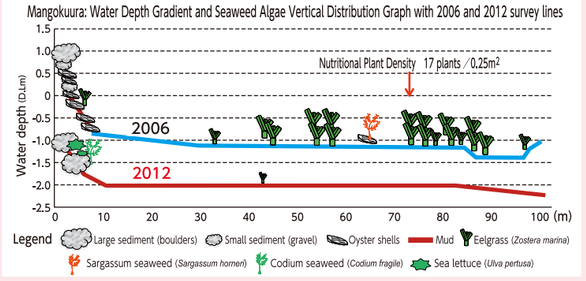
●Otsuchi

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)

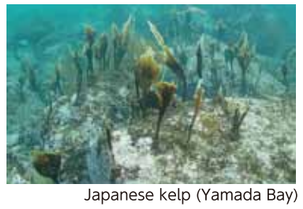
Before the earthquake According to a survey of the west coast of Kuroshima Island carried out near the center of the lagoon in Dec 2006, Zostera was observed to be growing from the coast up to about 100 meters out at sea.

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 horneri* 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 horneri* and *Undaria pinnatifida* (August 2012 survey).

*Aerial Photos: Taken by Geospatial Information Authority of Japan