A study of radiation effects on ecosystem and wildlife in areas affected by the Fukushima accident

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Background
The Great East Japan earthquake has occurred on 11 March, 2011

Moment Magnitude: 9.0
Deaths: 15,894
Missing persons: 2,558
Injured: 6,152
Flooded area: 561km²
Background

The Great East Japan earthquake has occurred on 11 March, 2011

Accident of *Fukushima Daiichi Nuclear Power Plant* (FDNPP)
Massive radioactive materials were spilled into the environment.

- Failure of the emergency cooling system
- Damaged the reactor's core
- Radioactive materials leaked out

Building housing reactors 1, 3 and 4 was damaged by hydrogen explosions
Contamination of radio-active materials in Fukushima

- 400 – 900 PBq of radioactive materials was released from the Fukushima Daiichi Nuclear Power Plant.
- Wild animals and plants are distributing in highly radiation-dose area.

Air dose rate of 1-meter-height from ground level:
- Over 50 mSv/year
- Difficult to return area
- 20 to 50 mSv/year
- Residence restriction area
- Less than 20 mSv/year
- No data

Wild animals and plants are distributing in highly radiation-dose area.
Overview of our researches at Fukushima

1. Monitoring of ecological change

- Spilled out of radioactive materials
- Accumulation on soil
- Evacuation
- Radiation

2. Radiation effects on wild organisms

- Effects for DNA, cell and individual

3. Forecasting model of ecological change

- Scenario A
- Scenario B

Forecasting ecological change in Fukushima
Current topics

- Ecological effects from evacuation
  Long-term monitoring of Biota and Landscape

- Effects of radiation to wild organisms
  Radiation effects on reproductive organ of wild rodents
Changes of Population Distribution and Land Use

The nuclear accident at Fukushima has significantly affected the population distribution of the surrounding area.

- Difficult to return area
- Residence restriction area
- Refuge in the prefecture
- Evacuation to outside the Fukushima

85,000 peoples have been to evacuate from their original living area.
Air dose rate will be decrease, and resident will be back

If air dose rate will decrease,

↓

Can start live, immediately?

Long term evacuation may change the environment

2012

2017 (5 year)

2022 (10 year)

2032 (20 year)
Overview of long-term biota monitoring

Aim of the study
Obtain knowledge
- the long-term evacuation affect biodiversity and ecosystems
- support return of residents

At primary school
- Birds, Frogs: recording research
- Insects: Traps

In forest
- Mammals: Motion sensor camera

Research points
- : Birds, Frogs, and Insects
- : Mammal
Hypothesized change of biodiversity

“traditional agricultural landscape” after stop of land management

Pest increasing?

Pollinators and/or natural enemies decreasing?

Loss of familiar nature?

“SATOYAMA”
Mammal monitoring

- 46 sites
- Full year

CAMERA trap
Wild animals taken by CAMERA trap

- Black Bear
- Wild Boar
- Antelope
- Japanese Monkey
- Invasive species
- Masked Palm
- Raccoon
Wild boar is most frequently observed in evacuation zone. Another species showed no significant difference between inside and outside of evacuation zone.

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- Another species showed no significant difference between inside and outside of evacuation zone.

Results of mammal monitoring (2014)

Should be continue further monitoring because these are invasive species.
Insect monitoring

- **Malaise Trap**

- 52 sites
- From May to July

Trapped insect

Sorting

Restricted to residence

- 52 sites
- From May to July
Result of insect monitoring (1)

Lower density in Evacuation zone

Carpenter Bee

The bee prefers large flowers such as garden plants. Reflection the loss of horticultural activity?

The bee has important role as pollinating insect, thus further monitoring is needed
Result of insect monitoring (2)

Higher density in Evacuation zone

Bees or Wasps

- Increase small wild flowers from abandonment of cultivation?

Beetles
Monitoring land cover and land use change

Importance of land-cover data

- Land cover is an important driving factor of **biota changes** in the disaster-affected region
- It can be utilize for basic data for the reconstruction of the disaster-affected areas

Map for distribution and current condition of deserted cultivated land are needed
A case of ecological response: Frogs

Decrease of deserted cultivated land (Paddy field)

→ May results in decrease of Frogs that are dependent on freshwater wetland

Photo by Matsushima
A case of ecological response: Waterfowls

Decrease of deserted cultivated land (Paddy field)

→ May results in decrease of Waterfowls that use freshwater wetland

Photo by Kumada
Making high resolution land use map

Satellite images

Rapid eye or Sentinel 2 (~10m resolution)

Ground-truth data

GIS
Now Running:
Land use change in evacuation zone

Before evacuation
(2008-2010)

After evacuation (2015)

Evacuation zone

Deserted paddy field
Variation of deserted cultivation land is also investigated.

Types of deserted cultivation land:
- Dry
  - Bushy tree
  - Grass
- Wet
  - Wetland
  - Grass
Future developments

Establish a ‘generalized state space model’ to estimate the parameters that define population

Trend forecasting of each species (animal damage or infective disease)
Summary of ecological monitoring

- Lower number of Carpenter Bee was trapped in evacuation zone
- Small bees, wasps and beetles was frequently captured in evacuation zone
- Higher density of Wild boar was observed in evacuation zone
- Map of deserted cultivation land will be made soon

We should continue the monitoring at least 10 years to detect effects of evacuation
Current topics

- Ecological effects from evacuation
  Long-term monitoring of Biota and Landscape

- Effects of radiation to wild organisms
  Radiation effects on DNA of reproductive organ in wild rodents
Background: Is the mutation increase at Fukushima?

There is no evidence for DNA mutation at Fukushima!


Max. exposure dose in Fukushima and ICRP effect levels

- Conifers
- Wild grass
- Soil invertebrates
- Rodents
- Brown seaweeds
- Benthic invertebrates
- Benthic flatfish

Max. dose in Fukushima soils and seawater

Material

Large Japanese field mouse (*Apodemus speciosus*)

- Endemic in Japan
- Head and body length: 80-140 mm
- Weight: 20-60 g
- Habitat: Forests, plantation, riverside fields with dense grasses, paddy fields and cultivated fields
DNA damage from gamma-ray

Gamma-ray

Direct effects

\[ e^- \rightarrow e^- \]

Indirect effects

\[ OH^- \]

\[ H_2O \]

\[ 1 : 3 \]

Gamma-ray

DNA damage

<table>
<thead>
<tr>
<th>DNA damage</th>
<th>Number of DNA damage with 1Gy irradiation</th>
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<tr>
<td>Chemical modification</td>
<td>&gt; 3000 (70%)</td>
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<tr>
<td>Single strand break</td>
<td>1000</td>
</tr>
<tr>
<td>Double strand break</td>
<td>40</td>
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<tr>
<td>DNA-Protein cross linking</td>
<td>150</td>
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</tbody>
</table>


DNA oxidization in sperm

1. Base modification by free radicals
   - Oxidation by radiation
   - Deoxyguanosine
   - 8-hydroxy-2’-deoxy guanosine (8-OHdG)

2. Mutation due to modified base
   - Oxidation
   - Base exchange

Sperm

Testis

G C
A T
T A
C G

G C
A T
T A
C G

G C
A T
T A
C G

G C
A T
T A
C G

8-OHdG
Capture sites of mice

Aomori Pref. 0.05 μSv/h

Toyama Pref. 0.10 μSv/h

Manie-town, Fukushima Pref.

Trapping site 20.33μSv/h
Methods

Skull (Age determination by tooth wear)

Bone, muscle, skin

Measurement of Cs-134 and Cs-137

Adult male (weight > 30 g)

Testes and epididymis

- Fixed by fixation solution
- Make cross section

8-OHdG immunostaining Gene expression analysis
Simulation of internal radiation-dose to testis

- Internal radiation-dose were simulated from Cs-137 and Cs-134 accumulation in body (Bq/kg) using Electron Gamma Shower (EGS) 5 program.
- Compositions of testis were assumed to TISSUE, SOFT (ICRP) and tissues surrounding testis were assumed to ADIPOSE TISSUE.

Evaluation of exposure dose in mouse testis

External radiation-dose rate

- The air dose rates of gamma radiation measured at ground level in capture sites.
Evaluation of exposure dose in mouse testis

- Radiation dose on mouse testis (mGy/day)

- ICRP effect level
  - 0.1 mGy/day: No information
  - 1.0 mGy/day: Reduced reproductive success

- Very low probability of effects

- Total exposure dose in Fukushima exceeded ICRP effect level
- External dose account for 70% of total exposure
Detection of 8-OHdG in testis

Testis: consisted with 100 seminiferous tubules

Immunostaining

8-OHdG antibodies

A seminiferous tubule
8-OHdG immunostaining on testis

- 8-OHdG positive sperms were observed only in Fukushima

Toyama  

Aomori  

Fukushima
The mice in Fukushima showed the highest accumulation of 8-OHdG
8-OHdG positive cells are decrease year by year
No 8-OHdG positive cell was observed in epididymis.
DNA repair by OGG1

OGG1
(8-oxoguanine DNA glycosylase 1)

Oxidation

Base exchange
The mice in Fukushima showed high level expression of DNA repair enzyme, OGG1
- Exposure dose in wild mice in Fukushima exceeded ICRP effect level
- Oxidized DNA level in testis relatively increase in Fukushima
- No 8-OHdG positive sperm cell was observed in epididymis

Base excision repair by OGG1 may occur during sperm maturation
No POKEMON was also found in evacuation zone