COMET Workshop:
Thirty years after the Chernobyl accident
what do we know about the effects of radiation
on the environment?

30 August 2016

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

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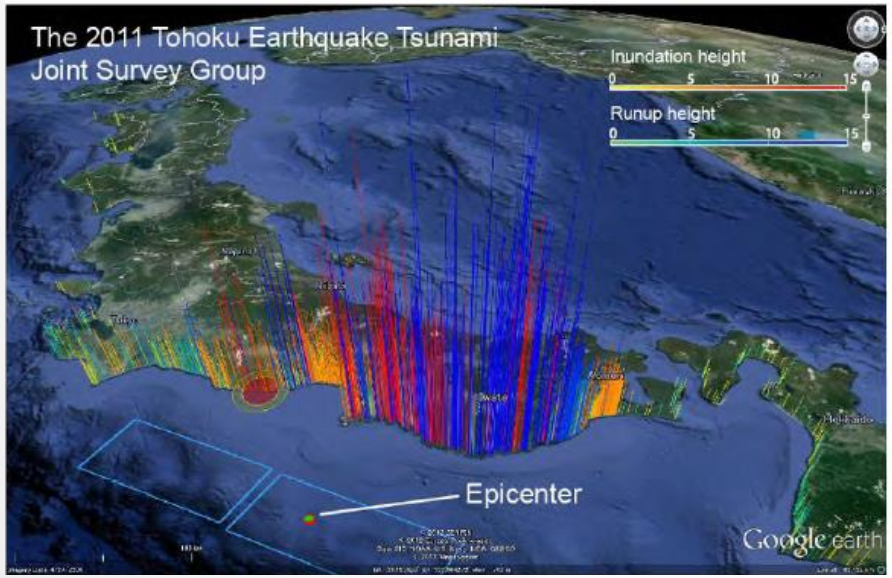
Background

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

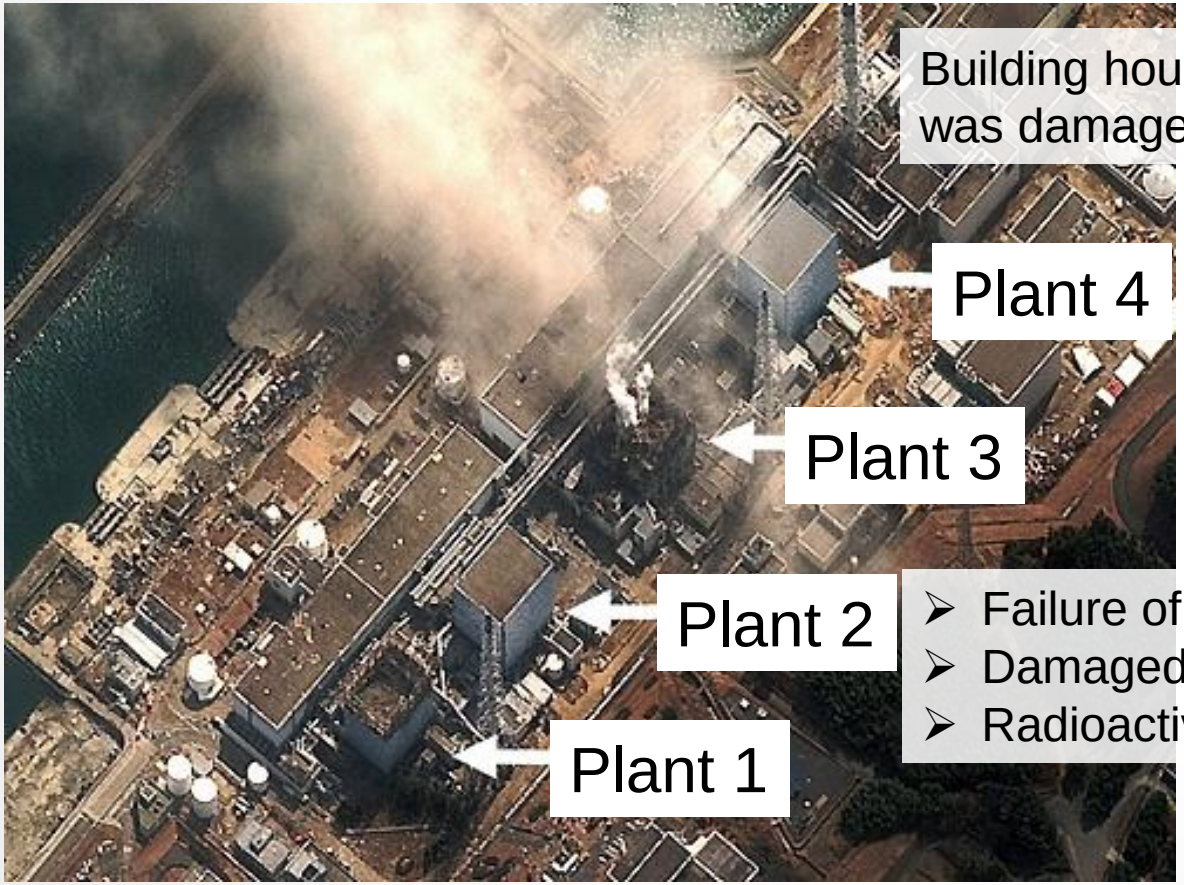
Moment Magnitude: 9.0
Deaths: 15,894
Missing persons: 2,558
Injured: 6,152
Flooded area : 561km^2



Background

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

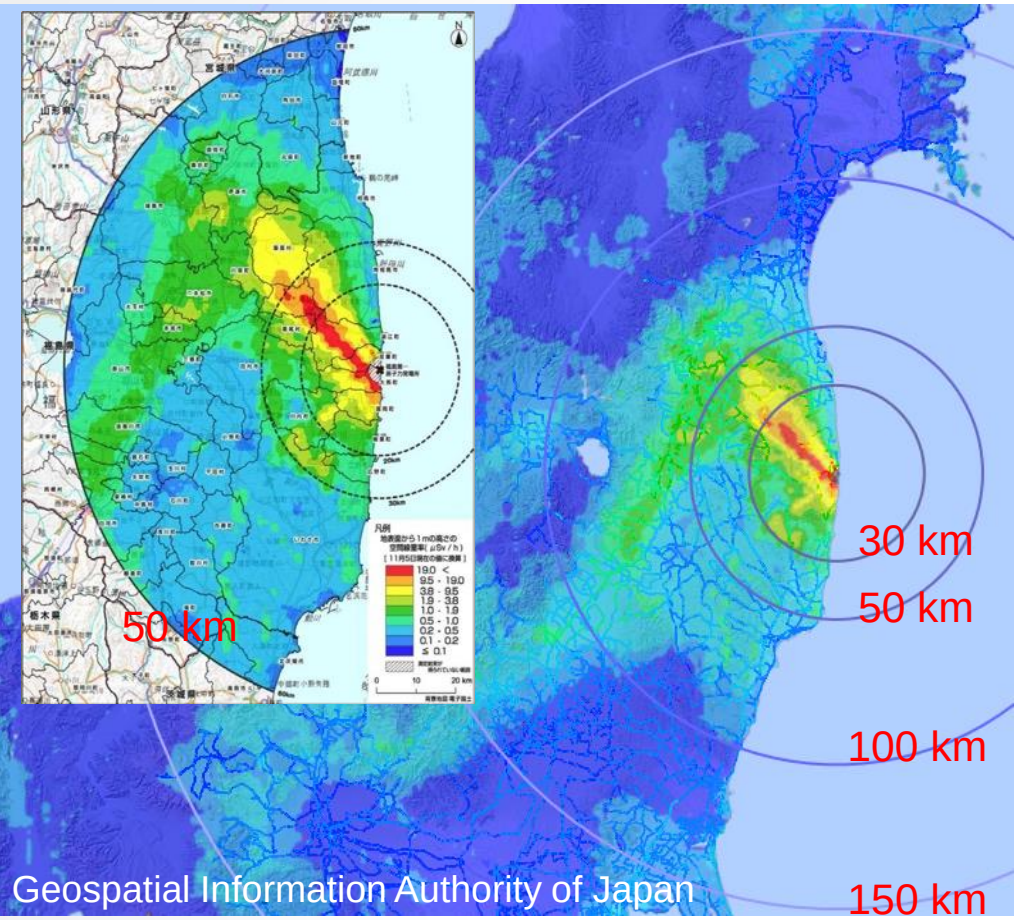
Accident of Fukushima Daiichi Nuclear Power Plant (FDNPP)
Massive radioactive materials were spilled into the environment.



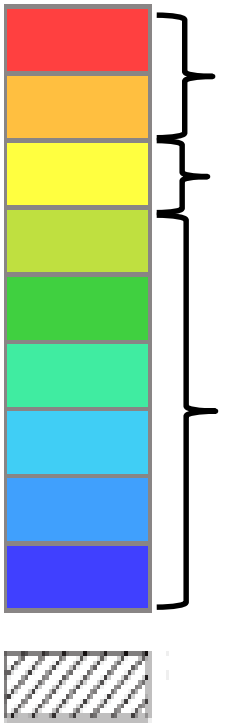
Building housing reactors 1, 3 and 4 was damaged by hydrogen explosions

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

Contamination of radio-active materials in Fukushima



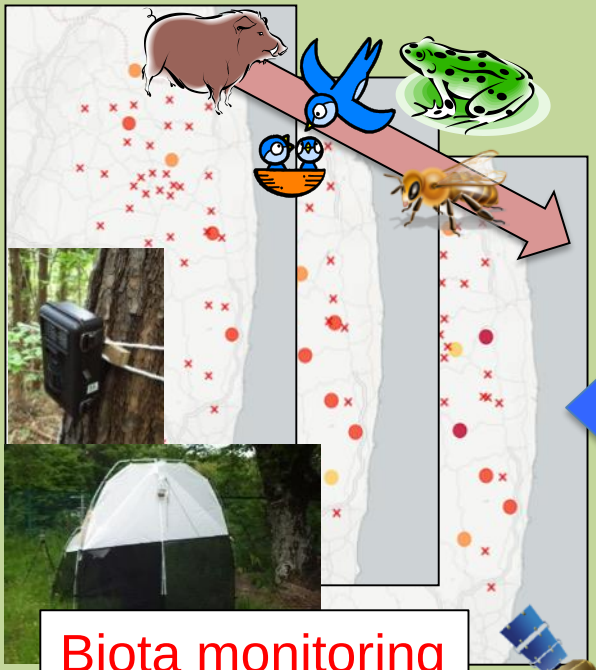
Air dose rate of 1-meter-height from ground level



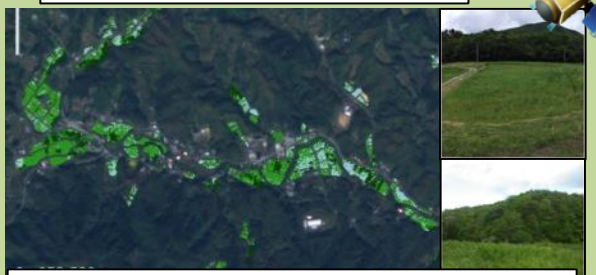
- 400 – 900 PBq of radioactive materials was released from the Fukushima Daiichi Nuclear Power Plant
- Wild animals and plants are distributing in highly radiation-dose area.

Overview of our researches at Fukushima

1. Monitoring of ecological change



Biota monitoring



Landscape monitoring

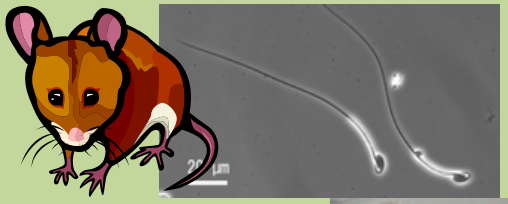
Spilled out of radioactive materials

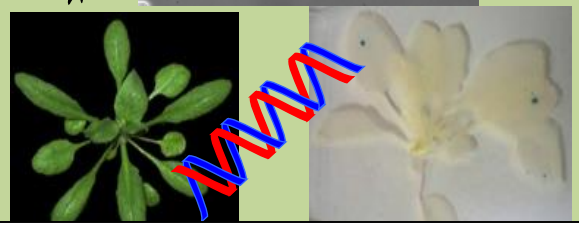
Accumulation on soil

Evacuation

Radiation

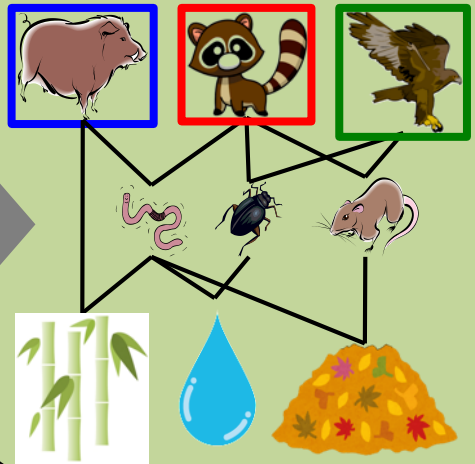
2. Radiation effects on wild organisms

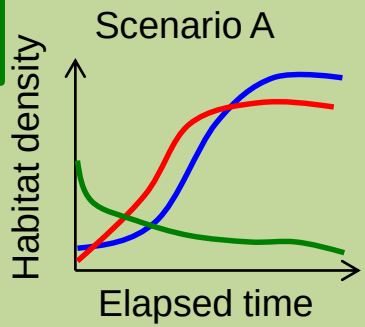


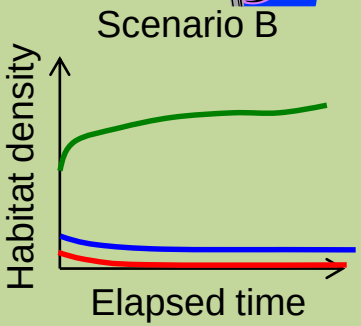


Effects for DNA, cell and individual

3. Forecasting model of ecological change







Forecasting ecological change in Fukushima

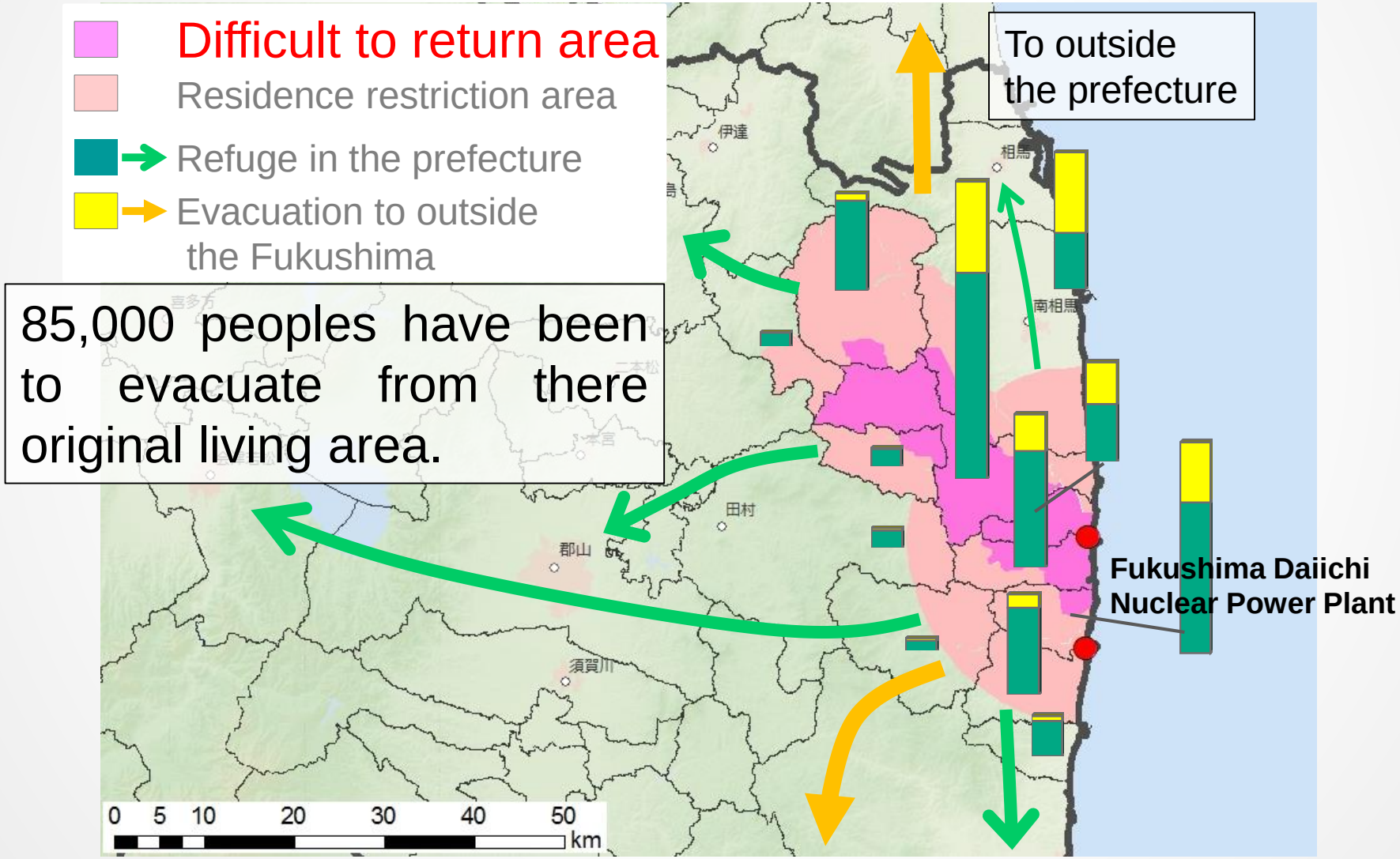
Current topics

- 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

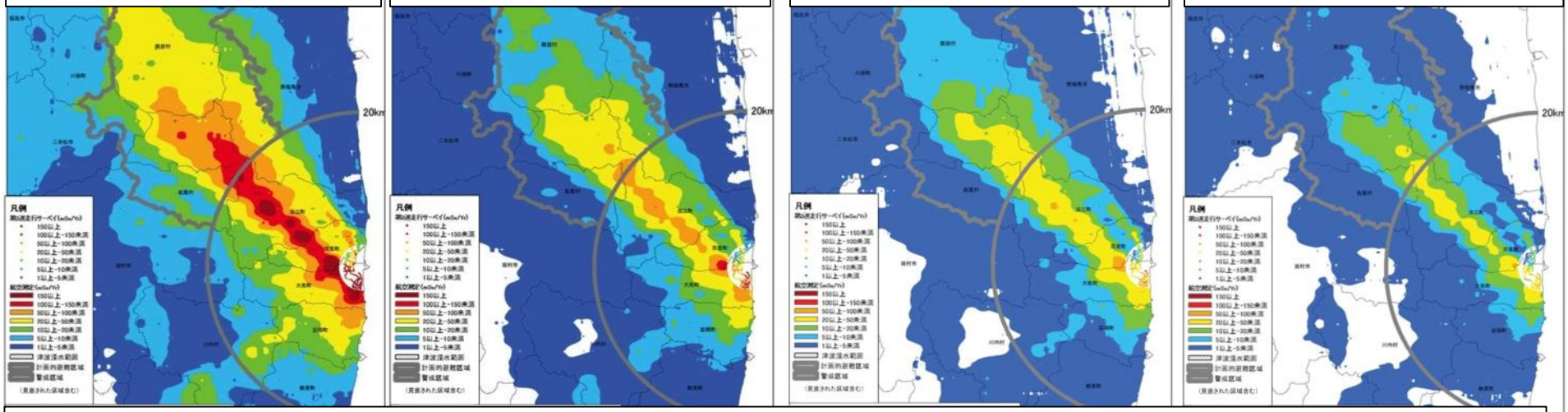
Changes of Population Distribution and Land Use

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

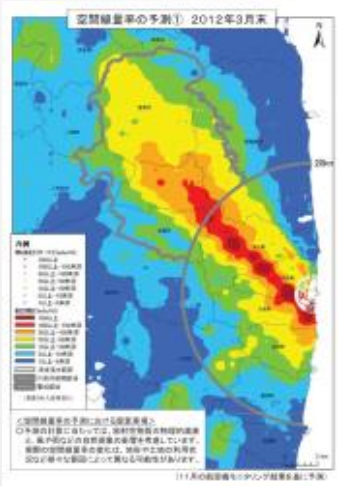


Air dose rate will be decrease, and resident will be back

2012	2017 (5 year)	2022 (10 year)	2032 (20 year)



Prediction of air dose rate change (April 26, 2012; Reconstruction Agency)

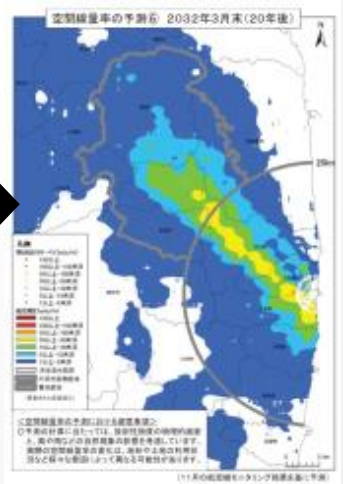


Long term evacuation may change the environment

If air dose rate will decrease,

↓

Can start live, immediately?



Overview of long-term biota monitoring

Aim of the study

Obtain knowledge

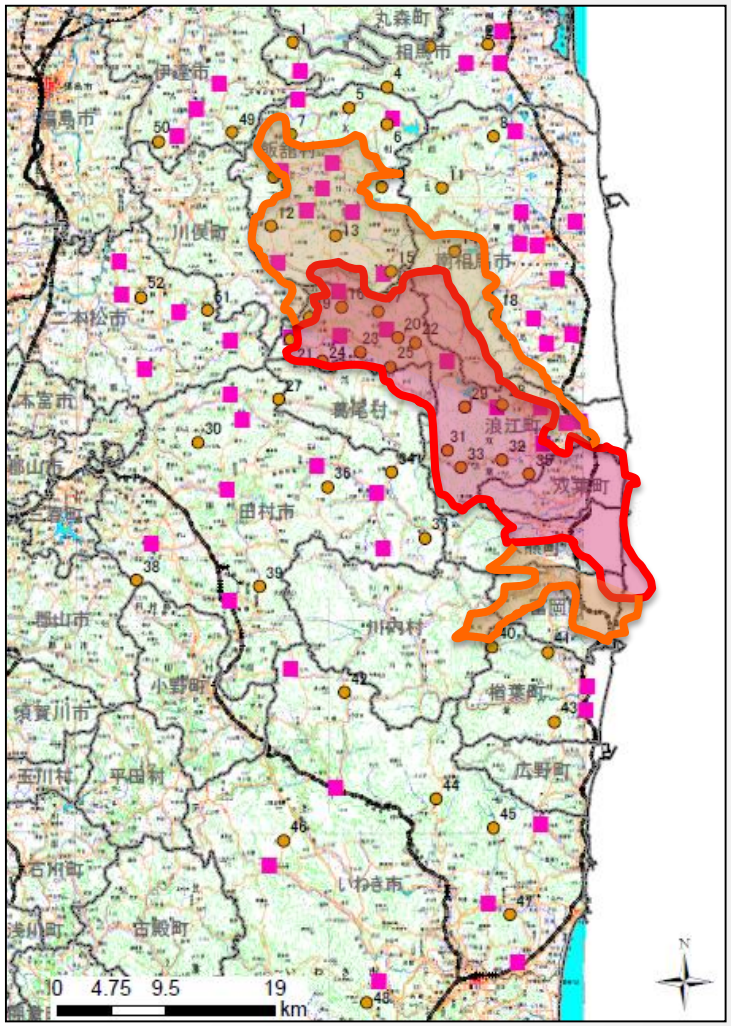
- the long-term evacuation affect biodiversity and ecosystems
- support return of residents

At primary school

- Birds, Frogs: recording research
- Insects: Traps

In forest

- Mammals : Motion sensor camera



Research points

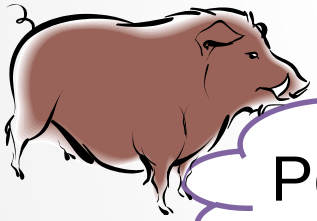
■ : Birds, Frogs, and Insects

● : Mammal

Hypothesized change of biodiversity

“traditional agricultural landscape”

after stop of land management



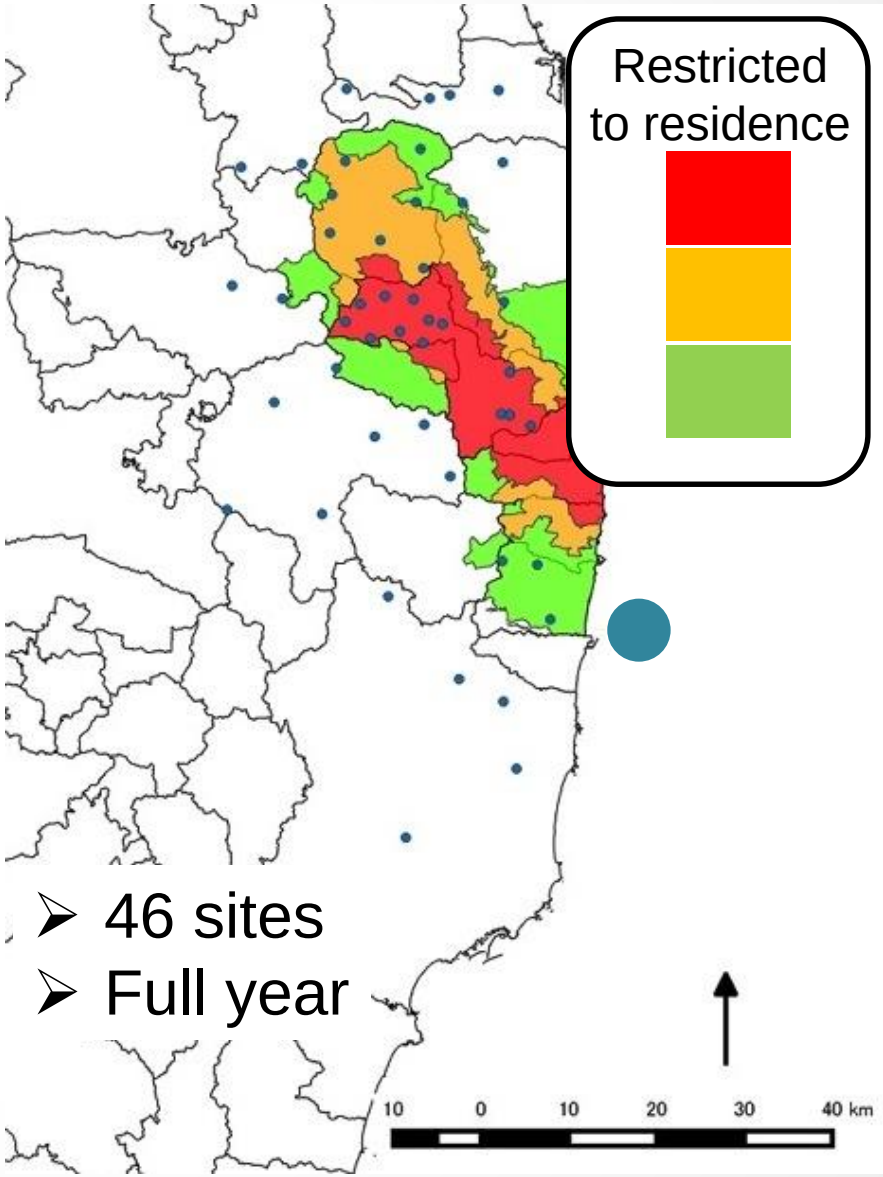
Pest increasing?

Pollinators and/or natural enemies decreasing?

Loss of familiar nature?

Mammal monitoring

CAMERA trap



- 46 sites
- Full year

Wild animals taken by CAMERA trap

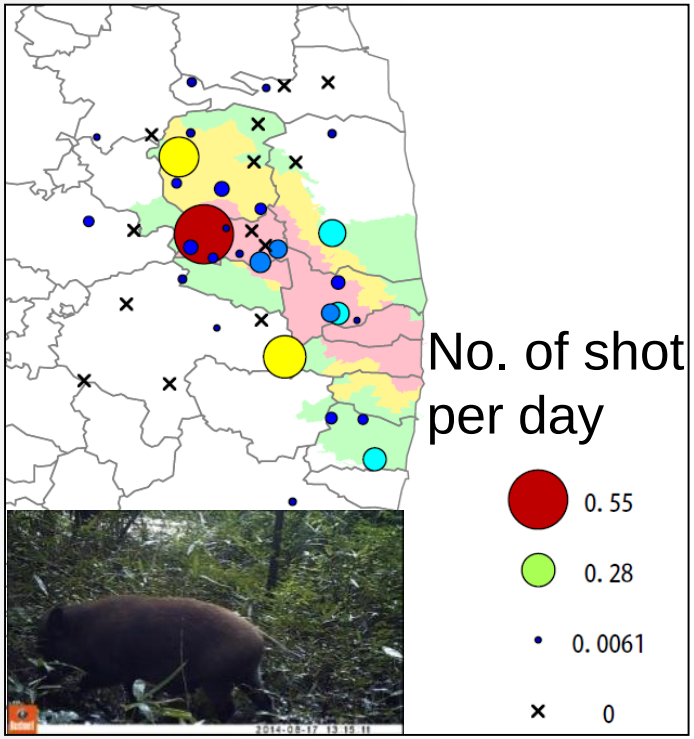
Invasive species

Results of mammal monitoring (2014)

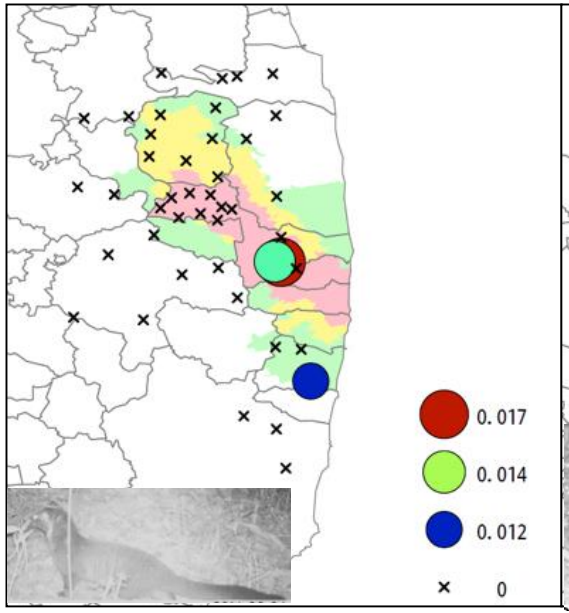
Native species

Invasive species

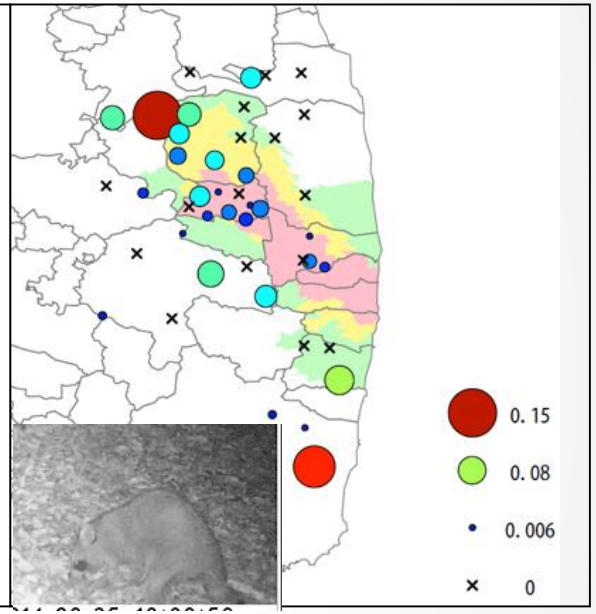
Wild boar



Raccoon



Masked Palm

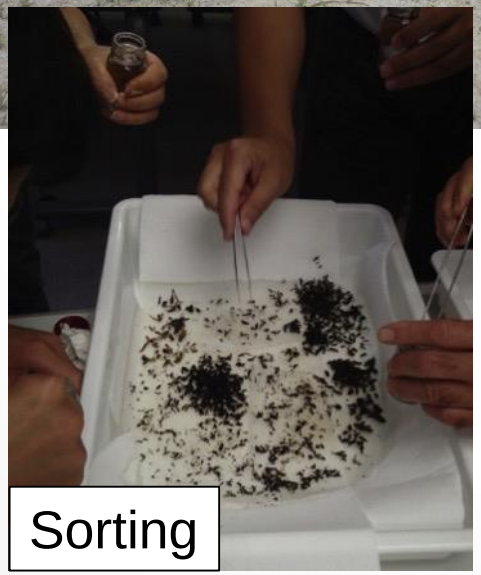


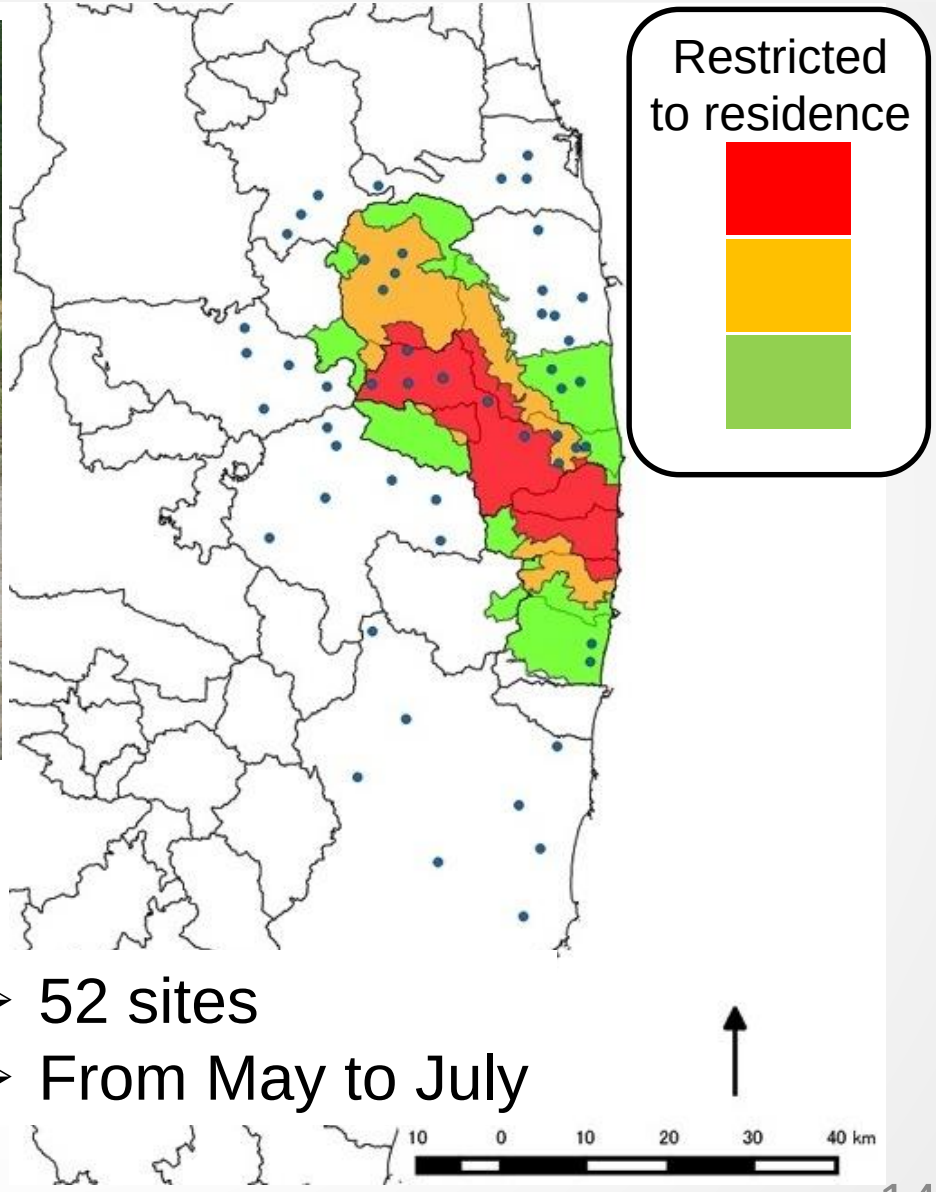
Should be continue further monitoring because these are invasive species.

- Wild boar is most frequently observed in evacuation zone
- Another species showed no significant difference between inside and outside of evacuation zone

Insect monitoring

Trapped insect



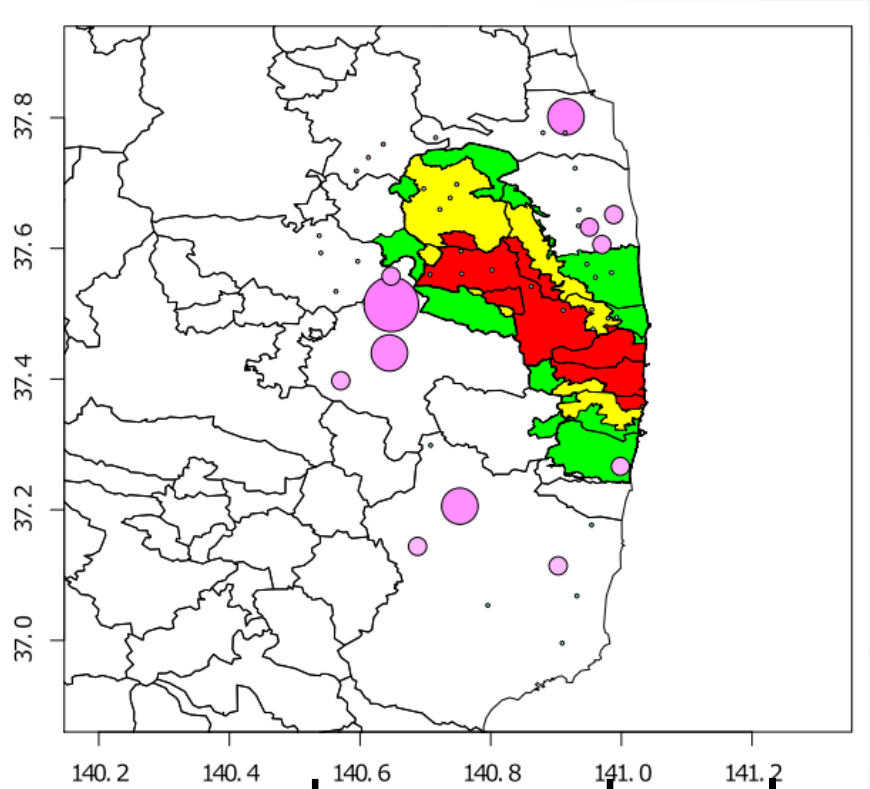


- 52 sites
- From May to July

Result of insect monitoring (1)

Lower density in Evacuation zone

Carpenter Bee

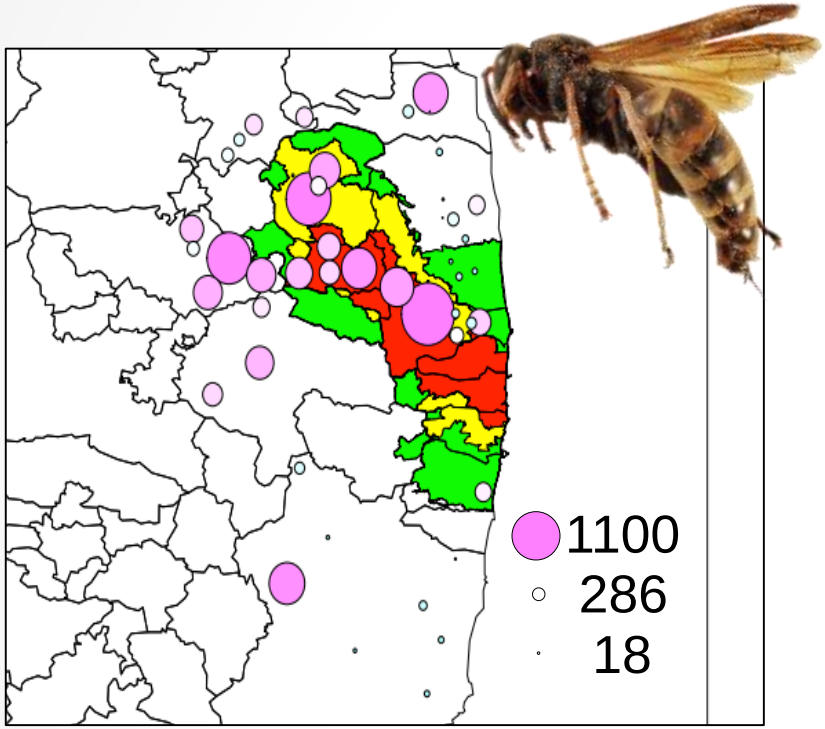


The bee prefers large flowers such as garden plants.
Reflection the loss of horticultural activity?

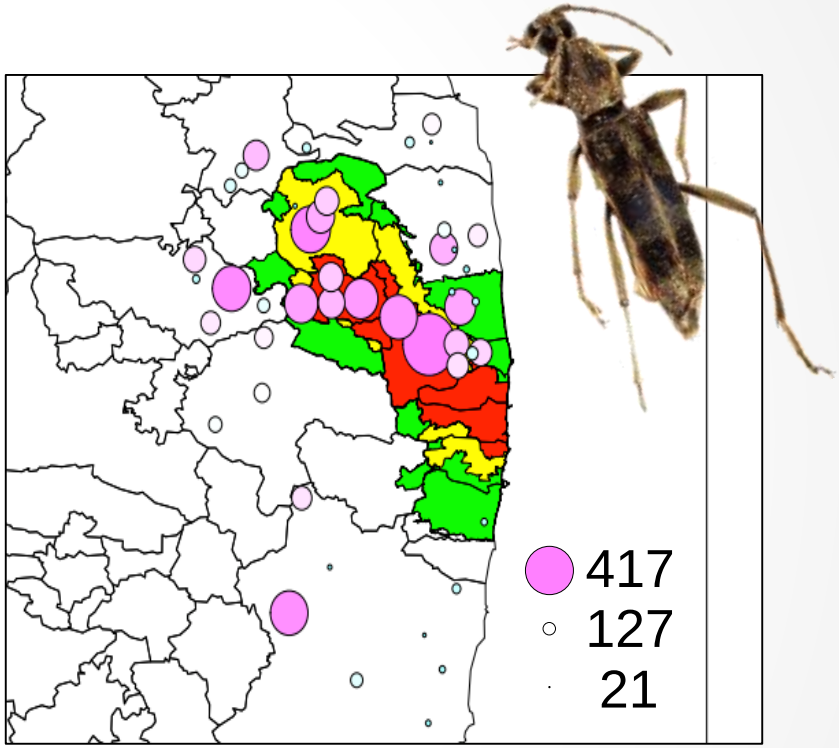
The bee has important role as pollinating insect, thus further monitoring is needed

Result of insect monitoring (2)

Higher density in Evacuation zone



Bees or Wasps



Beetles

- Increase small wild flowers from abandonment of cultivation?

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)

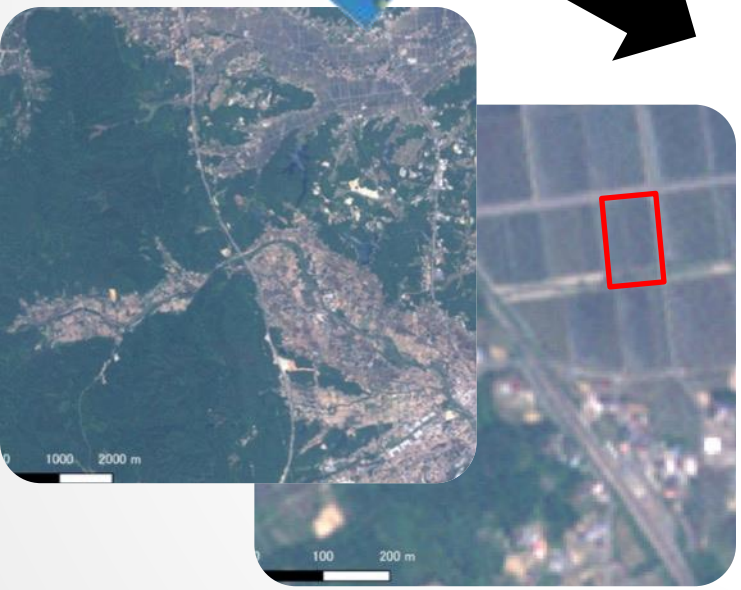
→ May results in decrease of Waterfowls that use freshwater wetland

Photo by Kumada

Making high resolution land use map

Satellite images

Rapid eye or Sentinel 2
(~10m resolution)



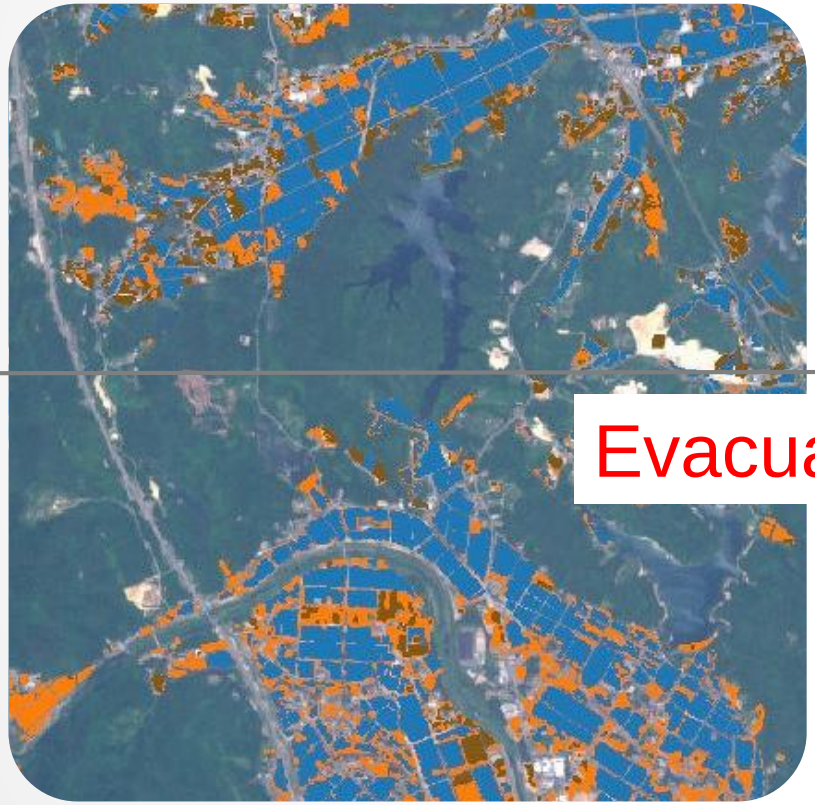
GIS

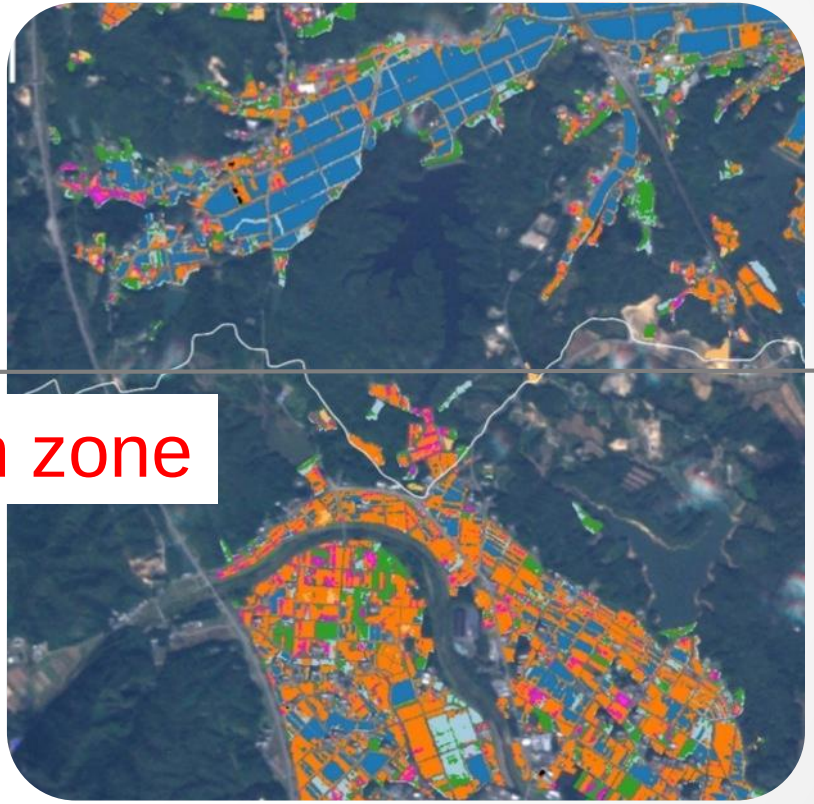
Ground-truth data

Now Running:
Land use change in evacuation zone

Before evacuation (2008-2010)

After evacuation (2015)

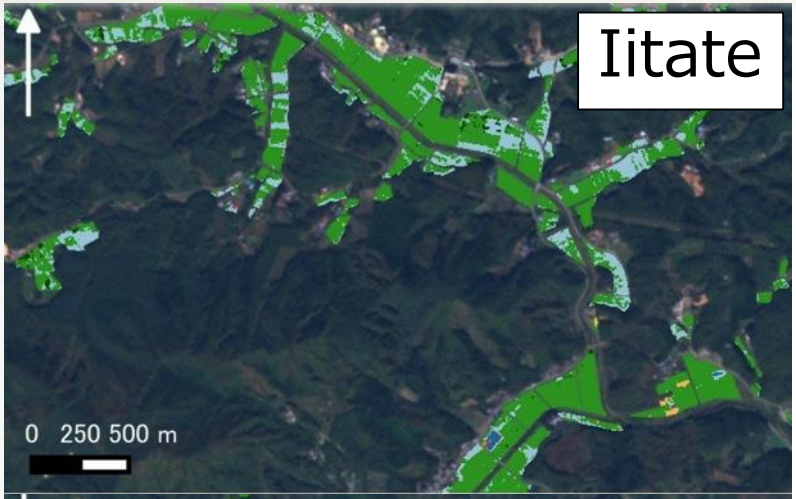


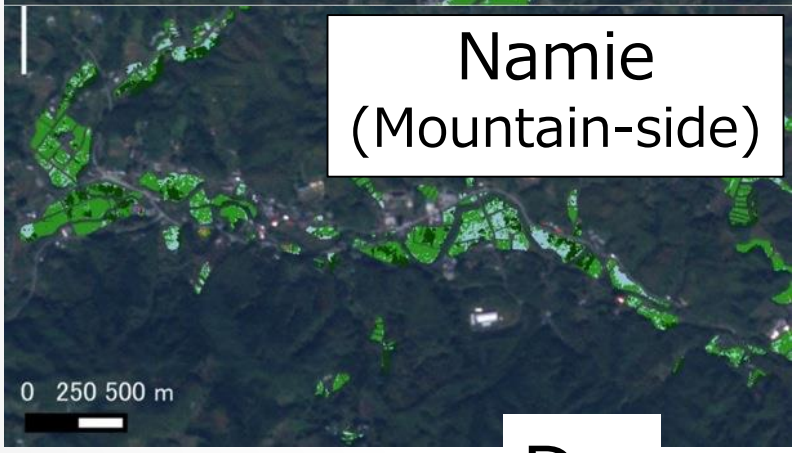


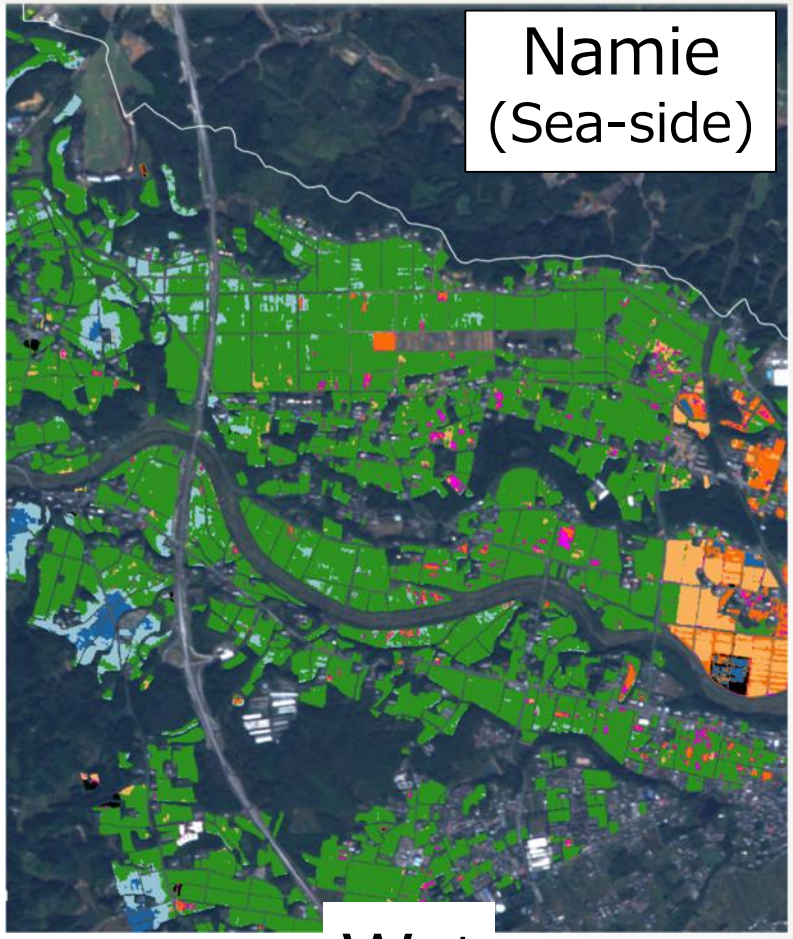
Evacuation zone

Deserted paddy field

Variation of deserted cultivation land is also investigated







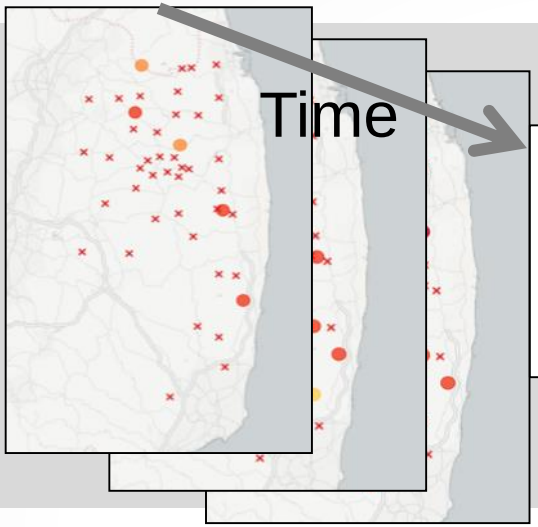
Types of deserted cultivation land

Dry

Wet

Future developments

Input

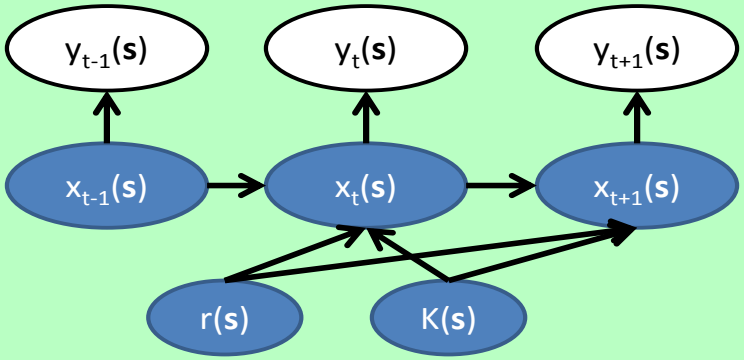


Appearance frequency of organisms

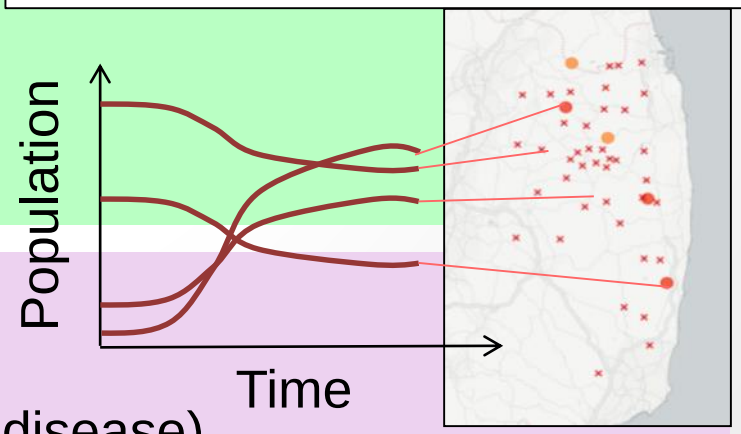
Change of land coverage

Evacuation and decontamination

Model



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



Output

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

Summary of ecological monitoring

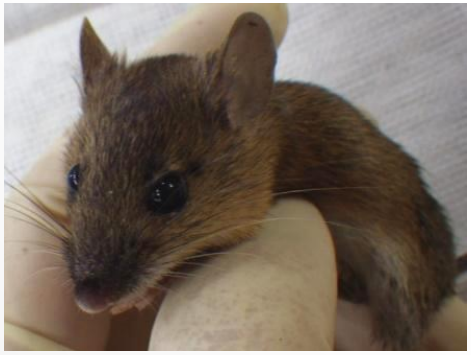
- Lower number of Carpenter Bee was trapped in evacuation zone
- Small bees, wasps and beetles was frequently captured in evacuation zone
- Higher density of Wild boar was observed in evacuation zone
- Map of deserted cultivation land will be made soon

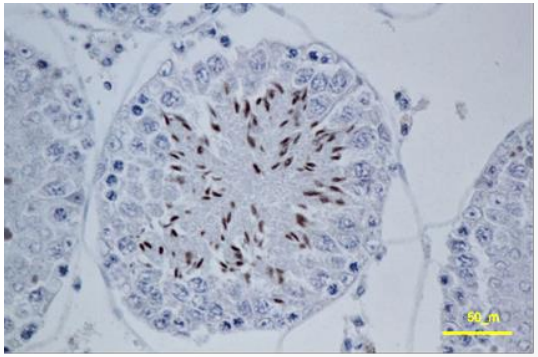
➡ We should continue the monitoring at least 10 years to detect effects of evacuation

Current topics

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

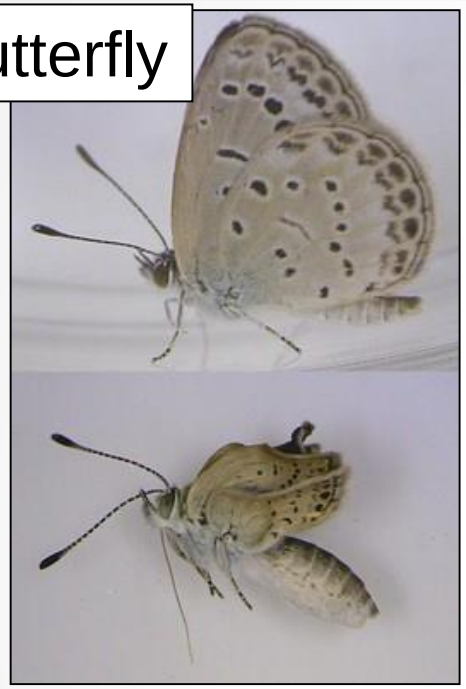
- Effects of radiation to wild organisms
  Radiation effects on DNA of reproductive organ in wild rodents

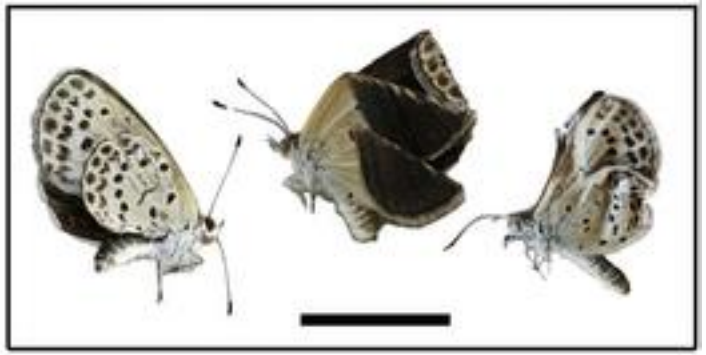




Background : Is the mutation increase at Fukushima?

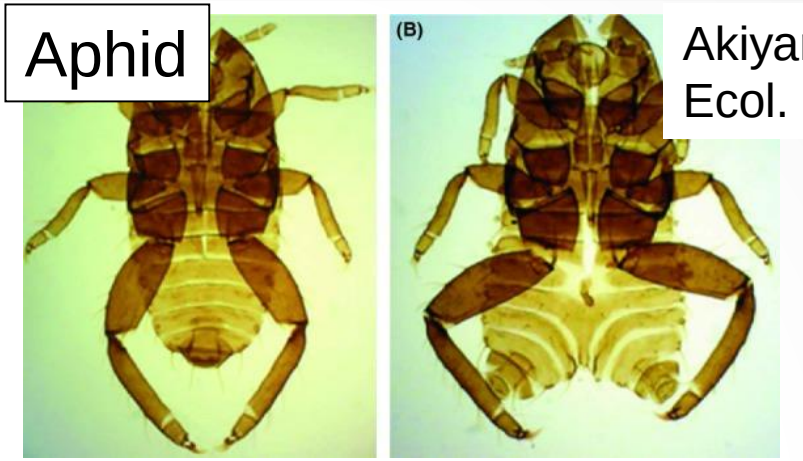
Butterfly





Hiyama *et al.* (2012)
Sci. Rep. 2, 570

Aphid



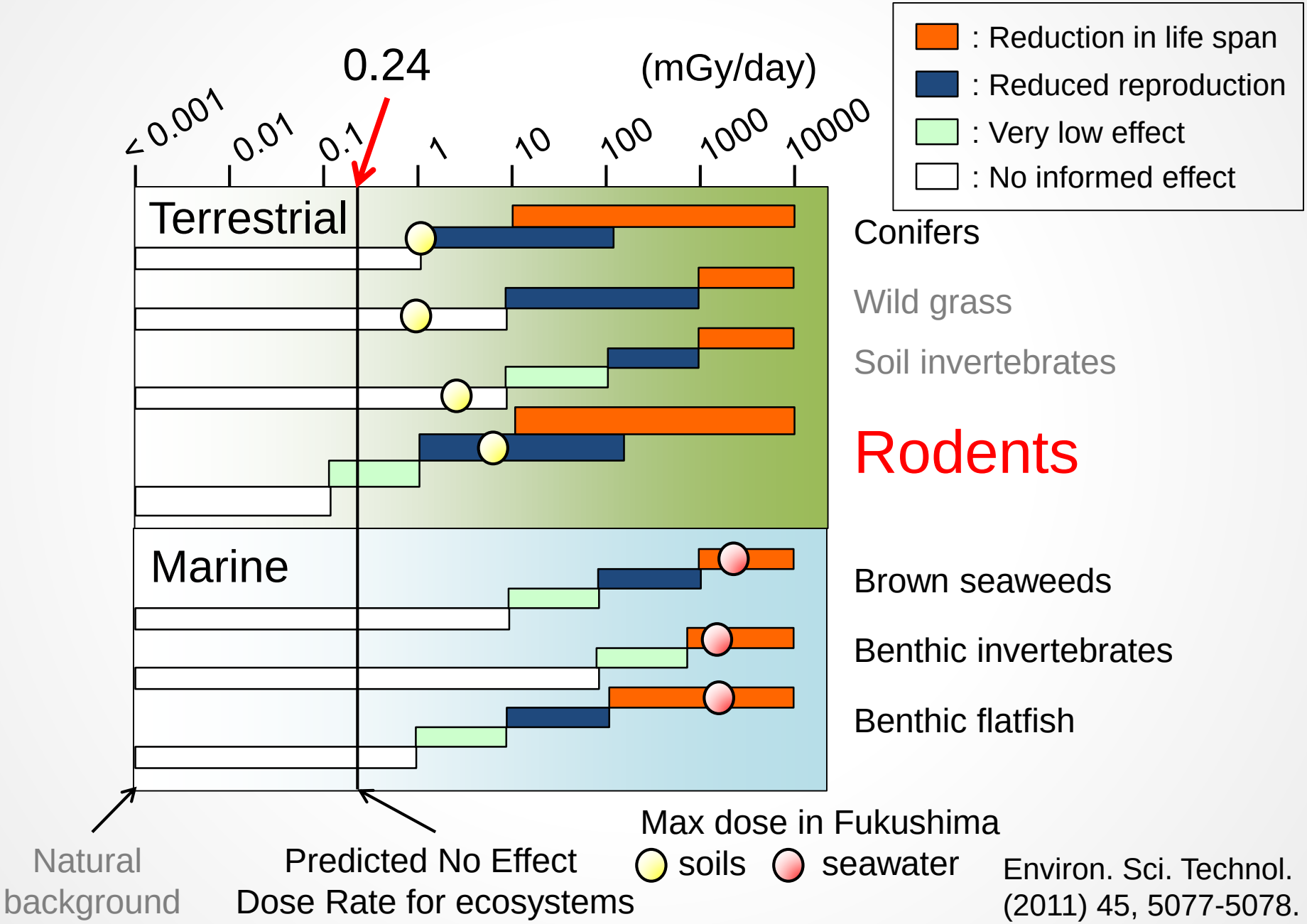
Akiyama (2014)
Ecol. Evol. 4, 355-369

Fir tree

Watanabe *et al.* (2015)
Sci. Rep. 5, 13232

There is no evidence for DNA mutation at Fukushima !

Max. exposure dose in Fukushima and ICRP effect levels

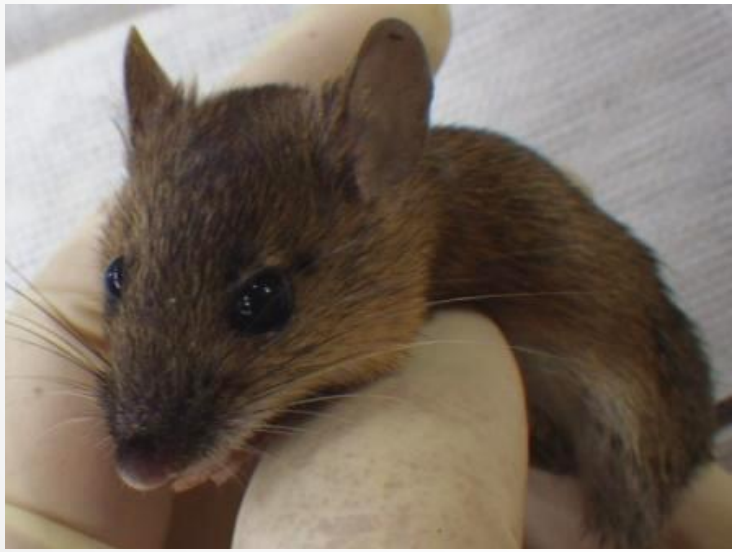


Environ. Sci. Technol. (2011) 45, 5077-5078.

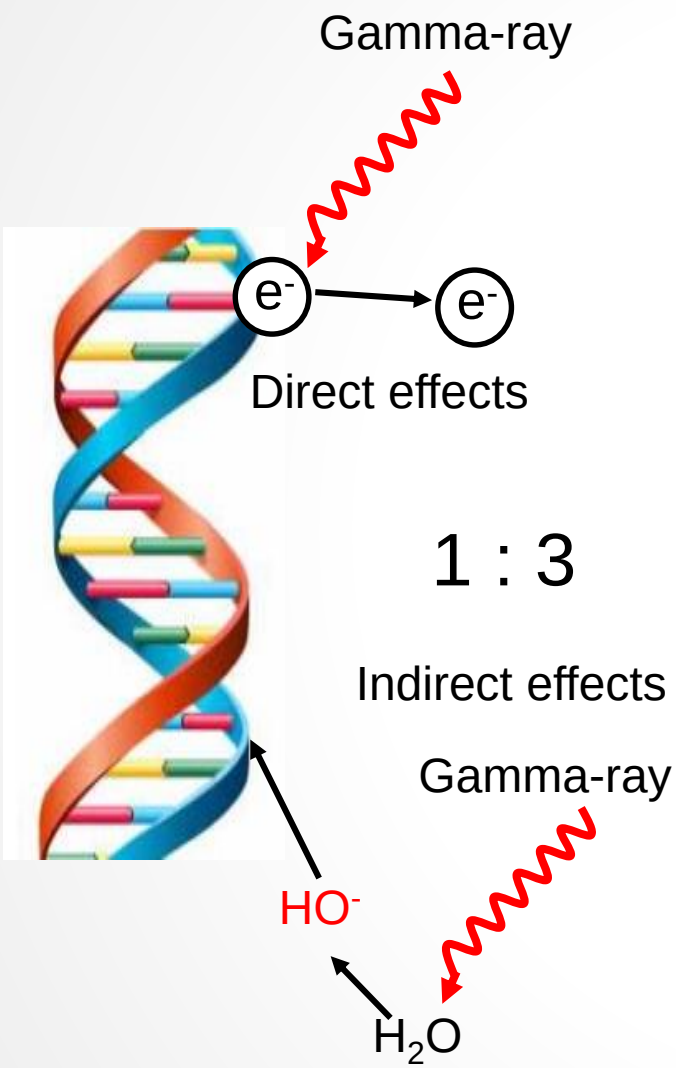
Material

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

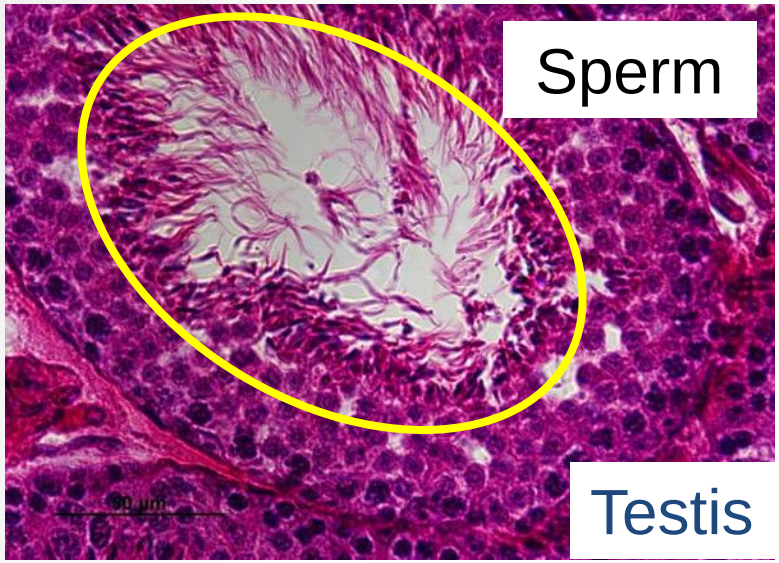


DNA damage	Number of DNA damage with 1Gy irradiation
Chemical modification	**> 3000 (70%)**
Single strand break	1000
Double strand break	40
DNA-Protein cross linking	150

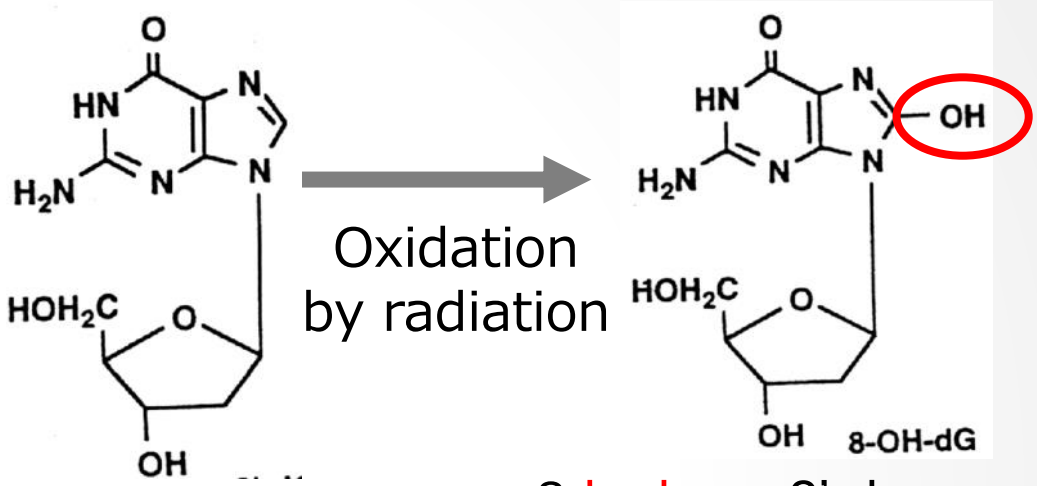
Goodhead, DT(1994) Int. J. Rad. Biol. 65; 7-17.
Ward JF (1988) Prog. Nuc. Acid Res. Mol. Biol. 35; 95-125.

Becker D and Sevilla MD (1993)
Adv. Rad. Biol. 17, 121-180.

DNA oxidization in sperm



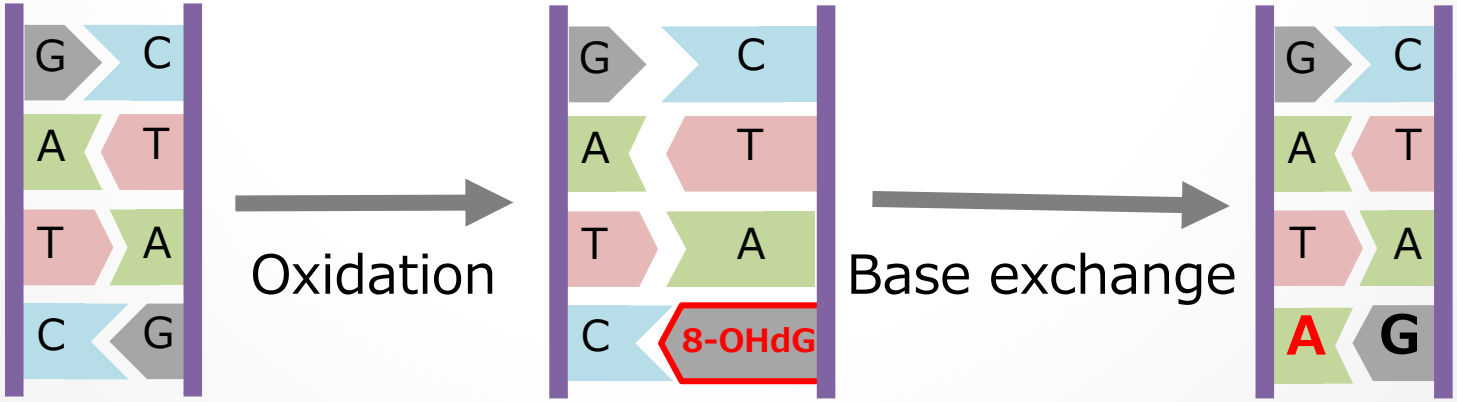
1. Base modification by free radicals



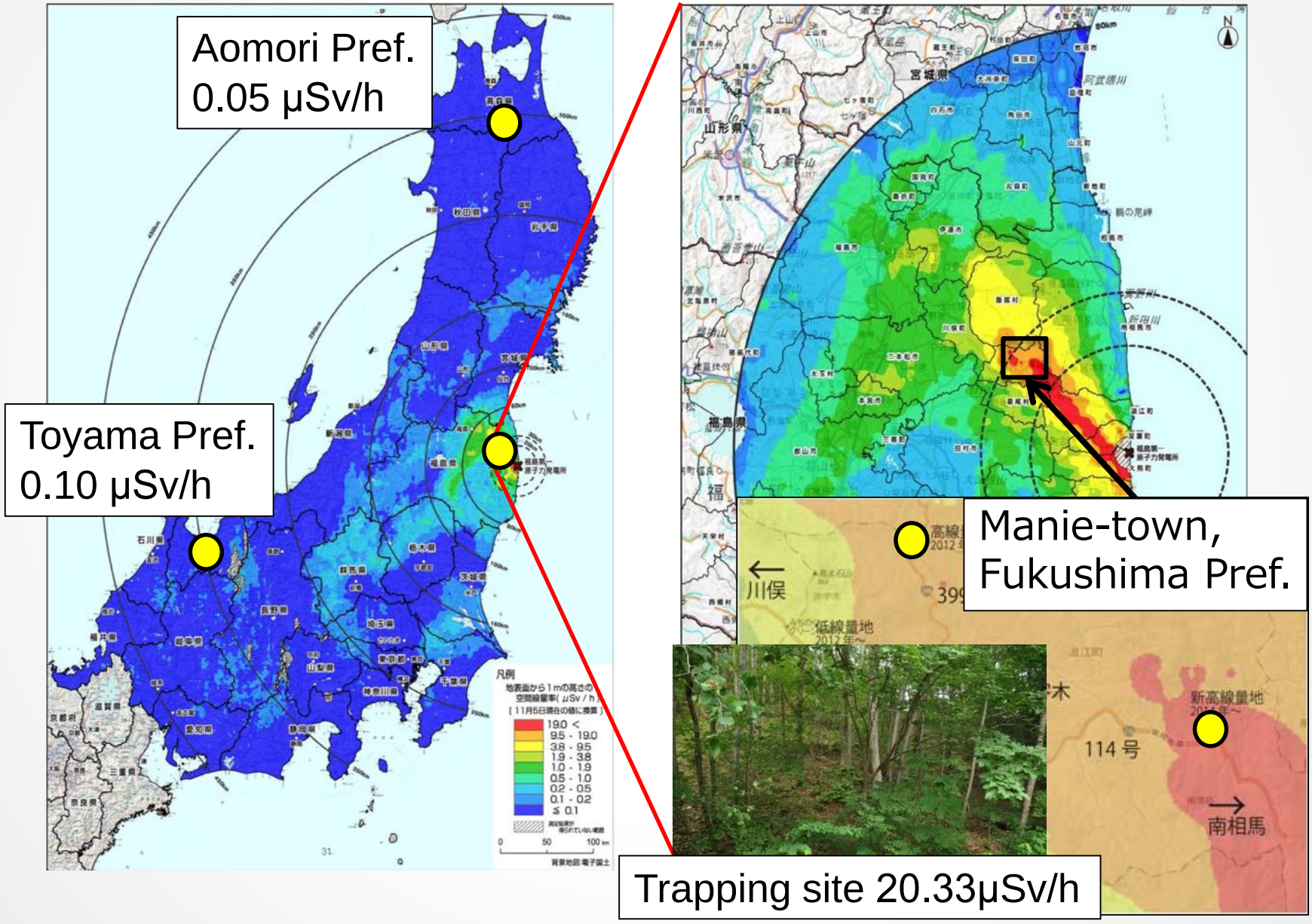
Deoxyguanosine

8-hydroxy-2'-deoxy guanosine (8-OHdG)

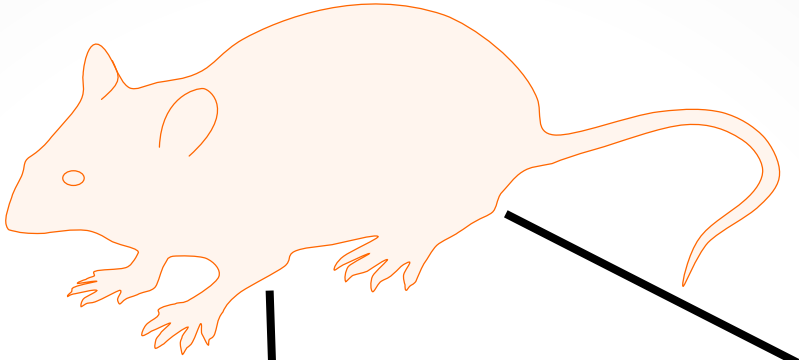
2. Mutation due to modified base



Capture sites of mice



Methods



Adult male
(weight > 30 g)

Skull
(Age determination by tooth wear)

Bone, muscle, skin

Measurement of Cs-134 and Cs-137

Testes and epididymis

- Fixed by fixation solution
- Make cross section

8-OHdG immunostaining
Gene expression analysis

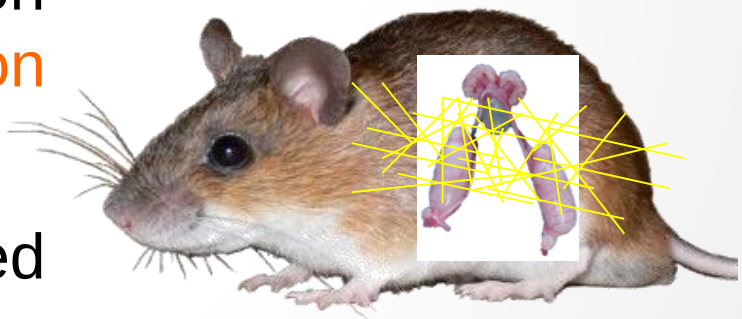
Evaluation of exposure dose in mouse testis

External radiation-dose rate

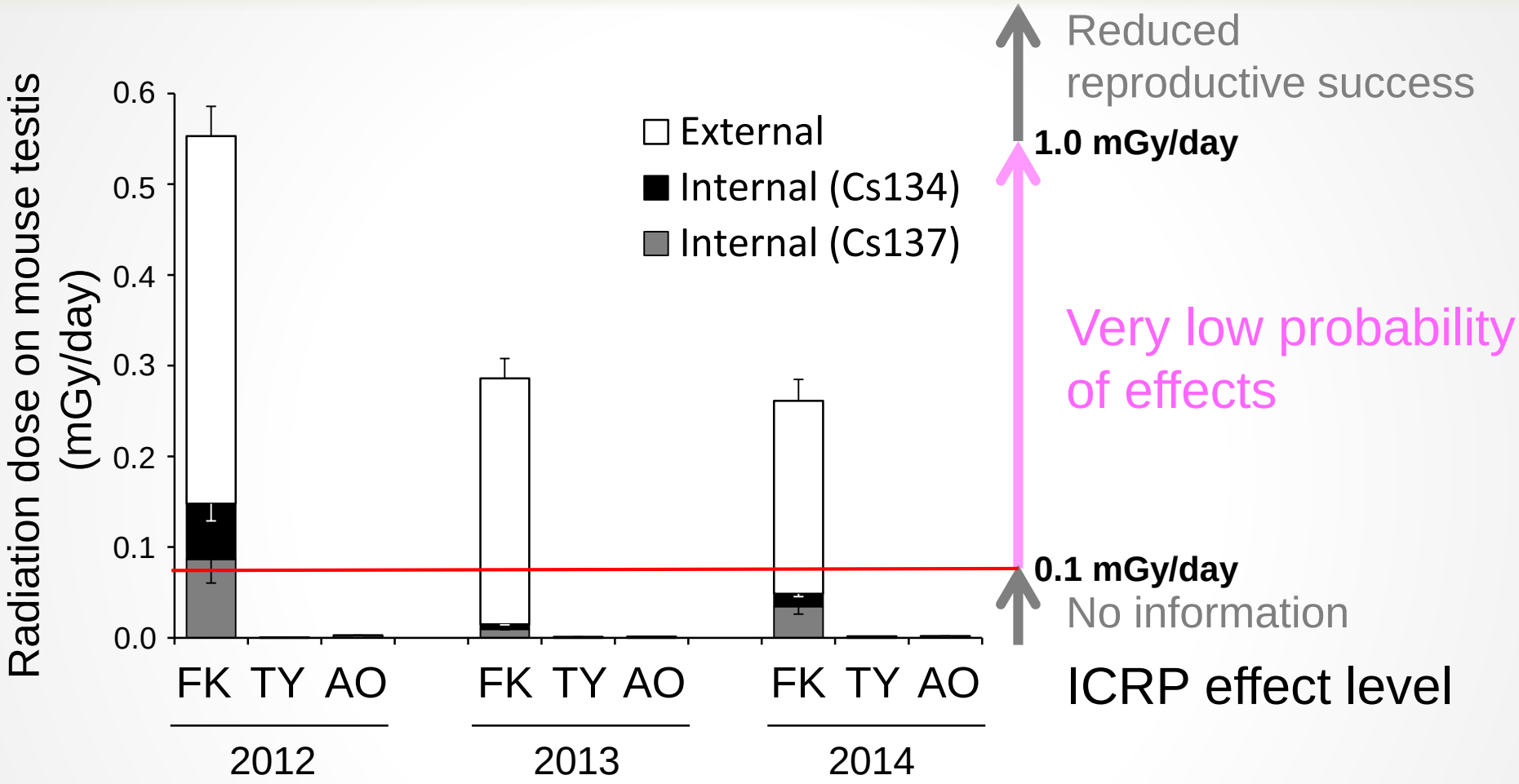
- The air dose rates of gamma radiation measured at ground level in capture sites

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.

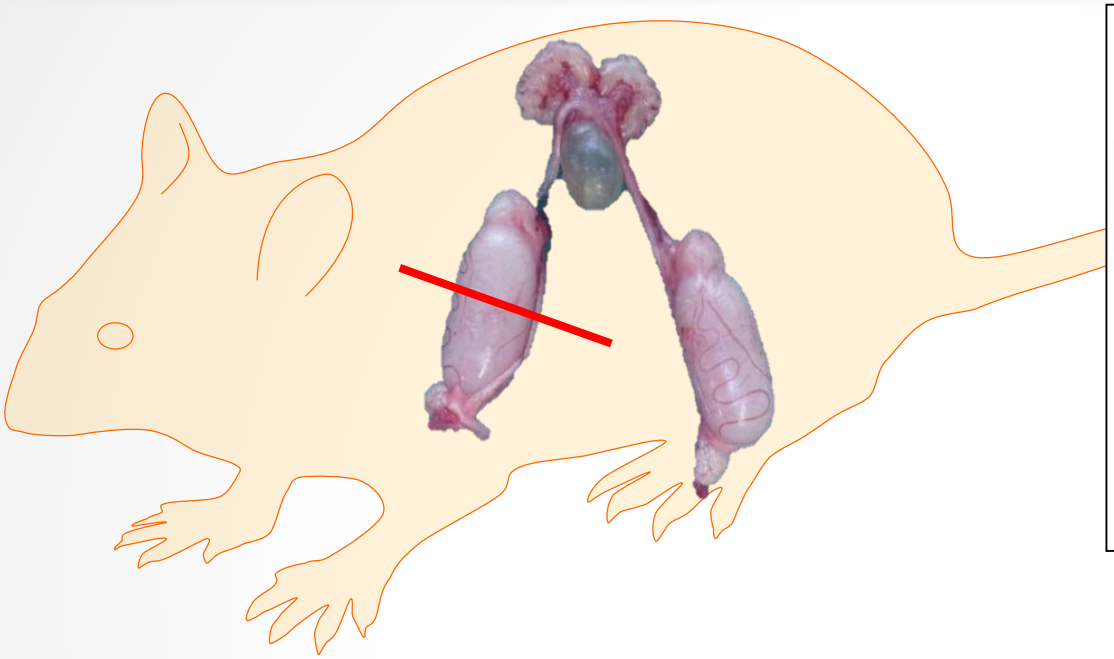


Evaluation of exposure dose in mouse testis



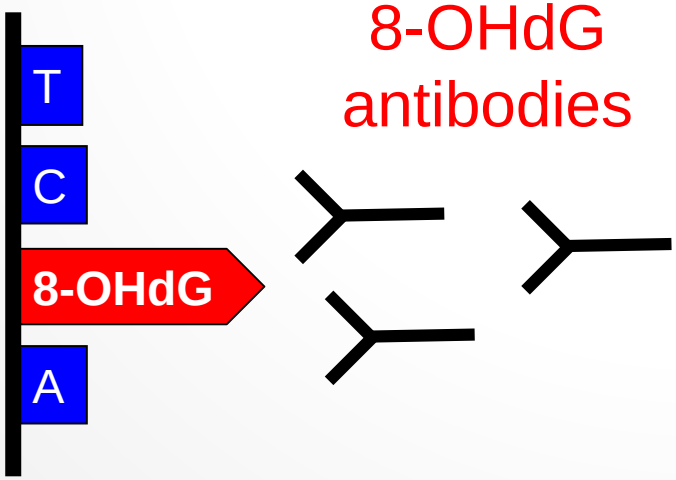
- Total exposure dose in Fukushima exceeded ICRP effect level
- External dose account for 70% of total exposure

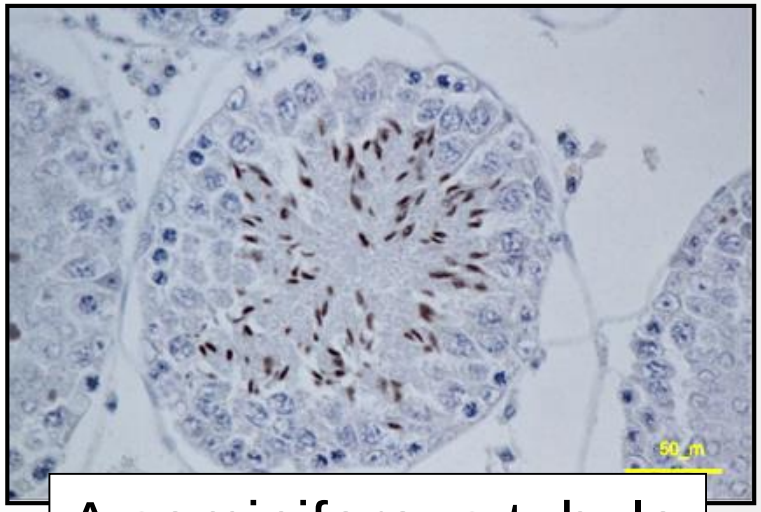
Detection of 8-OHdG in testis



Testis: consisted with 100 seminiferous tubules

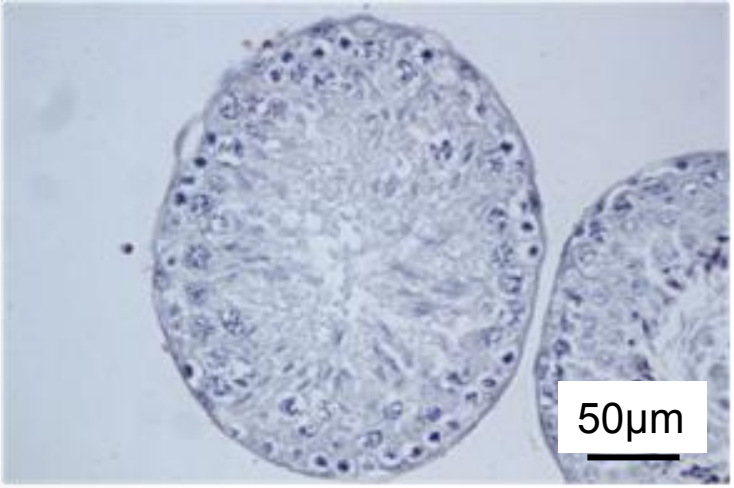
Immunostaining



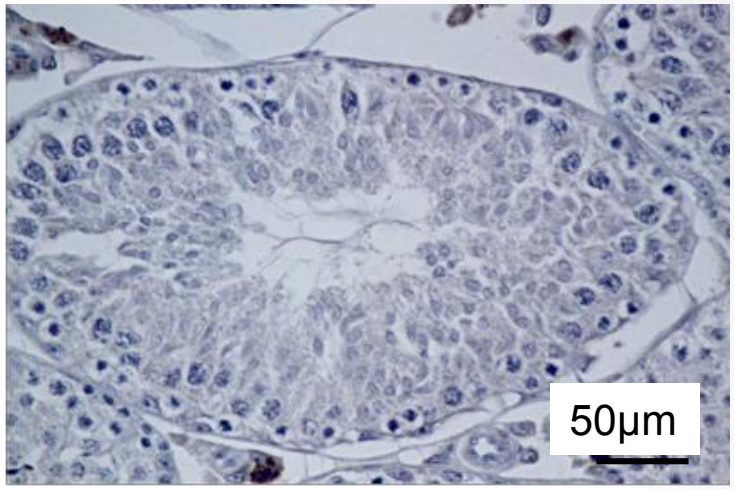


A seminiferous tubule

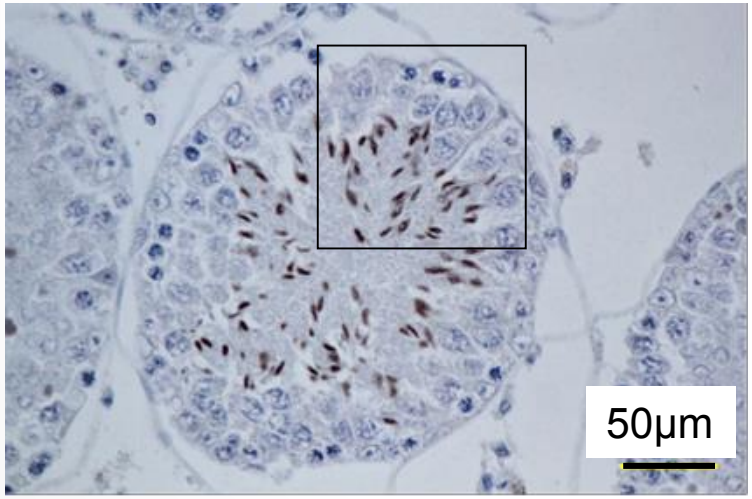
8-OHdG immunostaining on testis

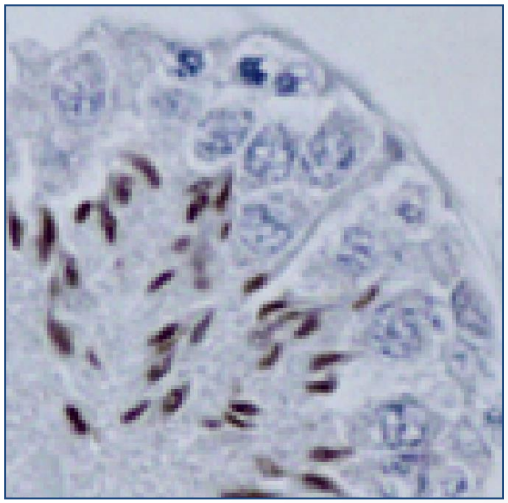


Toyama



Aomori

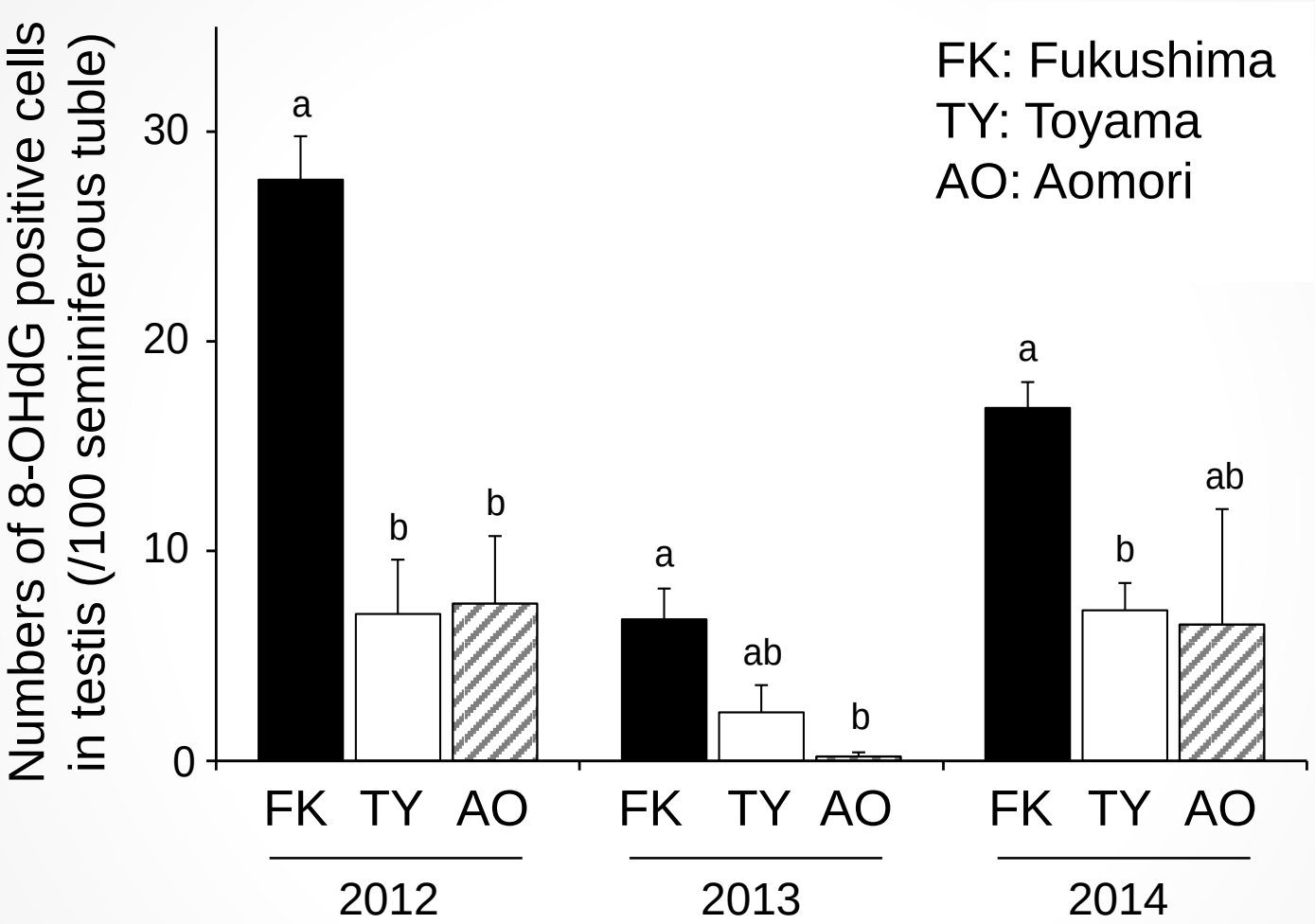




Fukushima

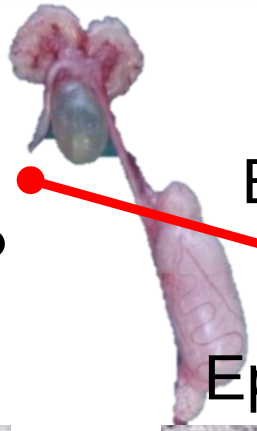
- 8-OHdG positive sperms were observed only in Fukushima

Change of 8-OHdG accumulation in testis



- The mice in Fukushima showed the highest accumulation of 8-OHdG
- 8-OHdG positive cells are decrease year by year

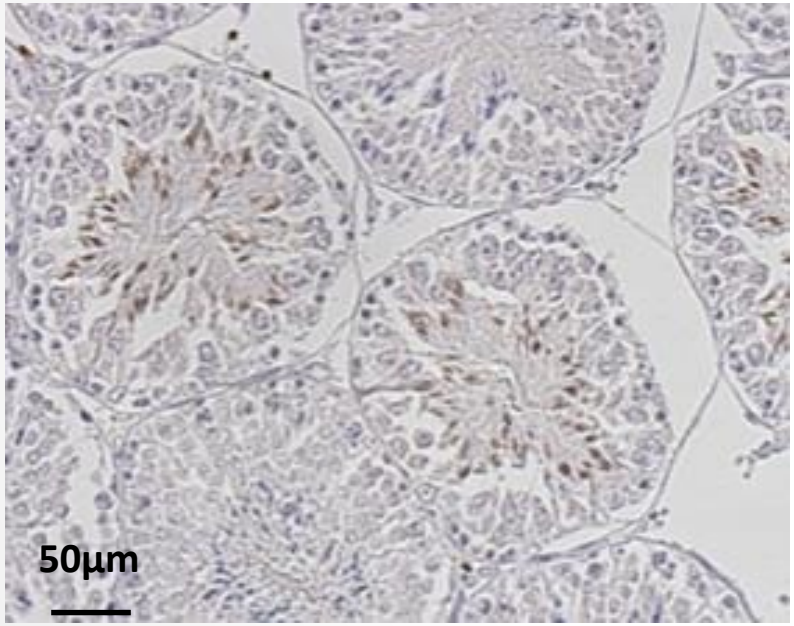
8-OHdG immunostaining on epididymis



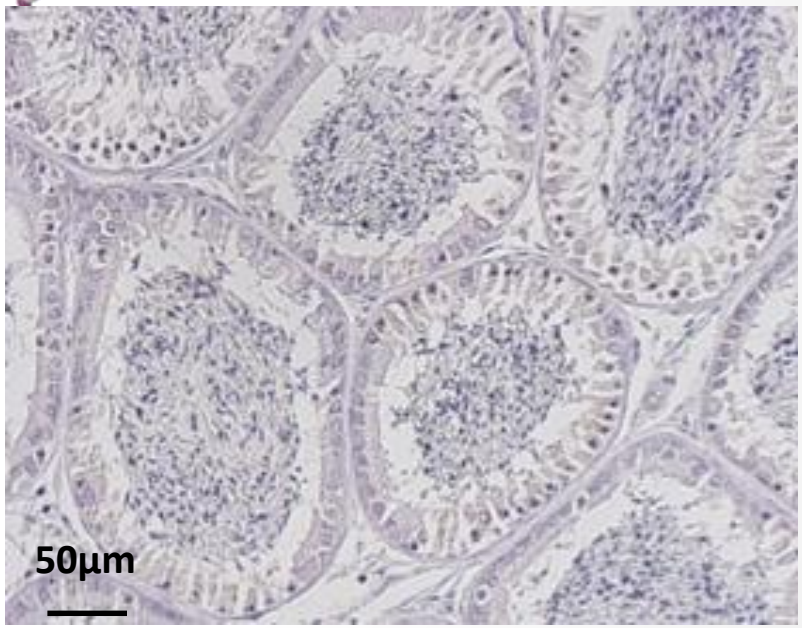
Testis

Epididymis

Testis（Fukushima）



Epididymis（Fukushima）

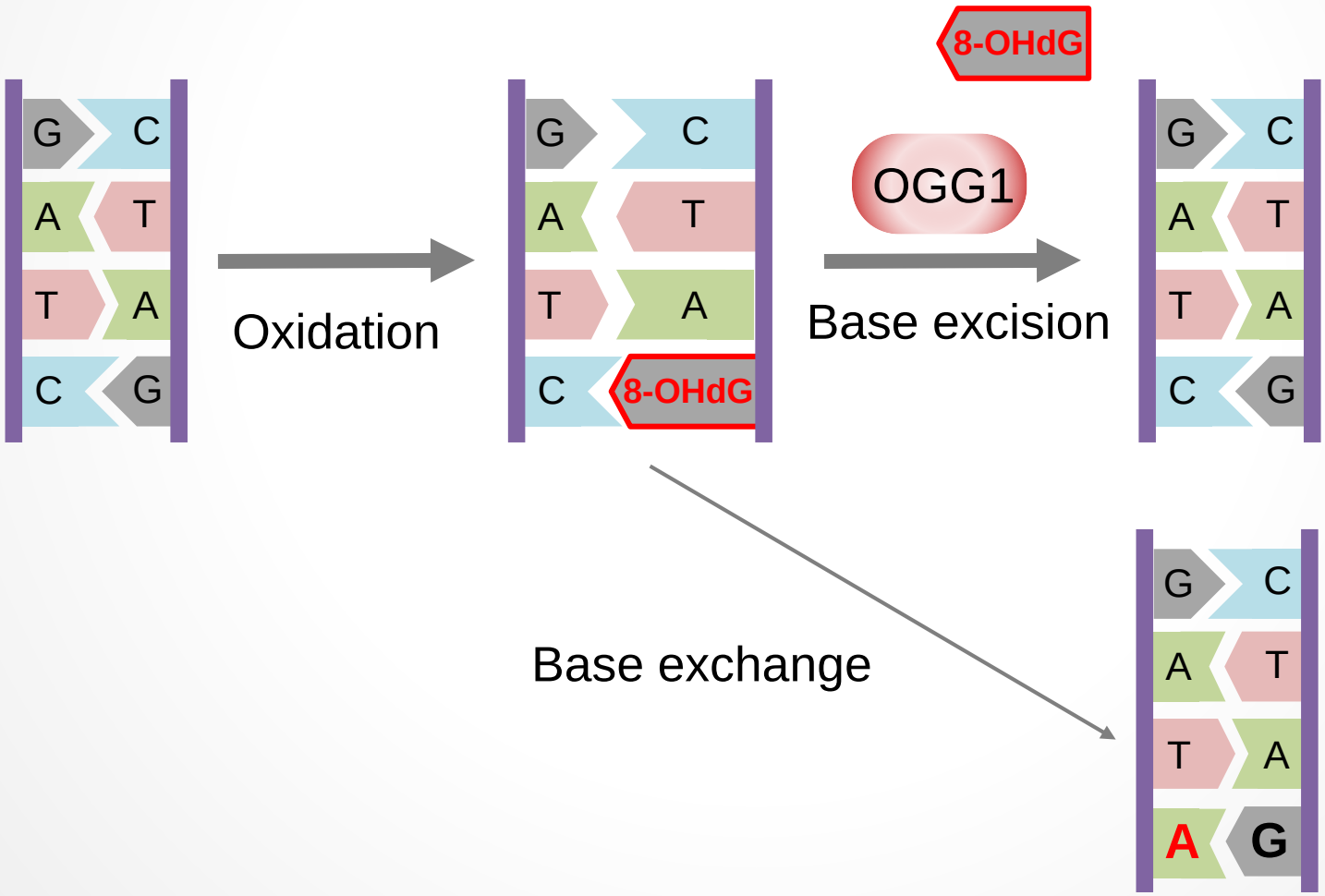


- No 8-OHdG positive cell was observed in epididymis

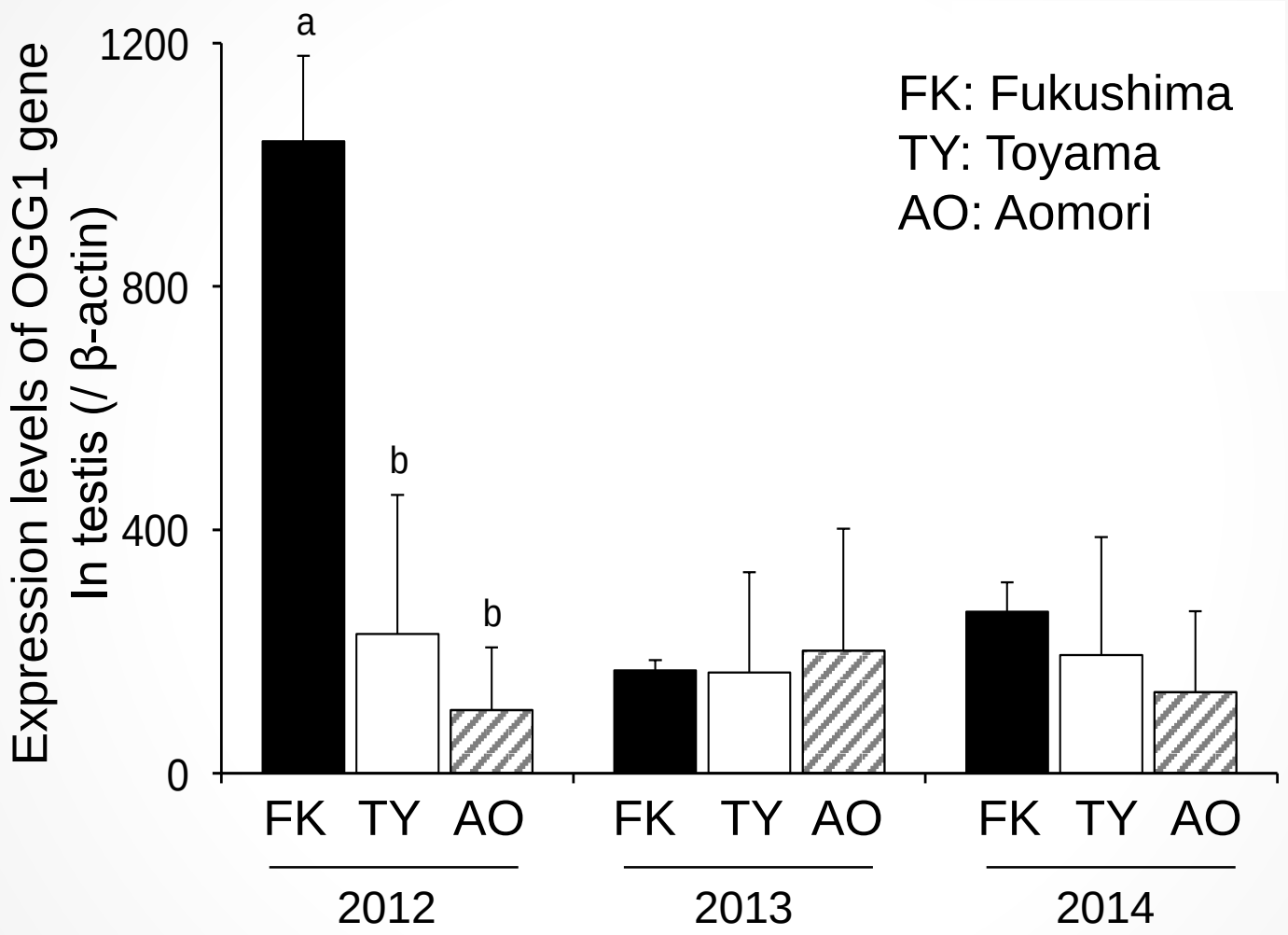
DNA repair by OGG1

OGG1

(8-oxoguanine DNA glycosylase 1)



Change of OGG1 expression levels in testis

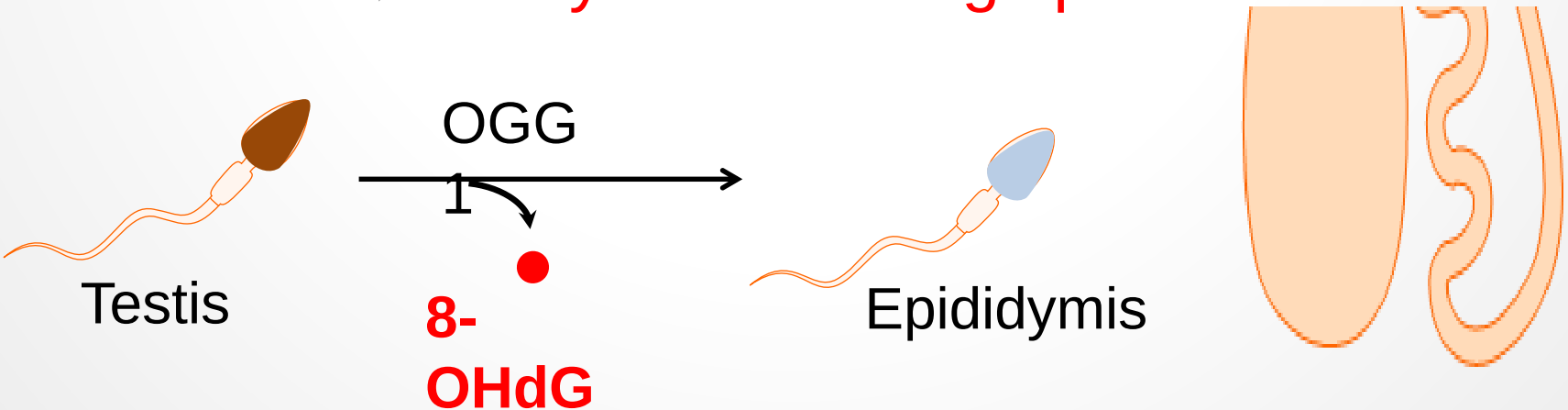


- The mice in Fukushima showed high level expression of DNA repair enzyme, OGG1

Summary and Discussion

- 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



Thank you for your attention!

No POKEMON was also found in evacuation zone