Morphological defects in native trees around the Fukushima Daiichi Nuclear Power Plant

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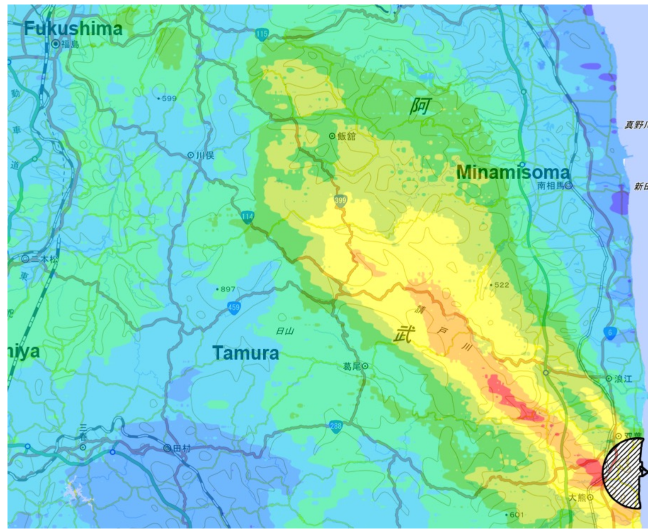
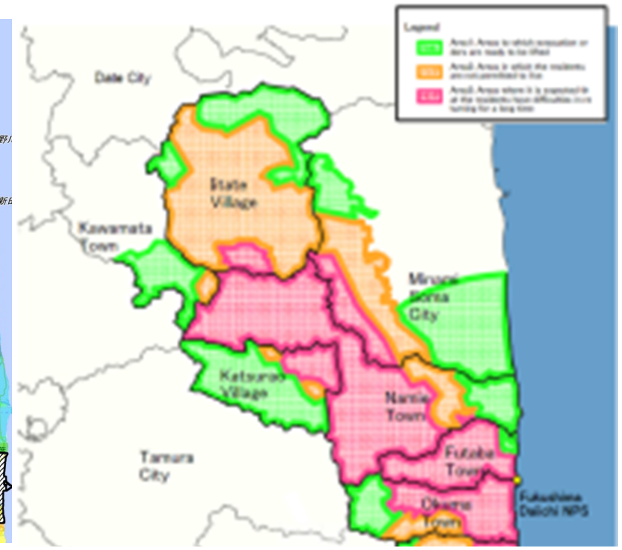
Studies in highly contaminated area near the Fukushima Daiichi NPP

Google



Airborne monitoring results on 2013.11.19.
(MEXT)



Areas to which Evacuation Orders are issued (Sep. 2015), (METI)

Released radionuclides from the F1NPP contaminated the surrounding environment.

??   The contamination had a biological impact on the environment ??

⇩

Field survey in heavily contaminated areas in the evacuation zone
(Nov. 2011～, by the Ministry of the Environment)

Highly contaminated Forests near the F1NPP in 2011

Forests in highly contaminated area near the Fukushima Daiichi NPP （November, 2011）

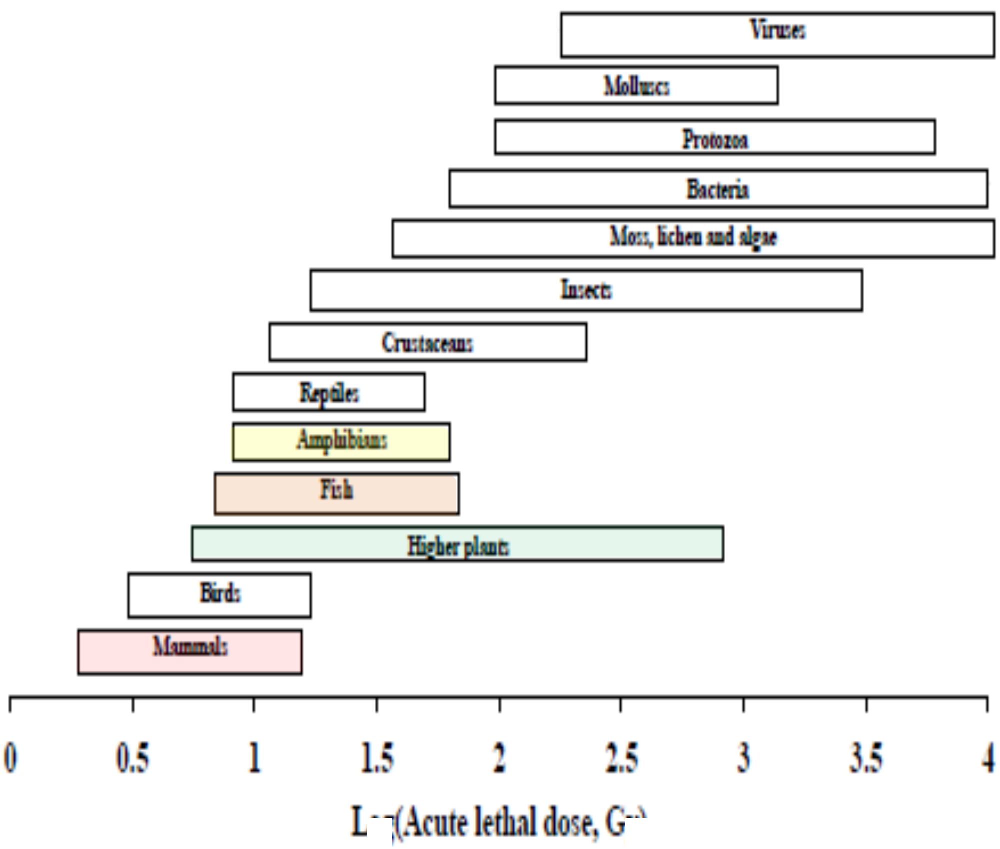
Drastic effects such as the "red forests" have not been observed.

Long-term effects should be estimated by suitable indicator organisms.

Red forest (Chernobyl, 1986）

Indicator organisms

Approximate acute lethal dose ranges for various taxonomic groups (UNSCEAR 1996)



Radiation sensitive animals & plants

Wild mouse

Medaka fish

Salamander

Conifers

Rich in radiological data	(Wild) mouse, Medaka fish
Highly radiosensitive	Wild mouse, Salamander, Conifers

Reference Animals and Plants (RAPs) in the ICRP system of radiological protection

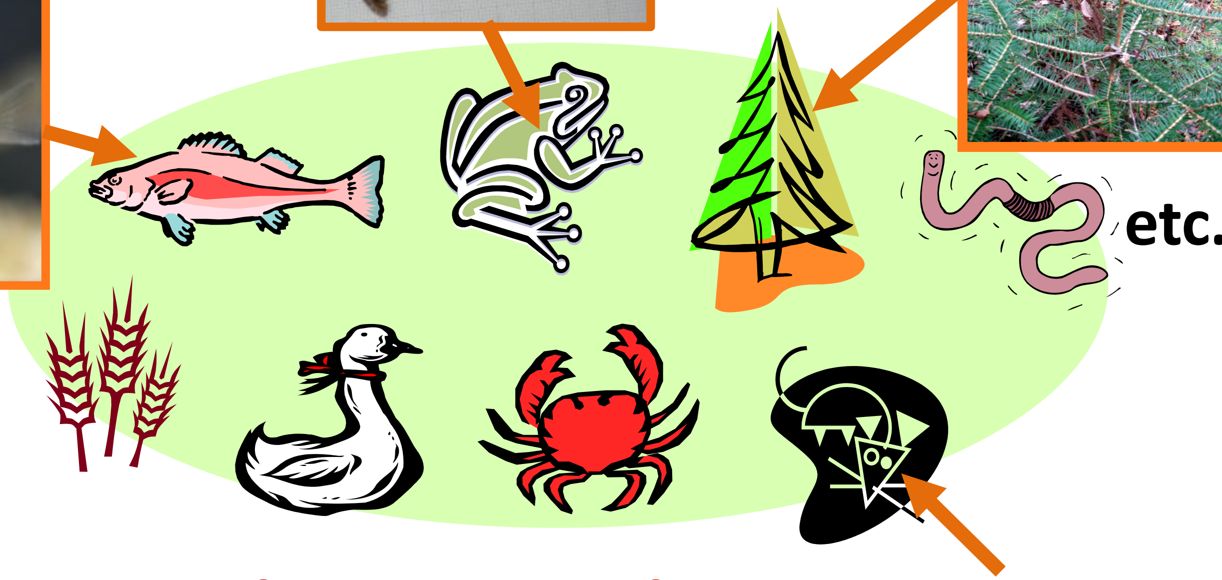
Growth & survival in Tohoku salamander

Fuma, S. et al. / J. Environ. Radioact. 143:123 – 134 (2015)
Fuma, S. et al ./ J. Environ. Radioact. 135:84 – 92 (2014)

Morphological defects in native Japanese fir trees

Watanabe, Y. et al. / Sci. Rep. 5:13232 (2015)

Micronucleous assay in medaka fish

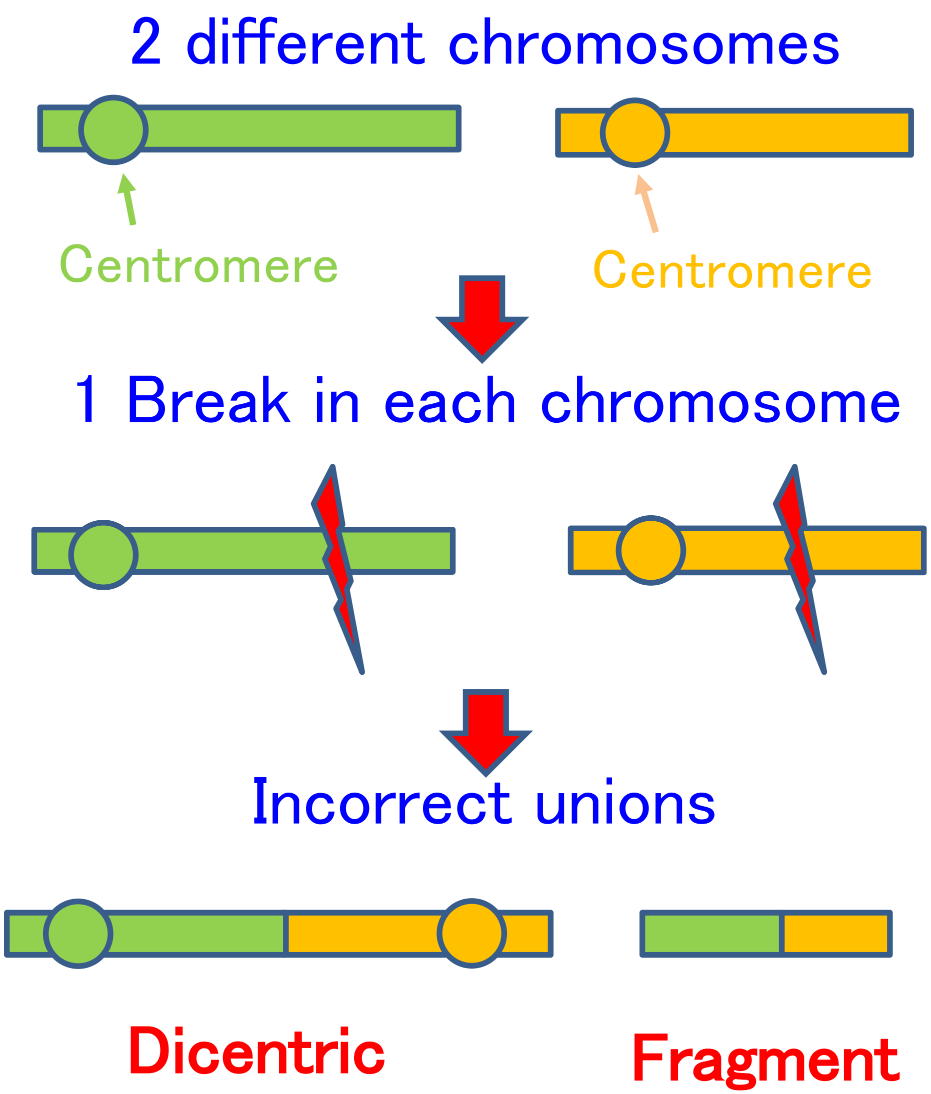


Chromosome aberration in wild mouse

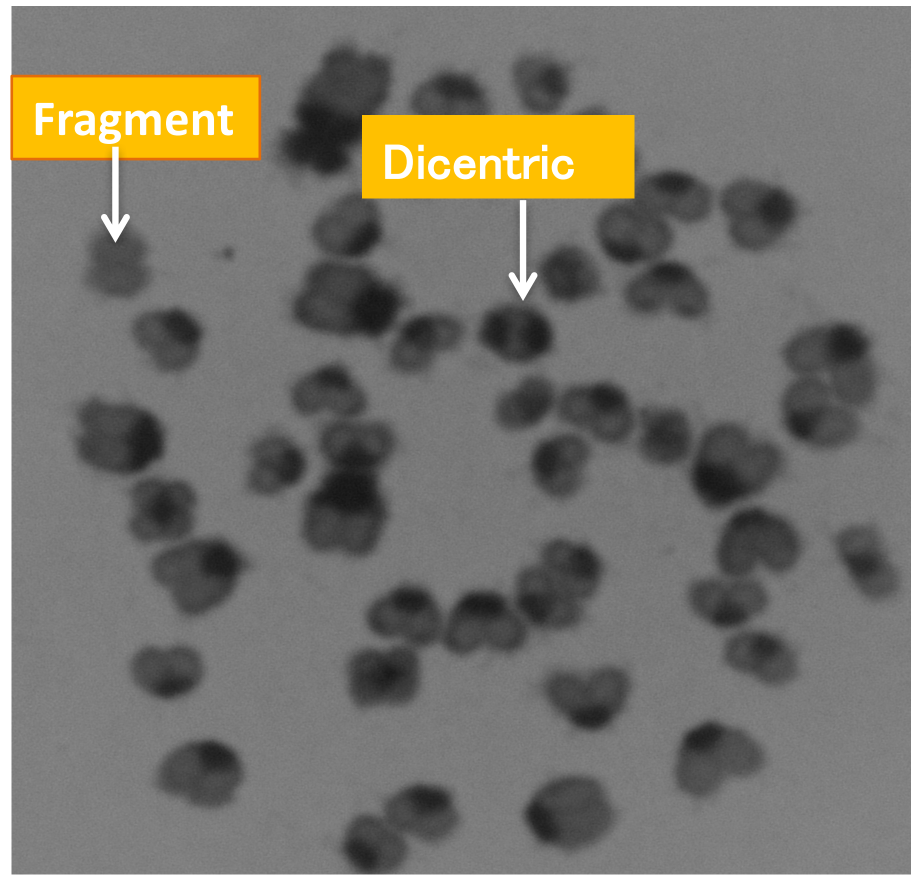
Kubota, Y. et al. / J. Environ. Radioact. 142:124-131 (2015)
Kubota, Y. et al. / Environ. Sci. Technol. 49:10074–10083 (2015)

Radiation-induced chromosome aberrations in mouse

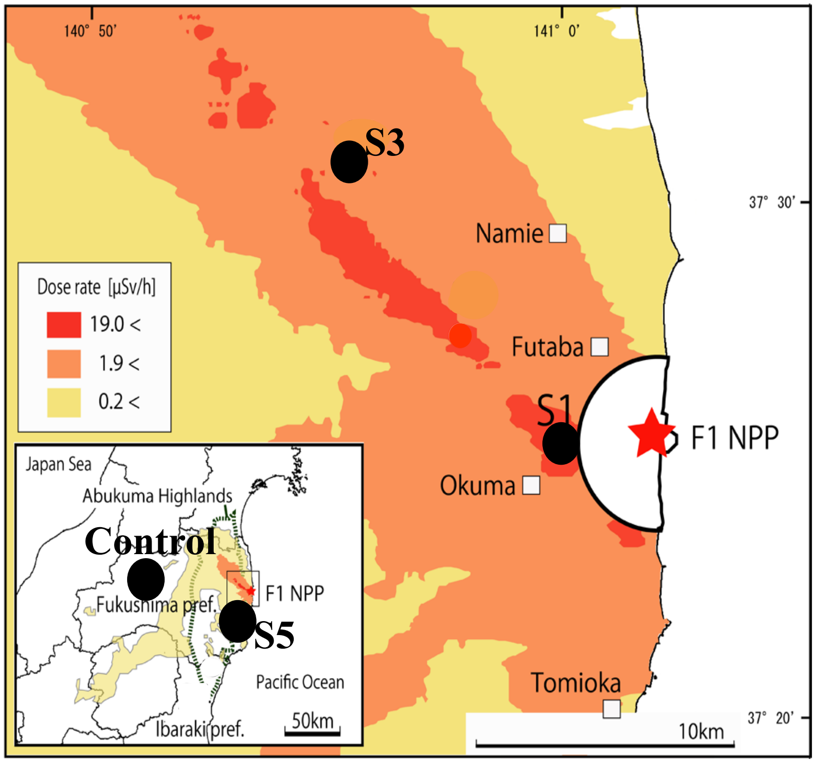
Formation of chromosome aberrations

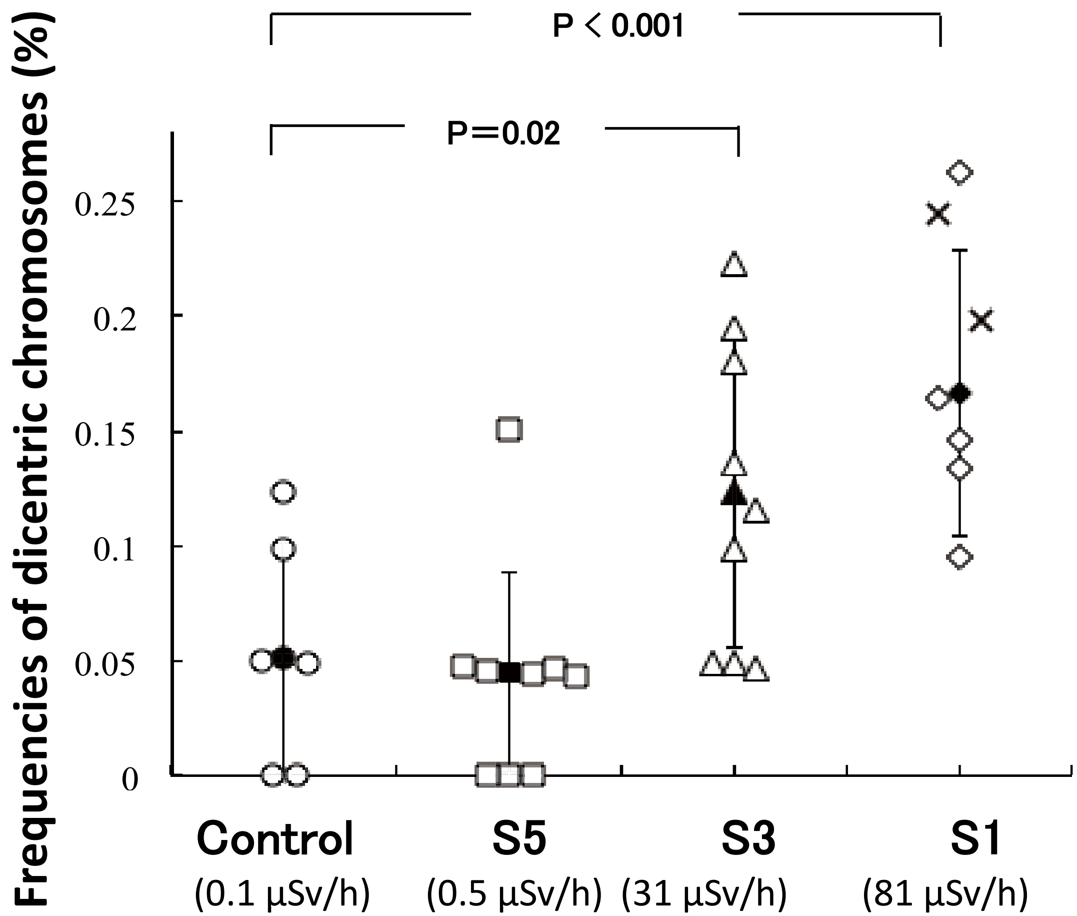


Small Japanese field mice (*Apodemus argenteus*)



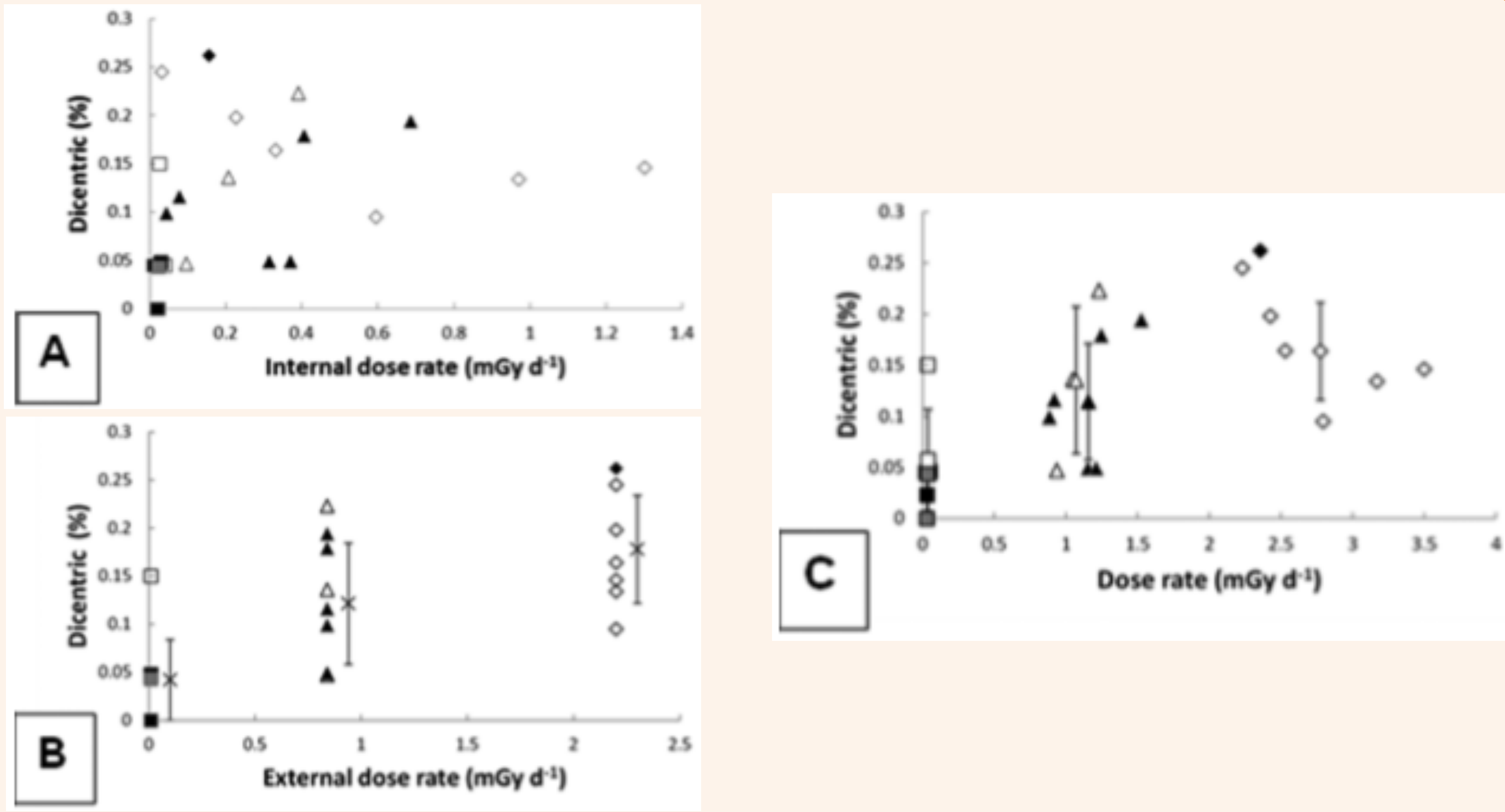
Chromosome aberration in wild mouse inhabiting heavily contaminated areas（July 2012)





- ✓ Mice in the heavily contaminated areas showed a significant increase in the frequencies of dicentric chromosomes.
- ✓ Radionuclide contamination should have contributed to the chromosome aberration.

Dose rate estimation and relationship to frequency of dicentric chromosomes in wild mouse



Dose calculation
- Internal: calculated from ^{134}Cs & ^{137}Cs in the body using the ERICA tool.
- External: calculated from ambient dose rate multiplied by a factor of 1.138

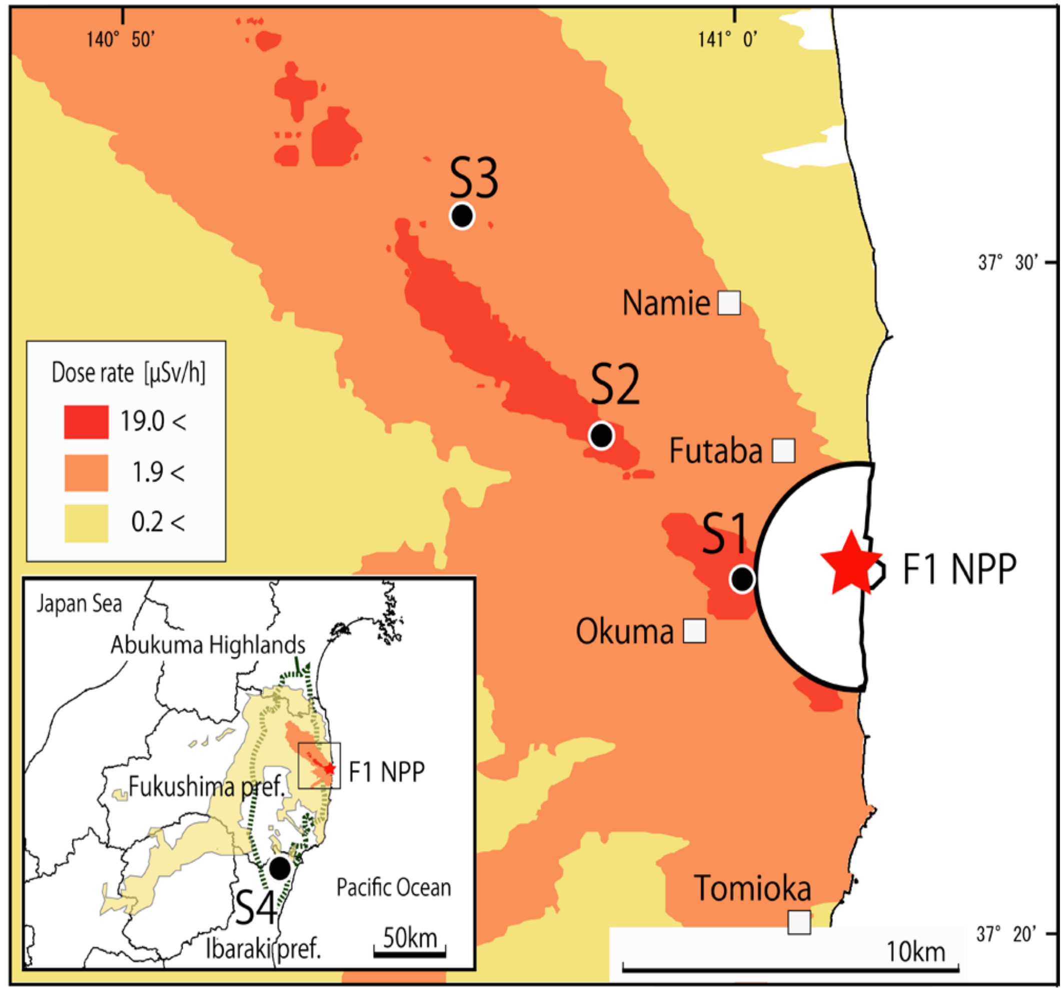
✓ The estimated dose rates mostly exceed DCRL in reference rat: 0.1-1 mGy/day (ICRP 108).

✓ Chromosomal aberration was dependent on the estimated dose rate.

Observation sites of fir trees in January 2015

S1-S3: Situated in "**Area 3**"
S4 : Control area

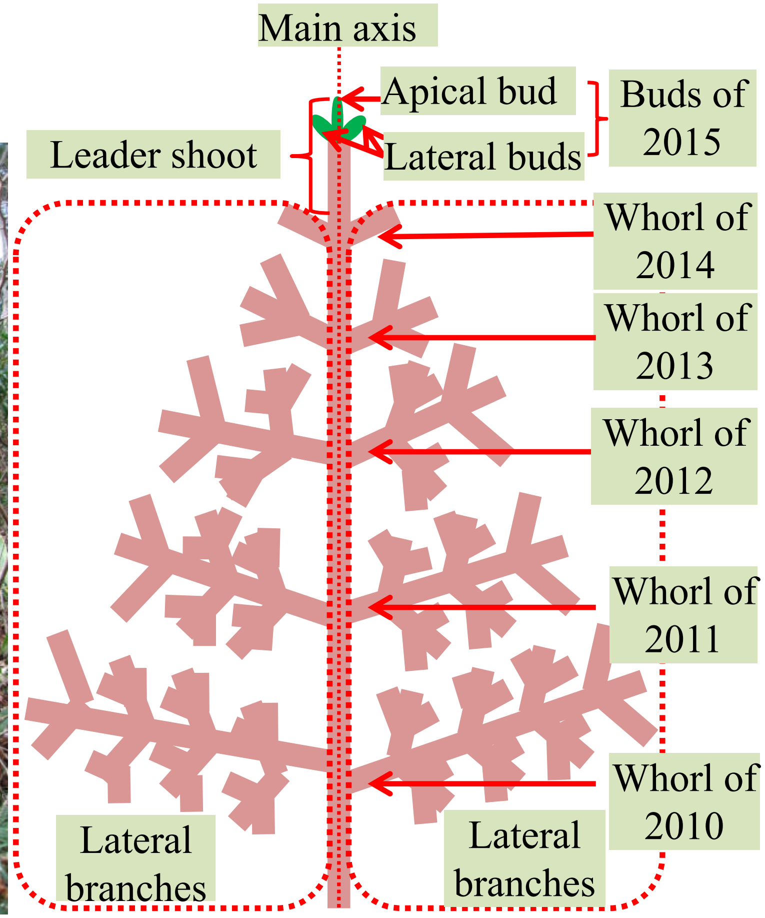
Site	Direction and distance from the F1NPP	Ambient dose rate (µSv/h)	Area (m^2)	Number of trees observed
S1	3.5 km NW	33.9 ± 5.1	1100	130
S2	8.5 km WNW	19.6 ± 1.0	1000	203
S3	15 km WNW	6.85 ± 1.19	800	111
S4	75 km SSW	0.13 ± 0.01	1200	189



Japanese fir trees

- ✓ A coniferous species native in Japan.
- ✓ Commonly grown in Fukushima.
- ✓ Young-tree populations are abundant in the forest.

➢ Short height of young-trees enables easy observation of morphological changes in the whole tree.



Schematic diagram of fir tree in January 2015

- ✓ Monopodial branching pattern
- ✓ A trunk with one main axis

➢ Easy in morphological analyses on the main axis.

- ✓ Regular annual branching.
- ✓ One whorl (node) is generated each year.

➢ Count of the number of whorl enables easy determination of the year that any morphological changes occurred.

Representative morphological defects on the main axis of the trunk in Japanese fir trees.

Normal tree

Defected tree (vertical forking)

Defected tree (horizontal forking)

- ✓ Normal trees : A monopodial branching pattern, a trunk with one main axis.
- ✓ Defected trees: ① Distinct deletion of the leader shoot
  ② Irregular branching at the whorls
  ③ The lateral branches extend vertical or horizontal

➢ These defects are caused by breakage of the leader shoot, which can due to an accidental damage, such as animal attack, wind damage, and pathogenic disease, or due to environmental stress such as frost.

Determination of the year that morphological changes occurred (January, 2015)

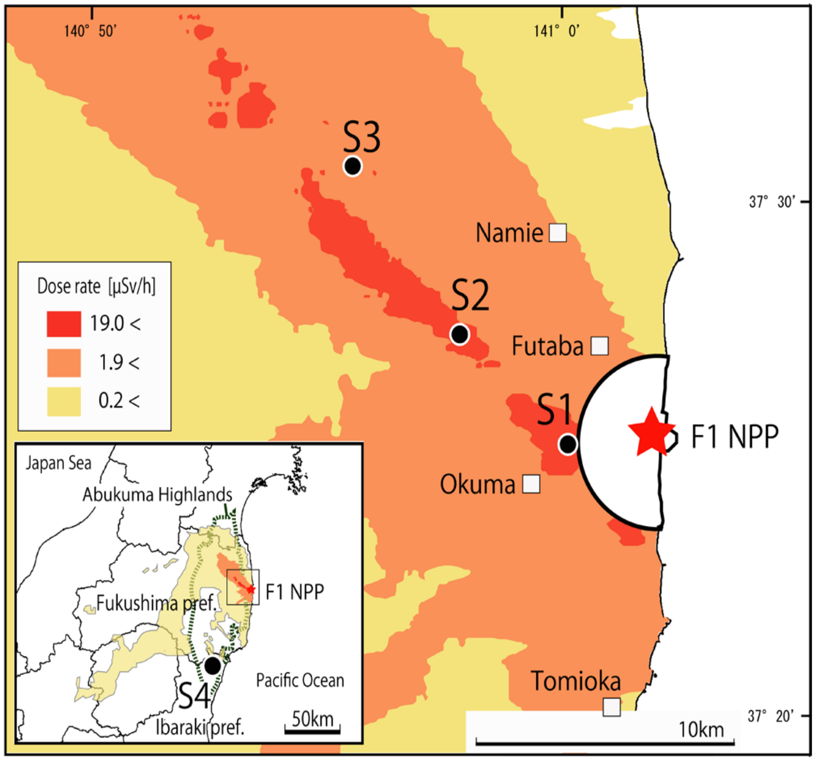
Normal tree

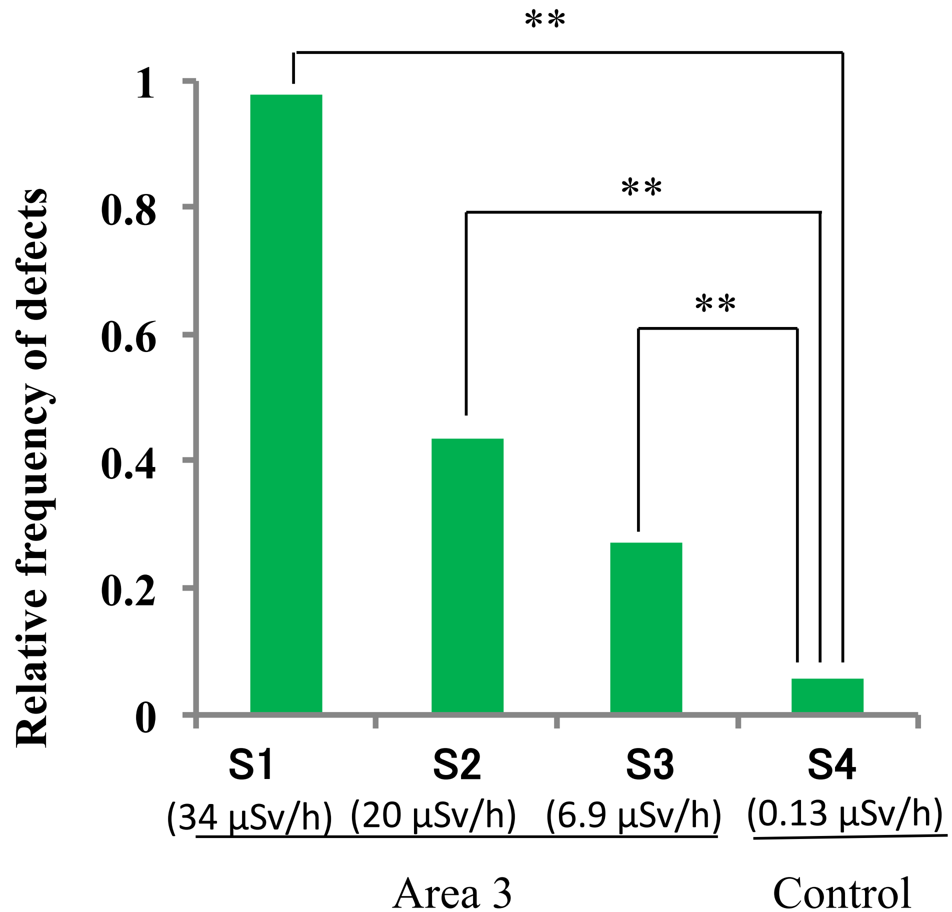
Deletion of leader shoot (2013)

Deletion of leader shoot (2013)

- Count of the number of whorl enables determination of the year that any morphological changes occurred.

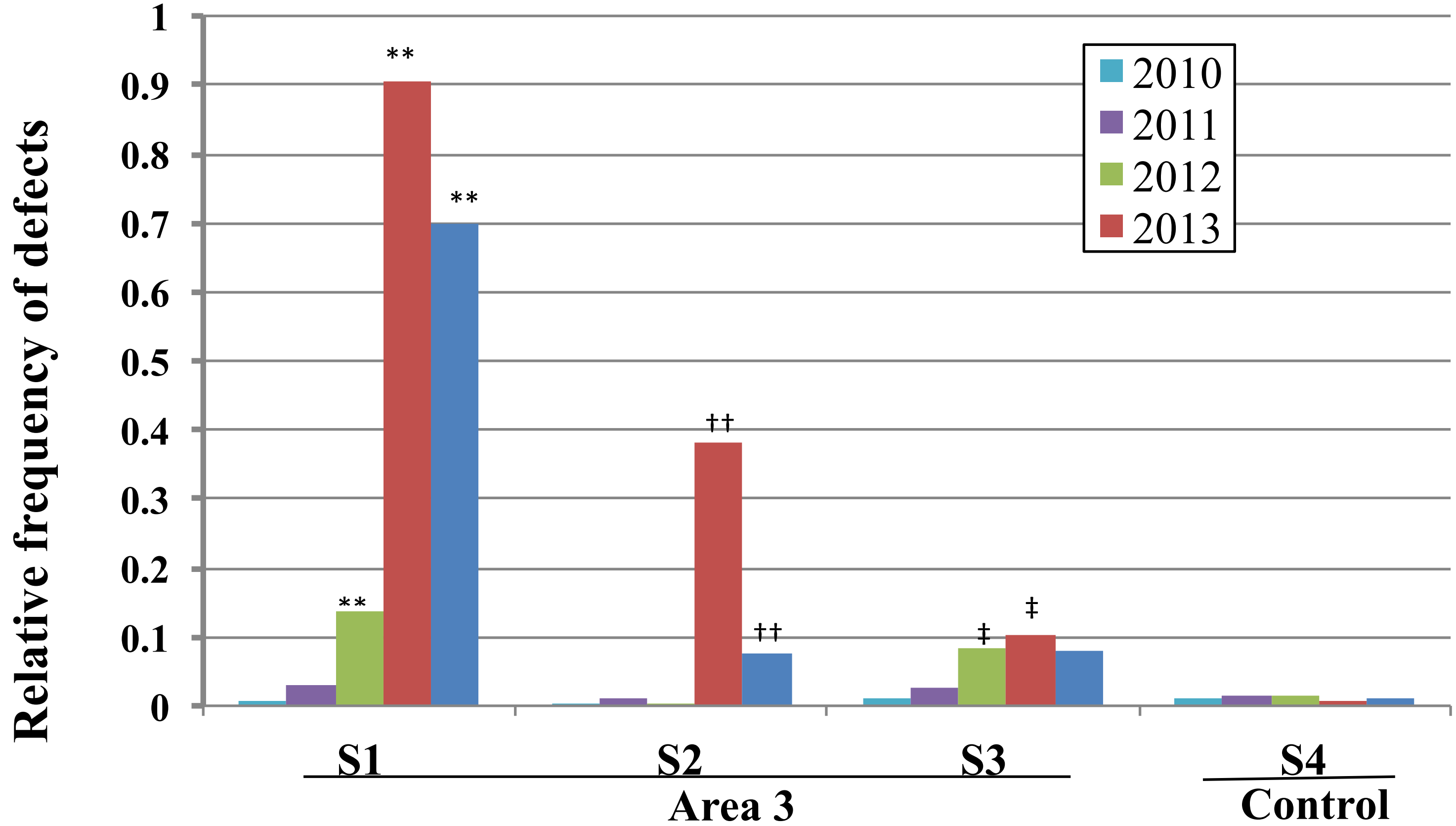
Relative frequency of main axis defects in Japanese fir trees





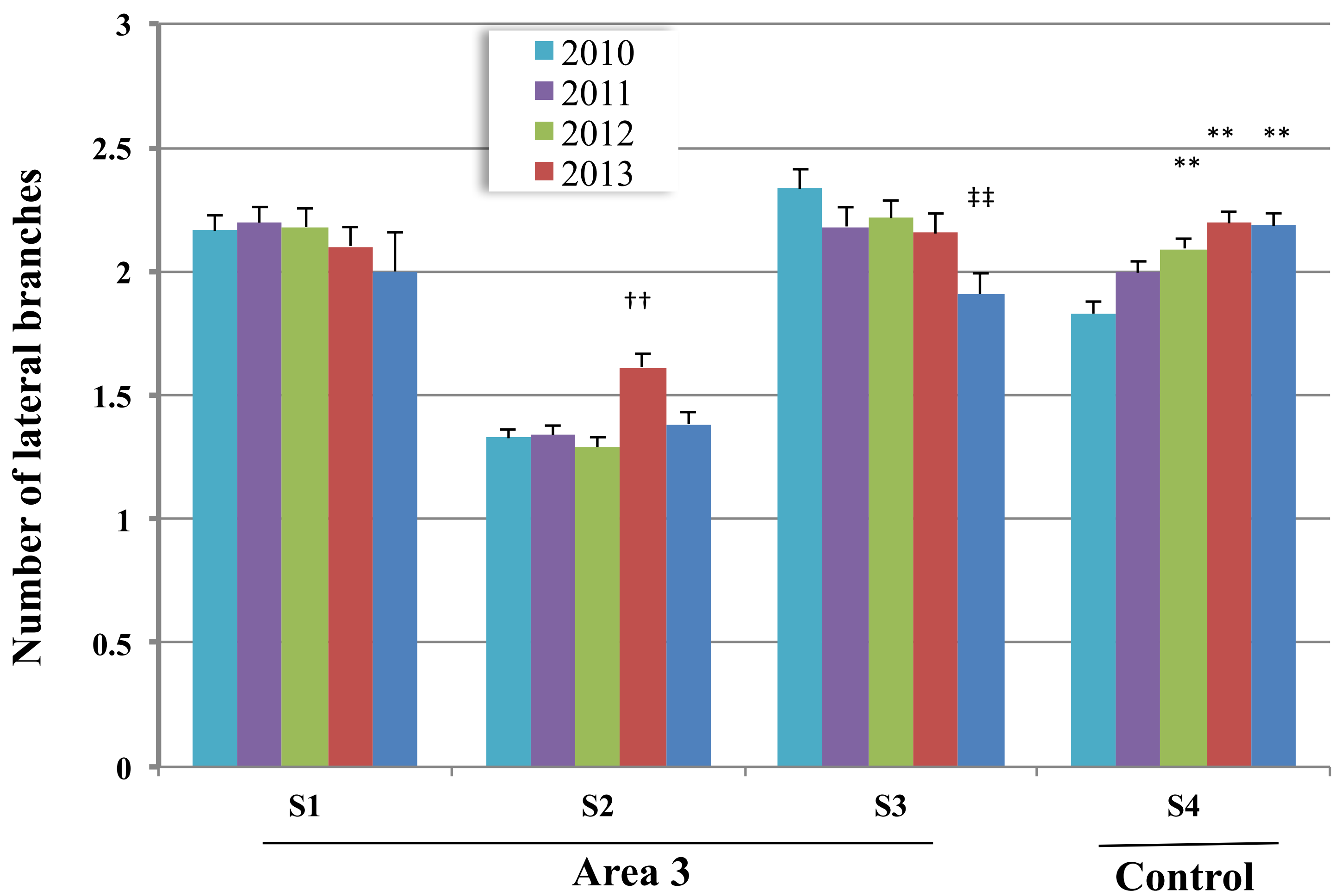
- ✓ Overall frequency of morphological defects was significantly higher in S1, S2,and S3.
- ✓ The frequency corresponded to the ambient dose rate at the sites.
- ✓ High frequency of defects was observed in S1 (more than 90%).

Relative frequency of deleted leader shoot in the annual whorls of the main axis



- ✓ Frequency of deleted leader shoots increased after 2012 or 2013 in S1-S3.
- ✓ The frequency peaked in 2013 and tended to decrease in 2014.
- ✓ The variation patterns were similar among S1-S3, whereas no annual variation in S4.
  - ➢ Deletion of leader shoots occurred most frequently during 2012–2013, 1-2 years after the accident.

Number of lateral branches from the annual whorls did not show similar variation as leader shoot



- ✓ The number of lateral branches was not lower in Area 3 than in control area.
- ✓ The number of lateral branches did not show annual variation.

➤ The deletion of leader shoots were independent of the deletion of lateral branch.

A close inspection of deleted leader shoot and apical bud

Annual whorl
of 2013

Winter buds
of 2015.

✓ The deleted leader shoots left no marks among normal lateral branches.

✓ Similarly, normal lateral buds with completely deleted apical buds were sometimes observed in the winter buds of 2015.

➢ The deletion of leader shoots probably resulted from the deletion of apical buds at an early stage of their development, independently of the formation of lateral buds.

Conclusion & works in progress

The field examination in Fukushima suggest possibility that
the contamination by radionuclides should have contributed to the morphological defects in Japanese fir trees.

To verify the causal relationship between radiation and morphological changes

Chronic irradiation on the tree should be investigated in irradiation facilities.

Gamma room
(NIRS, QST)

Gamma field
(National Agriculture and Food Research Organization)

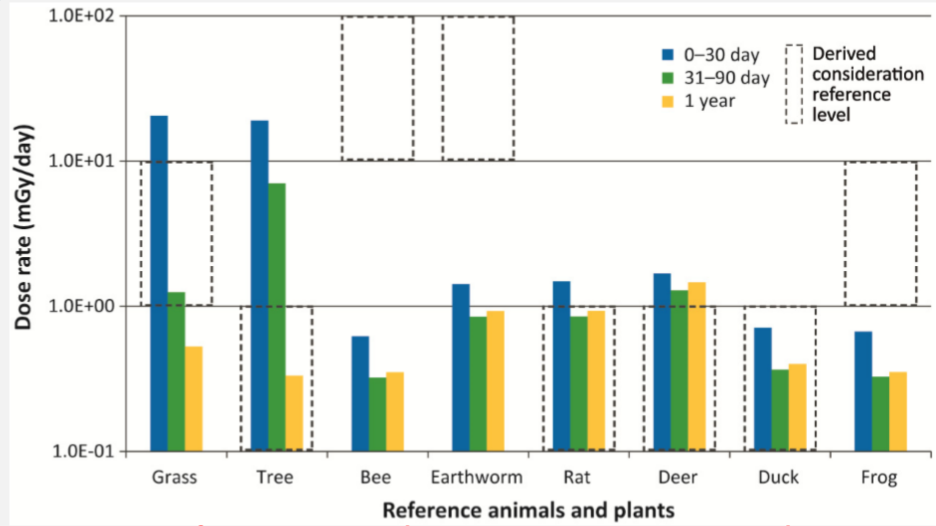
- Reproducibility of the morphological changes by artificial irradiation?
- Dose - Effect Relationship ?

Dose estimation in Japanese fir in contaminated fields

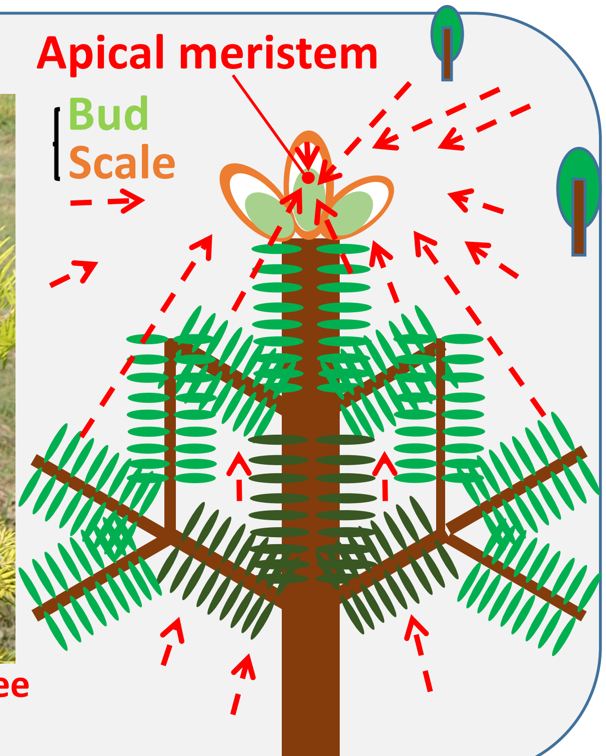
Dose rate for Reference Pine estimated by ERICA tool suggest high contribution of direct deposition on the plants in the early phase.
(IAEA 2015, UNSCEAR 2013)

Development of a detailed model to estimate the dose in apical meristem from inhomogeneous contamination.

Now ongoing



Dose rates for terrestrial RAPs versus time at Okuma Town. (IAEA, 2015)

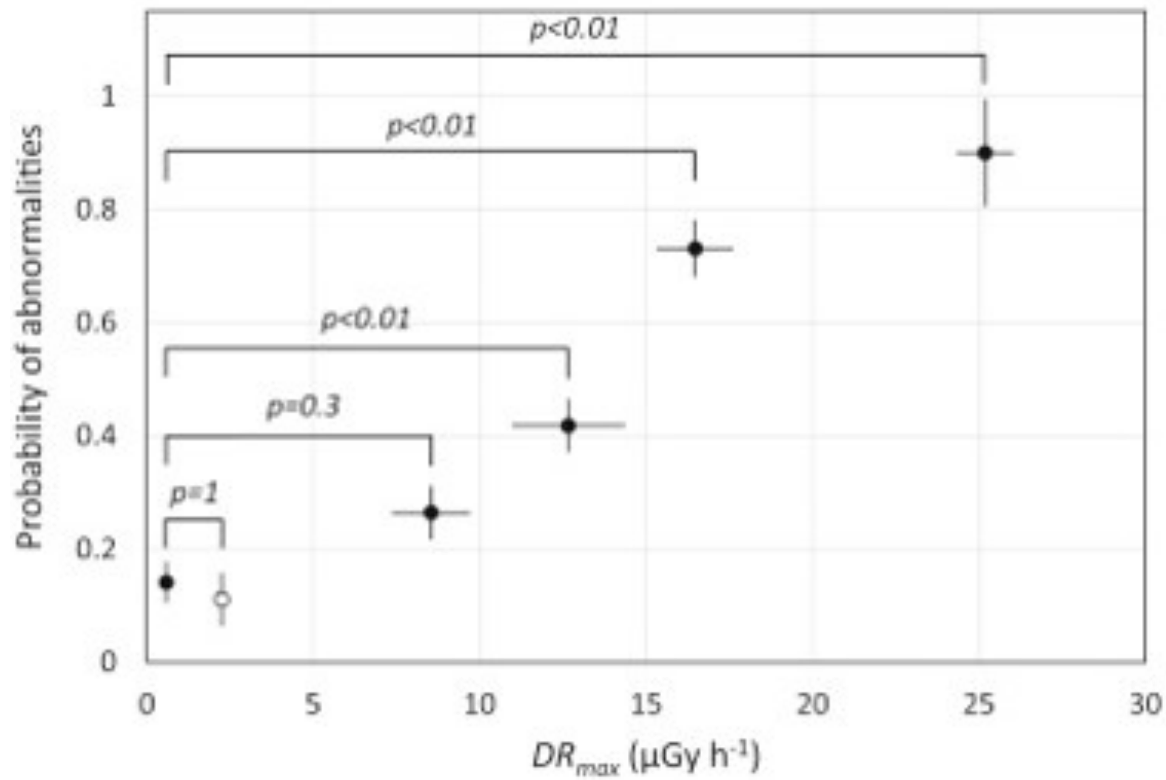


Detailed model for fir tree

Morphological abnormalities in Japanese red pine (Pinus densiflora)

Yoschenko, et al. / J Environ Radioact. 165: 60-67 (2016)

Cancellation of the apical dominance in Japanese red pine.



Probability of abnormalities as a function of the averaged absorbed dose rate DR_{max} in the highest year in which the trees were exposed.

- Typical abnormality was cancelling the apical dominance, i.e. branching of the trunk.
- The abnormality probability correlated with the dose rate received by the trees.

Thank you for your attention.