

# **Integrated system of radiological protection of people and the environment A View from Japan**

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Kazuo Sakai  
ICRP C1

Tokyo Healthcare University, Japan

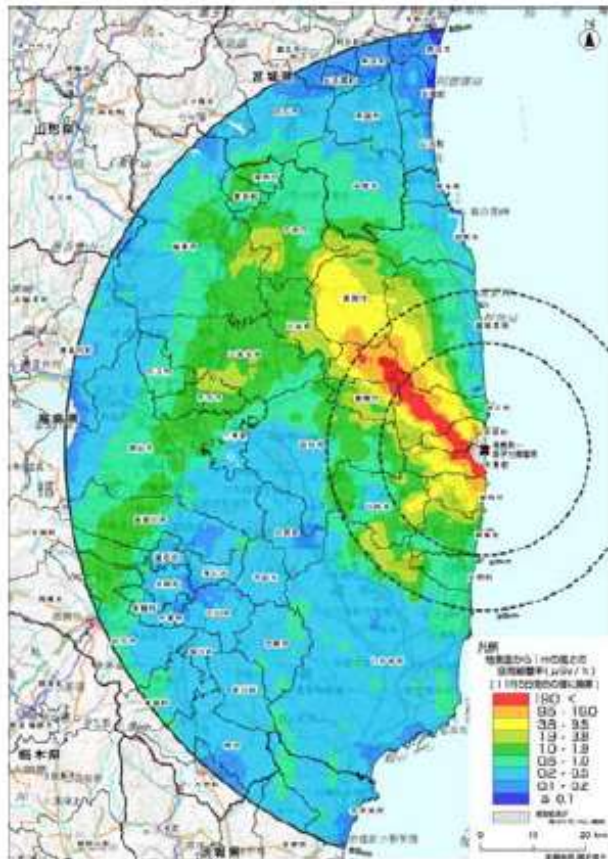
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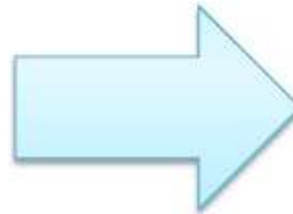
# Changes in Air Dose Rate

- The average air dose rate at 1m in height from the ground surface at a distance within 80km from Fukushima Daiichi Nuclear Power Station decreased by about 71%\* compared to levels in November 2011.

## November 2011

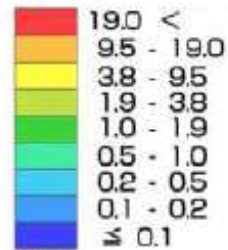


November 2011



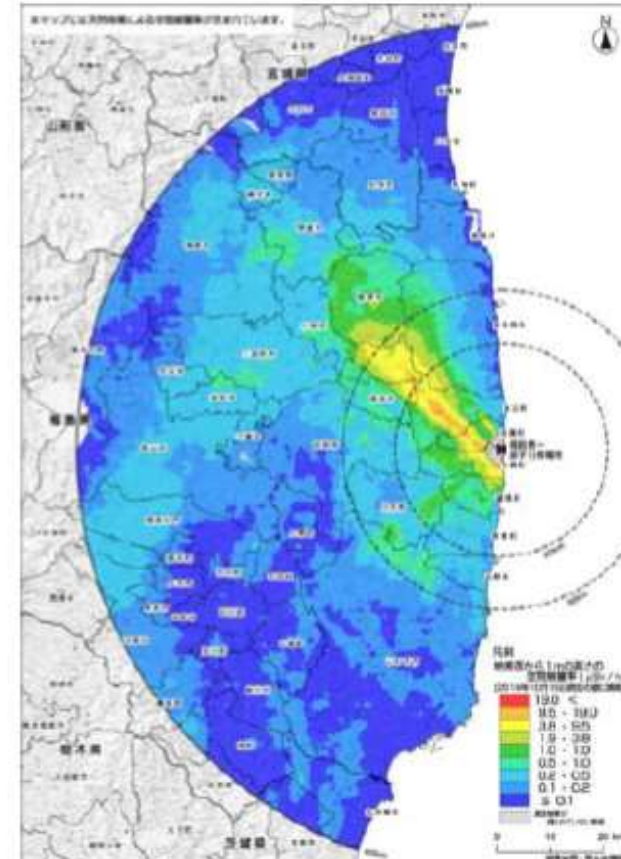
### Legend

Air dose rates at 1m in height from the ground surface ( $\mu\text{Sv/h}$ )



Range where measurement results were not obtained

## October 2016



October 2016

\*The target area is divided into 250m grid meshes and the value is calculated from the ratio of the measurement results in the central point of each grid mesh. The rate of reduction may differ when other comparative methods are used.

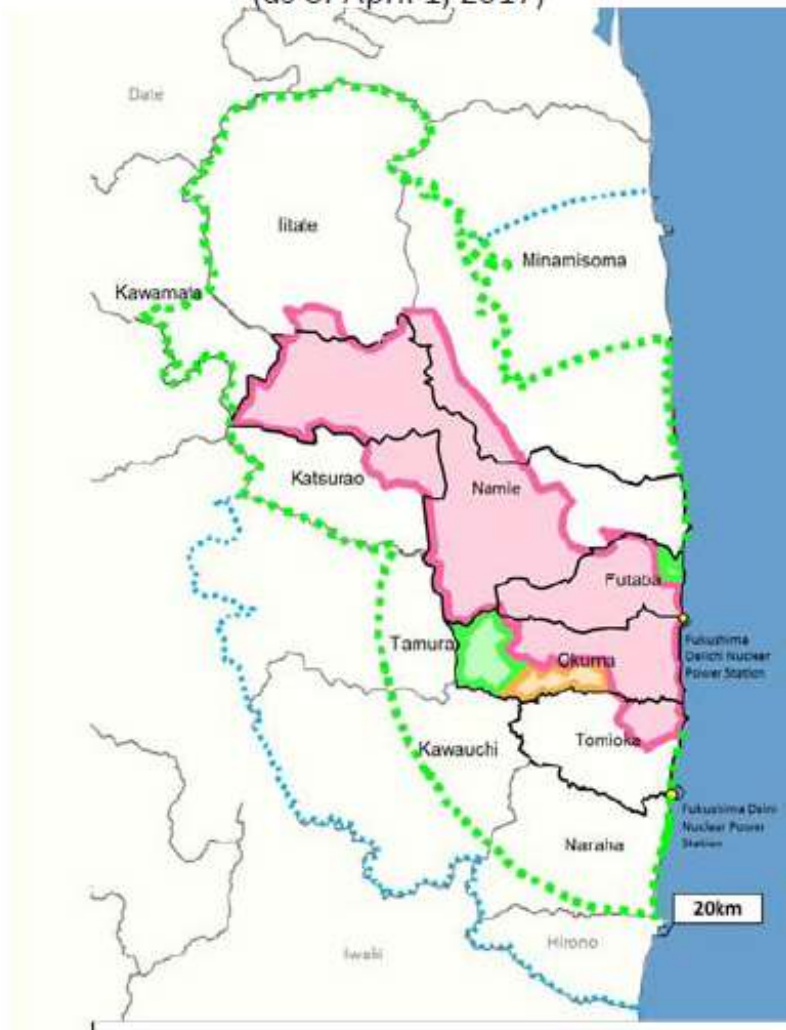
Source: Nuclear Regulation Authority, "Measurement Results of Monitoring by Aircraft in Fukushima Prefecture and Nearby Prefectures"

Most recent data: <http://radioactivity.nsr.go.jp/en/>

# Status of the Areas under Evacuation Orders ②

- By April 1, 2017, evacuation orders were lifted for Tamura City, Naraha Town, Kawauchi Village, Katsurao Village, Minamisoma City, Iitate Village, Kawamata Town, Namie Town and Tomioka Town, which are Preparation areas for lift of evacuation order and Habitation restricted areas.

Conceptual diagram of areas under evacuation orders  
(as of April 1, 2017)



Areas in which evacuation orders were lifted within one year after the disaster.



Areas in which evacuation orders were lifted between 2012 and 2017 spring.



**Preparation Areas for Lift of Evacuation Order:**

Of the areas under evacuation orders, areas that have been confirmed to have a clear annual concentrated radiation dose of less than 20 mSv from air dose rates (confirmed based on radiation dose as of March 2012).



**Habitation Restricted Areas:**

Of the areas under evacuation orders, areas that have been confirmed to have potential an annual cumulative radiation dose estimated from the air dose rate exceeding 20 mSv (confirmed based on radiation dose as of March 2012).



**Areas where Returning is Difficult:**

Areas where the annual cumulative radiation dose estimated from the air dose rate may not fall below 20 mSv even six years after the nuclear accident. Areas where the annual cumulative radiation dose estimated from the air dose rate exceeds 50 mSv as of March 2012.

# From a weather report; Temperature distribution (°C)



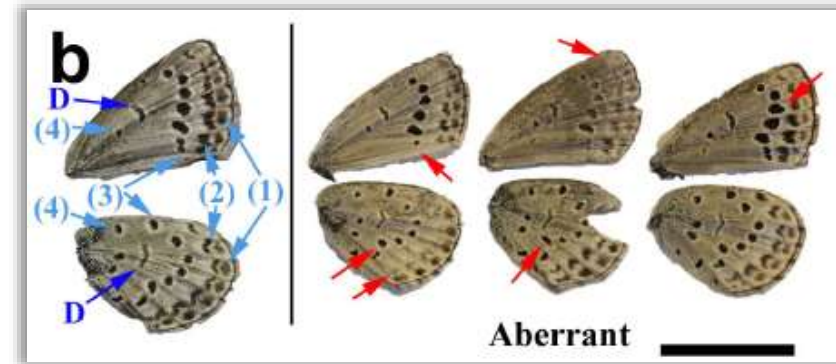
# From a weather report; Radioactivity Measurement ( $\mu\text{Sv/h}$ )



# Impacts on the environmental biota

## Phenotypic modification in butterflies

*Hiyama et al., Sci. Rep. 2, 570;*  
*DOI:10.1038/srep00570 (2012)*



## Loss of leader shoot in Japanese fir trees

*Watanabe et al., Sci. Rep. 5, 13232; DOI:*  
*10.1038/srep13232 (2015)*



## Follow-up Studies (1): butterflies

More samples collected.

External exposure/Internal exposure.

→ abnormality caused by radiation

Hiyama et al., 2017. Entomol Sci 20 (1): 100-110.

→ Relationship between radiation level and effects?

→ Mechanisms?

Experimental work

→ abnormality caused by other factors, such as micro particulate matters.

Otaki, 2016. Integr Environ Assess Manag 12(4): 667-672.

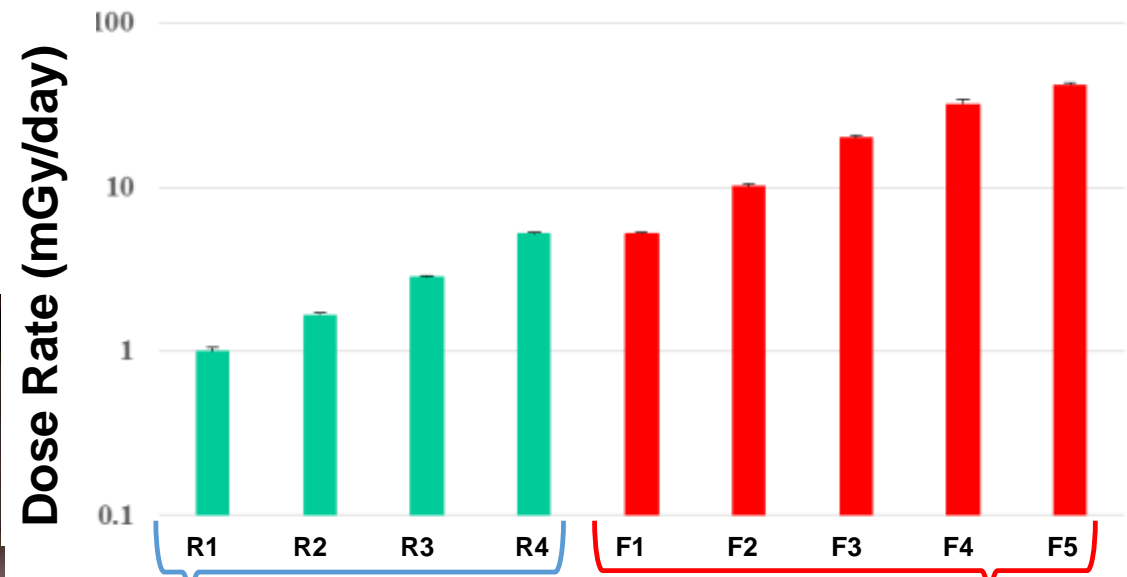


## Follow-up studies (2) : Japanese fir tree

- The effects of chronic irradiation have been investigated, using experimental irradiation facilities and a gamma field.

# Chronic irradiation on fir trees in irradiation facilities

Irradiation dose-rate on fir trees in irradiation facilities



**Chronic gamma-irradiation facility**  
(NIRS, QST)

1.3 years after start of irradiation



**Gamma field**

(National Agriculture and Food Research Organization)

2 years after start of irradiation



# Protection of the Environment (1)

## Reference animals and plants

- “A Reference Animal or Plant is a hypothetical entity, with the assumed basic characteristics of a specific type of animal or plant, as described to the generality of the taxonomic level of Family, with defined anatomical, physiological, and life-history properties, that can be used for the purposes of relating exposure to dose, and dose to effects, for that type of living organism. (ICRP 2007).

## Protection of the environment(2)

# Derived Consideration Reference Levels

As a benchmark for protection of the environment, Derived Consideration Reference Levels (DCRLs) are defined.

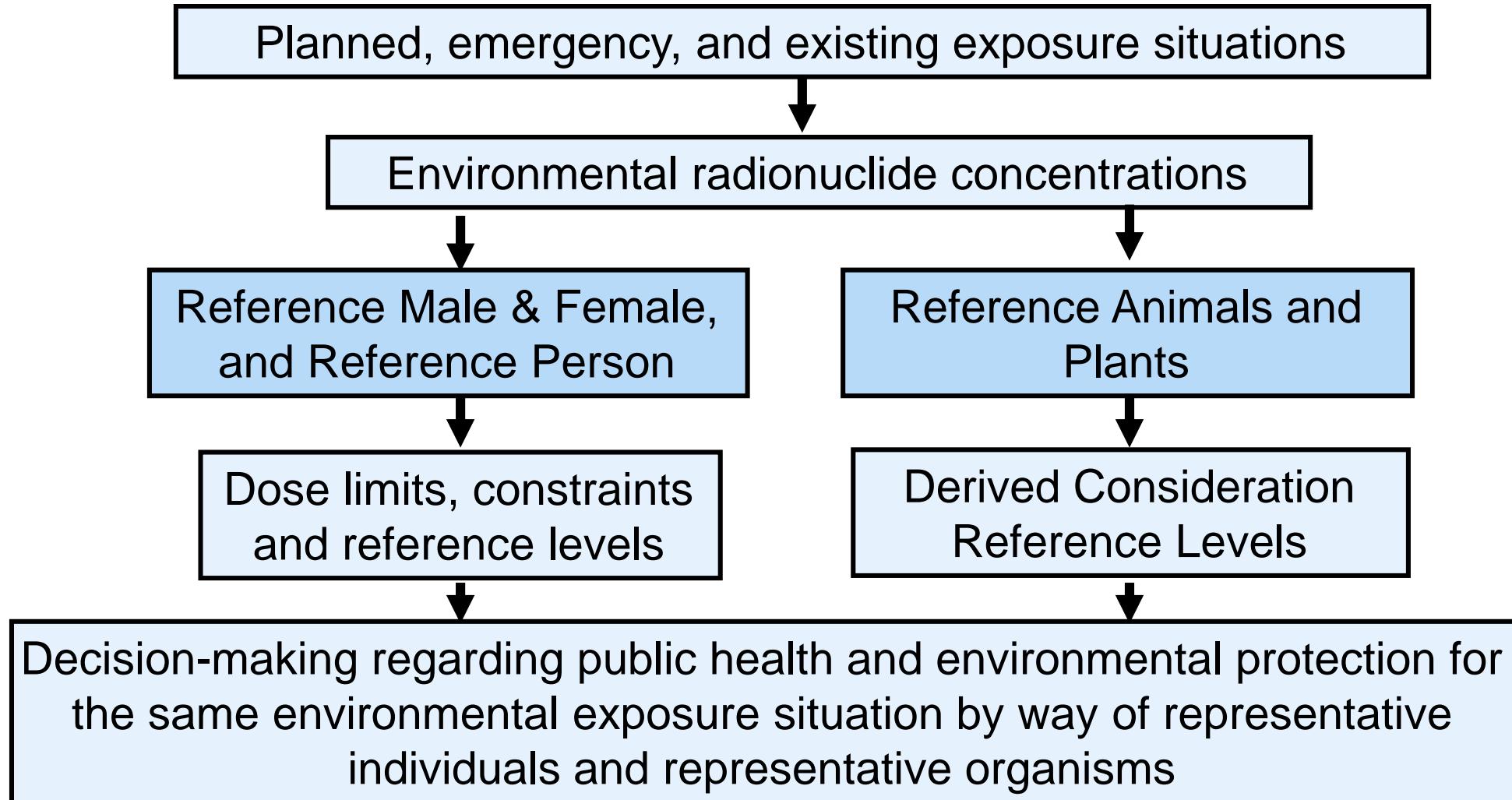
DCRL is “a band of dose rate within which there is likely to be some chance of deleterious effects of ionising radiation occurring to individuals of that type of reference animal or plant (derived from a knowledge of defined expected biological effects for that type of organism) that, when considered together with other relevant information, can be used as a point of reference to optimize the level of effort expended on environmental protection, dependent upon the overall management objectives and the relevant exposure situation.”(ICRP 2008)(underline by the author).

## DCRL and Life span of RAPs

RAP	DCRL (mGy/d)	Life span (y)
Deer	0.1-1	15
Rat	0.1-1	2
Duck	0.1-1	11
Frog	1-10	10
Trout	1-10	6
Flat Fish	1-10	10
Bee	10-100	3
Crab	10-100	15
Earthworm	10-100	4
Pine Trees	0.1-1	200
Wild Grass	1-10	Perennial
Brown Seaweeds	1-10	5

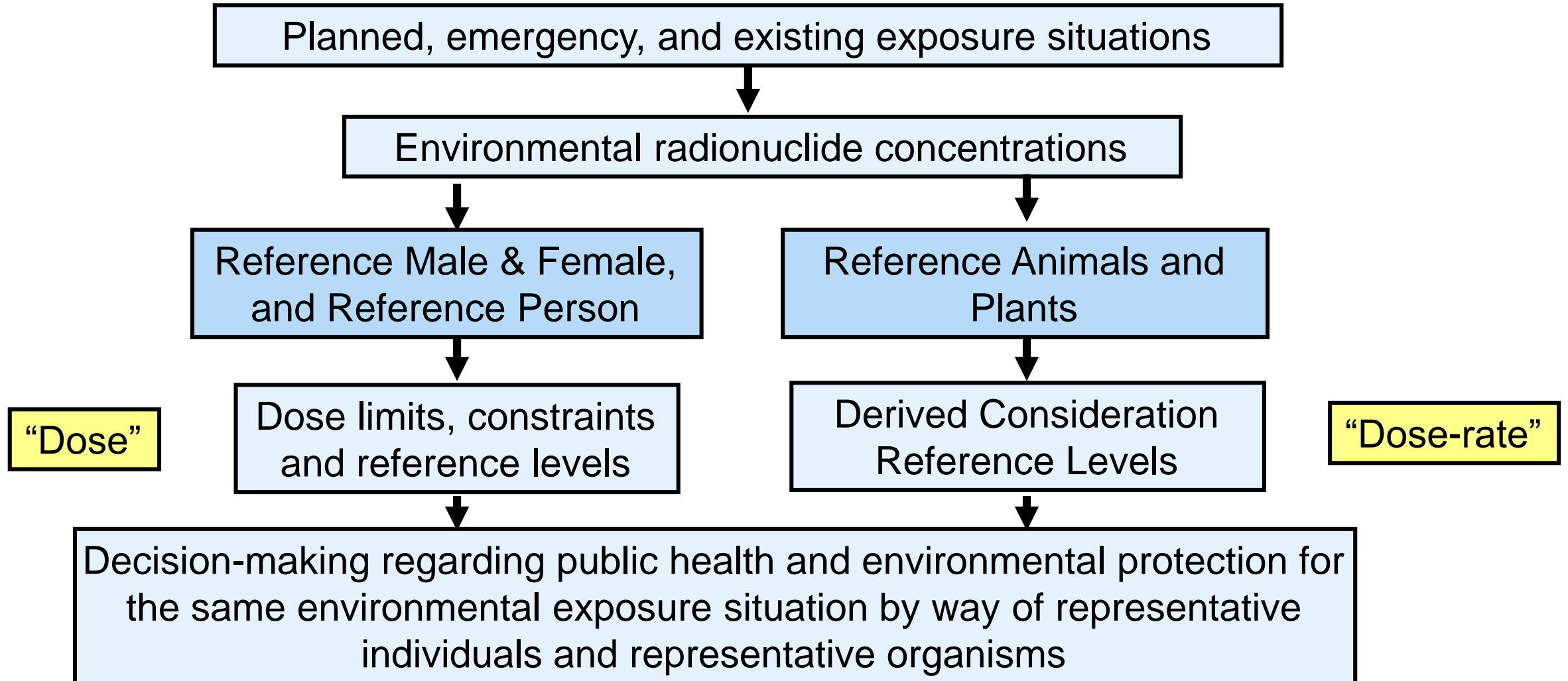
# Protection: the environment

## Evolution of two parallel pathways

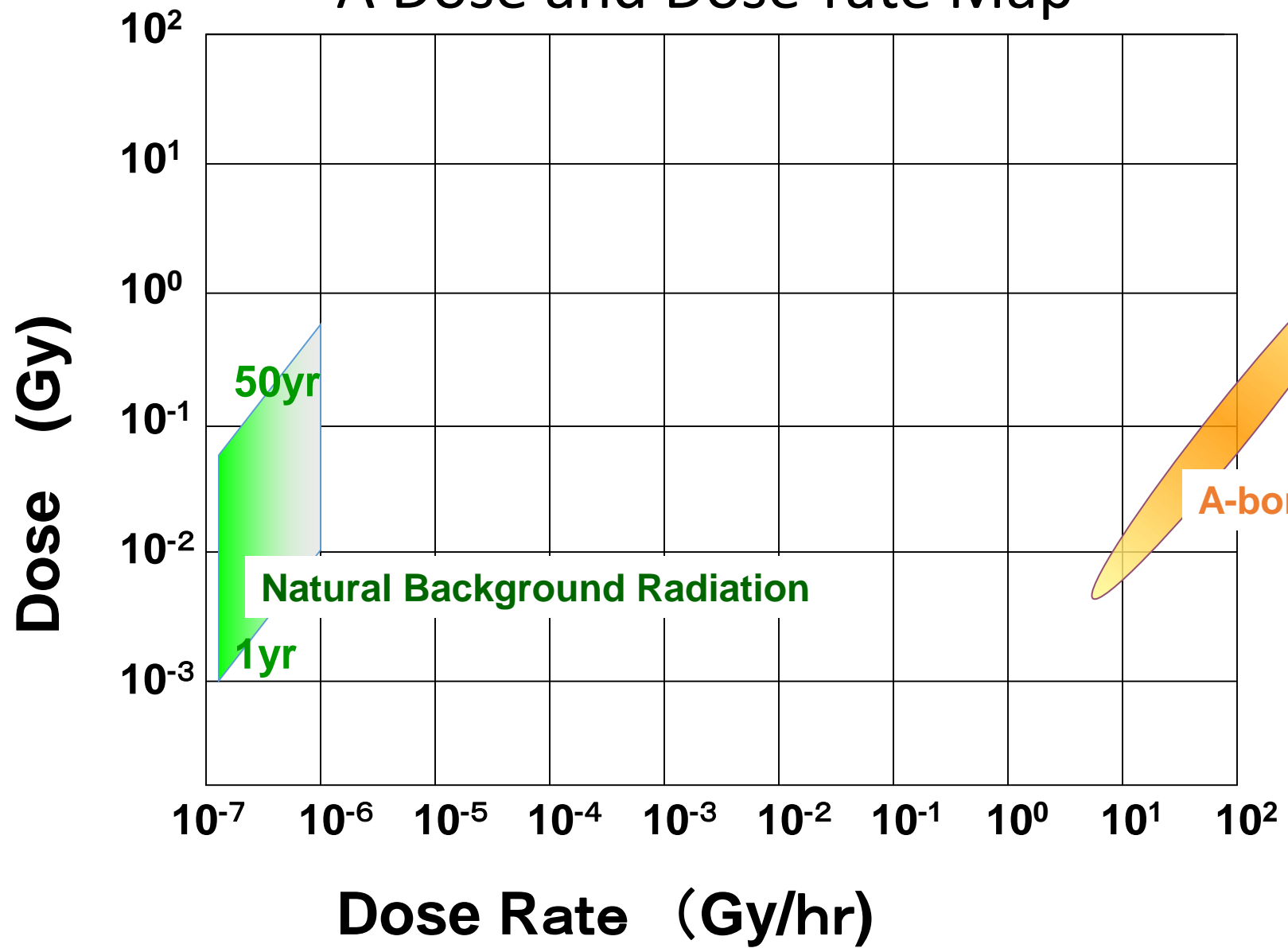


# Protection: the environment

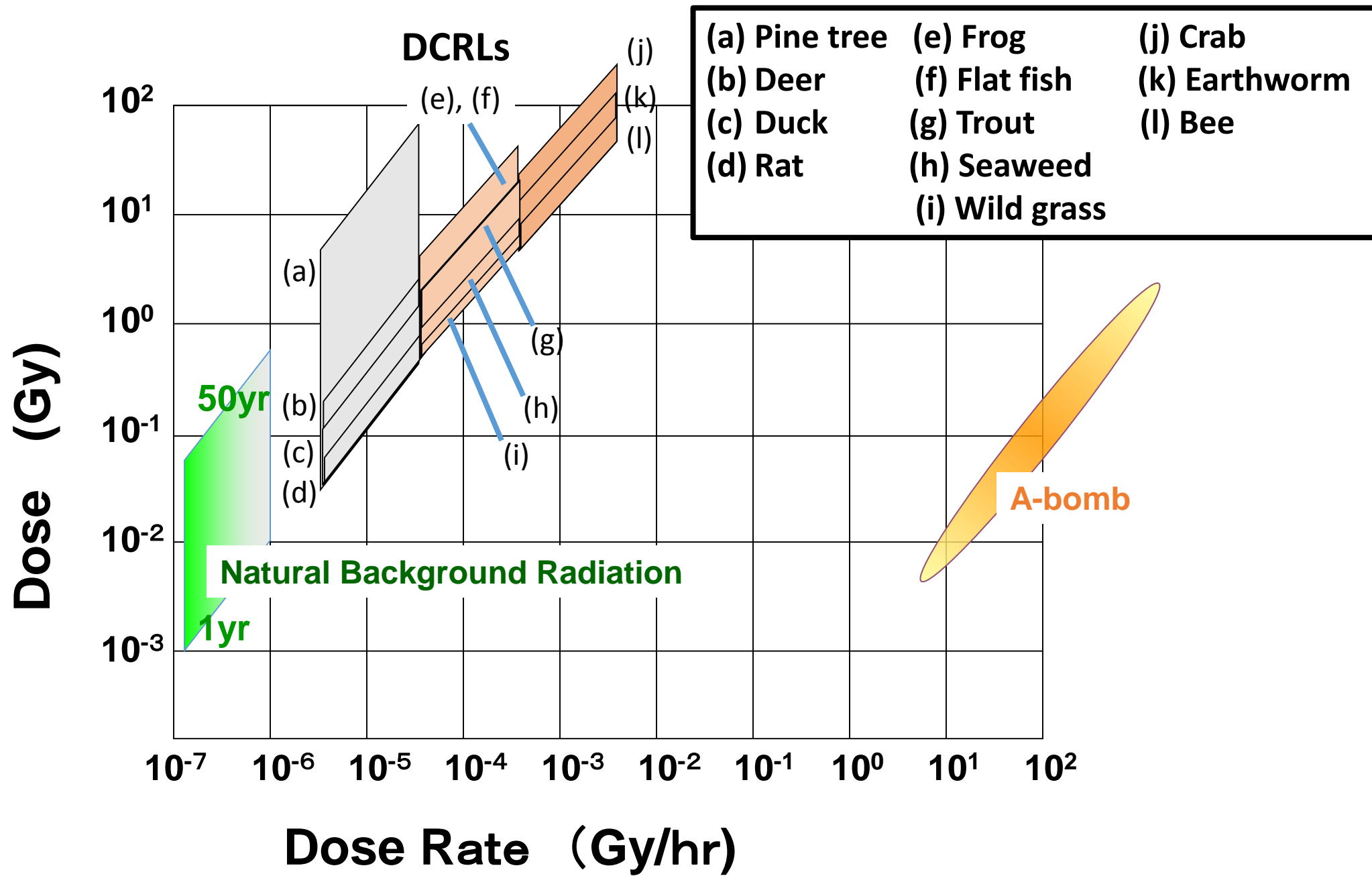
## Evolution of two parallel pathways



# A Dose and Dose-rate Map







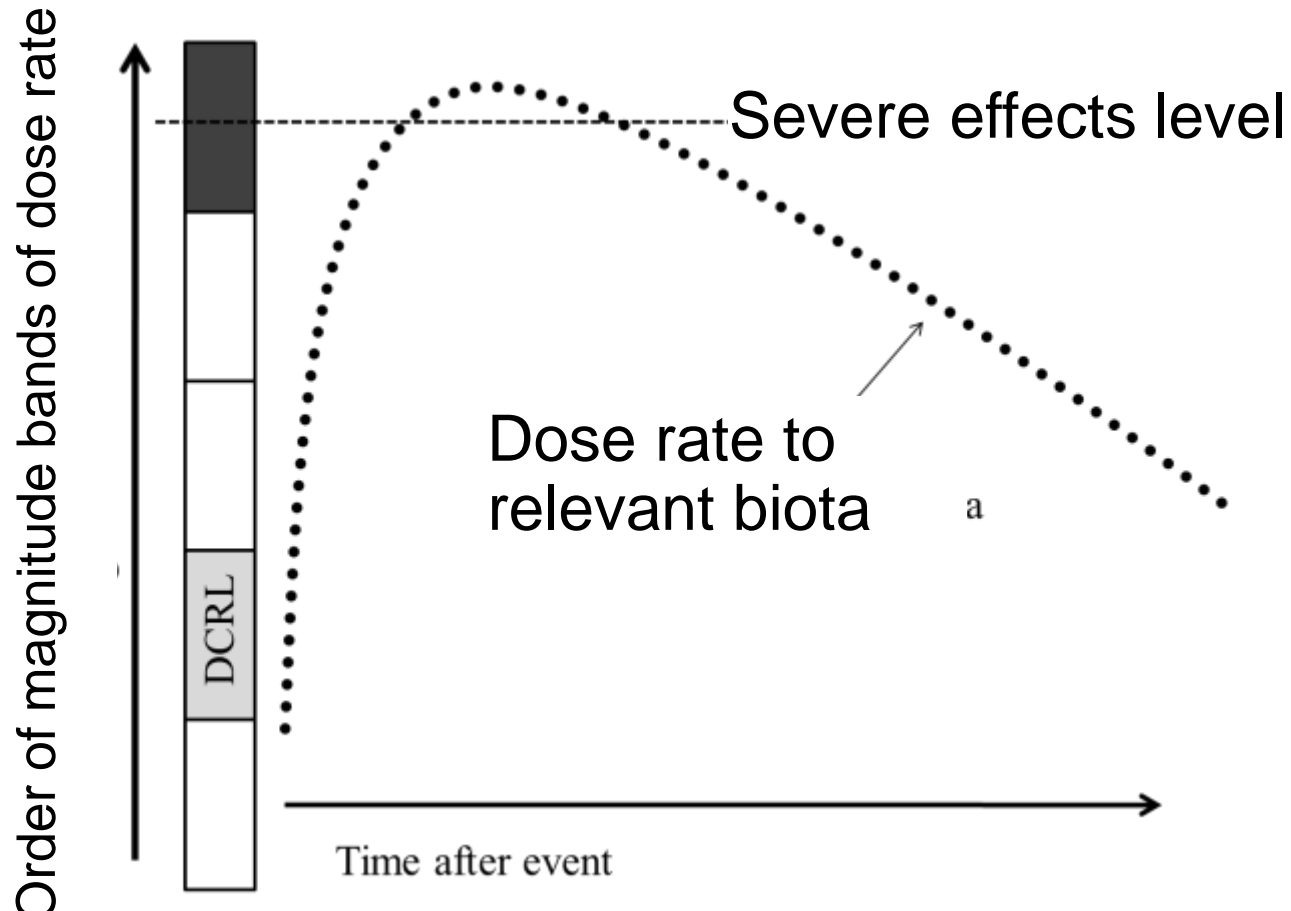
Dose and Dose-rate map

Is dose-rate enough to evaluate the impact of radiation exposure?

# Dose rates, Okuma Town, June 2011

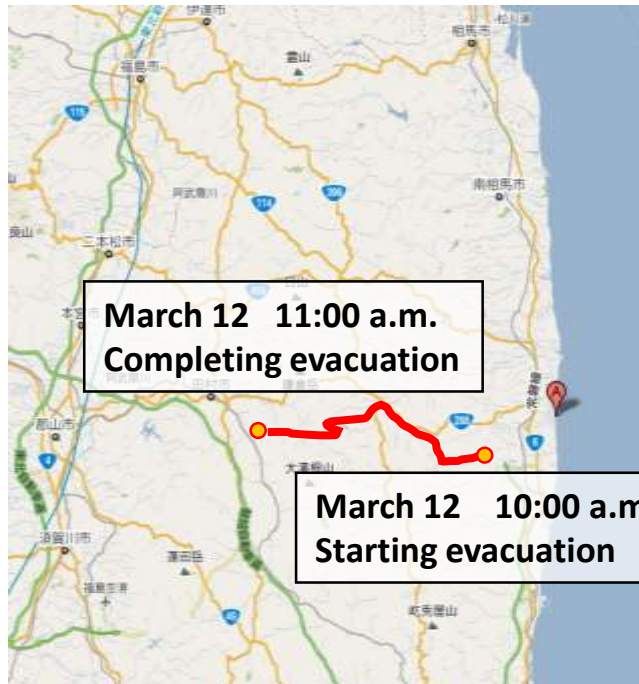
RAP	Dose-rate estimate	Lower end DCRL	Ratio of estimate to benchmark
	$\mu\text{Gy/h}$		
Bee	18	400	0.04
Deer	71	4	17.8
Duck	21	4	5.3
Earthworm	46	400	0.11
Frog	18	40	0.45
Pine tree	17	4	4.3
Rat	46	4	11.5
Wildgrass	26	40	0.65

# Application in emergency exposure situations (ICRP Publication 124)

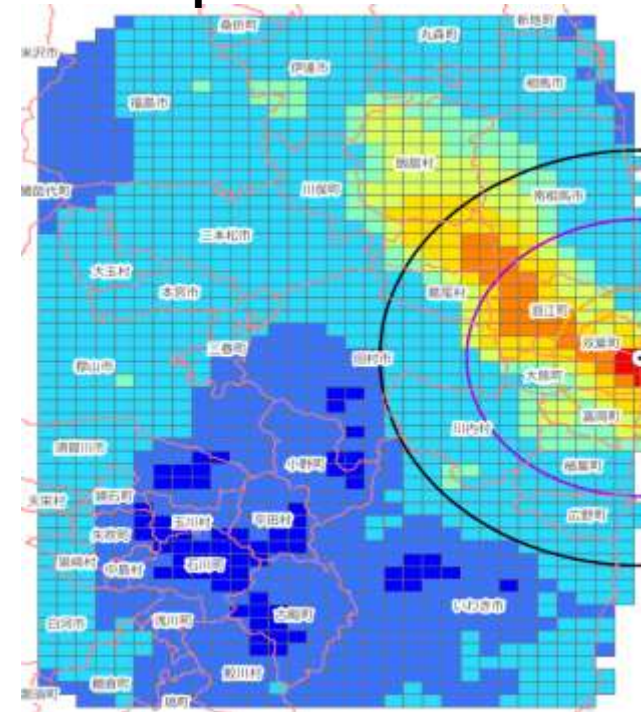


# External Dose Assessment of Residents

Based on questionnaires for residents about behavior in Fukushima prefecture after the earthquake



Time sequential maps of radiation dose rate near 1F with intervals of 1hour for initial phase and 1day for the remained period.



**Calculation of doses in residents  
during the period of 12 March – 11 July, 2011**

Another difference between protection of people and that of the environment and that of people: Aim of the protection (ICRP Publication 103)

**(30) ....aim is...preventing and reducing the frequency of deleterious radiation effects to a level where they would have negligible impact on the maintenance of biological diversity, the conservation of species, or the health and status of natural habitats, communities and ecosystems.**

# Summary

- Although the system of the environmental protection has been evolved in parallel to that of people, there are some differences as well as similarities.
- One of the differences is dose vs. dose-rate.
- Considering both dose and dose-rate together would lead to the integrated radiological protection system
- Toward the integrated protection of people and the environment, the difference, rather than similarities, in the current system should be taken into consideration.