F1NPP

5 years after the accident

Overview of ...

Overview of Radioecology Studies at Fukushima

~ Ecosystem Disturbance and Scales

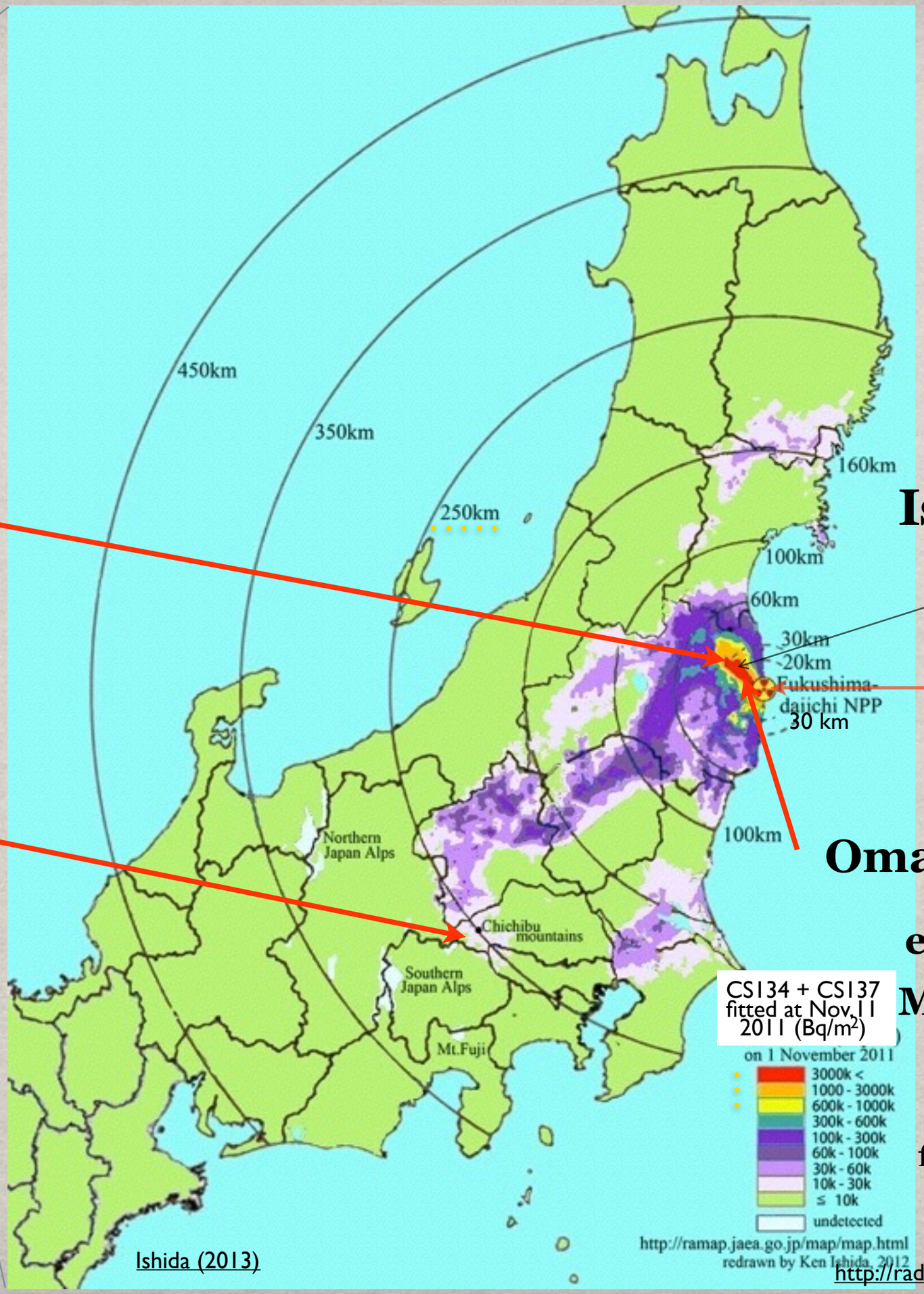
Ken Ishida

2016.10.3 Integrating Ecosystem Research into Radioecology in the Nuclear Age

15 July, 2011 13:58 p.m. Tamura (R288, 20km from F1NPP)

Akaugi

Chichibu



Ishida's research area

F1 NPP

Omaru

estimated fallout rate

MEXT air bone survey

fitted those on 11 Nov. 2011

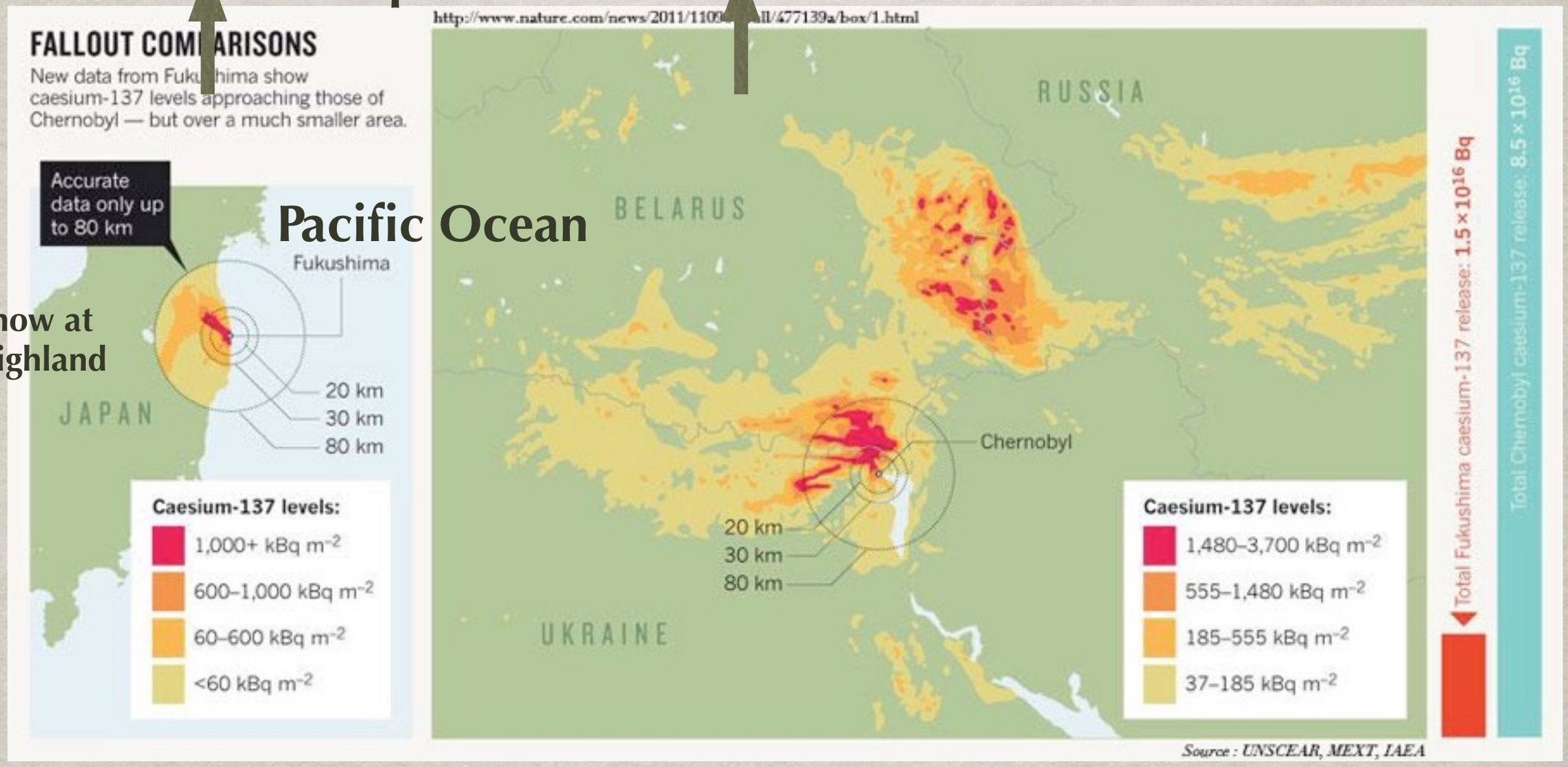
http://radioactivity.mext.go.jp/en/list/203/list-1.html

16 July, 2011 9:17 a.m. Akaugi

Fukushima & Chernobyl

15 March before p.s.

26 April ~ 6 May after plant shooting



snow at highland

Cs137 fallout , Nature 7 September, 2011

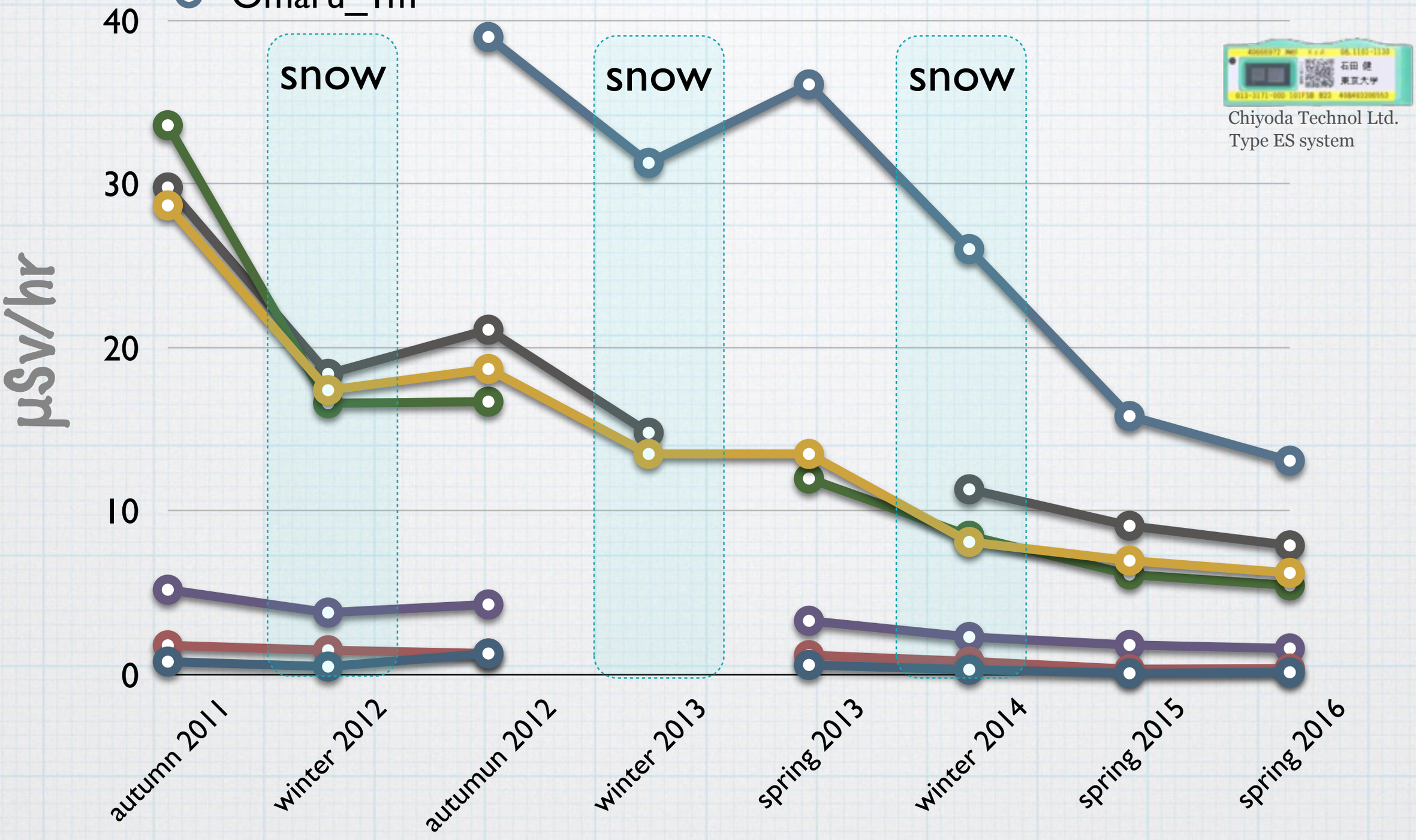
★ Season is one of the essential factors on the initial biological effects.

fallout estimation

radiation accident	I131	Cs134	Cs137	Str90	Pr239
Fukushima	160k.	18,000	15,000	14	0.0032
Chernobyl	170m.	44,000	85,000	8,000	30

area F1, 8,900Km^2; CB, 145,100Km^2

(Nakanishi 2013 Tab. 1-3)



Chiyoda Technol Ltd.
Type ES system

monitoring with 10 glass dose budges

K. Ishida

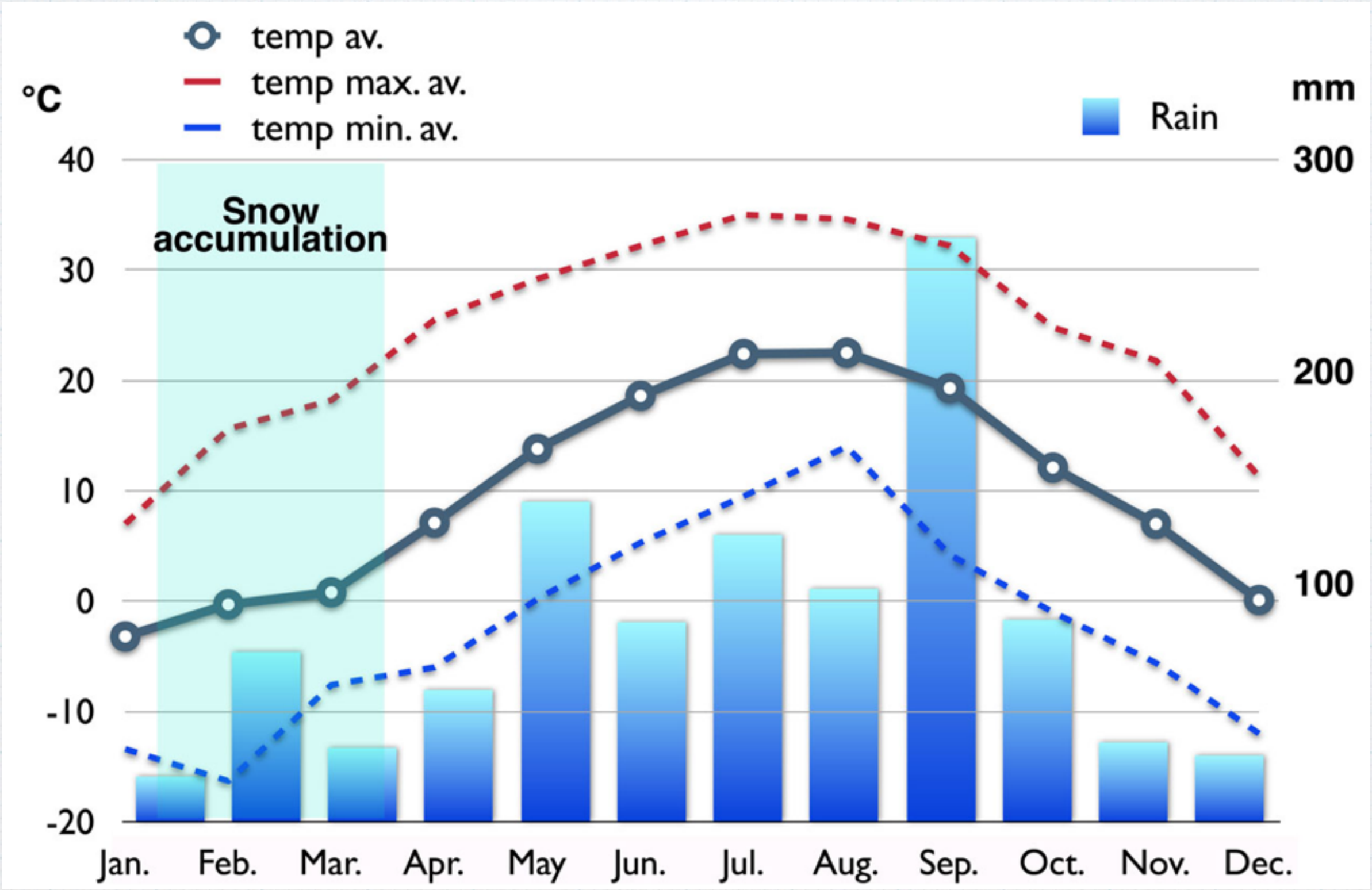
Fukushima

What place ?

- **environment**
- **climate**
- **geography**

society
history

…



climate of Abukuma highland

Iitate village, Japan Meteorological Agency

4 3 2 1

the main 4 landscapes
in the "main" contaminated area
i.e. >^{137}Cs 500kBq /m^2

"Nakadori" plain

gentle slopes, mixed landscape

steep slope

small valleys

highland

"Hamadori" plain

large cities
Shinkansen railway
Tohoku highway

more fallout

F1 NPP

Profile of Abukuma Mountains

“Hamadori” plain [1]

High RA

“40μSv/h.” (2012), “25μSv/h.” (2014)

East slope

Forest

Low population density

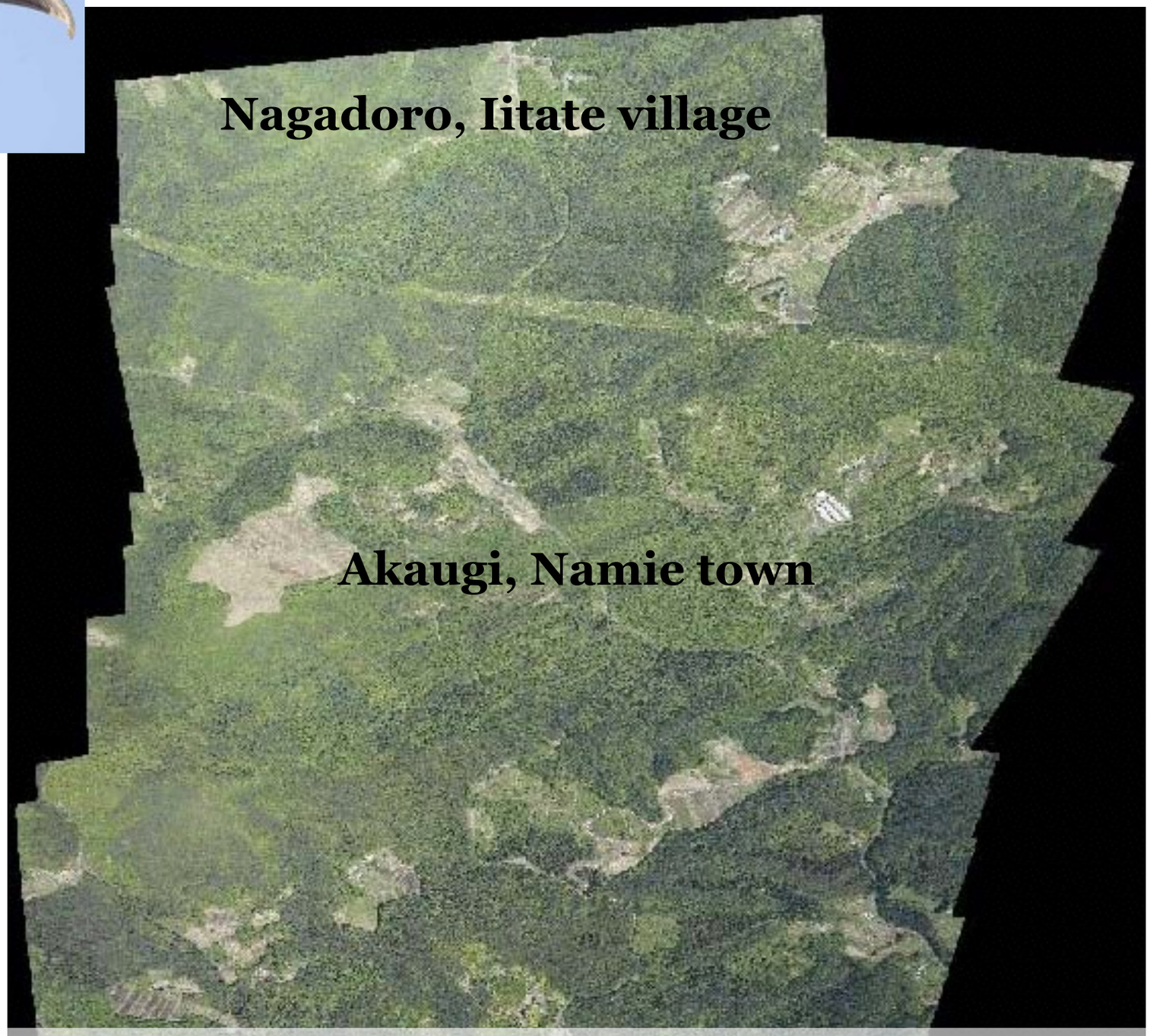
High RA

snow accumulation in winter

2012.1.31 Hiruzone, No.10

Landscape around Akaugi & Nagadoro

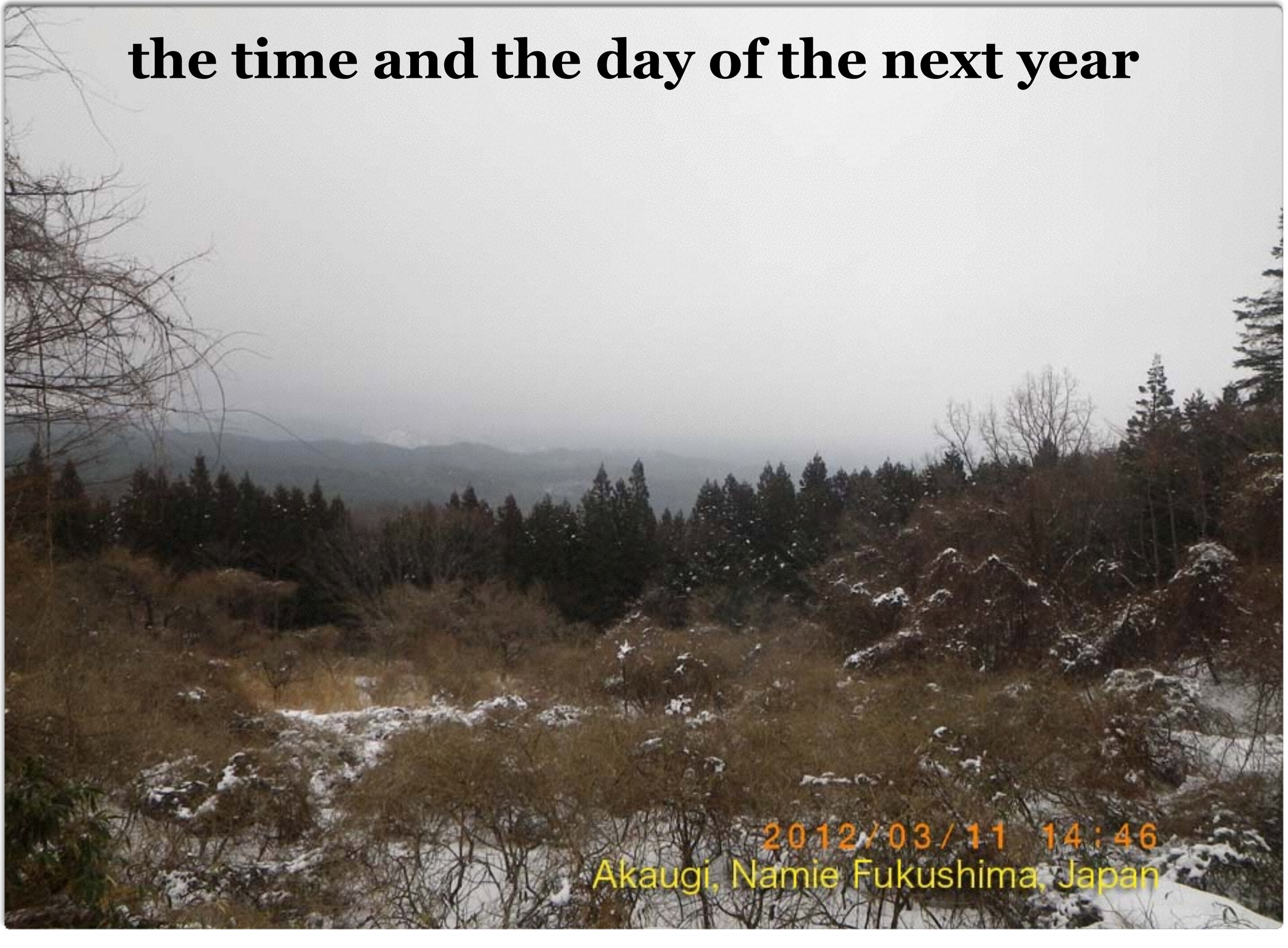
forest dominates



High RA

N

the time and the day of the next year



humid air

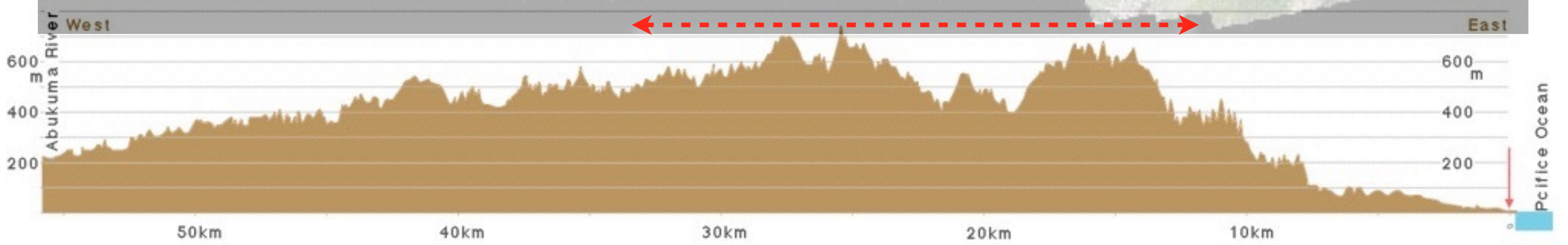
Yamakiya district of Kawabata Town

N

mixed forest and agricultural field

comparatively lower RA

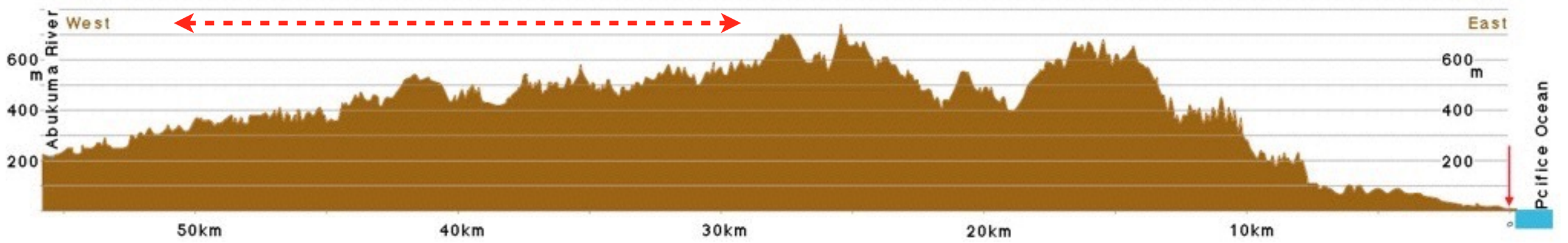
May, 2014 BIZWORKS Co.Ltd. Paramotor glider picture



Satoyama Landscape

pond
pine
cypress
orchard
mixed deciduous broad leaf
paddy
border
drain
grass
stream
mixed deciduous broad leaf
bank
2013.5.9 Kamitashiro, Yamakiya

gentle slope, forest and more open land



Satoyama & Yamazato Landscape

paddy fields

Many, many, many ・・・ measurements of dose rates

別記

摂取や出荷等を差し控えるよう要請している福島県産の食品について

（平成28年9月29日現在）

区分	品目	該当産出地 ※市町村名の表示は、野菜・果実類については昭和３８年１月１日現在、穀類については昭和２４年４月１日現在のものです。	差し控えるよう要請している内容
野菜	非結球性葉菜類	南相馬市（平成２４年３月３０日付け指示により設定された帰還困難区域に限る）、富岡町、大熊町、双葉町、浪江町、葛尾村（平成２４年３月３０日付け指示により設定された帰還困難区域に限る）、飯舘村	摂取・出荷
	結球性葉菜類		摂取・出荷
	アブラナ科花蕾類		摂取・出荷
	カブ		出荷
	ワサビ（畑において栽培されたものに限る）	伊達市、川俣町（山木屋の区域に限る）	出荷
	トウガラシ	浪江町	収穫
果実	ウメ	南相馬市（福島第一原子力発電所から半径２０km圏内の区域並びに旧計画的避難区域（平成２４年４月１６日から帰還困難区域、居住制限区域及び避難指示解除準備区域に設定）に限る）	出荷
	ビワ		
	ユズ		
	カキ		
	キウイフルーツ		
	あけび		
	ギンナン		
	クリ		
※６穀類	平成２３年産米		
	平成２４年産米		
	平成２５年産米		
	平成２６年産米		
	平成２７年産米		
	平成２８年産米		
山菜	くさそてつ（こごみ）	福島市、二本松市、伊達市、郡山市、田村市、相馬市、桑折町、国見町、川俣町、古殿町、三春町、広野町、楢葉町、大玉村、葛尾村	出荷
	くさそてつ（こごみ）（野生のものに限る）	会津美里町、南相馬市	出荷
	たけのこ	福島市、二本松市、伊達市、本宮市、郡山市、須賀川市、田村市、白河市、相馬市、南相馬市、いわき市、桑折町、川俣町、三春町、広野町、楢葉町、新地町、大玉村、天栄村、西郷村、川内村、葛尾村、富岡町、大熊町、双葉町、浪江町、飯舘村	出荷
	ふきのとう（野生のものに限る）	福島市、伊達市、本宮市、田村市、相馬市、南相馬市、桑折町、国見町、川俣町、広野町、楢葉町、葛尾村	出荷
	ぜんまい	二本松市、郡山市、須賀川市、田村市、相馬市、南相馬市、いわき市、川俣町、楢葉町、川内村、葛尾村	出荷
	ぜんまい（野生のものに限る）	広野町、大玉村	出荷
	たらのめ（野生のものに限る）	福島市、二本松市、伊達市、本宮市、郡山市、須賀川市、田村市、白河市、相馬市、南相馬市、いわき市、桑折町、川俣町、鏡石町、古殿町、鮫川村、石川町、玉川村、平田村、浅川町、三春町、小野町、広野町、新地町、大玉村、西郷村、泉崎村、鮫川村、川内村、葛尾村、楢葉町、富岡町、大熊町、双葉町、浪江町、飯舘村	出荷
	わらび	伊達市、南相馬市、いわき市、川俣町、楢葉町、鮫川村、葛尾村	出荷
	わらび（野生のものに限る）	福島市、二本松市、本宮市、広野町	出荷
	こしあぶら	福島市、二本松市、伊達市、本宮市、郡山市、須賀川市、田村市、白河市、相馬市、南相馬市、いわき市、桑折町、国見町、川俣町、鏡石町、古殿町、鮫川村、石川町、玉川村、平田村、浅川町、三春町、小野町、広野町、新地町、大玉村、西郷村、泉崎村、川内村、葛尾村、楢葉町、富岡町、大熊町、双葉町、浪江町、飯舘村	出荷
	こしあぶら（野生のものに限る）	只見町、西[illegible]	出荷
	ふき	葛尾村	出荷
	ふき（野生のものに限る）	桑折町、楢[illegible]	出荷
	うわばみそう（野生のものに限る）	須賀川市、[illegible]	出荷
	さんしょう（野生のものに限る）	いわき市	出荷
	うど（野生のものに限る）	須賀川市、[illegible]	出荷
	ねまがりたけ（野生のものに限る）	猪苗代町	出荷
	おおばぎぼうし（うるい）（野生のものに限る）	郡山市	出荷
きのこ	原木しいたけ（露地）	飯舘村	出荷
		福島市、二[illegible]町、浪江町、[illegible]	出荷
	原木しいたけ（施設）	川俣町	出荷
	原木しいたけ（施設）（県の定める管理計画に基づき管理されるものを除く）	伊達市	出荷
	原木なめこ（露地）	相馬市、い[illegible]	出荷
	野生きのこ（菌根菌類、腐生菌類）	南相馬市、[illegible]	出荷
		福島市、二[illegible]町、鏡石町、[illegible]町、三島町、[illegible]村、平田村、[illegible]	出荷
樹実類	くるみ	南相馬市	出荷
畜産物	原乳	田村市（福島第一原子力発電所から半径２０km圏内の区域に限る）、南相馬市（福島第一原子力発電所から半径２０km圏内の区域並びに旧計画的避難区域（平成２４年４月１６日から帰還困難区域、居住制限区域及び避難指示解除準備区域に設定）に限る）、川俣町（山木屋の区域に限る）、楢葉町（福島第一原子力発電所から半径２０km圏内の区域に限る）、富岡町、大熊町、双葉町、浪江町、川内村（福島第一原子力発電所から半径２０km圏内の区域に限る）、葛尾村、飯舘村	出荷
	牛（１２月齢未満のもの、及び県の定める出荷・検査方針に基づき管理されるものを除く）	全市町村	県外への移動
	牛（県の定める出荷・検査方針に基づき管理されるものを除く）	全市町村	と畜場への出荷
水産物	ヤマメ（養殖により生産されたものを除く）	新田川（支流を含む）	摂取・出荷・採捕
		秋元湖、猪苗代湖、檜原湖及び小野川湖並びにこれらの湖に流入する河川（支流を含む。ただし、酸川（支流を含む。）を除く。）、本県内の阿武隈川（支流を含む）、真野川（支流を含む）、太田川（支流を含む）、日橋川のうち東京電力株式会社金川発電所の上流（支流を含む）	出荷・採捕
	ウグイ	秋元湖、猪苗代湖、小野川湖及び檜原湖並びにこれらの湖に流入する河川（支流を含む。ただし、酸川及びその支流を除く。）、日橋川のうち東京電力株式会社金川発電所の上流（支流を含む）、真野川（支流を含む）並びに本県内の阿武隈川（支流を含む）	出荷・採捕
	イワナ（養殖により生産されたものを除く）	秋元湖、小野川湖及び檜原湖並びにこれらの湖に流入する河川（支流を含む）、長瀬川（酸川との合流点から上流の部分に限る）並びに本県内の阿武隈川（支流を含む）	出荷・採捕
	モクズガニ	真野川（支流を含む）	採捕
	アユ（養殖により生産されたものを除く）	真野川（支流を含む）、新田川（支流を含む）及び本県内の阿武隈川のうち信夫ダムの下流（支流を含む）	出荷・採捕
	ホンモロコ（養殖により生産されたものに限る）	川内村	出荷
	コイ（養殖により生産されたものを除く）	秋元湖、小野川湖及び檜原湖並びにこれらの湖に流入する河川（支流を含む）、阿賀川のうち大川ダムの下流（支流を含む。ただし、東京電力株式会社金川発電所の上流及び片門ダムの上流を除く。）、長瀬川（酸川との合流点から上流の部分に限る）並びに本県内の阿武隈川（支流を含む）	出荷・採捕
	フナ（養殖により生産されたものを除く）	秋元湖、小野川湖及び檜原湖並びにこれらの湖に流入する河川（支流を含む）、阿賀川のうち大川ダムの下流（支流を含む。ただし、東京電力株式会社金川発電所の上流及び片門ダムの上流を除く。）、長瀬川（酸川との合流点から上流の部分に限る）、真野川（支流を含む）並びに本県内の阿武隈川のうち信夫ダムの下流（支流を含む）	出荷・採捕
	ウナギ	本県内の阿武隈川（支流を含む）	出荷・採捕
	ドジョウ（養殖により生産されたものに限る）	郡山市	出荷
	イカナゴ（稚魚を除く。）、イシガレイ、ウスメバル、ウミタナゴ、カサゴ、キツネメバル、クロウシノシタ、クロソイ、クロダイ、サクラマス、シロメバル、スズキ、ヌマガレイ、ババガレイ、ムラソイ、ヒノスガイ	最大高潮時海岸線上宮城福島両県界の正東の線、我が国排他的経済水域の外縁線、最大高潮時海岸線上福島茨城両県界の正東の線及び福島県最大高潮時海岸線で囲まれた海域	出荷

Food

agricultural products and natural resources of many kind

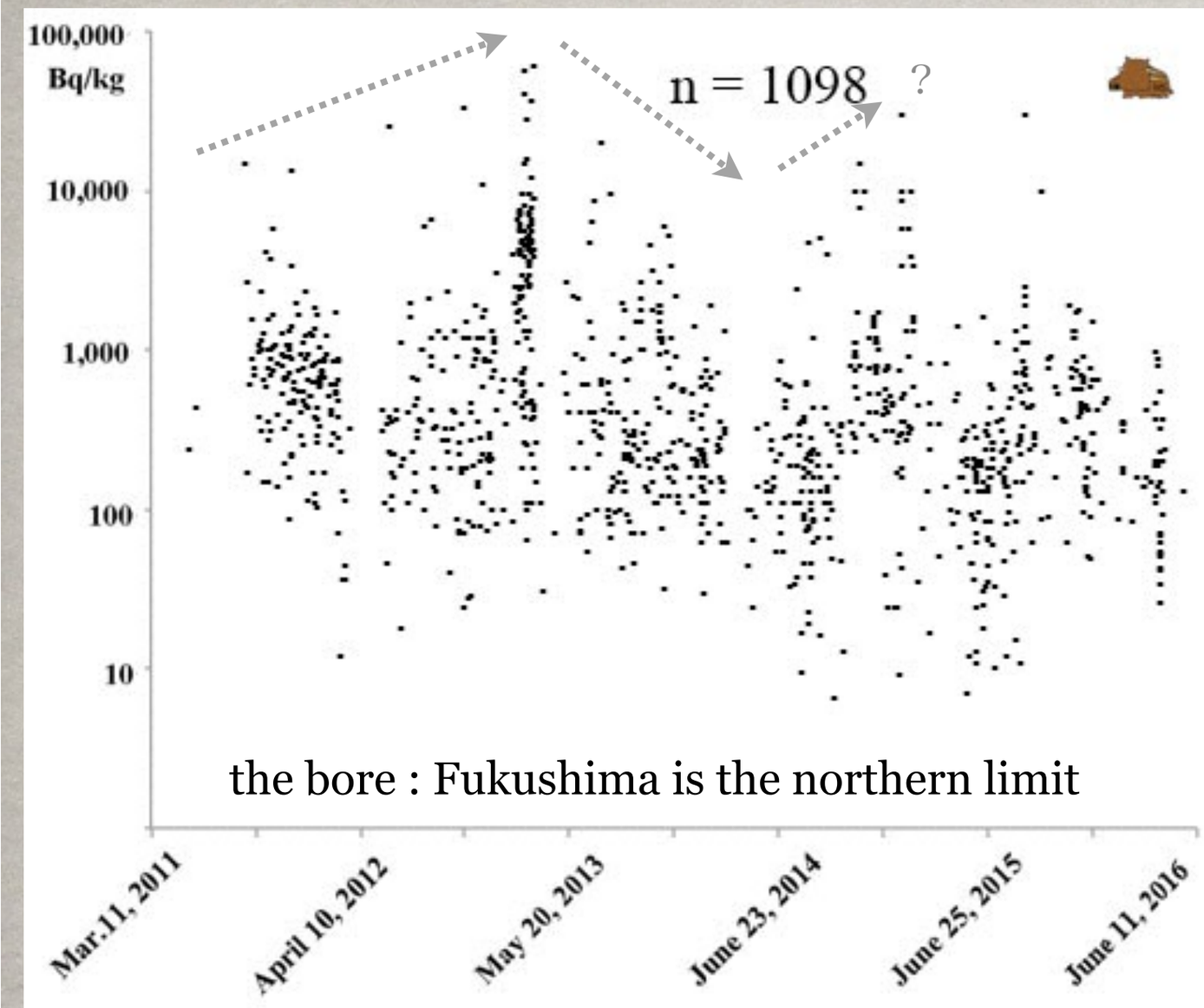
mushrooms, vegetables, fruits, bamboo shoots, milk, meat,

fish, crabs, etc.

http://www.pref.fukushima.lg.jp/uploaded/attachment/184258.pdf

Wildlife

Wild Boar and Black Bear
Cs134+Cs137 dose rate in the muscle

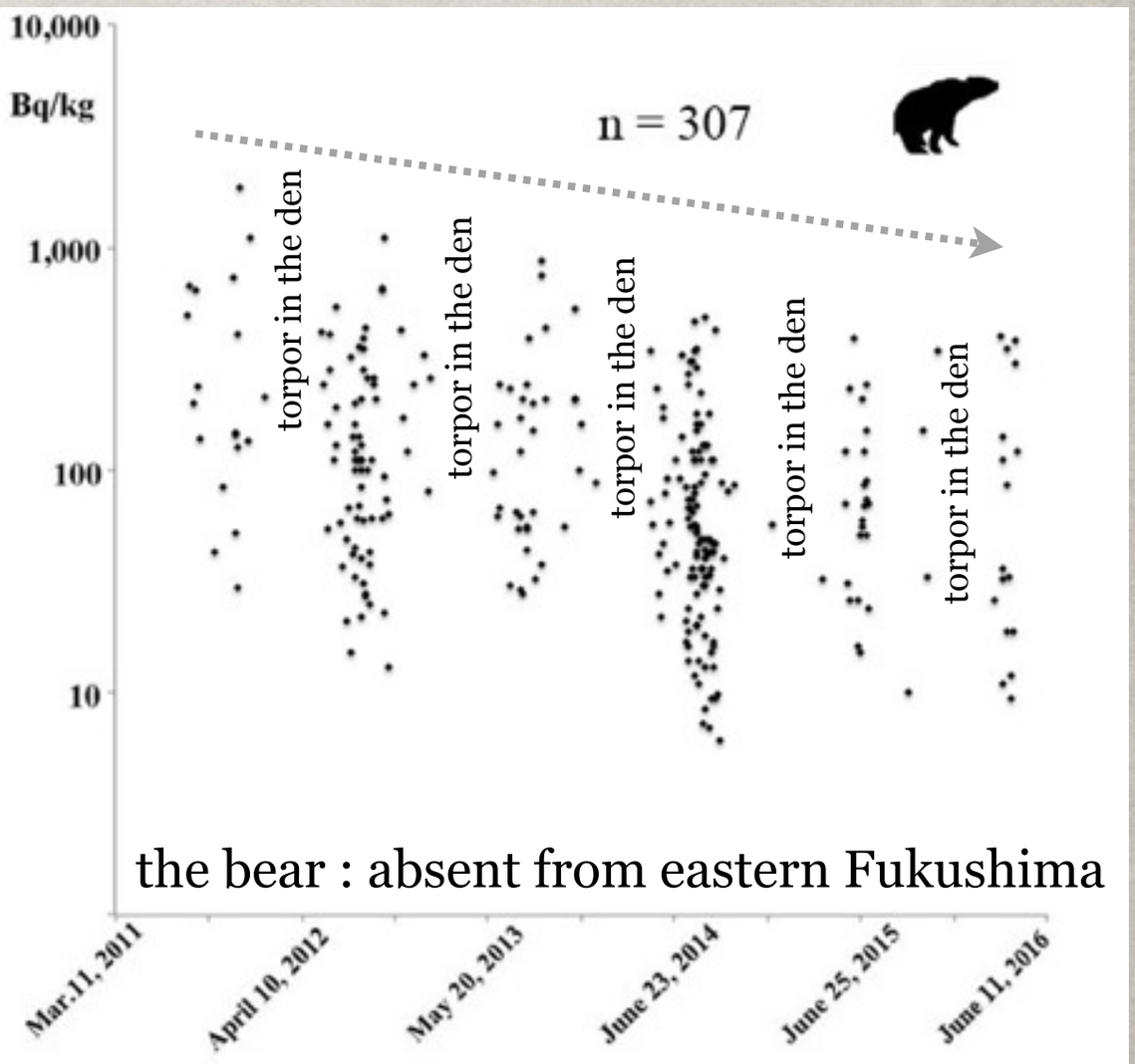


the bore : Fukushima is the northern limit

http://www.pref.fukushima.lg.jp/uploaded/attachment/158357.pdf

※no data at the highest dose area
in the earliest period

published data by Fukushima Prefecture Government

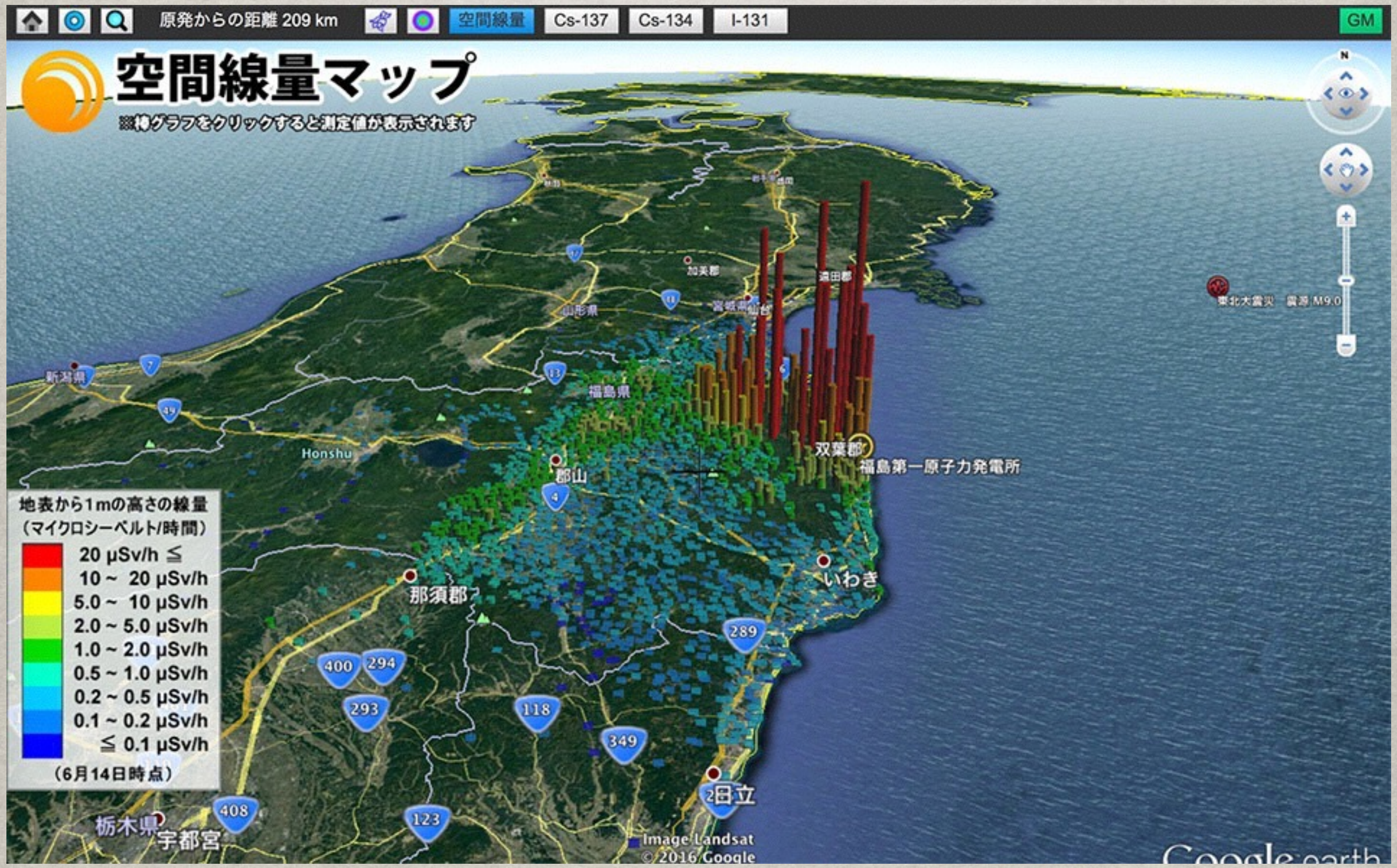


the bear : absent from eastern Fukushima

http://www.pref.fukushima.lg.jp/uploaded/attachment/174561.pdf

Many, many, many ・・・ measurements of dose rates

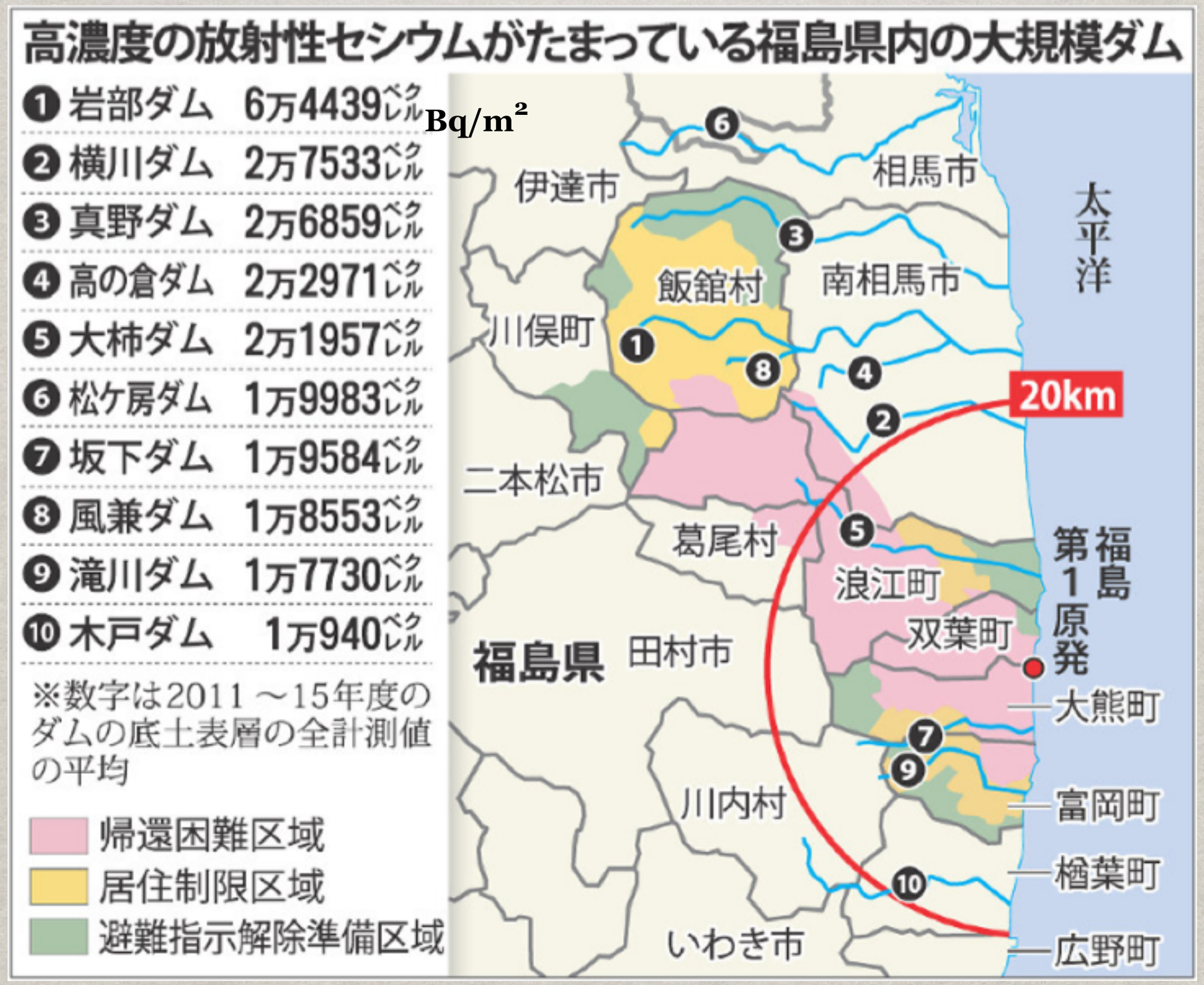
Soil



http://www.rcnp.osaka-u.ac.jp/dojo/

Many, many, many ・・・ measurements of dose rates

dam lake beds

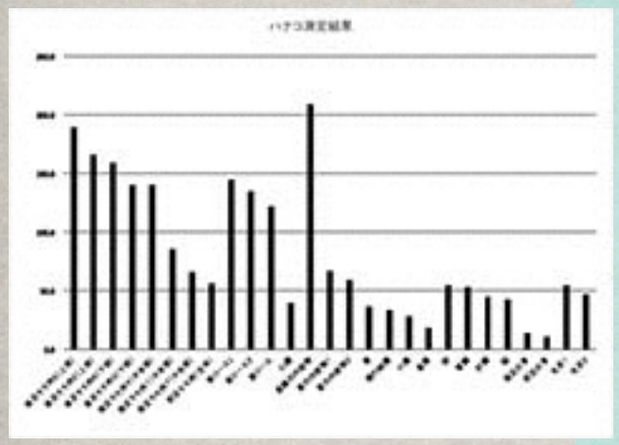


press by Ministry of the Environment, Japan 2016

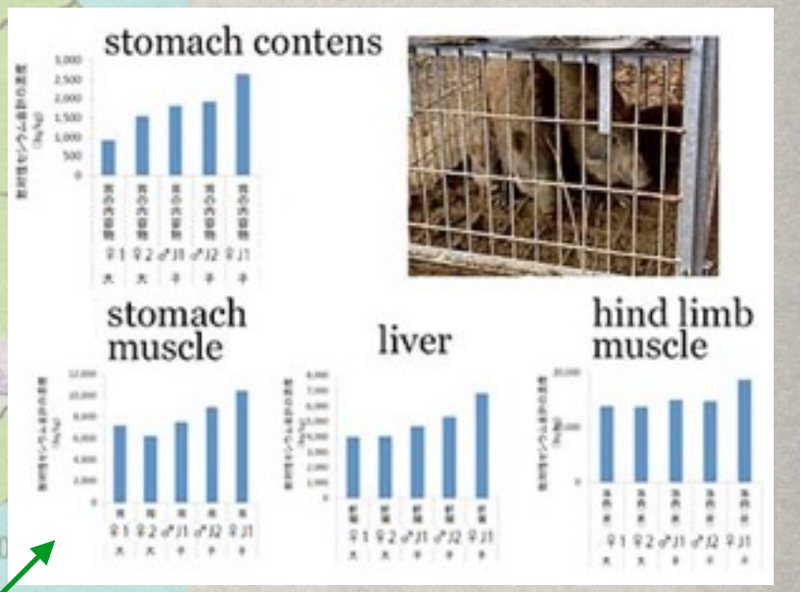
http://headlines.yahoo.co.jp/hl?a=20160925-00000011-mai-soci [Ken Ishida reads, on 13:00, 25 Sep. 2016]

Many, many, many ・・・ measurements of dose rates

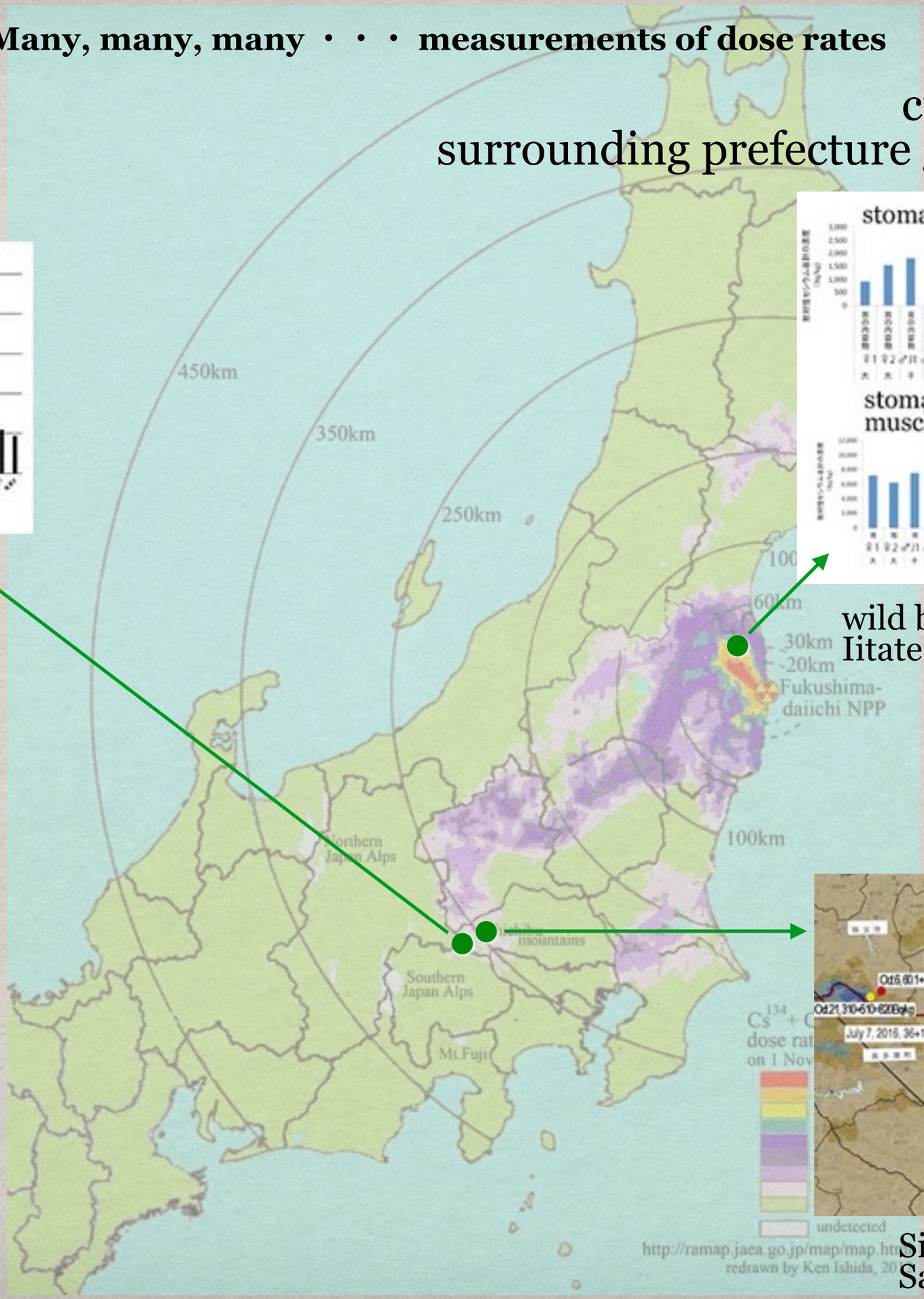
citizen science
surrounding prefecture governments



Sika deer organs ,
10 ~ 210 Bq/kg,
Chichibu citizen group



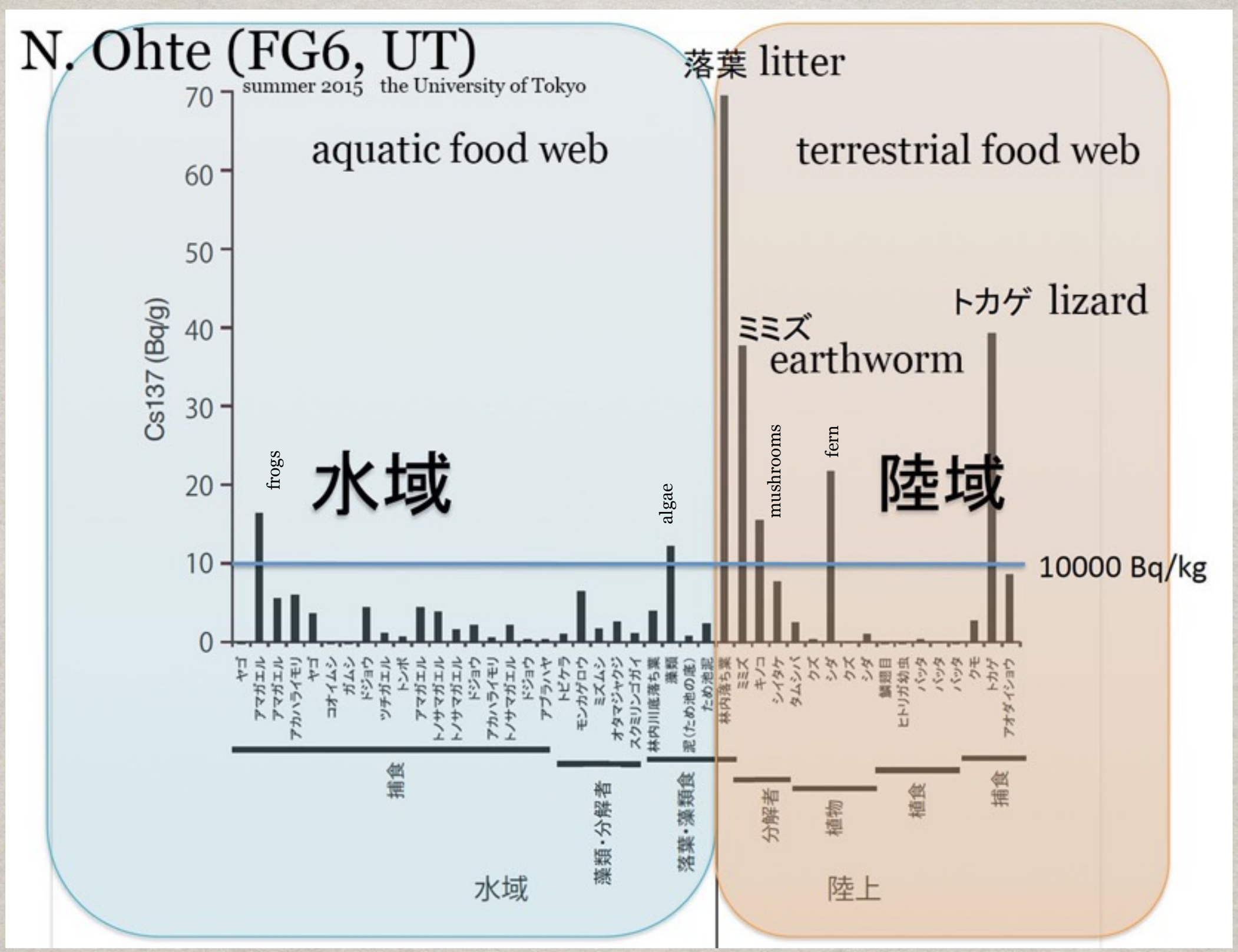
wild boar 1000 ~ 18000 Bq/kg,
Iitate citizen group



Sika deer 220 ~ 820 Bq/kg,
Saitama Prefecture

Many, many, many ・・・ measurements of dose rates

Food Web



Murakami, Ohte *et al.* (2013, 2015)

Many, many measurements of dose rates and few ecological consequence

four ecological consequences of Fukushima wildlife

examples,

- butterfly
- aphid
- fir
- bird

1. butterfly

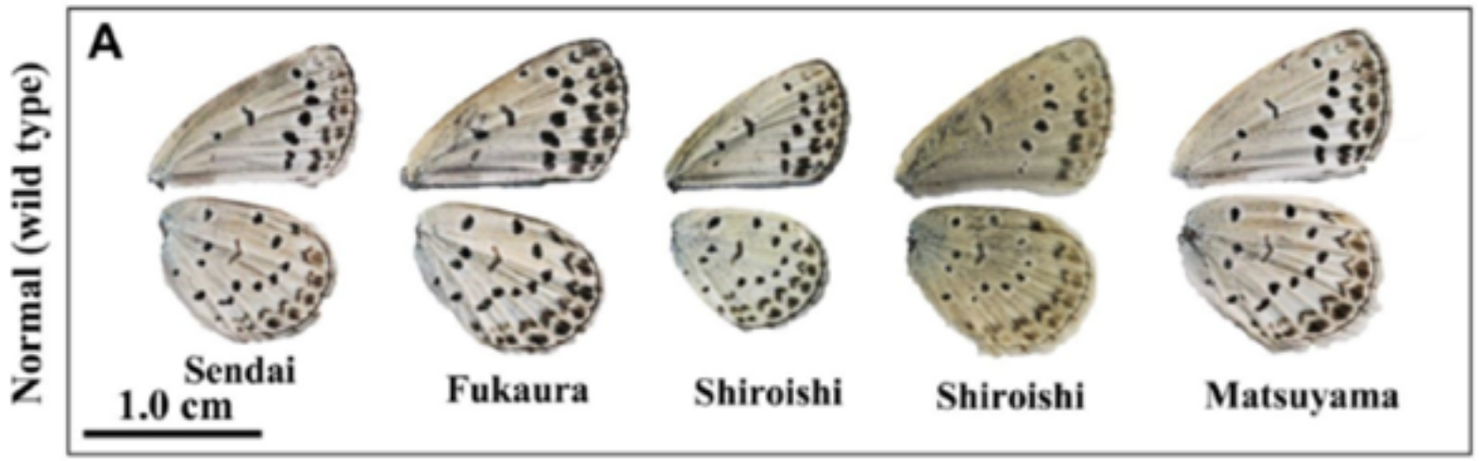
J. Ohtaki Labo. homepage

http://w3.u-ryukyu.ac.jp/fukushimaproj.html

These aberrants were found first at Fukushima in 2011.
Also antenna and wing anatomical aberrants were found.

2011

F1(子)・F2(孫)世代の斑紋異常



abnormal morp
by a heat shock

冷却ショック個体
【表現型可塑性】

斑紋変化は「異常」ではない

斑紋変化のみで他の形態異常は伴わない

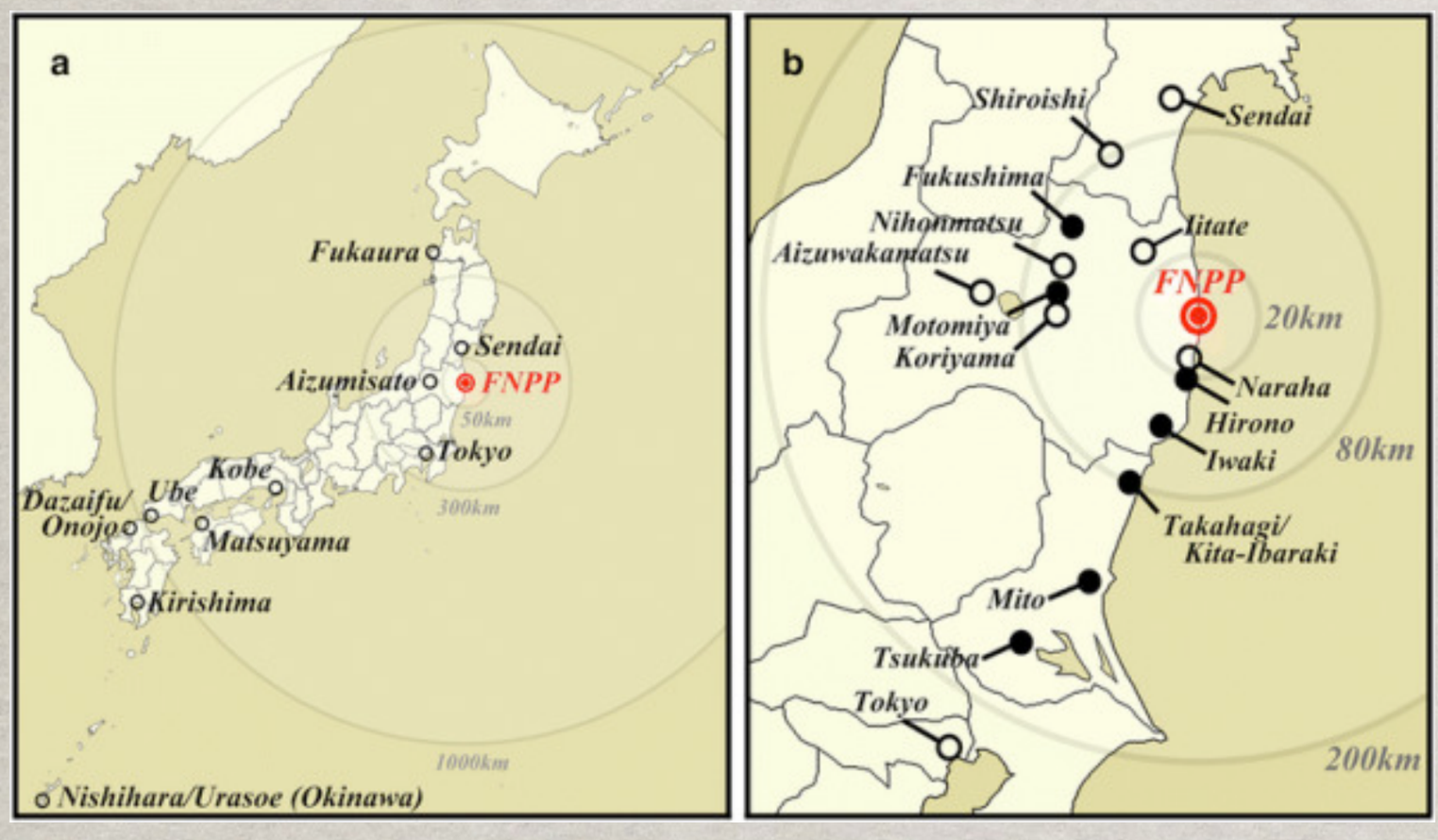
多様で法則性のない斑紋異常：他の形態異常・不妊・行動異常を伴うことが多い

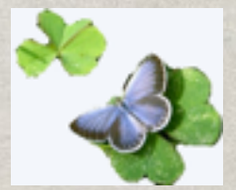
19

pale grass blue butterfly

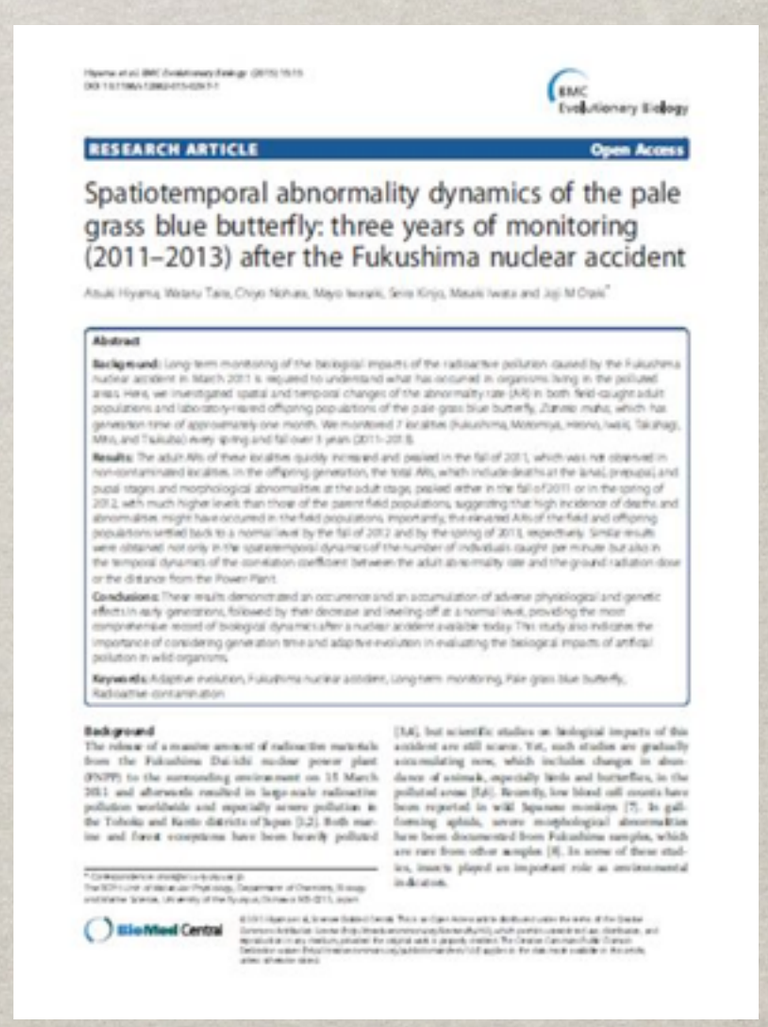
genetic effect

population recovered, abnormality decrease much in 3 years





close to the north limit of the species distribution



RESEARCH ARTICLE Open Access

Spatiotemporal abnormality dynamics of the pale grass blue butterfly: three years of monitoring (2011–2013) after the Fukushima nuclear accident

Abstract

Background: Long-term monitoring of the biological impacts of the radioactive pollution caused by the Fukushima nuclear accident in March 2011 is required to understand what has occurred in organisms living in the polluted areas. Here, we investigated spatial and temporal changes of the abnormality rate (Ab) in both field-caught adult populations and laboratory-reared offspring populations of the pale grass blue butterfly, *Zizeeria maha*, which has generation time of approximately one month. We monitored 7 localities (Fukushima, Motomiya, Hirono, Iwaki, Takahagi, Mito, and Tsukuba) every spring and fall over 3 years (2011–2013).

Results: The adult Ab's of these localities quickly increased and peaked in the fall of 2011, which was not observed in non-contaminated localities. In the offspring generation, the total Ab's, which include deaths at the larval, prepupal and pupal stages and morphological abnormalities at the adult stage, peaked either in the fall of 2011 or in the spring of 2012, with much higher levels than those of the parent field populations, suggesting that high incidence of deaths and abnormalities might have occurred in the field populations. Importantly, the elevated Ab's of the field and offspring populations settled back to a normal level by the fall of 2012 and by the spring of 2013, respectively. Similar results were obtained not only in the spatiotemporal dynamics of the number of individuals caught per minute but also in the temporal dynamics of the correlation coefficient between the adult abnormality rate and the ground radiation dose or the distance from the Power Plant.

Conclusions: These results demonstrated an occurrence and an accumulation of adverse physiological and genetic effects in early generations, followed by their decrease and leveling off at a normal level, providing the most comprehensive record of biological dynamics after a nuclear accident available today. This study also indicates the importance of considering generation time and adaptive evolution in evaluating the biological impacts of anthropogenic pollution in wild organisms.

Keywords: Adaptive evolution, Fukushima nuclear accident, Long-term monitoring, Pale grass blue butterfly, Radioactive contamination

Background

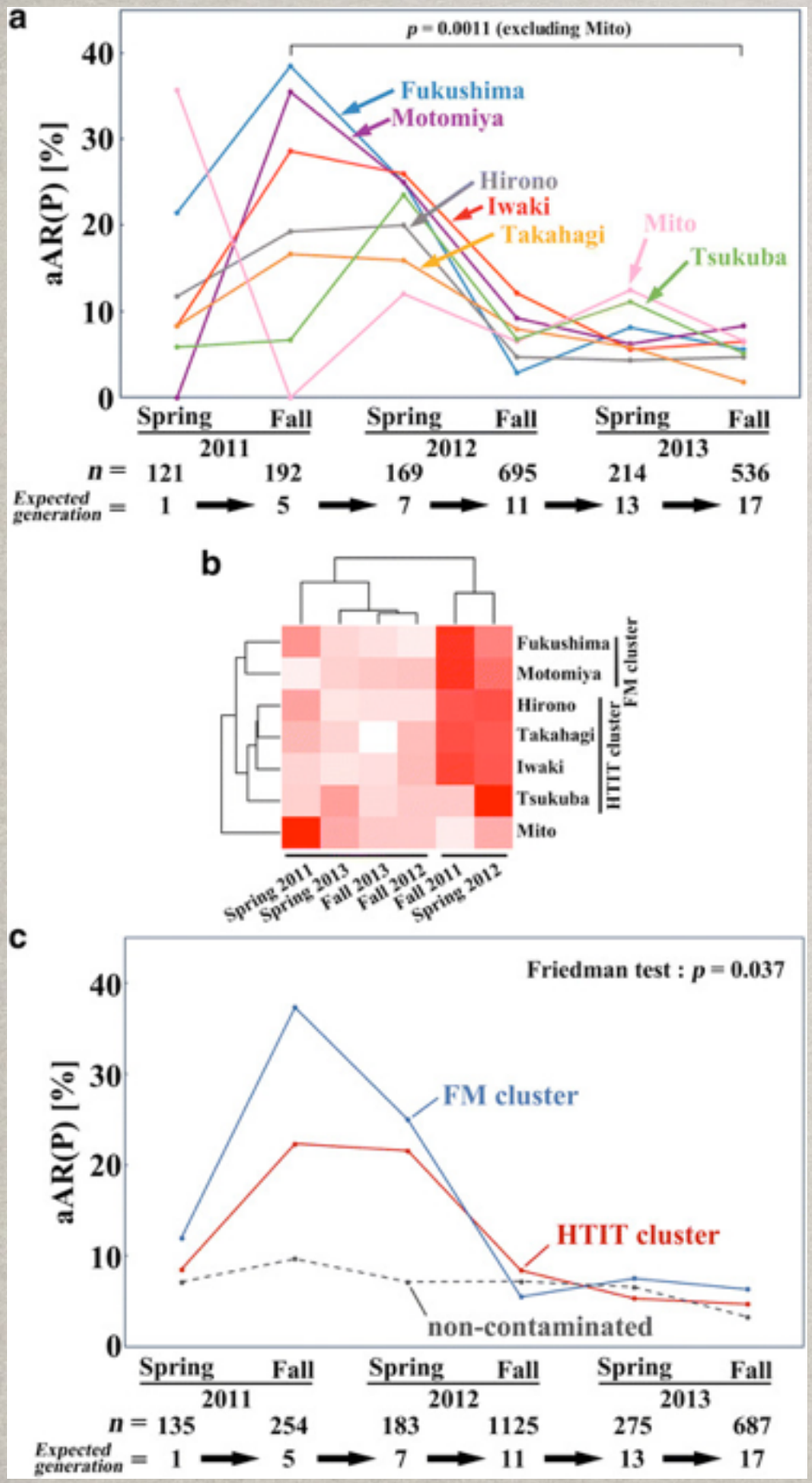
The release of a massive amount of radioactive materials from the Fukushima Dai-ichi nuclear power plant (FNPP) to the surrounding environment on 15 March 2011 and afterwards resulted in large-scale radioactive pollution worldwide and especially severe pollution in the Tohoku and Kanto districts of Japan [1,2]. Both marine and forest ecosystems have been heavily polluted [3,4], but scientific studies on biological impacts of this accident are still scarce. Yet, such studies are gradually accumulating now, which includes changes in abundance of animals, especially birds and butterflies, in the polluted areas [5,6]. Recently, low blood cell counts have been reported in wild Japanese monkeys [7]. In gall-forming aphids, severe morphological abnormalities have been documented from Fukushima samples, which are rare from other samples [8]. In some of these studies, insects played an important role as environmental indicators.

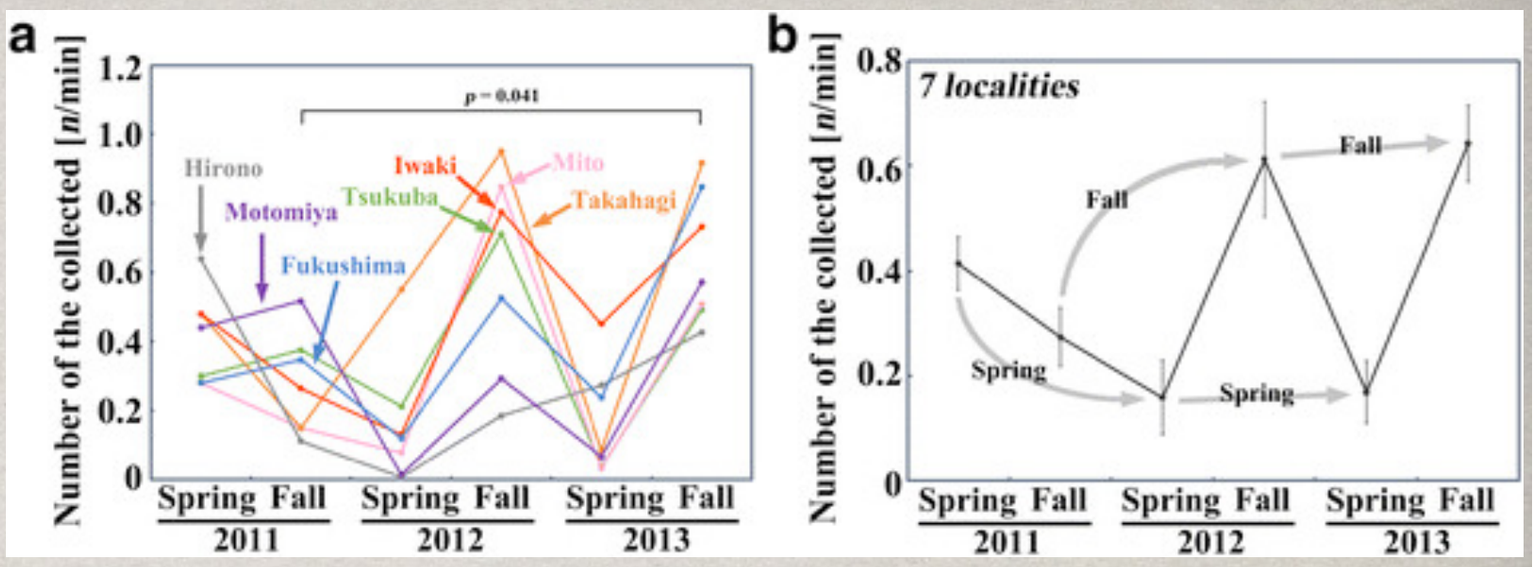
BioMed Central

capture adult butterflies in spring and autumn

capture / net swing time (min.)

count wing pattern aberrants





cap. rate / min. has recovered in 2012

higher density in autumn than in spring

the team is continuing the tests

wild individuals < ?

abnormal rate had decreased in autumn 2012

2. aphid

From Akimoto (2013)

Some of anatomical aberrants were found first at Fukushima in 2012.

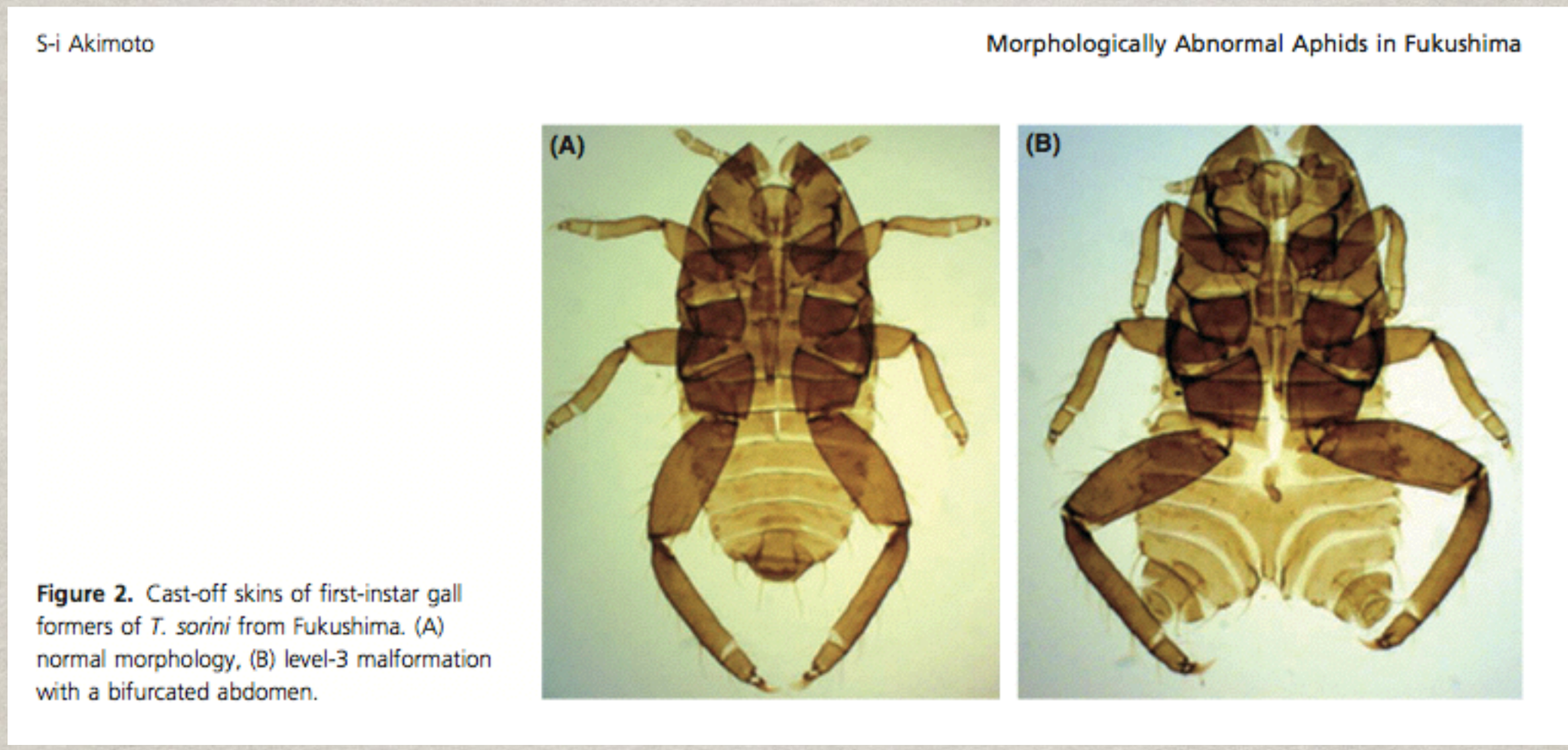


Figure 2. Cast-off skins of first-instar gall formers of *T. sorini* from Fukushima. (A) normal morphology, (B) level-3 malformation with a bifurcated abdomen.

no genetic effect

From Akimoto (2013)

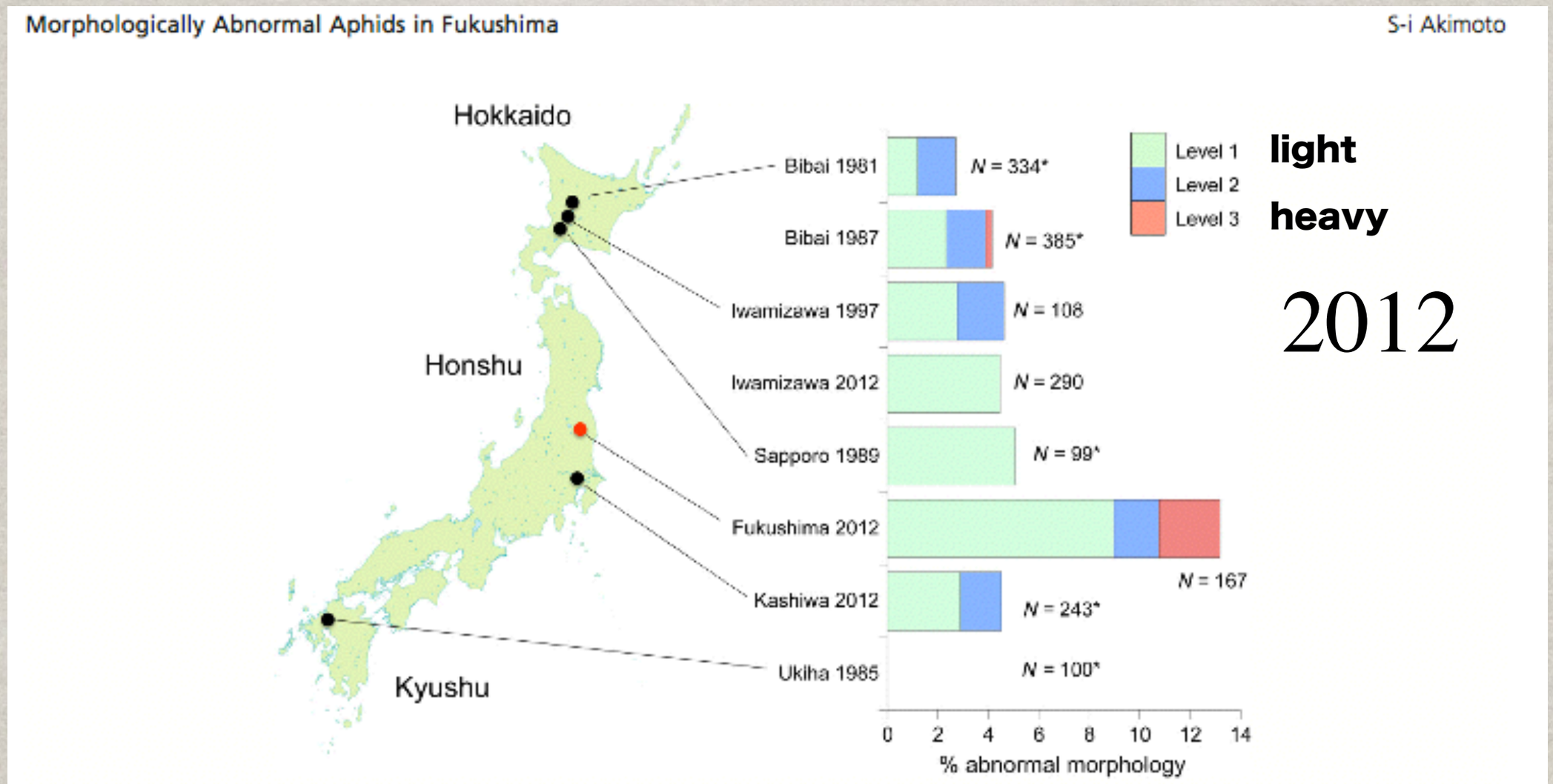


Figure 1. Percentage abnormal morphologies in *Tetraneura sorini* first-instar gall formers from eight populations. Asterisks in sample sizes indicate that first instars were collected from buds, whereas nonasterisked figures indicate that first-instars' cast-off skins were collected from galls. Level 1, slight abnormalities included the atrophy or bending of one leg (Fig. S2A,B), small ganglia on the ventral surface (Fig. S2C), partial fusion of adjacent abdominal tergites (Fig. S2D), and tissue necrosis in one leg or antenna (Fig. S3A,B). Level 2, abnormalities included the atrophy or bending of two legs and tissue necrosis in two or more appendages. I categorized the complete or partial loss of one appendage of first instars as level 2 (Fig. S3C,D). Level 3, intense abnormalities included the loss of two or more appendages, the loss of one leg and atrophy of another leg, the appearance of new features, and conspicuous asymmetry in bilateral characters.

Abnormal rate decreased in Fukushima in 2013.

3. *Abies firma* shoots

From Watanabe *et al.* (2015)

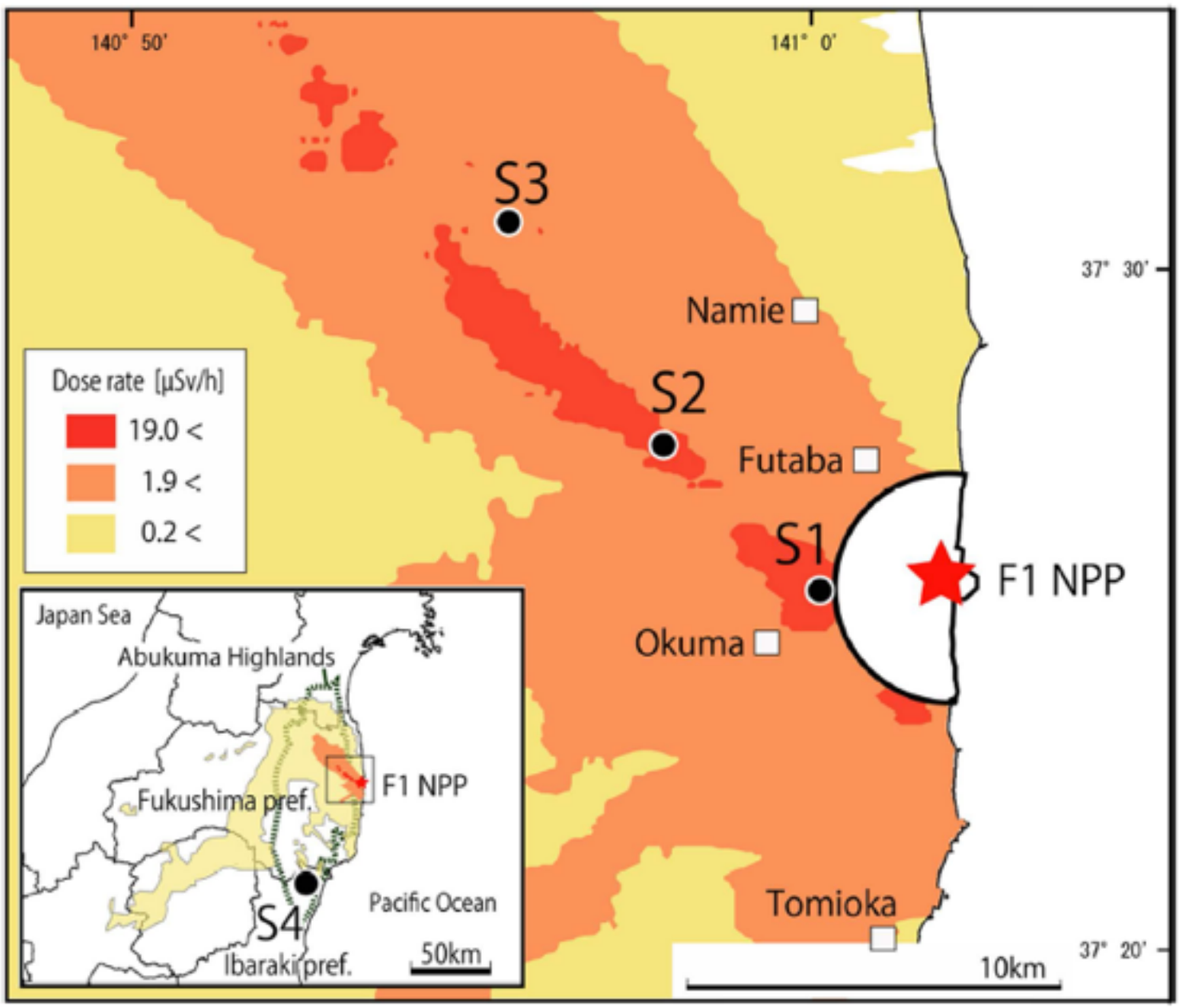
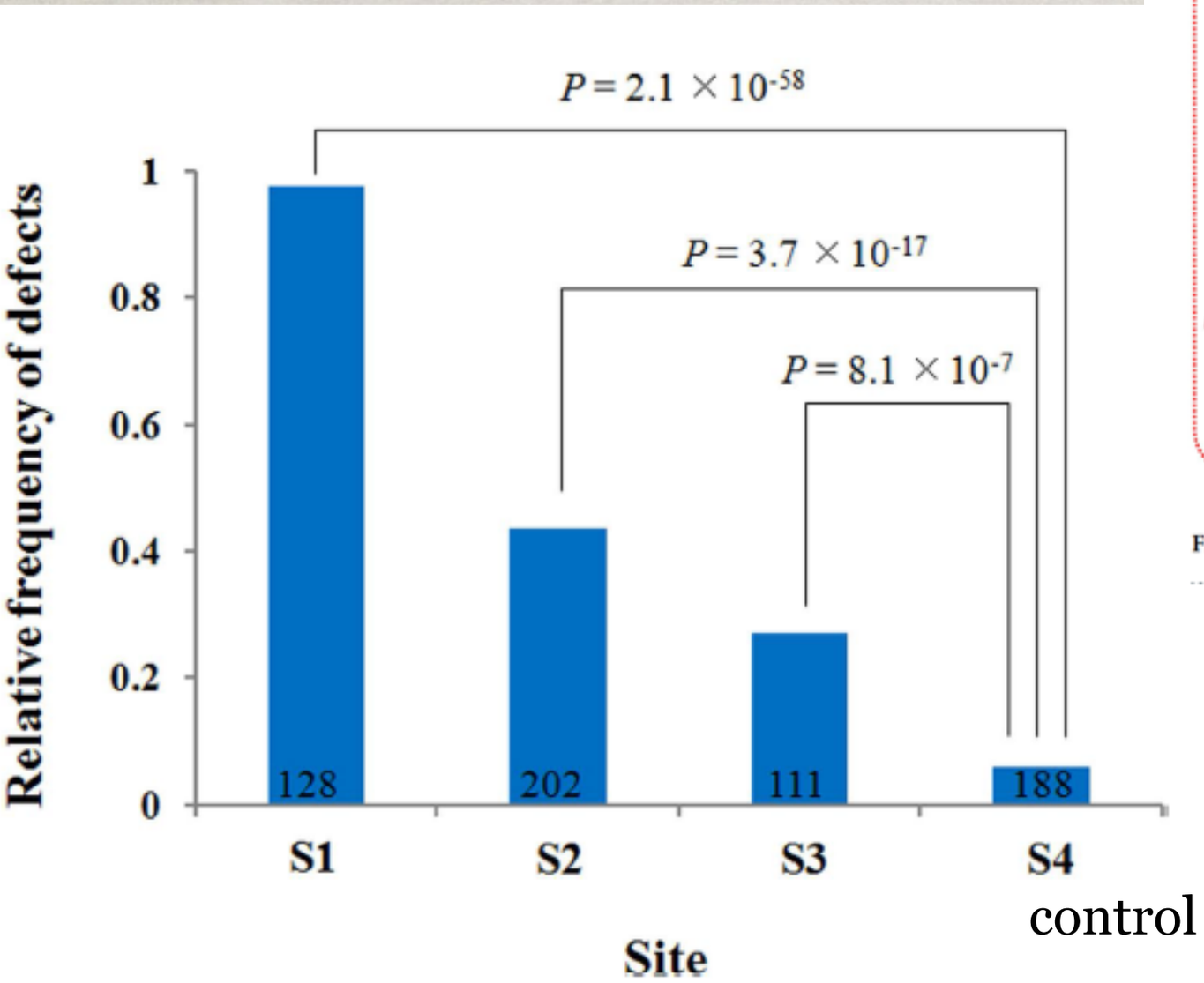


Figure 2. Map showing the observation sites. A red star indicates the location of the Fukushima Daiichi Nuclear Power Plant. The base map was modified from the Digital Japan Portal Web Site (Geospatial Information Authority of Japan; GSI). Airborne monitoring results on 2013.11.19; the "Extension site of distribution map of radiation dose, etc.,/Digital Japan"[13] was used as the source of the distribution of radiation dose.

northern limit

cf) 4. bush warbler study like plan

from Watanabe et al. (2015)



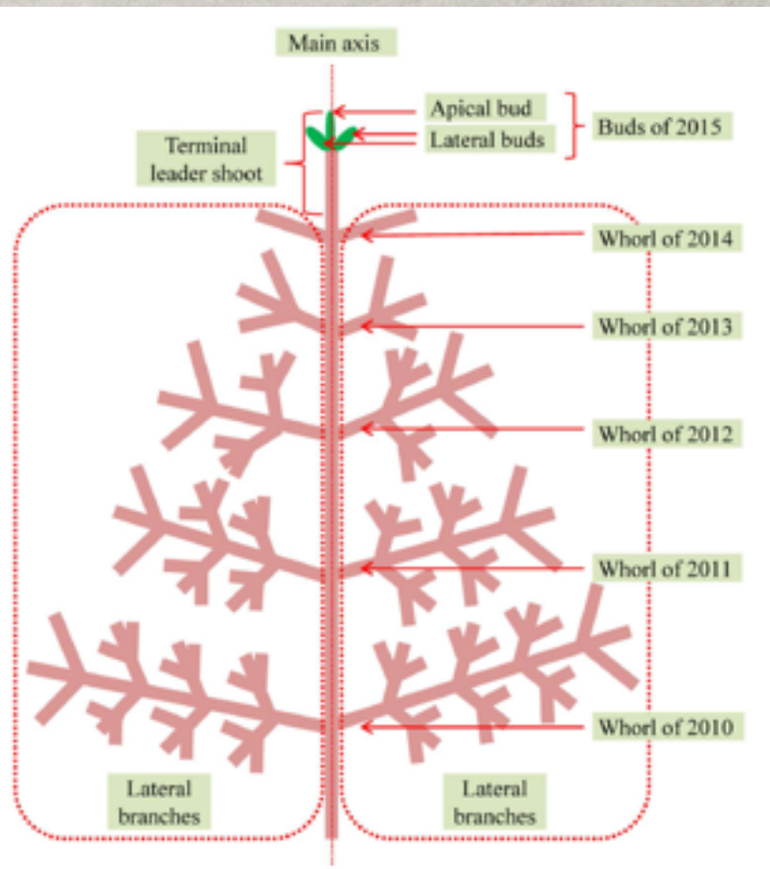


Figure 1. Schematic diagram of Japanese fir tree in January 2015.

control

Figure 4. Relative frequency of main axis defects in Japanese fir trees from different sites. The defects were counted by the observation of 5 annual whorls from the top of the trees. Trees with deleted or dead leader shoots in the lower whorls were excluded from observation; therefore the observed tree number for defects (n: indicated in the graph) were different from the total number of observed trees (Table 1). Bonferroni-corrected *p*-values are presented using Chi-square tests with df = 1.

4. bird *(Cettia diphone)*

Abukuma mountains

alt. 600～800m

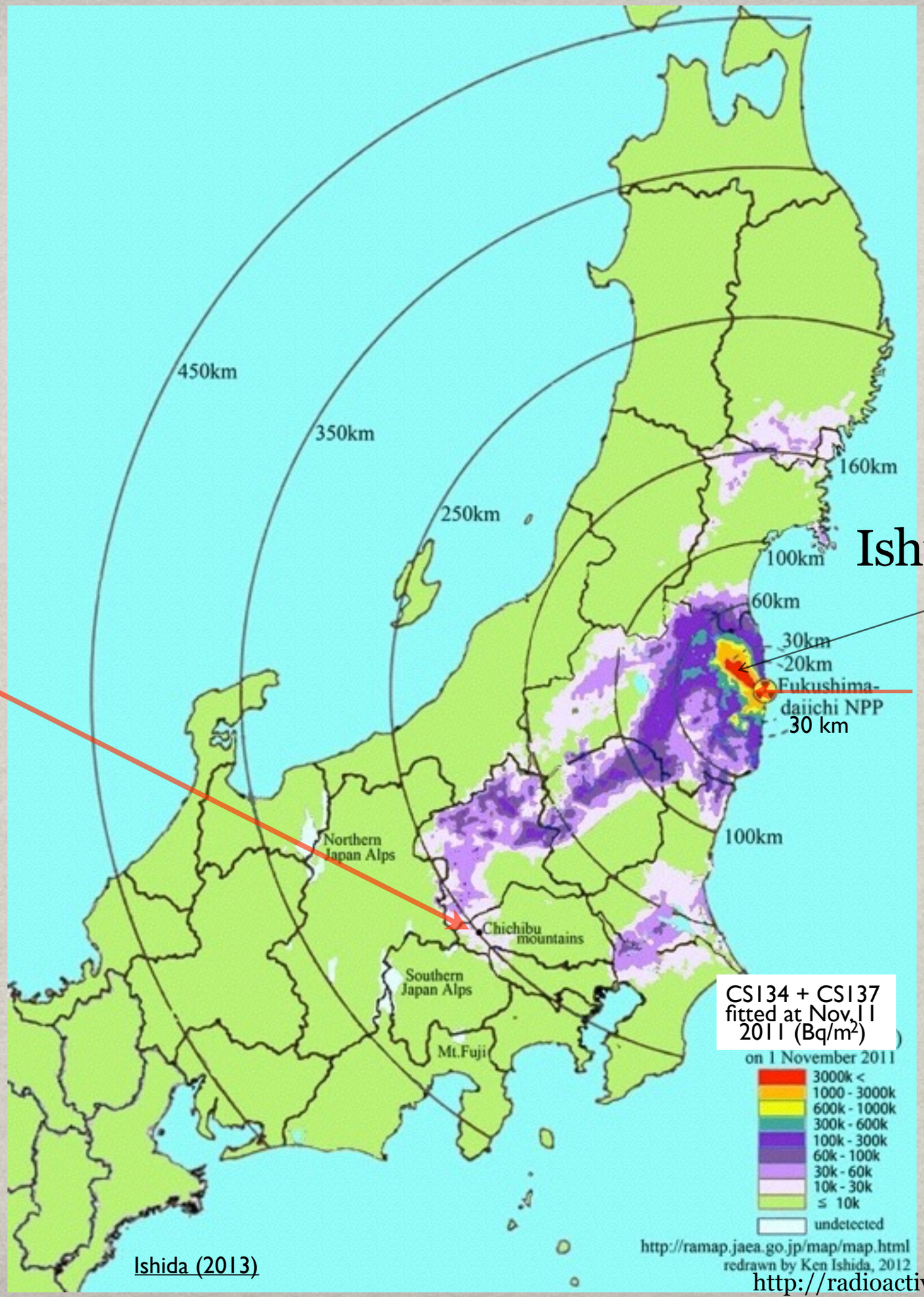
~170 km N - S,
(~ 50 km E - W)

cf) 3. fir study research plan

bush warbler

control

Chichibu Mts.



Ishida (2013)

Ishida's research area

F1 NPP

http://radioactivity.mext.go.jp/en/list/203/list-1.html

radio autography feather images

August 2011

3-day exposure

very short period

石田先生
EtOH洗浄後の羽

・・・効果なし！

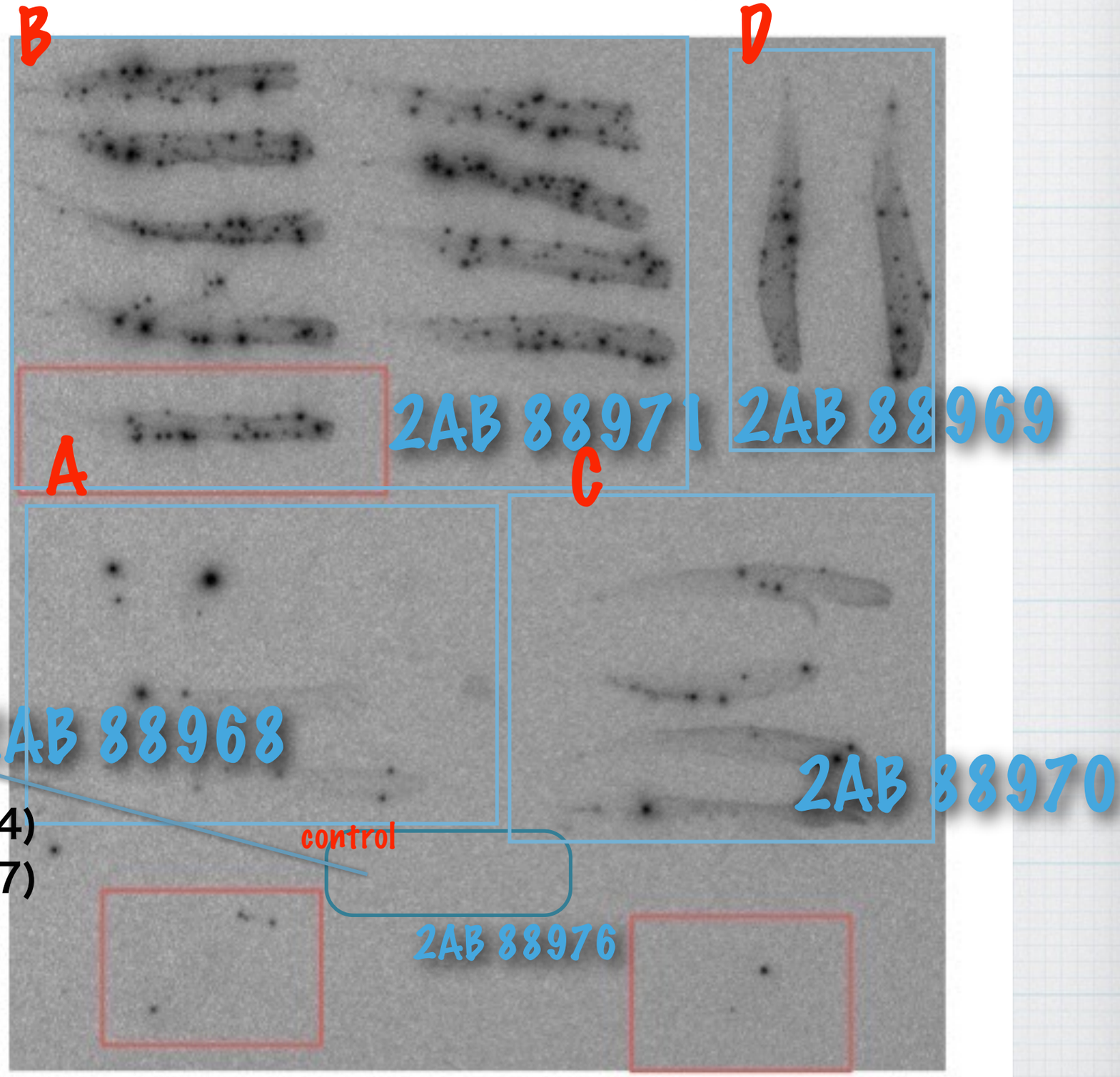
no image from October feathers

washed feather

赤枠が洗浄した羽と、
その時の脱脂綿2つ

no image for a feather from Chichibu
(∴ K40 is litte)

site B, D
B 50～230Bq/g (Cs134)
80～320Bq/g (Cs137)
D



IP test & nuclide analysis by Prof. K. Tanoi (BRC, U. Tokyo)

2012

BW feather contamination

change of contamination since August 2011

contamination -> lower, more scattered

~530 kBq/kg → ~120 kBq/kg

about a fifth

less and more scattered among feathers later (2013 ~)

ecological decrease = move of Cs's

conspicuous lesion and black head skin, bare on a male

2011

1 of the 3 in high dose area, all males

August, molting season

*, Other two examples of the same lesion in Wakayama prefecture in 2016

All were normal in 2012 ~ 2014 (n = 27)
2 of 6 in July, and 2 of 6 in August ; 3 of 5 totally were abnormal

2015

July and August

black head skin, bare

sequential observation of individuals in the wild (ecological)

2016

July and August

4 of 5 in July, and 5 of 6 in August ; 6 of 8 totally were abnormal
all the 6 males, 1 normal female

black head skin, bare

*, 1 in low does area was also abnormal

Tsushima

Akaugi

**, sequential observation of individuals in the wild (ecological)

other many observations and dose measurement of wildlife, some consequences of genetic - organ level dose effects

- Bird counts (Mousseau & Møller)
- Siberian Owl nest (Nishiumi)
- Tit nest box (WBSJ, Matsui &IRSN)
- Bird banding (MAPS, Nakamura & YIO)
- Mice (Yamada & FFPRI, NIE etc.)
- Bird capture (Murakami & Ohte)
- Insects (Ohtaki, Akimoto, … ?)
- Fish (Kaneko, Nakajima, … ?)
- Frogs and other amphibians ?
-
- Cattle (Okada, Fukushima Prefecture, … , …)

- There are a wide range of citizen scientists and activists. I know only a small part.

SUCCESSION IN PROCESSING

concluding remarks,

Fukushima-daiichi nuclear power plant accident and ecological consequence.

- **First one or two years were ecologically significant period in Fukushima.**
- **Ecological consequences are dynamic and continuing.**
- **Population level consequences are left to be detected, long term monitoring might show the recovery.**

- **Ecosystem level consequences will be analyzed by assembling and integrating the data, which is now collected individually at each research group.**

- **Scale , hierarchy, dynamic concept should be rethought on the integration.**