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IS NON-HUMAN SPECIES RADIOSENSIVITY IN THE LAB A GOOD INDICATOR OF RADIOSENSITIVITY IN THE WILD ?

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

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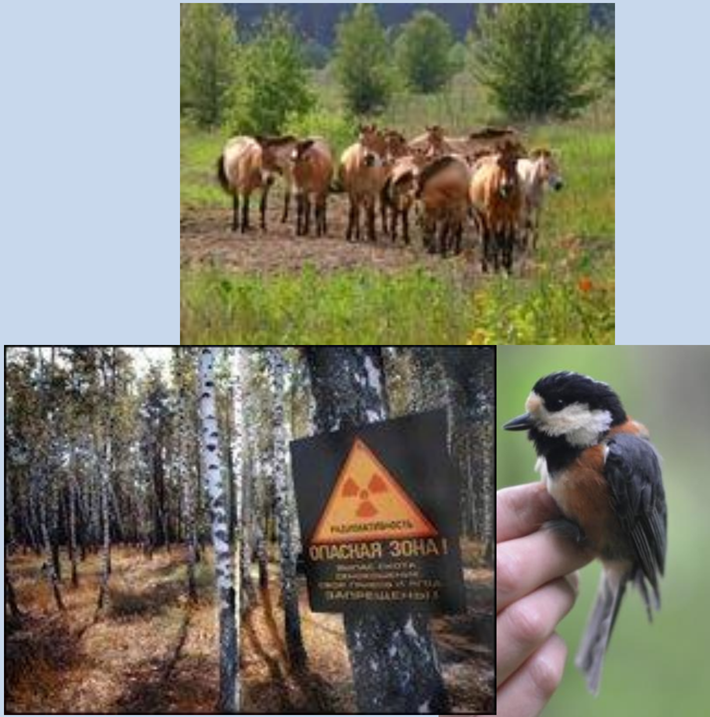


Why is this issue crucial?

- International recommendations on radiological protection are explicitly addressing the safety of the public and the environment (ICRP 103, 2007)

- Revised International and European Basic Safety Standards are pushing the development and/or the application of member state policy on environmental regulation in the field of radiological protection (IAEA and EURATOM BSS, 2014)

- Knowledge on effects of ionising radiation on non-human species is used to derive radiation benchmarks needed in any radiological risk assessment. Such benchmarks are to be science-based, transparently derived, and robust (i.e. applicable in many different situations)

- The vast majority of primary data which have been used to derive benchmarks are issued from laboratory or controlled field experiments. One important point is that only knowledge from hormetic and log-logistic dose-effect relationships has been explicitly used to derive those benchmarks (-> lab or field datasets reporting no effect are not explicitly integrated in the data treatment) (Garnier-Laplace et al., JRP, 2010)

- Challenging these benchmark values with real field cases is one way to make them more robust with a wider acceptability

Why are other sources of knowledge needed?

- Laboratory and semi-field tests constitute a too simplistic way to represent the complex nature as they generally ignore inter-individual and inter-species interactions, variety of routes of exposure and variety of responses from all species;

- Eventhough generally conservative to assess/predict risk, the derived knowledge from this simplified “virtual world” generally fails in supporting the prediction of complex ecological responses;

- The approach now largely promoted in the last EC recommendations for EQS derivation for chemicals (TG n°27: EC, 2011) is to use field data to enrich the information and to set even more robust benchmarks;

- Field data are representative of “real world” but they always document changes that are on-going or have already occurred (exposure levels may have already caused damages);

- Field observed effects may be caused or modified by simultaneously occurring stressors (issue of confounding factors)

Why laboratory data have been used preferably to establish these benchmarks?

- A robust way to characterize cause-effects relationships;
- Control of exposure of organisms in lab is easy to implement : the cause of the observed effects (if any) can be identified with certainty and can be quantified according to a gradient of exposure;
- Tests can be replicated;
- Under GLP, there is a certainty to face no significant cofounders;
- Dose (rate) effect relationships (when such a relationship exists) can be built with robustness (*ad hoc* experimental design will allow for a relevant statistical power and regression models);
- This preference was the one adopted for the EC-funded ERICA-PROTECT suite to derive screening benchmarks consistently with the approach applied for chemicals where laboratory tests have been the main basis of benchmarks until now (even the unique for a great number of chemicals).

What are the present used benchmarks?

From ICRP 108 (2008)

^{1}T, terrestrial; F, freshwater; M, marine

Wildlife group	**Ecosystem^1**	**RAP**	**DCRL, mGy d^{-1} (shaded)**		
			µGy/h *(rounded down, 1 digit)*		
			0.1-1	1-10	10-100
			4-40	*40-400*	*400-4000*
Large terrestrial mammals	T	Deer	🟩		
Small terrestrial mammals	T	Rat	🟩		
Aquatic birds	F, M	Duck	🟩		
Large terrestrial plants	T	Pine tree	🟩		
Amphibians	F, T	Frog		🟩	
Pelagic fish	F, M	Trout		🟩	
Benthic fish	F, M	Flatfish		🟩	
Small terrestrial plant	T	Grass		🟩	
Seaweeds	M	Brown seaweed		🟩	
Terrestrial insects	T	Bee			🟩
Crustacean	F, M	Crab			🟩
Terrestrial annelids	T	Earthworm			🟩

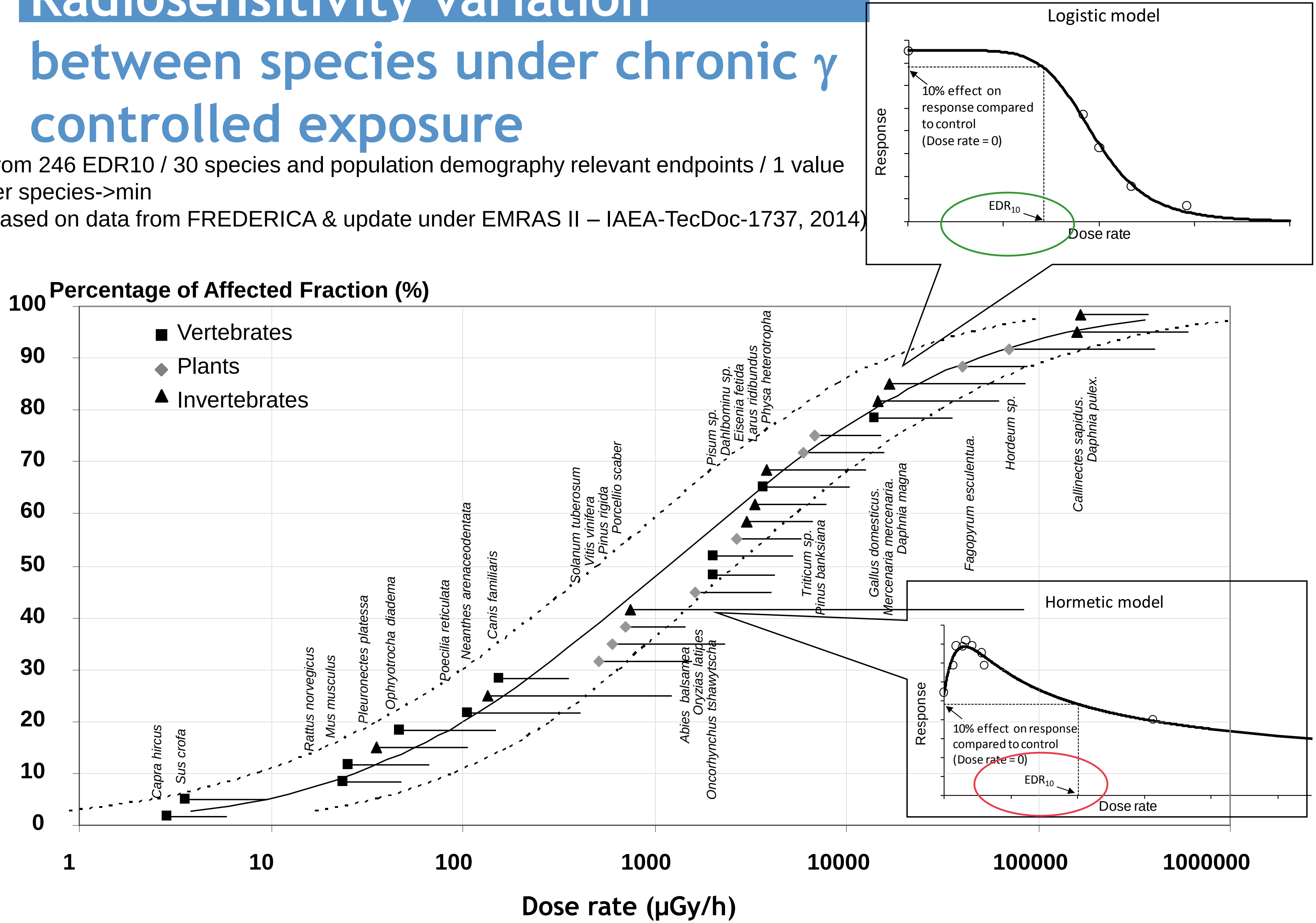
DCRL band of DR within which there is likely to be some chance of deleterious effects occurring to individuals of such type of organism

From EC-funded projects ERICA-PROTECT (Garnier-Laplace et al. JER 2008, Garnier-Laplace et al., JRP 2010)

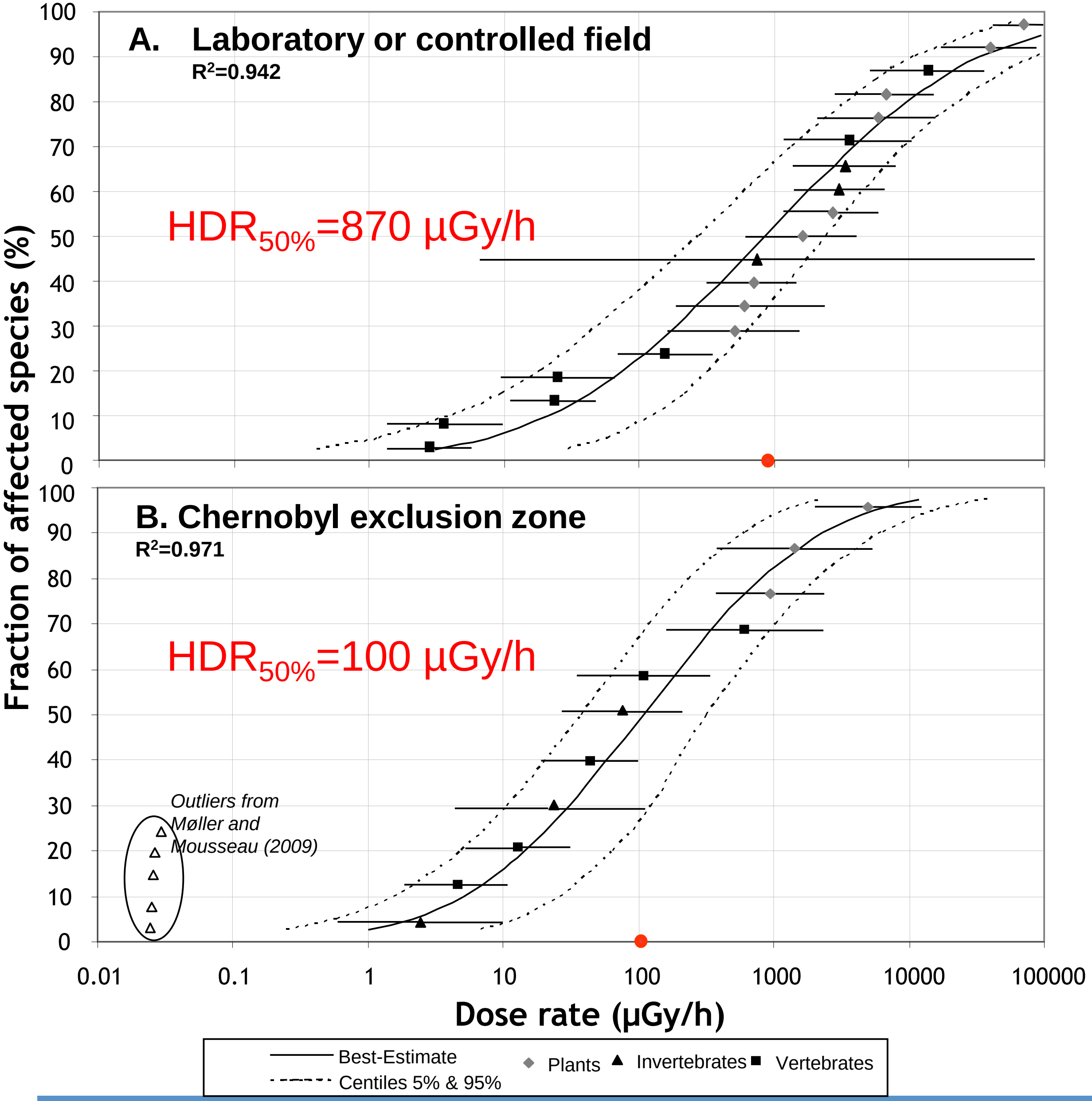
10 µGy/h for screening stage and generic ecosystems to be used in ERA (ERICA)
Consolidated by PROTECT where transitional organism-group specific screening values with 70, 200 and 2 µGy/h for plants, invertebrates and vertebrates respectively

Radiosensitivity variation between species under chronic γ controlled exposure

From 246 EDR10 / 30 species and population demography relevant endpoints / 1 value per species->min
(based on data from FREDERICA & update under EMRAS II – IAEA-TecDoc-1737, 2014)



Radiosensitivity variation between terrestrial species under controlled chronic γ exposure vs. realistic field exposure (CEZ)



In Garnier-laplace *et al.*, JER, 2013

- More sensitive in field than in lab with a shift by a factor of 5-10 to the left hand: still bad dose rate estimation for field? worse consequences through generations? sampling bias with seasons and life cycles? Other stressors?
- Higher relative sensitivity of invertebrates *vs.* vertebrates in field

Additional work to challenge these benchmarks

Three ways were implemented to make the comparison lab-field more robust

- (1) Improve the quality/quantity of radiotoxicity data constituting the basis for comparison between lab and field: For laboratory data by extending the knowledge making use of acute radiotoxicity data; use all the data (not only the minimum value per species); keep the same rules for data quality check than those used previously (see Garnier-Laplace et al., 2010; 2013)

- (2) challenge the comparison between lab and field at the “taxonomic level”

- (3) take account of human population evacuation from territories (limited to birds and Fukushima affected areas)

Brief reminder on the 2 methods used for data treatment

Distributions of Sensitivity (all endpoints except mutation/all terrestrial species): simply to inform transparently on the range of variation of radiosensitivity among species for a taxonomic group

- Principle: fit a statistical distribution to endpoints (of similar type) to examine the range of radiosensitivity among categories of endpoints/among species (of similar taxonomic group)
- Assumption: the data set is a representative sample in terms of radiosensitivity variation
- Method: apply to data set constituted by all endpoints for all species of a group, weight the data in order no species is given more importance than another, fit the distribution and CI

Acute – to- Chronic transformation (ACT):

- Principle: use knowledge from acute exposure to infer chronic exposure effects
- Assumption: « shift » from acute – to – chronic effects is similar among species of the same taxonomic class
- Method:

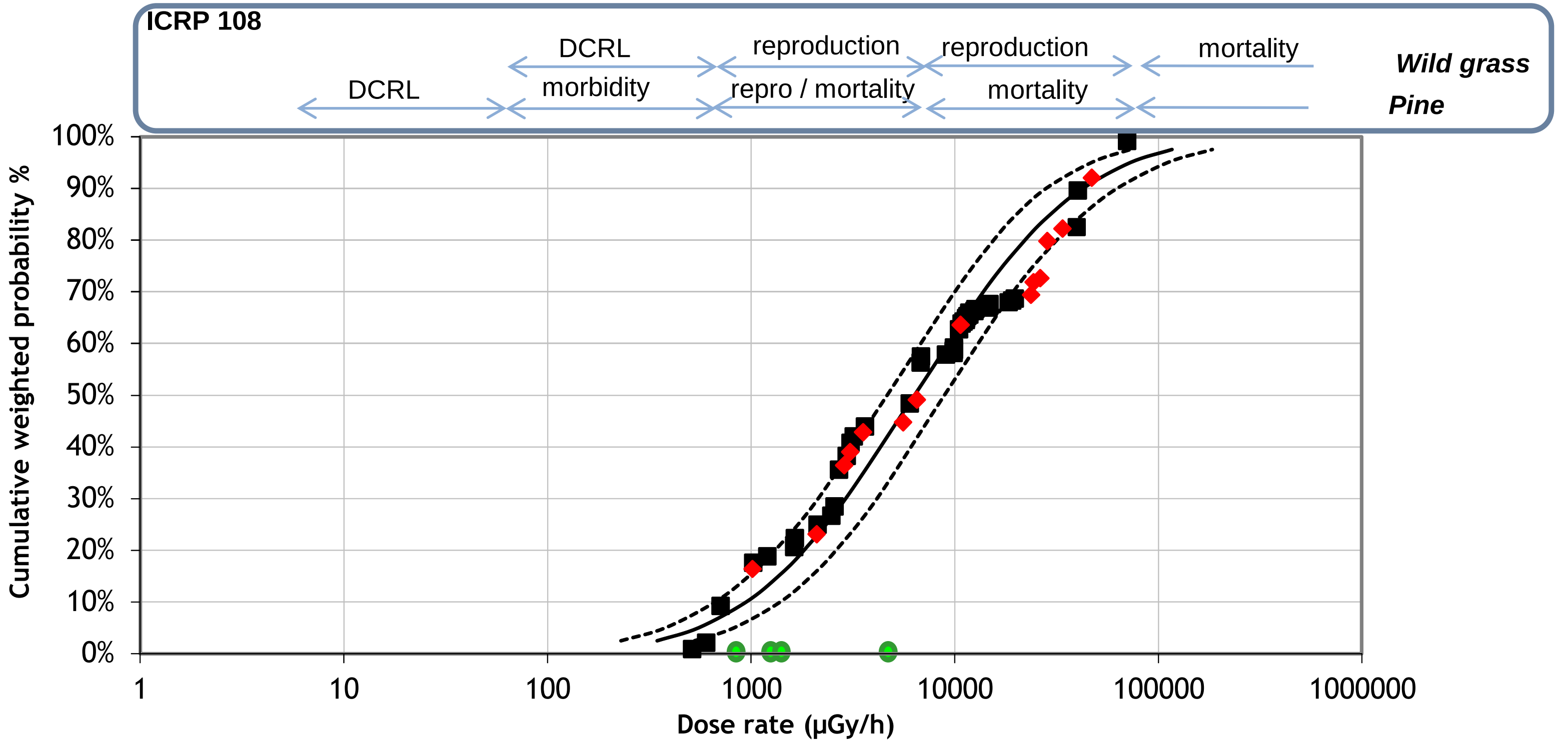
  (i) select and prepare the data set to establish ACT

  (ii) search for the best regression model between the statistical distribution parameters (μ, s) defining acute radiosensitivity and chronic radiosensitivity for all classes // compare observed to predicted chronic parameters to judge the global adequation of the regression

  (iii) validate the ACT model and use it

Results per taxonomic group - 2 groups with no discrepancy

Plants - distribution of chronic radiosensitivity among species for all endpoints



Other papers published dealing with CEZ or Fukushima area to be incorporated in the analysis but primary ecological data are not always accessible

SSWD - Log Normal

R² = 0.9284
KSpvalue = 0.048
Sp = weighted; TW: none
wm.lg = 3.80
wsd.lg = 0.64

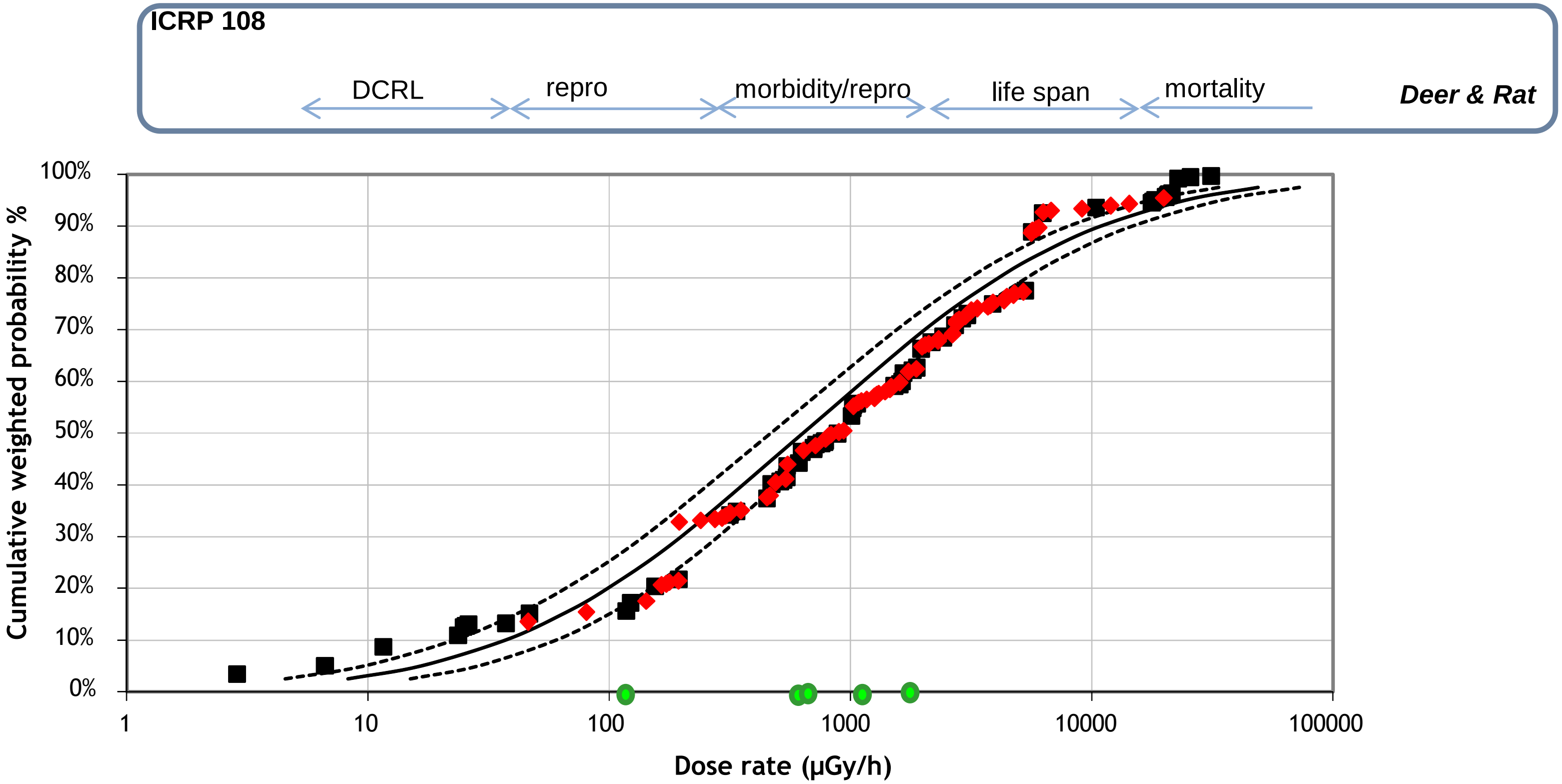
EDR_{10} estimated for (species, endpoint)

- ■ Lab chronic data
- ◆ Lab chronic data predicted from ACT
- ● Chronic data observed in CEZ

Draft version - Work in progress under TG99 – ICRP C5

Results per taxonomic group - 2 groups with no discrepancy

Mammals - distribution of chronic radiosensitivity among species for all endpoints



Other papers published dealing with CEZ or Fukushima area to be incorporated in the analysis but primary ecological data are not always accessible

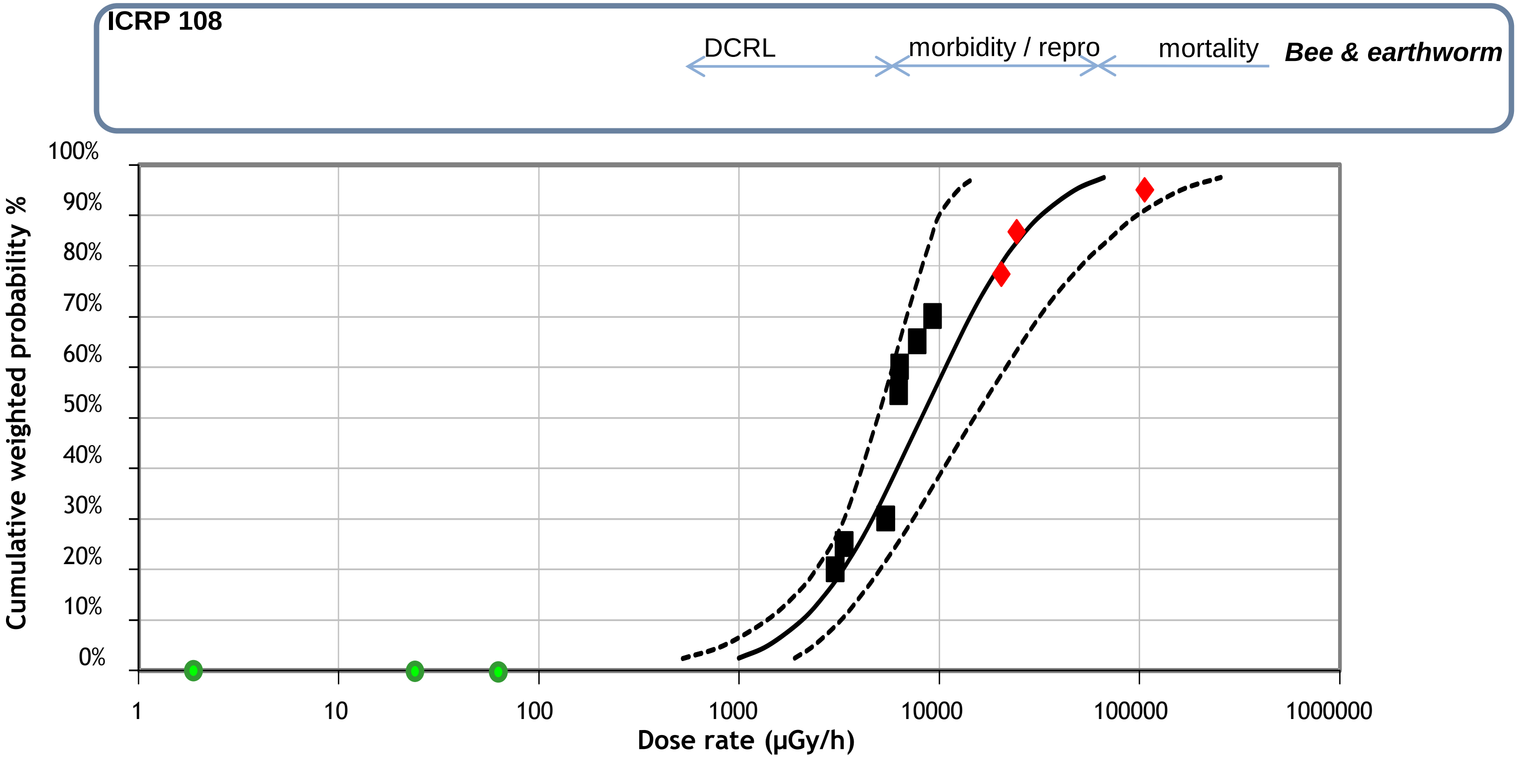
SSWD Log Normal
Sp = weighted; TW: none
R^2 = 0.9342
KSpvalue = 0.022
wm.lg = 2,80
wsd.lg = 0.96

■ Lab chronic data
♦ Lab chronic data predicted from ACT
● Chronic data observed in CEZ

⚠ Draft version - Work in progress under TG99 – ICRP C5

Results per taxonomic group - 2 groups with large discrepancy

Invertebrates - distribution of chronic radiosensitivity among species for all endpoints



Other papers published dealing with CEZ or Fukushima area to be incorporated in the analysis but primary ecological data are not always accessible

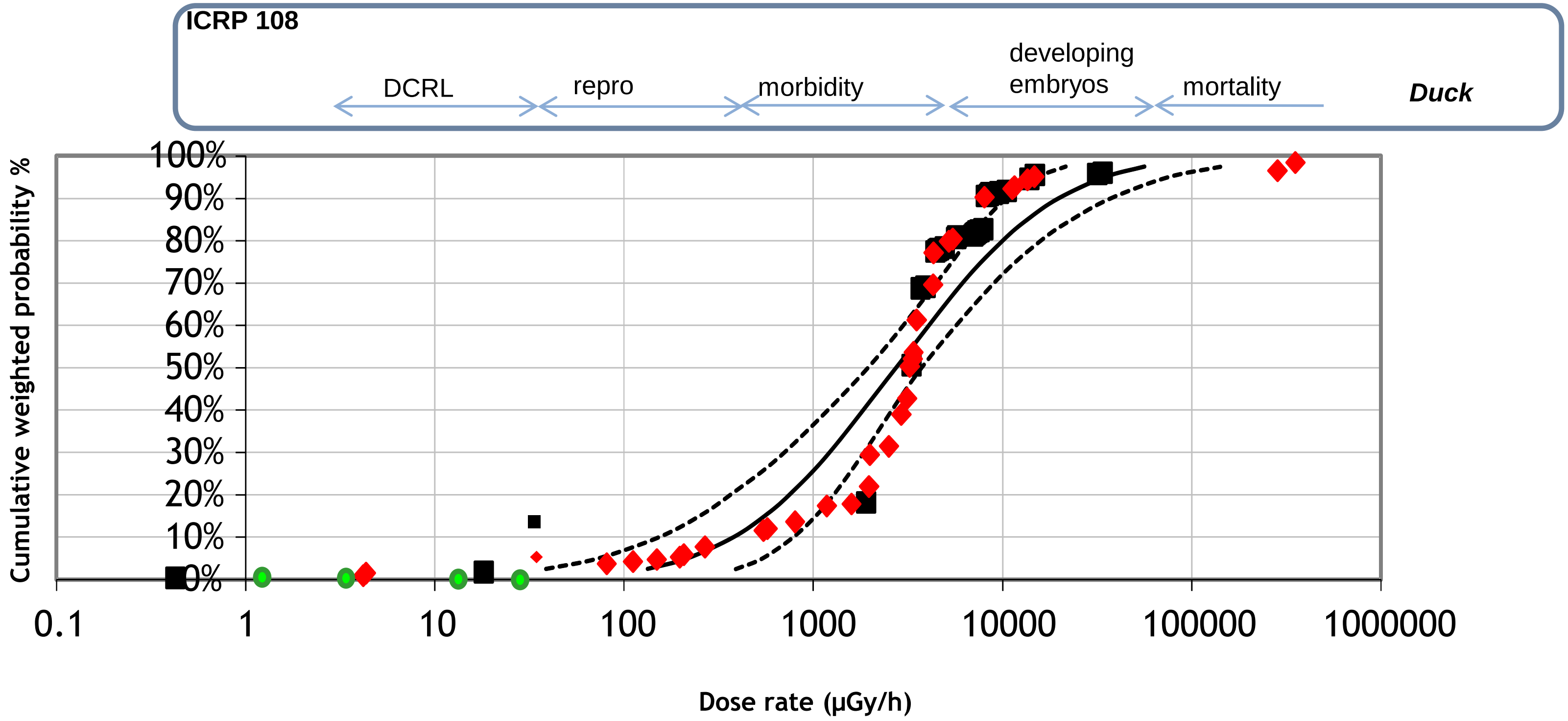
SSWD - Log Normal
$R^2 = 0.8874$
KSpvalue = 0.5
Sp = weighted; TW: none
wm.lg = 3.91
wsd.lg = 0.47

EDR_{10} estimated for (species, endpoint)

- ■ Lab chronic data
- ◆ Lab chronic data predicted from ACT
- ● Chronic data observed in CEZ

Draft version - Work in progress under TG99 – ICRP C5

Birds - distribution of chronic radiosensitivity among species for all endpoints



Other papers published dealing with CEZ or Fukushima area to be incorporated in the analysis but primary ecological data are not always accessible. For the present CEZ data coming from Moller & Mousseau (2007), several reasons may explain their very left-hand position in the distribution (please, wait for Sergei's talk)

SSWD Log Normal
Sp = weighted; TW: none
R^2 = 0.7745
KSpvalue = 0.000
wm.lg = 3.44
wsd.lg = 0.67

EDR_{10} estimated for (species, endpoint)

- ■ Lab chronic data
- ◆ Lab chronic data predicted from ACT
- ● Chronic data observed in CEZ

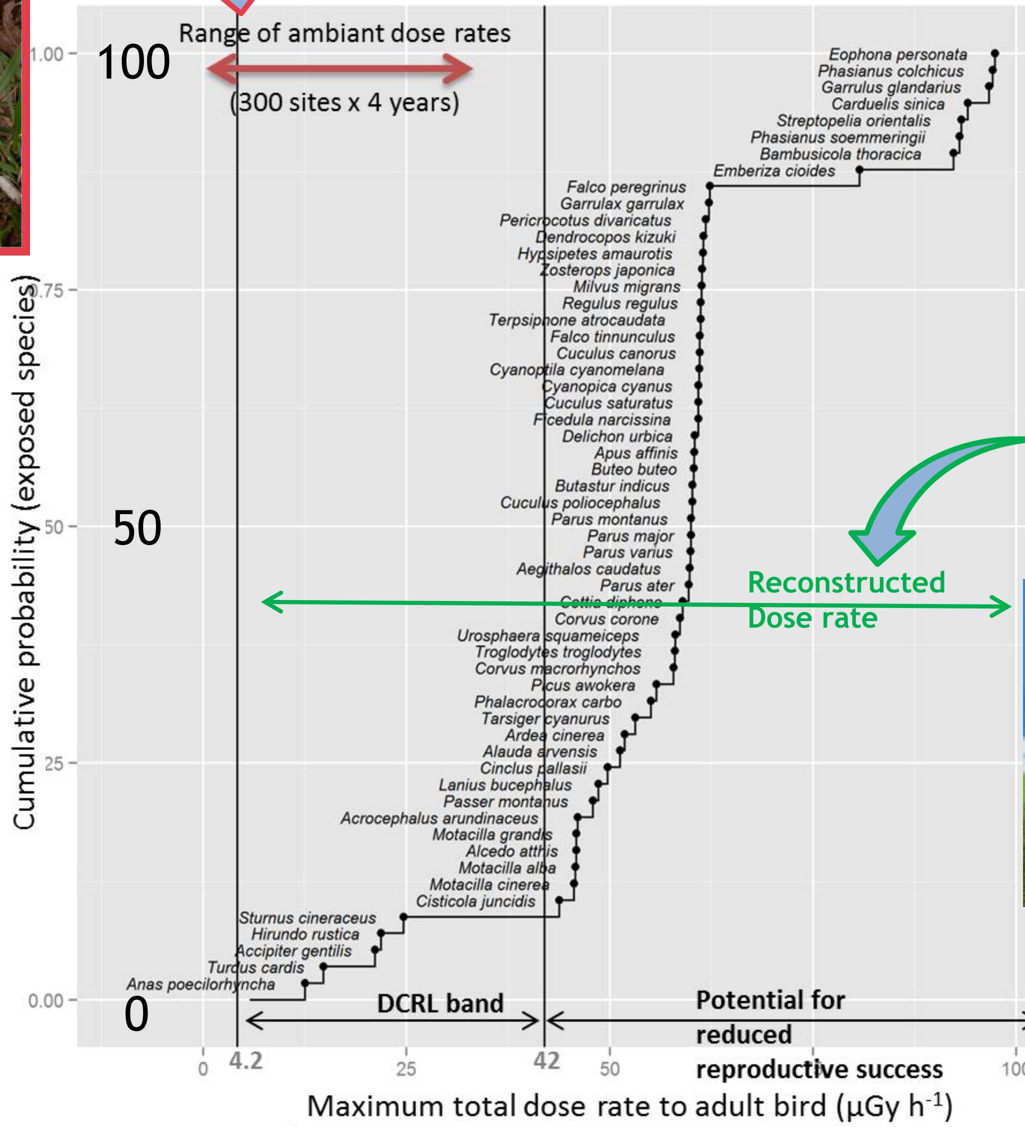
⚠ Draft version - Work in progress under TG99 – ICRP C5

Going further with birds and ecological data from Fukushima

Making our best for dose reconstruction

Field study in the 50-km NW FDNPP in 300 sites during 2011-2014

0.16 to 31 µGy/h



90% of 57 species were likely chronically exposed at a dose rate that could potentially affect their reproductive success

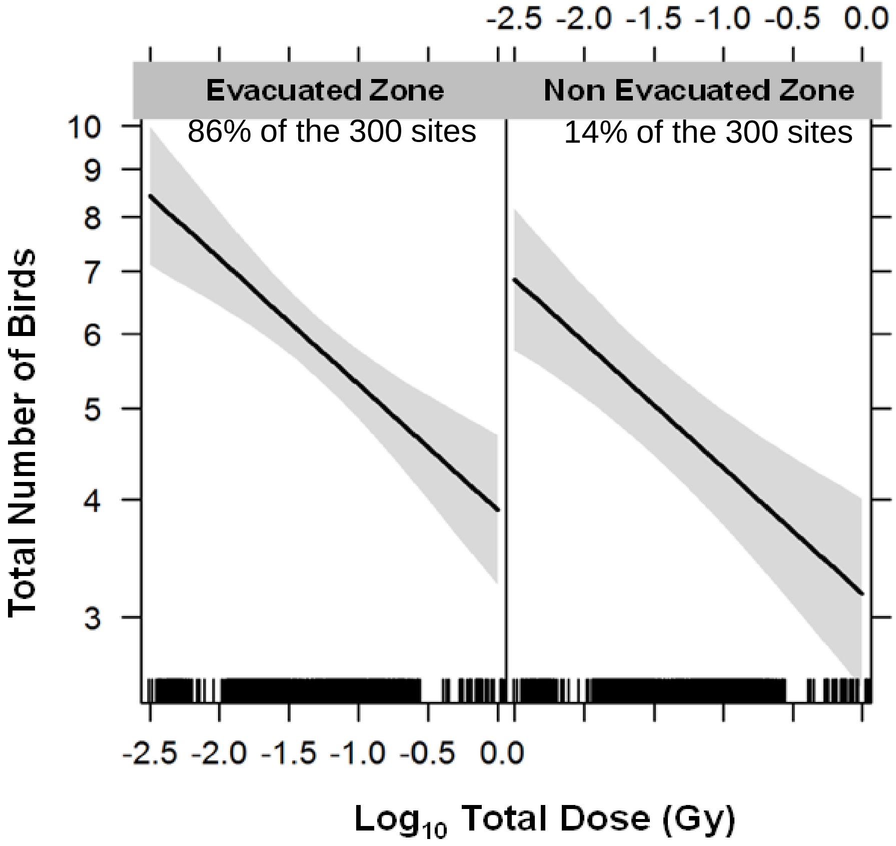
0.3 to 97 µGy/h

Adapted from Garnier-Laplace *et al.*, 2015

Going further with birds and ecological data from Fukushima

Other environmental factors may influence the conclusion - Evacuation of human populations from contaminated areas is among those the most controversial -

Combined effects of ionising radiation and human evacuation on abundance of birds in a unique statistical data treatment: Radiation dose has a greater impact on bird community than human abandonment in Fukushima radioactive contaminated territories



Quantification of Dose to abundance relationship by fitting a Global Linear Mixed Model to the dataset describing the Bird communitity in the FDNPP 50-NW area

- Similar decreasing effect (same slope) – loss of ca. 26% of the total number of individuals per increment of one unit $\log_{10}$-transformed total dose (in Gy), over the four-year post-accident period in the explored area.
- Higher abundance in evacuated zone.

Draft version - Work in progress

Some thought to share

- Comparison between lab and field is of major importance : since discrepancies appear at least for some groups, we need to investigate the reasons of such mismatch

- A number of interesting papers dealing either with CEZ or Fukushima impacted area has been published in the last 5 years. They are based on ecological data that are rarely accessible for several reasons (see Mills et al., TEE 2015). A meta-analysis of all these data would be of more than great added value to identify the main environmental/ecological/biological drivers and to deeply investigate the relevancy of effect benchmarks

- Relevant hypothesis to be tested in the lab could also outcome from such meta-analysis in order to improve our understanding of the mechanisms underlying the variation of radiosensitivity among living organisms (e.g., transgenerational effects)

Thank you for your attention!

With the present knowledge on radiation effect on reference deer (see ICRP 108), could you distinguish individuals tested in the lab from those living in the CEZ?

(adapted from Almudena’s postal card received for new year)