

CHERNOBYL 31 YEARS LATER: 'THE DEBATE'



A long time ago (well 31 years) in a land which no longer exists (the USSR) there was a

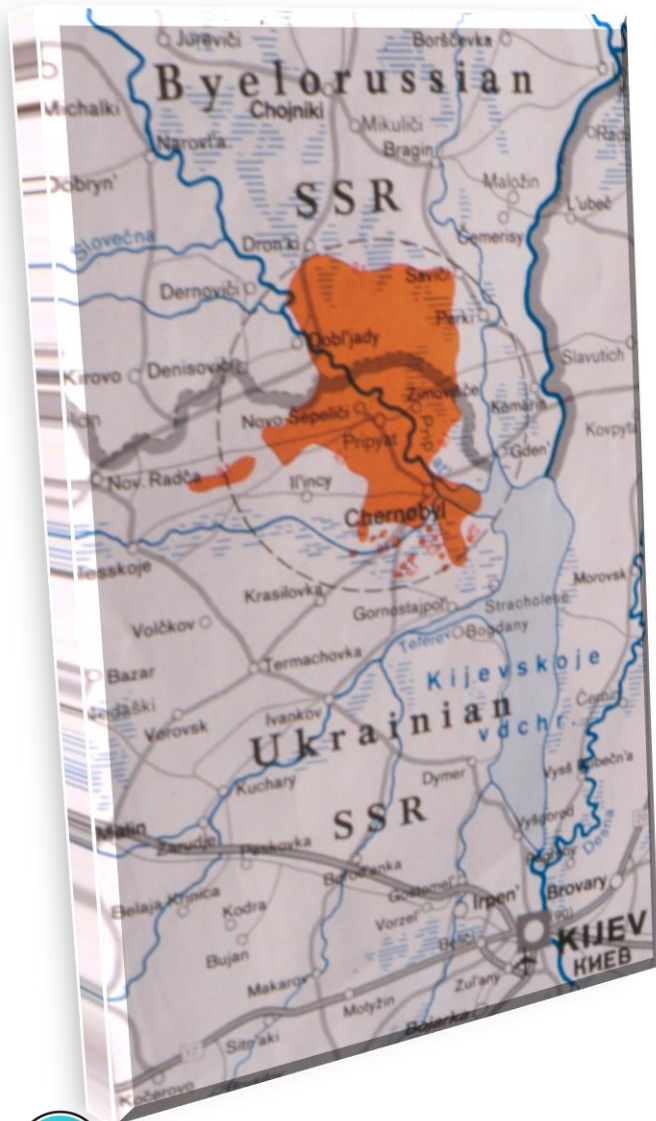


A long time ago (well 31 years) in a land which no longer exists (the USSR) there was a



And then somebody

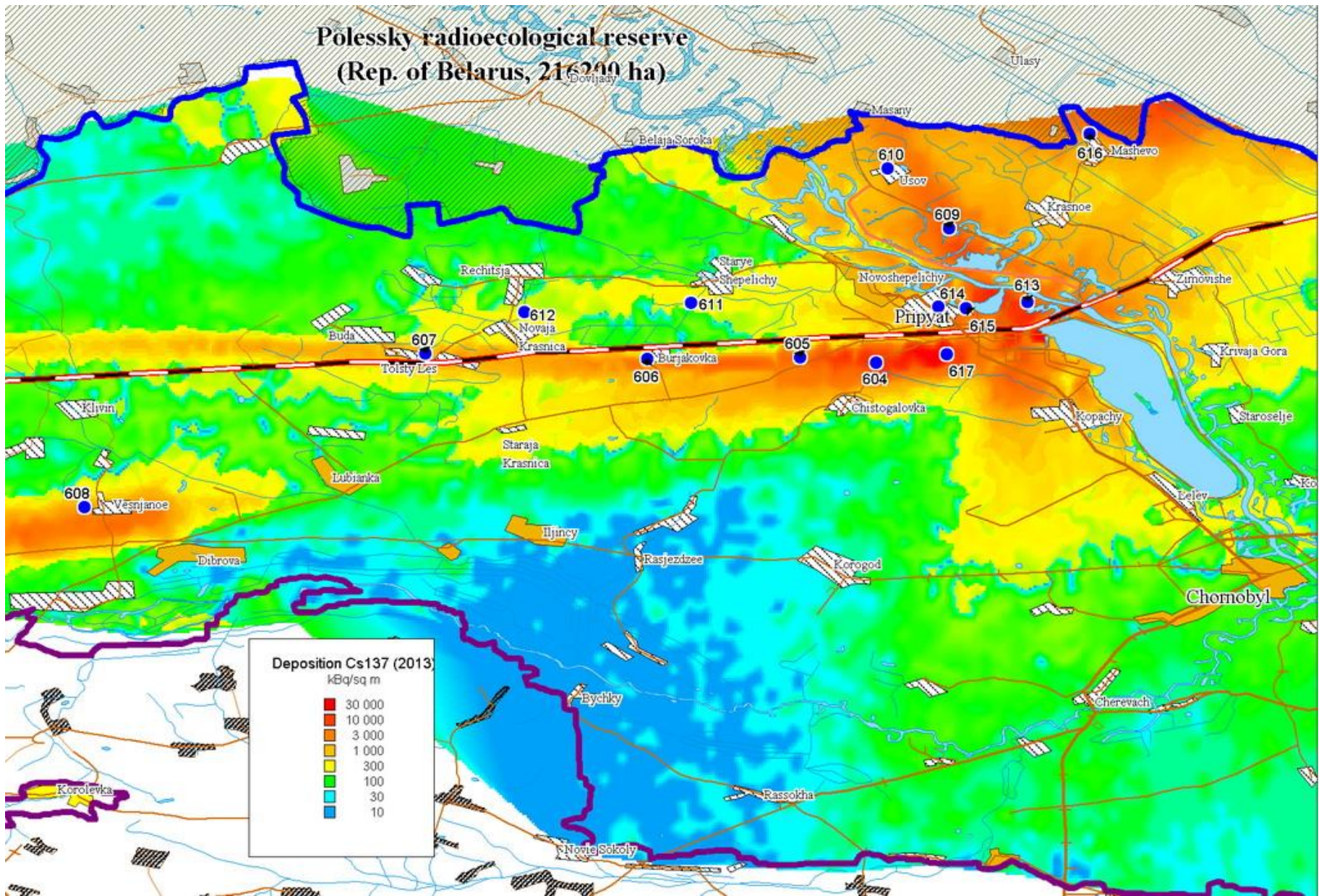




- Releases of radioactivity over 10 days
- 116,000 people and 60,000 cattle evacuated (initially)
- Creating the Chernobyl Exclusion Zone 3,500 km²



Chernobyl now



Chernobyl now

1993



2013



'Re-wilding'

Chernobyl now – Pripyat Town

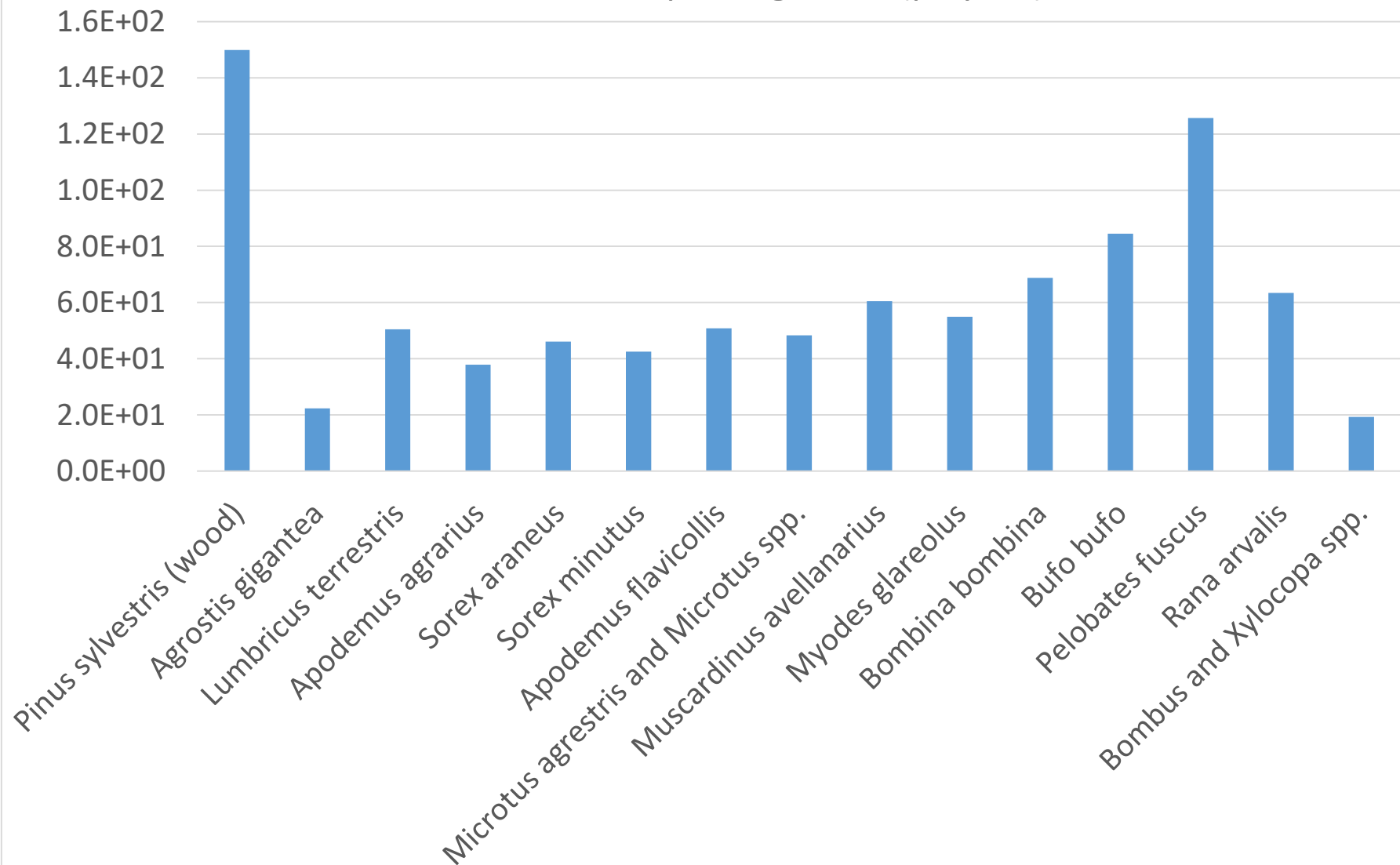


Chernobyl now – villages



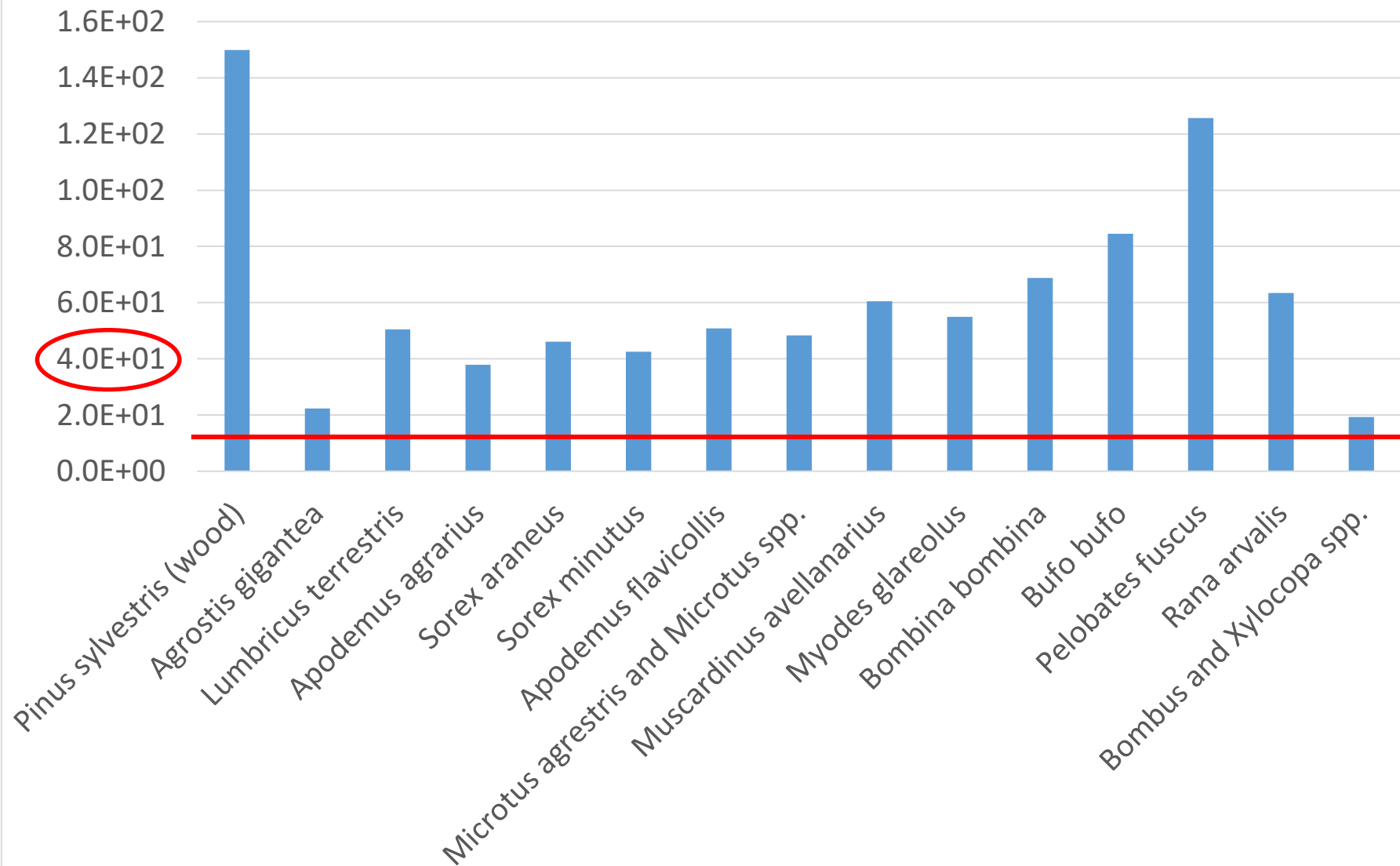
Dose rates now

Total dose rate per organism ($\mu\text{Gy h}^{-1}$)



Dose rates now

Total dose rate per organism ($\mu\text{Gy h}^{-1}$)



What is the debate?



Effects at Chernobyl



20 August 2010 Last updated at 10:17



Chernobyl species decline linked to DNA

By Victoria Gill

Science reporter, BBC News



The scientists have studied the exclusion zone for more than a decade

Scientists working in Chernobyl have found a way to predict which species there are likely to be most severely damaged by radioactive contamination.

The secret to a species' vulnerability, they say, lies in its DNA.

This discovery could reveal which species are most likely to decline or even become extinct in response to other types of environmental stress.

The researchers published their findings in the *Journal of Evolutionary Biology*.

Professor Tim Moussouris from the University of South Carolina, US, and

v's

Related stories

[Mammals decline in Chernobyl zone](#)

Last Updated: Thursday, 20 April 2006, 05:55 GMT 06:55 UK

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Wildlife defies Chernobyl radiation

By Stephen Mulvey

BBC News

It contains some of the most contaminated land in the world, yet it has become a haven for wildlife - a nature reserve in all but name.

The exclusion zone around the Chernobyl nuclear power station is teeming with life.

As humans were evacuated from the area 20 years ago, animals moved in. Existing populations multiplied and species not seen for decades, such as the lynx and eagle owl, began to return.

There are even tantalising footprints of a bear, an animal that has not trodden this part

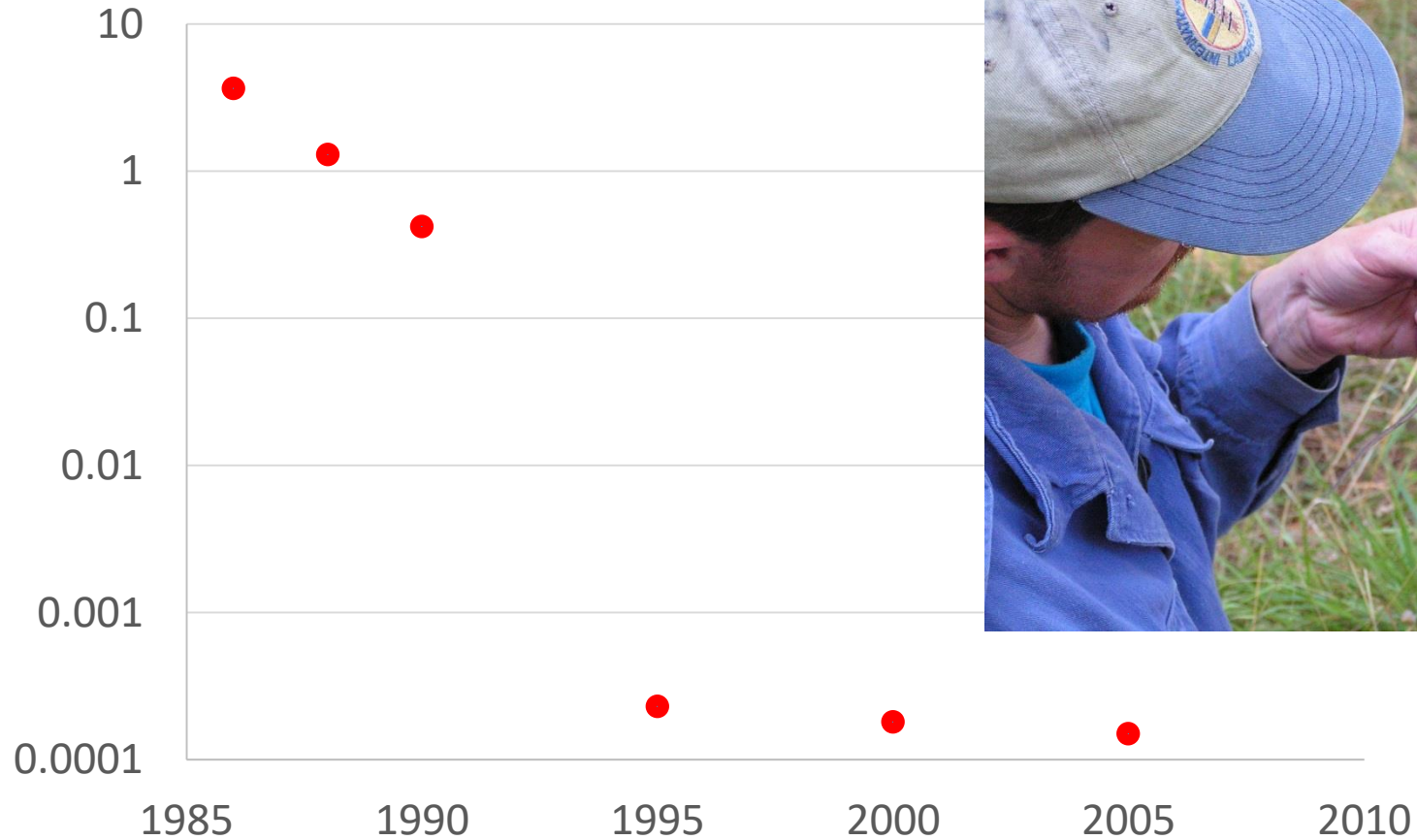


BBC website

Will look at results for different organism types



Mammals



Estimated absorbed dose rate (Gy/h) to small mammals in Red Forest (Gaschak et al. 2011, Health Physics)

Baker, Chesser, Rodgers, Meeks et al. COMET USA

Mostly small mammal work



Important conclusions (our selection):

Baker, Chesser, Rodgers, Meeks et al. USA



- Contaminated sites greater genetic diversity (2001), but: mutation or immigration?
 - Can't say and no significant detrimental effects
- Genetic diversity in Ukraine (bank vole) is 'widely variable' (2009), but:
 - contaminated areas no different
 - no support for a 'Chernobyl effect'
- Baker et al. 2009 '*high levels of genetic variation*' later withdrawn after new analyses

Baker, Chesser, Rodgers, Meeks et al. USA



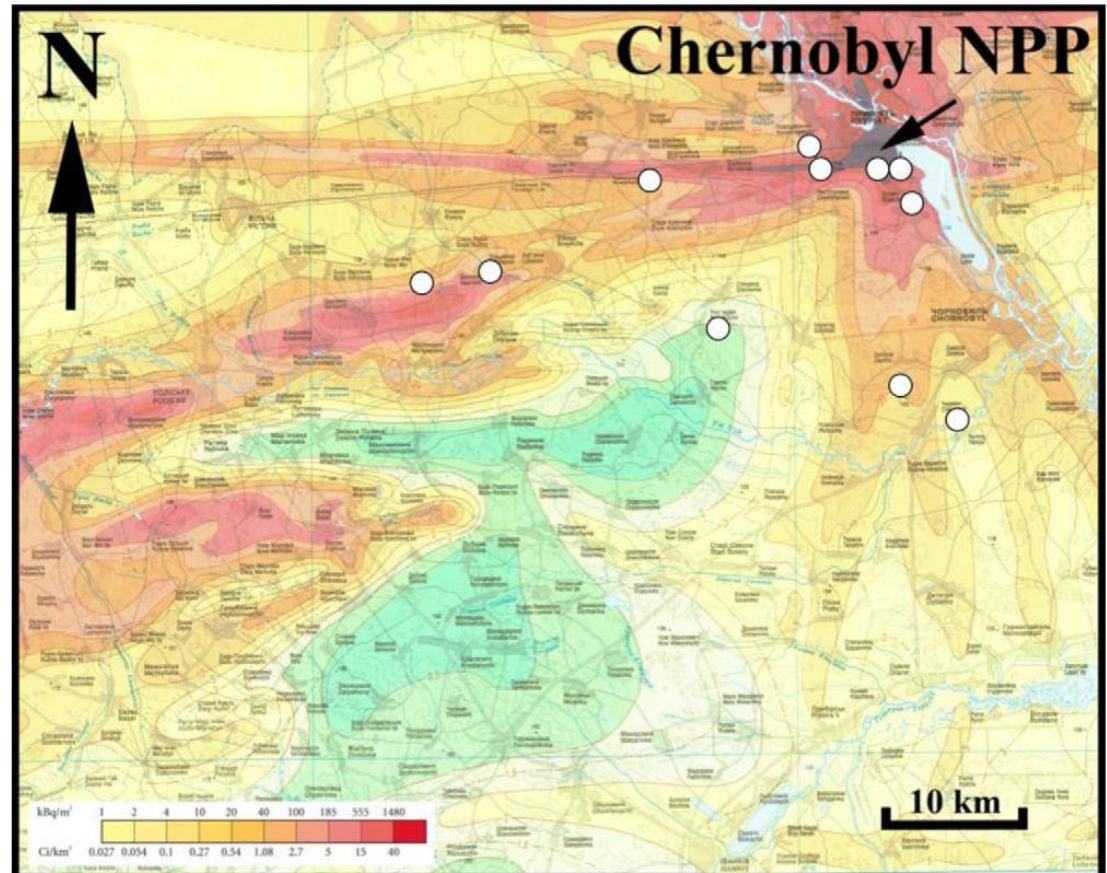
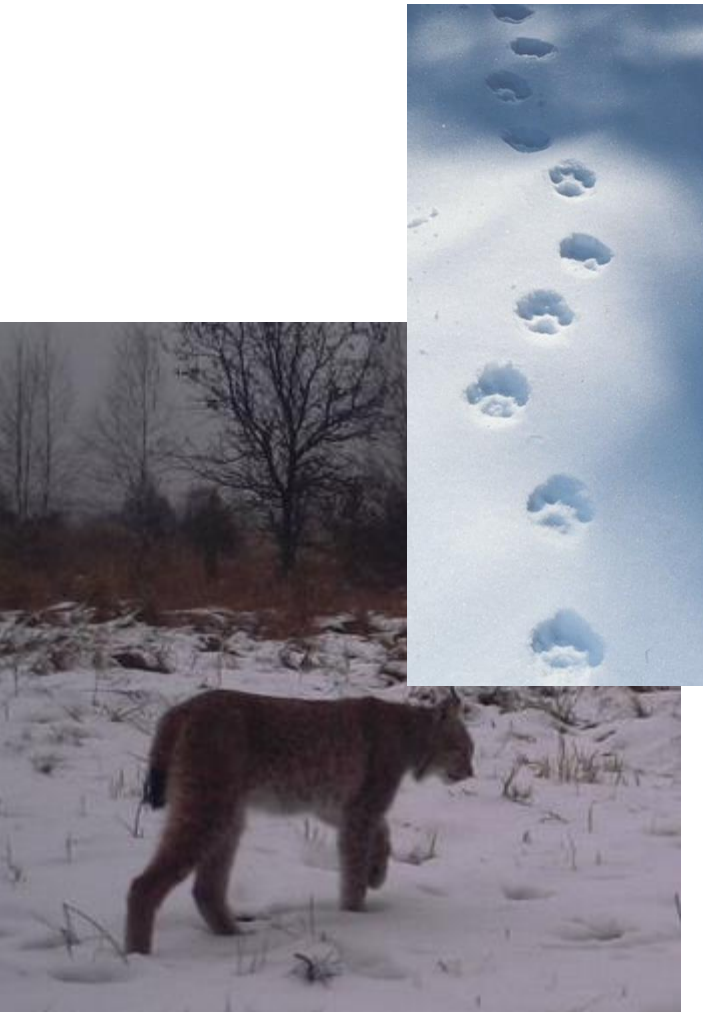
- No reduced small mammal abundance/diversity in CEZ
- No aberrant morphological features
- No gross chromosomal re-arrangements
- Introduced 'naive' bank voles to CEZ (36 mG/d)
 - No increase in micronucleus frequency
 - No evidence of development of radioresistance (*but only 30 d study?*)
- '*Beautiful theories (there'd be a radiation effect) destroyed by ugly facts*' [*Growing up with Chernobyl* Chesser & Baker 2006]

Study of mammals, Ukraine

161 x 100m snow tracks

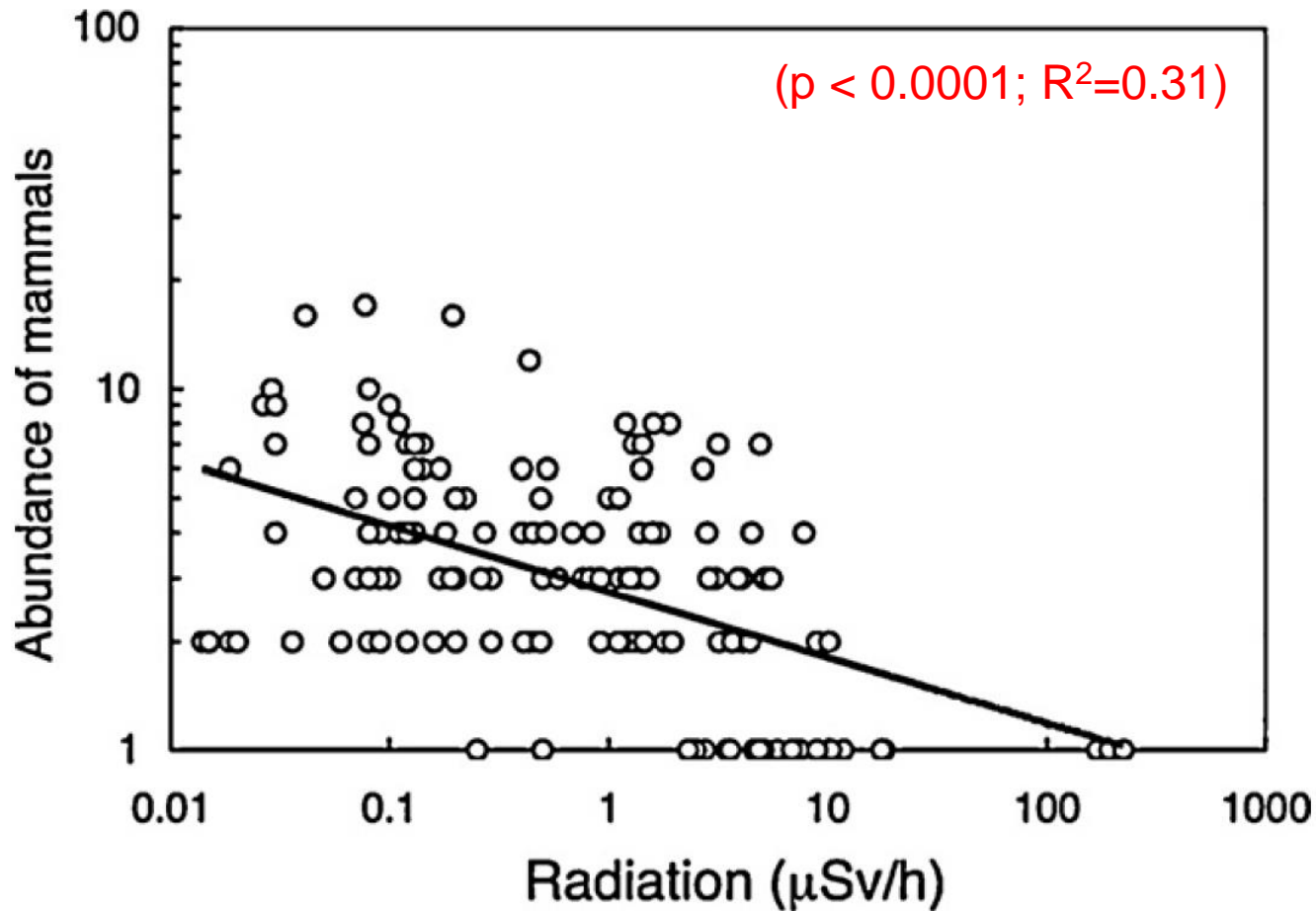
c. 16 km total over 1.5 day

Separation of transects of 50-500 m



Moller and Mousseau, 2013

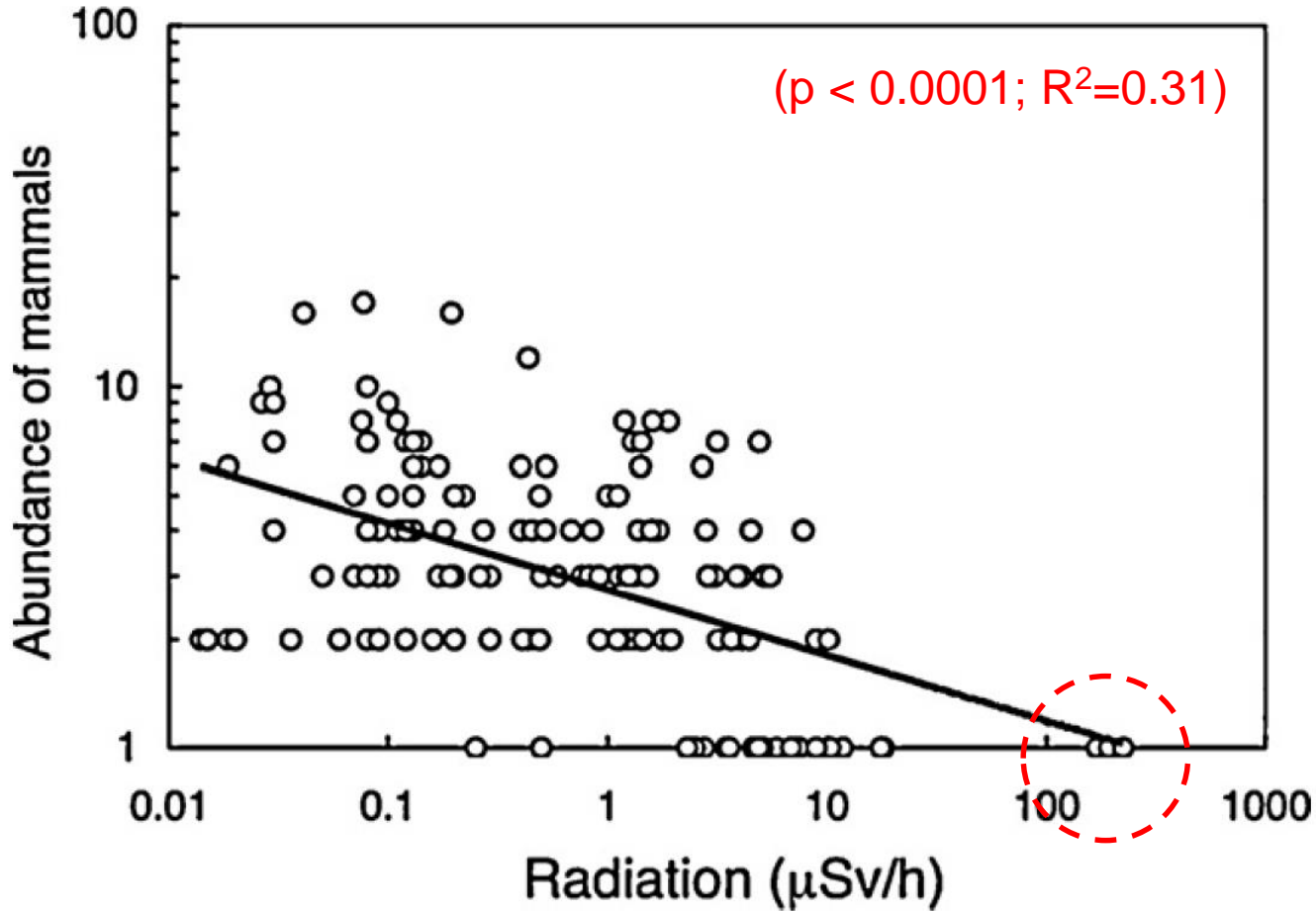
Mammals



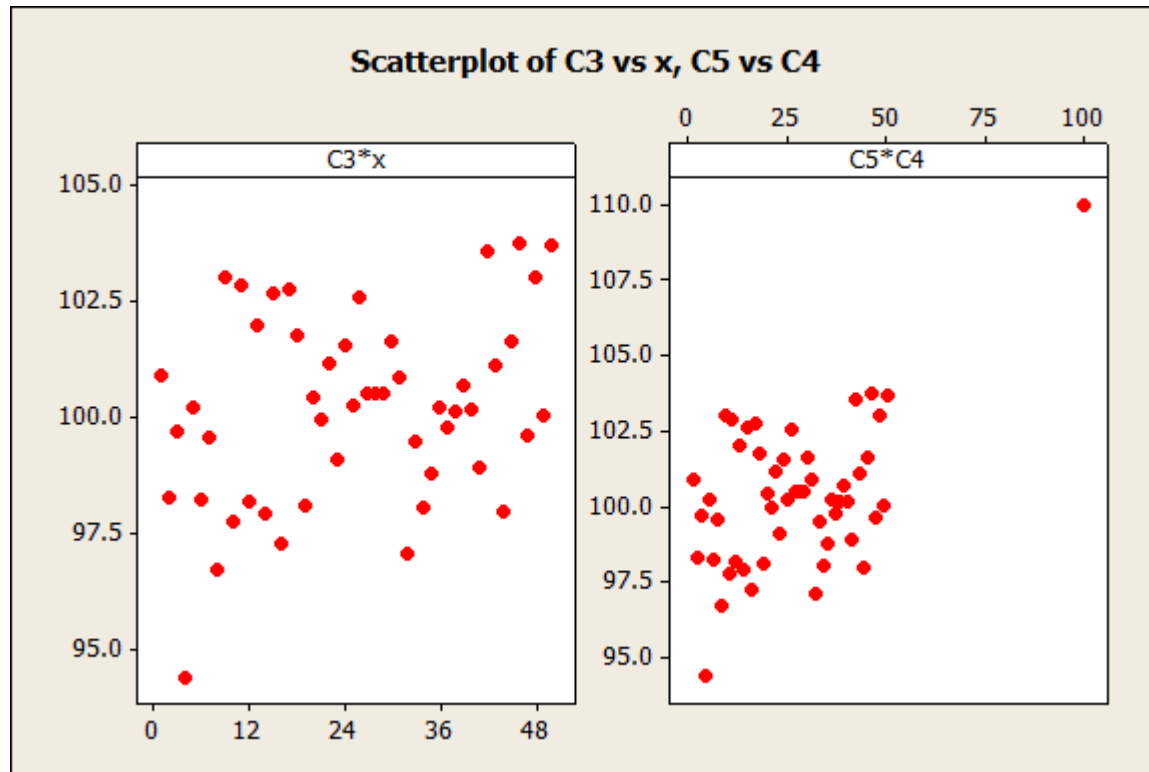
12 species

Dose meter measurement at ground level
(2-3 measurements per transect?)

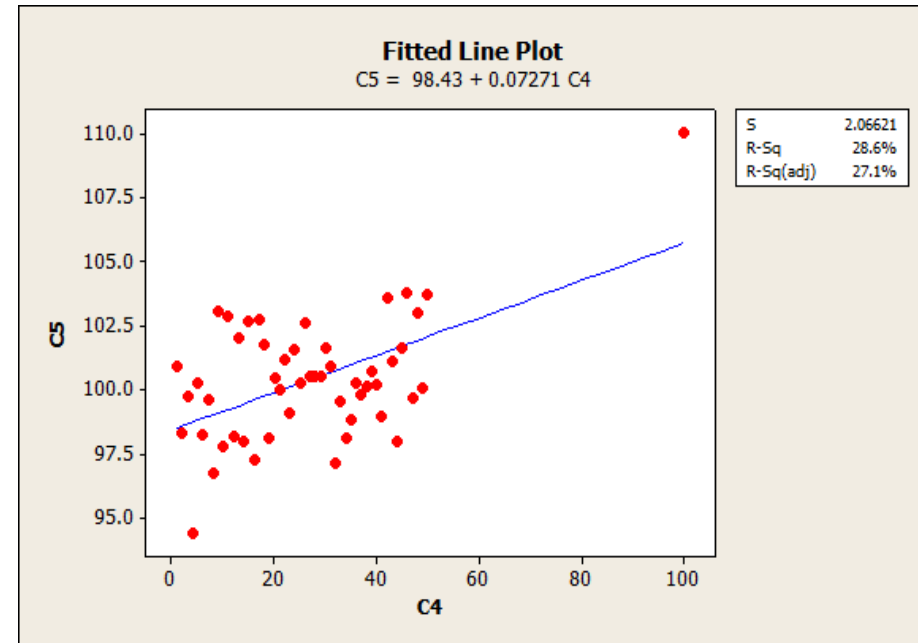
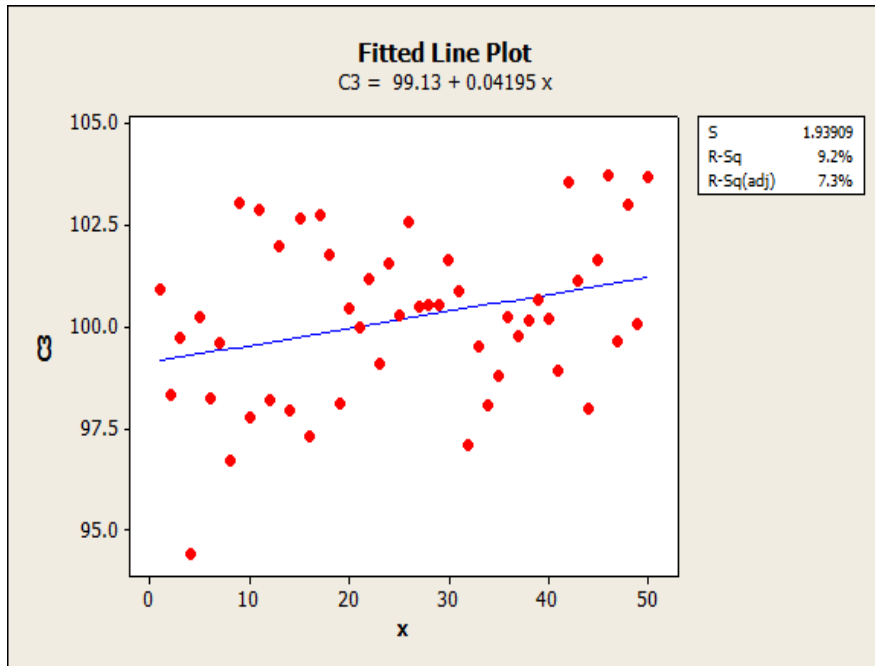
Mammals



Dose meter measurement at ground level
(2-3 measurements per transect?)

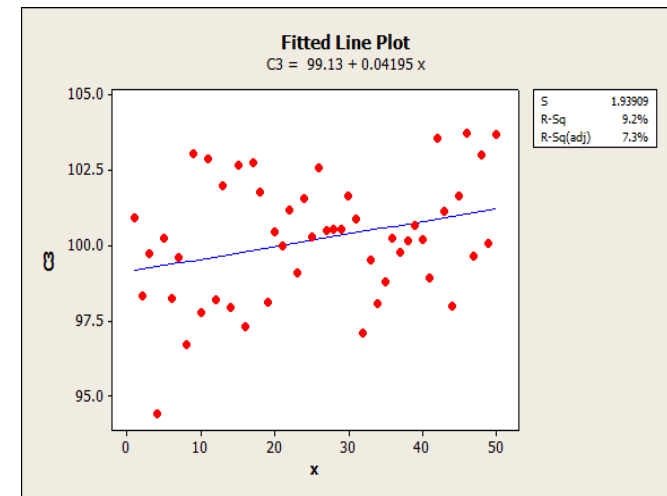


- An **influential observation** added to the data in the scatterplot on the left is shown on the right.



- Is there a relationship- is it statistically significant ?

- The regression equation is
- $y = 99.1 + 0.0419 x$
- The slope is 0.0419 with a standard error of 0.01900 and the **p-value** is **0.032**



Random numbers

- $R-Sq = 9.2\%$ $R-Sq(adj) = 7.3\%$
- So statistically significant, very little variation in y explained (7%), and the data were randomly generated with no relationship.

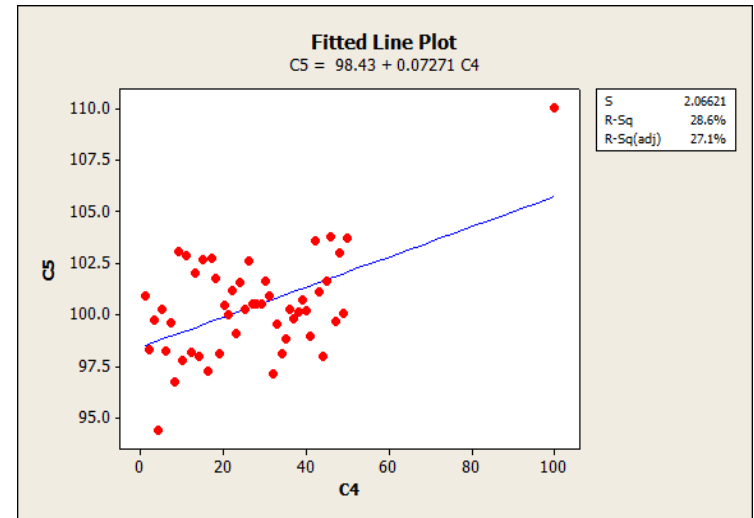
- The regression equation is

$$y = 98.4 + 0.0727 x$$

- The slope is 0.07271 with se 0.01641 and p-value 0.000

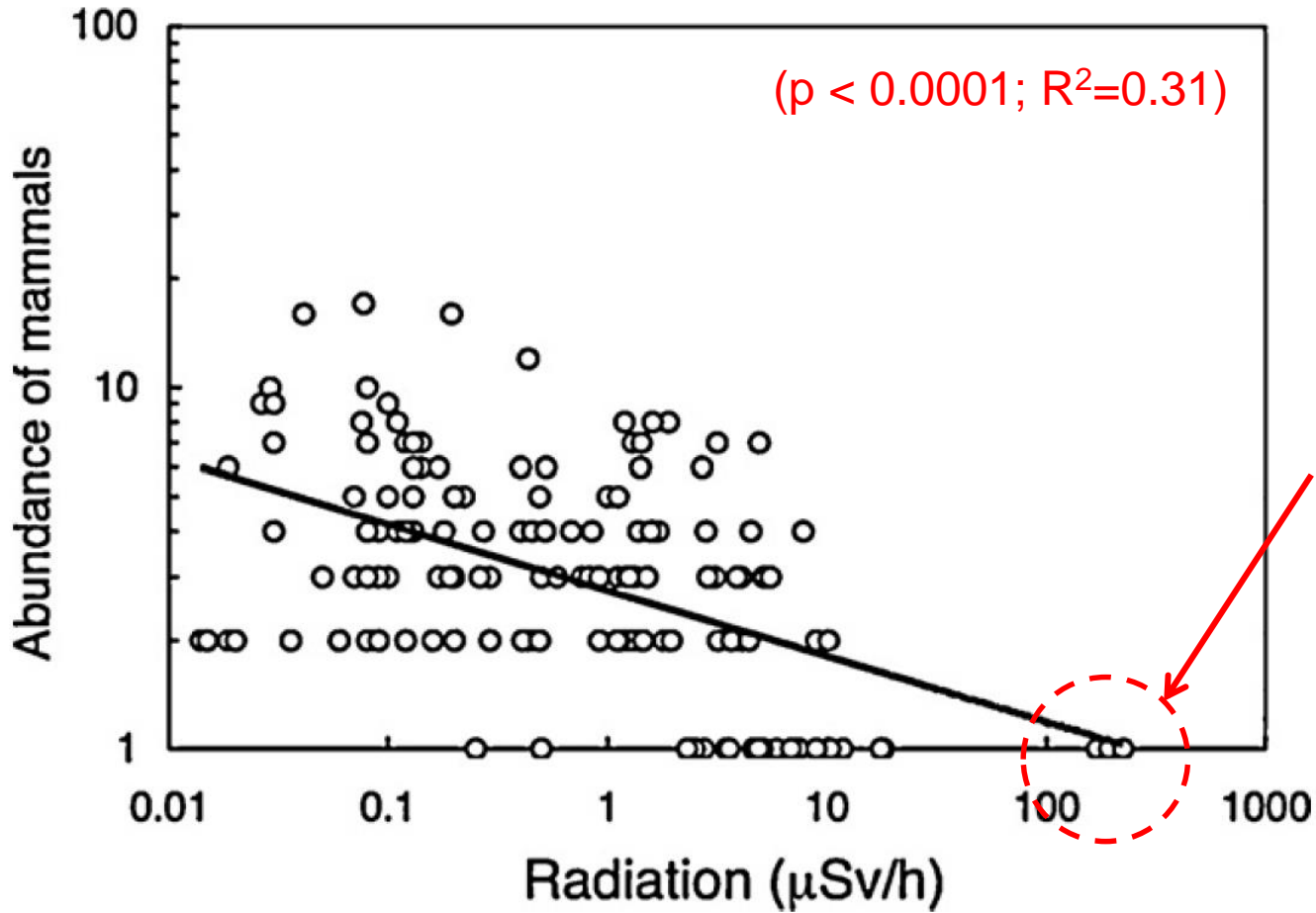
- R-Sq = 28.6% R-Sq(adj) = 27.1%

- So statistically significant, more variation in y explained (27%), and the slope has changed from 0.0419 to 0.0727



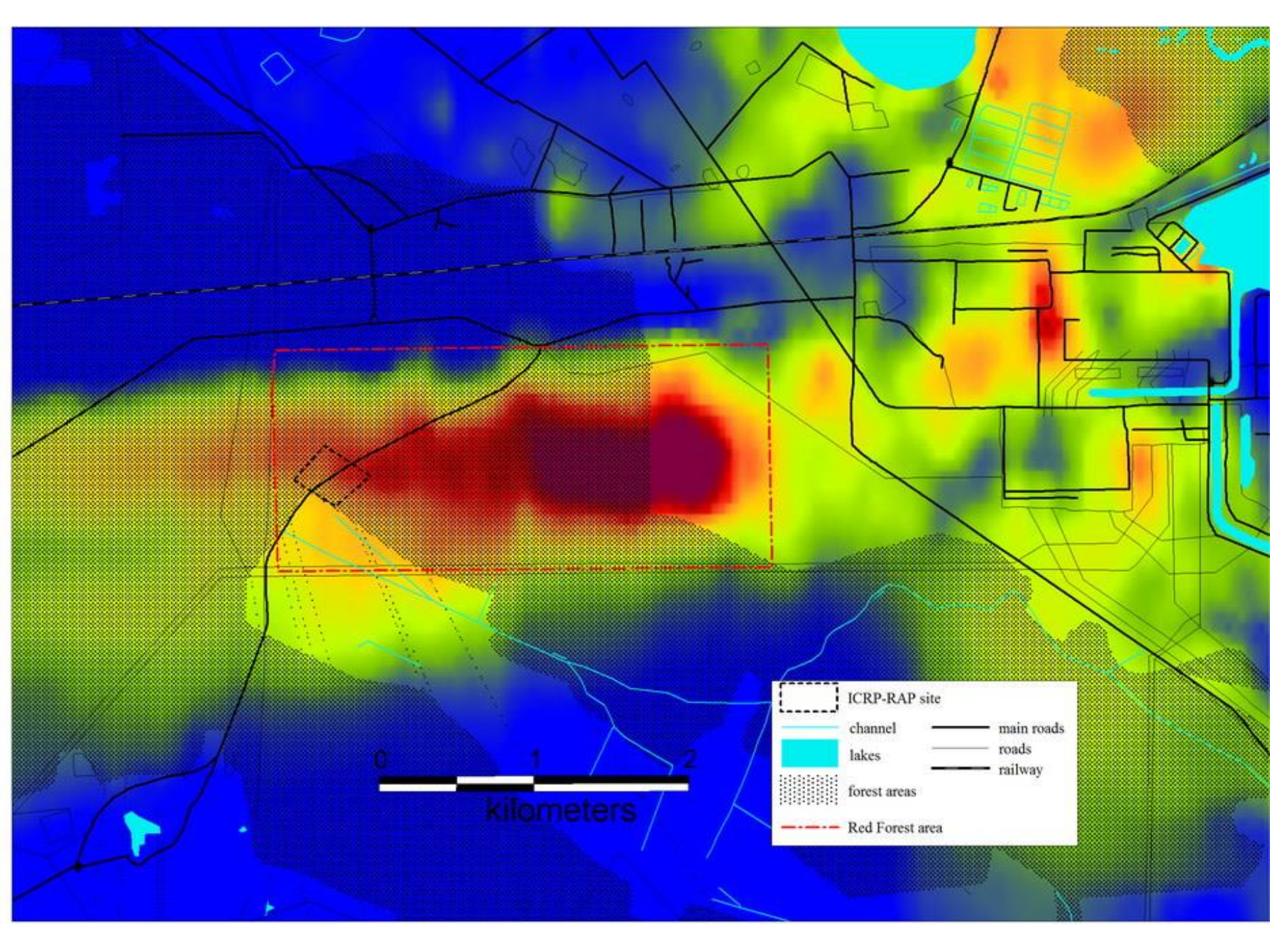
BUT?

Mammals



Red Forest?

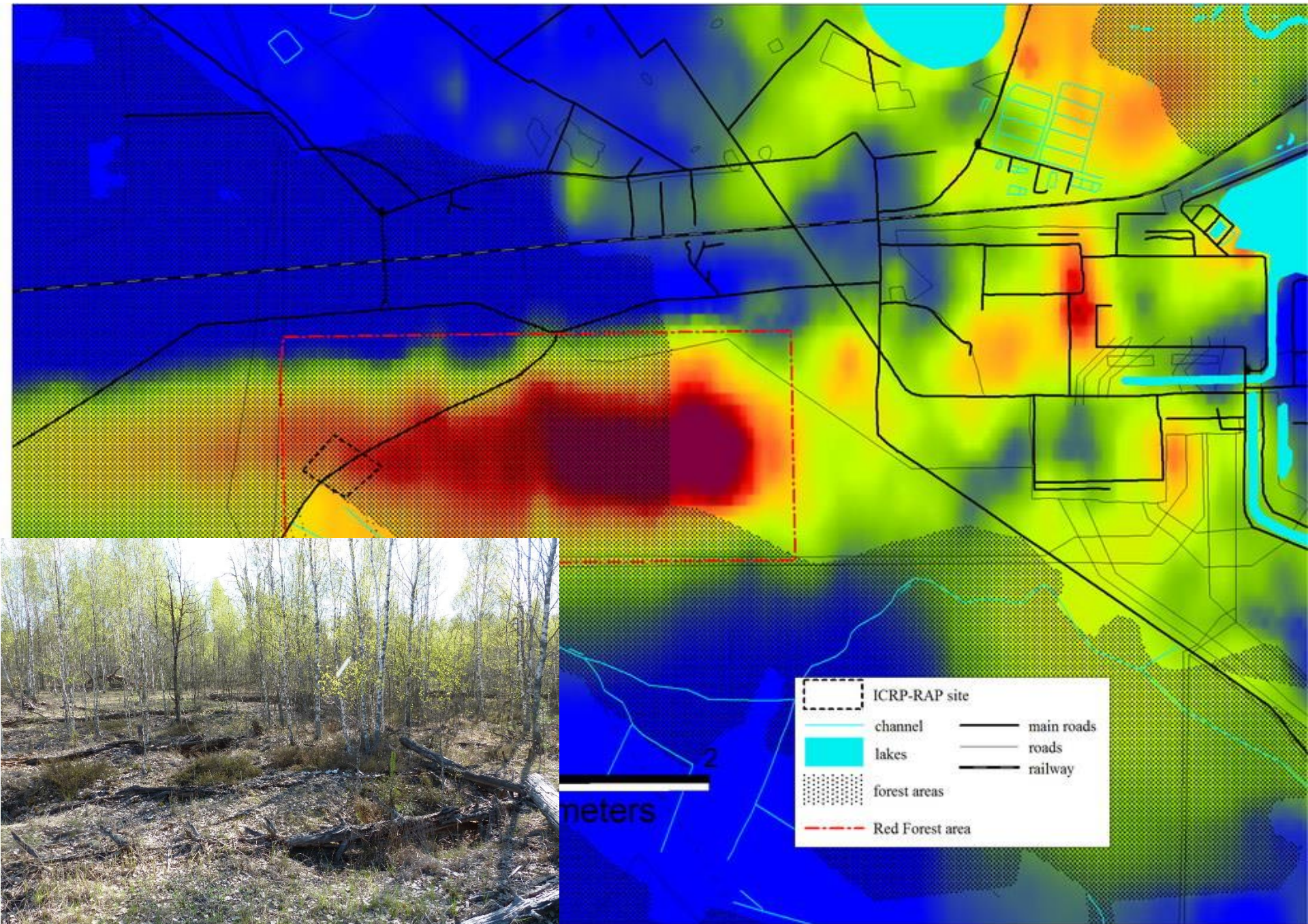
Dose meter measurement at ground level
(2-3 measurements per transect?)

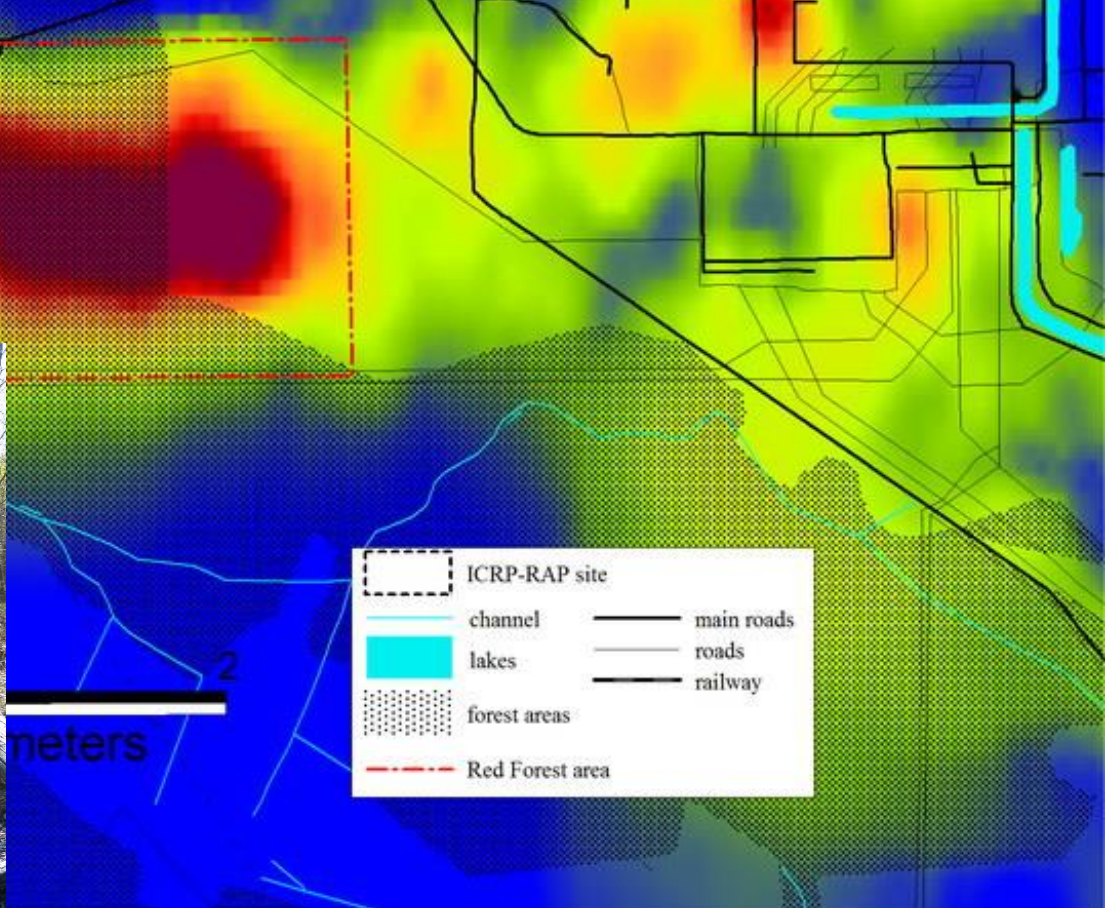
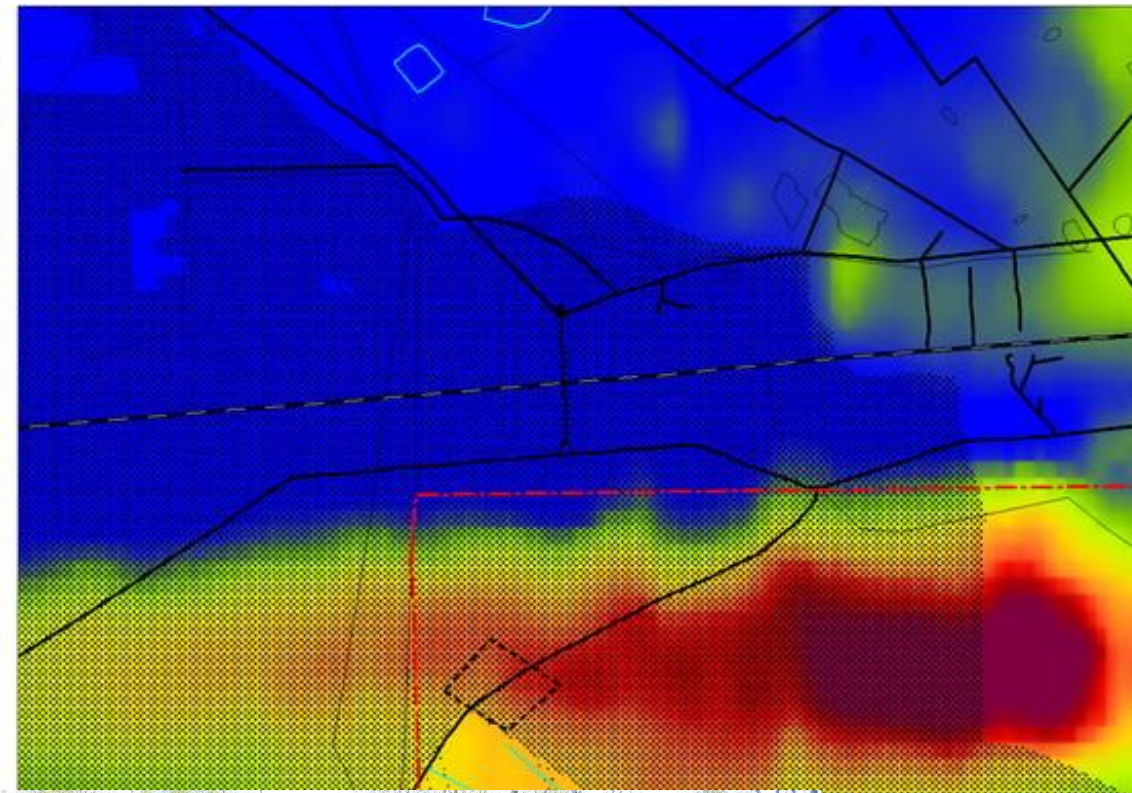


'Red Forest'

c. 4 – 6 km²

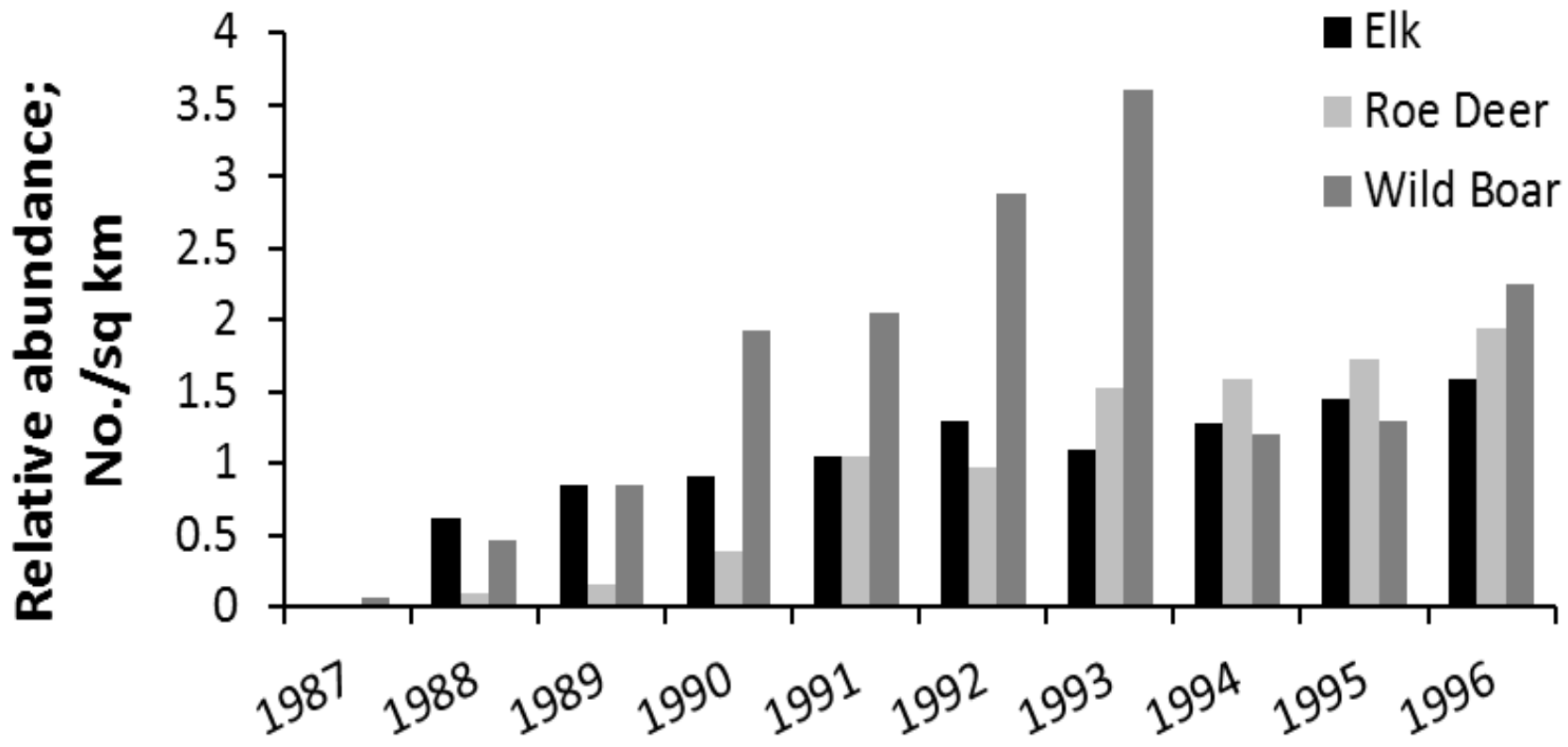






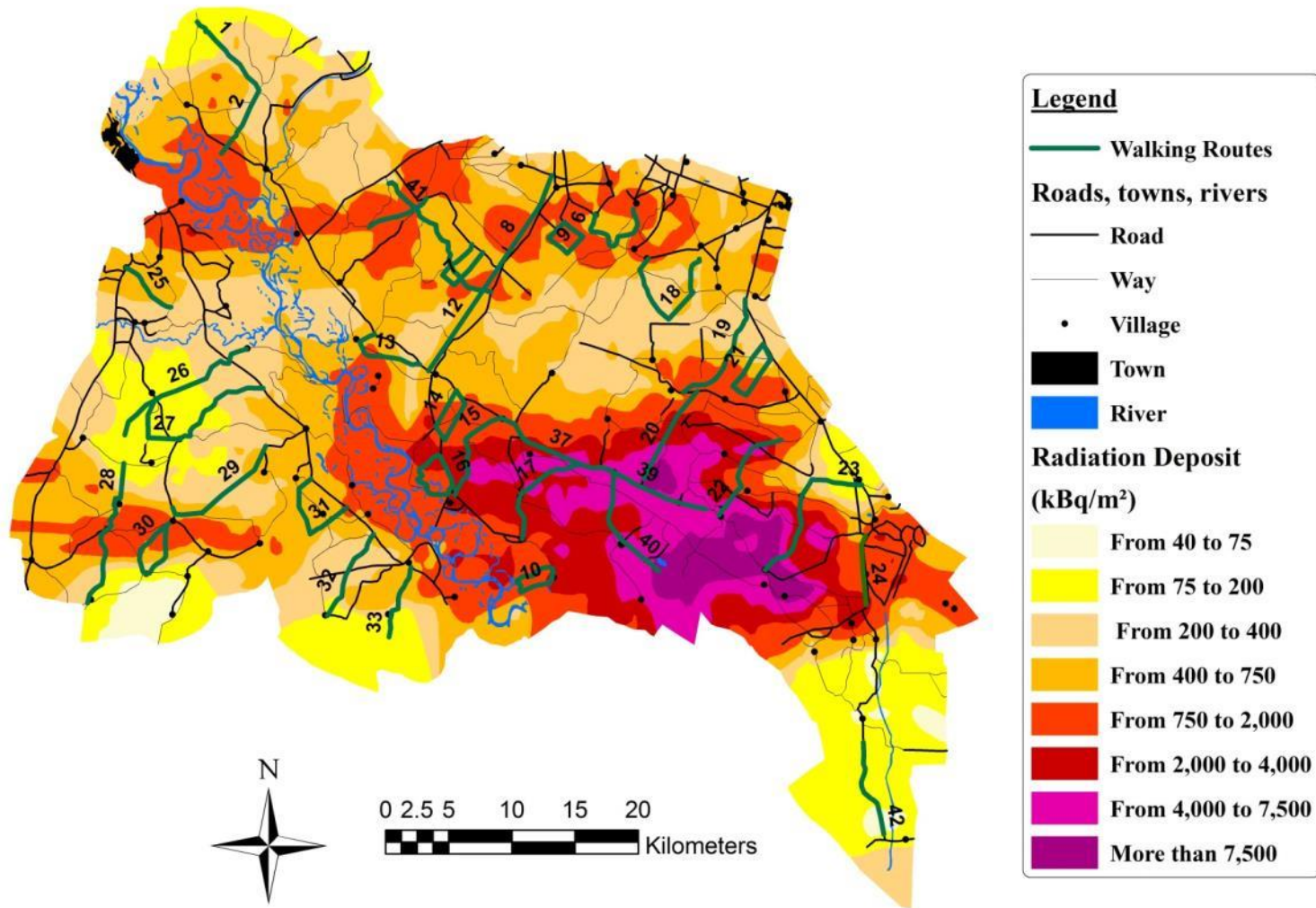
Large mammals 1-10 years after Chernobyl

Helicopter winter surveys



Deryabina, Kuchmel, Nagorskaya, Hinton, Beasley, Lerebours, Smith (2015) *Current Biology*

Winter tracks



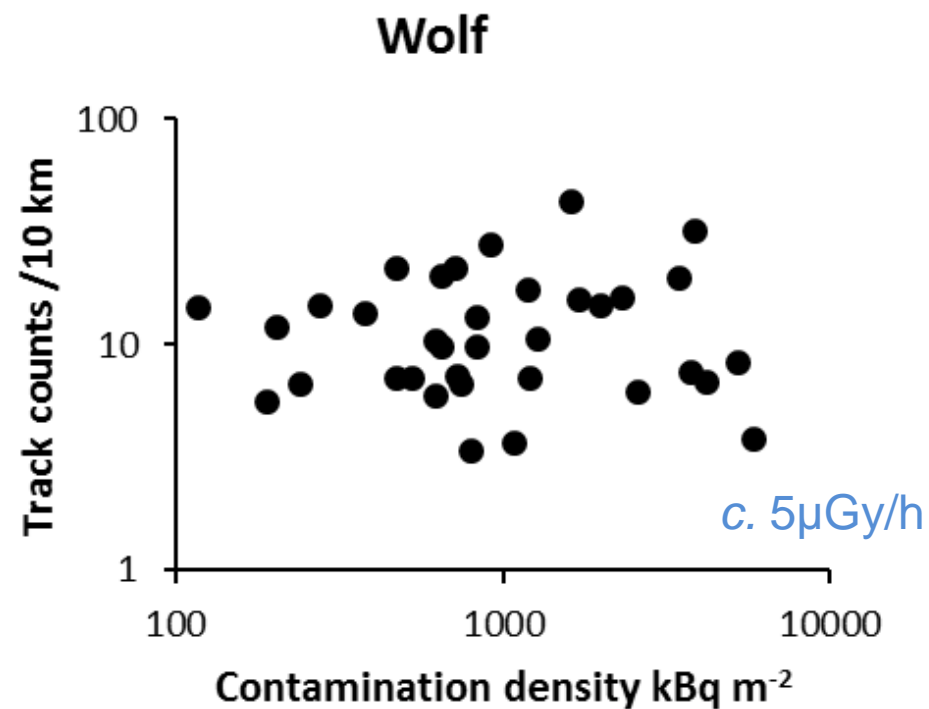
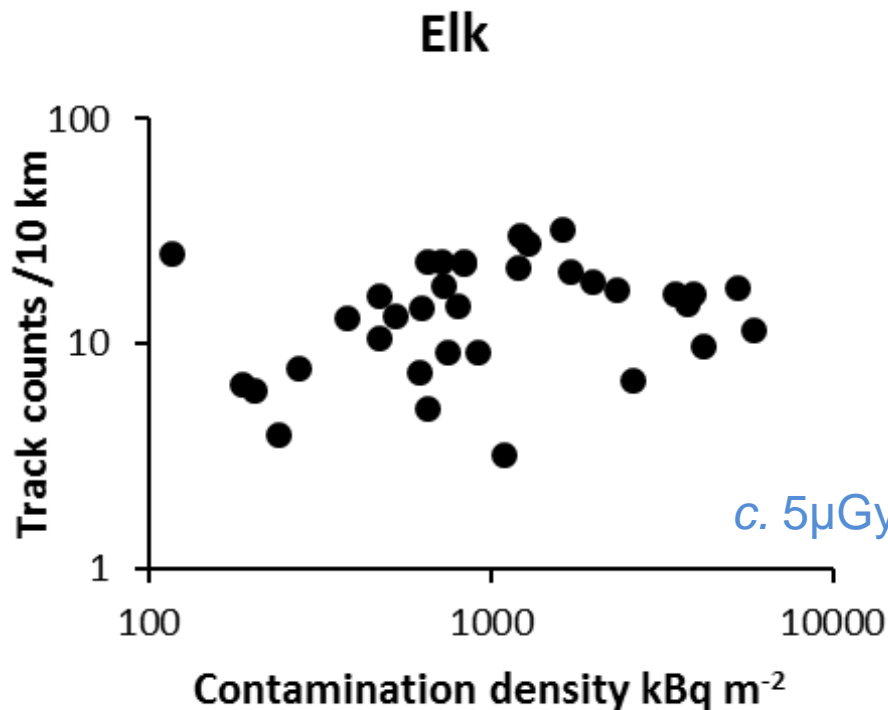
315 km total/mean track 9 km

Deryabina, Kuchmel, Nagorskaya, Hinton, Beasley, Lerebours, Smith (2015) *Current Biology*

Winter track survey data

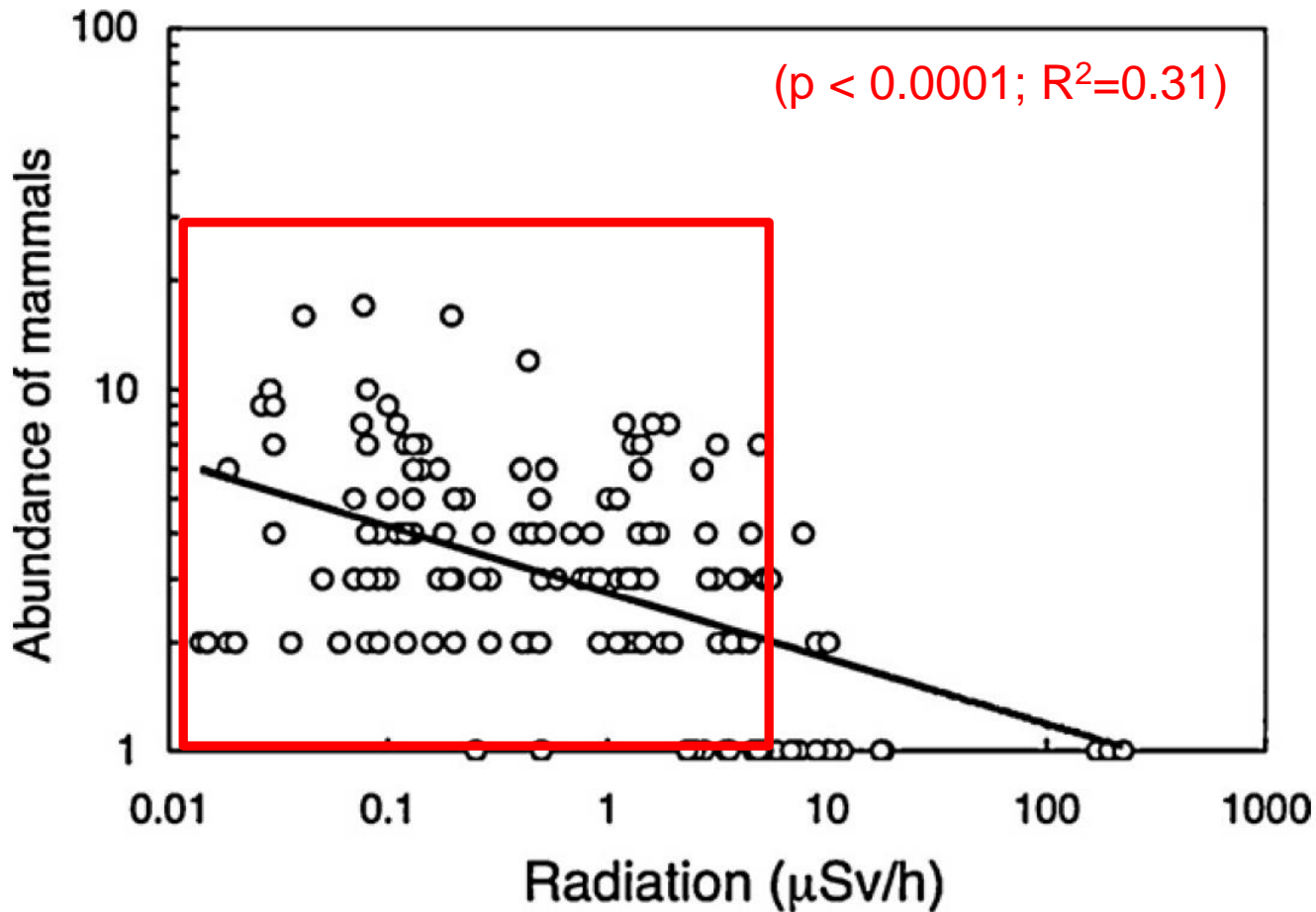


15 mammal species identified



Deryabina, Kuchmel, Nagorskaya, Hinton, Beasley, Lerebours, Smith (2015) *Current Biology*

Mammals



Equivalent dose range to Belarus study

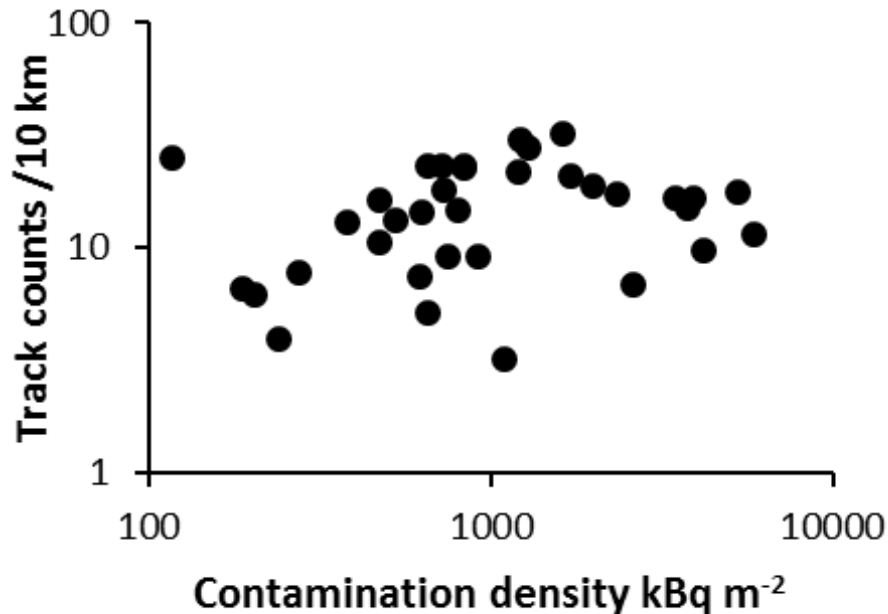
Dose meter measurement at ground level
(2-3 measurements per transect?)

Winter track survey data

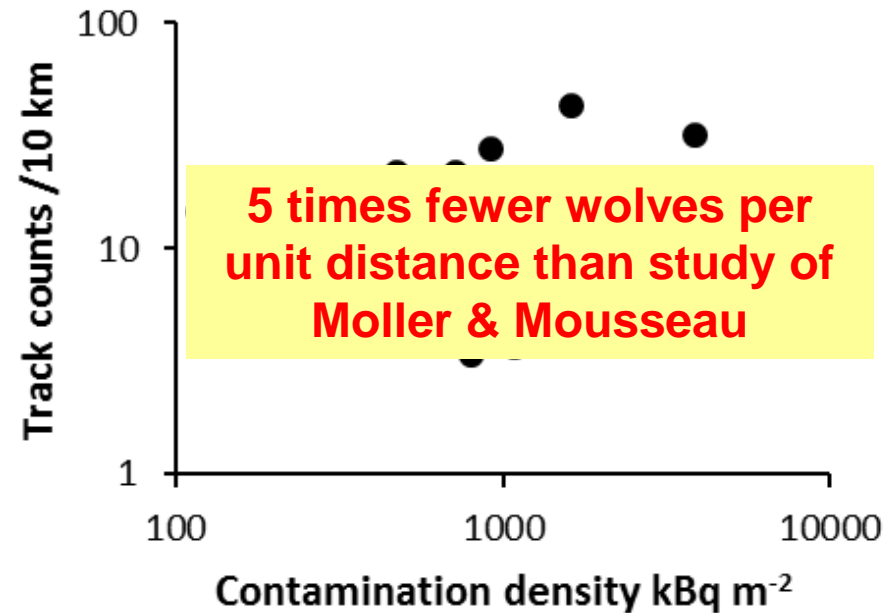


15 mammal species identified

Elk



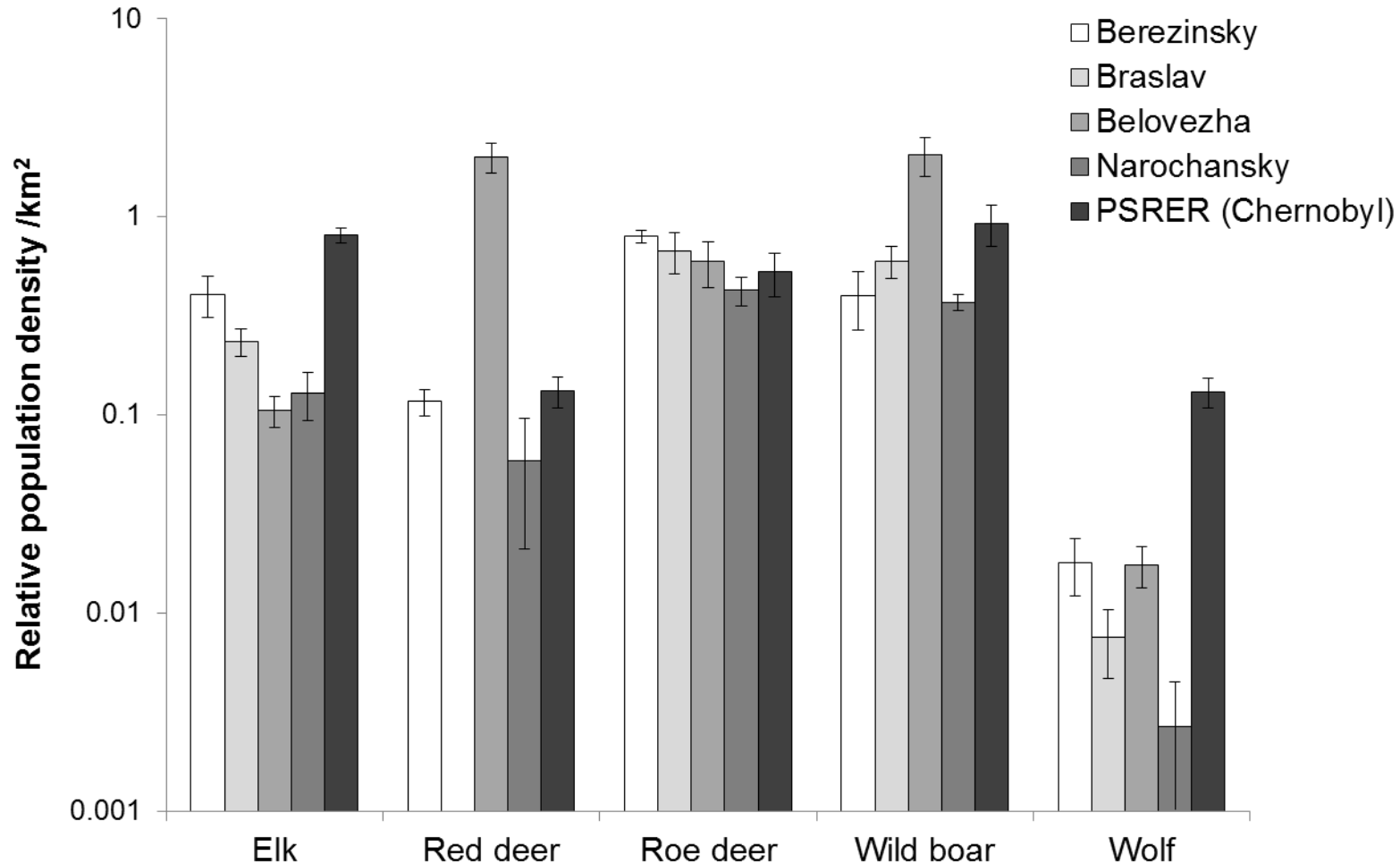
Wolf



5 times fewer wolves per unit distance than study of Moller & Mousseau

Deryabina, Kuchmel, Nagorskaya, Hinton, Beasley, Lerebours, Smith (2015) *Current Biology*

Chernobyl compared to nature reserves

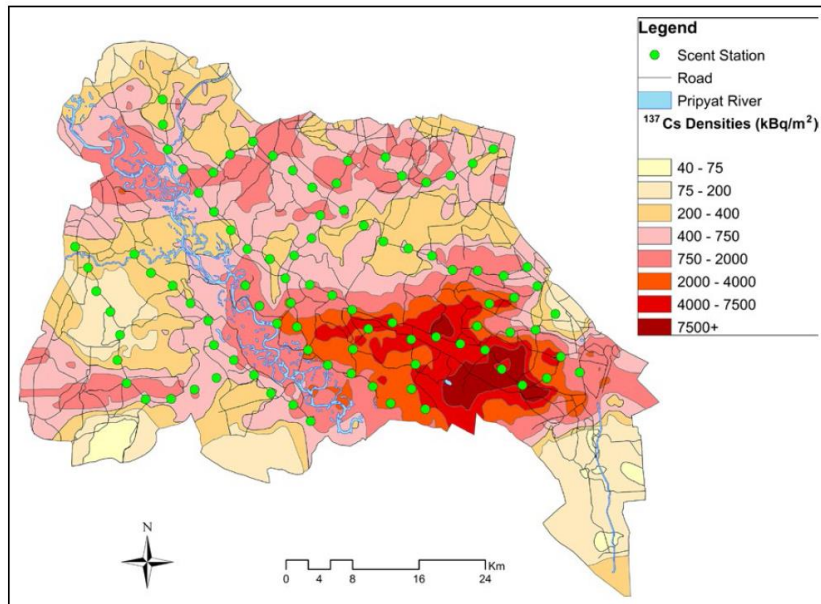


Similar winter track survey protocol

Deryabina, Kuchmel, Nagorskaya, Hinton, Beasley, Lerebours, Smith (2015) *Current Biology*

Scent station camera trap study

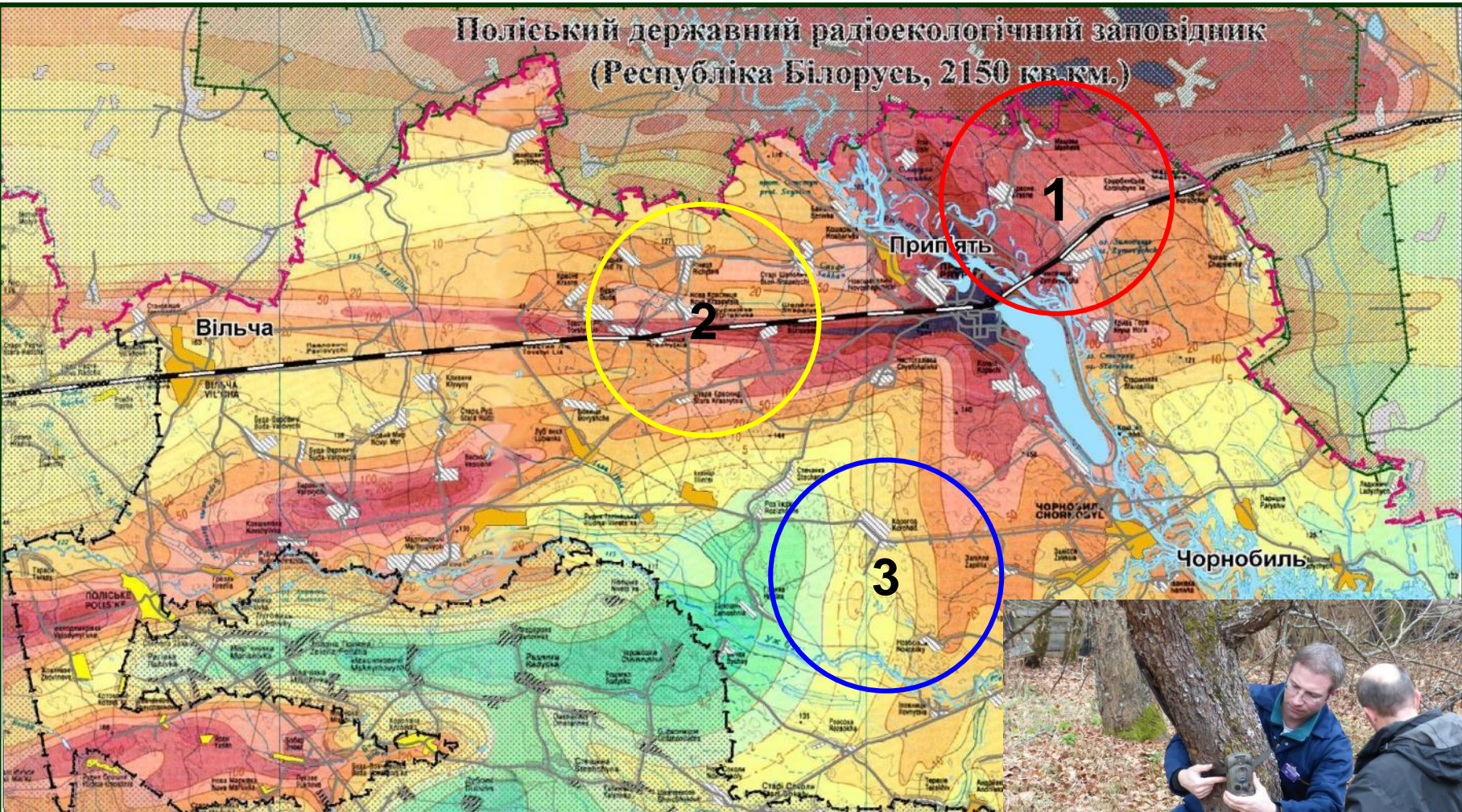
Webster et al. *Frontiers in Ecol. and Environ.* 2016



- No correlation with contamination density in grey wolf, red fox, wild boar
- Raccoon dog showed statistically significant *positive* correlation with contamination density

Random placement trap study

Поліський державний радіоекологічний заповідник
(Республіка Білорусь, 2150 кв. км.)



TREE



Transfer - Exposure - Effects:

integrating the science needed to underpin radioactivity assessments for humans and wildlife

What did we see?



Ltl Acorn

2307

(

027°F - 003°C

02/15/2015 12:11:49

First observations



Birds

- Over 40 publications on effects of radiation on birds re Chernobyl (& Fukushima)
 - One of the most studied taxa
- >90% of papers by one research group
- Largely ‘negative’ effects reported



Some observed effects

- Fluctuating asymmetry and mutation rates 2 - 10 fold higher in Chernobyl
- **Cataracts**, partial albinism, tumours and other deformations all negatively associated with increasing radiation
- Reproduction effects

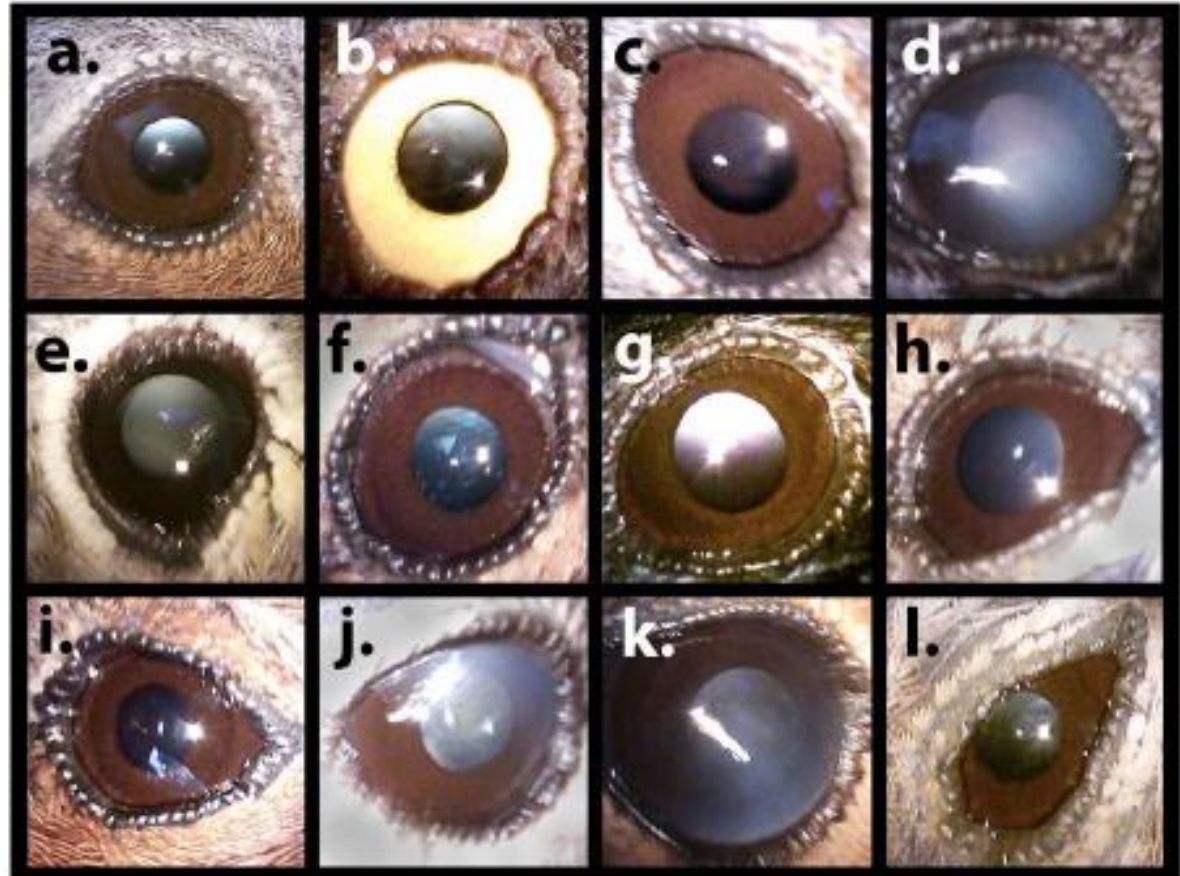


Figure 2. Photographs of selected eyes from Chernobyl birds.

Some observed effects

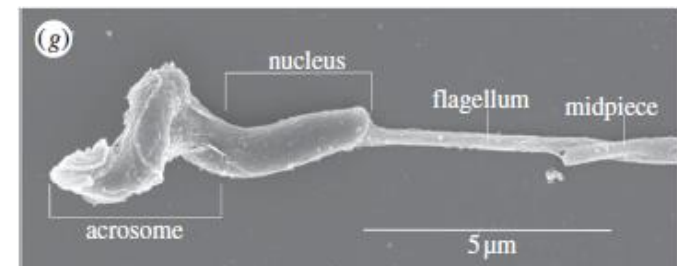
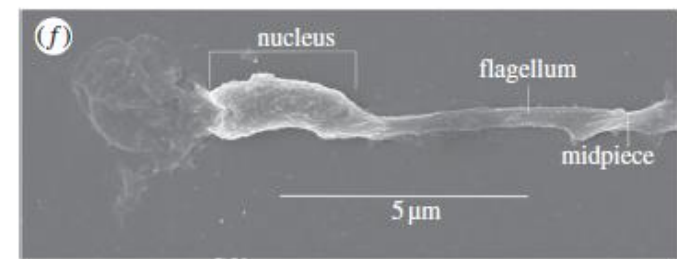
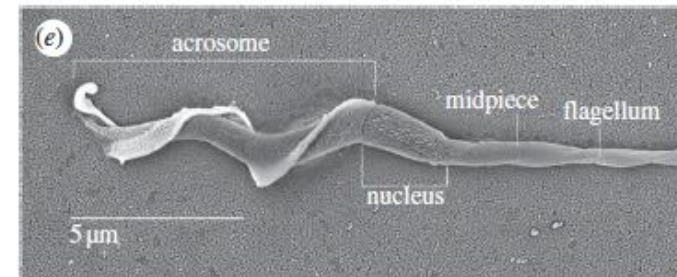
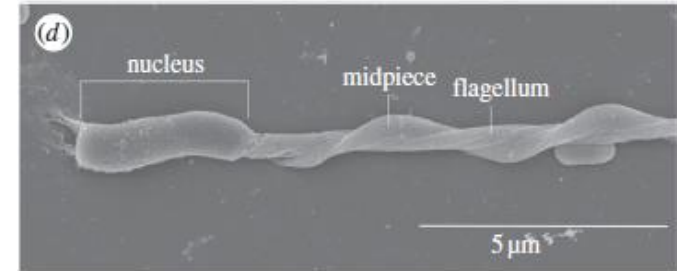
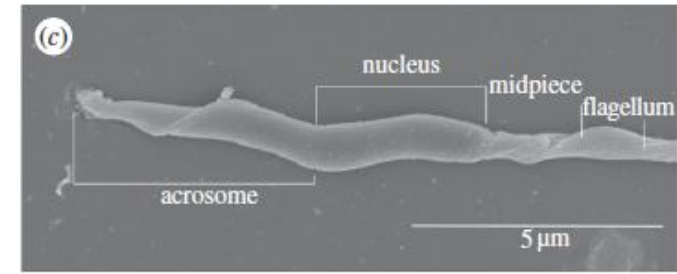
- Fluctuating asymmetry and mutation rates 2 - 10 fold higher in Chernobyl
- Cataracts, **partial albinism, tumours and other deformations** all negatively associated with increasing radiation
- Reproduction effects



Birds displaying albinistic feathers, tumours and developmental aberrations. Møller et al., 2011 - High frequency of albinism and tumours in free-living birds around Chernobyl

Some observed effects

- Fluctuating asymmetry and mutation rates 2 - 10 fold higher in Chernobyl
- Cataracts, partial albinism, tumours and other deformations all negatively associated with increasing radiation
- **Reproduction effects**



Statistical significance - **real world relevance or not**

A p-value helps determine statistical significance (i.e. the effect observed is unlikely to have occurred by chance).

It does **not** translate always to real world importance.

Statistical significance - **real world relevance or not**

A p-value helps determine statistical significance (i.e. the effect observed is unlikely to have occurred by chance).

It does **not** translate always to real world importance.

..... or maybe nuclear power really is bad for you (especially if you cannot swim)?

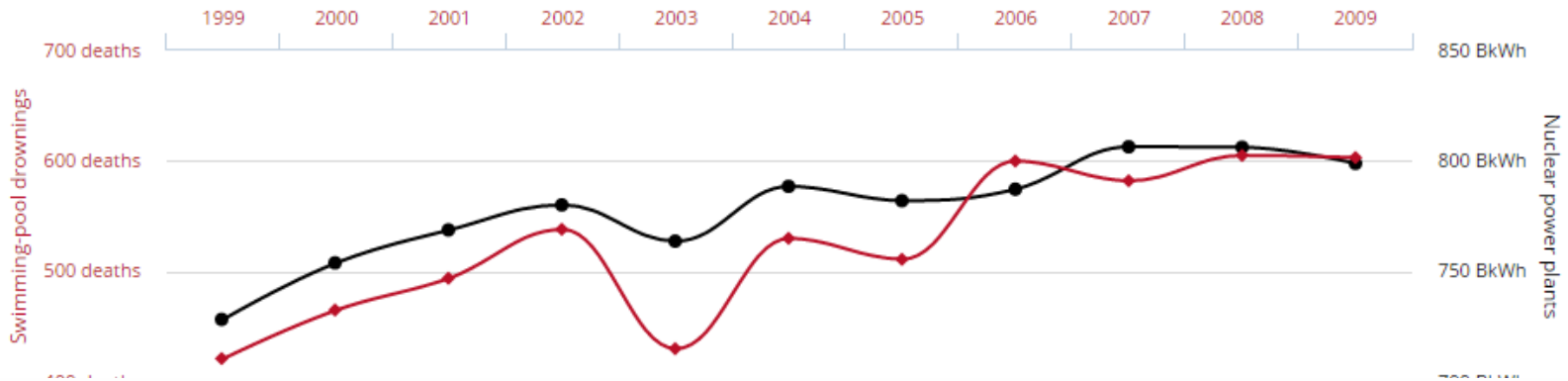
..... or does uranium create mathematicians?

Number people who drowned while in a swimming-pool

correlates with

Power generated by US nuclear power plants

Correlation: 90.12% ($r=0.901179$)

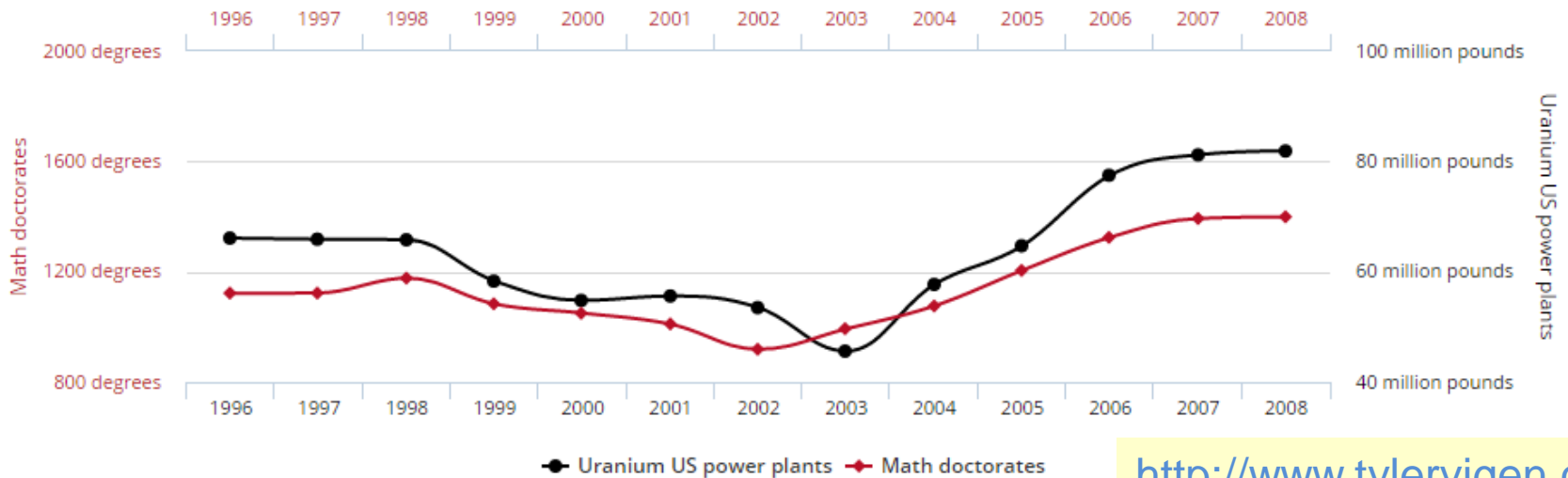


Math doctorates awarded

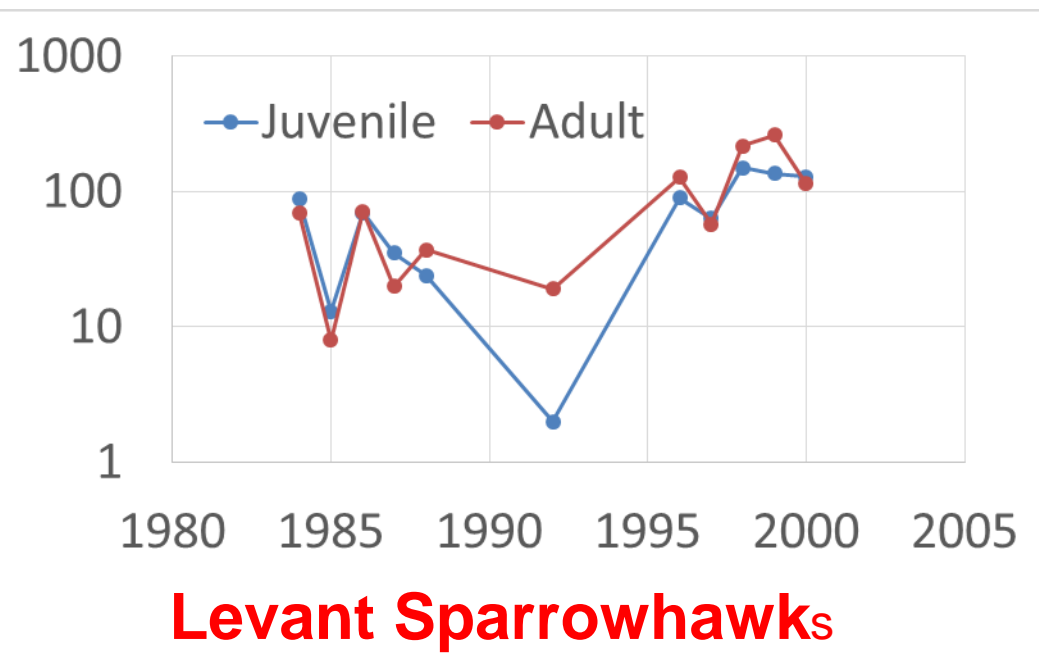
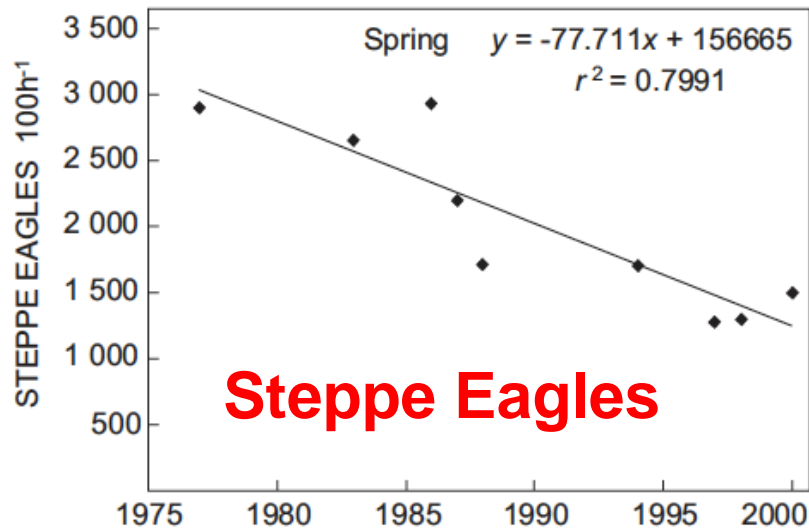
correlates with

Uranium stored at US nuclear power plants

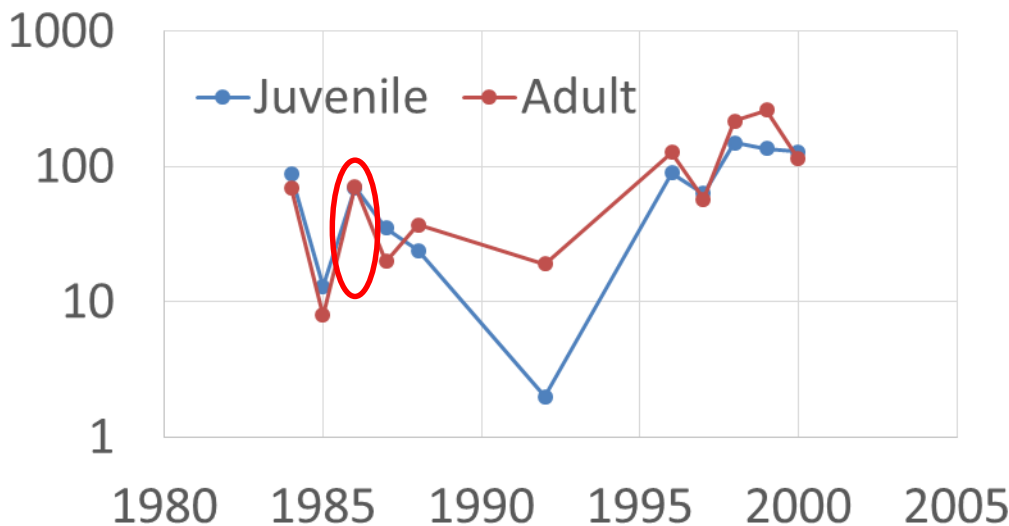
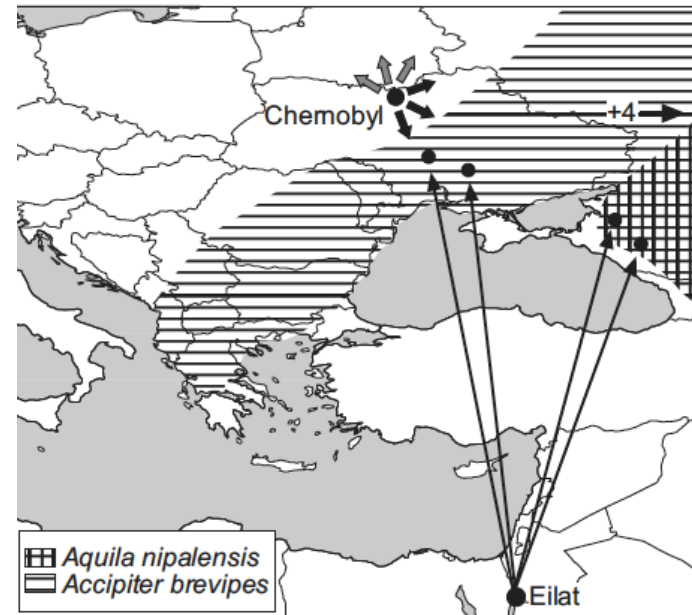
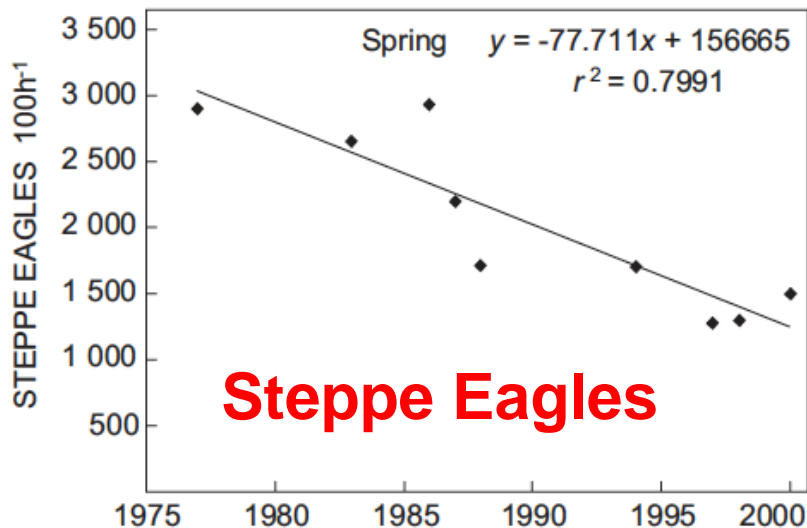
Correlation: 95.23% ($r=0.952257$)



Migratory raptors - Israel



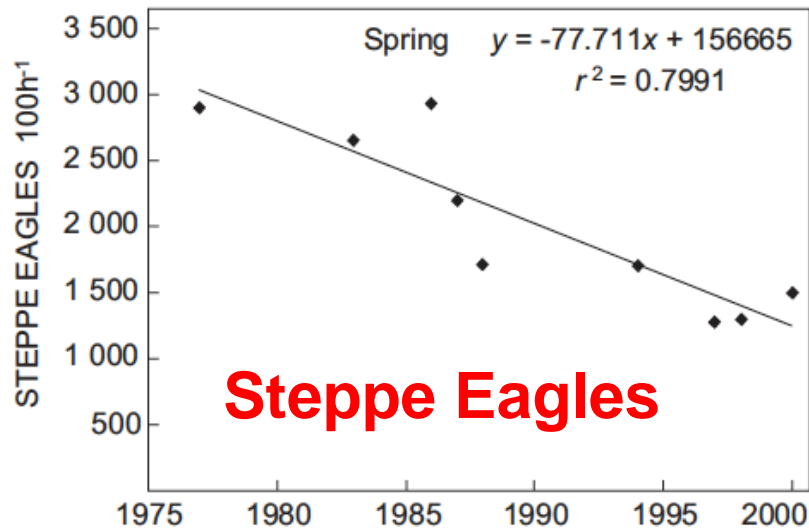
Migratory raptors - Israel



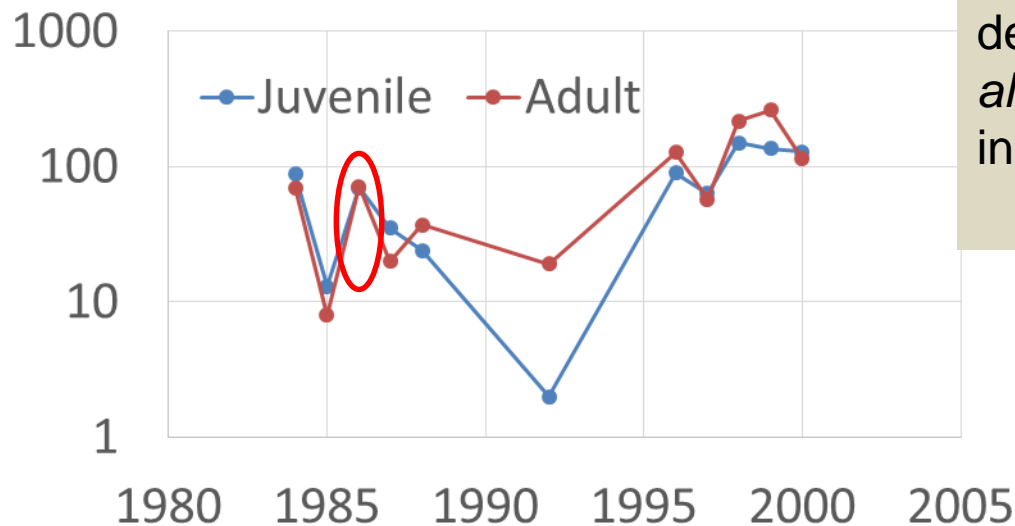
Levant Sparrowhawks

“...the fact that the decline occurred immediately after 1986 and that the radioactive plume following the 1986 Chernobyl accident was blown in the direction of the known breeding grounds of the species (Figure 3), suggests that radioactive contamination could have negatively affected not only the survival of the adults but also their reproductive ability...”

Migratory raptors - Israel



There have been large, whole scale and often severe declines in many Afro-Palearctic migrants species over the last three decades, with no single causative factor identified, though a combination of habitat loss or deterioration on the wintering and/or breeding grounds, loss of staging areas, hunting pressure in southern Europe and North Africa, and climate change all play some part in this decades long pattern. - (Sanderson, *et al.*, 2006. Long-term population declines in Afro-Palearctic migrant birds).



Levant Sparrowhawk_s

Invertebrates

1986:

Pine forest 3 km from NPP

- 30-fold reduction soil dwelling mites (29 Gy)
- Larvae/nymphs of many species absent

Agricultural soils 3-7 km from NPP

- Lower abundance of young earthworms

1988/89:

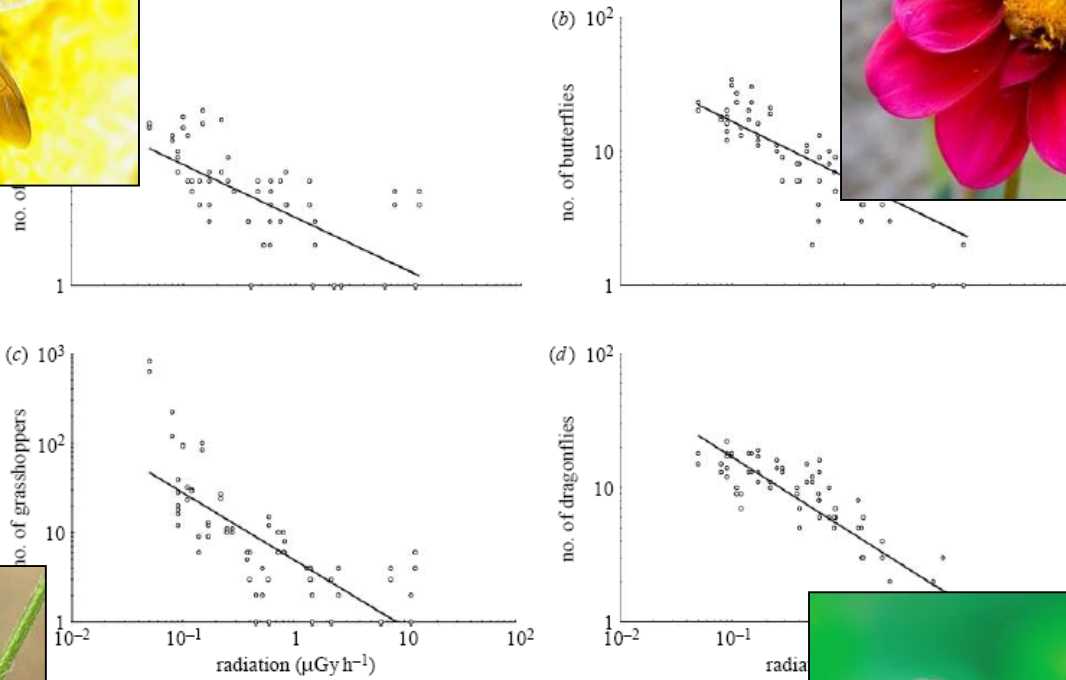
- Mesofauna population size restored

Mid-1990's:

- Changes in species composition as consequence of changing ecosystems
- Reduced mesofauna diversity

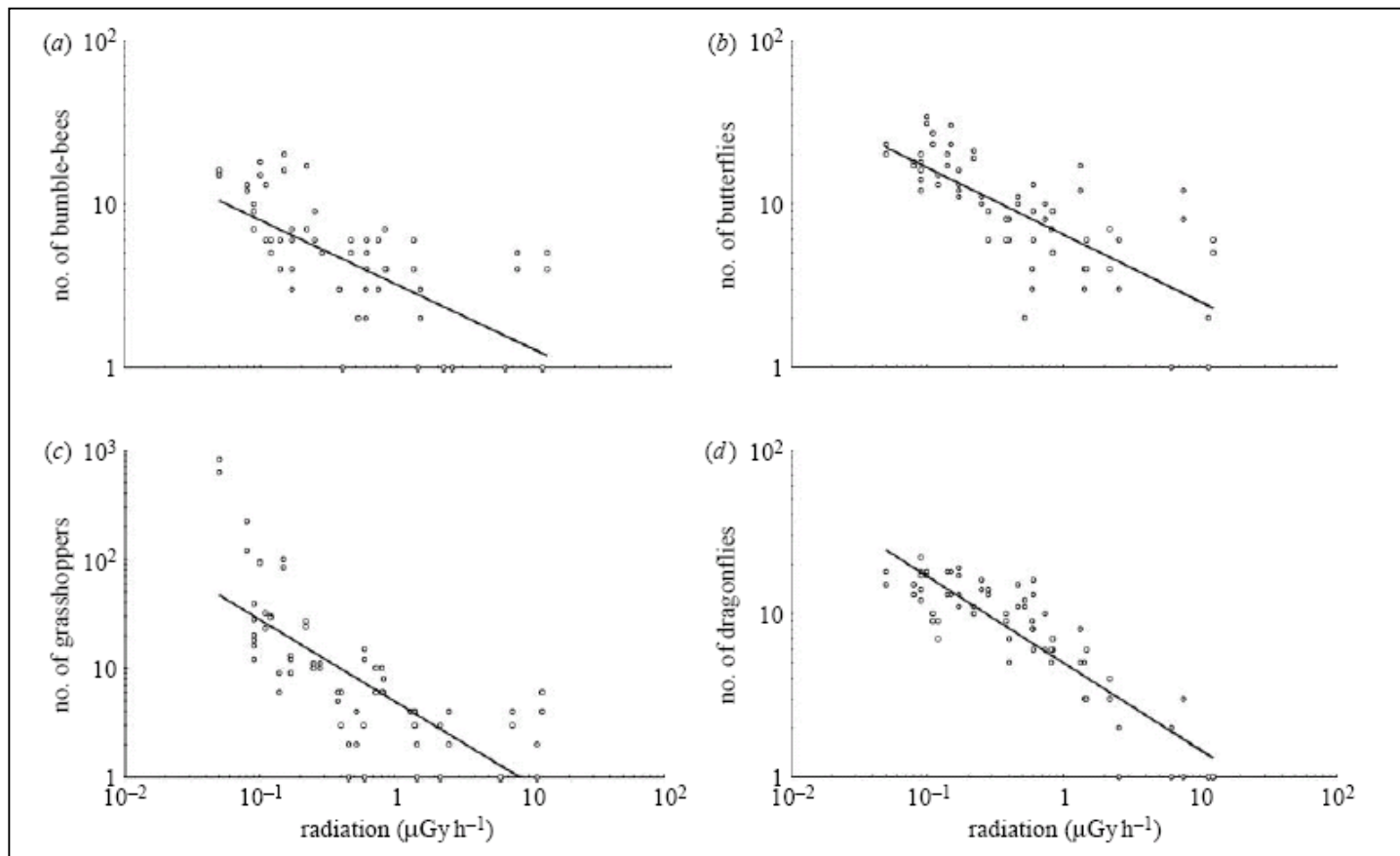


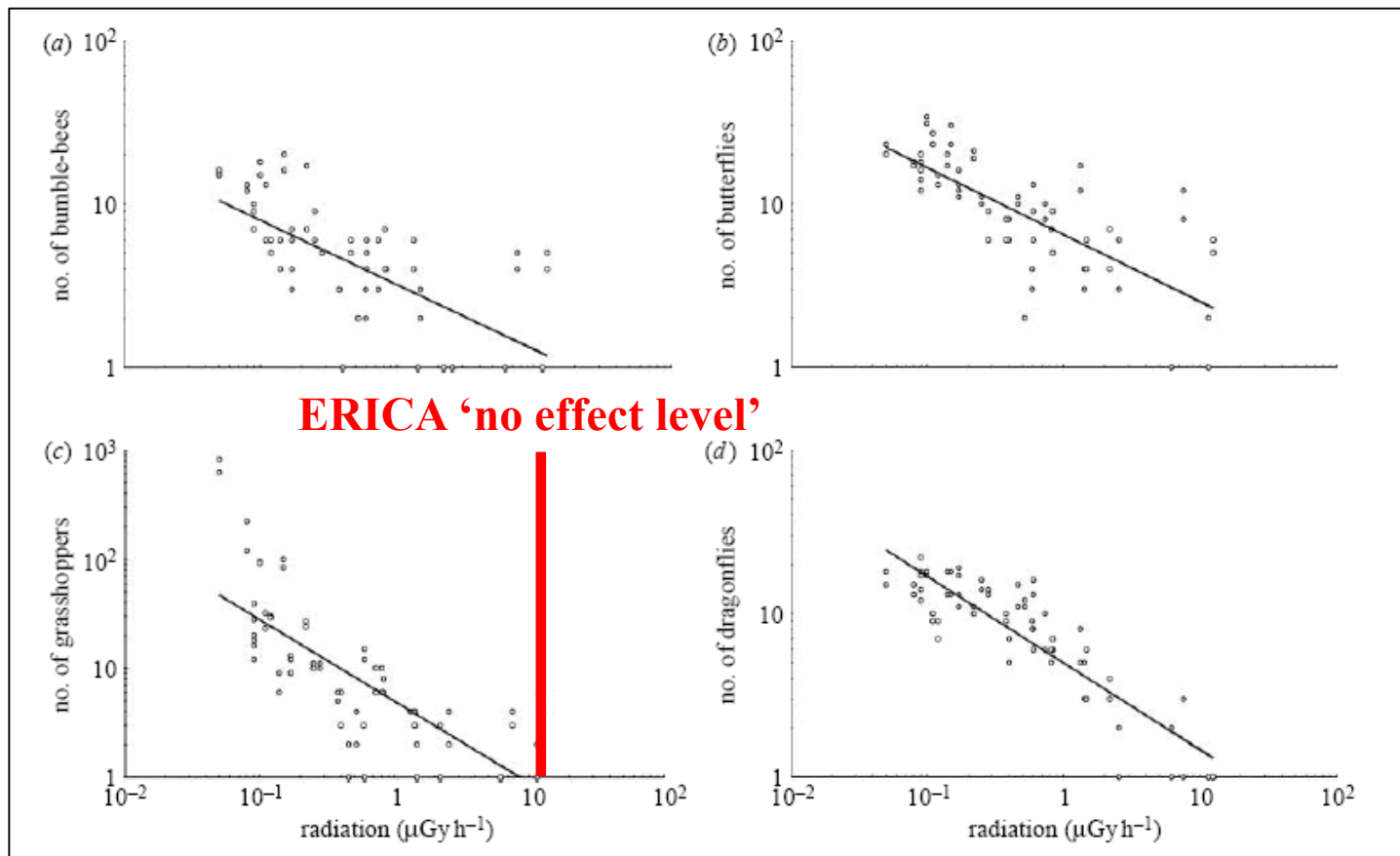
Invertebrates

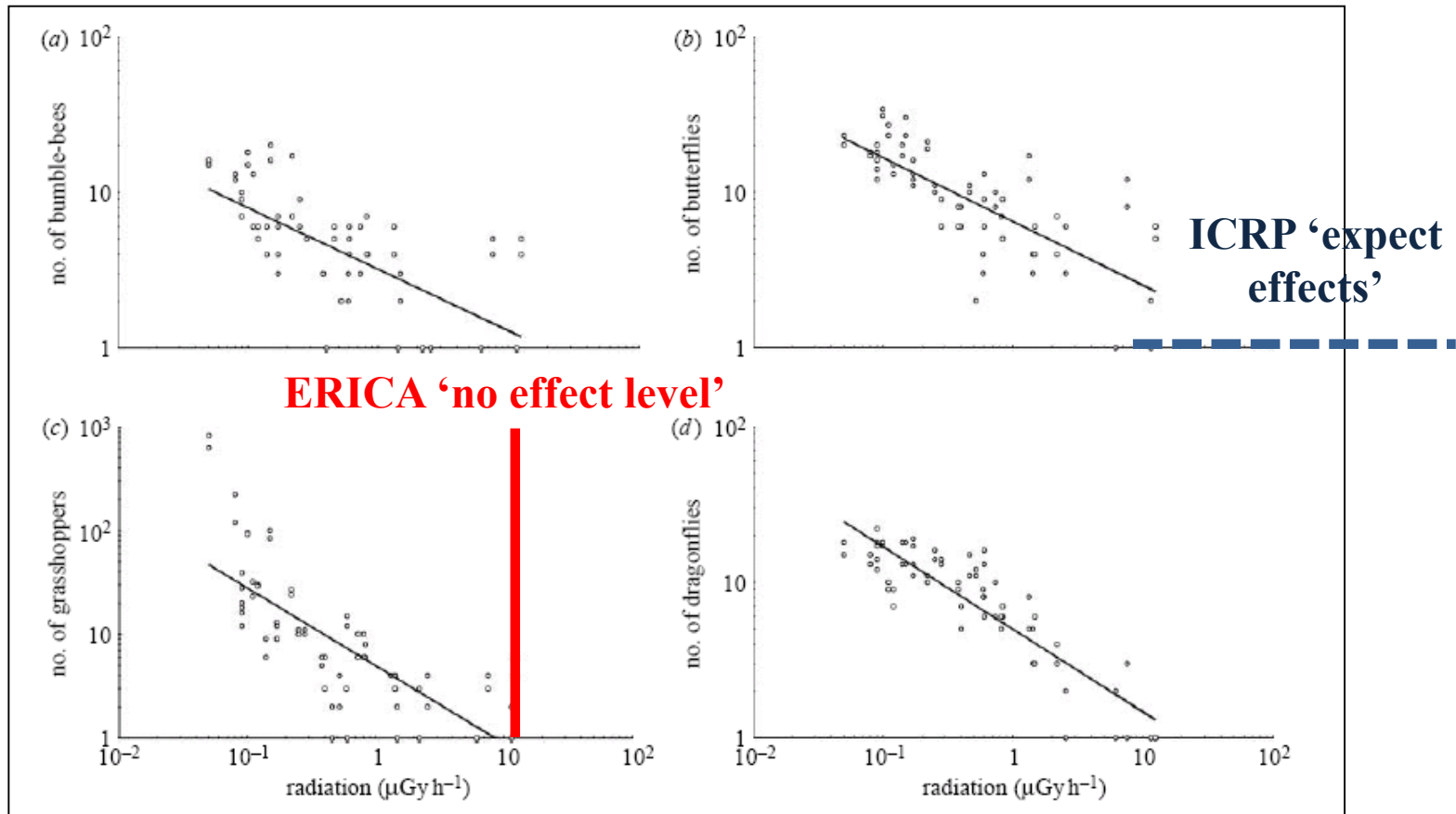


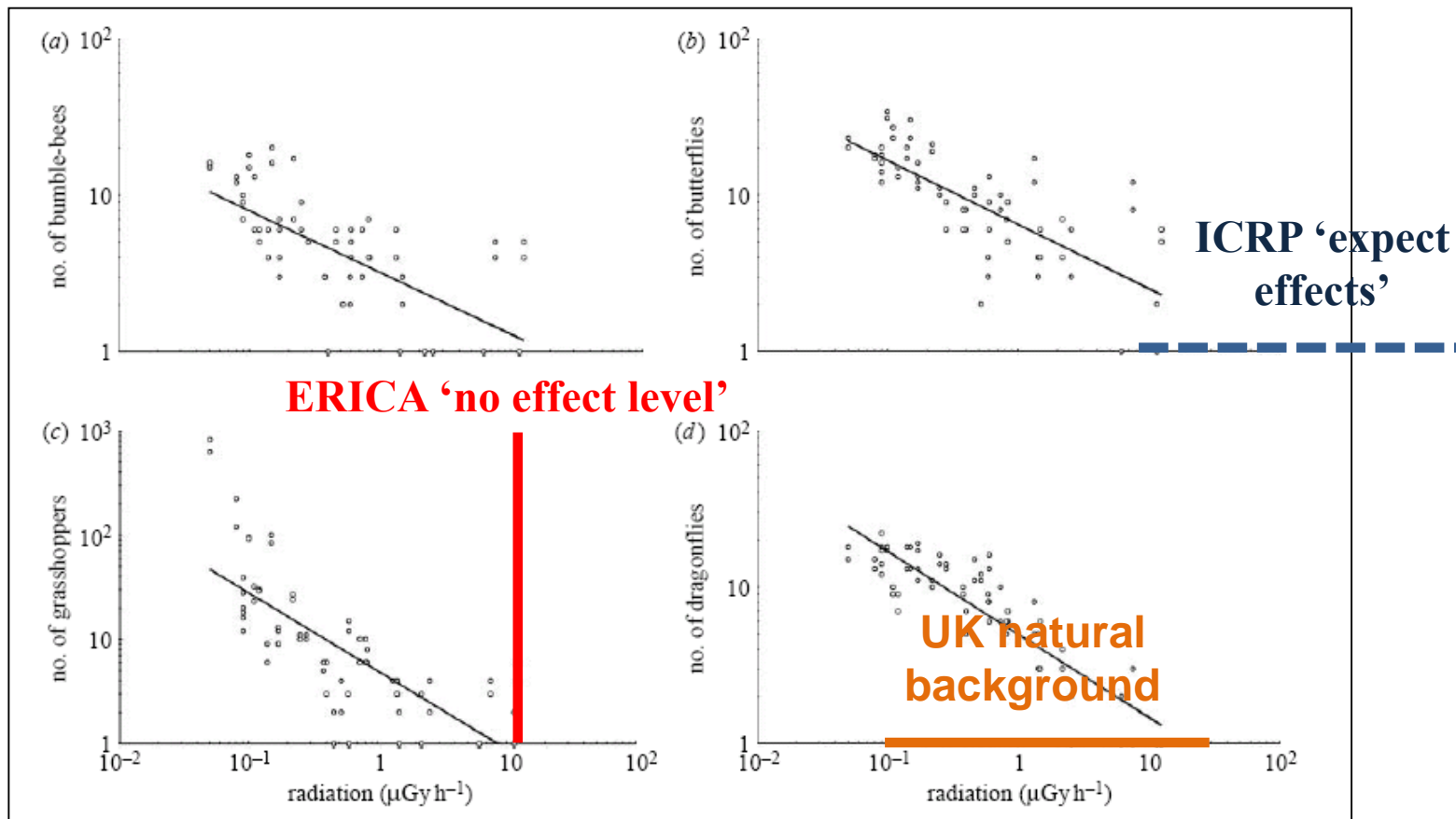
Chernobyl

Møller & Mousseau 2009
Biol. Lett.

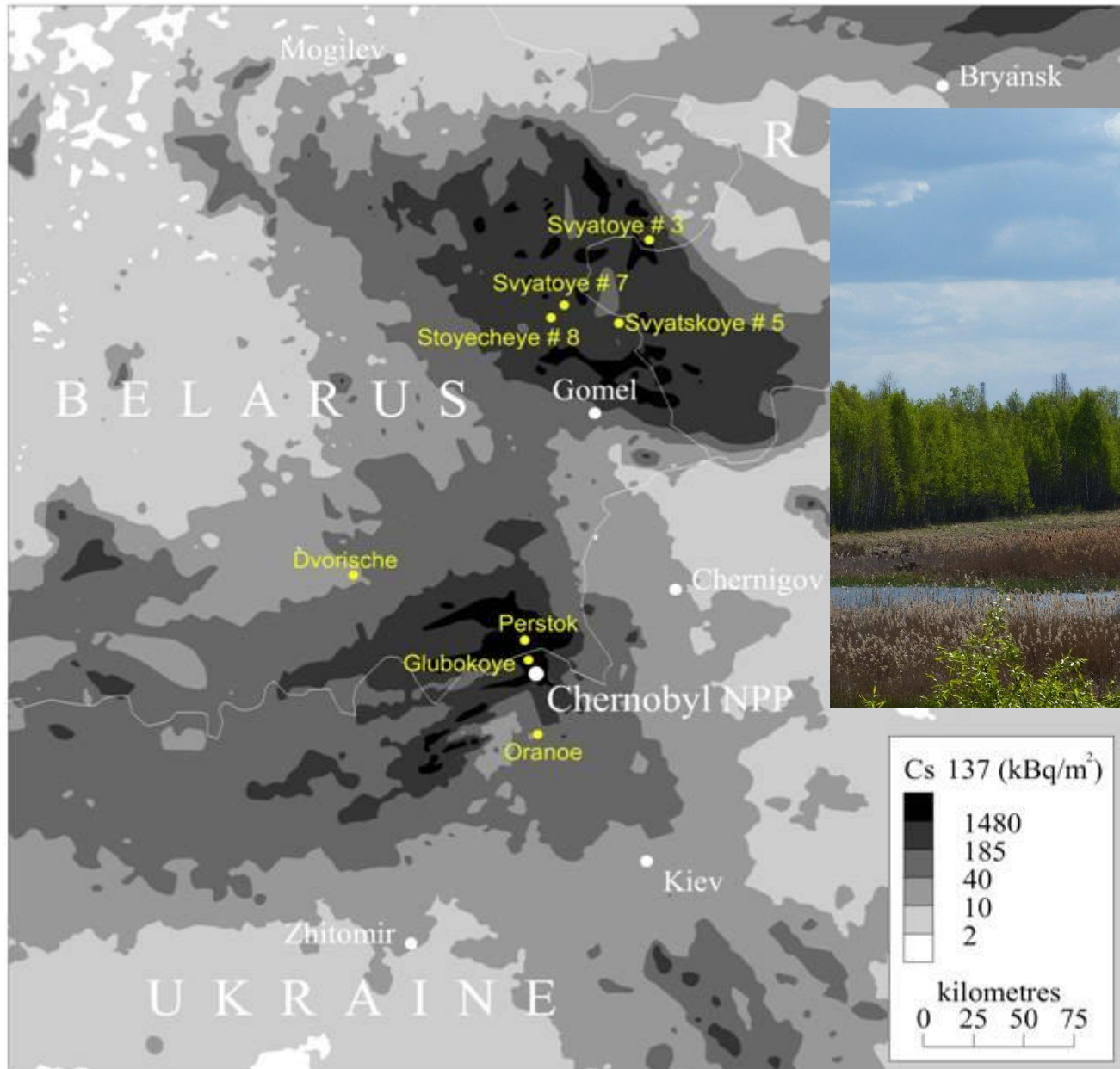




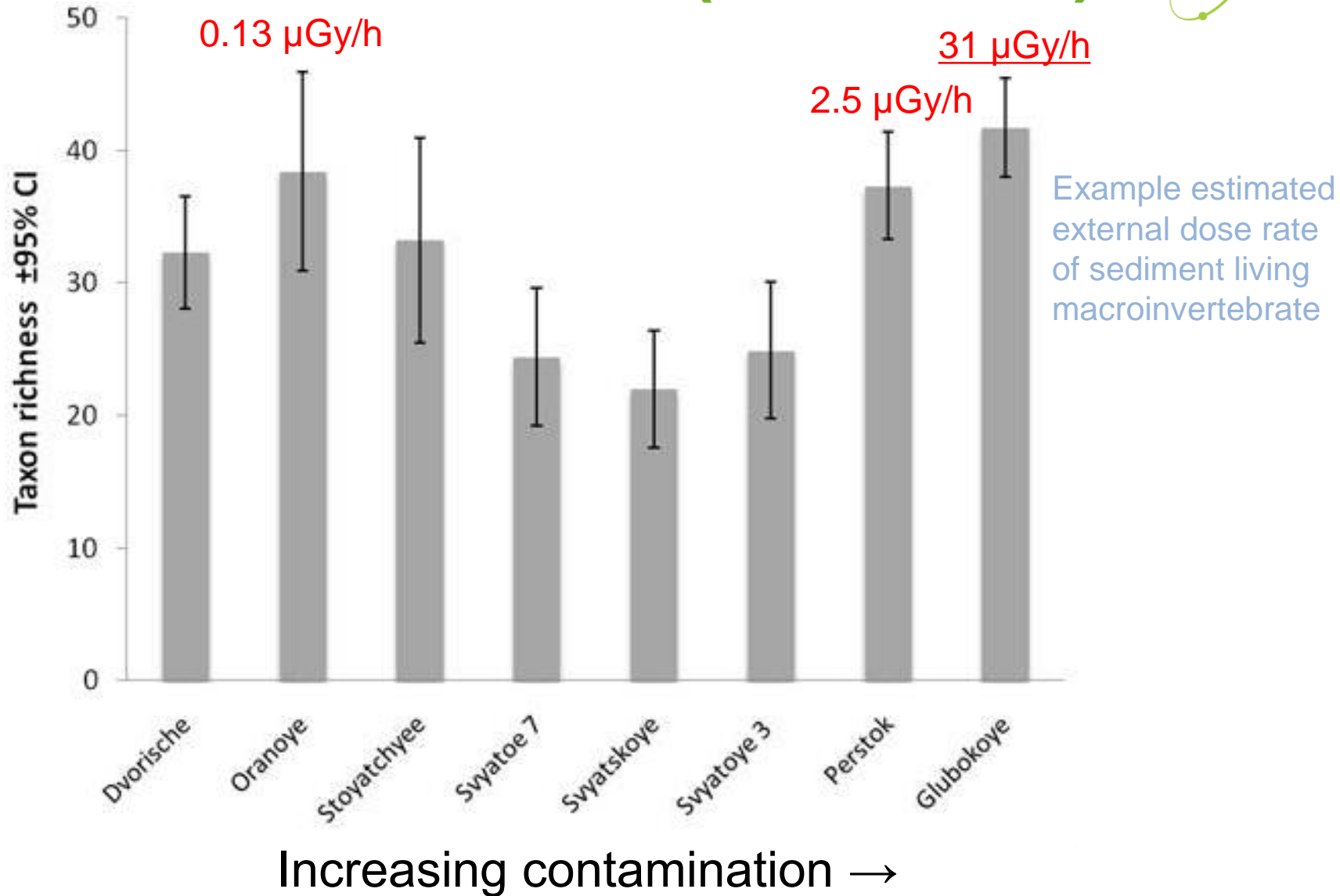




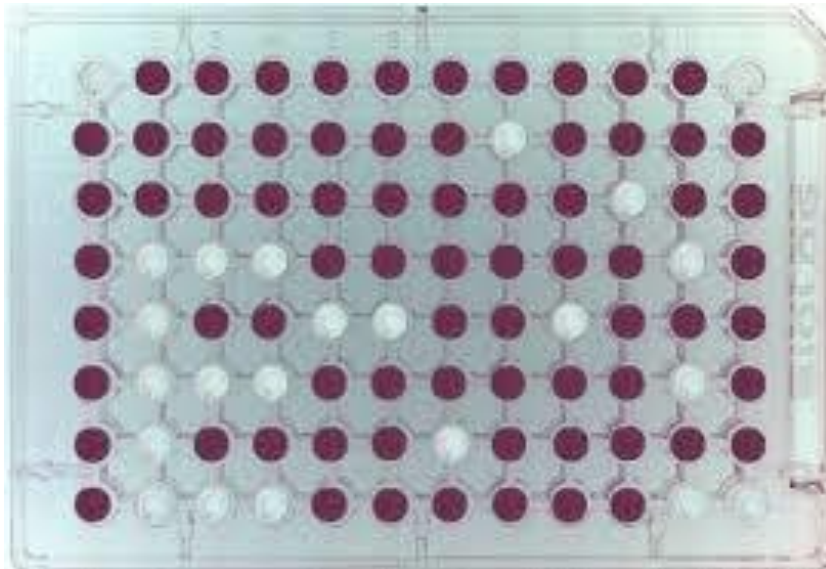
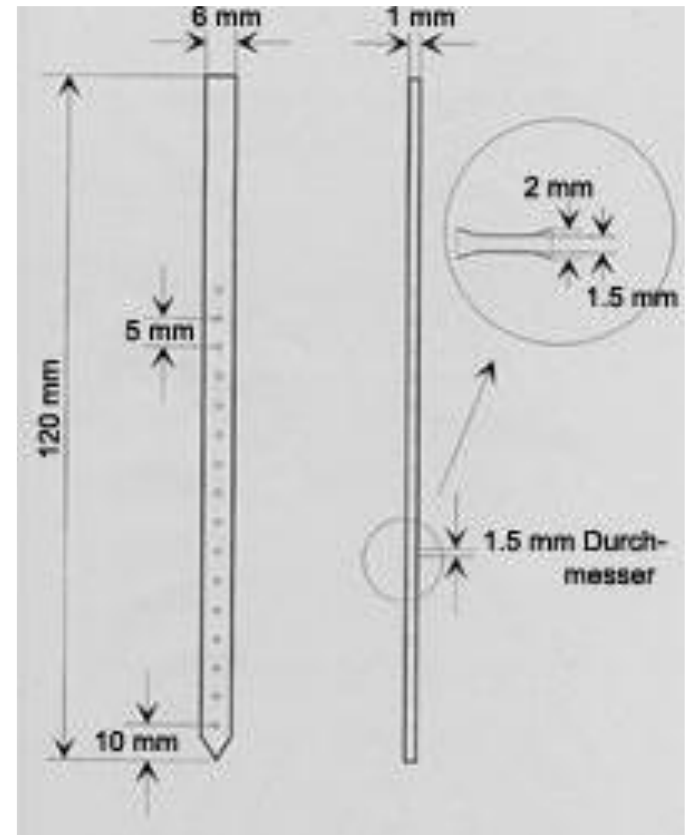
Aquatic invertebrates (2003-2004)



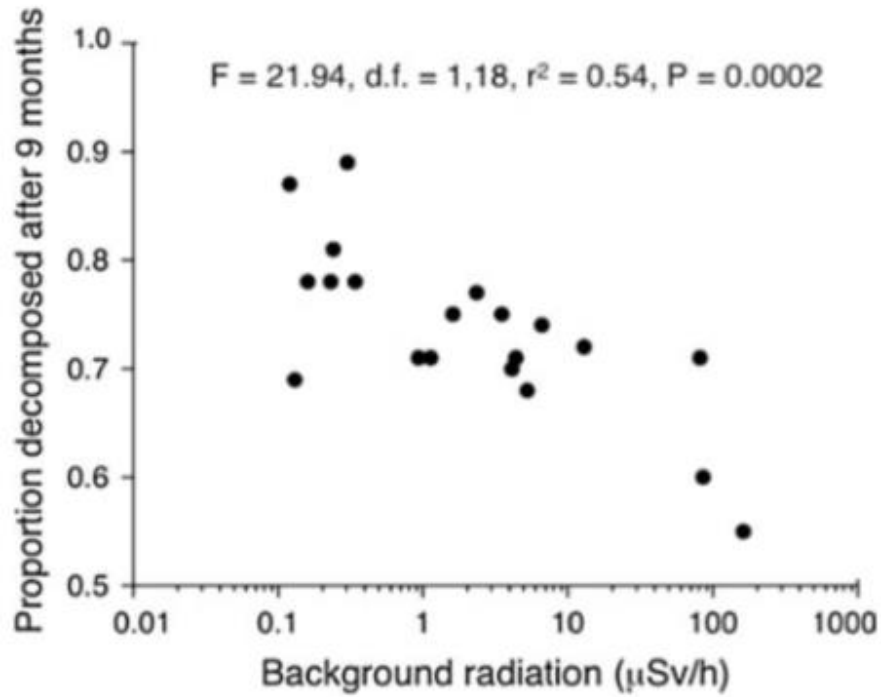
Aquatic invertebrates (2003-2004)



Soil function

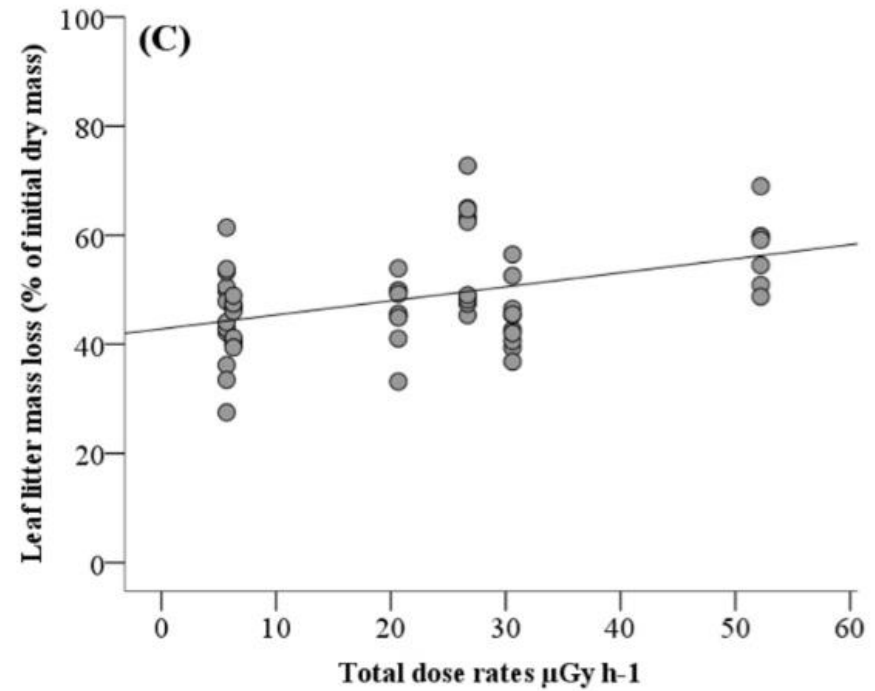


Mousseau et al, 2014

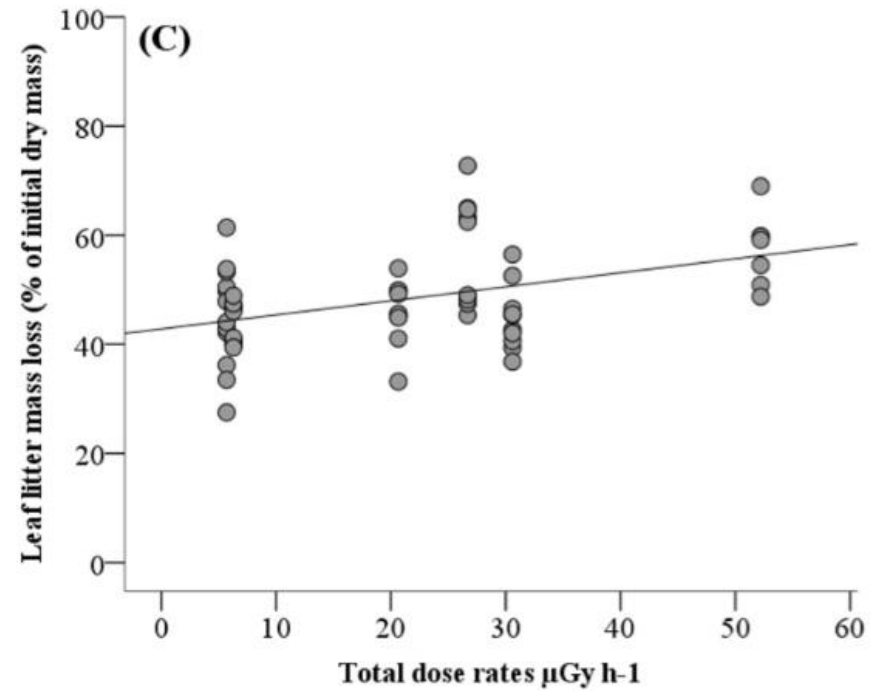
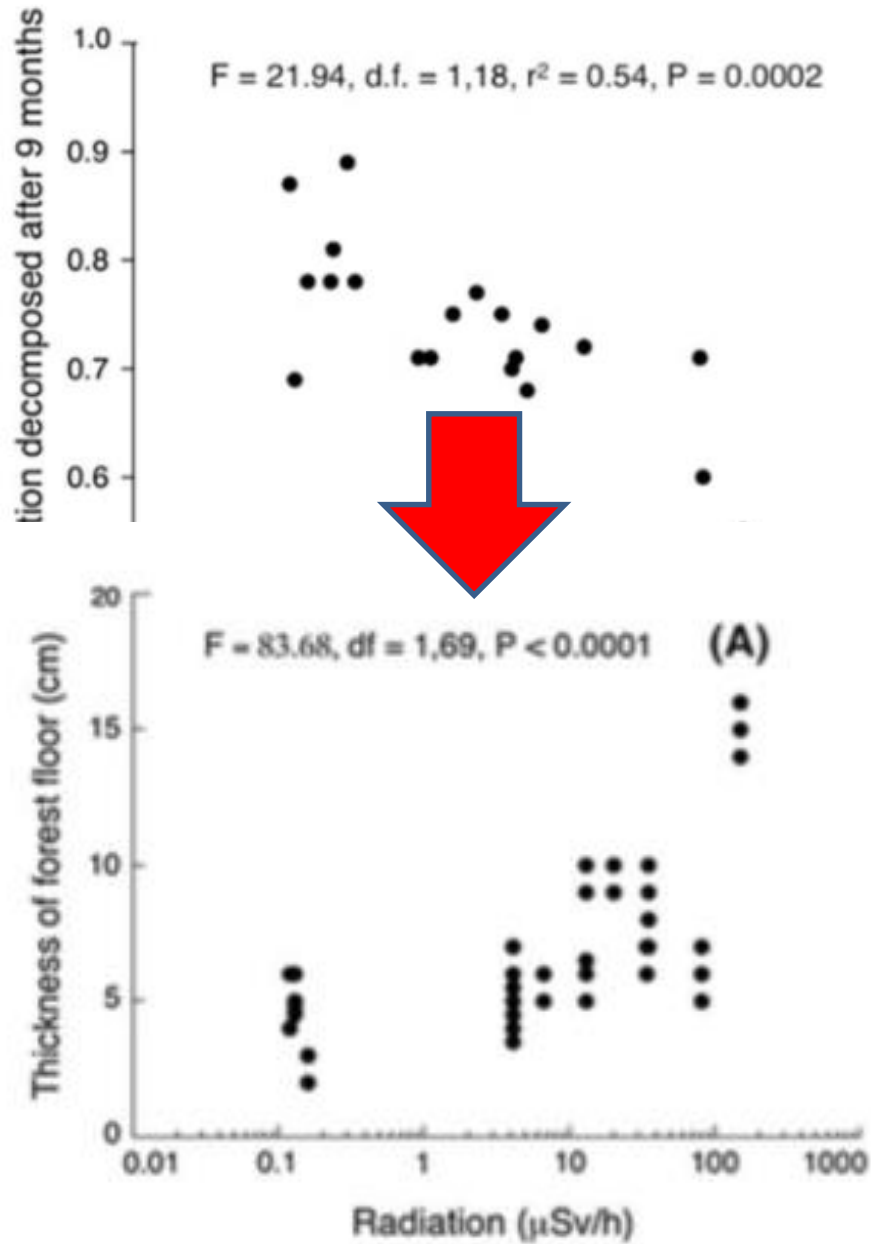


0.2 cm and <0.5 mm mesh
0.75 year

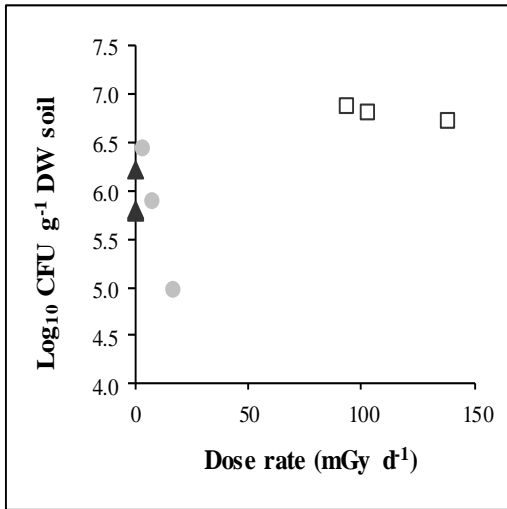
Bonzom et al, 2016 



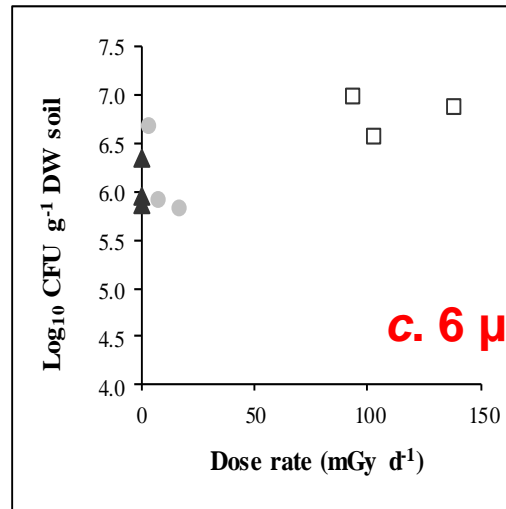
1 cm mesh
0.44 year



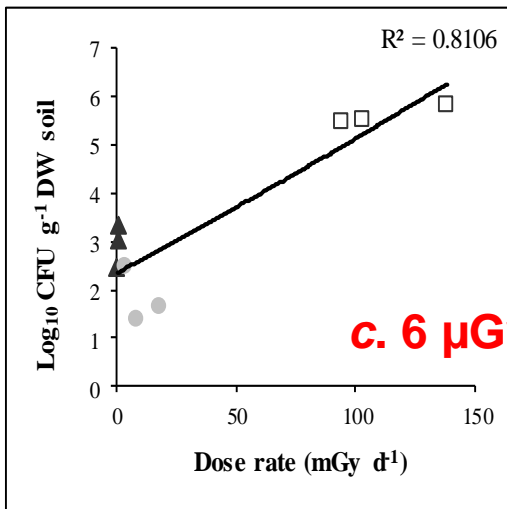
Soil microbiota (CEZ 2002)



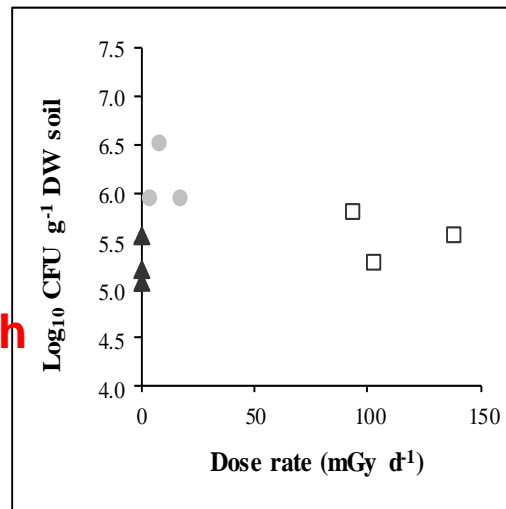
Bacteria nutrient poor



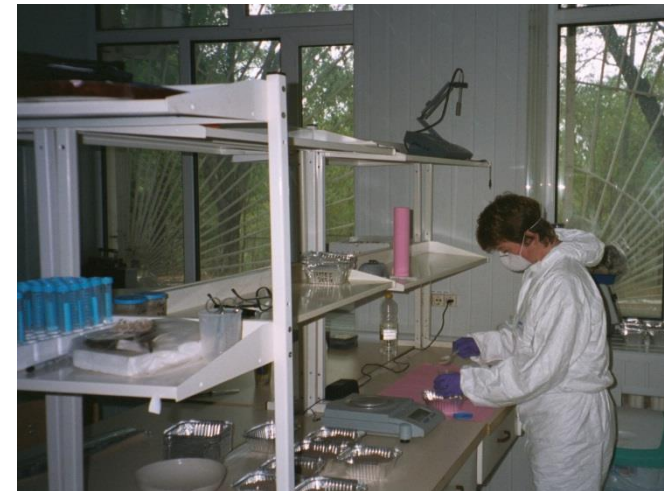
Bacteria nutrient rich



Pseudomonad

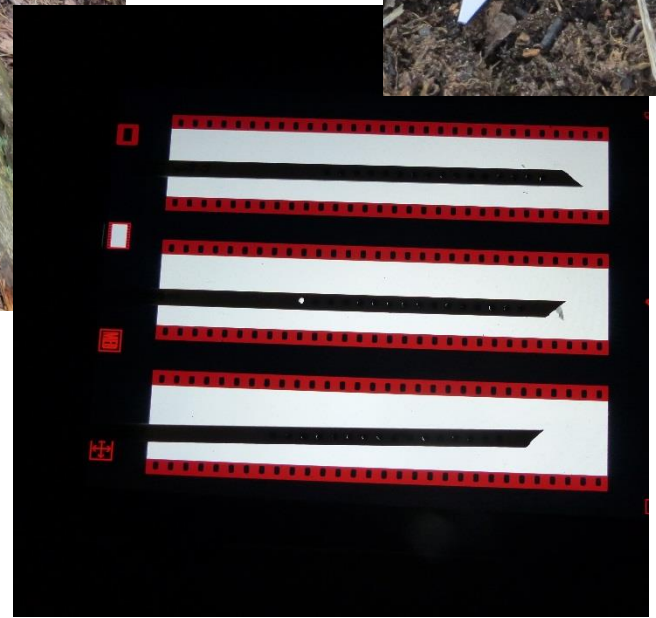


Fungi



Jones 2004
Uni. of
Nottingham

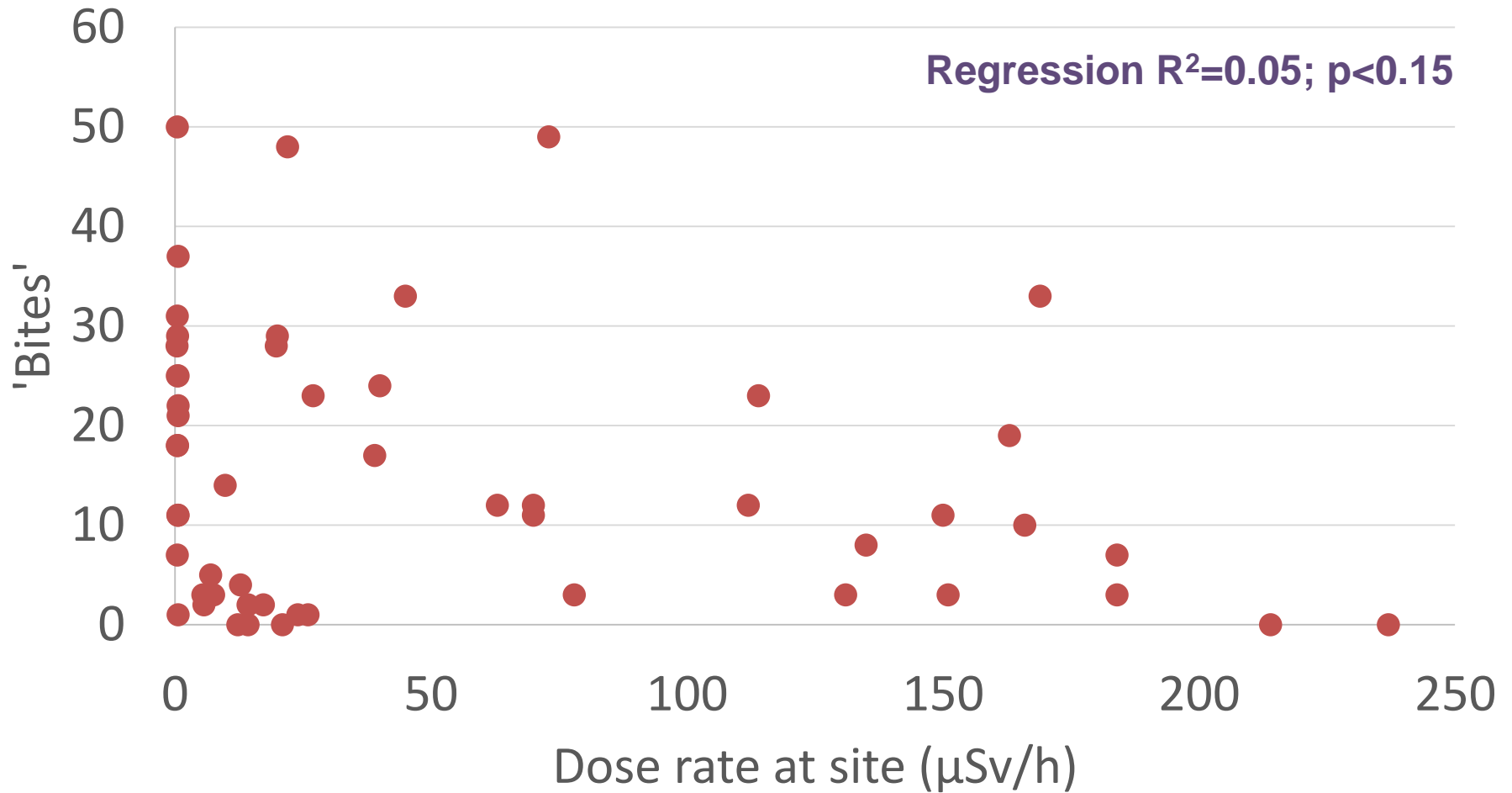
Bait lamina





April 2016

Total 16 sticks v's dose rate

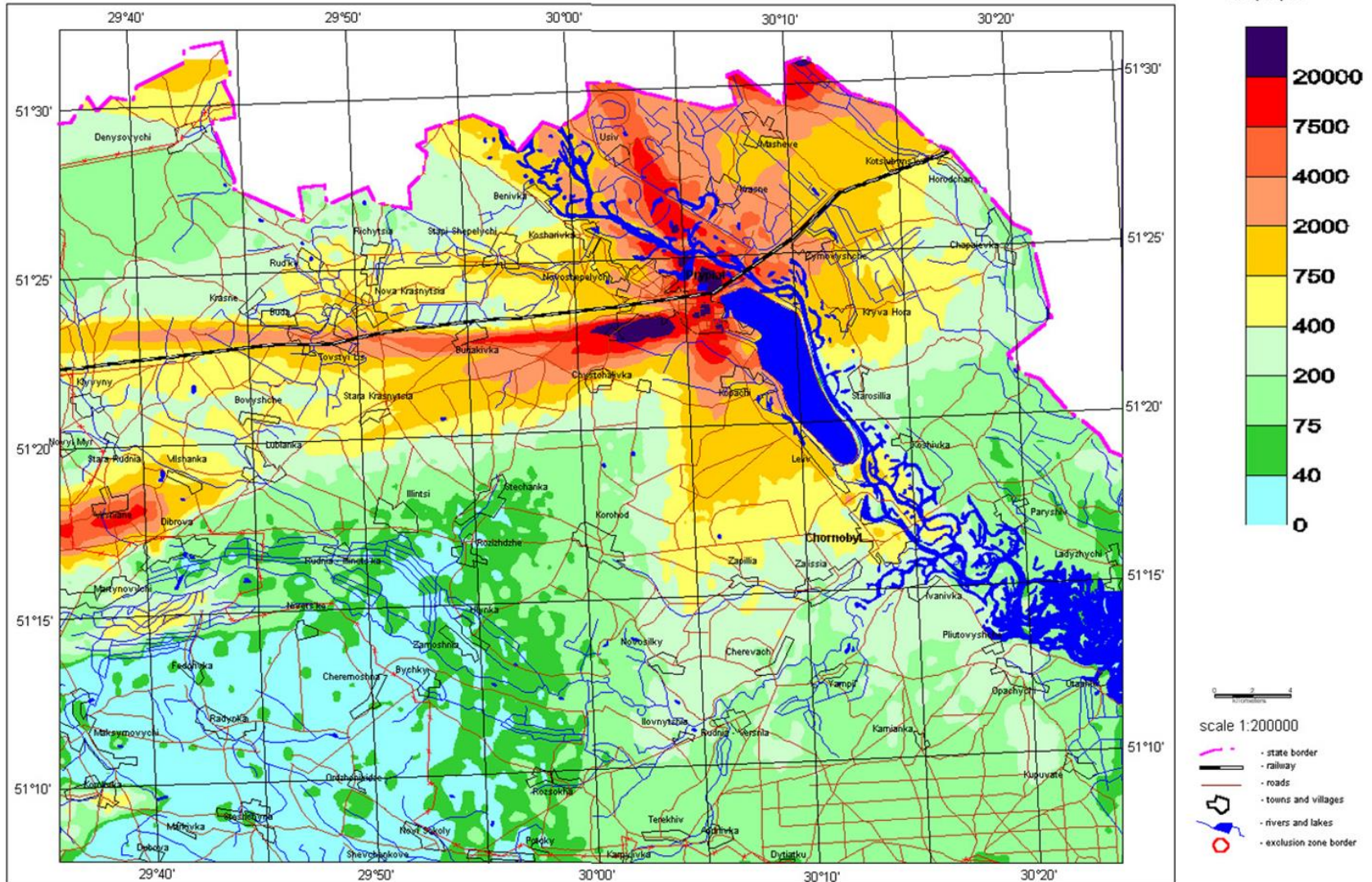


Thinking about how exposure is estimated in the field

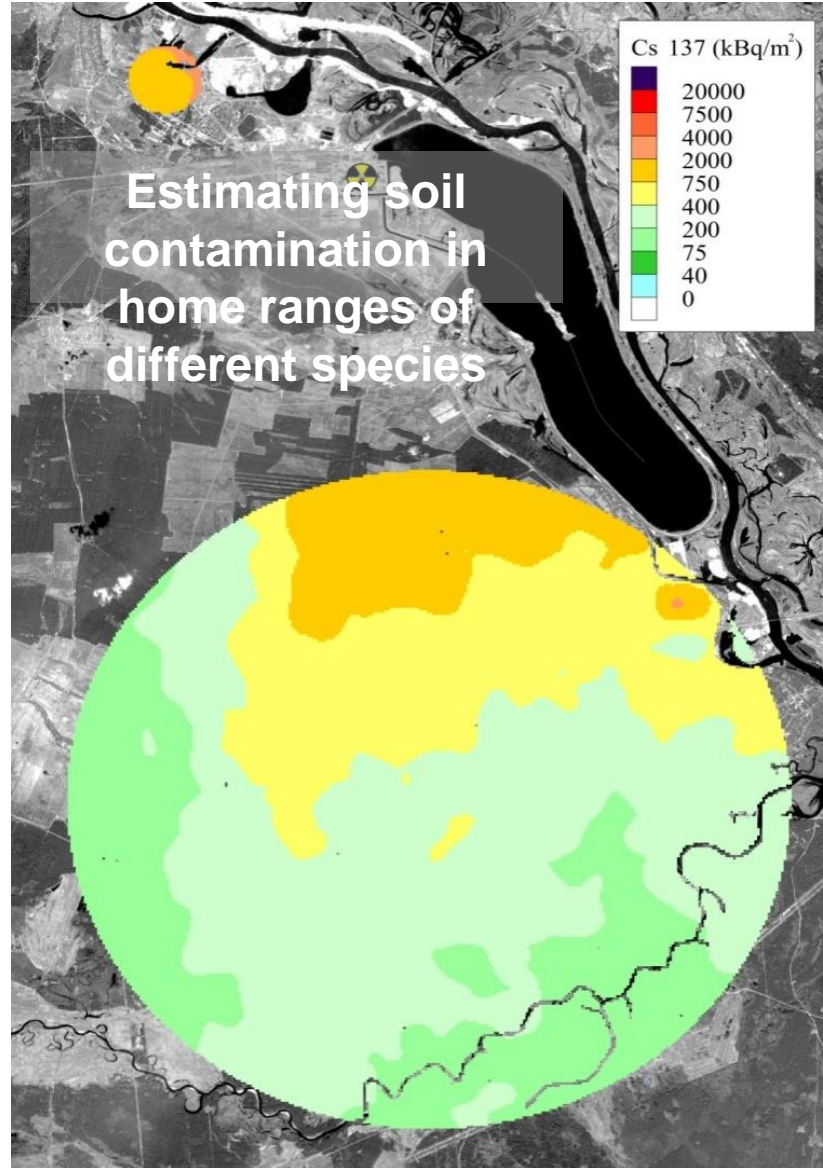
- Often using dose rate meters (at ground surface) reporting in $\mu\text{Sv/h}$
 - Sometimes relatively few measurements (e.g. 2-3 per 100 m transect)

Deposition in CEZ – is highly variable

The map of the 30-km Chernobyl zone terrestrial density of contamination with cesium-137 (on 1997)



So need to consider home ranges



Variable at small scale as well



Journal of Environmental Radioactivity 99 (2008) 1496–1502

Contents lists available at ScienceDirect



Journal of Environmental Radioactivity

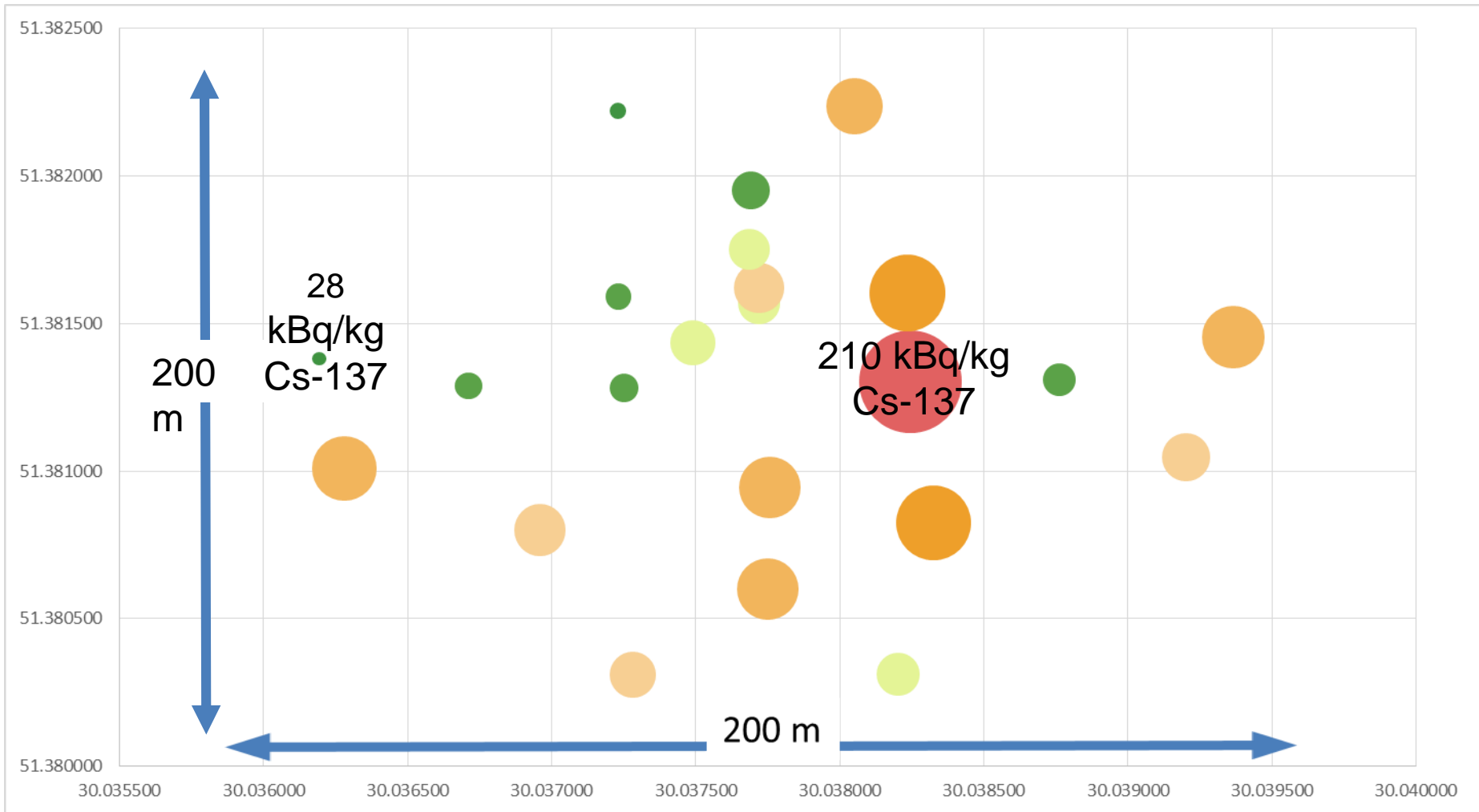
journal homepage: www.elsevier.com/locate/jenvrad



Estimating the exposure of small mammals at three sites within the Chernobyl exclusion zone – a test application of the ERICA Tool

N.A. Beresford^{a,*}, S. Gaschak^b, C.L. Barnett^a, B.J. Howard^a, I. Chizhevsky^b, G. Strömman^c, D.H. Oughton^c, S.M. Wright^d, A. Maksimenko^b, D. Copplestone^d

Variable at small scale as well



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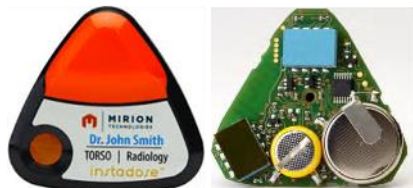
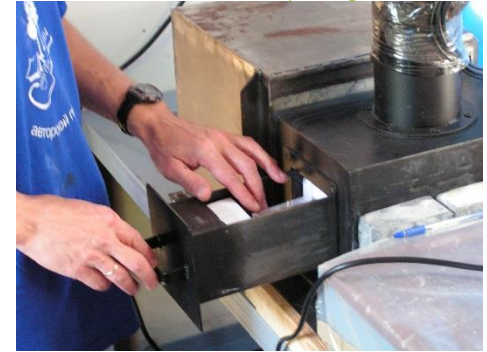
Variable at very small scale as well



Estimating dose – by measurement



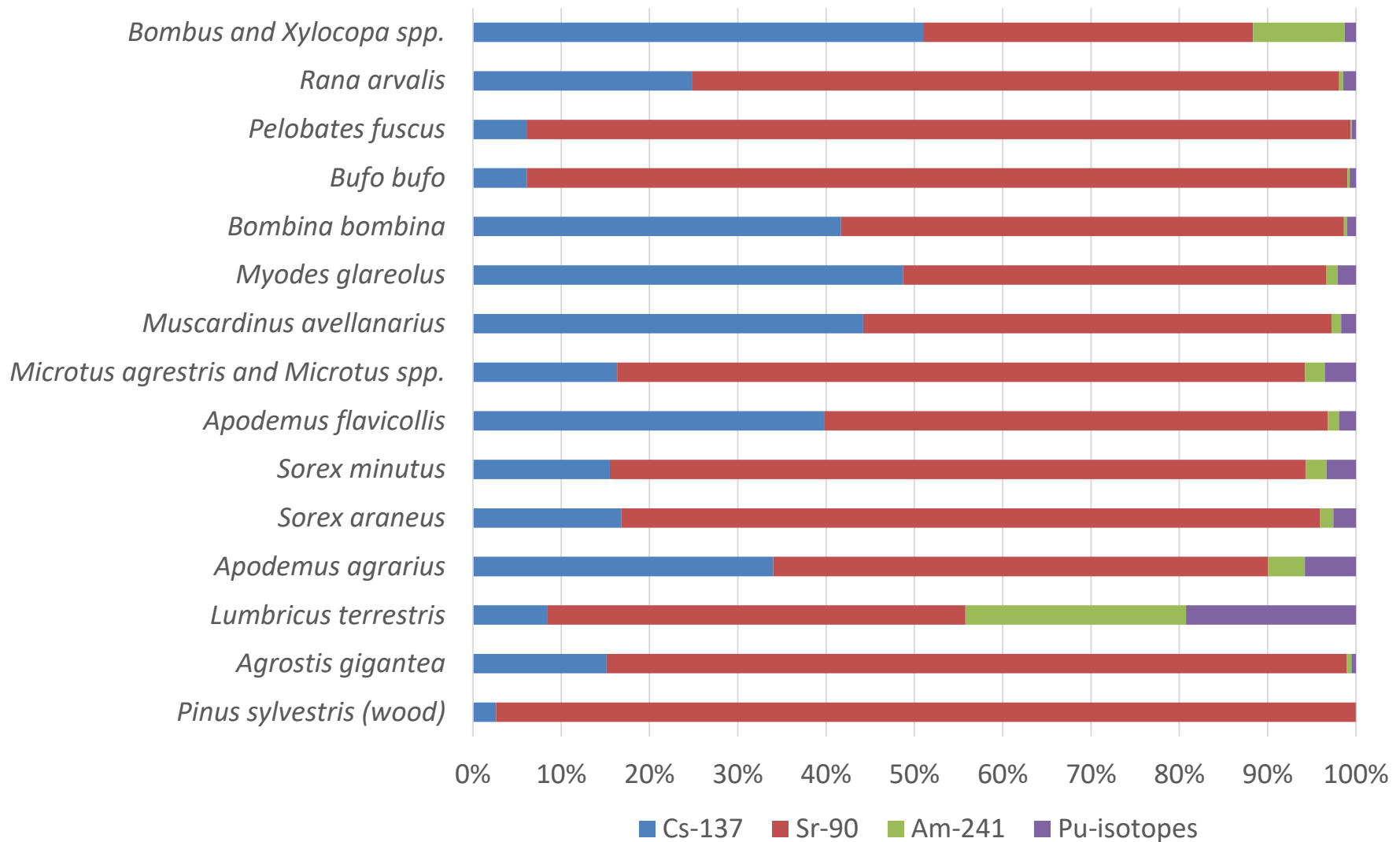
TLD
(LiF:Mg,Cu, P)



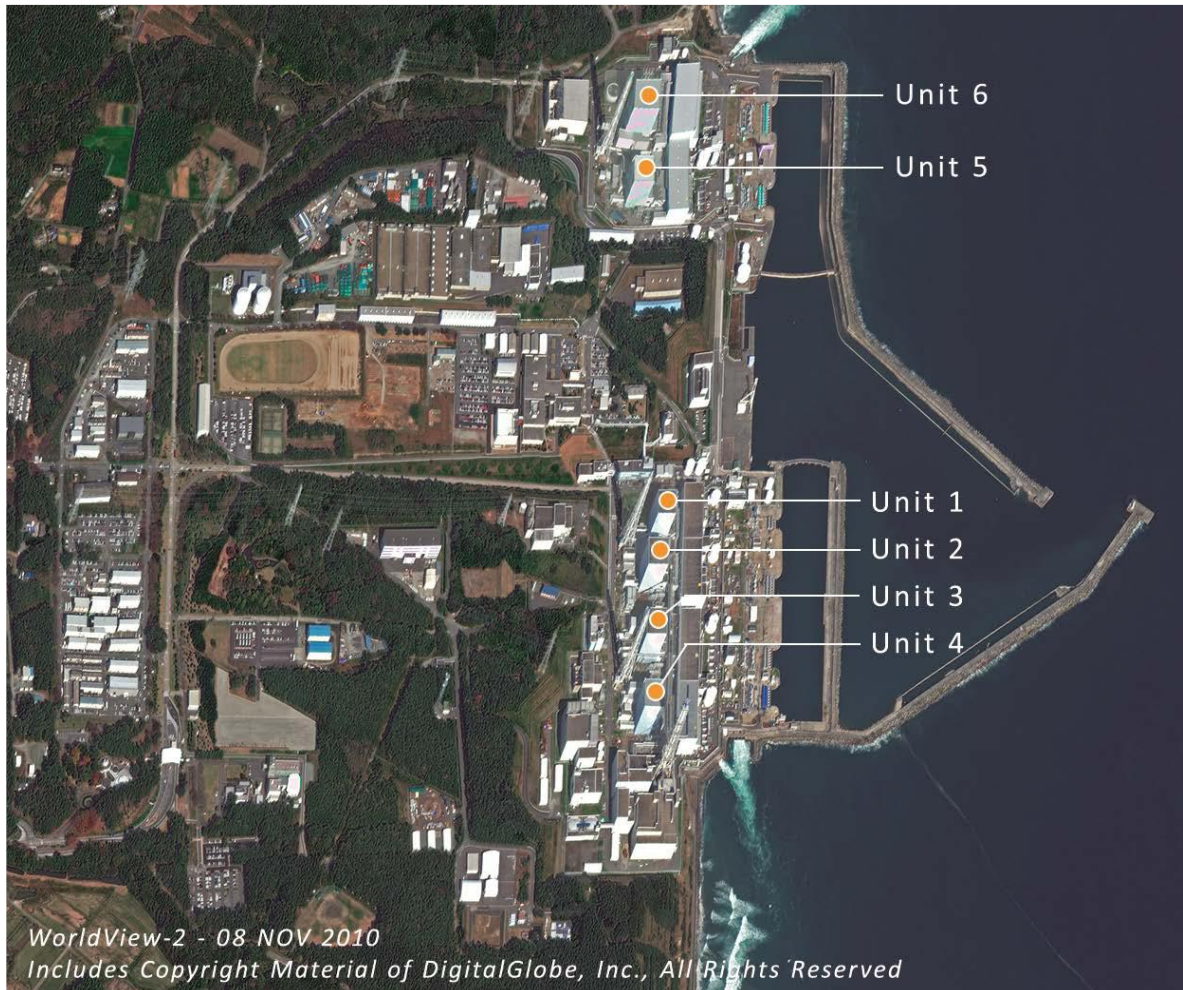
Instadose 2



Internal dose rate



Now starting to see similar things from Fukushima related studies



Japan butterflies

- Butterfly larvae fed plants harvested from Fukushima evacuated area
- $LD_{50} = 1.9 \text{ Bq}$



Japan butterflies

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- $LD_{50} = 1.9 \text{ Bq}$
- LD_{50} equates to a maximum of c. $8\mu\text{Gy/h}$
 - Below 'no-effect' and in natural background range?

Comment by Copplestone & Beresford, 2014, *The Conversation*



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- LD_{50} equates to a maximum of c. $8\mu\text{Gy/h}$
 - Below 'no-effect' and in natural background range?
- From previous studies LD_{50} for sub-adults $\geq 1 \text{ Gy}$



Chernobyl – wildlife controversy

- There are [as would be expected] effects on wildlife in Chernobyl
 - We are observing these ourselves
- But many reports have ‘significant’ effects at unbelievably low dose rates
 - Dosimetry
 - Interpretation [significant v’s meaningful]
 - Confounding factors
 - Lack of controls
 - Exposure history



Questions?



Workshop recommendation

- Make data openly available
 - *a significant step would be made to addressing the disagreement on the magnitude of effects due to exposure to ionising radiation observed in the CEZ/Fukushima areas by enabling its re-evaluation by others*

The screenshot shows the STOREDB website interface. On the left, there is a teal sidebar with a 'Logout' link and a red 'SIGN IN USING ORCID' button. The main content area is divided into two columns. The left column has an 'About STOREDB' section with an information icon, describing the platform's purpose and funding. The right column has a 'Sustainability' section with a globe icon, stating it is maintained by the Bundesamt fuer Strahlenschutz. Below these are search results for 'Para-dichlorobenzene and Tetrachlorobenzyltoluene' and two entries for 'Tumours and Lifespan in Rats After Irradiation From Different Neutron Sources' and 'Tumours and Lifespan in Rats After Gamma Irradiation At Different Ages'. A footer contains the logo of the Bundesamt fuer Strahlenschutz.

