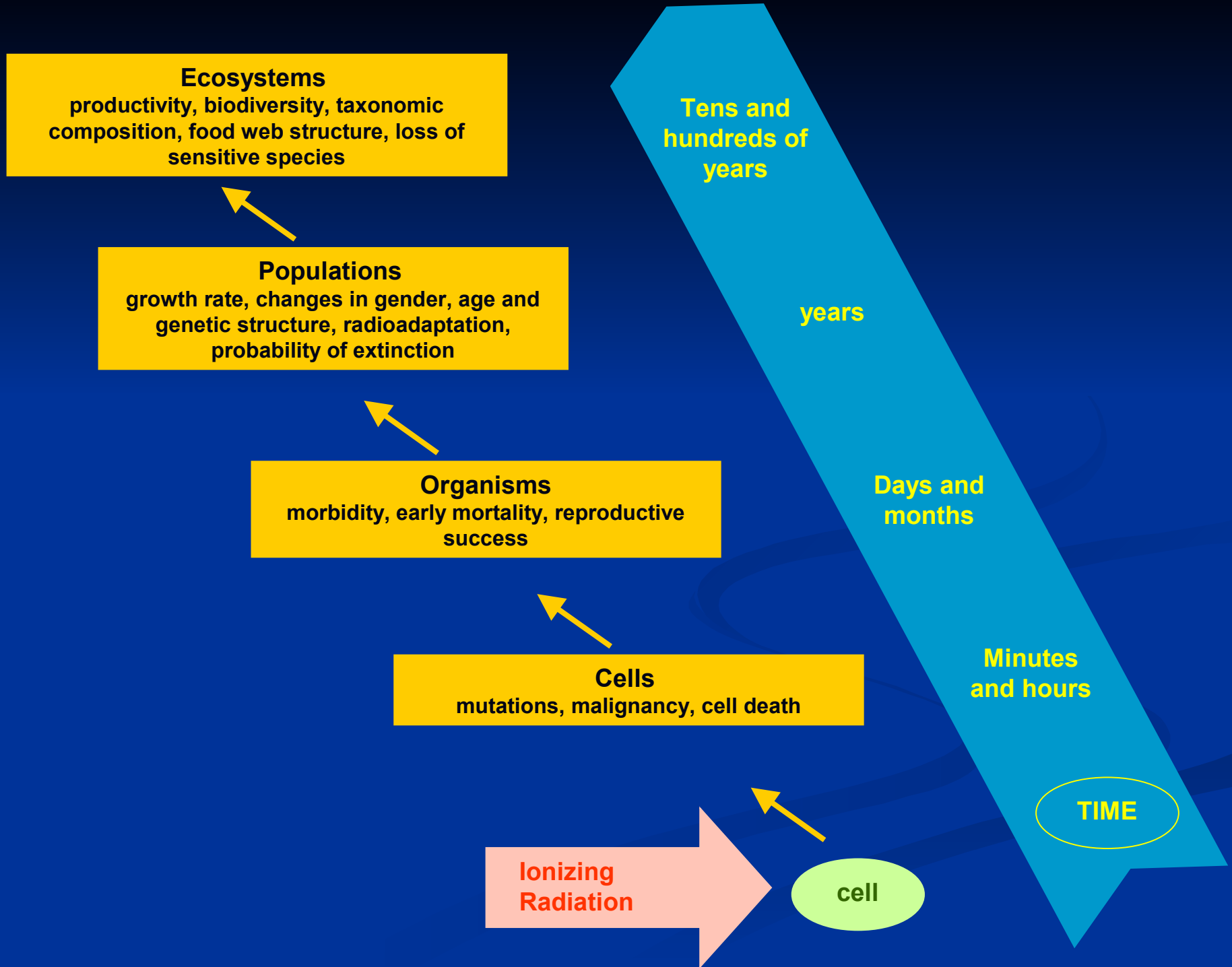
# Effects of radiation on populations and ecosystems, the Chernobyl and Kyshtym cases

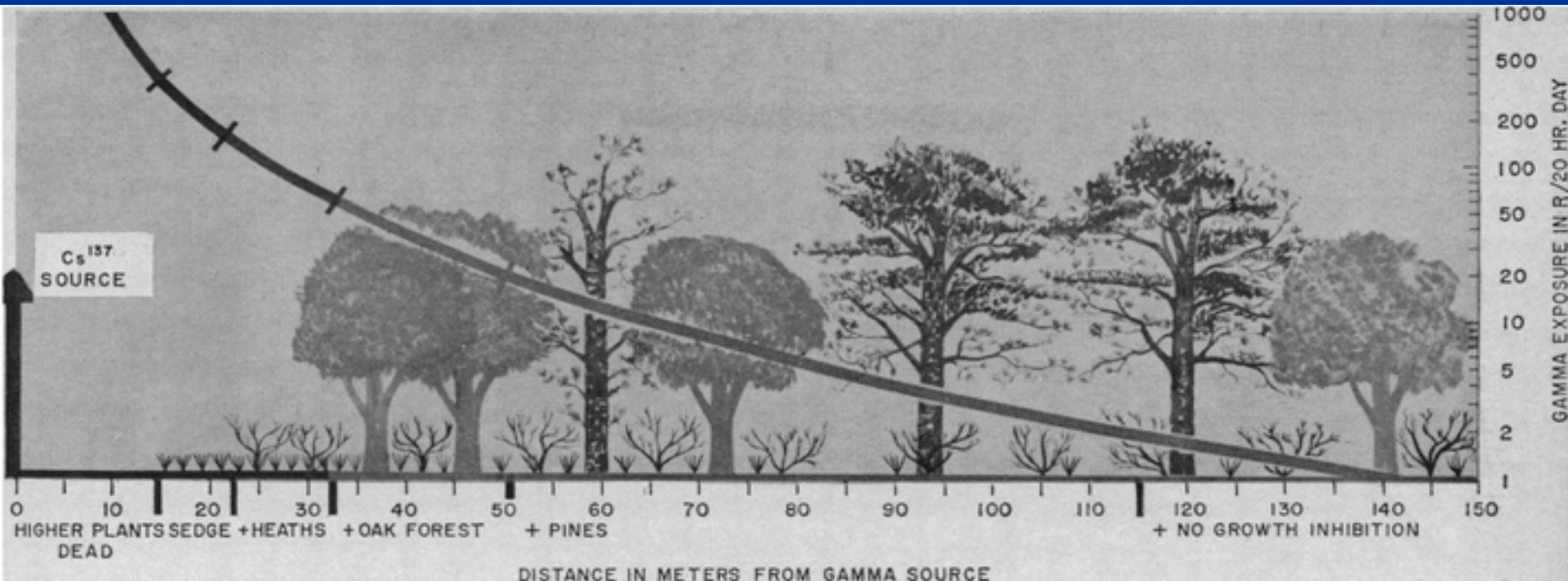
**Geras'kin S.**

***Russian Institute of Radiology and Agroecology, Obninsk, Russia***


Ecosystems
productivity, biodiversity, taxonomic composition, food web structure, loss of sensitive species
Populations
growth rate, changes in gender, age and genetic structure, radioadaptation, probability of extinction
Organisms
morbidity, early mortality, reproductive success
Cells
mutations, malignancy, cell death
Ionizing Radiation
cell
Tens and hundreds of years
years
Days and months
Minutes and hours
TIME

# What are the patterns of radiation effects on the structure, function, and development of natural communities?

**The typical reactions of phytocenosis to irradiation are reduction in species diversity, changes in species dominance, reduction in productivity and changes in a community structure**



# Classification of ecosystems on radiosensitivity *(Alexakhin, 1982)*

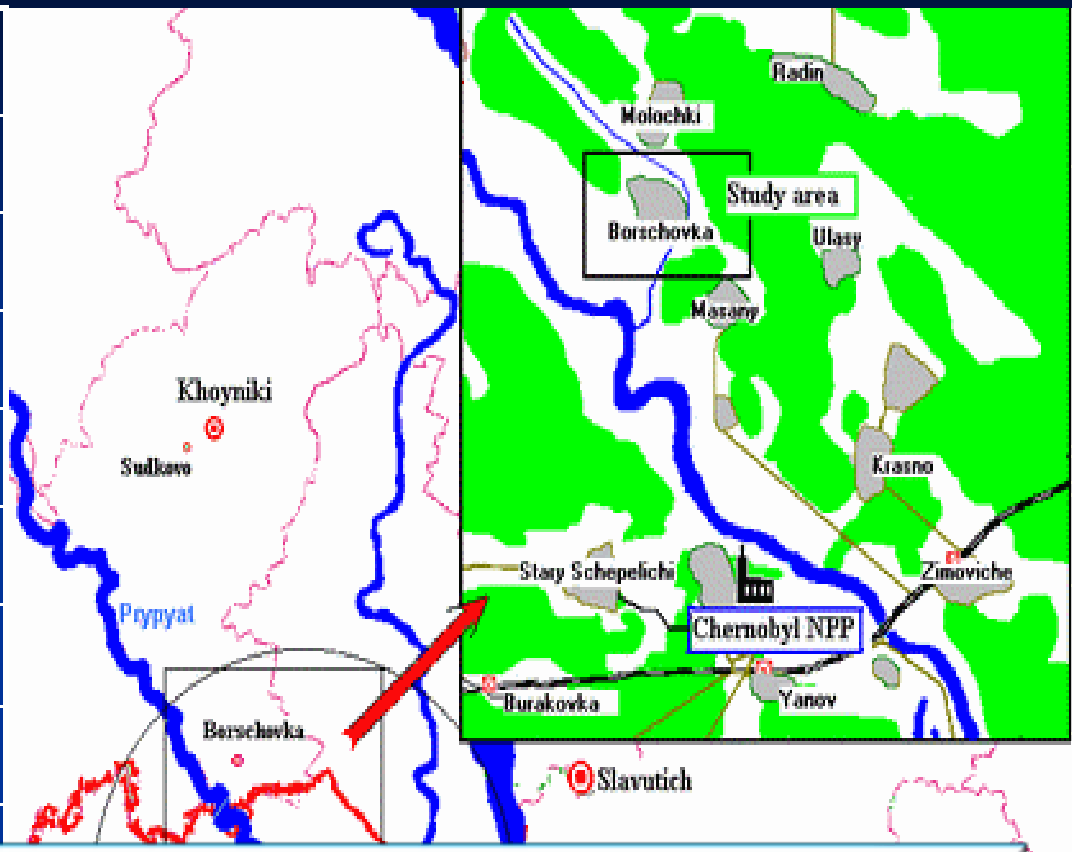
| Type of ecosystems | The extent of damage at a dose, Gy | | |
|---|---|---|---|
| | Low | Medium | Heavy |
| Agricultural crops | 2 | >2 | - |
| Pine forest | 2 | 2-20 | >20 |
| Deciduous forest | 2 | 2-100 | >100 |
| Meadow phytocoenosis | 20 | 20-200 | >200 |
| Abandoned field | 40 | 40-70 | >70 |

# Why the results of experiments with external irradiation cannot be used for explanation of situations related to the accidental release of radionuclides?

| | External exposure | Radiation accident |
|---|---|---|
| Source of irradiation | Point source | Distributed source |
| Type of radiation | γ or neutrons | α, β, γ in different combinations |
| Type of irradiation | External | External and internal |
| Distribution of the absorbed doses in ecosystem | Relatively uniform. Dose decreases with distance from the source | Extremely heterogeneous |
| Dose distribution over time | Uniform | Intensive short-term, followed by a slow decline in chronic dose rate. Redistribution of radiation exposure in the ecosystem components due to the migration of radionuclides |

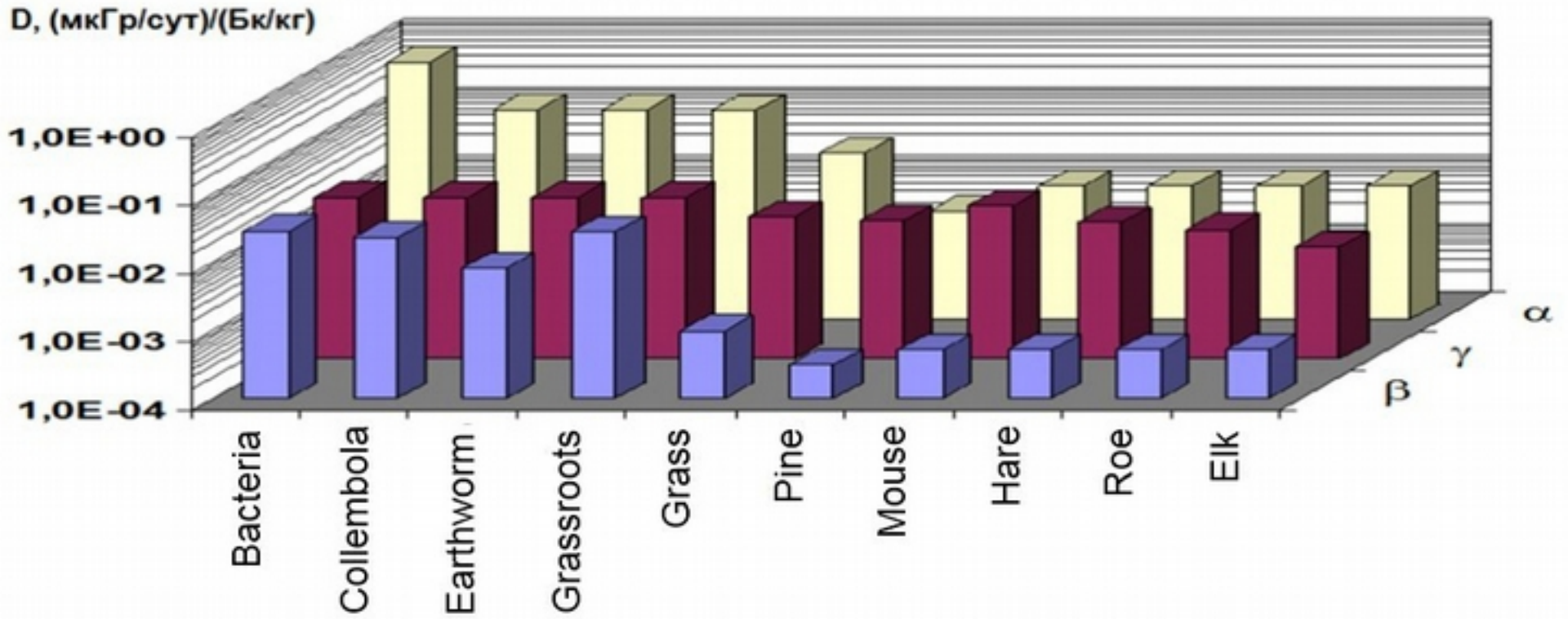
# A COMPARATIVE ASSESSMENT OF RADIATION IMPACTS ON BIOTA AND HUMANS

| | Dose, Gy 1986 |
|---|---|
| Pine | 3.7 |
| Meadow grass | 15 |
| Crops | 8 |
| Cattle | 1.6 (150) |
| Rodents | 0.6 |
| Invertebrates | 4.6 |
| Phytoplankton | 0.06 |
| Z | 0.18 |
| Z | |
| F | |
| M | |




In this radioecological situation a man is obviously can't be considered as the most exposed component of the ecosystem

# A comparative assessment of radiation impacts on biota and a man in case of contamination with the decay chain of $^{238}U$ and $^{235}U$ (Spirin et al., 2013)




| $D_{biota}/D_{man}$ | $^{238}U$ | $^{235}U$ |
|---|---|---|
| Soil biota | 10 - 45 | 100 - 480 |
| Plants | 0.4 - 10 | 3 - 20 |
| Mammals | 0.7 -5 | 10 |

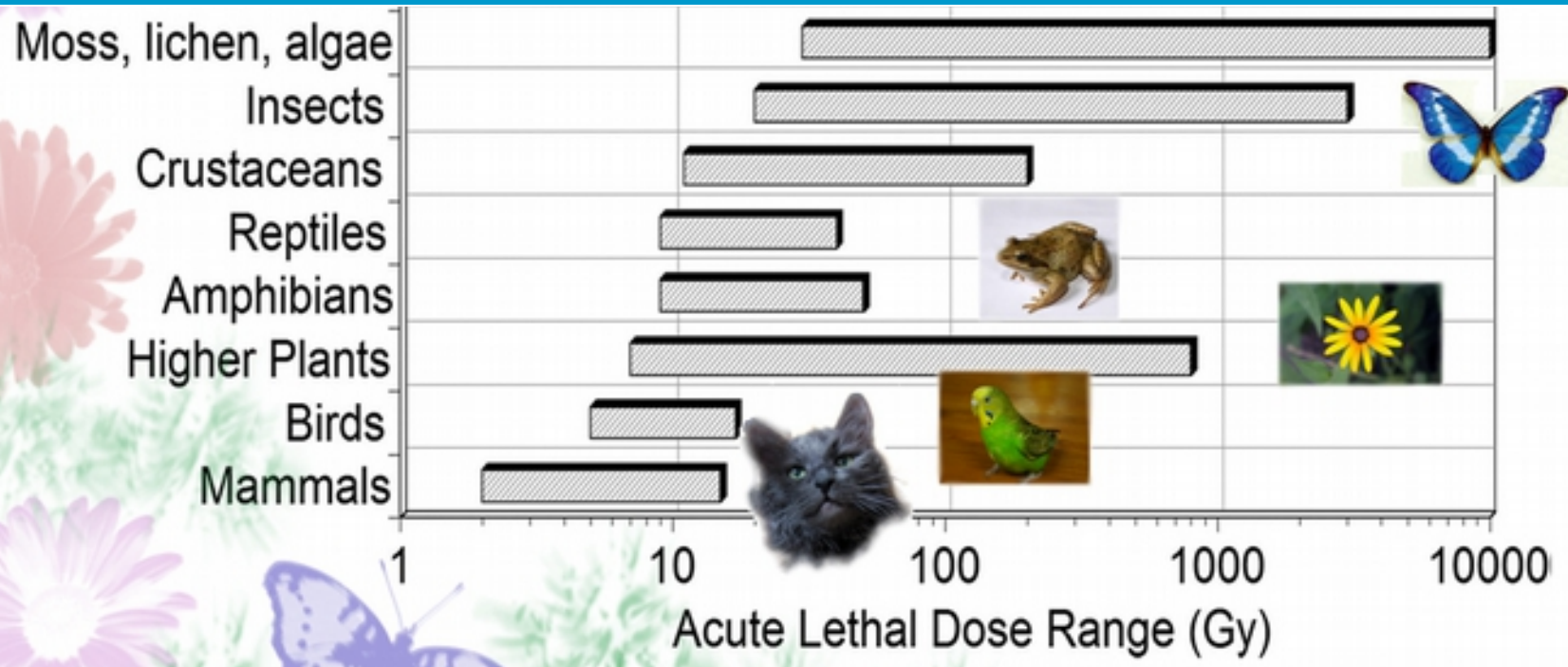
# Forest ecosystems are the most sensitive to radiation exposure

Radiation damage to coniferous forests in the vicinity of the Chernobyl NPP

# Dose ranges that result in 100% mortality in various taxonomic groups

*Whicker, Schultz, 1982*

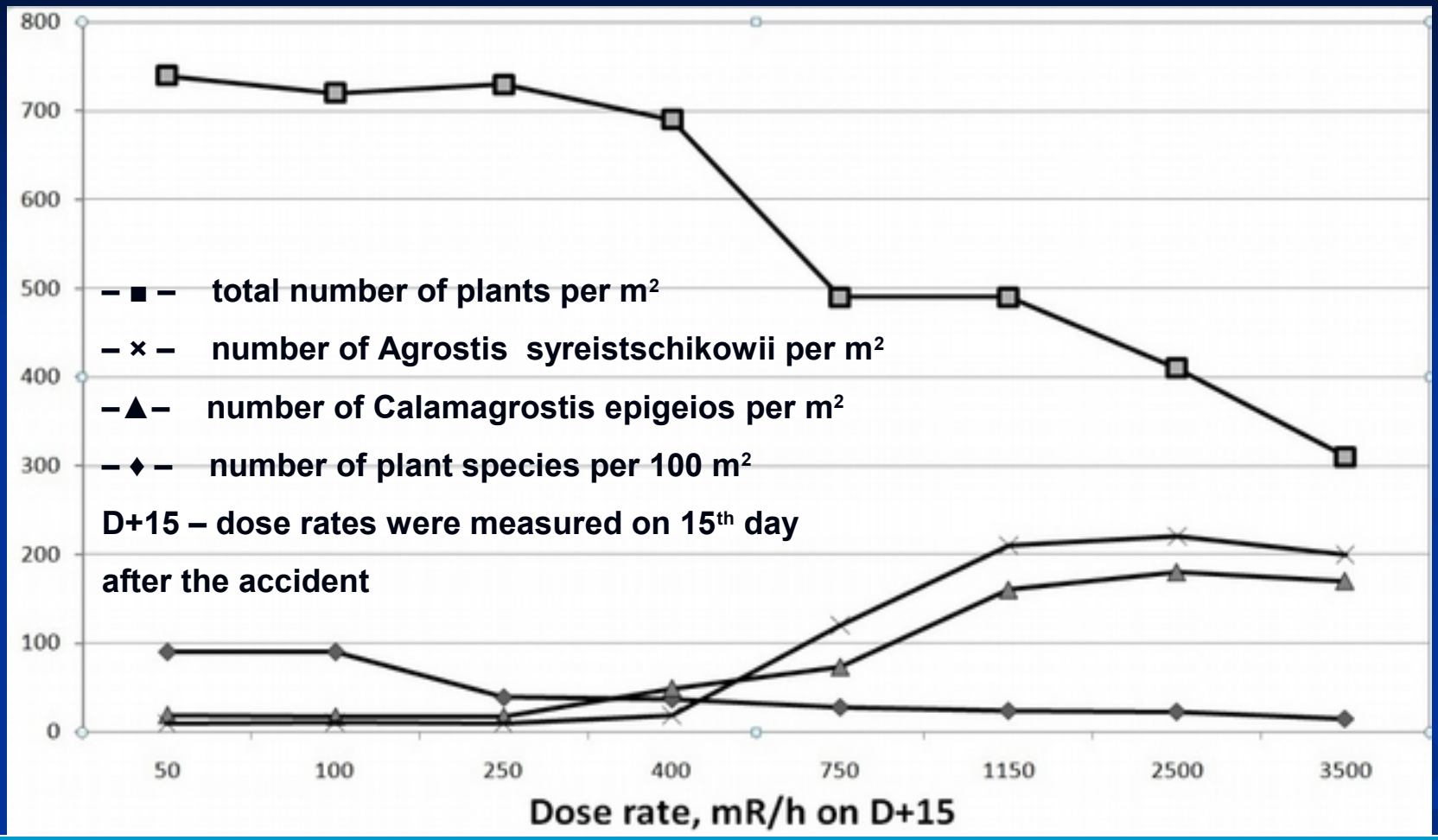
**Differences in the radiosensitivity of different taxa create the backgrounds for the secondary radiation effects**



# Secondary radiation effects are associated with the disruption of ecological relationships in an ecosystem

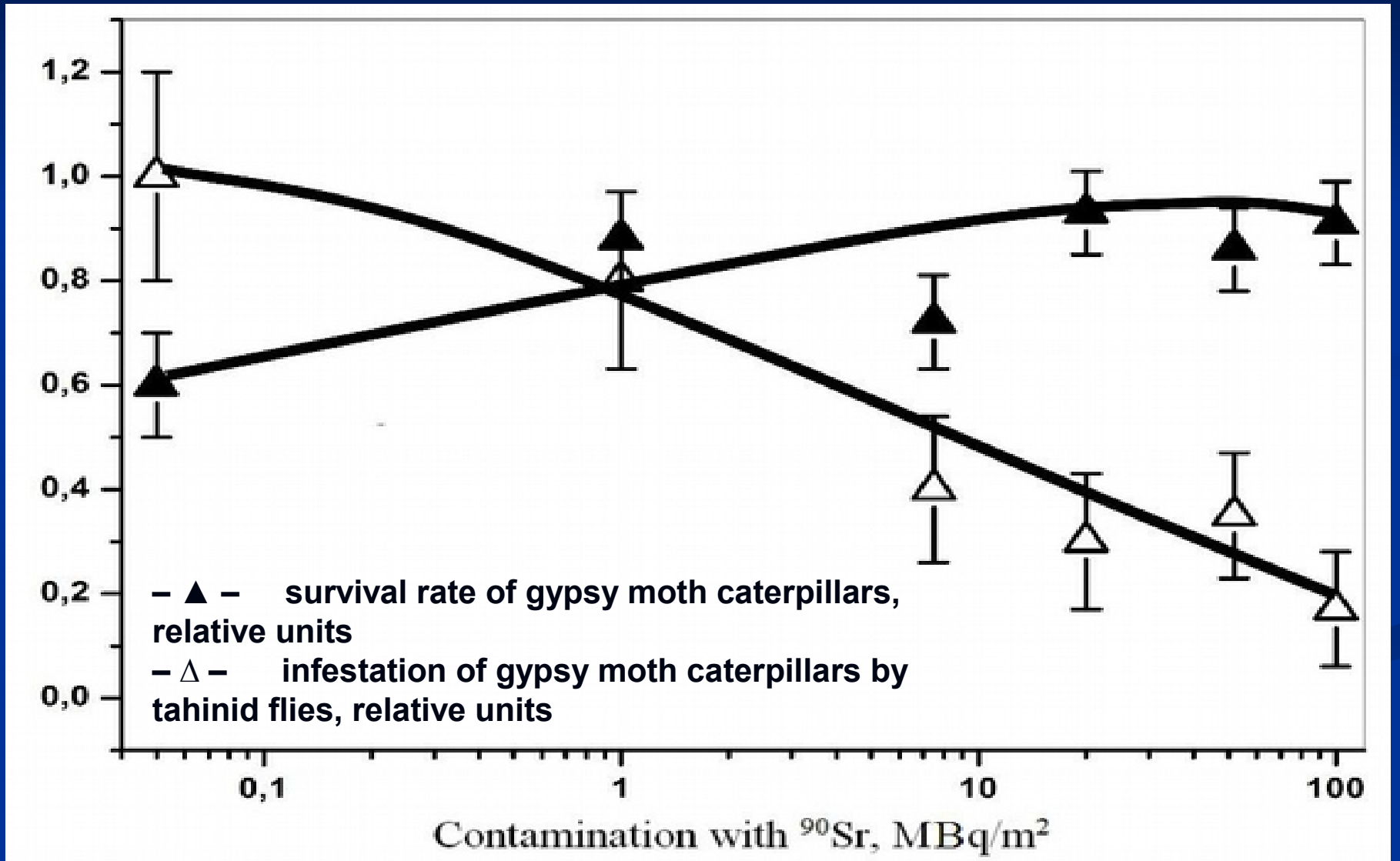
- Suppression of radiosensitive species and intensive development of radioresistant species.
- A large amount of organic residues leads to increase in the number of insect pests.

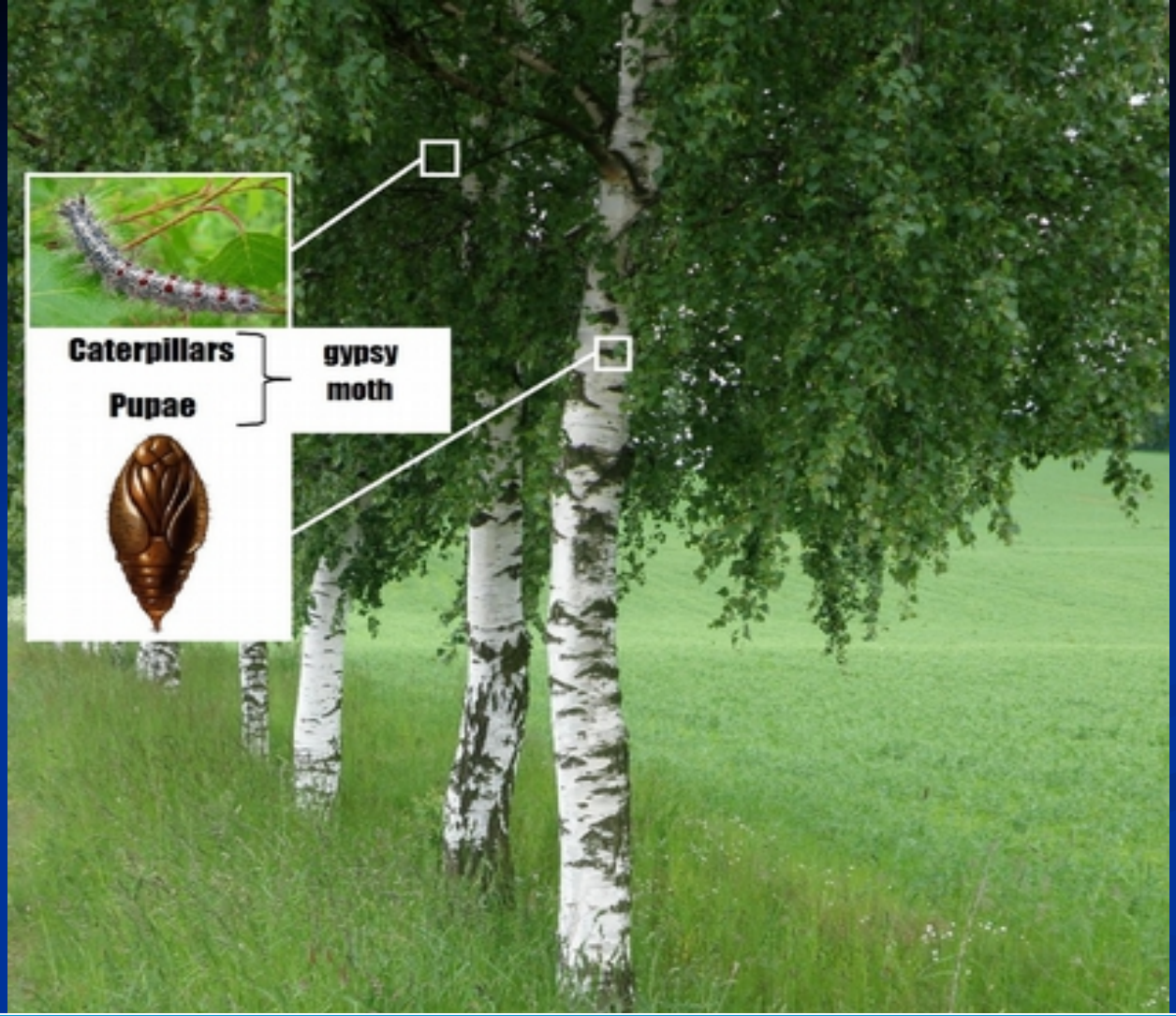
# Radiation effects in meadow phytocenoses (Yanov, near ChNPP, 1987) (Smirnov, Suvorova, 1996)




Exclusion of radiosensitive species attenuates competition for others

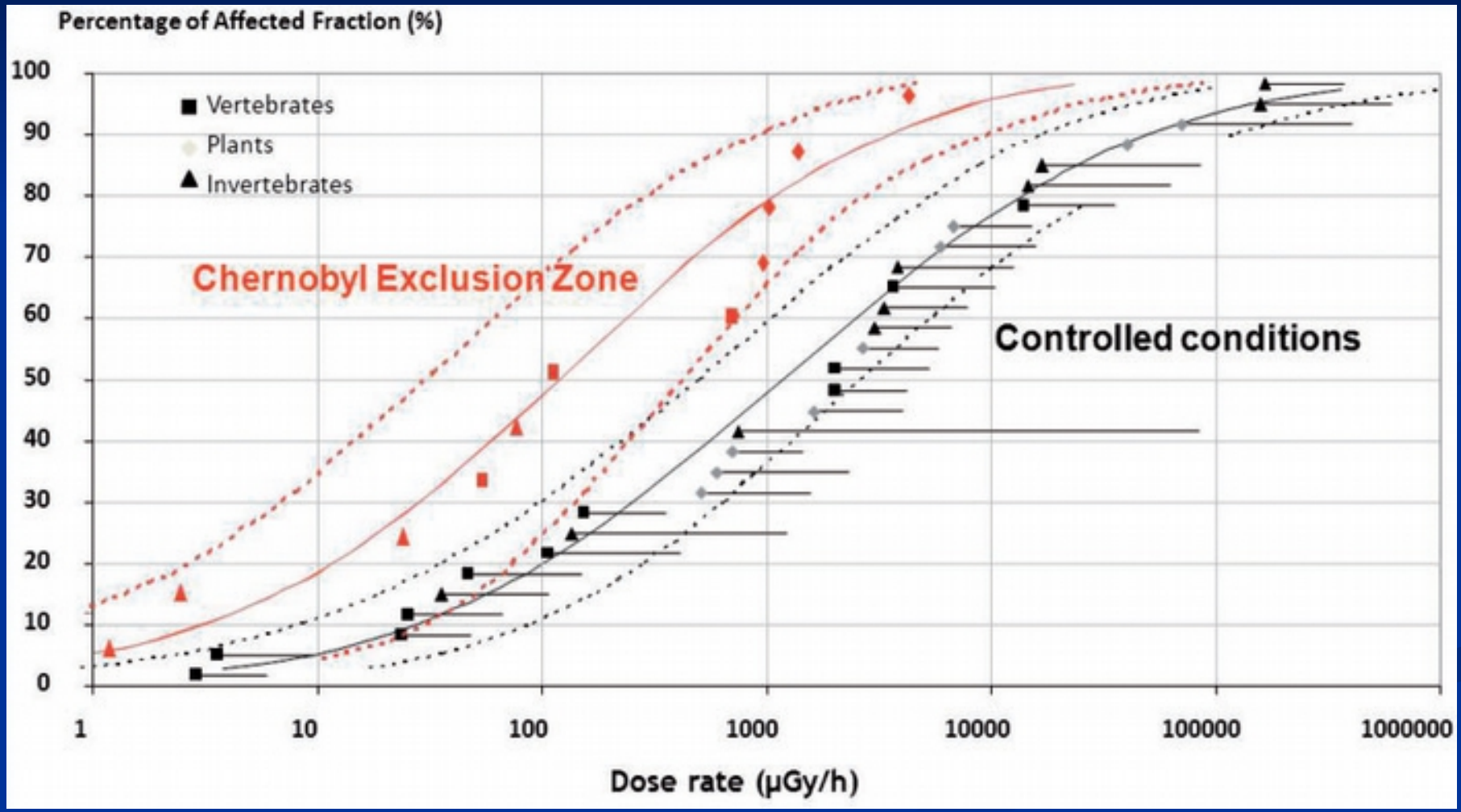
# Effect of radioactive contamination ($^{90}Sr$, the Southern Urals) of the birch forest on gypsy moth populations and their parasite tahinid flies (Krivolutsky et al., 1988)






Ecological factors can be more important than radiation

# Comparison of species radiosensitivity: external exposure versus field observations



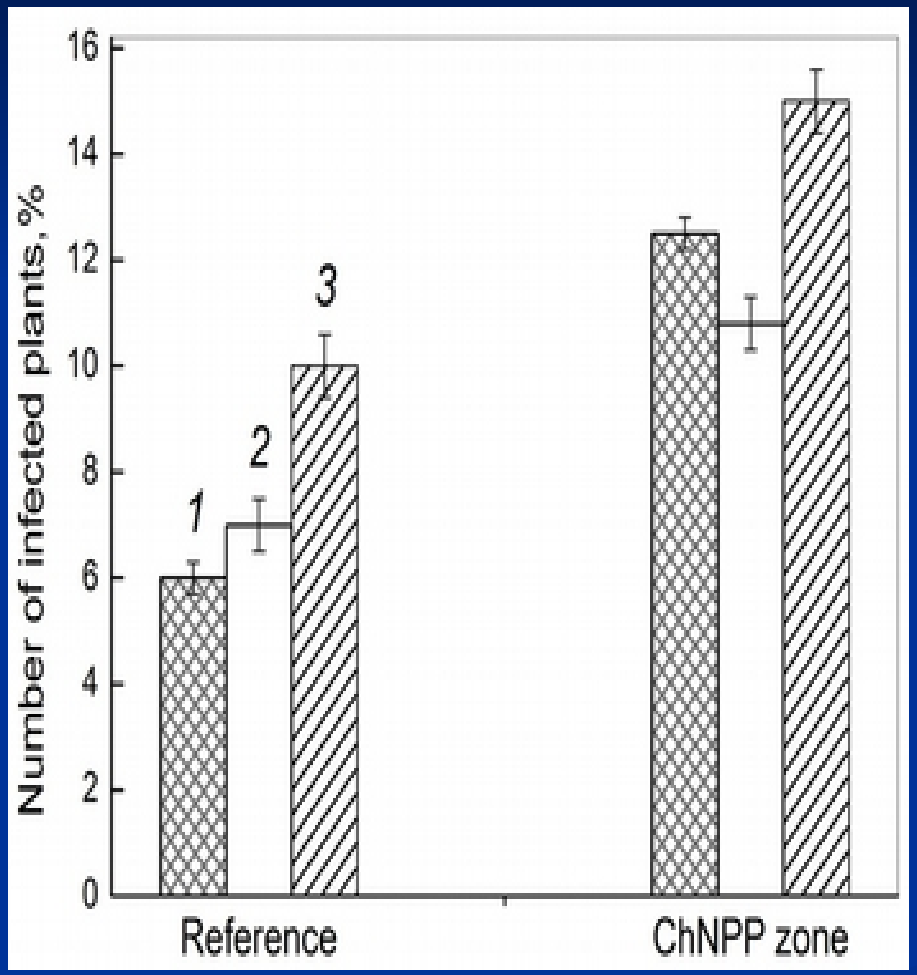

Garnier-Laplace et al. J Environmental Radioactivity. 2013. V. 121. 12-21

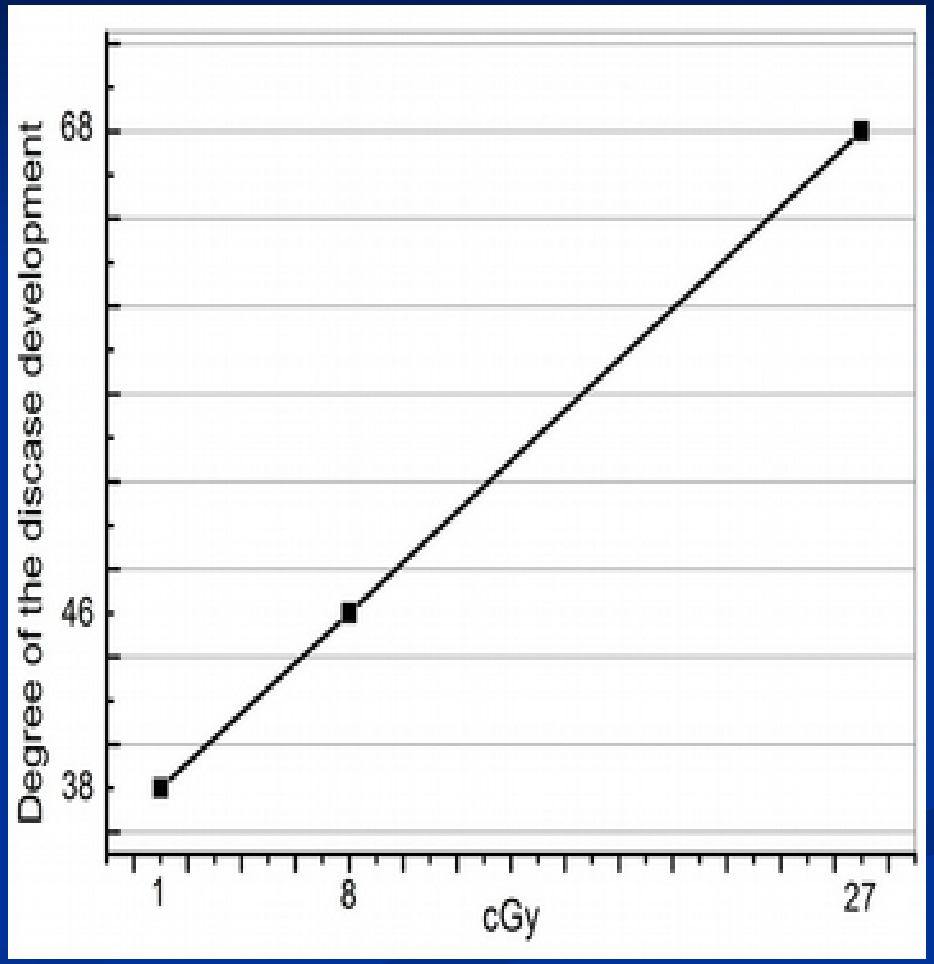
# What are the reasons for discrepancy between external exposure and field studies?

| External exposure | Radiation accidents |
| --- | --- |
| An accurate assessment of doses are available | The lack of robust dosimetry |
| Are generally limited in the duration of exposure | Wildlife is generally exposed across generations |

**The absorbed doses may be much higher in the field than in external exposure experiments**

# Effect of radiation exposure on host-pathogen relationships

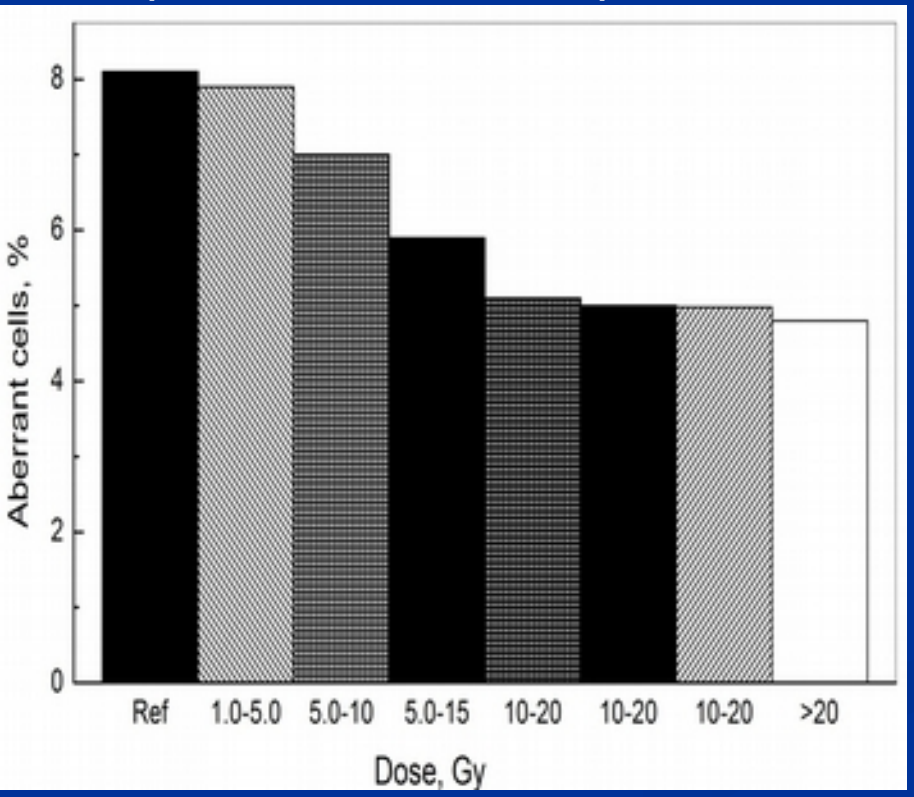


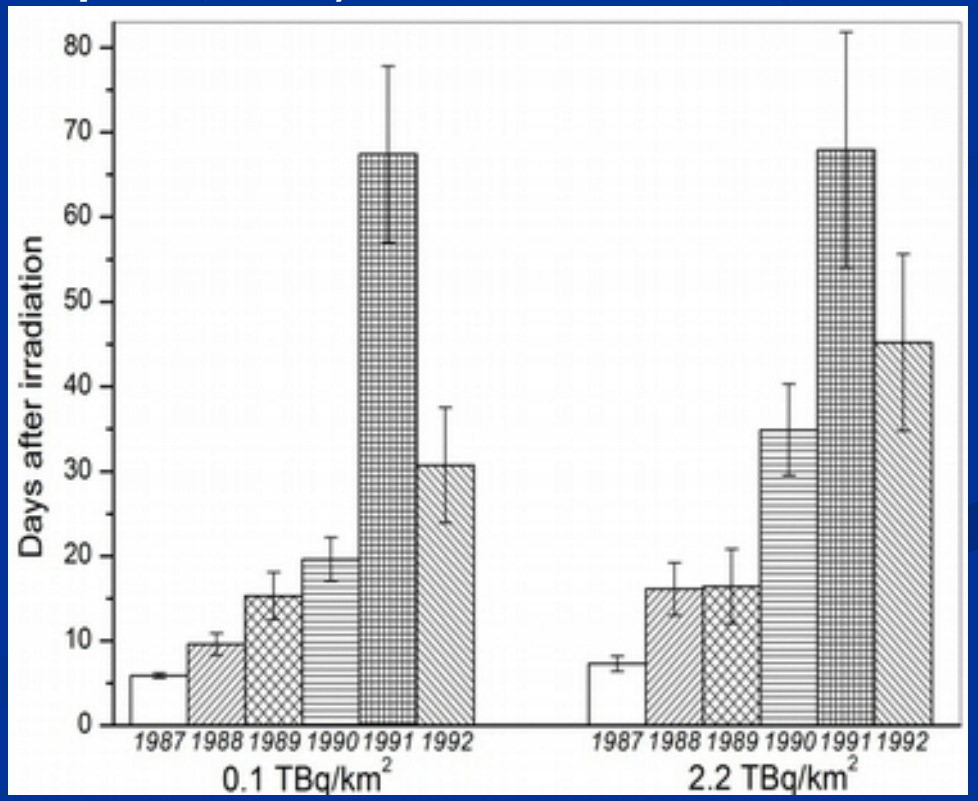

Dmitriev et al. Rus. J. Plant Physiol. 2011. V. 58. 1062-1068

# Examples of radio-adaptation in Scots pine and bank vole populations

**Radioresistance of pine seeds from populations inhabiting contrasted in the level of radioactive contamination sites within the Chernobyl NPP zone, 1997 (Fedotov et al., 2006)**

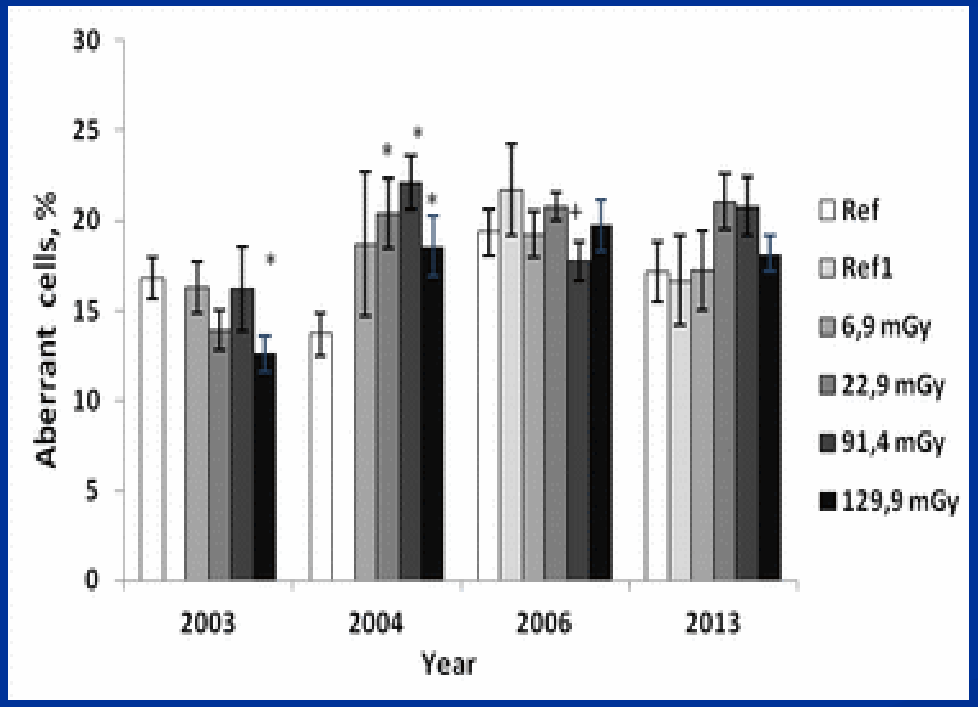



**Changes in life expectancy of irradiated (14 Gy) bank voles from contrasted in the levels of radioactive contamination sites within the Chernobyl NPP zone (Ilyenko, Krapivko, 1998)**



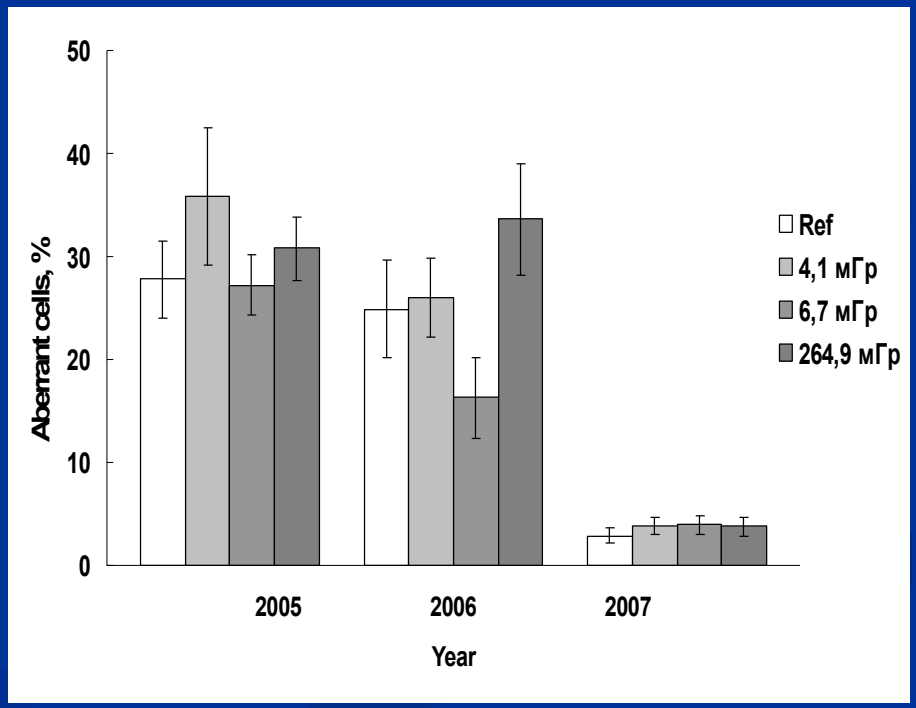
# Examples of lack of radio-adaptation in plant populations

**Pine seeds from the Bryansk region**
(γ-exposure: 15 Gy at 36 Gy/h )




Geras'kin et al. Ecotoxicology. 2011. V. 20. 1195-1208

**Crested hairgrass seeds from the Semipalatinsk Test Site**
γ-exposure: 2005, 2006 - 69 Gy at 2790 Gy/h; 2007- 50 Gy at 39 Gy/h )




Geras'kin et al. J. Env. Radioactivity. 2012. V. 104. 55-63

# Why sometimes we fail to detect any signs of radio-adaptation in plant populations?

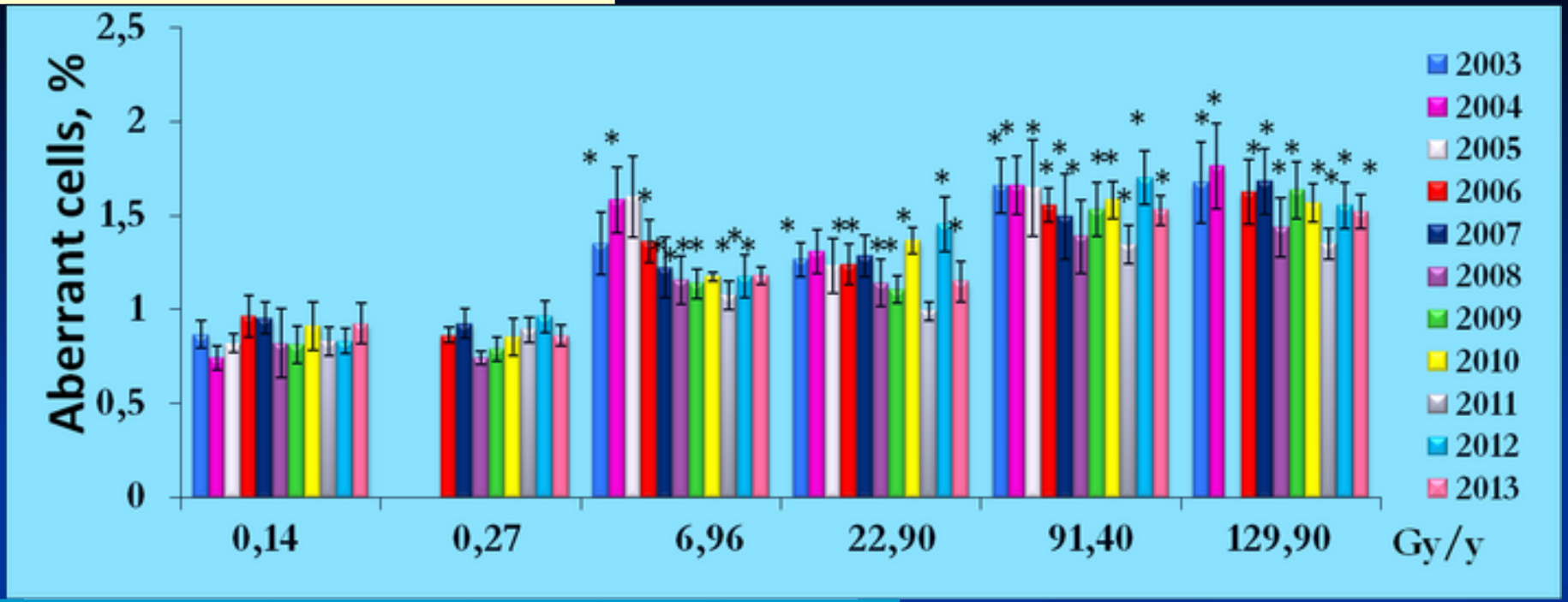
- Increased fitness in unfavorable environment is associated with decreased fitness in favorable environment. As a result, there are situations when enhanced radioresistance does not evolved or does not persisted

- In situations where radio-adaptation is observed for one species, often none is found in others despite equivalent opportunity

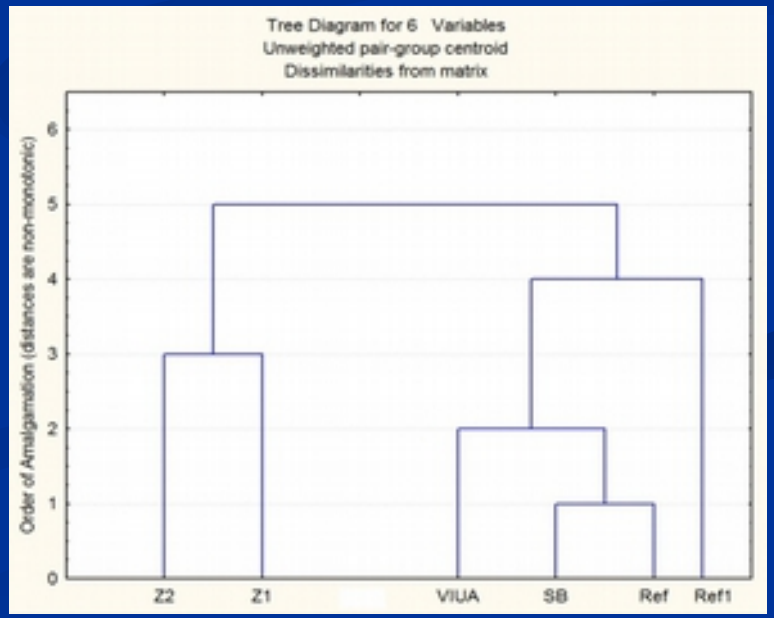
- The response of a population to radiation exposure depends both on the type of organism and on the biophysical characteristics of the radiation

Scots pine *Pinus sylvestris* L.

**Bryansk region, Russia 2003-2014**

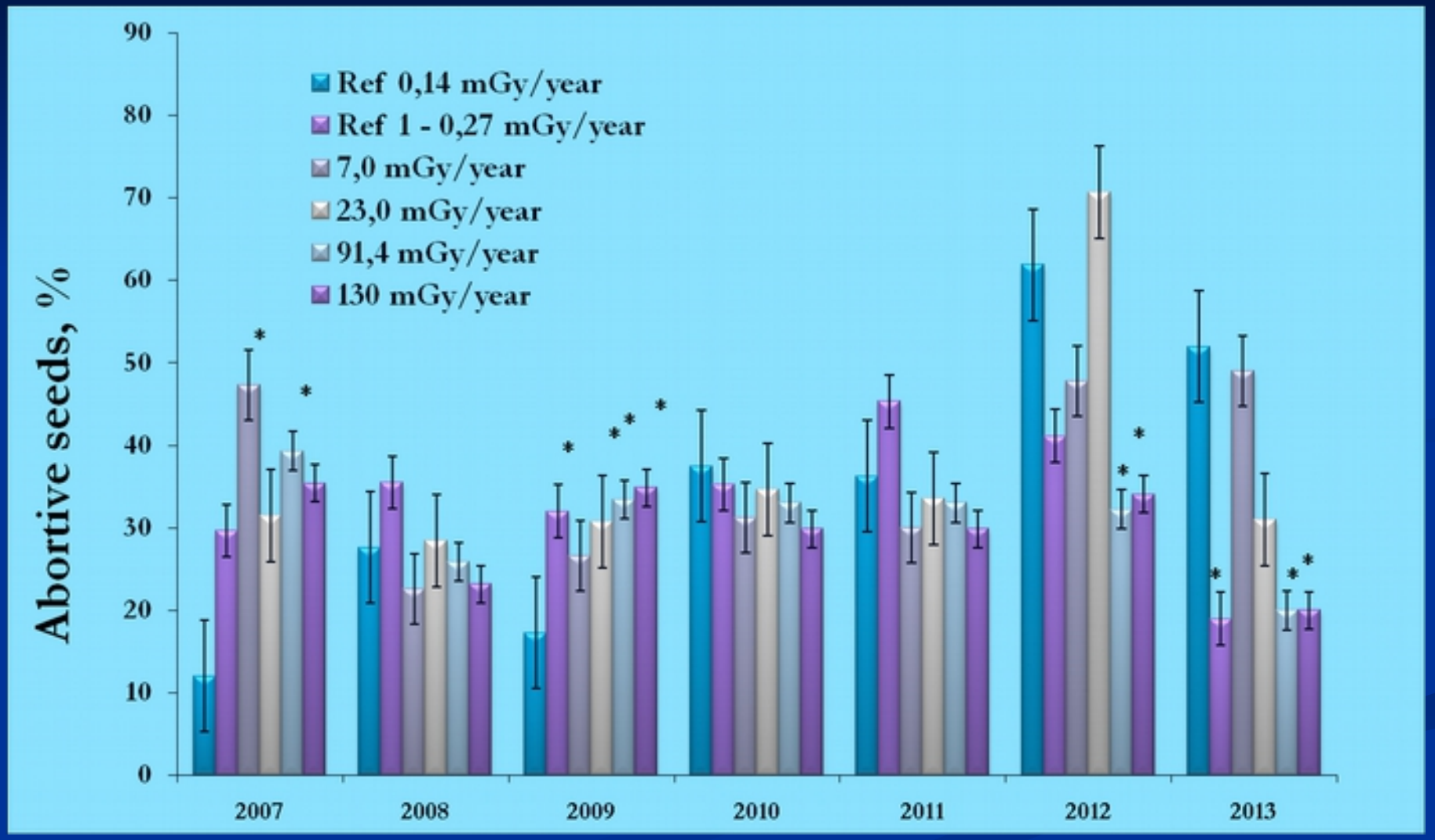



**High mutation rates is intrinsic for progeny of the affected pine trees, and genetic diversity is essentially influenced by radiation exposure**




Geras'kin et al. Ecotoxicology. 2011. V. 20. p. 1195-1208; Geras'kin, Volkova. Science Total Environment. 2014. V. 496. p. 317-327

# Could the revealed high mutation rates have any effect on the population fitness?

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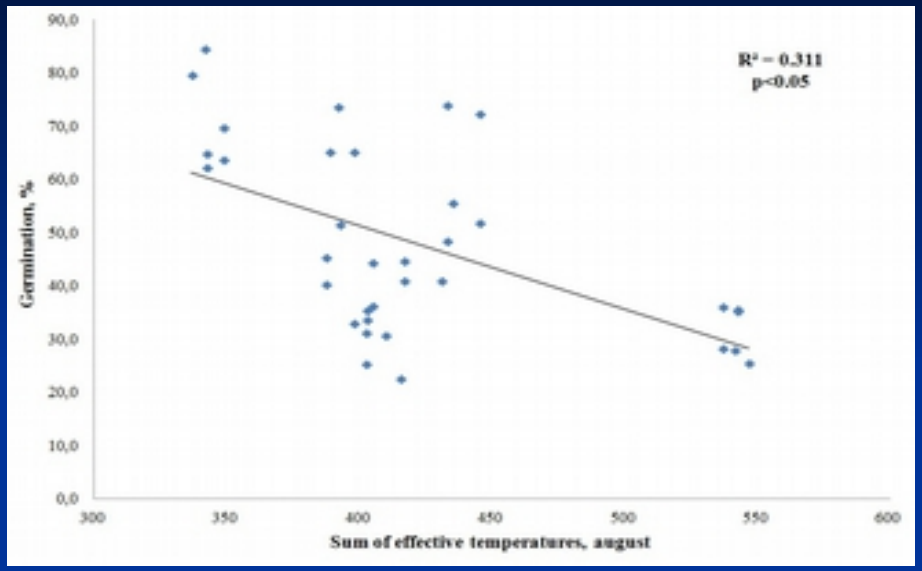
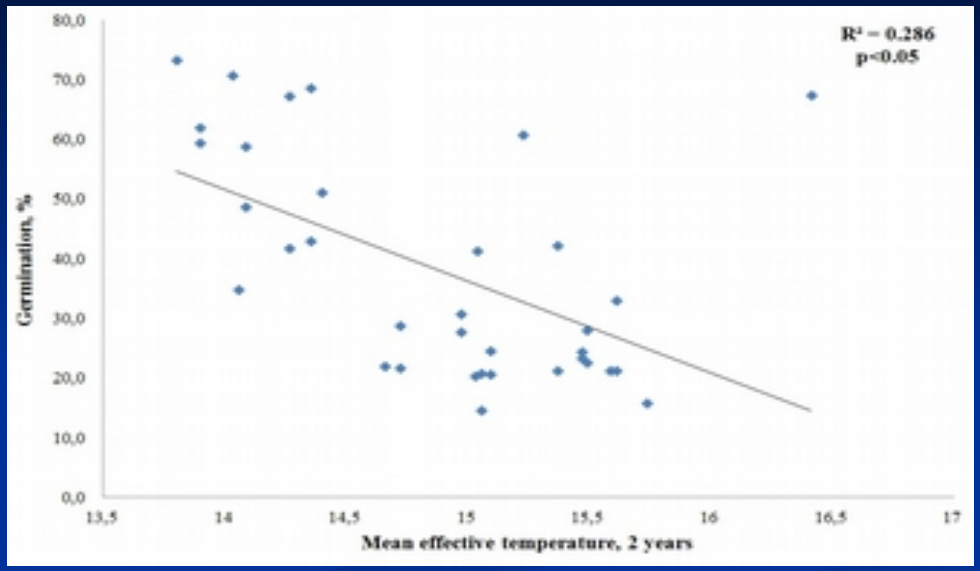
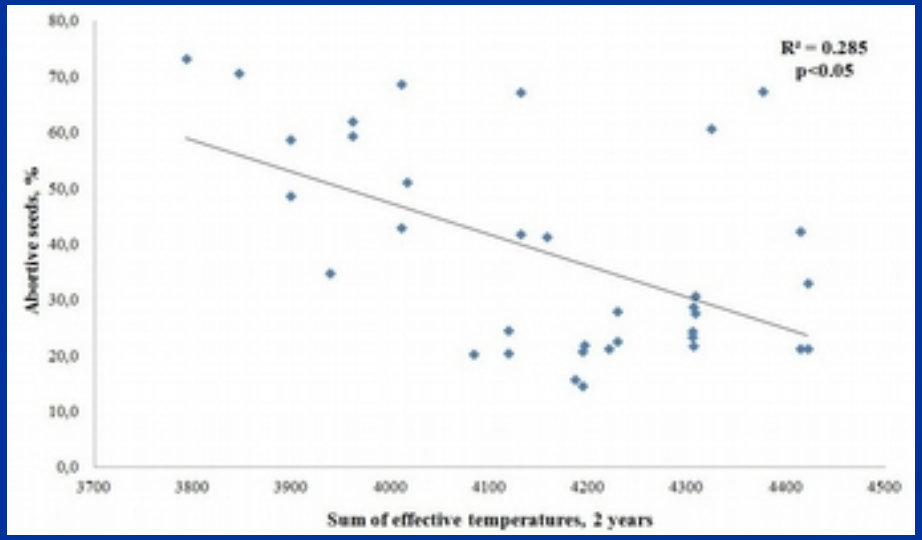
# Are there any relationship between reproductive ability and weather conditions?




Geras'kin et al. Radiation Biology. Radioecology. 2015. V. 55. p. 539-547 (in Russian)

# CONCLUSIONS

- To properly understand the effect of real-world contaminant exposures, we should consider actual field conditions.

- The use of the ecological knowledge is essential for understanding the responses of populations and ecosystems to radiation exposure.

# That's all!