Calculations of radiation effects to animal populations using the EMRAS II benchmark scenario

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The objective of the study was application of the model, which simulates the development of radiation effects in an isolated, chronically exposed population to the EMRAS II benchmark scenario.

The following species were considered: mouse, rabbit, wolf

The following endpoints were taken into consideration:

- Decrease of population number from the initial size (1000) after 1, 2, 3, 4, 5 years of chronic exposure with dose rates 10, 20, 30, 40, 50 mGy/day

- Decrease of reproduction capacity (in %) after 5 years of chronic exposure

The effects caused by chronic irradiation in population are considered to be a result of superposition of three major processes –

- **creation of damage by radiation,**
- **recovery of damage by means of repairing mechanisms,**
- **natural growth of population**

An isolated generic population has been modelled,

living under ideal conditions (no predators, no limitation by food, optimal temperature and other environmental factors),

which is exposed to chronic ionizing radiation with a dose rate *p* (mGy/day)

We assume, that organisms composing the exposed population may be in one of the following states:

- undamaged,
- reversibly damaged,
- lethally damaged

Reversible damages are recovered by the repairing mechanisms, the repairing pool is spent for the repairing processes.

Effect on morbidity of organisms in the population depends on decrease of the repairing pool (in % from its initial value). The ionizing radiation also cause a direct damage to the repairing pool itself.

Reproduction system increases number of normal organisms in the population,

but itself is affected by the ionizing radiation

A system of differential equations describing the effects of chronic radiation exposure on fish population can be written as:

$$\frac{dx}{dt} = -\alpha p x + \kappa y R + \mu \cdot (x_{\max} - x) \cdot F$$

$$\frac{dy}{dt} = \alpha p x - \varepsilon y - \kappa y R$$

$$\frac{dR}{dt} = \mu_r \cdot R \cdot (R_{\max} - R) - \kappa_r \cdot yR - \alpha_r \cdot p \cdot R$$

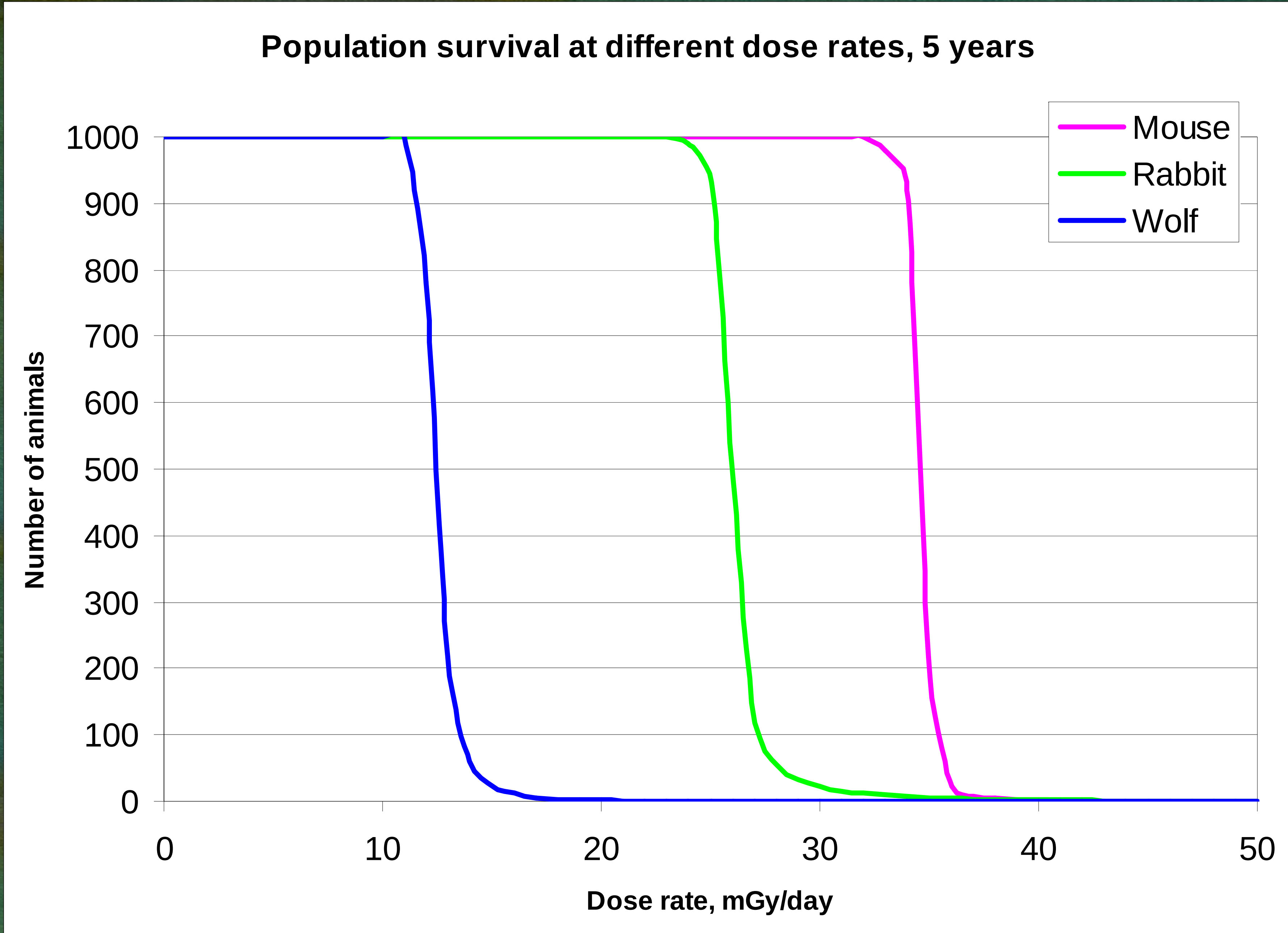
$$\frac{dF}{dt} = -\alpha_f \cdot p \cdot F - \mu \cdot F \cdot (x_{\max} - x) + \mu_f \cdot F \cdot (F_{\max} - F)$$

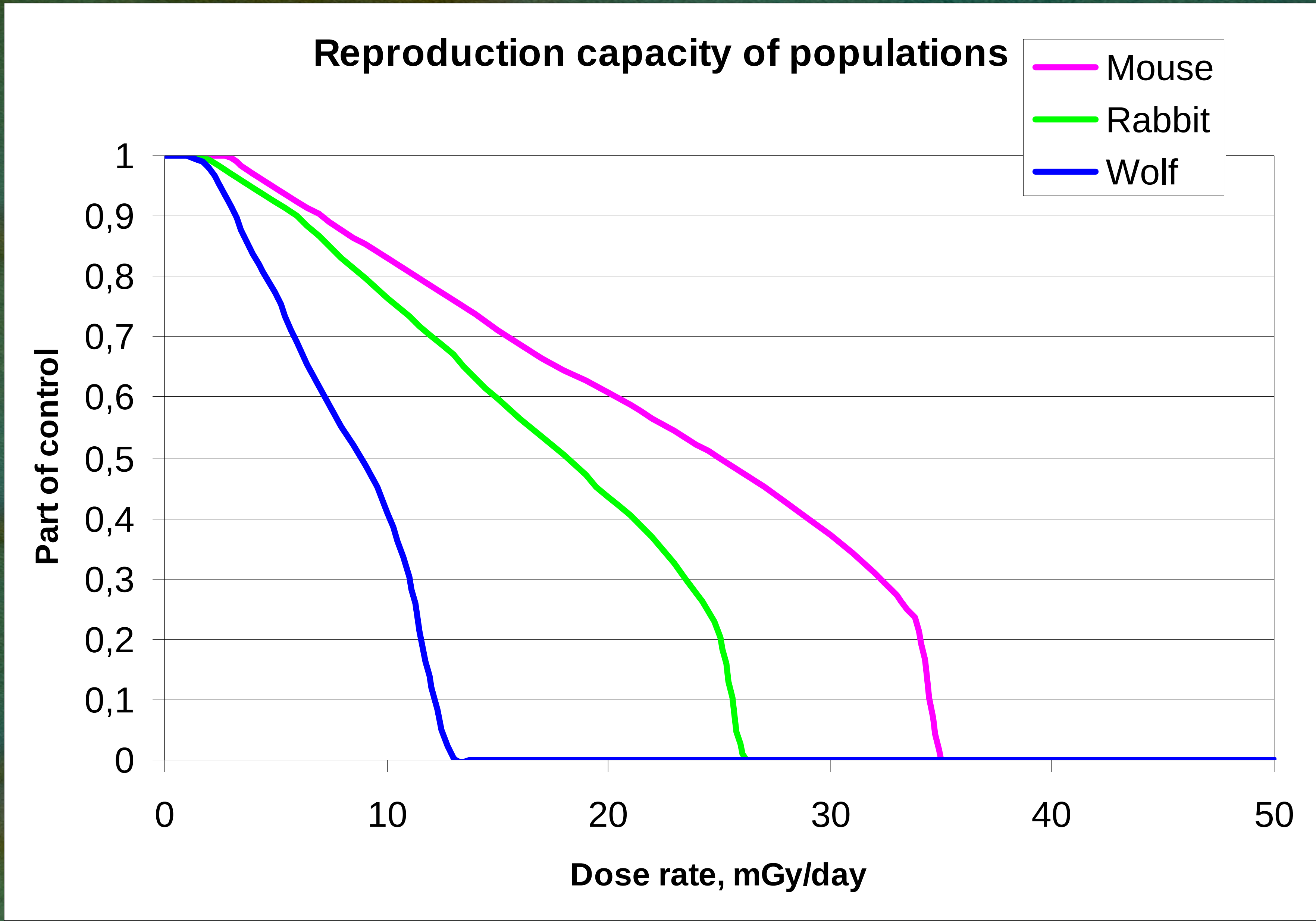
$$x(0) = x_{\max};\, y(0) = 0;\, R(0) = R_{\max};\, F(0) = F_{\max}$$

Parameter of radiation damage:

α=ln2/LD50, where LD50=6.2 Gy (mouse); 7.25 Gy (rabbit); 2.75 Gy (dog/wolf)

(estimates was taken from Blend M.J. Course notes in medical radiation biology. University of Illinois at Chicago. www.uic.edu/com/uhrd/manual/section4/section4.html)


Population survival at different dose rates, 5 years
Number of animals
1000
900
800
700
600
500
400
300
200
100
0
0
10
20
30
40
50
Dose rate, mGy/day
Mouse
Rabbit
Wolf



Reproduction capacity of populations
Mouse
Rabbit
Wolf
Part of control
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
10
20
30
40
50
Dose rate, mGy/day