Radiation Protection of the Environment Where we come from and where we want to go to

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2nd EMRAS II Technical Meeting
IAEA Headquarters, Vienna
25–29 January 2010

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Initiation

- Effects of ionizing radiation to biota early recognized
  - Many experiments were made
  - e.g.: Khyshtym accident 1957: biota largely affected by radioactivity released to the environments
- Dumping of low level radioactive waste to the sea
  - Doses to humans supposed to be small due to the enormous dilution
    - Dumping sites in remote areas
    - Activities dumped were comparatively small
- Concerns on effects to biota that live at the dumping sites
  - London Convention: Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

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Radiation and the Environment
Some flashlights on the development

- **ICRP 1977**
  - *Level of safety ... required for ... humans ... thought likely to be adequate to protect other species, although not necessarily individual members of those species*
- **ICRP 1990**
  - *The standards of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk*

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Remarks

- Approach focuses on the consideration of man only
- No quantitative support on the validity of this statement is given
- Environmental protection has got more attention meanwhile
- Validity is likely, if humans and biota considered are in the same ecosystem, but final proof is needed
- What about the level of protection, if man is not present
  - Remote areas
  - Marine ecosystems
  - Freshwater ecosystems

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Radiation Protection and Environment
Some flashlights on the development

- UNSCEAR, ICRP, IAEA
  - Reports, conferences, meetings on Radiation Protection of the Environment
- IAEA Safety Fundamentals (2006)
  - Principle 7:
    Protection of "People and the environment, present and in the future, must be protected against radiation risks
- ICRP
  - Publication 103:
    - Recommends the explicit consideration of Radiological Protection of the Environment
  - Publication 108
    - Provides a Concept and Use of Reference Animals and Plants

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Protection targets (ICRP 103)

- Maintain biological diversity
- Conservation of species
- Protect health and status of
  - natural habitats
  - communities
  - ecosystems
- Targets are all related to
  - Populations or
  - Higher organisational levels

  => No concern on individual organisms

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QUESTION:

Which dose levels do not affect populations and ecosystems ?

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Problems in estimating impacts on populations

- Enormous variability of species, habitats and communities
- Even in at a defined location population sizes may vary considerably due to
  - Weather
  - Diseases
  - Predator-prey relationships
  - Competition with other species in the same ecological niche

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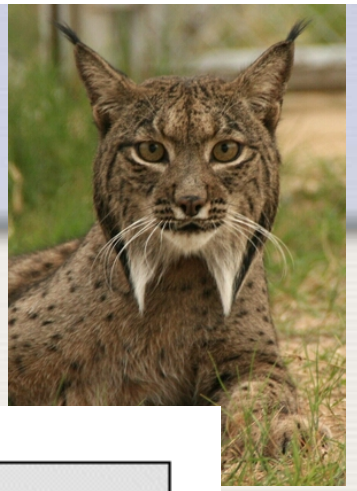
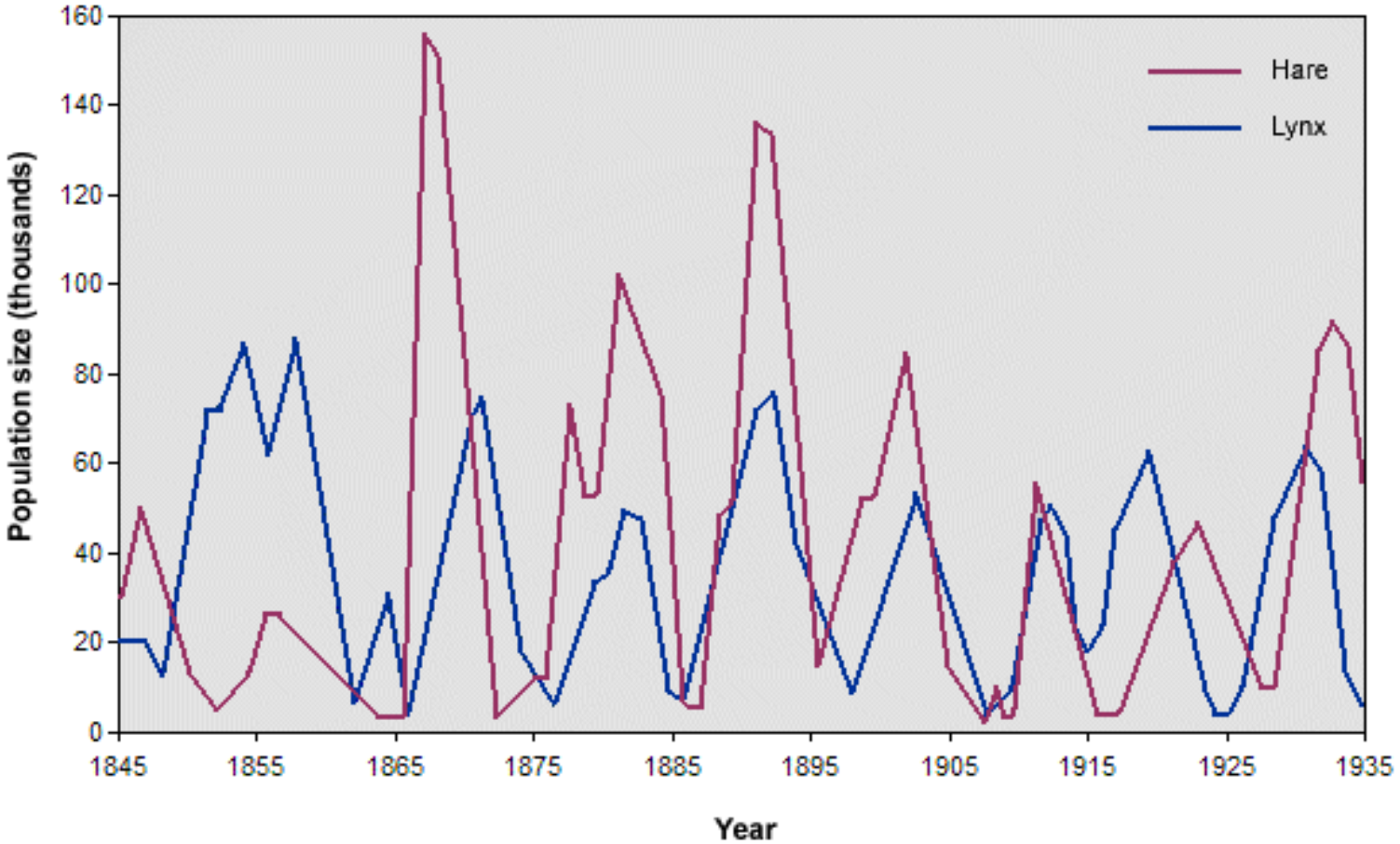
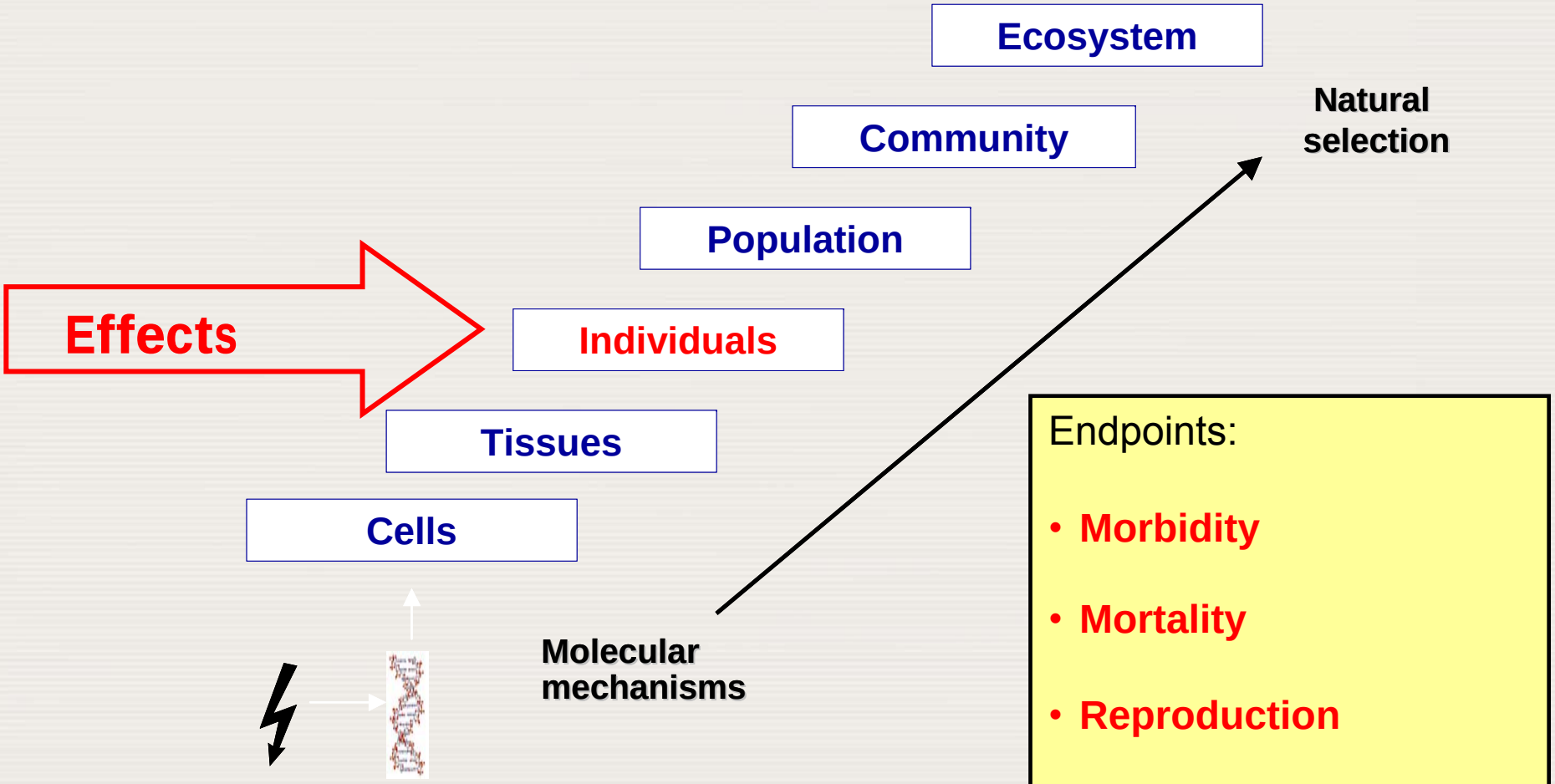
Population of hare and lynx





Effect studies



Endpoints:

- **Morbidity**
- **Mortality**
- **Reproduction**
- **Mutations**

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How to manage the enormous variability of life?

- Enormous variability requires definition of references
  - Reference Animals and Plants (ICRP)
  - Reference Organism (EU-funded projects FASSET and ERICA, 2000-2007)
- Criteria for selection
  - Global occurrence
  - Plants and animals
  - Terrestrial and aquatic
  - Different life stages considered
    - E.g.: eggs, larvae, adults
  - Different habitats
    - In soil, on soil, above soil
    - In water, in sediment

⇒However, any selection is to some extent arbitrary

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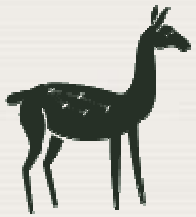
Reference Organisms (FASSET and ERICA)
Reference Animals and Plants (ICRP)

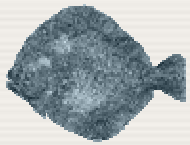
- Deer
- Rat
- Bee
- Earthworm



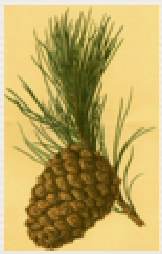
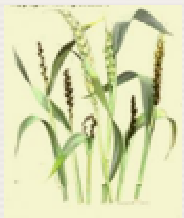

- Duck
- Frog
- Trout



- Marine Flatfish
- Crab




- Pine Tree
- Grass
- Seaweed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Reference Animals and Plants — Reference Organism
What are they?

RAPs and ROs are ***hypothetical*** entities

- Derived with the same principles and for the same purpose as the **reference person**
- Defined anatomical, physiological, and life-history properties
- Defined habitats
- Used to estimate internal and external exposures for that ***type*** of living organism

=> ***Provide a range of exposures that might occur in the environment under specific circumstances***

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Identification of dose levels that cause no or very minor effects

Conclusions from effects studies

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Dose effects studies

- FASSET and ERICA (2000-2007)
  - Analysis of the existing literature to derive relationships between exposures to biota and effects
- UNSCEAR (2008)
  - Analysis of data on effects on biota
- ICRP 108 (2009)
  - Dose Consideration Reference Levels
  - Bands of exposure for Reference Animals and Plants that cause no or minor effects
- PROTECT (2007-2009)
  - Statistical Analysis of dose effects relationships to derive screening values

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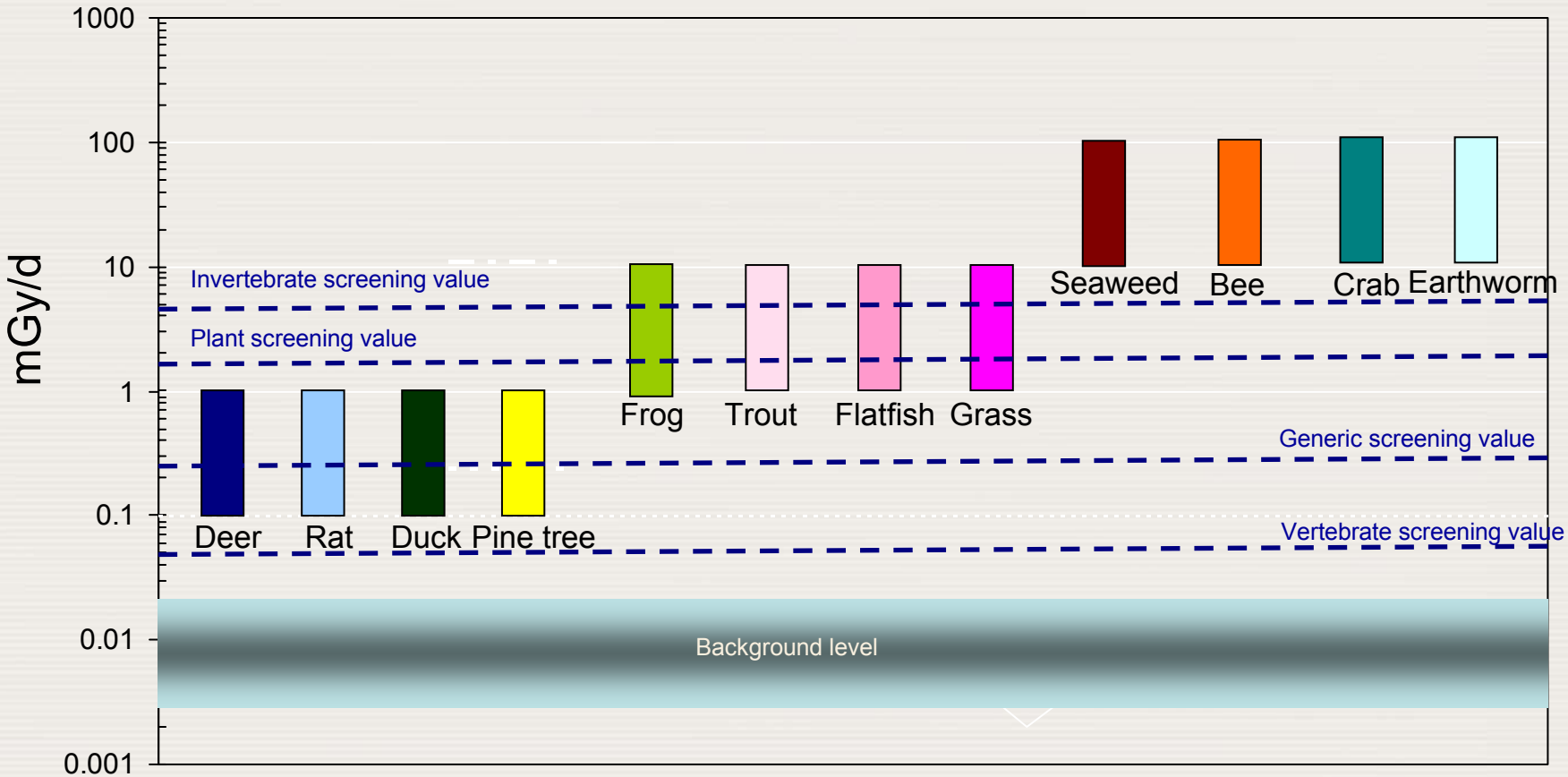
Summry of DCRLs



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Summary of effects studies

- FASSET (2003):
  - Minor effects for dose rates ***< 100 µGy/h***
- ERICA (2007)
  - Joint statistical analysis => No effects at ***10 µGy/h***
- UNSCEAR (2008), draft
  - ***Dose rate*** to the **most highly exposed individual** unlikely to have significant effects on communities:
    - ***100 µGy/h*** for terrestrial species
    - **400 µGy/h** for aquatic communities
    - ***< 1 Gy*** for acute exposures
- PROTECT (2009):
  - ***10 µGy/h*** and below is an appropriate generic screening value
- ***ICRP: DCRL 4-40 µGy/h for most sensitive RAPs***

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Natural background to flora and fauna

- Terrestrial above-ground animals and plants
  - In the order of **1 μGy/h**
  - Burrowing mammals
    - Lung doses: **up to 70 μGy/h** due to Radon & daughters (McDonalds 1998)
- Aquatic organisms
  - Typical: up to **a few μGy/h**
  - Maximum: **a few ten μGy/h**

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Screening levels in relation to background

The values for

- Screening levels derived by ERICA and PROTECT
- Derived Consideration Reference Levels as derived for the most sensitive species proposed by ICRP
- Upper range of natural Background exposure

are very similar

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Application of DCRLs and screening levels

The values are no dose limits !

- Whether the data relate to actual or theoretical studies,
- The type of exposure situation
- The size of the area affected
- The status of the population
- The fraction of a population exposed, and
- The legal framework within which management action are taken

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How to estimate exposures to biota ?

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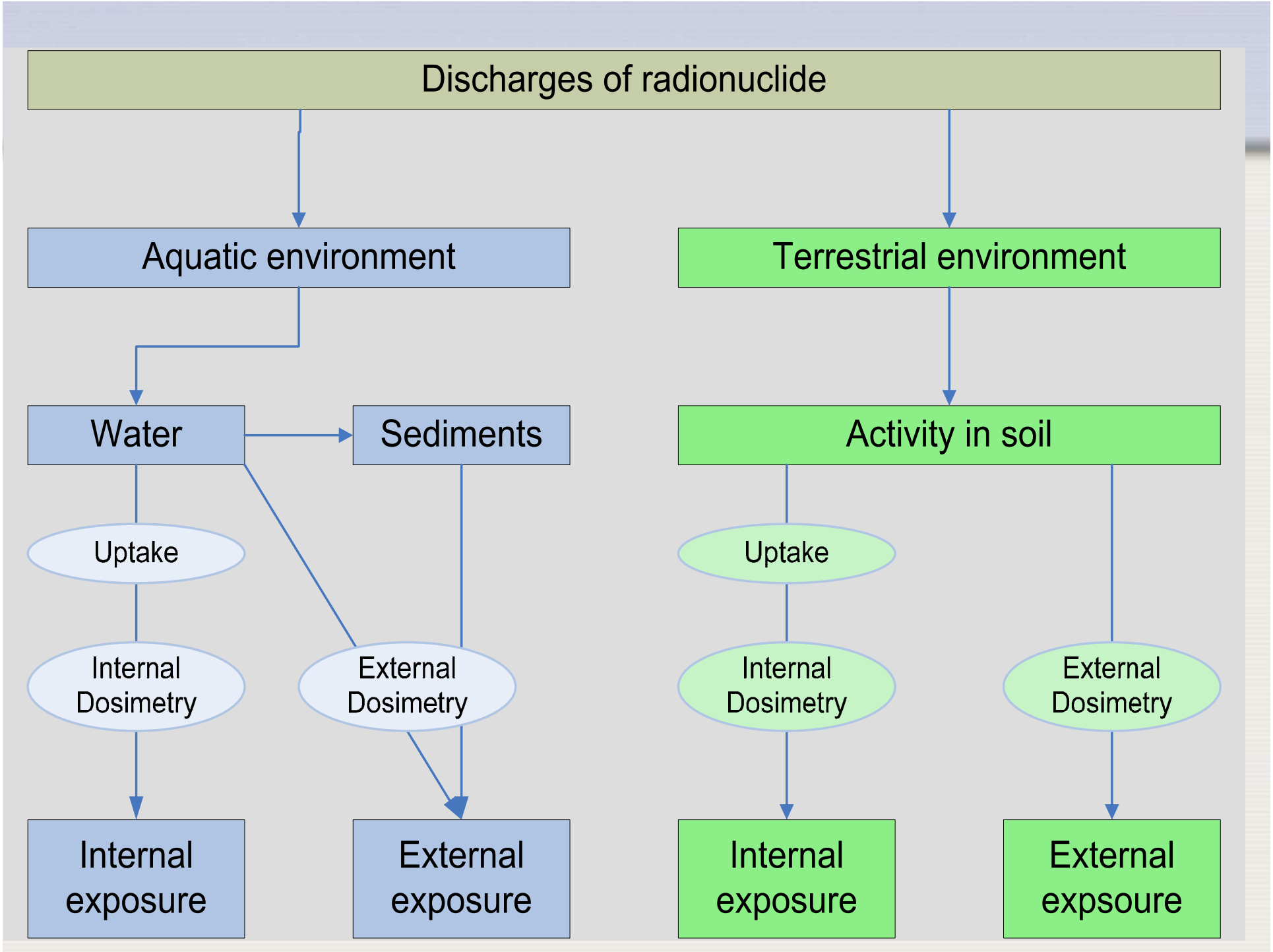
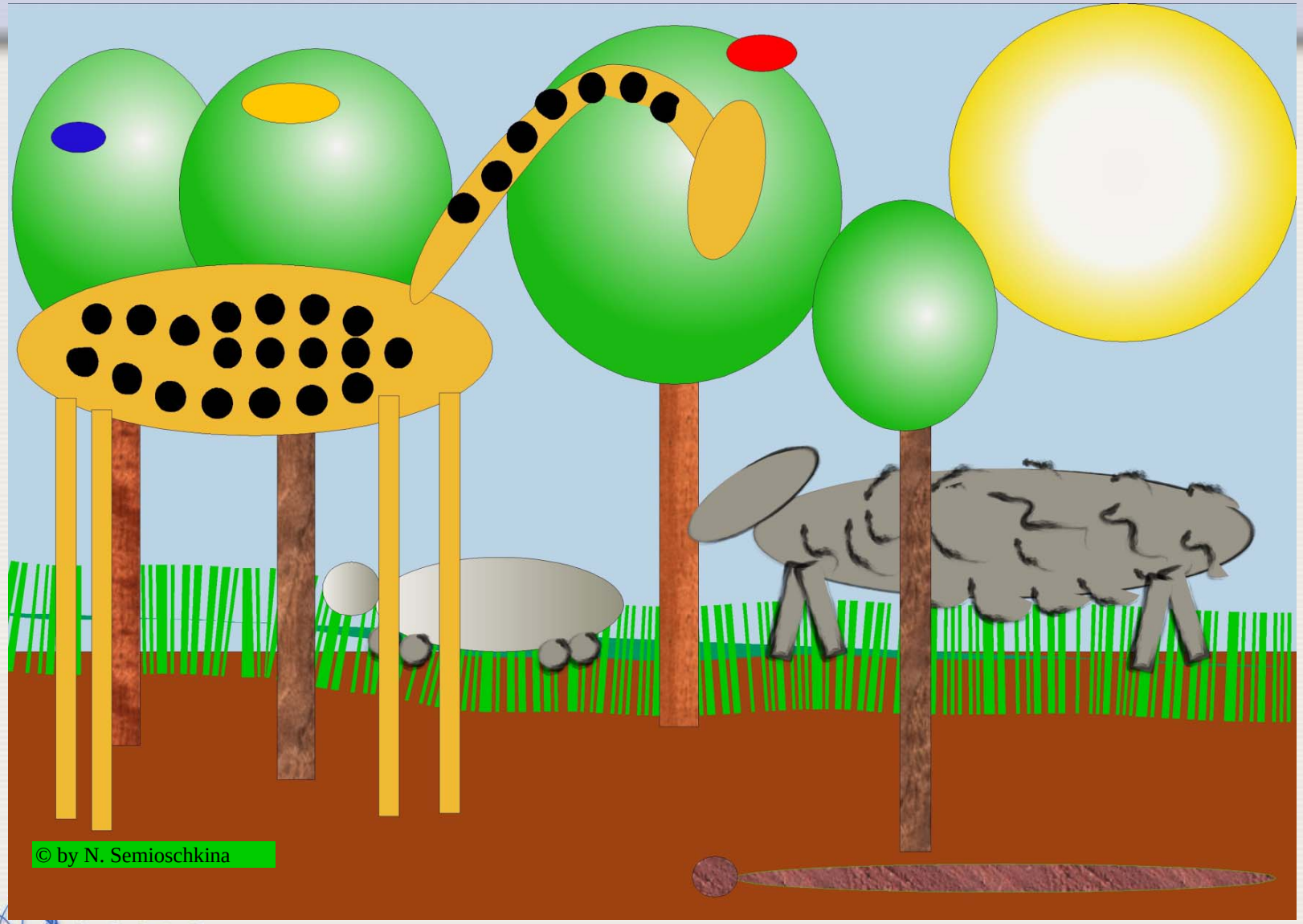

Discharges of radionuclide
Aquatic environment
Terrestrial environment
Water
Sediments
Activity in soil
Uptake
Uptake
Internal Dosimetry
External Dosimetry
Internal Dosimetry
External Dosimetry
Internal exposure
External exposure
Internal exposure
External expsoure

Dosimetry: Simplified geometries



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Dosimetry

- Internal and external exposure
  - Aquatic and terrestrial organisms
- Mass of organisms: 10^{-6} – 10^{3} kg
- Simplified assumptions
  - Spheres and ellipsoids
  - Homogeneous distribution
- Results consistent with dosimetry for humans
- Remaining issues
  - Impact of non-homogeneous distribution
  - Impacts of more complex shapes
  - Contribution of inhalation and exposure from the cloud

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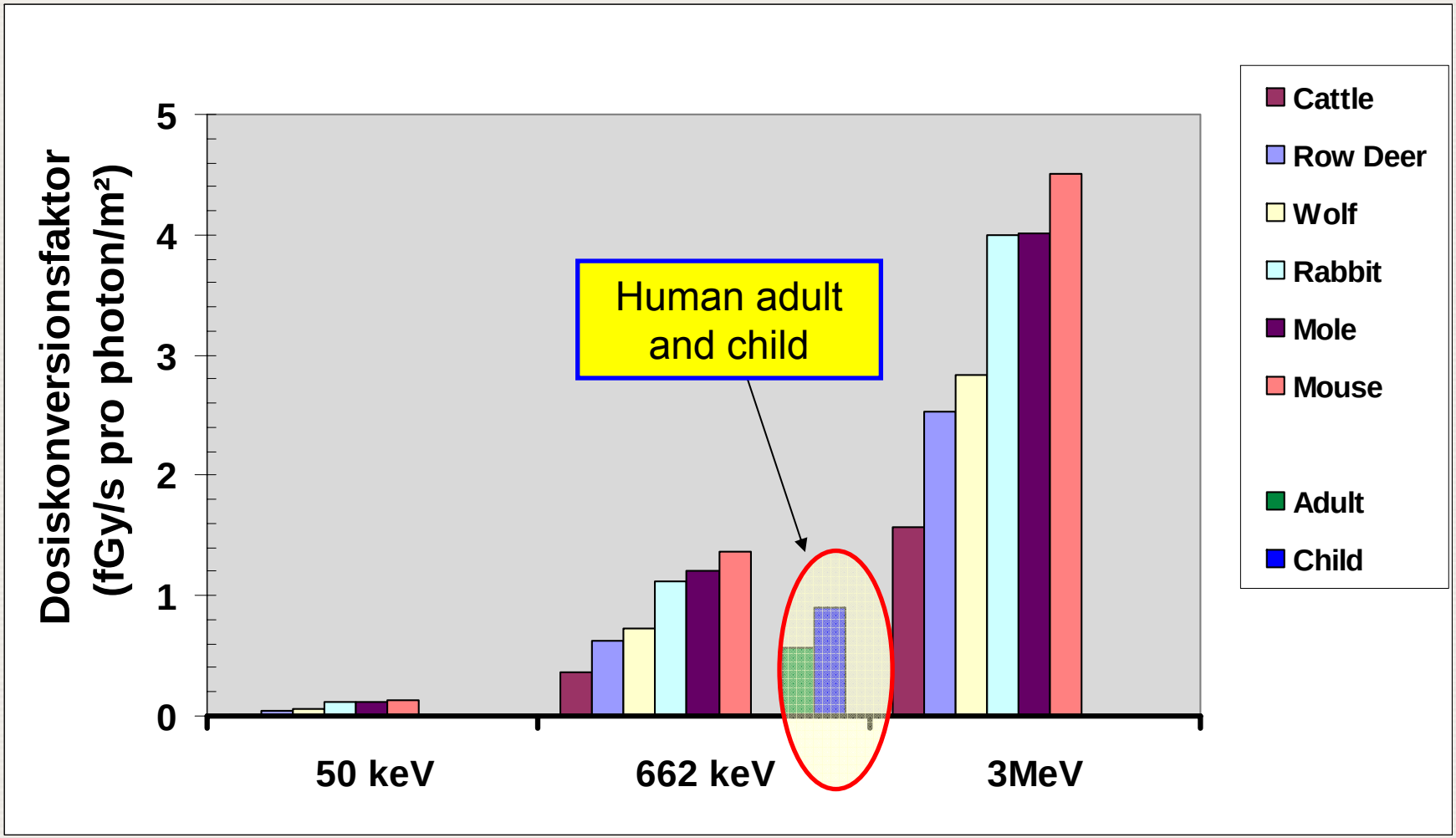
Comparison of external exposures to monoenergetic photons for humans and animals



Cs-137 line

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Transfer of radionuclides to biota

- Quantity: Concentration Ratios
  - Water-aquatic organism [Bq/kg per Bq/L]
  - Soil – terrestrial organism [Bq/kg per Bq/kg]
- Intensive review and collection of data
  - EU Projects FASSET and ERICA
  - ICRP
  - EMRAS I and II
- General findings
  - Large variability within and among species
  - Considerable data gaps
  - Many conservative values

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Transfer of radionuclides to biota (cont.)

- Overall uncertainty higher than for the dosimetry
- Limited number of species is included in the estimation of the transfer
  =>Broadening the data base
- Data allow a rough estimate of activity concentrations in the References selected for flora and fauna

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Relation of exposures to biota and humans

- What does it mean for humans, if biota receive 10 mGy/h ?
- 2 Examples:
  - **1** Internal dose to a fish => Internal dose to a person eating that fish
  - **2** External exposure to a deer => External exposure to person being at the same place

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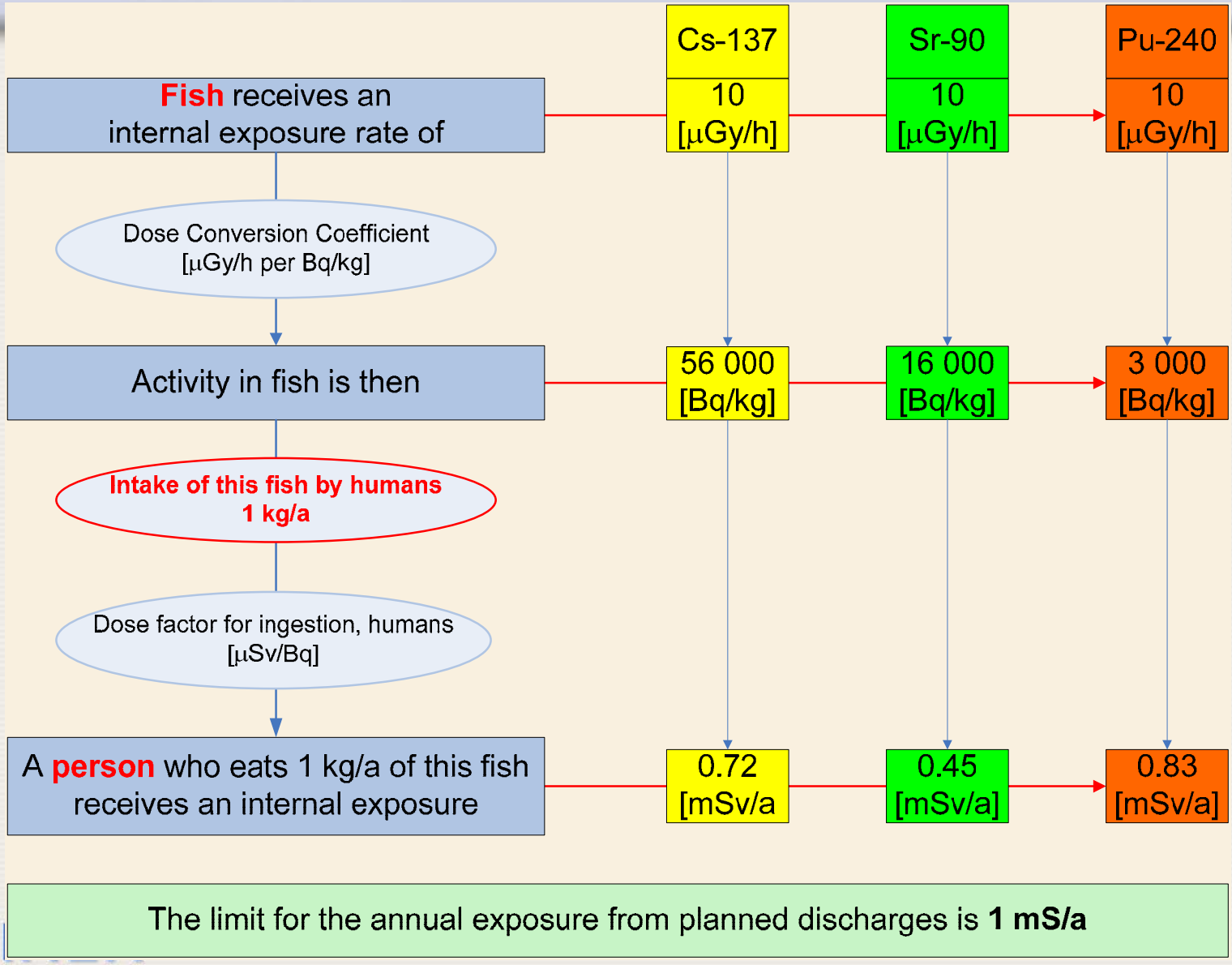
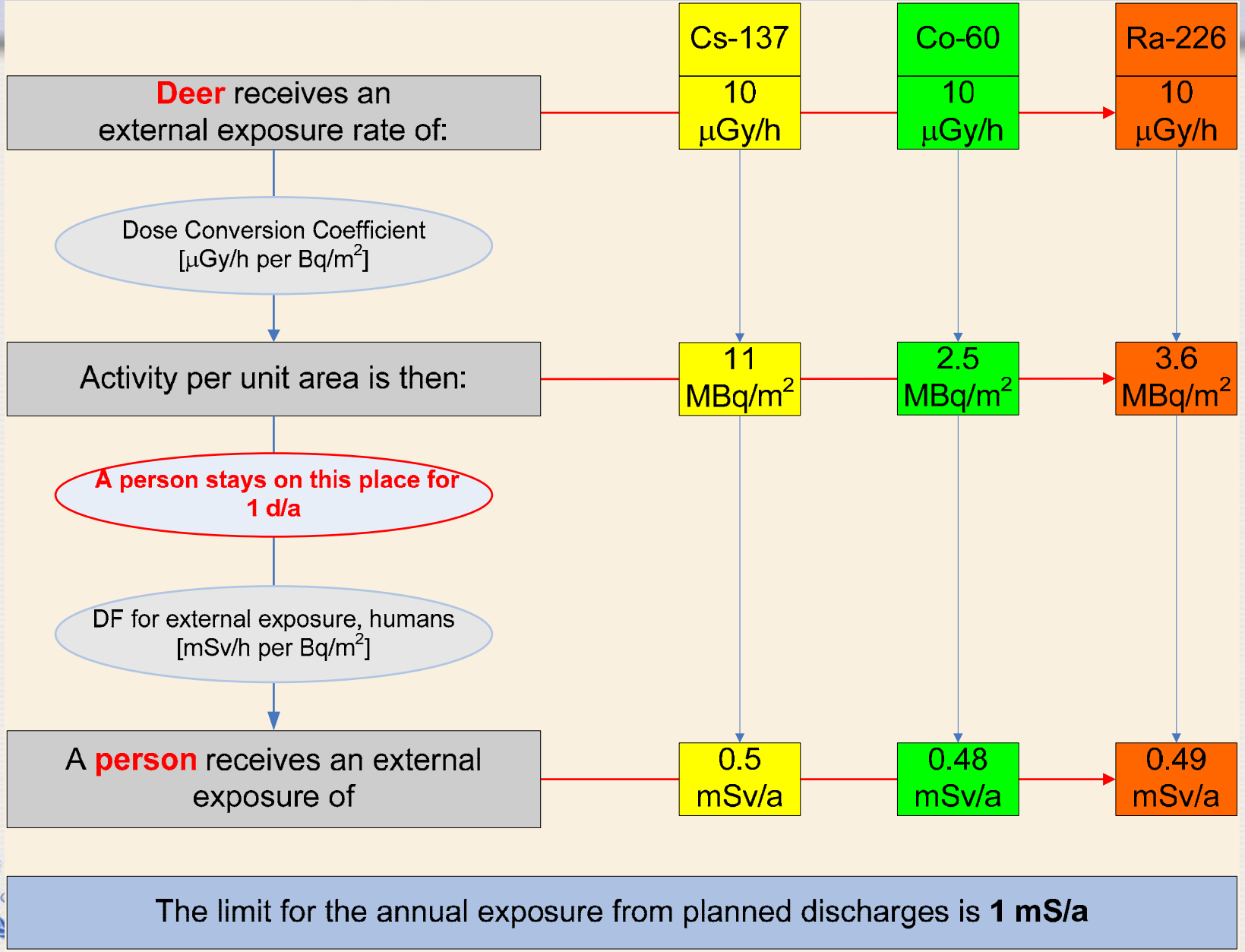
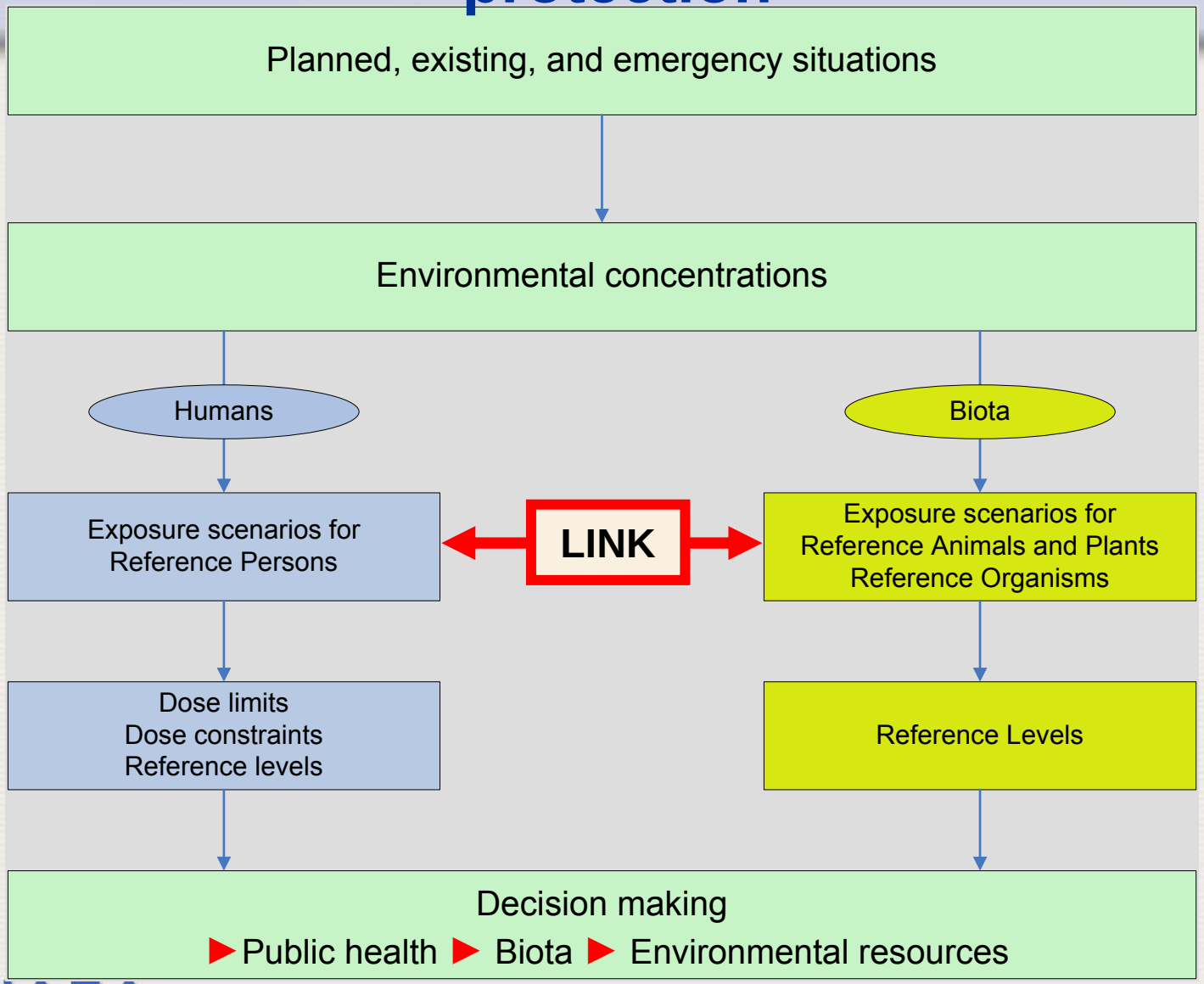
Link of internal exposure: Fish — Man



Link of external exposure Deer — Man



Integration of human and environmental protection



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Conclusions

- General consensus on dose rate levels that do cause effects to flora and fauna
  - Limited knowledge on effects on population
  - Relatively little number of species involved
  - Migration
  - Size of affected area
- Estimation of radionuclide concentrations in flora and fauna is possible – uncertainties remain
  - Many radionuclides with gaps
  - Broadening the spectrum of species
- Simple dosimetry provides consistent results – some fine tuning is still needed
  - Impact of non-homogeneous distribution
  - Submersion from the cloud and inhalation
  - Background exposure to radon

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Conclusions (cont.)

- Link to humans
  - Exposure levels around 10 μGy/h do not affect biota
  - However, such exposures restrict the use of environmental resources as water bodies and land for humans
    - Food production
    - Staying on such areas
  - More detailed and systematic considerations are needed

⇒For radiological protection of the environment an integrated approach is needed that involves

⇒Protecting of biota

⇒Protecting people

⇒Ensure the use of environmental resources

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Thank you very much

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