Mount Ste Victoire, Aix en Provence, France

Radioecology in 2021

The IUR vision to guide developments

"Ensuring the sustainable development of nuclear activities with respect to man, the environment and future generations"

International Union of Radioecology

Union Internationale de Radioécologie
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Radioecology is a multidisciplinary scientific discipline...

biology, chemistry, physiology, ecology, biogeochemistry, geophysics, ecotoxicology, mathematics (models, statistics), metrology, …

- **centered on the environment,**
- **aimed at describing, understanding and predicting:**

  - **the fate of radioactivity in environmental systems,**

    (artificial and natural)

  - **its impact on man (via the environment) and on the environment itself (biota, ecosystems)**

    (human and ecological risk assessment)

  - **biogeochemical processes by means of tracer studies**

Baseline research directions in Radioecology

Axis 1: Source term

- Speciation, mobility (in the various environmental media)

Axis 2: Transfers

- In abiotic compartments, within the human food chain
- In abiotic compartments, within the biota trophic network

Axis 3: Effects

- (On man)
- On biota, populations, ecosystems

Axis 4: Risk assessment

- Human risk assessment
- Ecological risk assessment (organism-based/ecosystem-centred approach)

Axis 5: Tracer studies

- Biogeochemical cycles, ocean streams, run-off

AXIS 2

Transfers

In abiotic compartments

Within the human food chain

Within biota trophic networks

AXIS 3

Effects

(On man)

On biota, ecosystems

Life support

Services

AXIS 4

Risk assessment

Human risk assessment

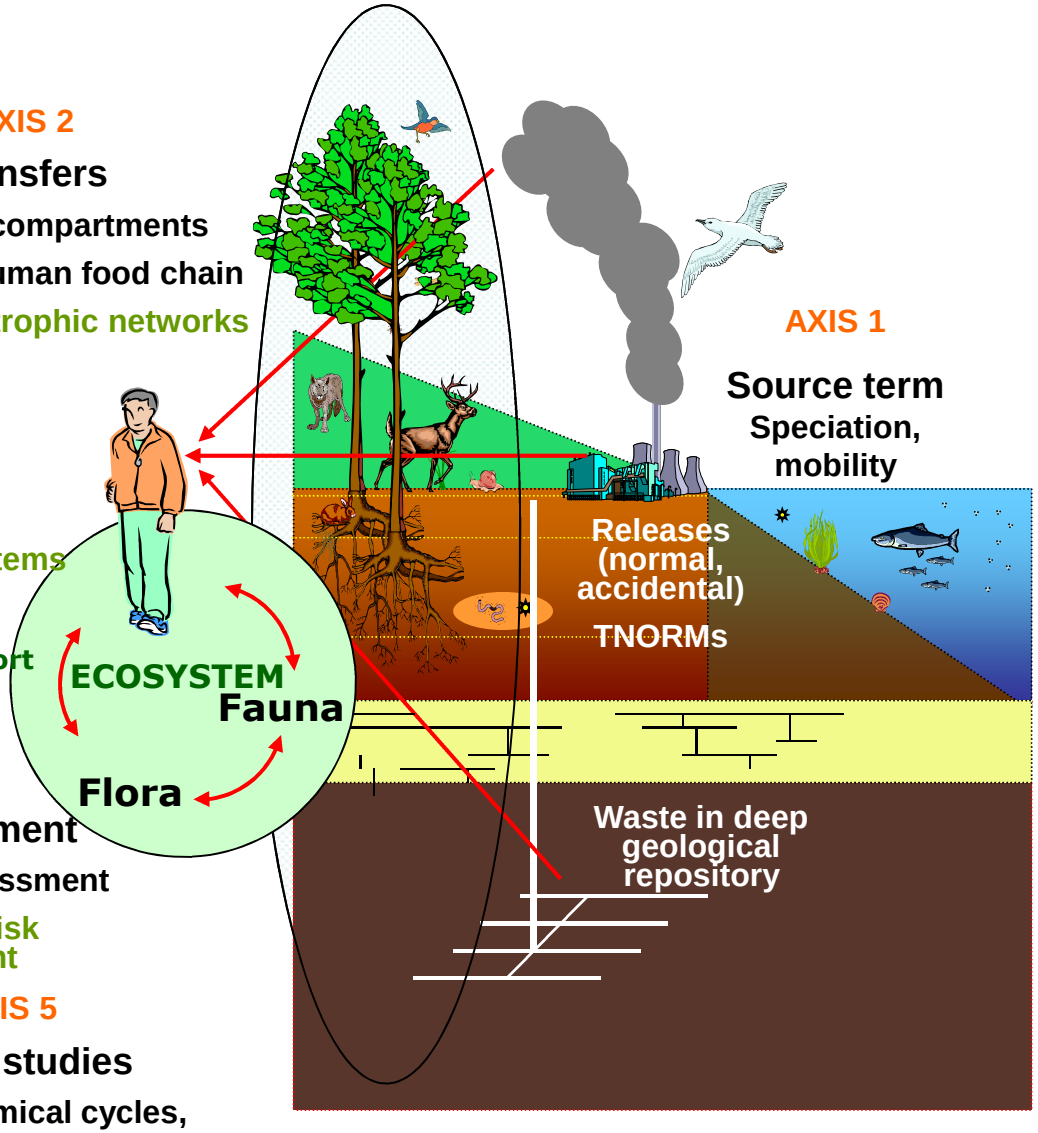
Ecological risk assessment

AXIS 5

Tracer studies

Biogeochemical cycles, streams,

run-off…



AXIS 1

Source term

Speciation, mobility

ATMOPHERE

BIOSPHERE

GEOSPHERE

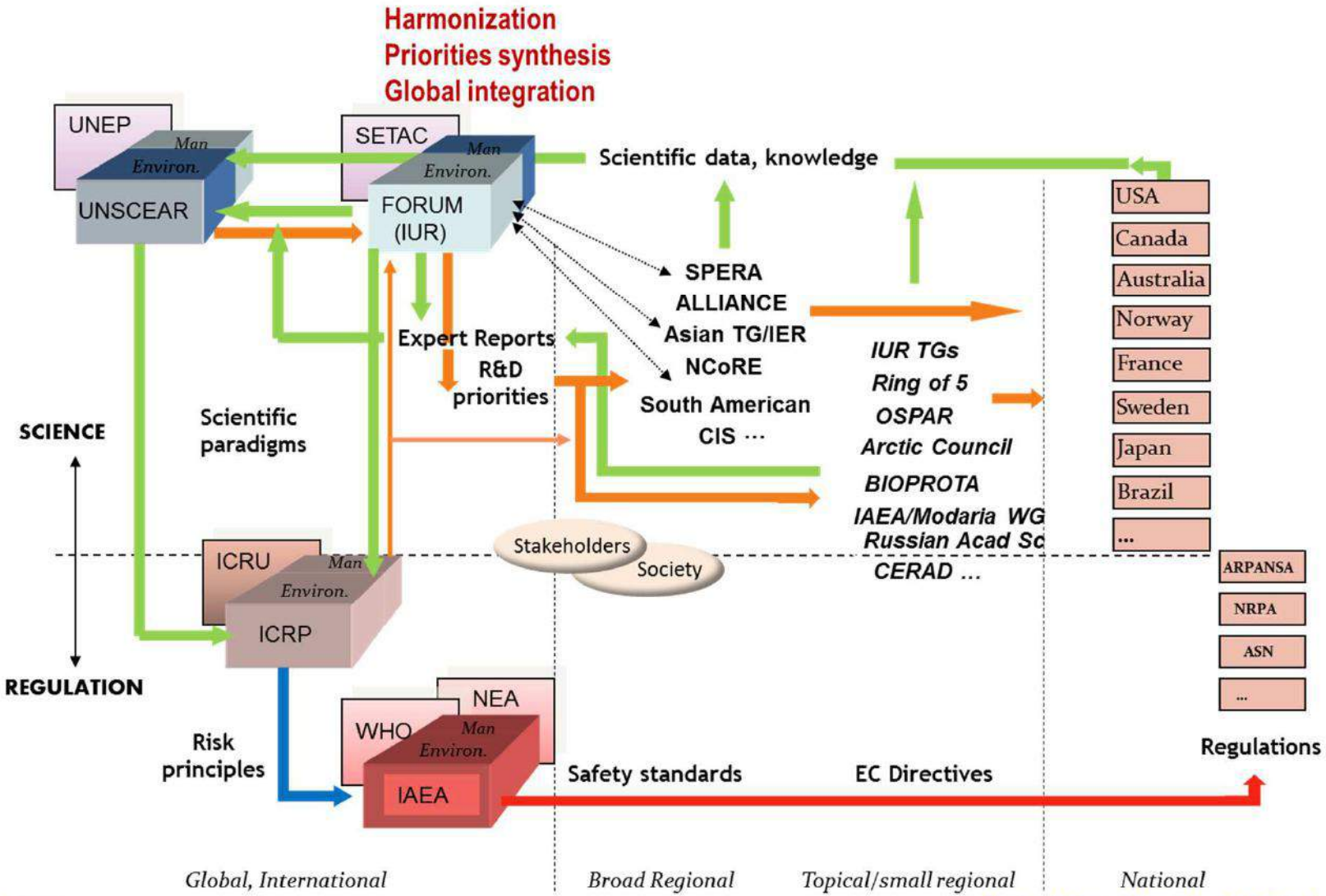
Scientific approaches

Experimental designs, models, field investigations

Hot issues:

- Worldwide networking for expertise maintenance
- Consensus development
- Building an ecocentric vision
- Uncertainties jeopardizing predictions

Worldwide networking: the IUR Forum



Consensus development

Is everything known on ecological impact of radiation?

Obviously not, as interpretations still diverge... At Chernobyl...

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

30 July 2010 Last updated at 16:00

Chernobyl zone shows decline in biodiversity

By Victoria Gill
Science reporter, BBC News

Scientists say contamination in the Chernobyl exclusion zone has affected biodiversity

The largest wildlife census of its kind conducted in Chernobyl has revealed that mammals are declining in the exclusion zone surrounding the nuclear power plant.

The study aimed to establish the most reliable way to measure the impact on wildlife of contamination in the zone.

It was based on almost four years of counting and studying animals there.

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Consensus development

... And at Fukushima as well !

Environmental Pollution 169 (2012) 137–138

Contents lists available at SciVerse ScienceDirect

Environmental Pollution

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

Reply to Letter to the Editor

Reply to "Comment on "Abundance of birds in Fukushima as judged from Chernobyl" by Møller et al. (2012)"

Dear Editor,

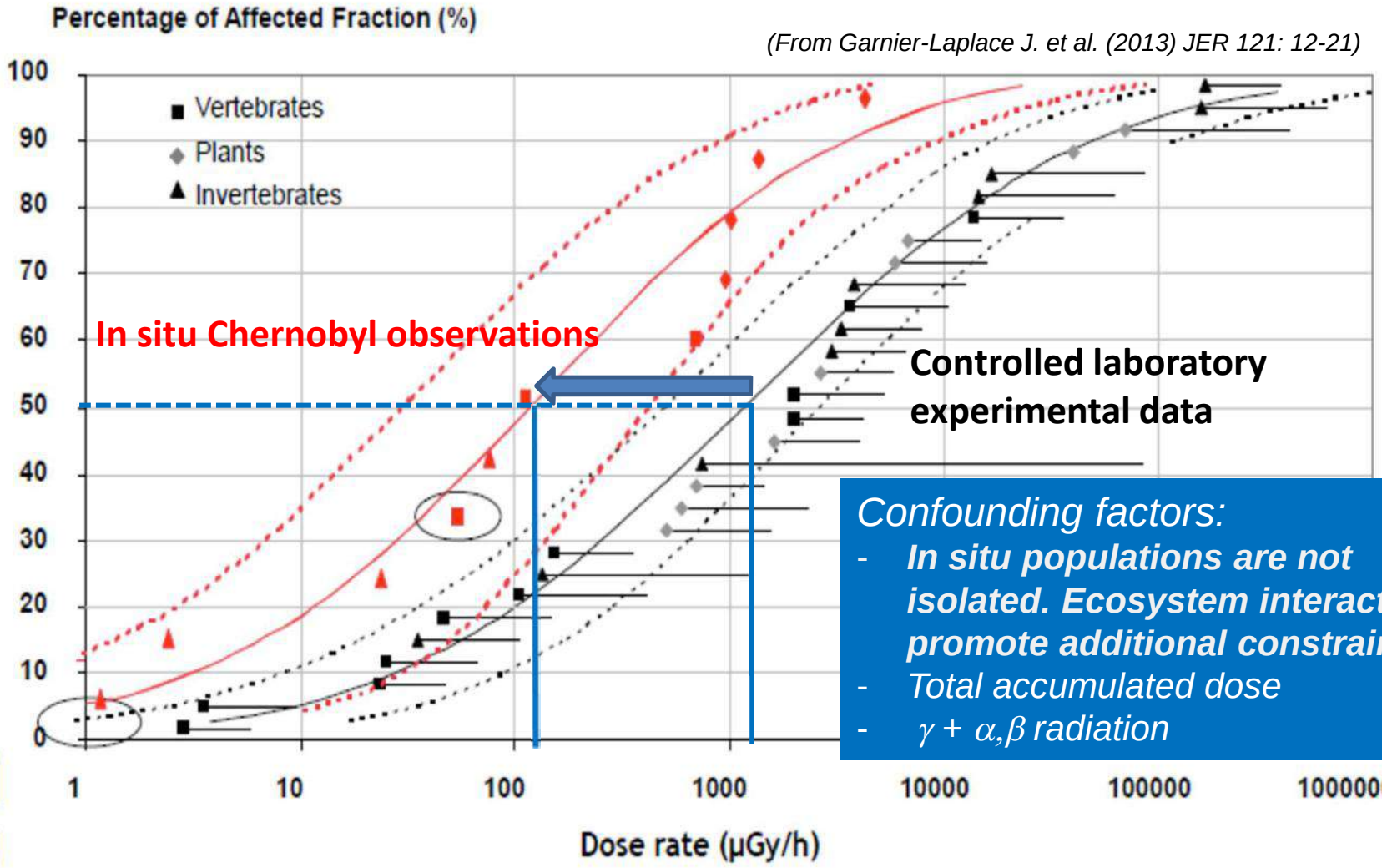
We have received many inquiries concerning the results reported in our recent paper, "Abundance of birds at Fukushima as judged from Chernobyl" (Møller et al., 2012), and we are delighted to have this opportunity to further explain in print our methods of data collection and analysis as they are at once simple, conventional (Voříšek et al., 2010), and yet highly revealing of the shifts in bird community structure that have been observed first at Chernobyl, and now at Fukushima.

In essence, for this first study of wildlife in Fukushima in relation to radioactive contamination, we visited 300 locations scattered recently in Fukushima (Møller et al., 2012), and the methods employed have been extensively and repeatedly described in detail in these papers.

At each of 300 sites in Fukushima every bird detected was identified and recorded. These observations were recorded on a spreadsheet that also included a large number of independent environmental variables (e.g. elevation, latitude, longitude, vegetation coverage, radiation, etc.) in addition to the frequency of occurrence of each species at that site. This multivariate dataset was then subjected to a statistical analysis that generated a model to assess the relationship between contamination levels and bird abundances while controlling for the effects of other potentially impor-

Why no consensus on ecological impact ?

Field/laboratory: what data should be used to derive risk standards?



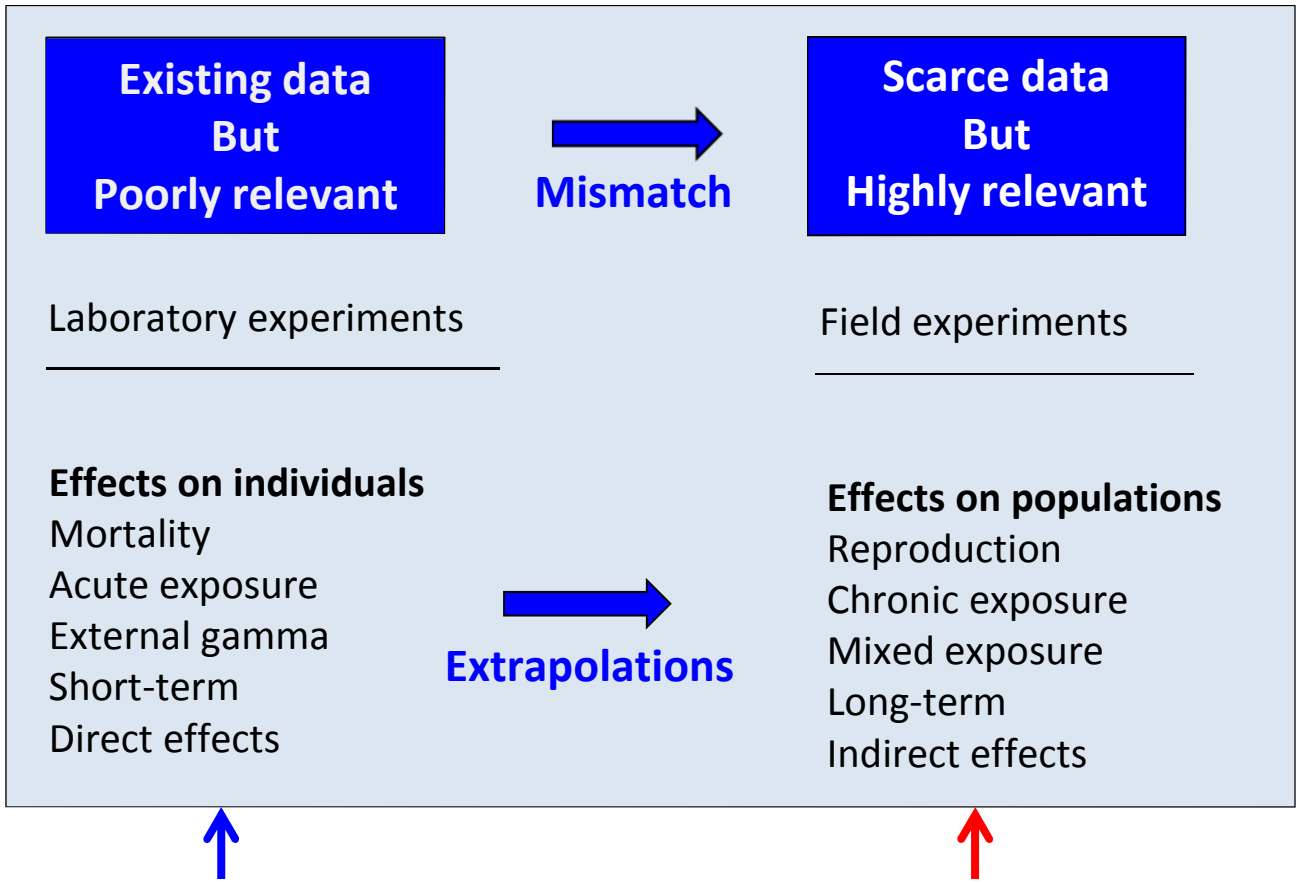
(From Garnier-Laplace J. et al. (2013) JER 121: 12-21)

Confounding factors:

- ***In situ populations are not isolated. Ecosystem interactions promote additional constraints***
- *Total accumulated dose*
- *γ + α,β radiation*

Addressing ecological risk assessment at low doses

Resolving the mismatch between current data and ecological relevance



Resolving the mismatch

Protection target

Individuals of endangered species

Populations / communities

Structure and functions of ecosystems

Mismatch

Methods to achieve protection goals

Reference organism approach

Individual organism level endpoints:

- Early mobidity
- Mortality
- Reproductive success
- Chromosome damage

Ecosystem approach

Population level endpoints:

- Population growth rate
- Population density
- Population size (numbers, biomass)
- Population age/size structure
- Net reproduction rate
- Probability of extinction

Community-level endpoints:

Structural

- Biodiversity
- Taxonomic composition
- Trait distribution
- Food web structure

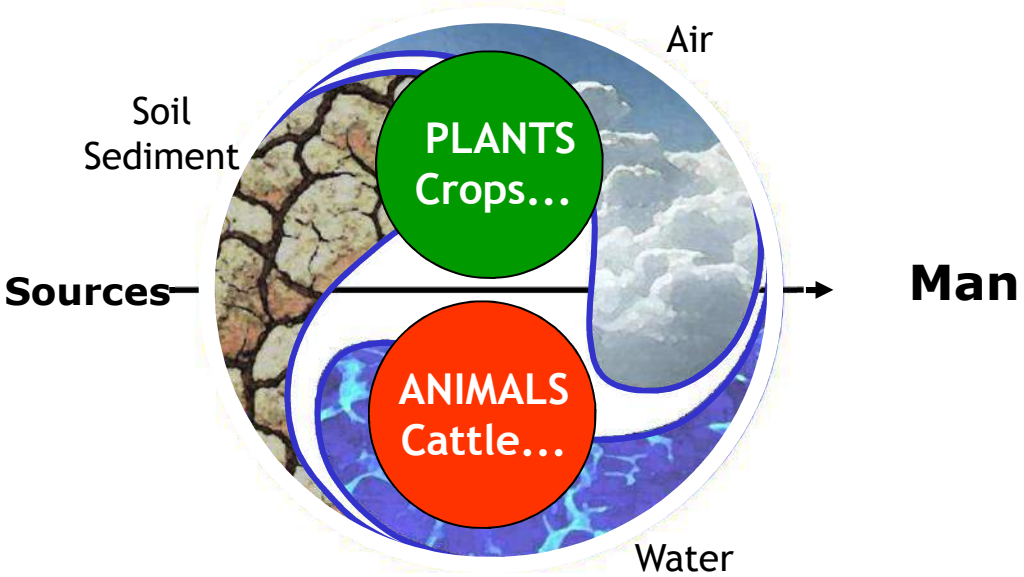
Functional

- Primary production
- Biomass/energy flow
- mineralization

Moving from anthropocentric to an ecocentric vision of risk

Anthropocentric → Biocentric → Ecocentric

Long historical domination of radionuclides transfer to support human radioprotection purposes



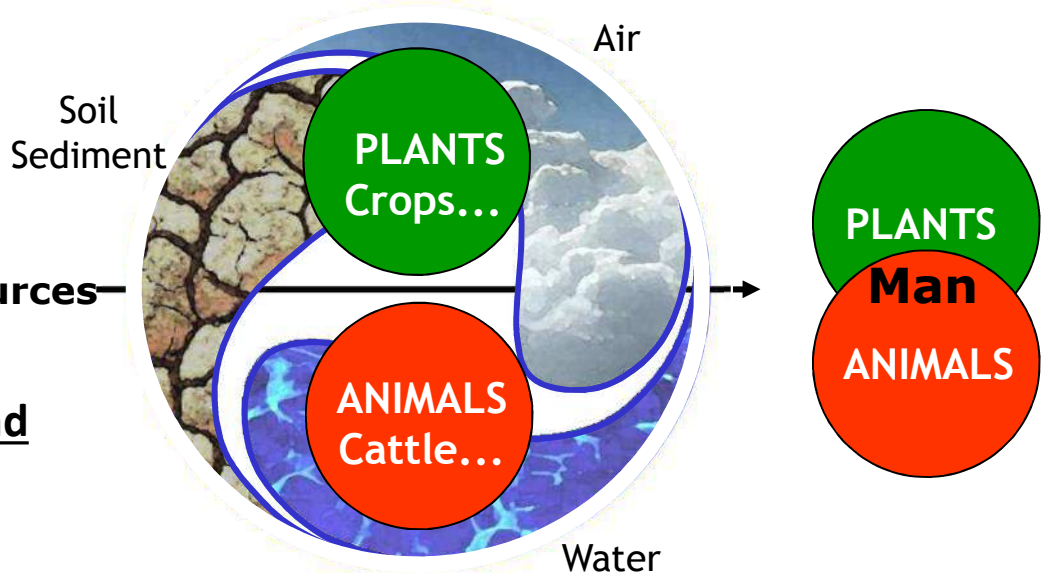
Moving from anthropocentric to an ecocentric vision of risk

Anthropocentric → **Biocentric** → Ecocentric

Move to effects on animals and plants: Current « Reference organism approach » for risk assessment (protection at individual organism level)

A big mismatch:

Because the protection goals sit at <u>population and ecosystem</u> levels



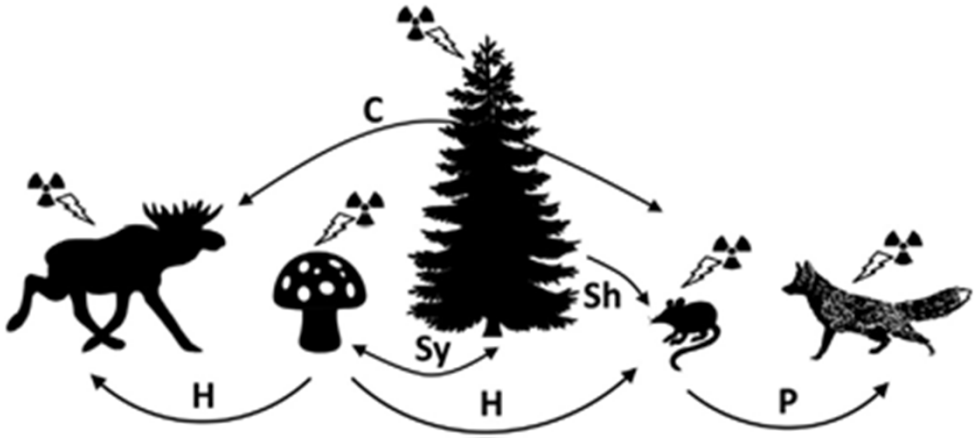
Individual organism/species-based frameworks do not address ecosystems

- Interactions between species and indirect effects not considered
- Non-linear responses, emergent properties, resilience, etc…, not addressed
- Effects at ecosystem level cannot be predicted/extrapolated from effects at individual organism/species level
- **Adequate to address biological effects, but may over- or underestimate ecological effects / risk**
- **May explain why in situ population/ecosystem level studies exhibit different/conflicting effects results …**

An “ecosystem approach” is needed

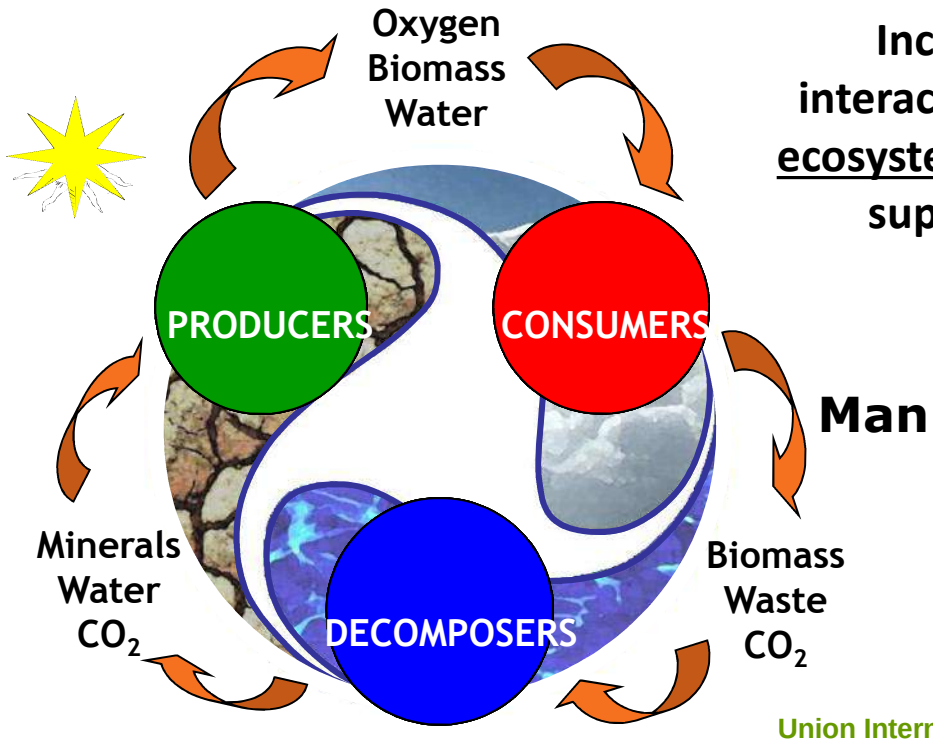
- Because objectives of protection are most usually set at population/ecosystem levels
- Because all organisms can only survive in the context of an ecosystem featuring obligatory interactions
  - Interactions between species, populations, biotic/abiotic
  - Emergent properties
  - Resilience, …

Bradshaw et al (2014) Fig 2.
C = competition, P = predation,
H = herbivory , Sy = symbiosis ,
Sh = shelter



The “ecosystem approach” builds an ecocentric vision

Anthropocentric → Biocentric → **Ecocentric**



Including species interactions that provide <u>ecosystem services</u> and life support functions

Focus on effects on <u>ecosystems</u> to support real ecological risk assessment

Ecocentric vision centred on the ecosystem…

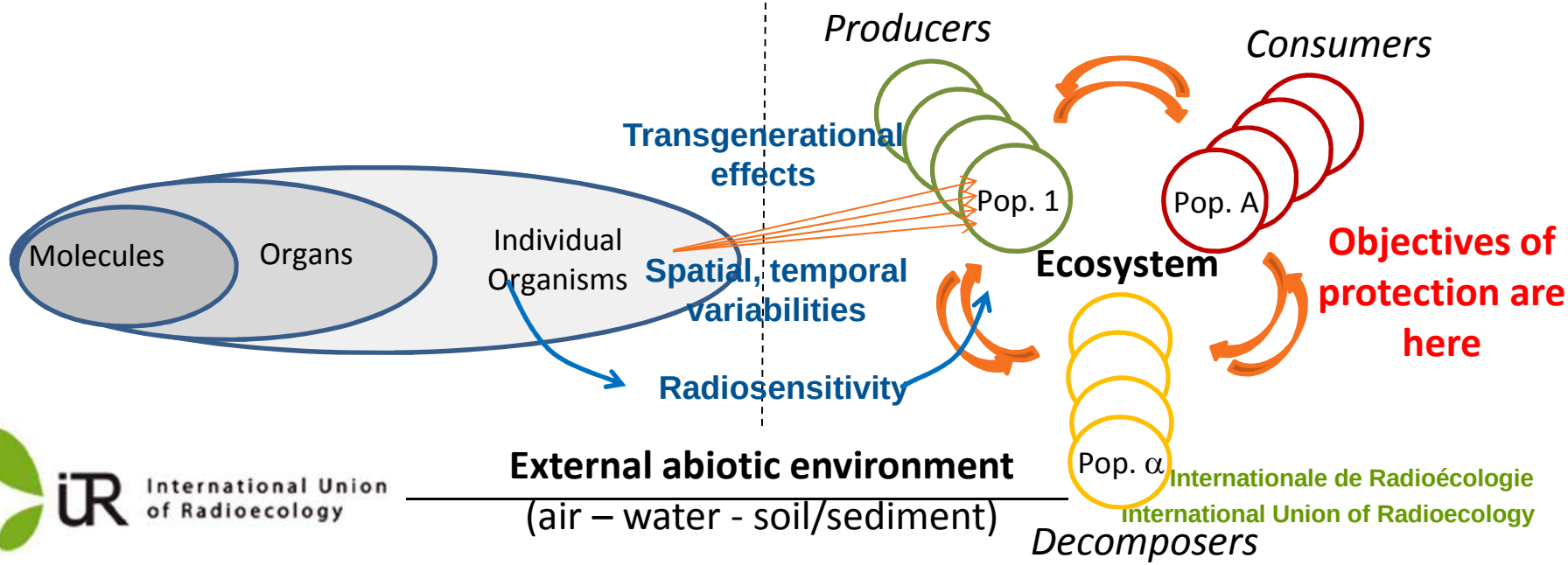
Field/lab communities address populations/individual organisms and use different inference strategies

Biological impact of radiation
(current method for man and biota)

Nested system
(homeostatic stability)

Ecological impact of radiation
(method needed for populations and ecosystems)

Network of species interactions
(submitted to abiotic variability)



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… provides a conceptual basis for human-environment integration

Integration of human and enviromental risk assessment of radiation ?

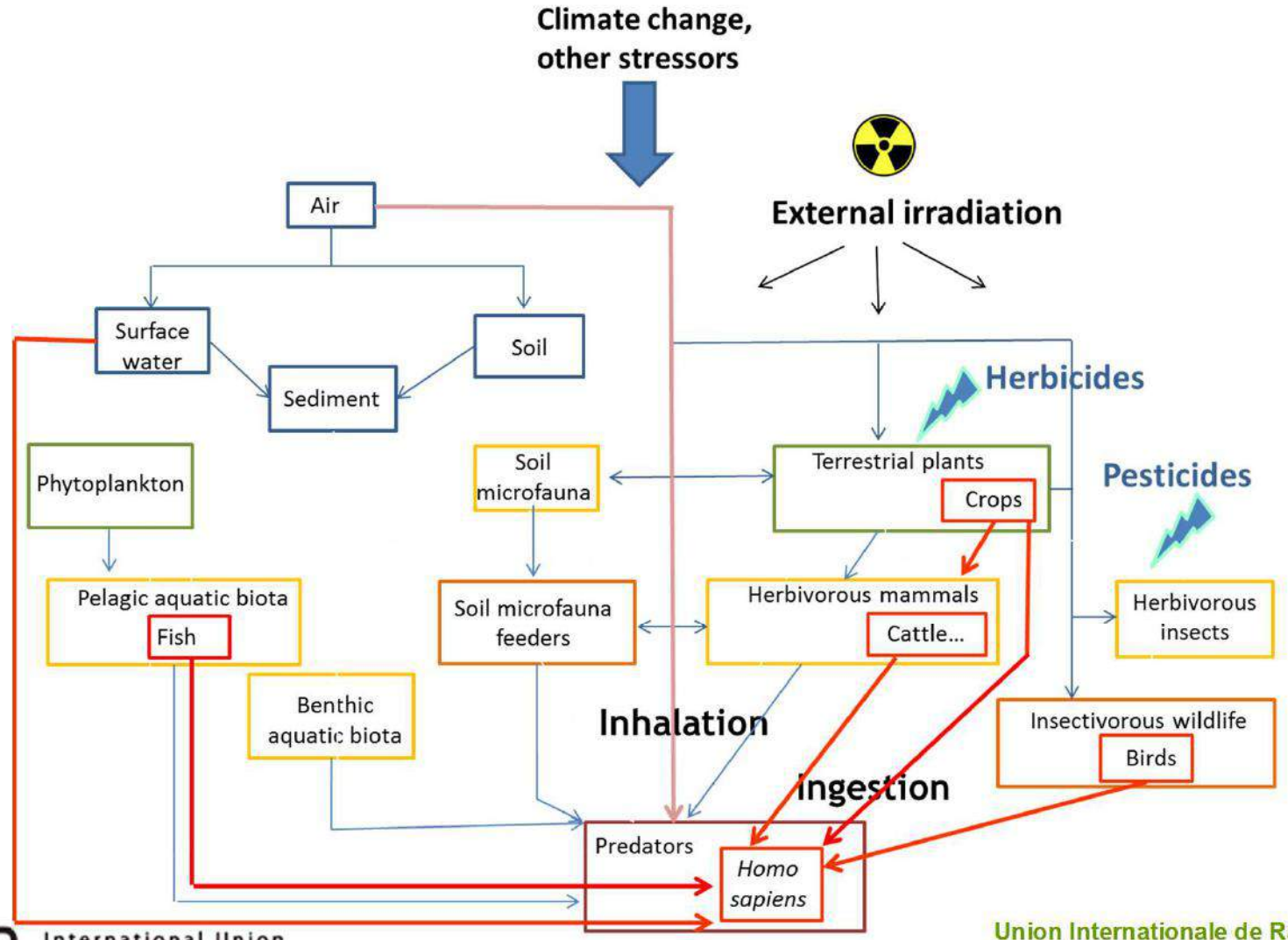
Need for an integrated conceptual model to start with

An « ecosystem approach » provides a fully integrated conceptual model

- Addressing populations and ecosystems (instead of organisms)
- Featuring man as part of the environment
- Including interactions between species (the missing link)

Radioecology is best legitimate to develop an integrated framework for human and environmental risk assessment of radiation

Man is part of the environment, one among many species interacting in the ecosystem



Uncertainties jeopardizing predictions

Uncertainties arise from:

- Knowledge gaps
- Variability (spatial and temporal)
- Poor (too much simplified) conceptual models
- Extrapolations (especially in risk assessments)
- Non-verified assumptions

From Salbu et al., JER (2016)

High-level priorities for the future

More on dynamics -> transfer processes, populations and ecosystem attributes

Systemic vision -> effects on populations, mixtures of contaminants, trans-generational impacts, ecosystem approaches…

Inference strategies -> Better integration of the continuum hypothesis-lab-field-model

Better integrated multidisciplinarity

Feeding radioecology with radiobiology and ecology

- Influence of radiation type
- Internal/external radiation
- Radiosensitivity

Radioecology ⟷ Radiobiology

- Ecosystem approach
- Laboratory microcosms
- In situ experiments
- Low dose rates/accumulated doses

Radioecology ⟷ Ecology