Using ecosystem science to improve protection of the environment from radiation

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IUR report 3 (2002)

IUR report 7 (2012)

and other papers..

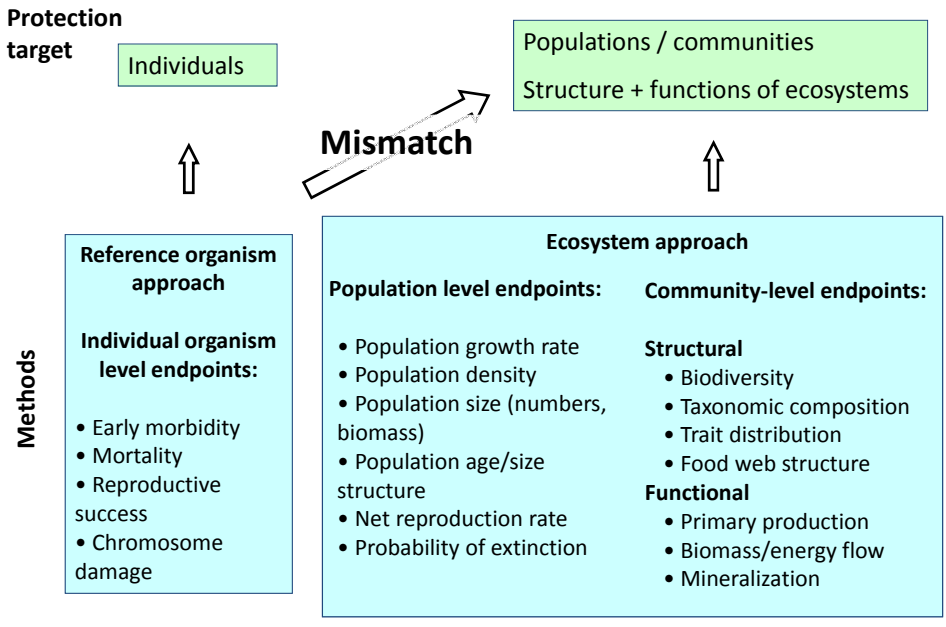
JER (2014) 136: 98-104

Stated protection aim

ICRP 103 (2007):
…to have negligible impact on
- maintenance of biological diversity,
- conservation of species,
- health and status of natural habitats, communities and ecosystems

IAEA BSS (2014) (GSR Part 3):
Protection of the environment includes the protection and conservation of:
- non-human species…and their biodiversity;
- environmental goods and services…;
- natural processes such as carbon, nitrogen and water cycles.

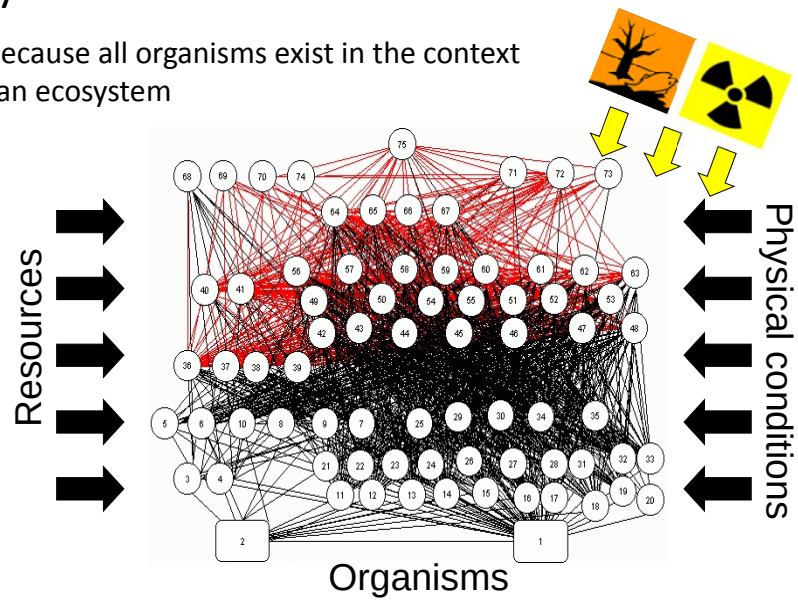
But is this really what we measure/assess?



(the approaches are complementary)

Why is there a mismatch?

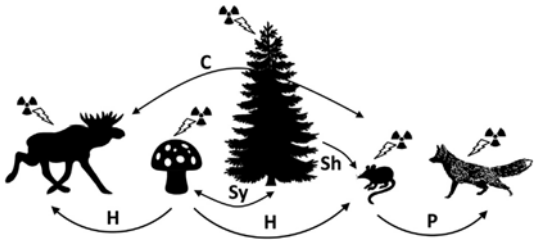
…because all organisms exist in the context of an ecosystem



NW Atlantic Shelf Ecosystem adapted from Link et al (2002)

Why focus on ecosystems instead of individuals or species?

- Because in reality individuals or single species do not exist in isolation
  - 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

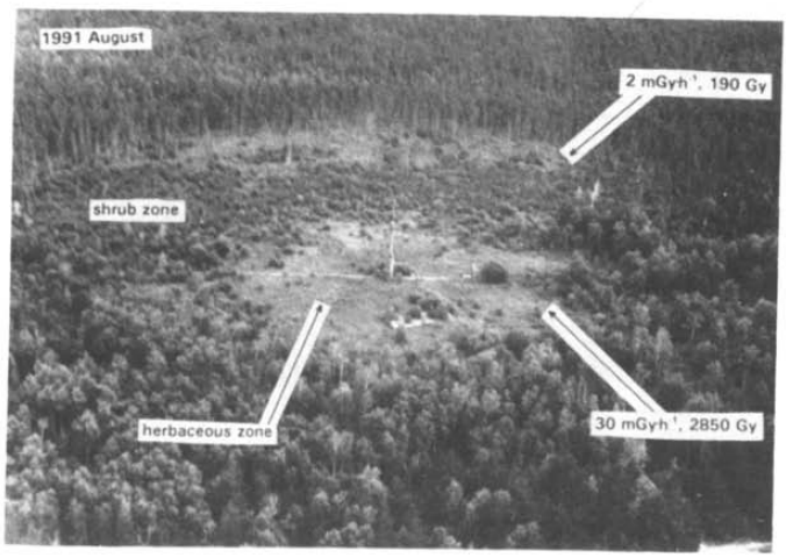
Why do individual (organism/species)-based frameworks not address ecosystems?

- Interactions between species and indirect effects not considered
- non-linear responses, emergent properties, resilience, etc

→

- effect at ecosystem level cannot be predicted/extrapolated from effects on individual species
- may over- or under-estimate effects / risk

Evidence for ecosystem effects from the field



14y chronic gamma irradiation of boreal forest, Canada
Amiro and Sheppard (1994)

Acute (8 day) high dose exposure, South Urals area – mixed pine and birch

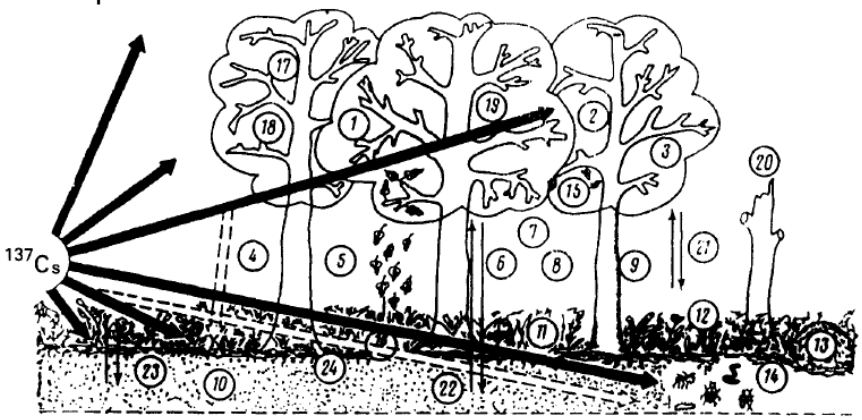
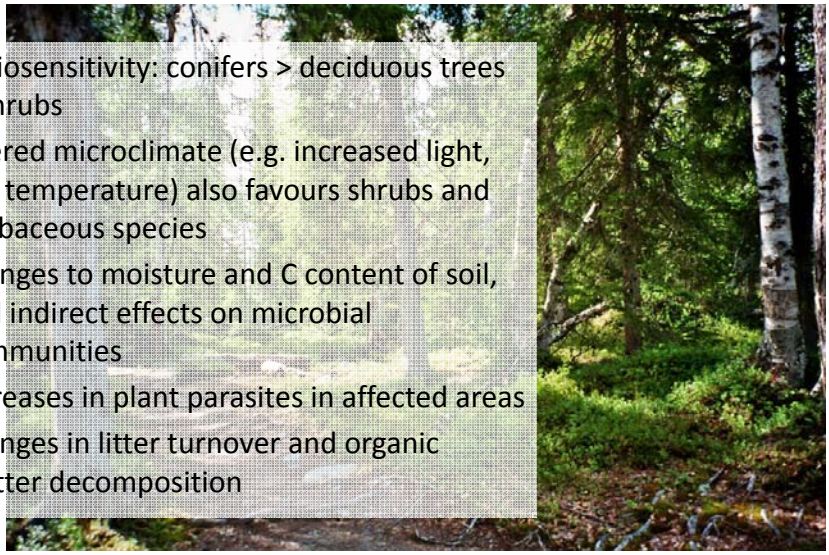


Fig. 2. General scheme illustrating major primary and secondary radiation reactions in the forest biogeocenosis. **1**, phenology; **2**, growth of the tip and side branches; **3**, leaf fall; **4**, precipitation; **5**, wind speed; **6**, temperature; **7**, light under canopy; **8**, humidity; **9**, annual wood ring; **10**, soil temperature; **11**, biomass and yield of grass seeds; **12**, structure and phenology of grass cover; **13**, ants; **14**, meso- and microfauna of soils; **15**, insects in canopy; **16**, forest litter; **17**, yield and quality of tree seeds; **18**, cytogenetic properties of buds and pollen; **19**, biomass of above ground parts of plants; **20**, damage and death of trees; **21**, tree and herb relations; **22**, tree and soil relations; **23**, grass and soil relations; **24**, yield and quantity of seeds in litter.

Alexakhin et al. (1994) Science of the Total Environment 157: 357-369

Ecosystem effects in forest field studies



- radiosensitivity: conifers > deciduous trees > shrubs
- altered microclimate (e.g. increased light, soil temperature) also favours shrubs and herbaceous species
- changes to moisture and C content of soil, and indirect effects on microbial communities
- increases in plant parasites in affected areas
- changes in litter turnover and organic matter decomposition

(note – external doses only)

What is the Ecosystem Approach?

- Scientific approach
  - with ecosystem as the central conceptual unit
- Management/risk assessment:
  - "management of human activities, based on the best understanding of ecological interactions and processes, so as to ensure that ecosystem structure and functions are sustained for the benefit of present and future generations"
    (IUR report 7)

How do other legislative frameworks address ecosystems?

- Convention on Biological Diversity (CBD)
- Marine examples
  - OSPAR
  - Ecosystem Approach to Fisheries (FAO)
  - EU Marine Strategy Framework Directive
- EU Water Framework Directive
- EU Habitats Directive
- Ramsar Convention on Coastal Wetlands
- Canadian Environmental Protection Act
- …etc…

(See IUR report 7 for a full summary)

EU Marine Strategy Framework Directive (MSFD) (2008, 2010)

- *"to protect more effectively the marine environment across Europe" … "to achieve good environmental status of the EU's marine waters … to protect the resource base upon which marine-related economic and social activities depend"*
- *"applies an integrated approach to ecosystems and strives to contain the collective pressure of human activities within sustainable levels".*

"overall state of the environment…taking into account the **structure, function and processes** of … marine ecosystems together with the natural physiographic, geographic, biological, geological and climatic factors, as well as physical, acoustic and chemical conditions, including those resulting from human activities inside or outside the area concerned"
Good environmental status should "allow those ecosystems to function fully and to maintain their resilience to human-induced environmental change".

MSFD specifically outlines criteria necessary to achieve good environmental status, including 11 qualitative descriptors needed to determine them:

1) **Biological diversity** is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions

6) Sea-floor integrity is at a level that ensures that the **structure and functions of the ecosystems** are safeguarded …

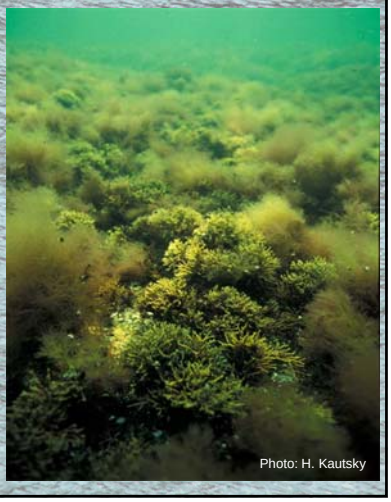


Photo: H. Kautsky

Ecosystem approach

Advantages

- ✓ enables implicit consideration of the net effects of contamination, integrating all direct and indirect effects (multiple stressors/ contaminants, species interactions, different responses to different types of radiation, spatial and temporal issues and natural variation)
- ✓ consistent and compatible with the Ecosystem Services concept
- ✓ complements the reference organism concept by enhancing their ecological contextualisation
- ✓ consistent with most stated management objectives

Challenges

- ? lack of good experimental and field data to evaluate ecosystem-level effects
- ? multi-species dynamic models lacking
- ? ecosystem models require knowledge of many parameters that are not readily available
- ? modelling may need to explicitly consider ecosystem complexity and/or emergent properties
- ? ecological factors and variability can be more important than radiation effects – may need a different conceptual methodology?

Next steps for the IUR Task Group:

Develop practical methods for ERA in line with an Ecosystem Approach

- review studies of ecosystem-level effects of contaminants including radiation
- review models and tools from other fields of environmental protection that could be applicable to radiation protection
- review the field of ecosystem modelling and ecological network analysis to identify approaches suitable for accounting for and detecting systems level processes.
- select of a small suite of integrative endpoints to describe population-level, community-level and ecosystem-level effects, particularly those that complement organism-level based approaches
- theoretically explore, through modelling and analysis, the importance of species/population interactions, connectivity, biodiversity and differences in radiosensitivity between species for effects seen at the ecosystem-level.
- identify critical ecosystem configurations that might lead to greater susceptibility to radiological impacts at the ecosystem level than lower levels in the biological hierarchy

References

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