

AOP & ECOLOGICAL RADIATION PROTECTION – CHALLENGES & INSIGHTS

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CONTEXT – ECOLOGICAL RADIATION PROTECTION

■ Reference levels for ERA based on relationship exposures <-> effects

- **Several** (10 – 400 $\mu\text{Gy}/\text{h}^{1,2,4}$ + Derived Considered Reference Levels³)
- **Some limits:** amount of chronic data, umbrella individual endpoints (mortality, reproduction, morbidity), lab experiments, monospecies, monostressor, mainly γ
- **Some knowledge gaps** (e.g. species radiosensitivity¹, SSD field versus lab⁴)

¹ Garnier Laplace 2010, FASSET ² UNSCEAR, 2008 ³ ICRP Publication 108 2008, ⁴ Garnier-Laplace et al. 2013, ⁵ Schmeisser et al., 2023

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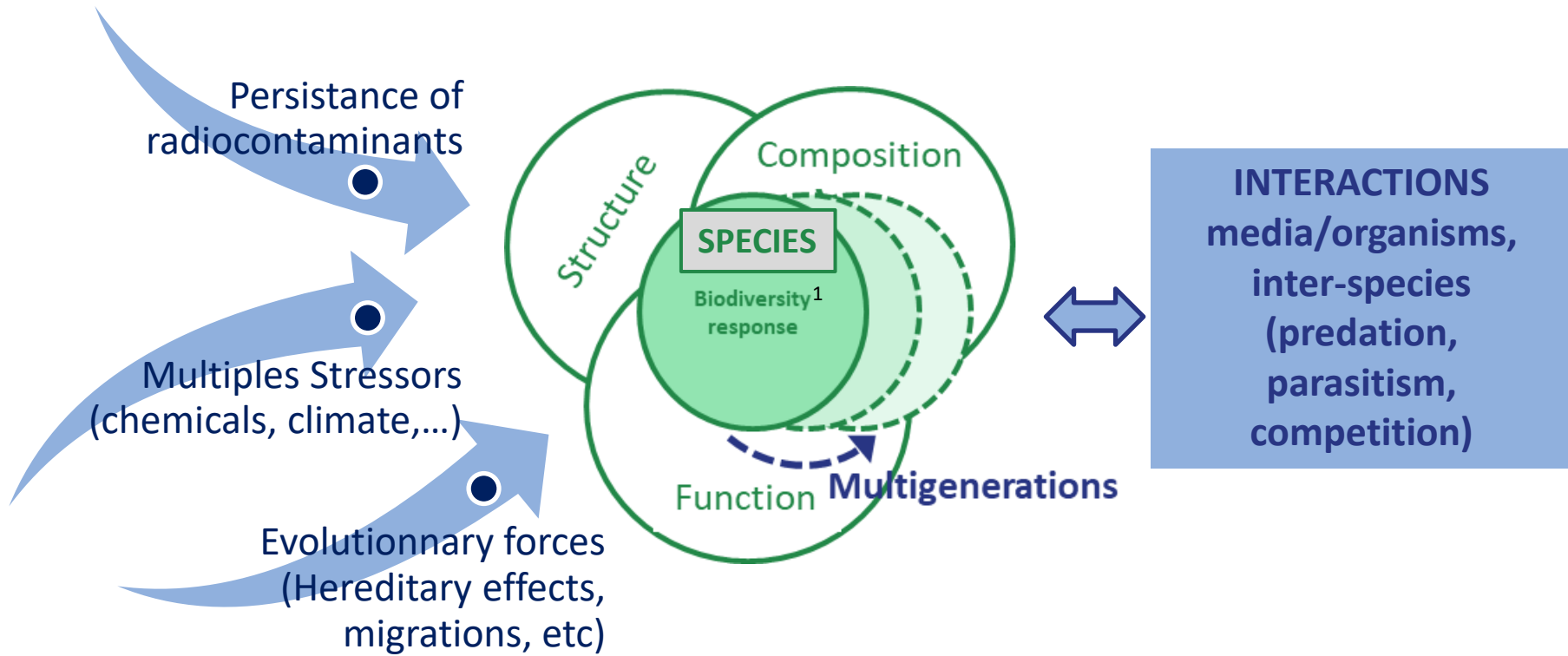
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Upcoming challenge identification

- To increase the number of data used in **regulatory assessments** (e.g. using New Approach Methodologies (NAMs)⁵, including molecular omics data)
- To bring **more realism** in data acquisition and considered endpoints

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CHALLENGES OF ECOLOGICAL RADIATION PROTECTION



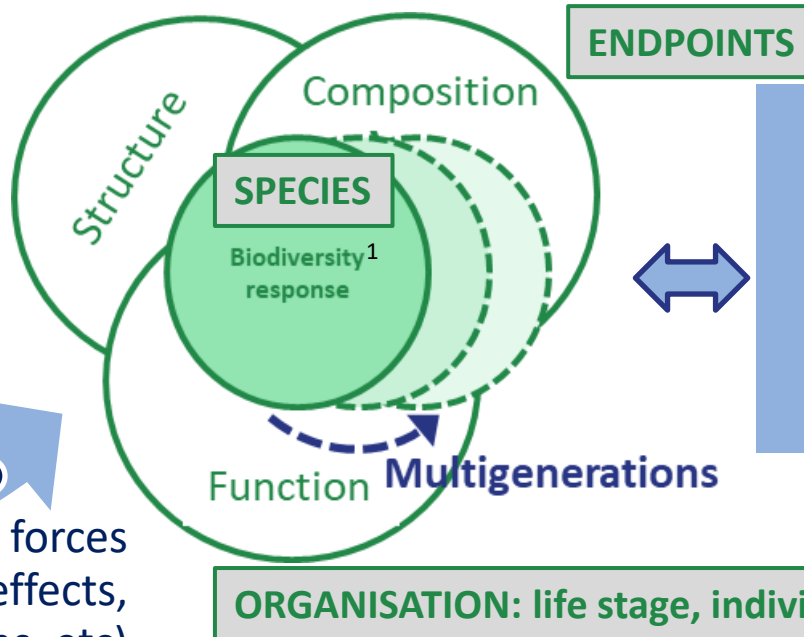
CHALLENGES OF ECOLOGICAL RADIATION PROTECTION

EXPOSURE : chronicity^{2,3}, long-term⁴, multi-stress

Persistence of radiocontaminants

Multiples Stressors (chemicals, climate,...)

Evolutionary forces (Hereditary effects, migrations, etc)



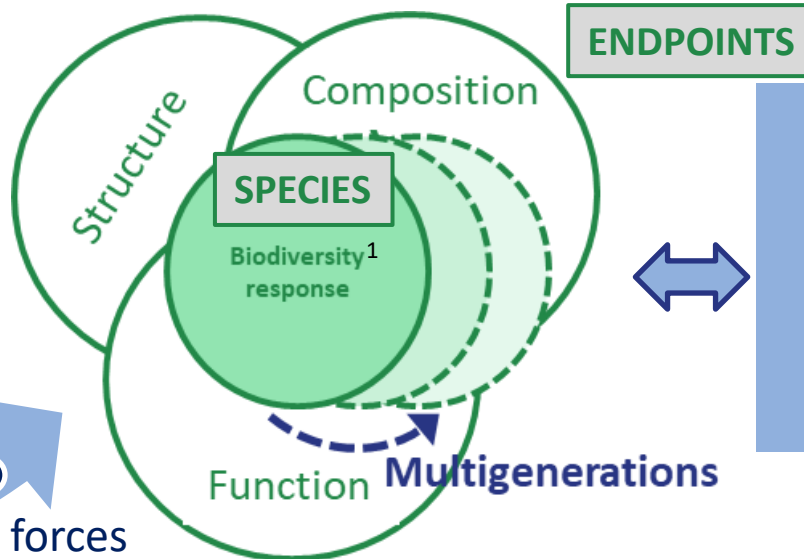
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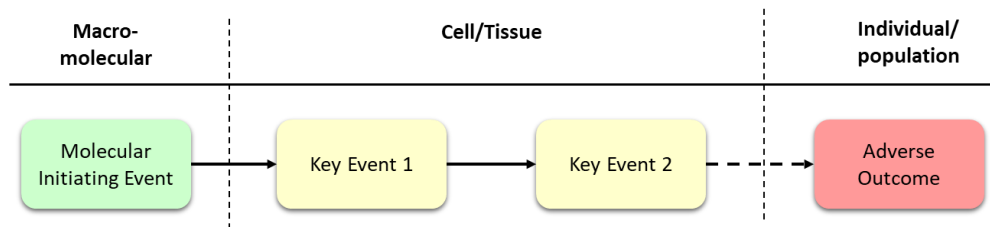


➔ **Investigation regarding the recent AOP framework**

THE ADVERSE OUTCOME PATHWAY (AOP) FRAMEWORK

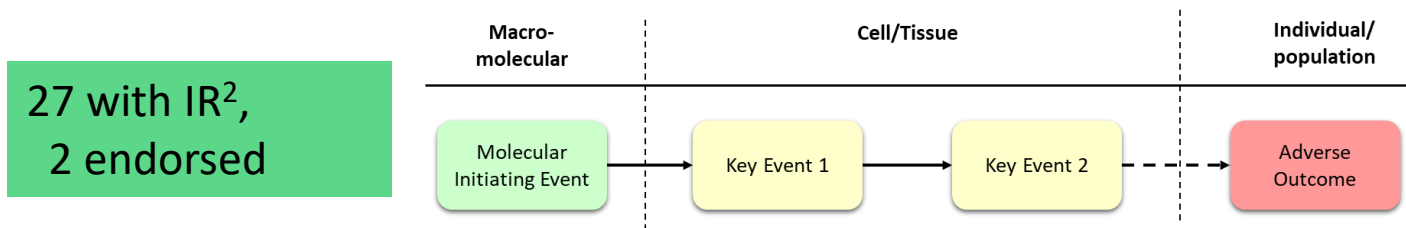
■ AOP¹ = Tool for data structuration: from an initiating event (MIE) to an adverse outcome (AO), mostly phenotypical (individual, population), used for ERA

27 with IR²,
2 endorsed



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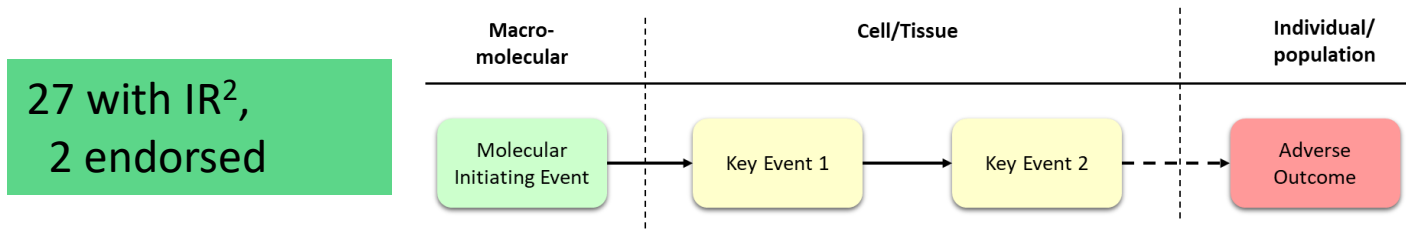


AOP framework enables:

- Linking different biological levels, with WoE assessment
 - Main steps leading to an Adverse Outcome and relative knowledge gaps
 - Possible use of molecular data
- Common tool between radiations and other stressors (AOP networks),
- Sharing common tool between researchers and regulators³

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ERA of IR



=> EXPOSURE / ENDPOINTS

SOME CHALLENGES OF AOP REGARDING ERA

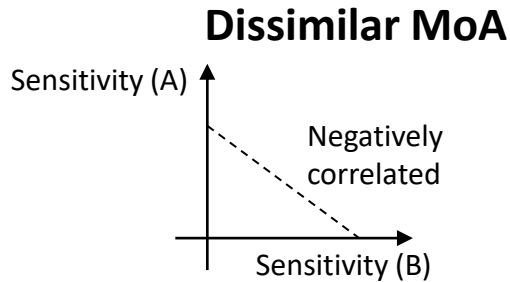
EXPOSURE: chronicity, long-term, multi-stressors

■ **Multi-stressors:** to rank stressors with their **modes of action (MoA)**

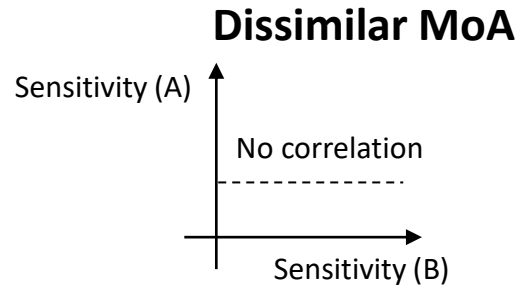
⇒ helps in prediction of interaction between stressors (additivity, synergism, antagonism¹⁻³)

⇒ **calculation of mixture assessment factor.**

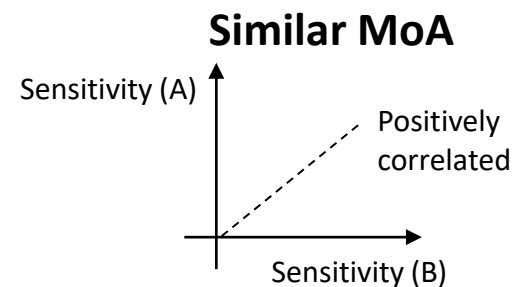
Adapted from Schafer and Pigott 2018¹



⇒ Simple Addition



⇒ Multiplicative

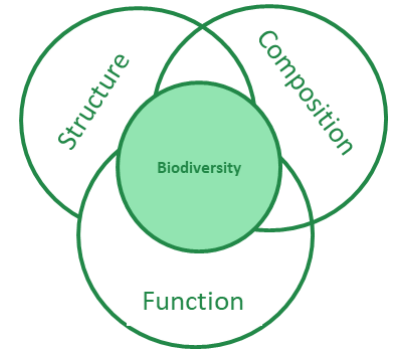


⇒ Dominance

SOME CHALLENGES OF AOP REGARDING ERA

ENDPOINT LEVEL:

- **Determination of KE / AO more ecologically relevant** i.e. in relation with the different biodiversity components (composition, structure and function (Noss et al, 1990))
- **From literature analysis of IR effects (16 papers, *in situ*)**
=> List of descriptors for relevant cascade of events leading to outcomes for ecosystems



DEFINITION OF ECOLOGICALLY RELEVANT DESCRIPTORS (KE, AO)

Type/Level of Organisation	Event	AOP wiki ID	Parameter analysed / Ref
KE/Population structure	Sex ratio, skewed	#417	Sex ratio measurement over population exposed ¹
„	Adaptive potential, decrease		Affiliation rate, increase ²⁻³
KE/Population composition	Mutation rate, increase, Mutations, increase	#185	Population genetic inference (genetic diversity) ⁴⁻⁸
„	Nuclear Genetic diversity, decrease		Genetic markers (e.g., mitochondrial), SSRs, SNPs ²⁻³
AO/Population KE/Ecosystem	Population size, decrease / Population demography, decrease	#997	Standard counts (e.g., bird point counts, track analysis, motion activated camera traps, etc.) ^{5,9-13}
AO/Population KE/Ecosystem	Abundancy, decrease/increase		Modelling, Fruit tree numbering (indirect; pollinator and bird disturbance), Tracks analysis ⁹⁻¹³
AO/Ecosystem	Pollination, decrease		Indirect; pollinator disturbance ¹⁴⁻¹⁵
AO/Ecosystem structure	Organic matter cycling, increase/ decrease		Indirect; litter detritivore numbering ¹²⁻¹³
AO/Ecosystem composition	Biodiversity richness decrease		<i>All previous parameters/upcoming eDNA methods</i>

¹Quevarec et al. 2022, ²Car et al. 2023, ³Shimalina et al. 2020, ⁴Baker et al., 2017, ⁵Car et al. 2022, ⁶Ellegren et al. 1997, ⁷Goodman et al. 2022, ⁸Møller & Mousseau 2015, ⁹Bonzom et al. 2016, ¹⁰Deryabina et al., 2015 ¹¹Moller & Mousseau 2007, ¹²Mousseau et al 2014, ¹³Møller et al 2012, ¹⁴Burrows et al 2022, ¹⁵Raines et al 2020, ¹⁶Sakauchi et al., 2021

CONCLUSIVE REMARKS

[STILL ONGOING WORK BUT...

AOP seems to be useful for:

- event cascade building and analysis,
- knowledge gap identification
- hazard identification,

Difficulties:

- to go beyond the population to predict a risk
- limited by lack of knowledge

Long-term investigation

Developing Adverse Outcome Pathways to support Radioecological Risk Assessment: Challenges and Insights

Dufourcq-Sekatcheff, E. ^{†*1}, Quevarec, L.¹, Delignette-Muller, M.-O., Car, C.¹, Bonzom, J.-M.¹, Gilbin, R., Tollefsen, K-E.^{3,4}, Armant, O.^{†*1}, Frelon, S. ^{**}

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