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► To cite this version:

B. Charrasse, Amanda Anderson, Juan C. Mora, Justin Smith, Emilie Cohenny, et al.. Investigation of the importance of site-specific fauna in environmental risk assessment for routine atmospheric radionuclides releases. Modelling and Data for Radiological Impact Assessments - IAEA, Oct 2018, Vienne, Austria. cea-02339469

HAL Id: cea-02339469

<https://cea.hal.science/cea-02339469>

Submitted on 27 Nov 2019

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DE LA RECHERCHE À L'INDUSTRIE



INVESTIGATION OF THE IMPORTANCE OF SITE-SPECIFIC FAUNA IN **ENVIRONMENTAL RISK ASSESSMENT FOR ROUTINE ATMOSPHERIC RADIONUCLIDES RELEASES**

Sent to Sci.Tot.Env. – summer 2018

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In all the cases, methodologies for determining the potential impact of radiation to wildlife involves several key steps:

- (1) identification and characterization of potentially affected ecosystems and wildlife species of interest;
- (2) assignment of geometries and occupancy factors within environmental media for the species of interest;
- (3) determination of the transfer of radionuclides to biota from their surrounding medium;
- (4) calculation of the absorbed dose rate for both internal and external exposure;
- (5) evaluation of effects on species and the ecosystem using dose-effects relationships.

In all the cases, methodologies for determining the potential impact of radiation to wildlife involves several key steps:

- (1) identification and characterization of potentially affected ecosystems and wildlife species of interest;
- (2) assignment of geometries and occupancy factors within environmental media for the species of interest;

Reference Organisms (ROs) (FASSET)

Reference Animal and Plant (RAPs) (ICPR)

Organisms by media (RESRAD-BIOTA)

...

Several entities (with different form / different number)



A major challenge in environmental radiological protection due to the immense variability in and within species (Penthreat and Woolead, 2001)

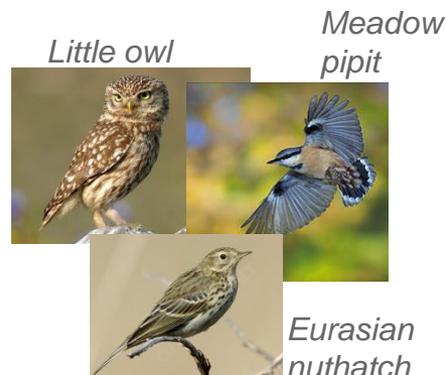
Risk assessments of ionising radiation impact to wildlife is mainly conducted using



the default ROs or RAPs (Batlle et al., 2011; Brown et al., 2016; Carolan et al., 2011; Kautsky et al., 2016; Lavrentyeva et al., 2016; Robinson et al., 2010; Shishkina et al., 2016; Smith et al., 2010; Vandenhove et al., 2013, Stark et al., 2017)

Are the ROs / RAPs representative of the diversity of flora and fauna?

Does the use of ROs / RAPs in a risk assessment really protect* all species in the different target ecosystems in terms of dosimetry?



*Dose rate point of view

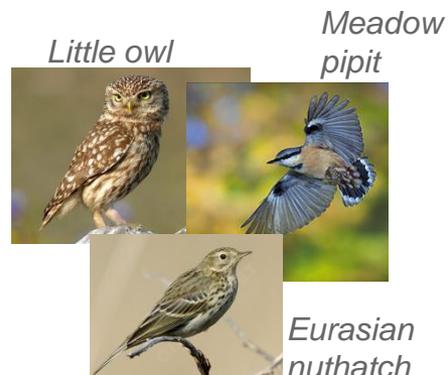
Risk assessments of ionising radiation impact to wildlife is mainly conducted using



identified species relevant to the study site

(Batlle et al., 2016; Jaeschke, B et al., 2013; Posiva, 2014; Torudd and Saetre, 2013, Stark et al., 2017)

Does the creation of new organisms within the methodologies increase the relevancy of the analysis?

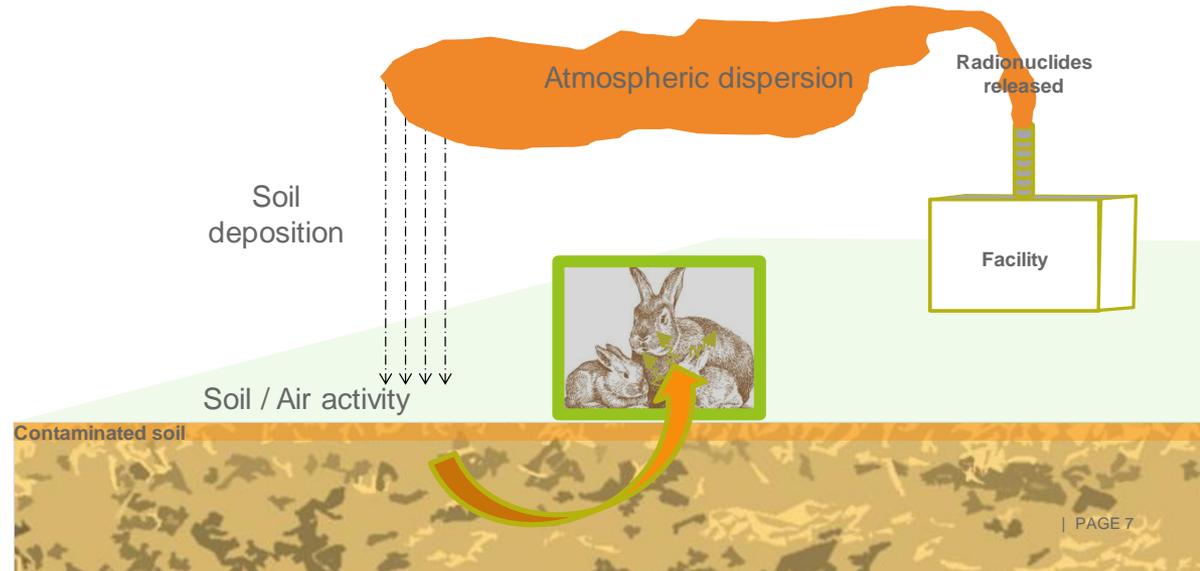


GENERIC approach (simplified and conservative not realistic)

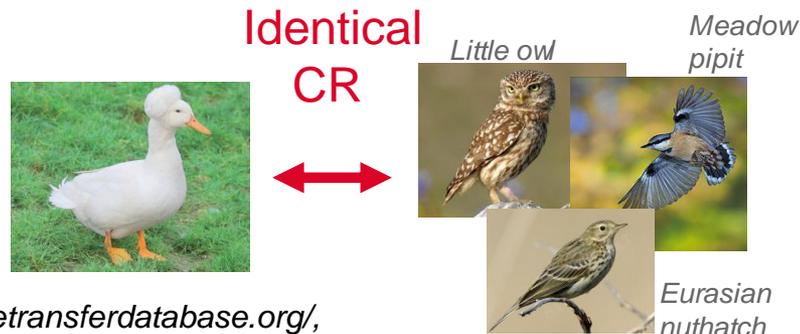
Activity concentration in the media (max or average)

Concentration ratio*

Concentration into organism



In case of endangered/protected species or not well characterized species, a major assumptions is made :



*ICRP, 2008; 2009; WTD; www.wildlifetransferdatabase.org/, Copplestone et al., 2013, Beresford et al, 2016

FEW CLARIFICATIONS

GENERIC approach (simplified and conservative)

Activity concentration in the media (max or average)

Concentration ratio

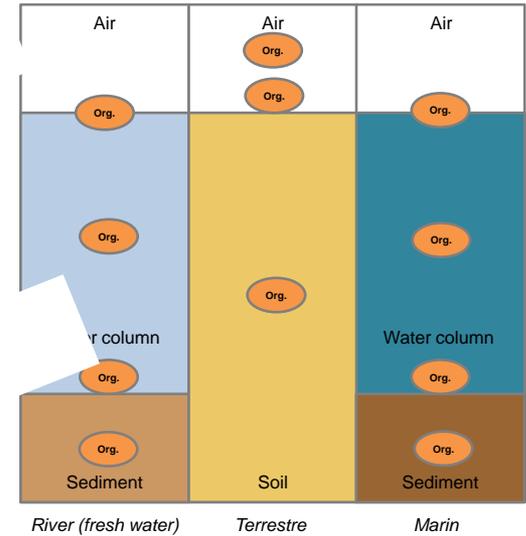
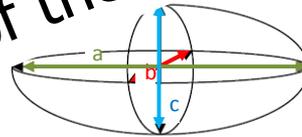
Concentration in organism

Dose coefficient (int/ext)

Dose rate

ABOVE ALL : Diversity of the size and shape of the ellipsoid ...

AND Diversity of habitats



Geometric shape → Spherical, ellipsoidal (prolate/oblate)

Mass → elementary composition (density fixed at 1.0 g cm^{-3})

Habitat → On soil, in soil, on air + position in the different media and occupancy factor

PART 1. SPECIFIC CASE STUDY

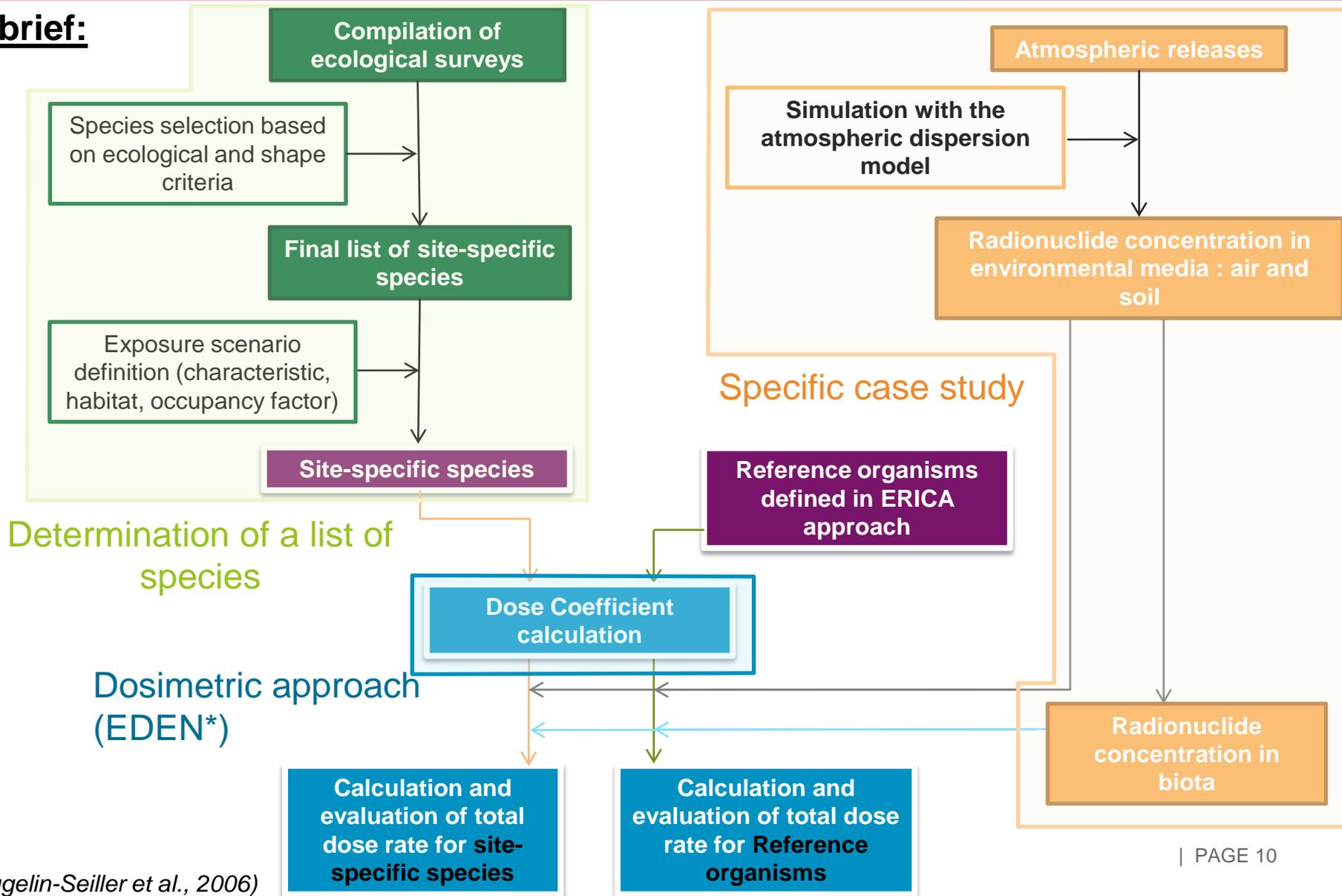
**PART 2. IMPLICATIONS FOR
ENVIRONMENTAL RISK ASSESSMENTS**

PART 1. SPECIFIC CASE STUDY

**PART 2. IMPLICATIONS FOR
ENVIRONMENTAL RISK ASSESSMENTS**

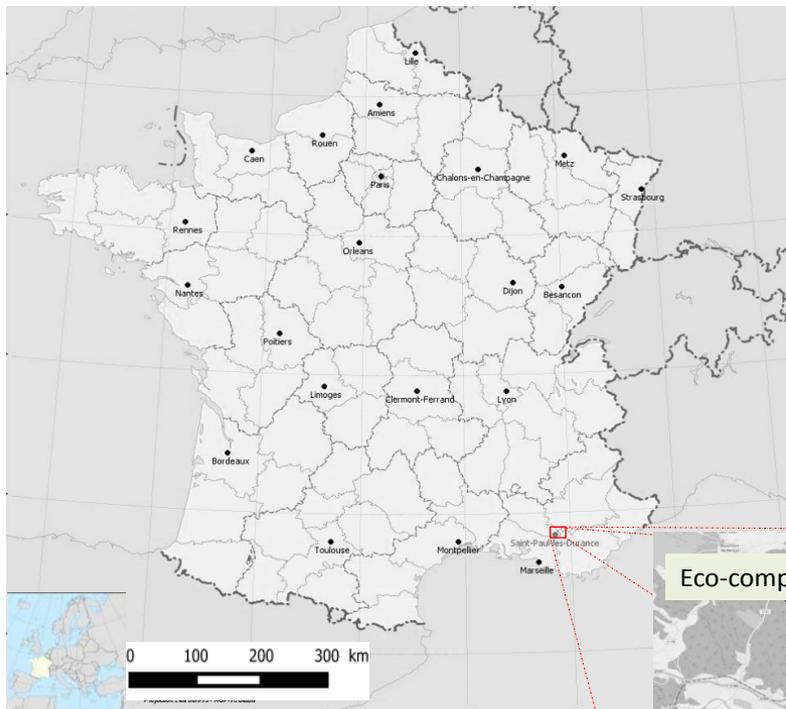
CONCEPTUAL FLOWCHART OF THE METHODOLOGY

In brief:

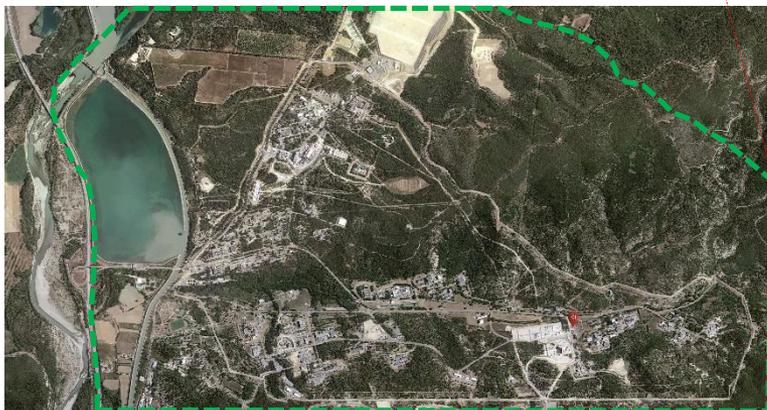
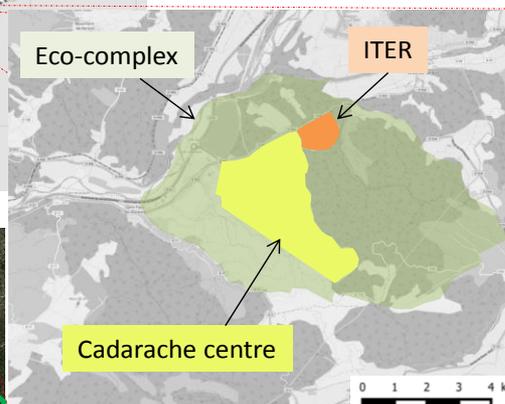


*(Beaugelin-Seiller et al., 2006)

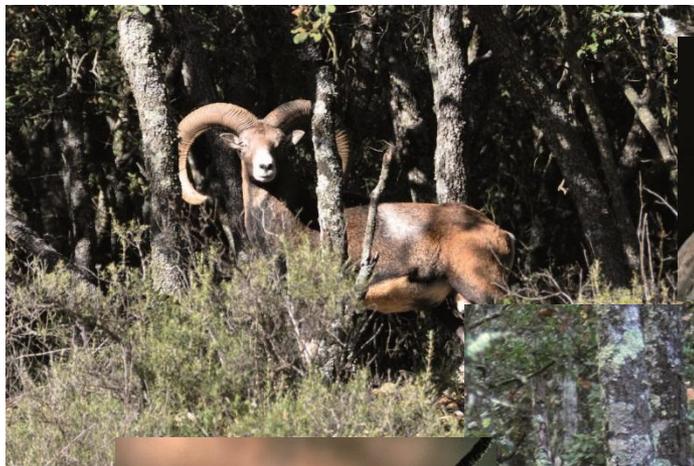
DETERMINATION OF A LIST OF SPECIES



- more than 1,600 hectares
- the vast majority of which are wooded areas, dry grass, or Mediterranean scrub
- the remainder of the property consists of urbanized areas, including large areas of maintained lawns and cleared lands

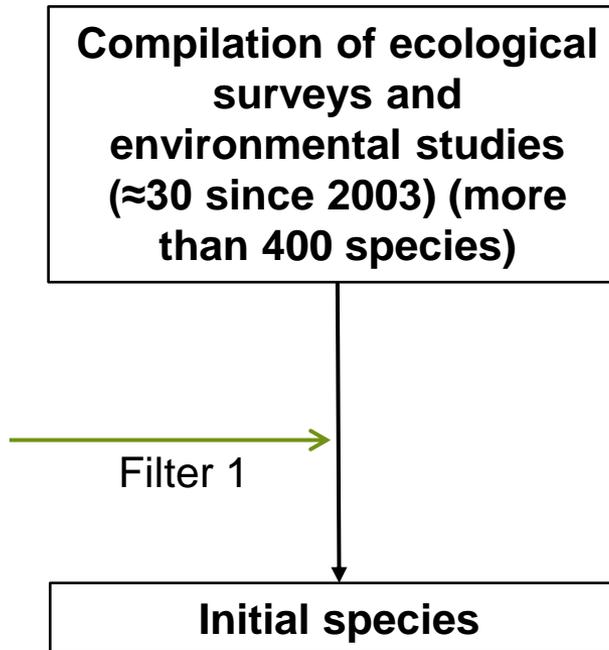


DETERMINATION OF A LIST OF SPECIES

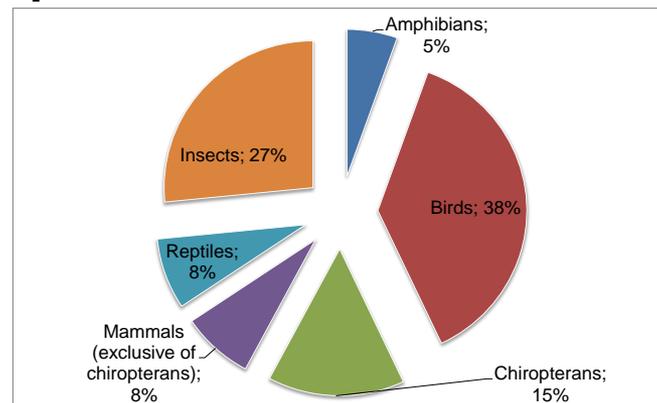


DETERMINATION OF A LIST OF SPECIES

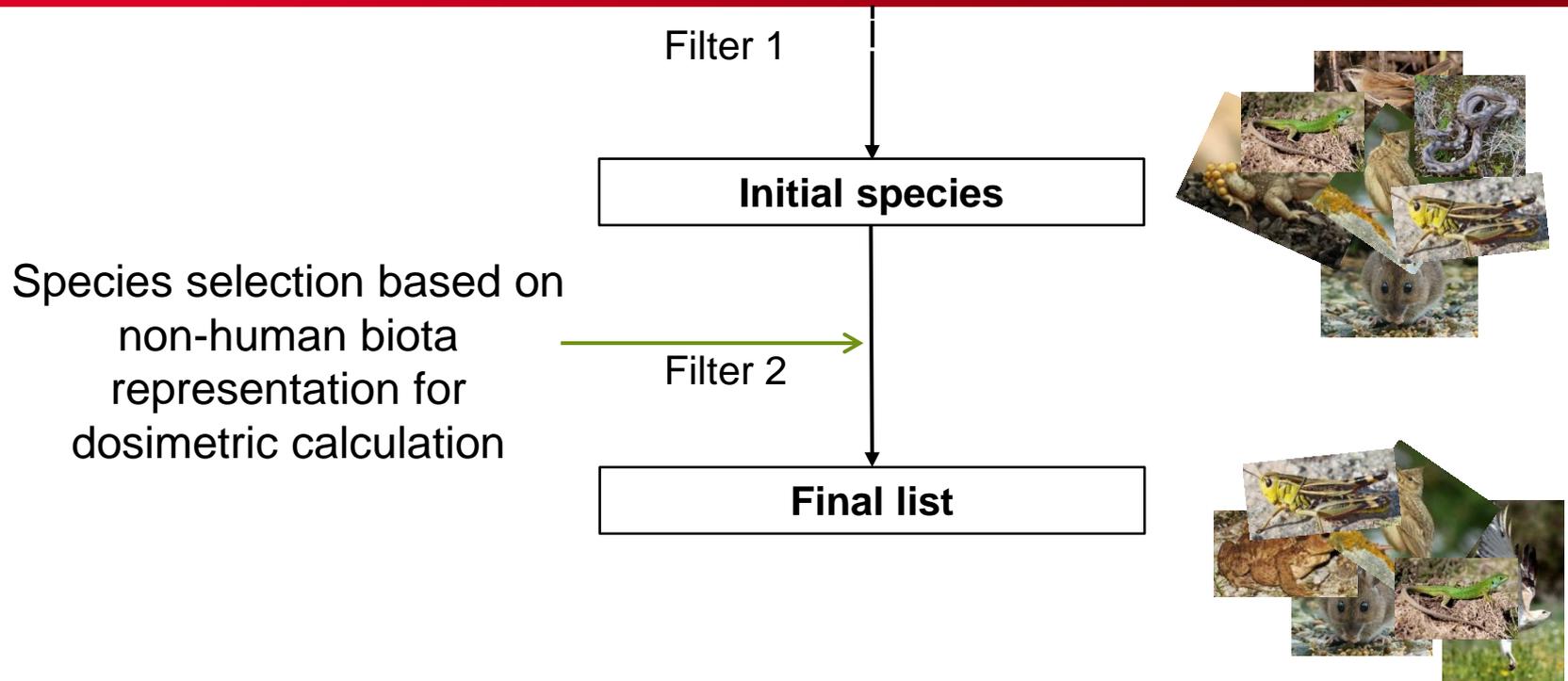
Species selection based on ecological stakes : listed on the conservation of natural habitats and of wild fauna and flora / on the red lists, on the protected species in France...



□ From the first filter → 128 species remained



DETERMINATION OF A LIST OF SPECIES



□ The second filter:

- Species with geometrical characteristics relatively different from the geometrical characteristics of the ROs;
- Species with different lifestyles from the ROs, specifically their position and frequency in their habitats

DETERMINATION OF A LIST OF SPECIES

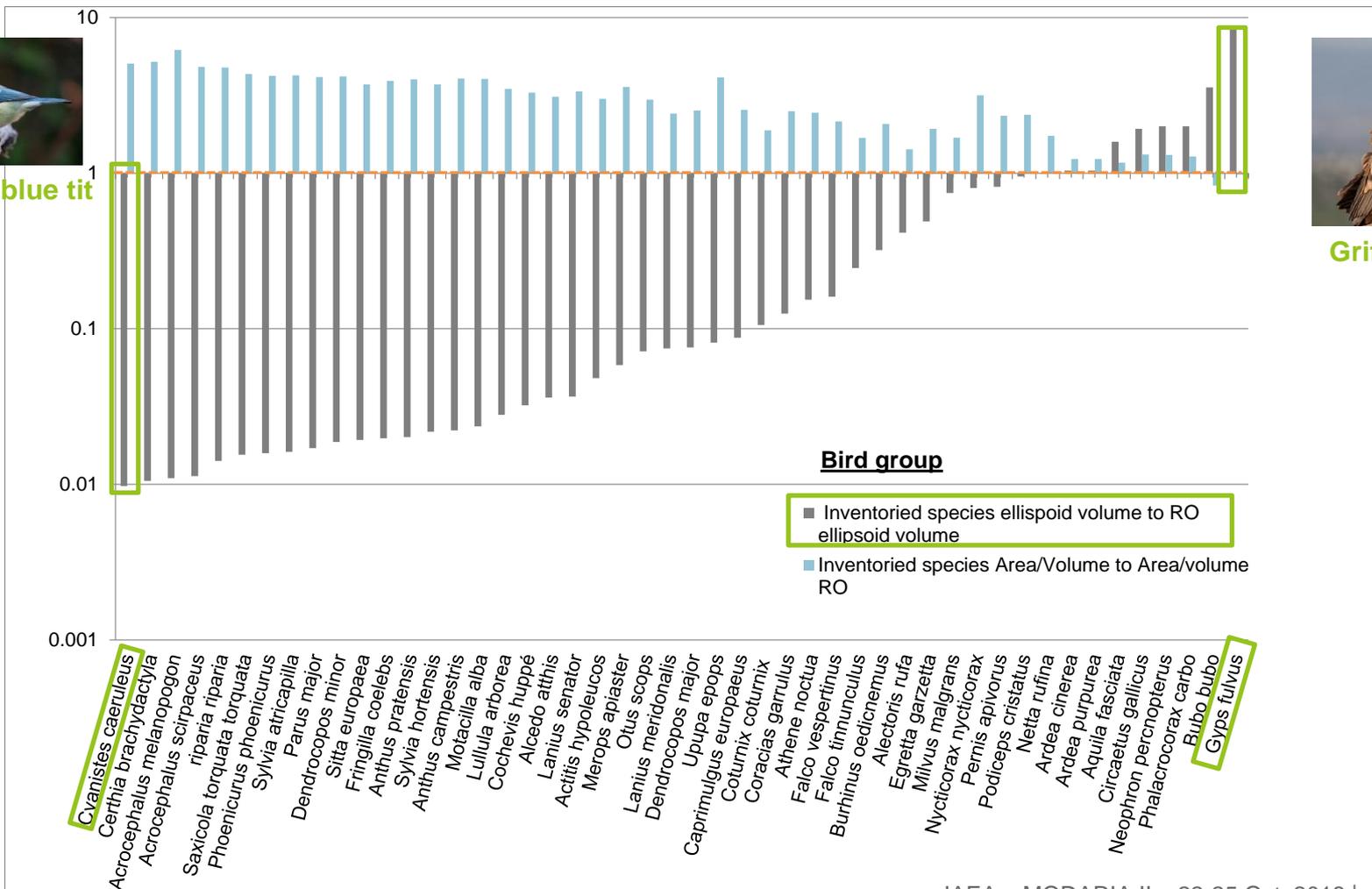
→ An example of species selection (case of bird) :



Eurasian blue tit

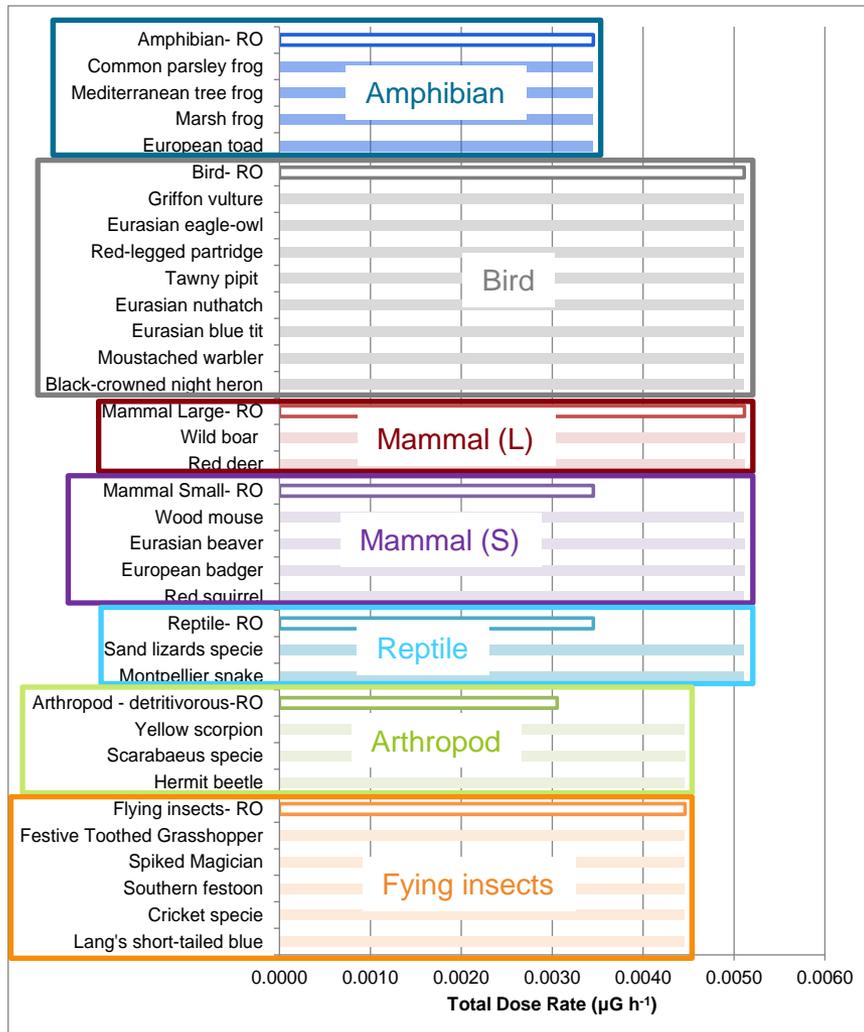


Griffon vulture



RESULTS : DOSE RATE CALCULATION

→ 28 species finally selected



→ **intra-** species DR_{tot} difference range from 0.1 % to 48 %



Difference less than a factor of 2



Considered as marginal by comparison with significant uncertainties associated with the transfer models

Despite the range of geometric characteristics, habits and habitats of the site-specific species and ROs



Do not improve the numerical risk assessment quality for any selected biota in this release scenario

CONCLUSION (PART 1)

- ❑ Are the ROs / RAPs representative of the diversity of flora and fauna?

In term of habitat and size → No BUT the aim of the ERA is to be conservative and not necessarily realistic

- ❑ Does the use of ROs / RAPs in a risk assessment really protect* all species in the different target ecosystems in terms of dosimetry?

For this specific case study → DR within a factor of 2 (between site-specific organisms and ROs)

- ❑ Does the creation of new organisms within the methodologies increase the relevancy of the analysis?

Not necessarily in this case, BUT what about for other cases



*Dose rate point of view

Extending to other release facilities

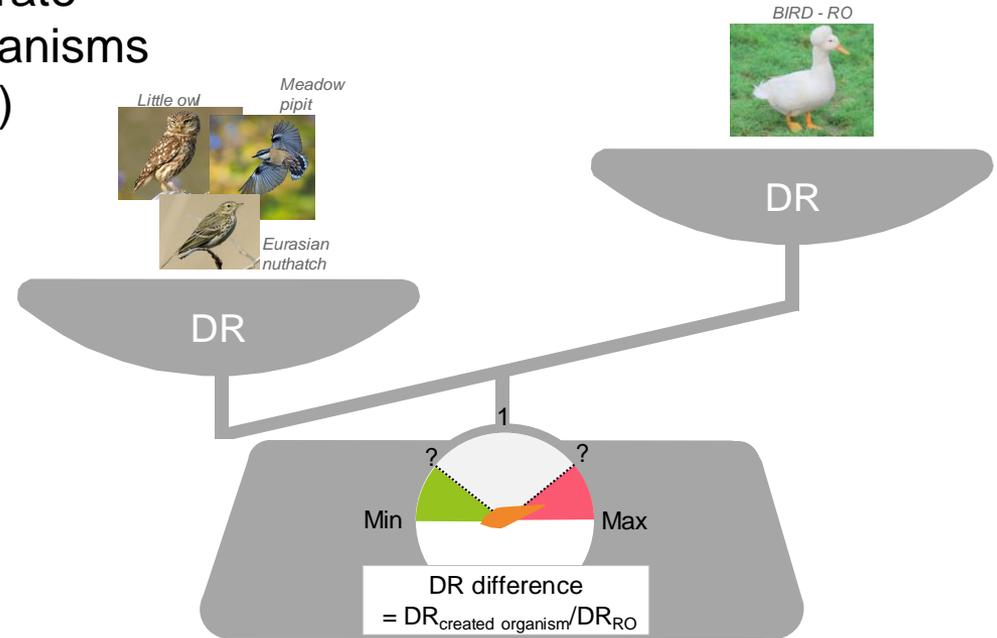
PART 1. SPECIFIC CASE STUDY

**PART 2. IMPLICATIONS FOR
ENVIRONMENTAL RISK ASSESSMENTS**

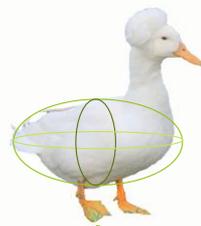
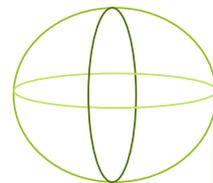
EXTENDING TO OTHER RELEASE FACILITIES

→ Estimation of the maximal dose rate difference between hypothetical organisms and ROs (assumptions from ERICA) released (**routine** atmospheric radionuclides releases)

- Creation of fictitious organisms with extreme dosimetric characteristics (masses, shapes and habitats)



Spherical bodies = conservative for external exposure to gamma-radiation (Ulanovsky, A., 2014)



Max. mass



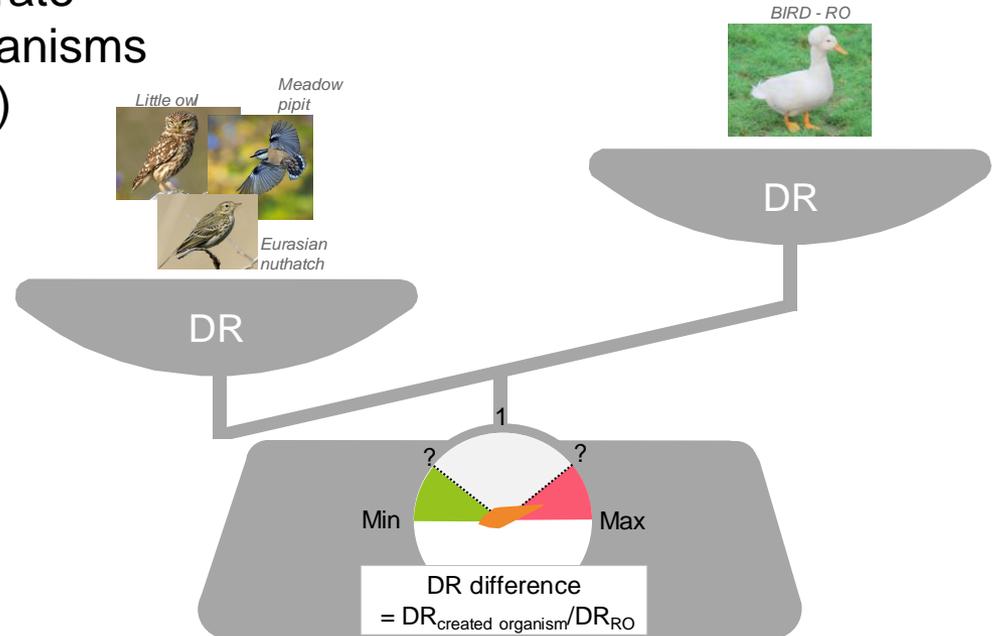
Mass, shape and habitat of the RO



EXTENDING TO OTHER RELEASE FACILITIES

→ Estimation of the maximal dose rate difference between hypothetical organisms and ROs (assumptions from ERICA) released (**routine** atmospheric radionuclides releases)

- Creation of fictitious organisms with extreme dosimetric characteristics (masses, shapes and habitats)
- Source term : 81 radionuclides (except nobles gases)



Ag-110m	Cr-51	La-140	Pu-240	Te-132
Am-241	Cs-134	Mn-54	Pu-241	Th-227
Ba-137m	Cs-135	Nb-94	Pu-242	Th-228
Ba-140	Cs-136	Nb-95	Ra-226	Th-230
C-14	Cs-137	Ni-59	Ra-228	Th-231
Ca-45	Cs-138	Ni-63	Ru-103	Th-232
Cd-109	Eu-152	Np-237	Ru-106	Th-234
Ce-141	Eu-154	P-32	S-35	U-234

Ce-144	H-3	P-33	Sb-124	U-235
Cf-252	I-125	Pa-231	Sb-125	U-236
Cl-36	I-129	Pa-234	Se-75	U-238
Cm-242	I-131	Pa-234m	Se-79	Zn-65
Cm-243	I-132	Pb-210	Sr-89	Zr-95
Cm-244	I-133	Po-210	Sr-90	
Co-57	I-134	Pr-144	Tc-99	
Co-58	I-135	Pu-238	Te-123m	
Co-60	Ir-192	Pu-239	Te-129m	

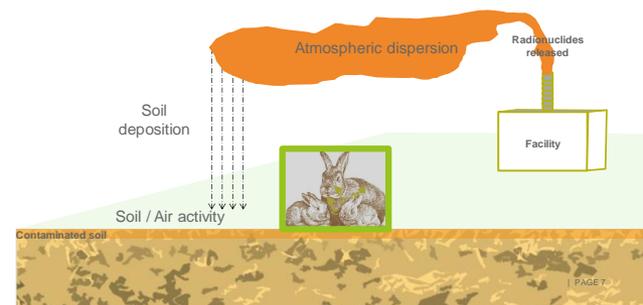
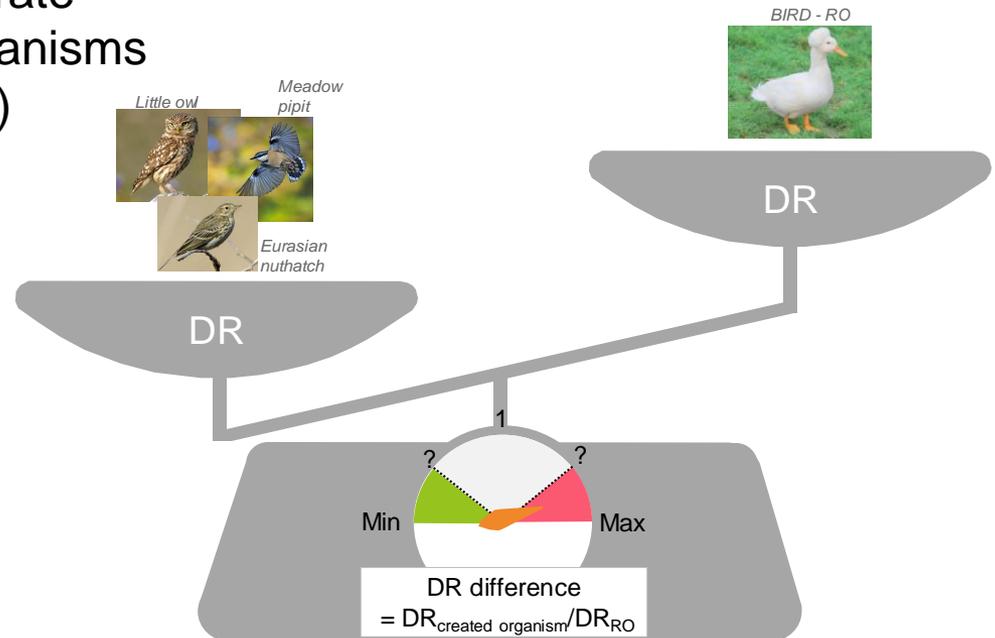
EXTENDING TO OTHER RELEASE FACILITIES

→ Estimation of the maximal dose rate difference between hypothetical organisms and ROs (assumptions from ERICA) released (**routine** atmospheric radionuclides releases)

- Creation of fictitious organisms with extreme dosimetric characteristics (masses, shapes and habitats)
- Source term : 81 radionuclides (except nobles gases)
- DR for created organism (fictitious) and ROs

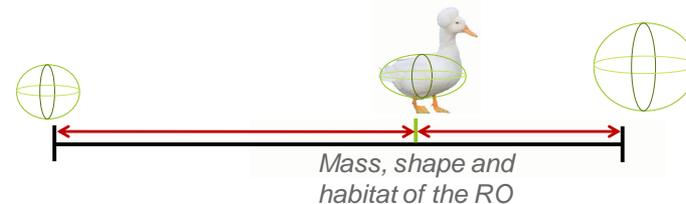
→ $1 \text{ Bq}\cdot\text{m}^{-3} / 1 \text{ Bq}\cdot\text{kg}^{-1} \text{ dw}$

→ ERICA tool



Estimation of the maximal dose rate difference between hypothetical organisms and ROs (assumptions from ERICA)

$$DR = DR_{\text{int}} + DR_{\text{ext}}$$



Terrestrial fauna ROs	Created organism with a mass lower than the RO (minimal mass)		Created organism with a mass higher than the RO (maximal mass)	
	Maximal DR _{created} org. / DR _{RO}	Considered Rn	Maximal DR _{created} org. / DR _{RO}	Considered Rn
Flying insects	1.07	²⁴¹ Pu	1.50	⁹⁰ Sr
Mollusc - Gastropod	2.60	¹²⁴ Sb	2.93	⁶⁵ Zn
Mammal small	1.11	²³¹ Th	1.38	¹³⁴ Cs
Mammal large	1.40	²³¹ Th	1.09	⁶⁵ Zn
Bird	1.09	¹⁹² Ir	1.56	⁶⁵ Zn
Reptile	1.18	²³¹ Th	1.07	⁹⁰ Sr
Amphibian	1.04	²³⁴ Th	1.32	⁶⁵ Zn
Annelid	1.02	⁵⁴ Mn	1.60	⁷⁵ Se
Arthropod- detritivorous	1.05	⁸⁹ Sr	1.82	⁹⁰ Sr

- ❑ Does the use of ROs / RAPs in a risk assessment really protect all species in the different target ecosystems in terms of dosimetry?

Weak influence of the mass and the size (quantified) (Stark 2017, Publication 136 ICRP, 2016, Ulanovsky, 2014)

- ^3H and ^{14}C are classically the **main radiation contributors** (main activities released) to the total dose rate

GBq y ⁻¹	Chinon NPP - annual (France)	Spain	Spent fuel (FIN)	LILW (France)	Research center (France)	KOR (Not recommended)
^3H	2.12E+03	1.98E+02	2.50E+00	9.50E-2	5.43E+1	3.44E+04
^{133}Xe	1.15E+03	1.78E+03			7.02E+03	3.00E+04
^{14}C	6.10E+02		1.00E-02	3.60E-2	7.58E-01	2.70E+02
^{135}Xe	1.73E+02				3.69E+00	
^{41}Ar	1.36E+02					1.26E+03
^{85}Kr	2.94E+01		3.00E+01		1.14E+04	1.81E+05

- **Dose coefficients** for ^3H and ^{14}C are **size** and **shape independent**, whatever the radiation type (only internal contribution)

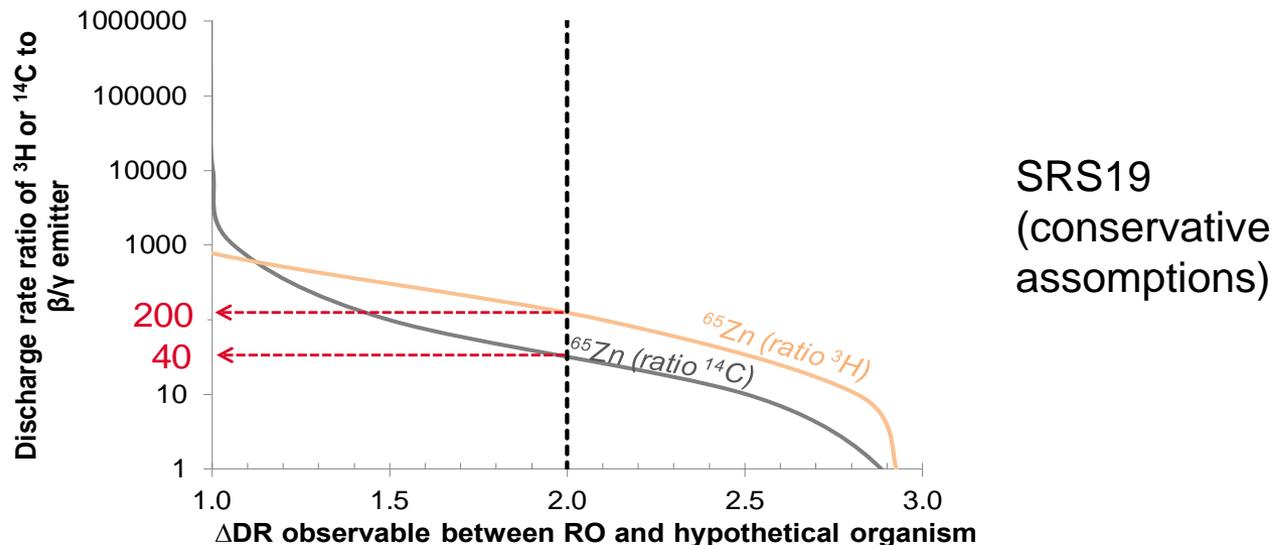


Higher the ^3H or ^{14}C contribute to the DR, smaller is the DR difference between the RO/RAP and a site-specific specie

CONCLUSIONS (PART 2)

- ❑ Does the use of ROs / RAPs in a risk assessment really protect all species in the different target ecosystems in terms of dosimetry?

Weak influence of the mass and the size (quantified) (Stark 2017, Publication 136 ICRP, 2016, Ulanovsky, 2014)



For the RO of "Mollusc- Gastropod", **generic organism is sufficient when the sum of the $\beta+\gamma$ emitters represent 1/40 of the ^{14}C OR 1/200 of the ^3H releases**

CONCLUSIONS (PART 2) AND PERSPECTIVES

- Does the use of ROs / RAPs in a risk assessment really protect* all species in the different target ecosystems in terms of dosimetry?

Weak influence of the mass and the size (quantified) (Stark 2017, Publication 136 ICRP, 2016, Ulanovsky, 2014)

- Does the creation of new organisms within the methodologies increase the relevancy of the analysis?

Not necessarily (in term of dose) but perhaps for communication strategy

Further works should be done to confirm those results

- Extending the mass ranges
- Consideration of all the exposure pathways (plume irradiation)
- Extending to a wider range of radionuclides (including noble gases)
- Evaluate the influence of the life stage/life span
- Modification of the CR value (predictive vision)
- Influence of deposition parameters

Applying this methodology to terrestrial flora (**Done**) and for aquatic organisms

THANK YOU FOR YOUR ATTENTION

AND

**A SPECIAL THANKS TO ALL
THE PARTICIPANTS FROM THE WG3
AND THE SCIENTIFIC SECRETARIES**