A radionuclide model for the main basins of the Baltic Sea – Identification of representative biota

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Background

- Evaluation of the exposures of plants and animals is an integral part of the international (ICRP) radiation protection system
- There are several models developed to simulate the radionuclide transport and radiological implications in the Baltic Sea
  - With varying resolutions and level of detail (*e.g.* Periáñez *et al.* 2015)
  - Some incorporate dynamic food web models (*e.g.* Maderich *et al.* 2018)
  - The availability and/or applicability of these models is rather limited
- EnviroCase is investing in the development of a *modern and flexible* radionuclide transport and exposure model of the main basins of the entire Baltic Sea, facilitating also probabilistic assessments and uncertainty/sensitivity analyses (Ikonen & Kangasniemi 2019)

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Purpose

- Assessing the implications of past, present and future releases of radioactivity in the scale of the main basins of the Baltic Sea
  - Both direct and indirect inputs (atmospheric deposition, runoff, aquatic discharges)
- Holistic assessments of radiation exposures of (the public and) the environment
  - Employing deterministic and probabilistic approaches
  - Including state-of-the-art sensitivity and uncertainty analyses
- Here, focus is on the identification of the representative plant and animal species for the actual sea areas of the Baltic Sea
  - Biota of the shoreline areas will be included in the overall model at a later stage

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Baltic Sea

- High degree of freshwater input and limited oceanic connection
  - Brackish water conditions
  - Distinct biota communities → high environmental protection values
- Sources of radioactivity (HELCOM 2018a)
  - Natural radioactivity (sea itself and from the catchment)
  - Radioactive fallout (Chernobyl, nuclear weapons tests)
  - Nuclear reactors in operation, under construction, planned, closed or under decommissioning
  - Other nuclear-cycle facilities (mining, fuel manufacturing, waste conditioning and disposal)
  - Research and medical facilities
  - Industry dealing with naturally occurring radioactive materials (NORM)
  - Past dumping of radioactive waste
  - Possible accidents with nuclear-powered vessels or nuclear waste transports

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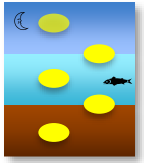
Methods

- In the dose rate calculations, the ICRP recommendations (ICRP 2014) will be followed, with practical guidance drawn from the ERICA assessment tool (Brown *et al.* 2016)
  - Reference Animals and Plants (RAPs) extended with supplementary set of *representative* organisms
- Selection criteria for these supplementary representative species:
  - **Common species**
  - **Food web importance** (*e.g.* Tomczak *et al.* 2012, Posiva 2013, HELCOM 2018b)
  - **Exposure potential**: highest plausible exposure of the species within its group due to its habits
    - Coverage of the main exposure configurations and their combinations (sediment, water, air)
    - To maximise the time of presence, the non-migratory species were favoured



  - Public and conservation interest
  - Information availability
- Expert judgement & lists of potential candidate species for the various selection criteria were used

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Results – part of the list

Organism type (trophic role in the food web)	Representative species for the Baltic Sea	ICRP RAP / ERICA Reference Organism	Selection criteria				
			Common species	Food-web importance	Exposure potential [a]	Public/conser-vation interest [b]	Information availability
Phytoplankton	– [c]	– / phytoplankton	x	x	W	–	??
Zooplankton	– [c]	– / zooplankton	x	x	W		??
Submerged macrophyte	Eelgrass	– / vascular plant	x	x	SsW	n	??
Emergent macrophyte	Common reed	– / vascular plant	x	x	SsWwA	–	?
Macroalga	Bladder wrack	Seaweed/macroalgae	x	x	sW	n	?
Detritivorous macrobenthos	*Marenzelleria* spp.	– / polychaete worm	x [d]	x	S	[d]	??
Filter-feeding macrobenthos	Baltic macoma	– / bivalve mollusc	x	x	S [e]		?
Scavenging macrobenthos	*Saduria entomon*	Crab / crustacean	x	x	s		?
Pelagic fish	Baltic herring	Trout / pelagic fish	x	x	W	+	?
Benthic fish	European perch	Flatfish / benthic fish	x	x	sW	+	?
Piscivorous fish	Cod	{Fish [f]}	x	x	sW	+ n	?
Bird feeding on plants	Mute swan	Duck / bird	x	x	wA	+	??
Bird feeding on macrobenth.	Common eider	Duck / bird	x	x	WwA	+ n	??
Bird feeding on fish	Herring gull	Duck / bird	x	x	wA	+	??
Bird, top predator	White-tailed eagle	Duck / bird	x	x	A	+ n	??
Aquatic mammal	Grey seal	– / mammal	x	x	Ww	+	??

Table 1. Representative species selected for the food-web positions typical to the sea areas of the Baltic Sea, with the selection criteria applied and the corresponding globally generic aquatic ICRP Reference Animals and Plants (RAPs) (ICRP 2014) *and/or marine Reference Organisms in the ERICA Assessment Tool* (Brown et al. 2016)*. For details, see the full paper in the symposium proceedings.*

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Discussion

- Some groups considered in ICRP RAPs and/or ERICA Reference Organisms left out:
  - Sea anemones and true corals – require saline water (although could be present at the boundary zone, the Danish Strait)
  - Amphibians and reptiles – shoreline species
- Balancing and expert decisions needed to keep the suite of representative species manageably small, for example
  - Benthic fish: **European perch** vs. **eelpout** (ecologically important)
  - Pelagic fish: **Baltic herring** vs. **three-spine stickleback** (ecologically important, well studied)
  - Bird feeding on fish: **Herring gull** vs. **great cormorant** (piscivorous, public interest)
- Not considered so far:
  - Life-stage differences in occupancy (and size and radionuclide transport properties)
  - Seasonal characteristics, e.g. wintering in sediment burrows
  - Shoreline areas (shallow-water/littoral species) and transitory species
  - Data availability
  - Radiosensitivity (little information so far even in general…)

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Conclusions

- The generic ICRP/ERICA reference organisms lack in some key characteristics of the Baltic biota communities, but no major difficulties encountered to complement
- The distinct biota communities of the Baltic Sea invite further study of radiological protection
  - At least for scientific and public credibility
- The model development continues; more to come depending on the time (made) available

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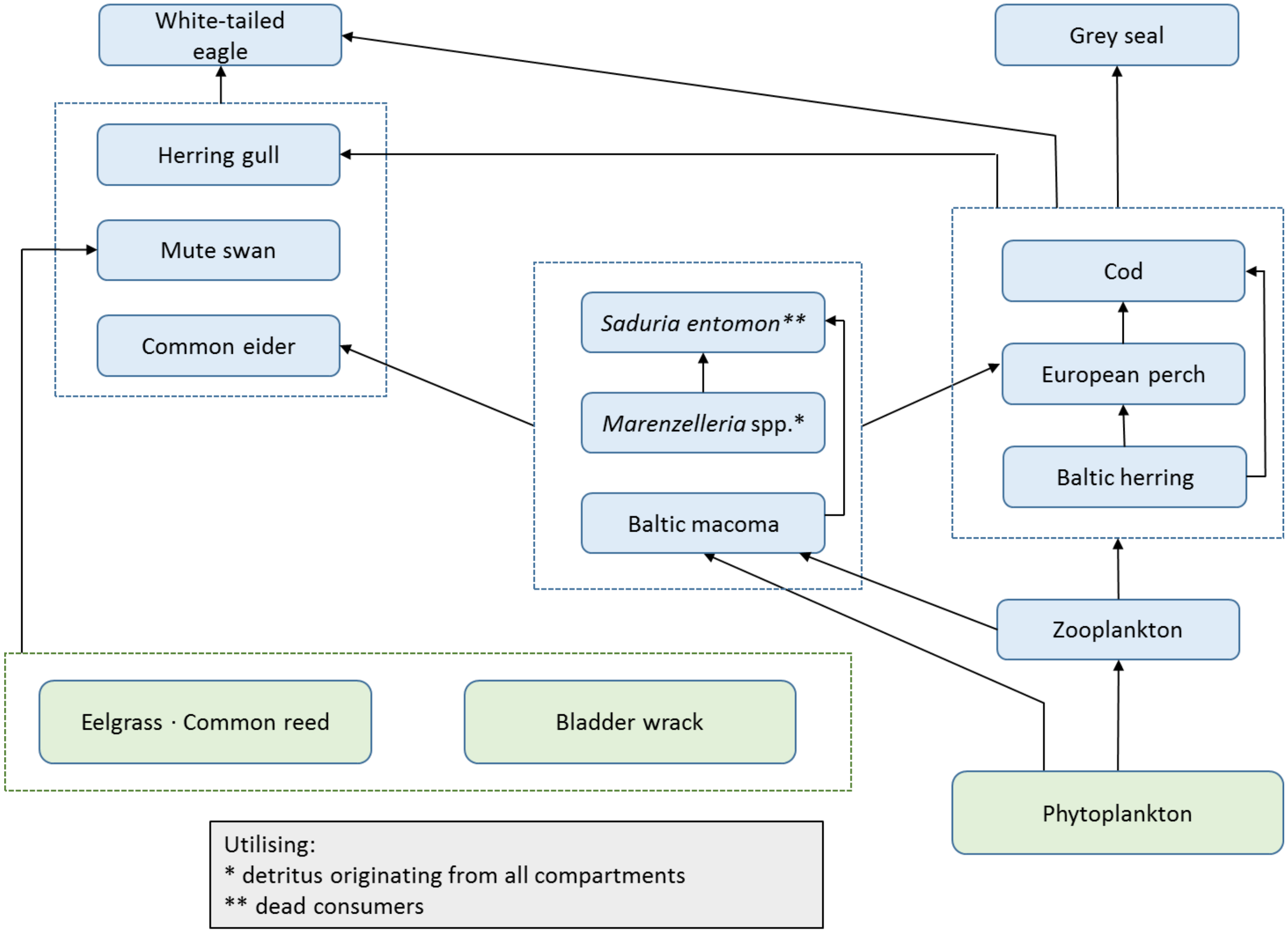
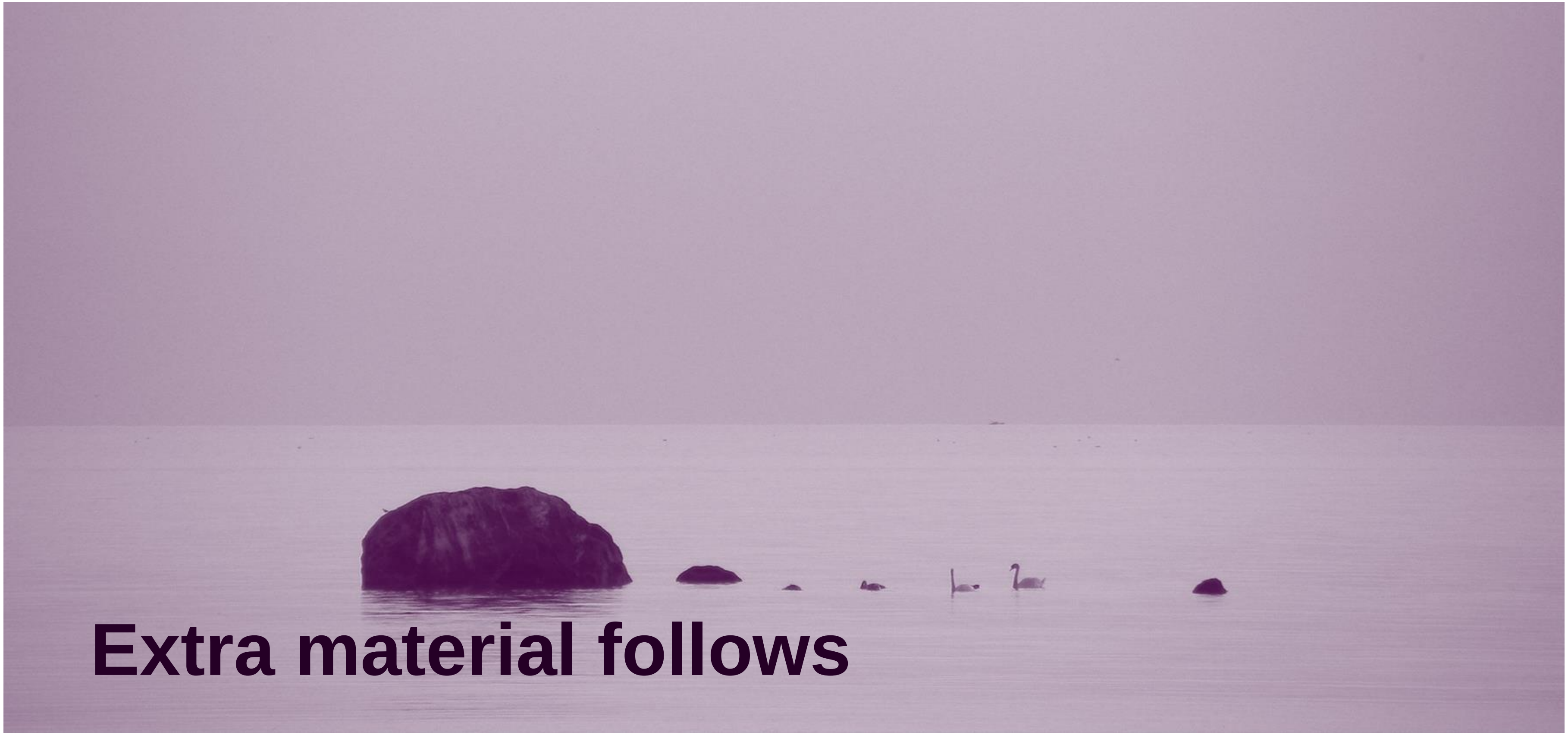
Thank you!



This is how the Baltic Sea food web covered by our representative species looks at the moment…



Extra material follows

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Full paper – species list (1/2)

Table 1. Representative species selected for the food-web positions typical to the sea areas of the Baltic Sea, with the selection criteria applied and the corresponding globally generic aquatic ICRP Reference Animals and Plants (RAPs) (ICRP 2014) and/or marine Reference Organisms in the ERICA Assessment Tool (Brown et al. 2016). For details, see the full paper in the symposium proceedings.

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a) Coded here through the main environmental (exposure) positions typically occupied by the species: **S** in sediment (burrowed), **s** on the sediment/water interface, **W** in water, **w** on water, **A** in air.
b) Coded here with **+** for positive and **–** for negative public interest (e.g. socioeconomically important and/or emblematic or nuisance species), and **n** for nature conservation interests (e.g. endangered species).
c) No specific representative single species for the phytoplankton or the zooplankton has been identified, but they are planned to be parameterised through typical communities acting in these two trophic roles very fundamentally important to the functioning of the ecosystem.
d) A family of invasive species living relatively deep in the sediment and tolerant to anoxia; possibly competes with the native ragworm exhibiting similar lifestyle and present in decreasing numbers.
e) Also, typical to the soft (accumulation) bottoms unlike the foolish mussel that favours harder substrates.
f) Inhabits both the pelagic and benthic environments.

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Full paper – references

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