Preliminary results from modeling of radionuclide transfer through marine food web using a multi-organ fish model

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Brief description on the evolvement of marine radionuclide transfer biota model POSEIDON

Lepicard, S., Raffestin D., 1999. POSEIDON 3.0

- **Equilibrium biota model with pelagic food chain**

Heling, R. et al, 2002. BURN-POSEIDON

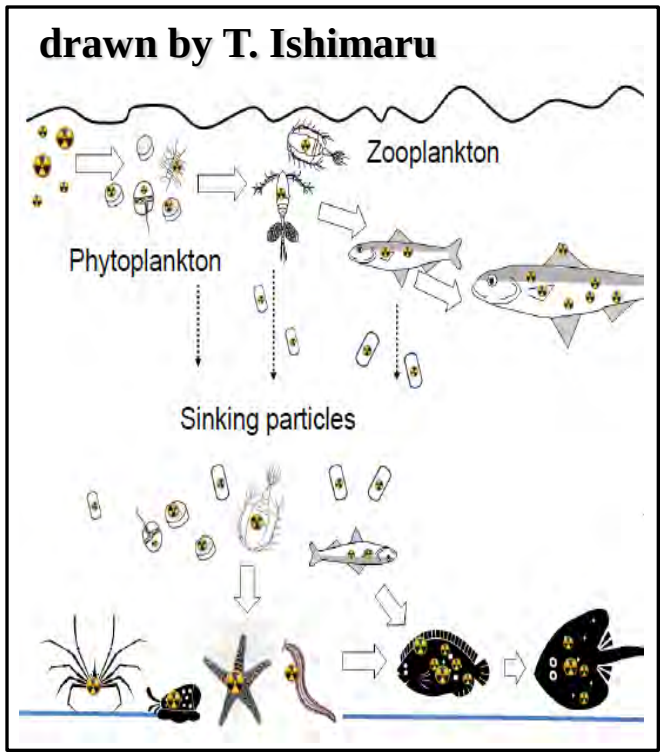
- **Non-equilibrium biota model with pelagic food chain**
- **developed in the European system RODOS (Real-time On-line DecisiOn support System) for the emergency response to nuclear accident**

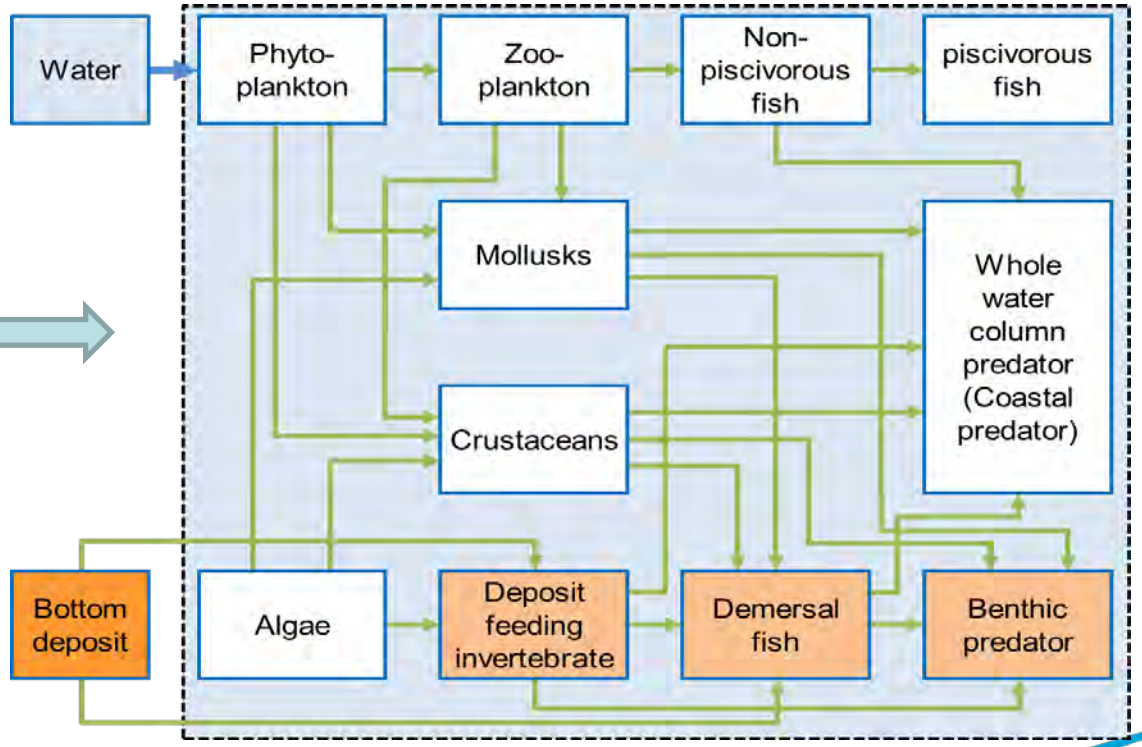
Bezhenar et al, 2016. Extended BURN-POSEIDON

- **Non-equilibrium biota model with pelagic+benthic food chains**

Marine food chain in Extended BURN-POSEIDON

13 state variables for pelagic + benthic marine species
Application to Fukushima for Cs137 (Bezhenar et al, 2016)





Radionuclide in bottom sediment is transferred to benthic marine species & subsequently to pelagic species.

Eqs. in original & Extended BURN-POSEIDON

Phytoplankton and Algae : equilibrium approach

$$C_{phpl}(t) = C_w(t)\ CF_{phpl}$$

Other organisms : dynamical approach.

$$\underbrace{\frac{dC_{(pred)}}{dt}}_{\text{Accumulation}} = \underbrace{a\ K_{1,prey} C_{f,prey}}_{\text{Uptake from food}} + \underbrace{b\ K_w C_w(t)}_{\text{Uptake from water}} - \underbrace{\frac{\ln 2}{T_{0.5}} C_{(pred)}}_{\text{Losses}}$$

where

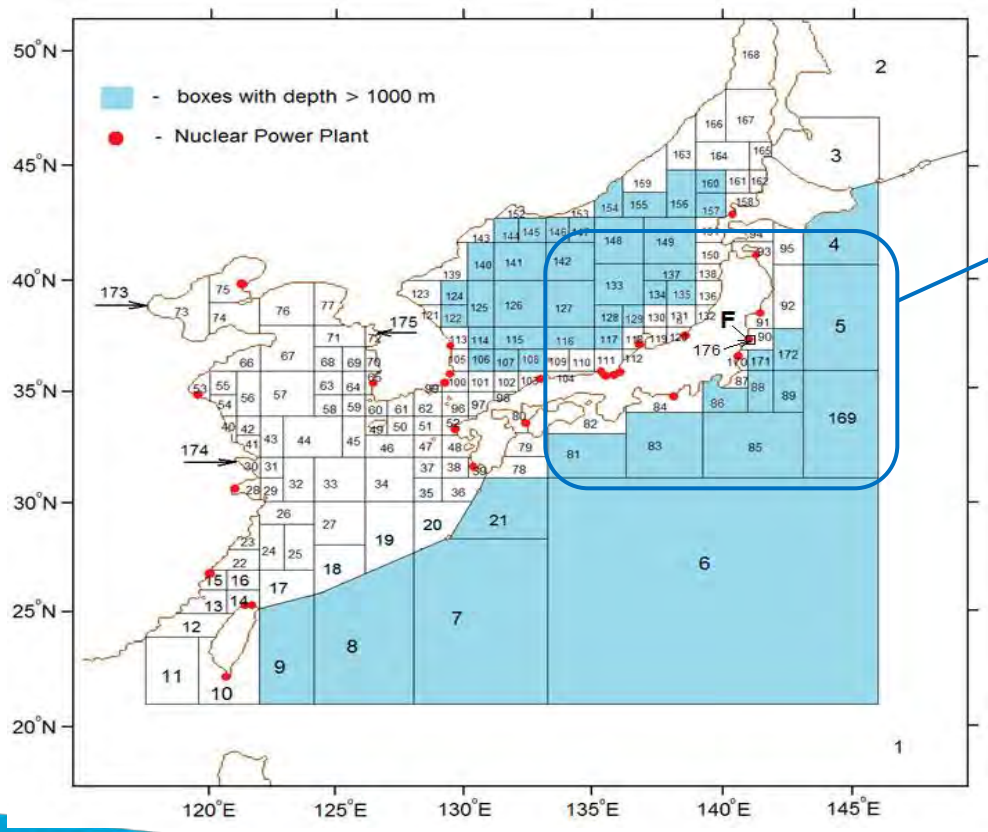
- a : **Assimilation coefficient**
- b : **Extraction coefficient**
- $T_{0.5}$: **Biological half life**

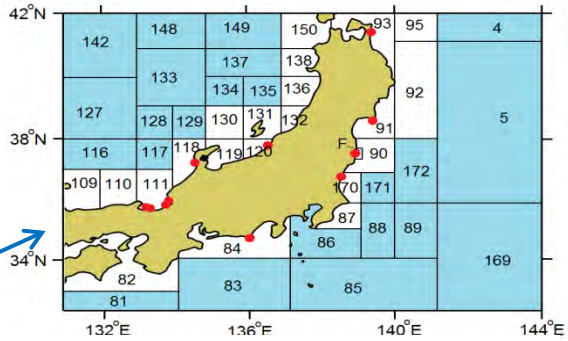
NW Pacific marine biota model boxes

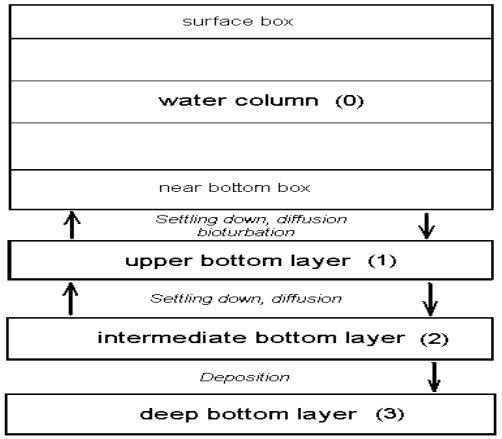
Global fallout

Fukushima release :137Cs 4PBq+8.2PBq

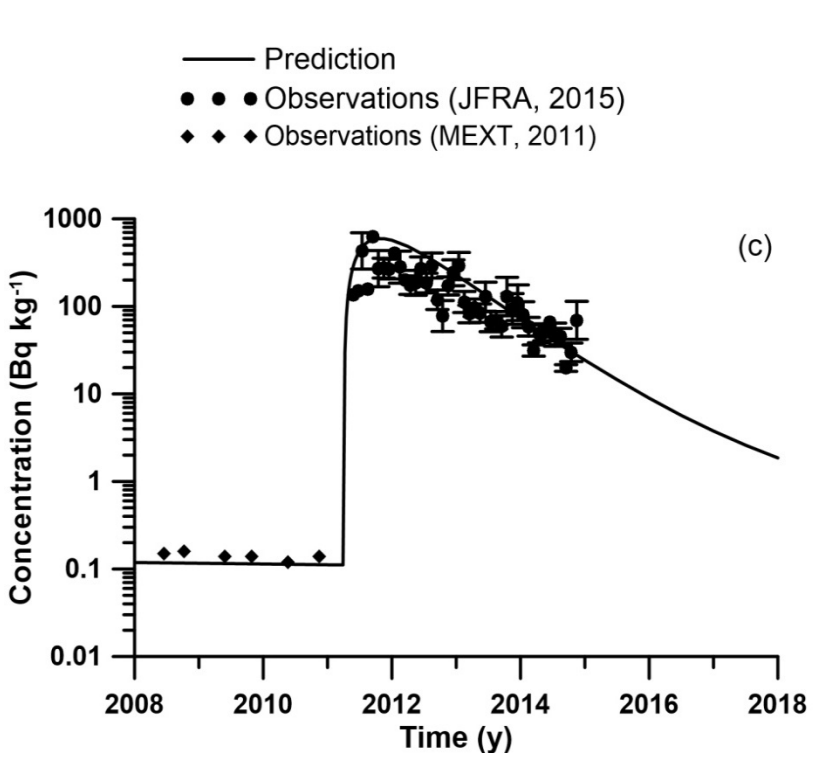
:90Sr 80~640TBq (2014), recently 160TBq



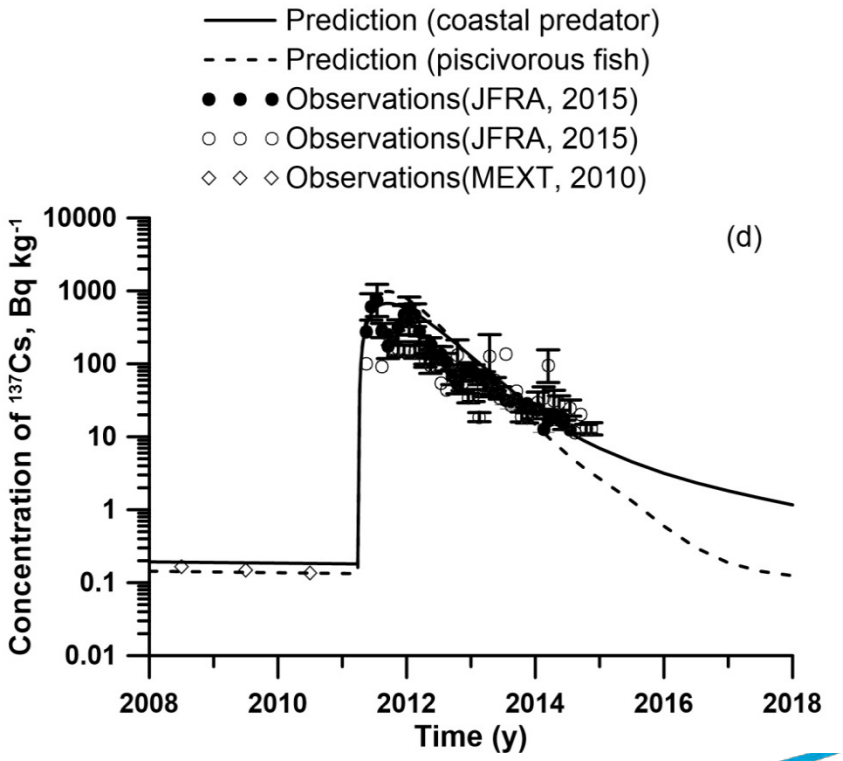




Results from the application of the extended BURN-POSEIDON model to Fukushima accident (^{137}Cs release)



Bottom predator



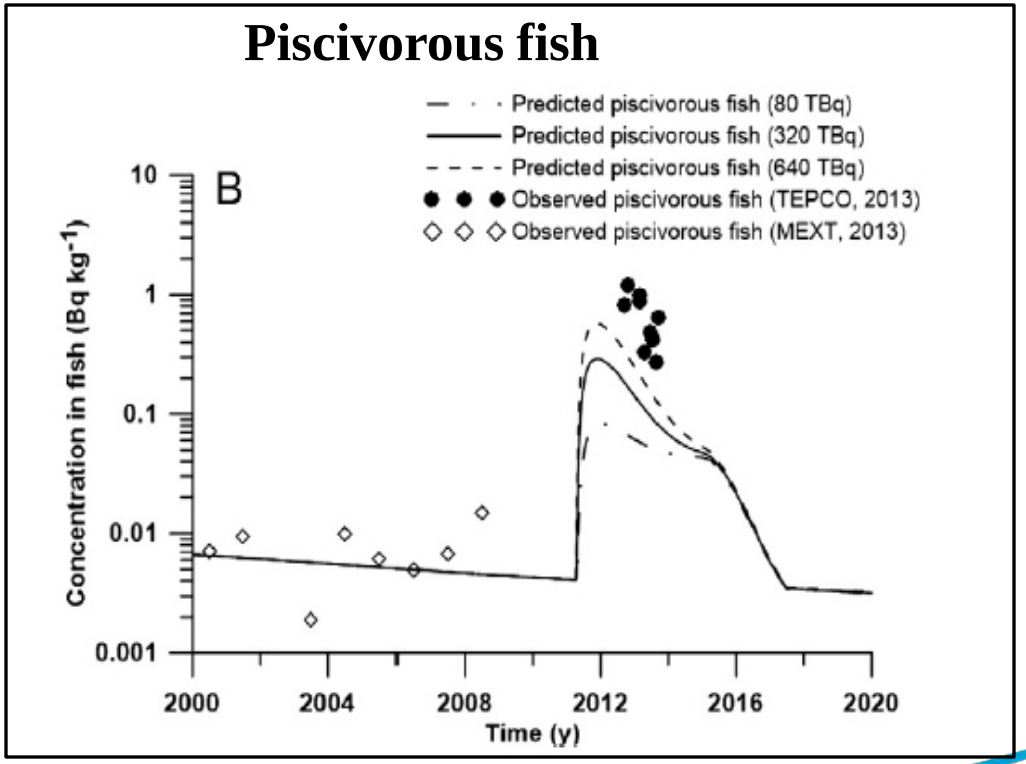
Coastal predator

Problems in applying the extended BURN-POSEIDON model to Fukushima accident (^{90}Sr release)

-Little validation data, especially for deposit feeding invertebrates,

-No appreciable improv. when model parameters for 137Cs were used, notably underestimating concentration in fish

-Such tendency was also found in Baltic Sea.



Radionuclide accumulation in different tissues

Estimated according to the whole body-specific tissue concentration ratios (Yankovich et al, 2010)

Radionuclides*:* ^{134}Cs, ^{137}Cs, ^{3}H

Flesh	Bones	Organs
90%	9%	1%

Radionuclides*:* ^{90}Sr, ^{45}Ca, ^{226}Ra, ^{235}U, ^{238}U

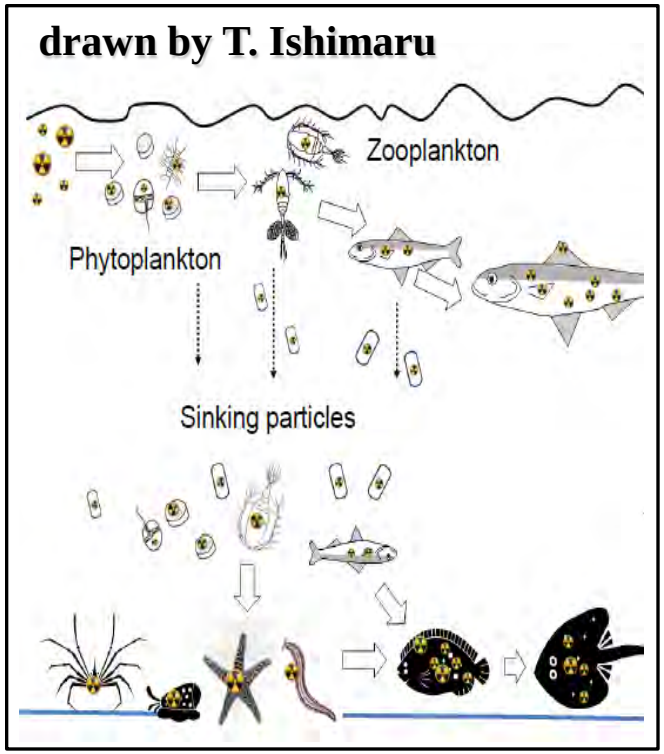
Flesh	Bones	Organs
28%	62%	10%

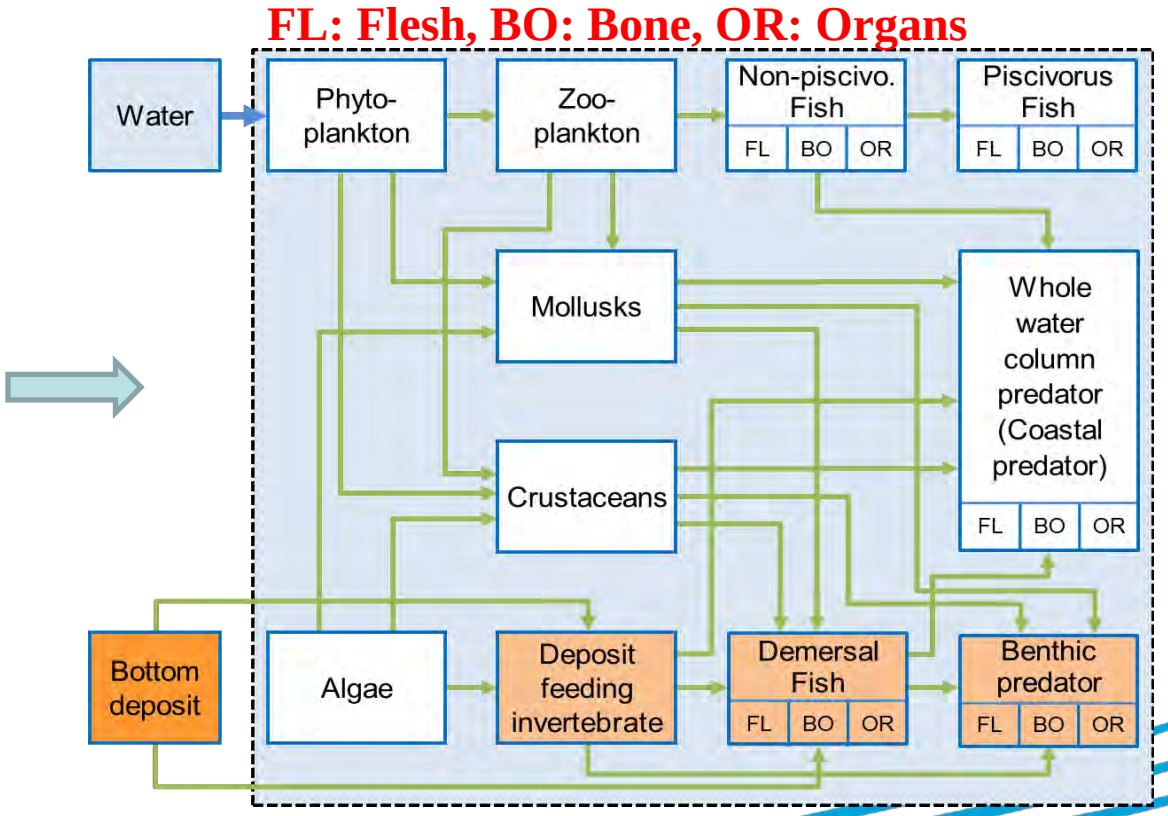
Radionuclides*:* ^{60}Co, ^{54}Mn, ^{65}Zn, ^{125}Sb, ^{131}I, ^{210}Pb…

Flesh	Bones	Organs
32-44%	17-39%	25-40%

Marine food chain in POSEIDON-multi-organ fish model (Multi-BURN)

13 state variables for pelagic + benthic marine species with three target tissues for fishes (thus, 23 state variables)





Equations for Multi-BURN fish model with three target tissues

Concentration in flesh

$$\frac{dC_{flesh}}{dt} = a_f \; K_{1,prey} C_{f,prey} + b \; K_w C_w(t) - \frac{\ln 2}{T_{0.5,flesh}} C_{flesh}$$

Concentration in bones

$$\frac{dC_{bone}}{dt} = a_b \; K_{1,prey} C_{f,prey} + b \; K_w C_w(t) - \frac{\ln 2}{T_{0.5,bone}} C_{bone}$$

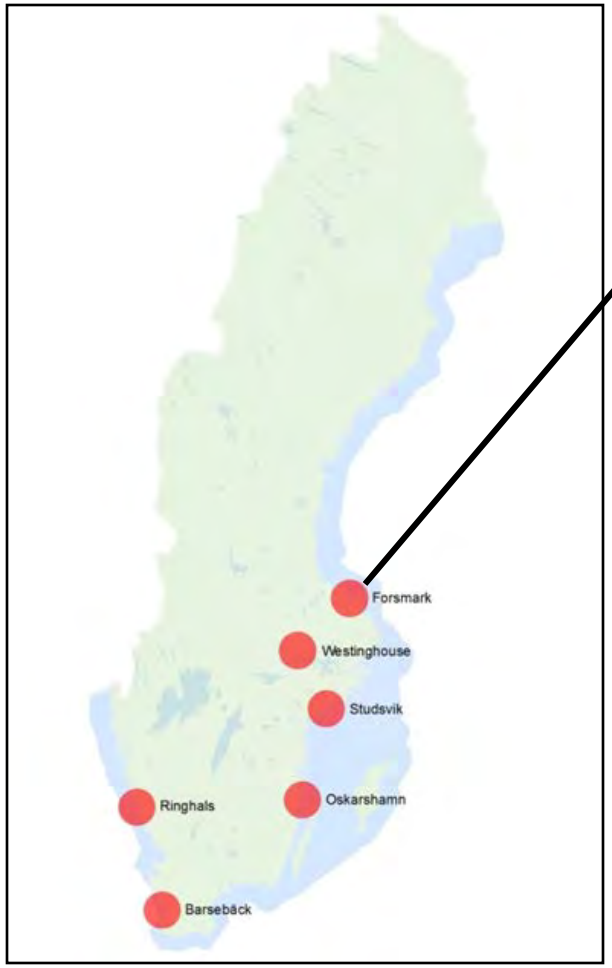
Concentration in organs

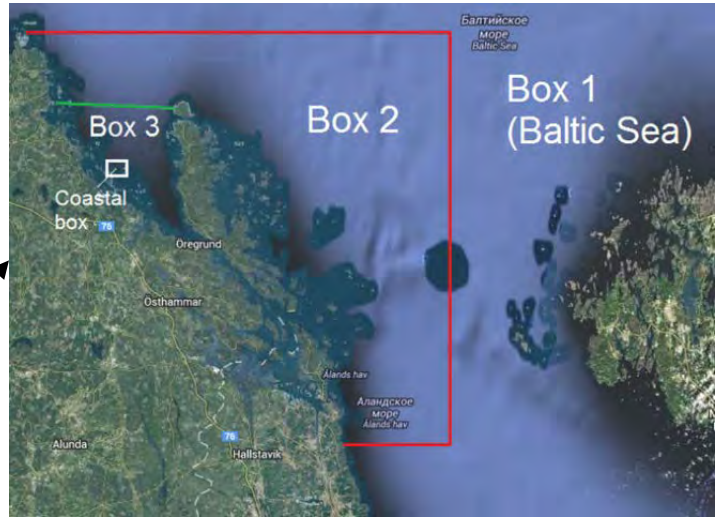
$$\frac{dC_{organ}}{dt} = a_o \; K_{1,prey} C_{f,prey} + b \; K_w C_w(t) - \frac{\ln 2}{T_{0.5,organ}} C_{organ}$$

Concentration in whole fish with consideration of mass fractions

$$C_{(fish)} = f_{flesh} \; C_{flesh} + f_{bone} \; C_{bone} + f_{organ} C_{organ}$$

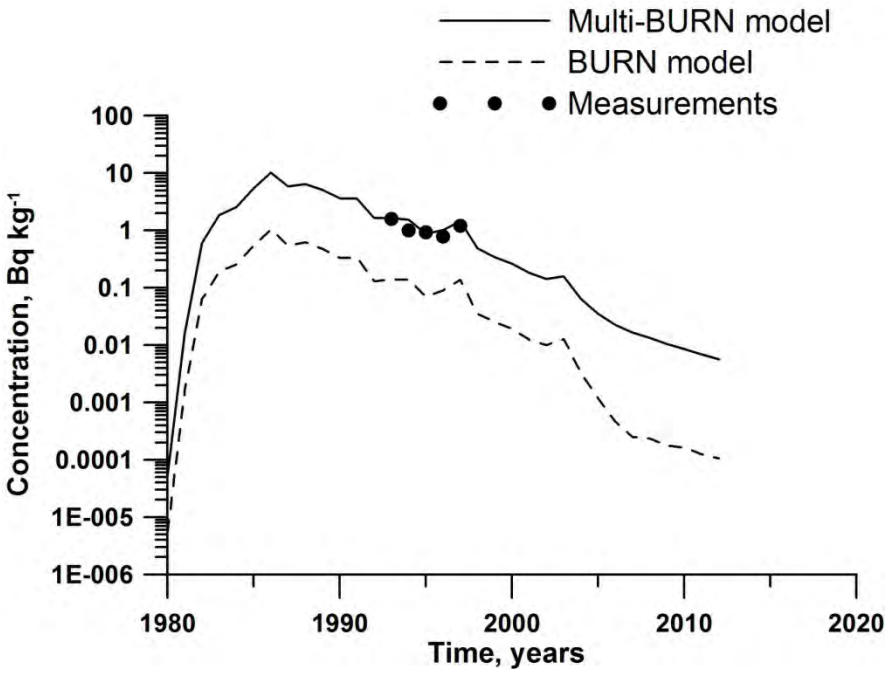
Application of the Multi-BURN to Forsmark NPP



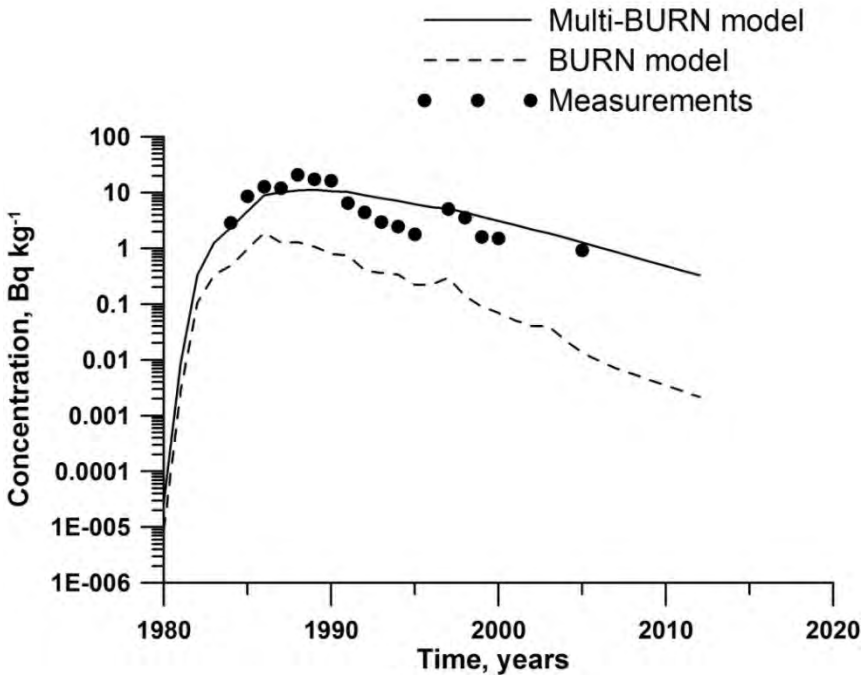


Forsmark NPP in Sweden

^{60}Co accumulation in fish for the Forsmark NPP case computed using Multi-BURN POSEIDON (benthic food chain included)

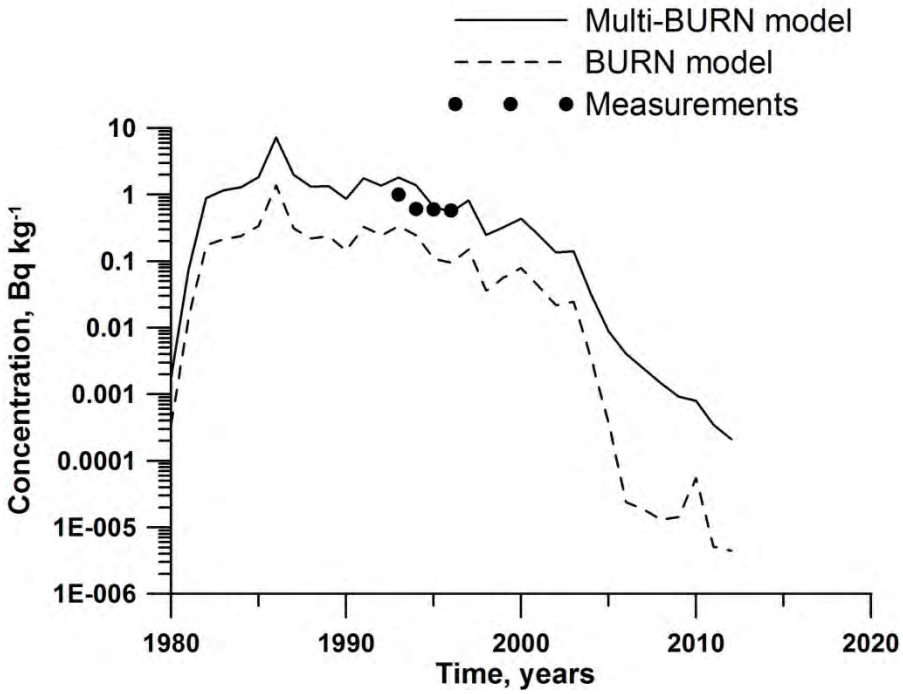


Non-piscivorous fish (herring)

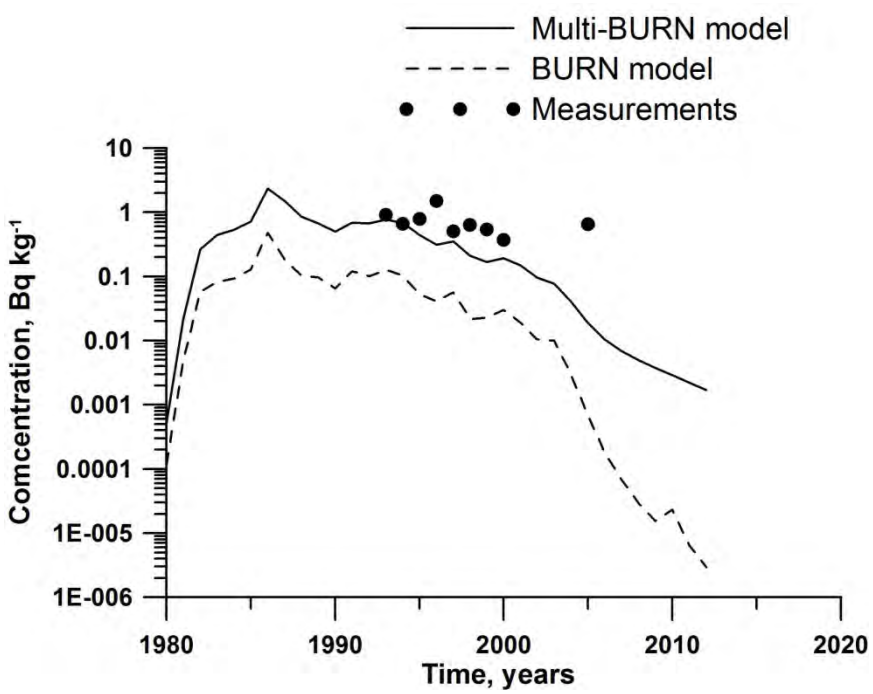


Coastal predator (pike)

^{54}Mn accumulation in fish for the Forsmark NPP



Non-piscivorous fish (herring)



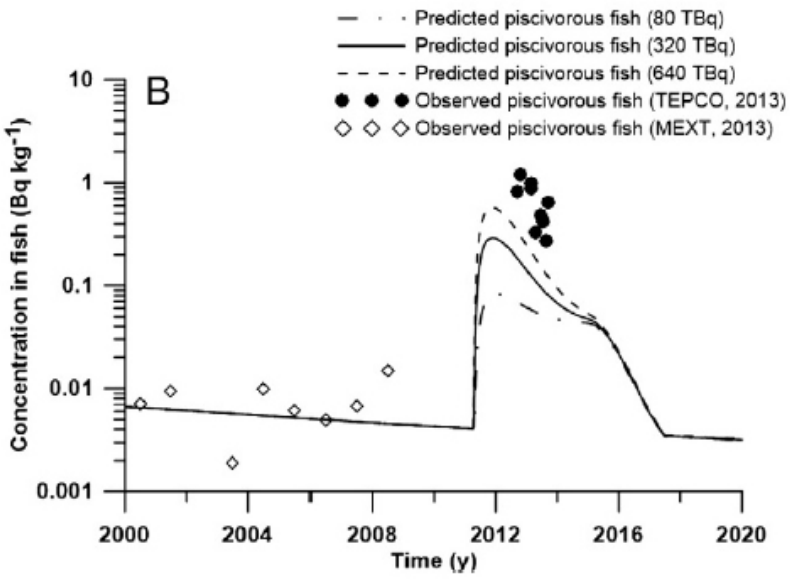
Coastal predator (pike)

Re-calculation of ^{90}Sr concentrations in Fukushima

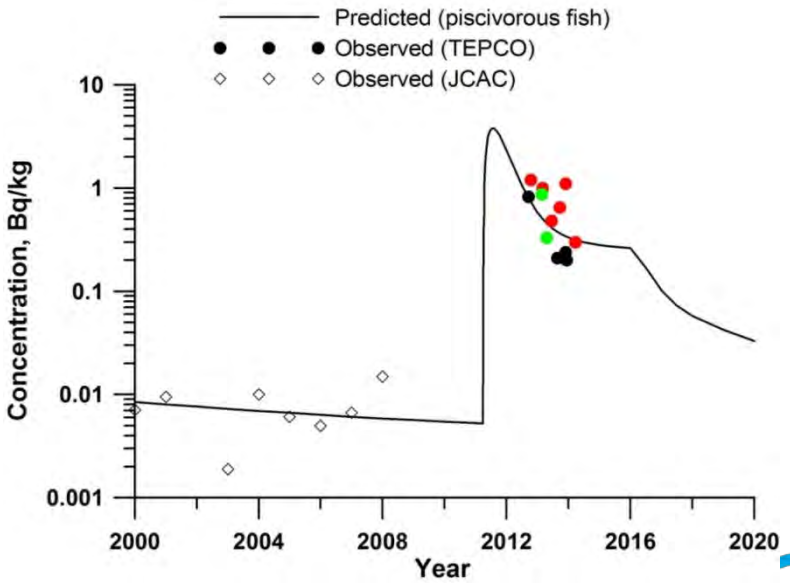
Accidental release: 160 TBq in April 2011
Continuous release: 1 TBq/yr
Enhanced vertical mixing at the water-sediment interface

Conc. in piscivorous fish in the small coastal box

BURN (2014)



Multi-BURN



shark (black), seabass (green), rockfish (red)

Conclusions

- **Application of the new simple food chain model Multi-BURN to the near field of Forsmark NPP in Sweden for reproducing of ^{60}Co and ^{54}Mn concentrations in the fish shows good agreement with measurements**

- **Application of the new model to area around Fukushima Dai-ichi NPP gives better agreement with measurements than standard BURN model for concentration of ^{90}Sr in fish**

- **A more complex model which allows interaction between different organs are under development.**

Thanks for your attention !!!!!