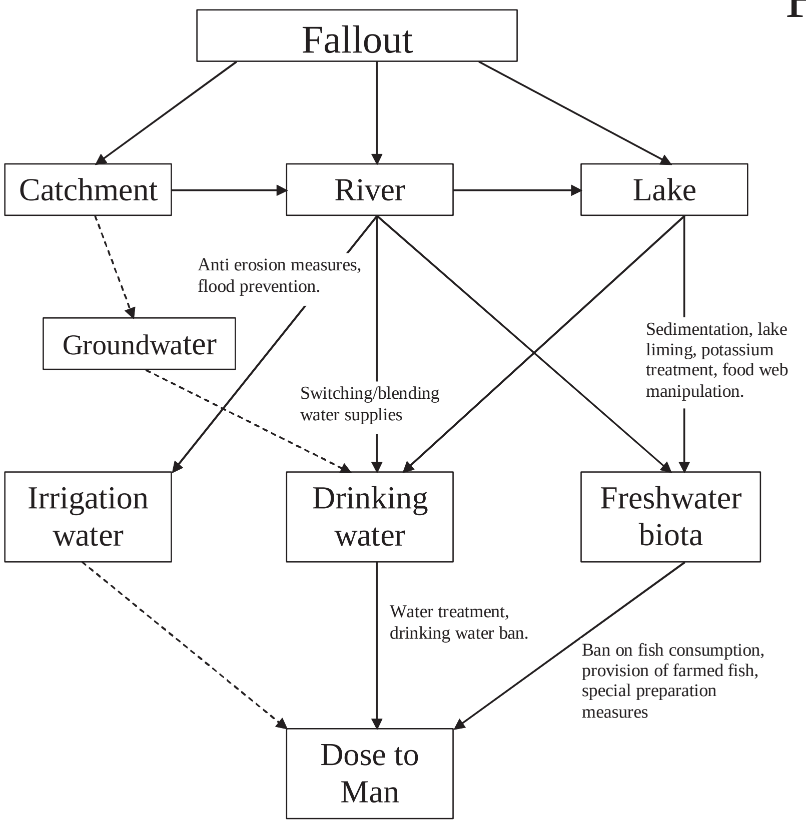
Relating aquatic models to public concerns

Prof. Jim Smith
University of Portsmouth

Integrated dose assessment and aquatic pathways

Freshwater dose pathways



Smith, J.T., Voitsekhovitch, O. et al. A critical review of aquatic countermeasures *J. Env Rad.* **56, 11-32.**

Freshwater internal doses - minor compared to terrestrial

- Drinking water: dose very minor at this stage (c.f. ~ 6 Bq/l in some natural waters);
- Freshwater fish/foodstuffs – activity concentrations/doses can be very high, but doses generally low (low consumption rates) except to critical groups;
- Important to focus on dose, not activity concentration (where possible).

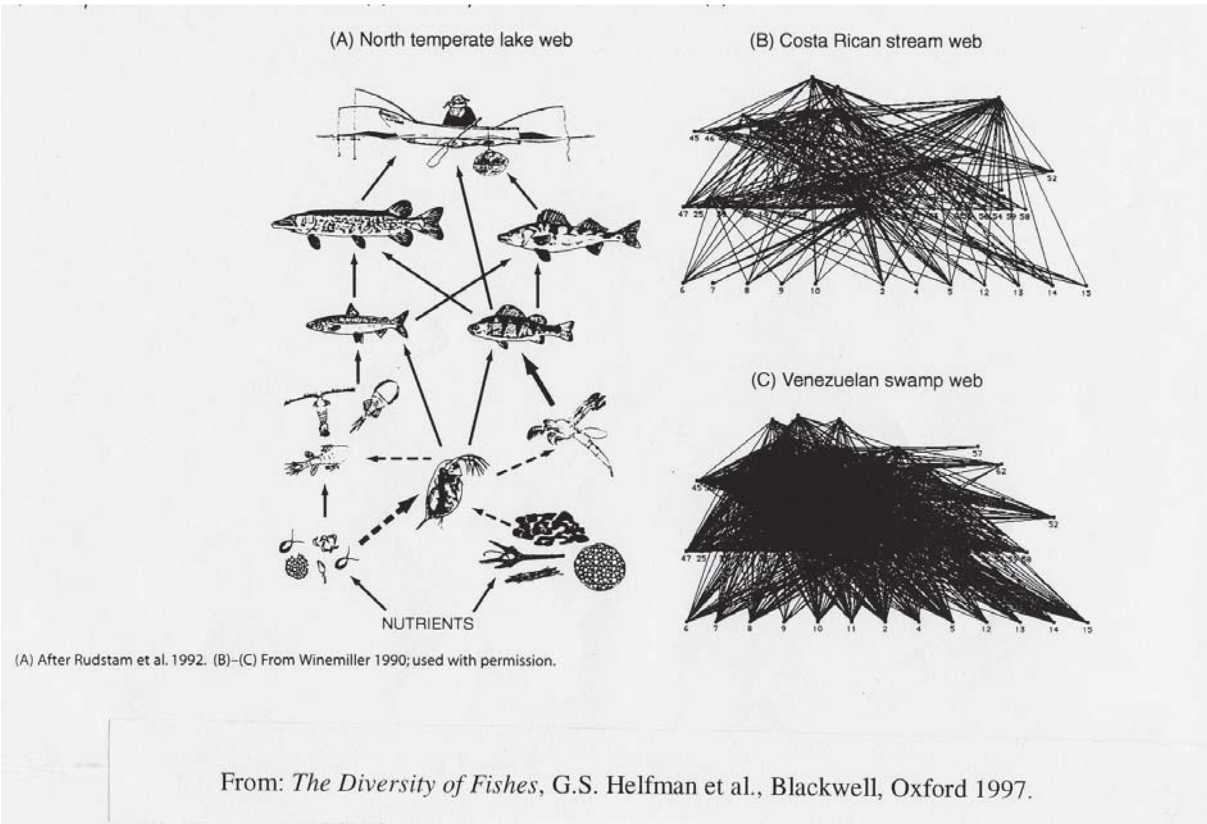
External doses

- River bank/coastal occupancy;
- Very minor dose from water;
- Swimming ? Minor except possibly for close contact with contaminated sediment.

Assessing aquatic foodchain doses from $^{137,134}Cs$ and ^{3}H

- ^{3}H: Weak beta ~ Annual Limit of Intake ca. 24 MBq for 1 mSv y^{-1} effective equivalent dose (c.f. 75 kBq for Cs-137).
- For ^{3}H: If input not OBT then no bioconcentration: Equilibrium CF ~ 1
- Past high ^{3}H input to catchment could reach aquatic food chain with delay via sediment/detritus, but not expected to be important in dose formation.

Aquatic food webs



(A) After Rudstam et al. 1992. (B)–(C) From Winemiller 1990; used with permission.

From: *The Diversity of Fishes*, G.S. Helfman et al., Blackwell, Oxford 1997.

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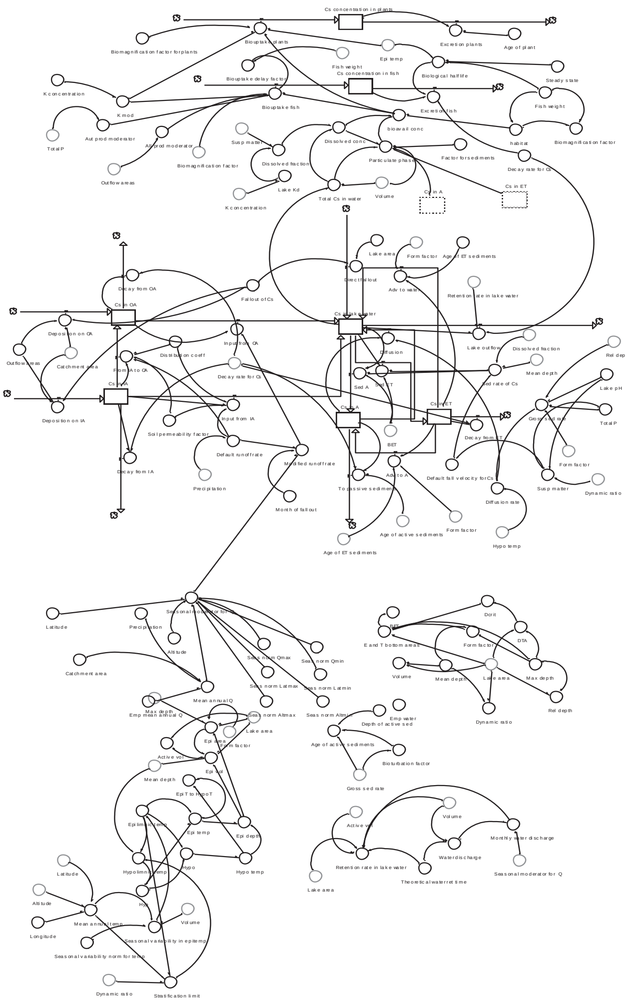
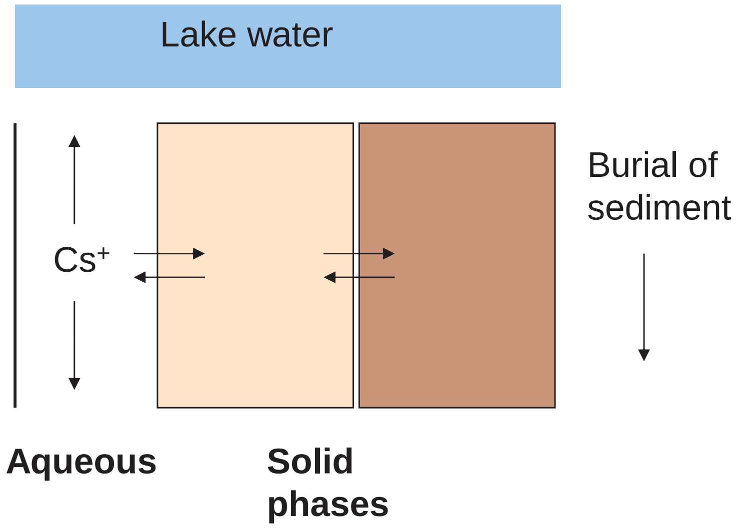


Lake model;
Lars Hakansson,
University of Uppsala

Interaction of Cs-137 with lake sediments



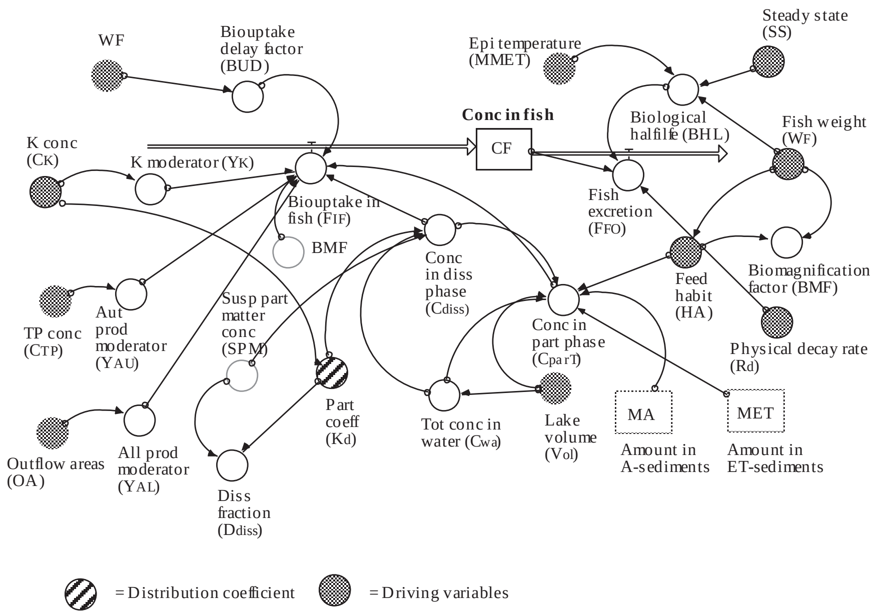
$$\frac{\partial C_e}{\partial t} = \frac{\partial}{\partial x}\left[\phi\psi D_o \frac{\partial}{\partial x}\left(\frac{C_e}{\phi + sK_d^e(x)}\right) - rC_e\right] - k_f C_e + k_b s C_i - \lambda C_e$$

$$s\frac{\partial C_i}{\partial t} = -\frac{\partial (rsC_i)}{\partial x} - k_b s C_i + k_f C_e - \lambda s C_i$$

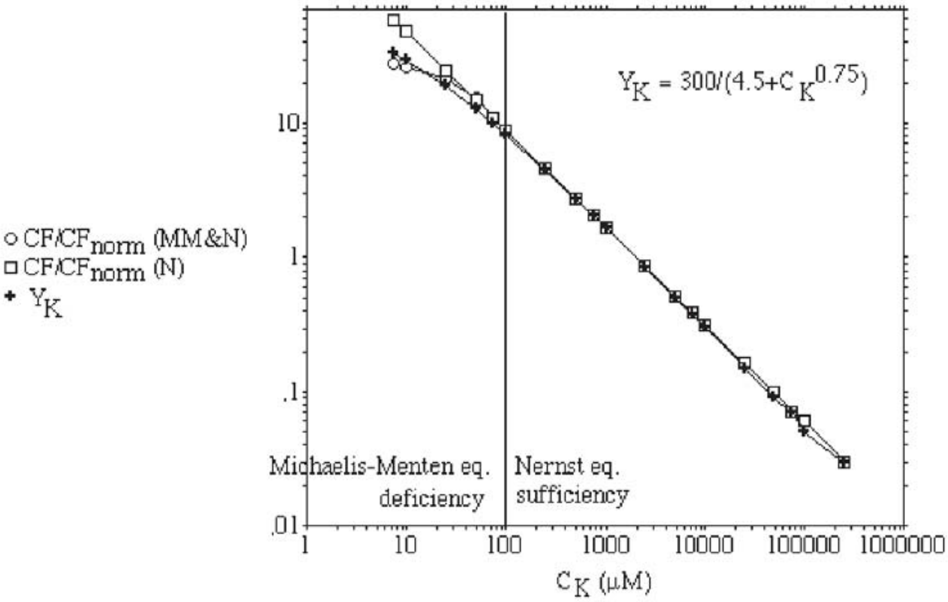
(Smith & Comans, *Geochim. Cosmochim. Acta*,1996)

Fish sub-model

Fish sub-model

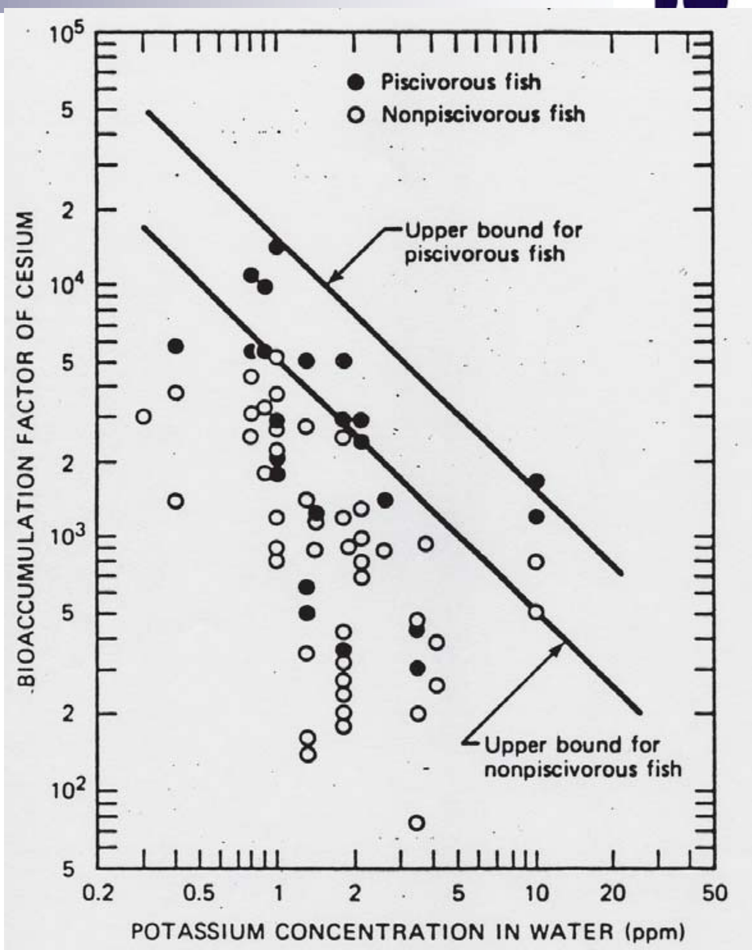


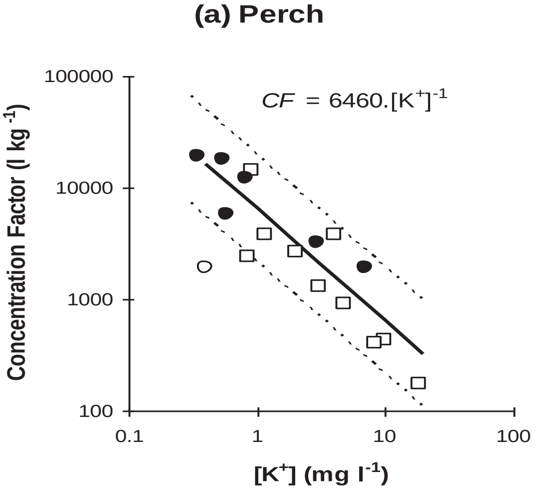
Caesium-potassium model

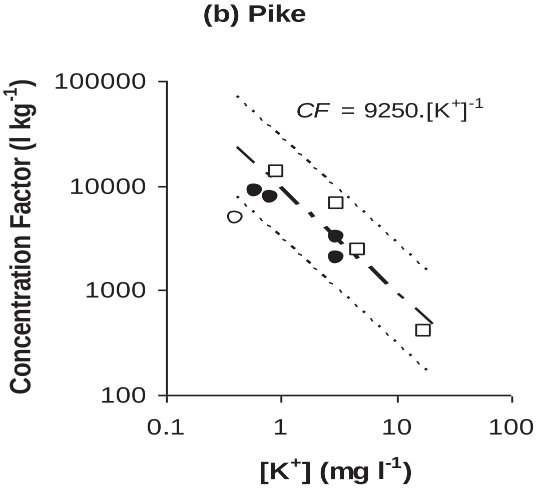


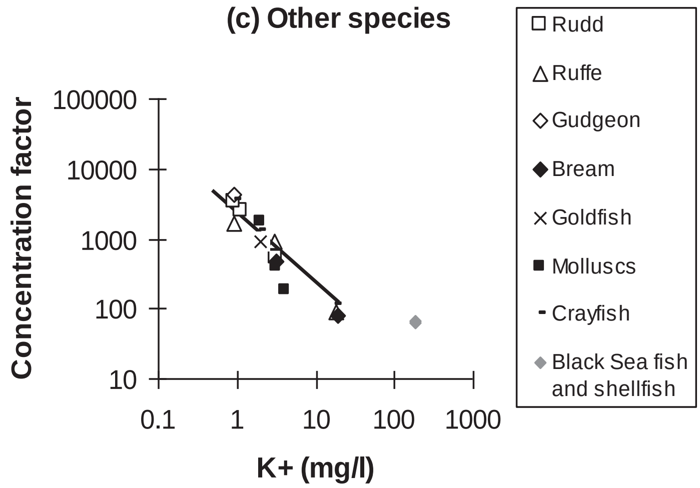
Caesium-potassium model from measurements in lakes

Vanderploeg et al. 1975



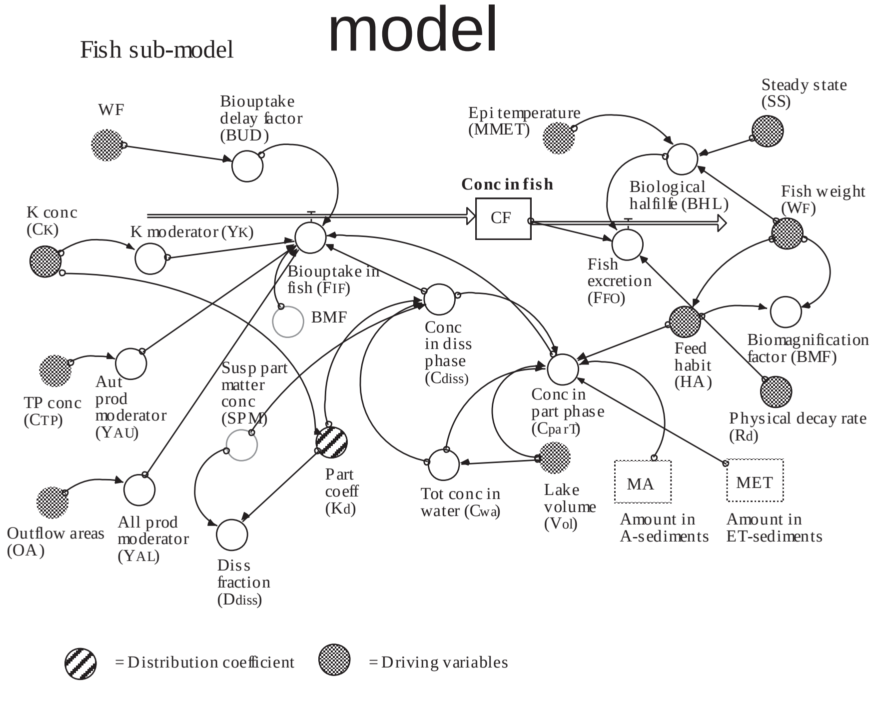




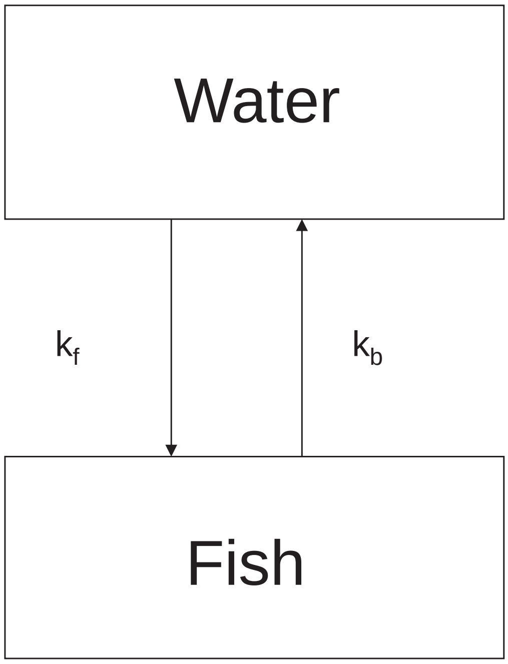


Equilibrium CF of Cs-137 in fish and potassium concentration

Fish sub-model



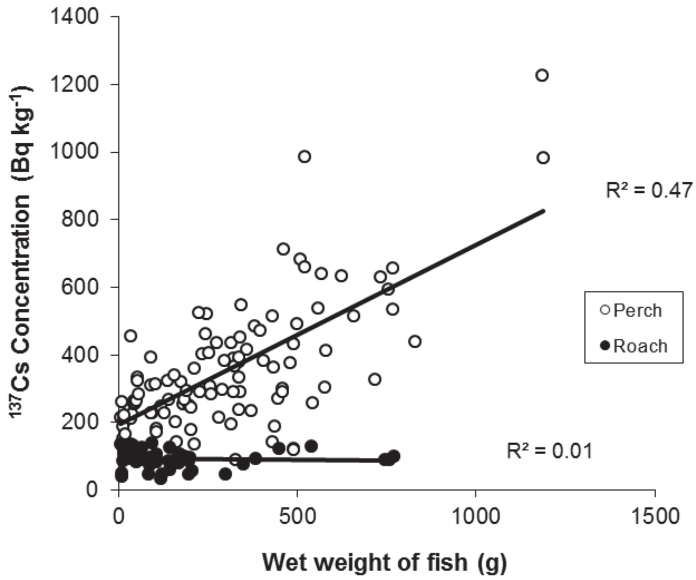
New Model:



Models should be as simple as possible…

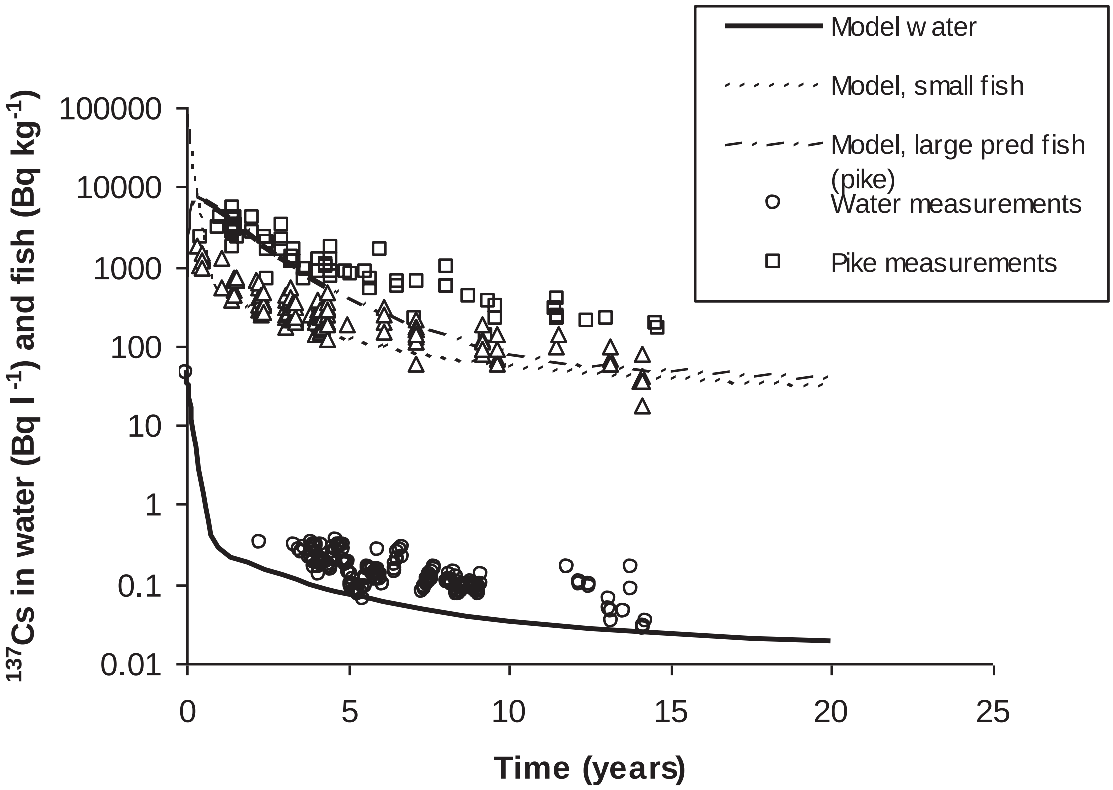
…but no simpler:

Size/trophic level/age effect

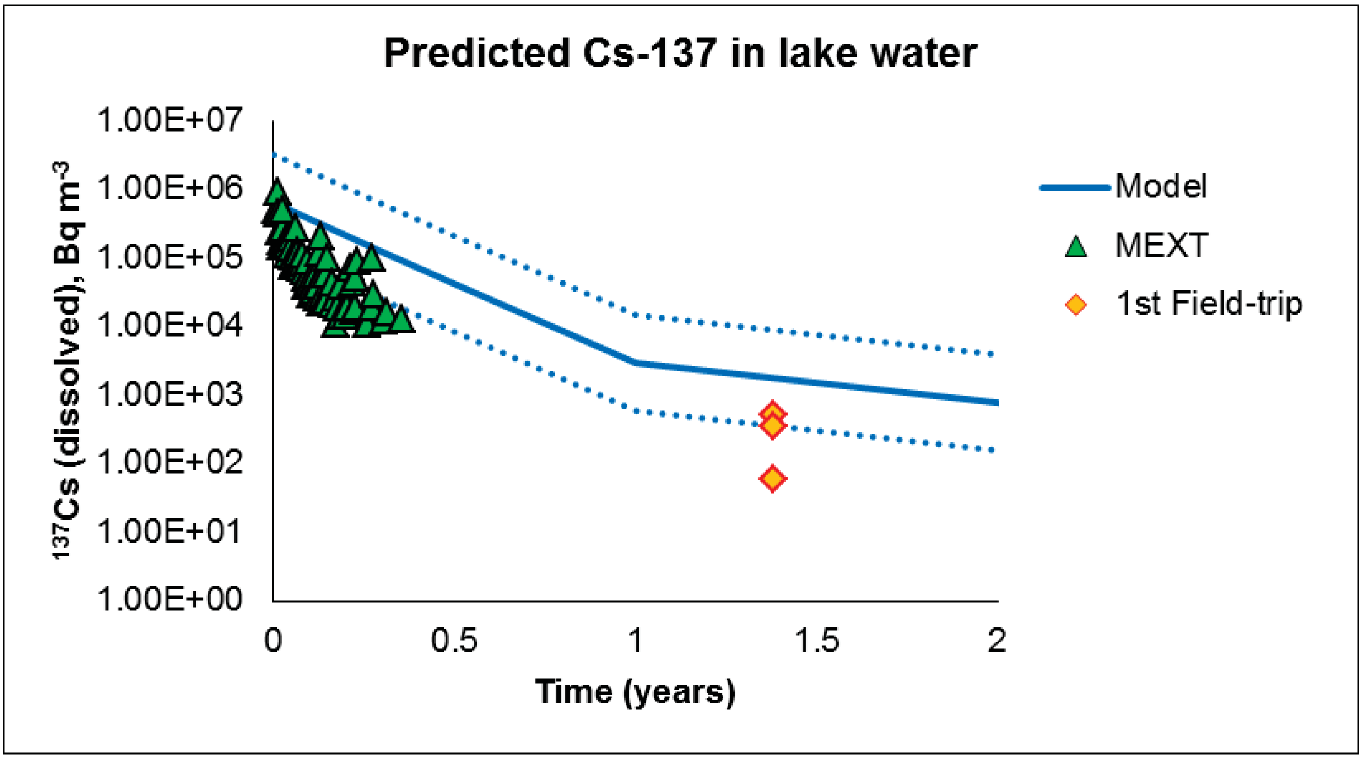


Radiocaesium in fish in the Kiev Reservoir
(Sansone and Voitsekhovitch, 1996)

Cs-137 in Lake Vorsee, Germany

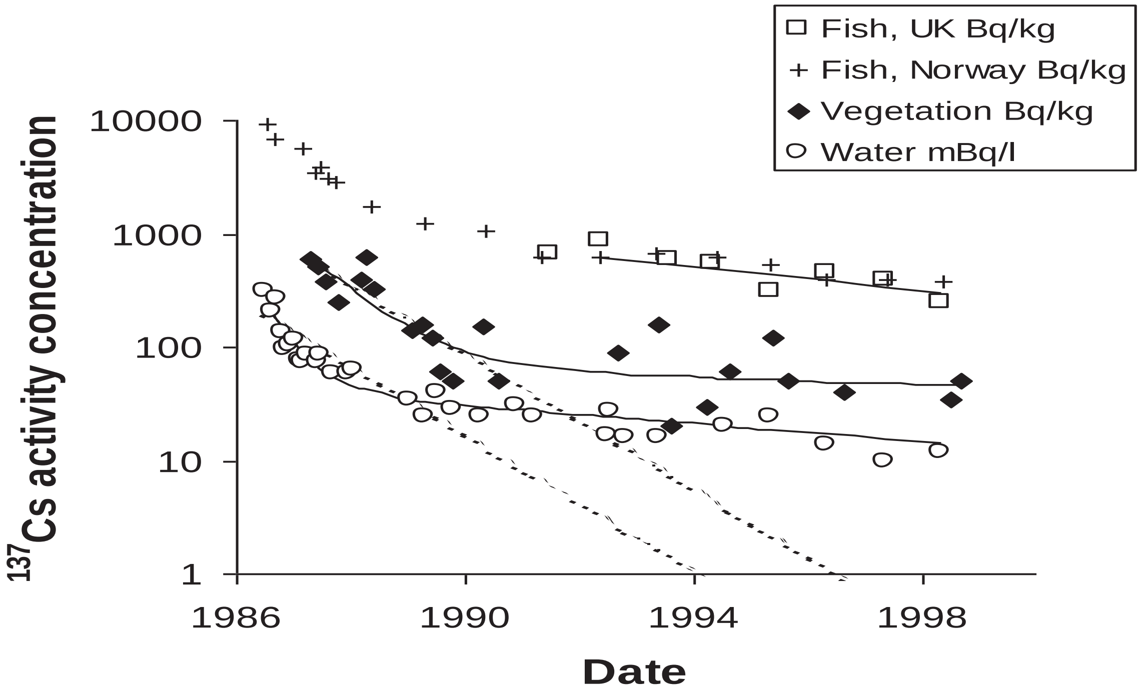


Iitate lake water



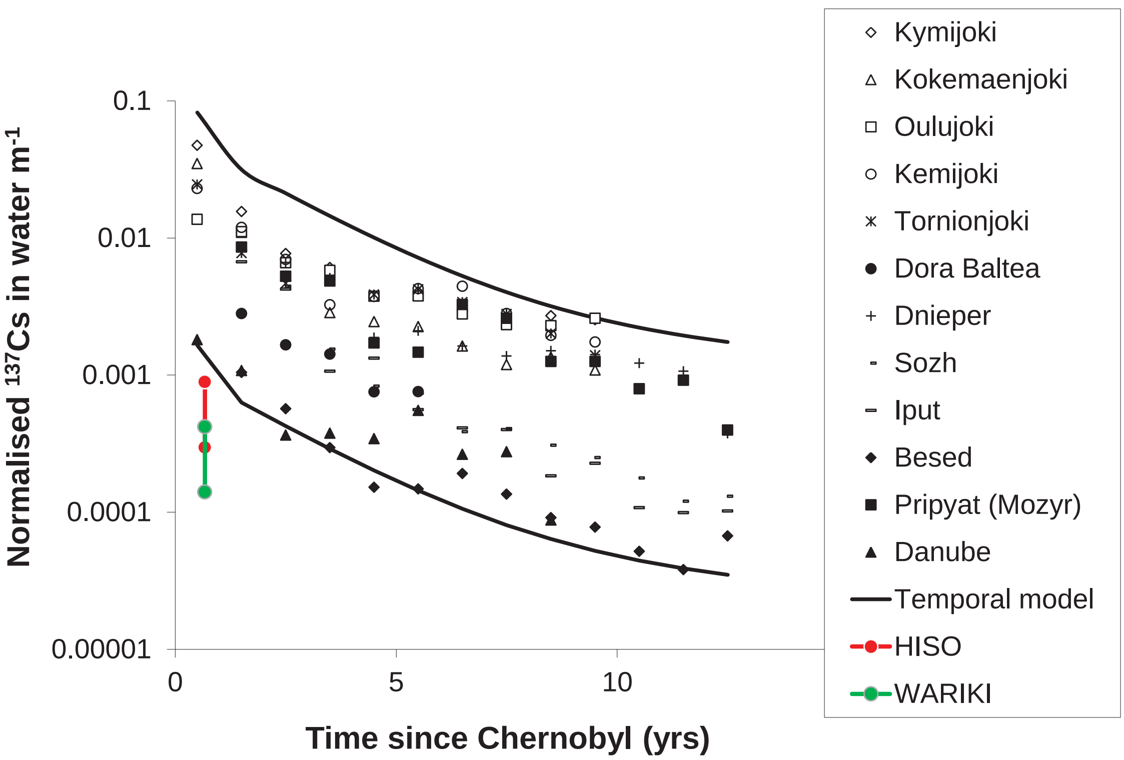
Blind prediction of AQUASCOPE model – Iitate Lake
Chaisan, K., Kameda, Y. (Chiba Inst Technol.), Smith J.T., unpubl. res.

Long timescale changes…



Smith, J.T. et al. (2000) Chernobyl's legacy in food and water. *Nature*, 405.

Cs-137 in European Rivers (Dissolved)



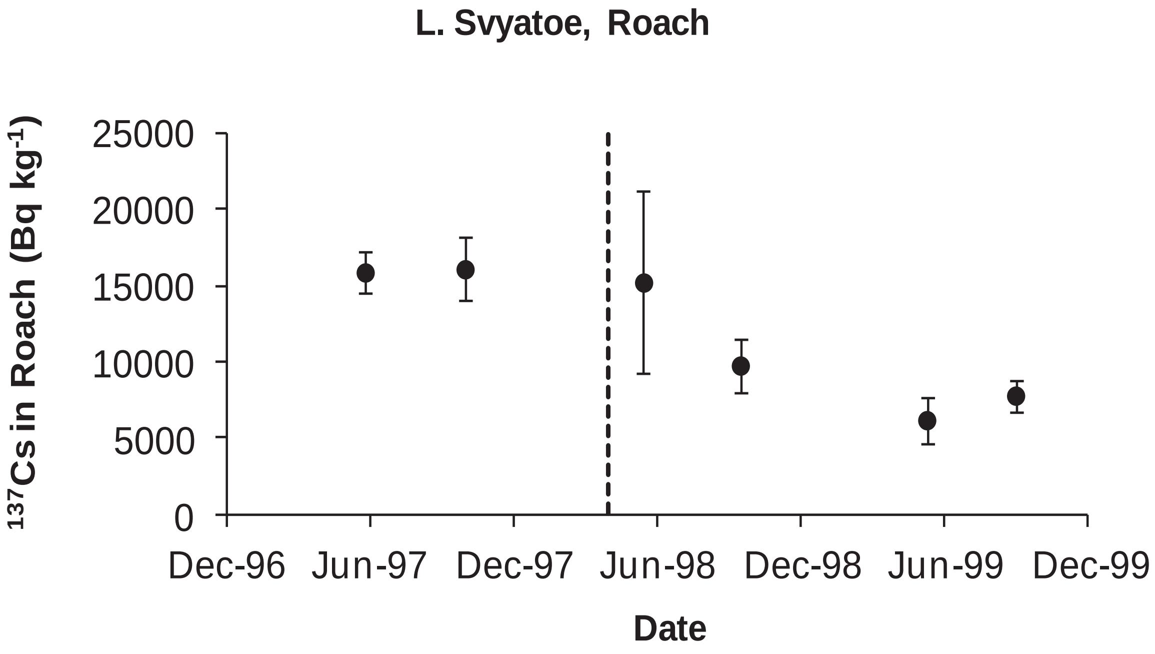
Smith J.T., et al. (2004) *Env. Sci. and Technology*, 38, 850-857.
Ueda et al. (2013) *J. Env. Radioactivity,*118; 96-104

Assessing the impacts of countermeasures/ lifestyle changes

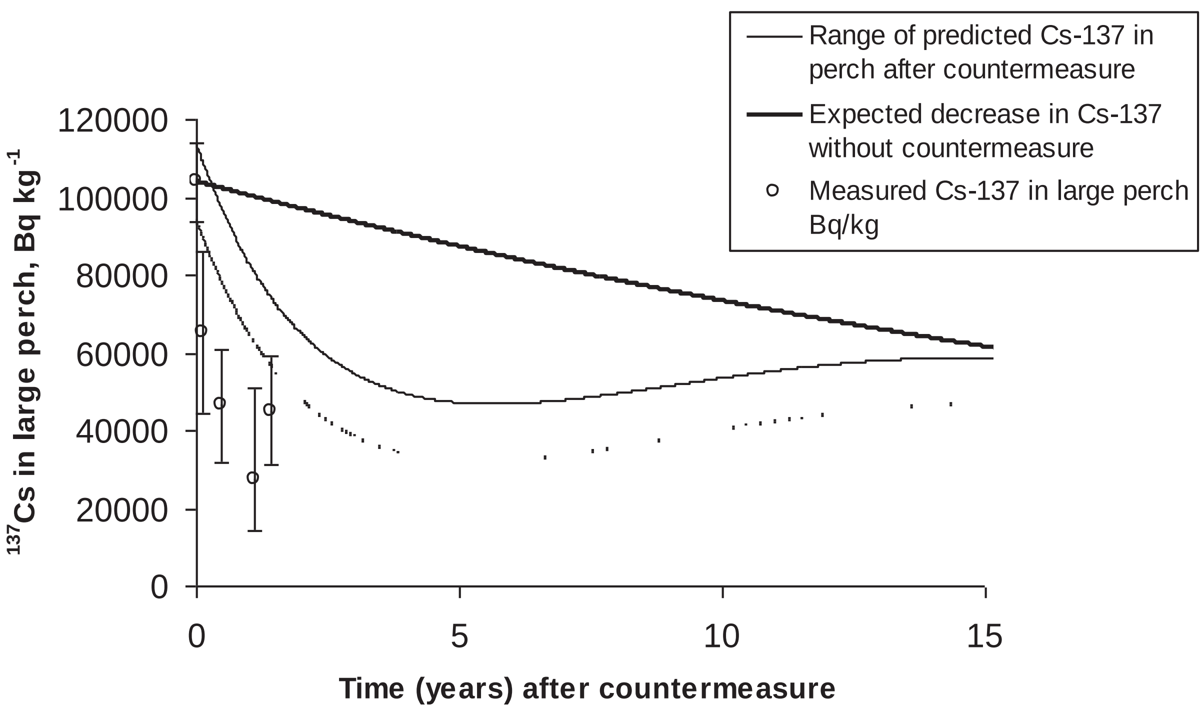
A countermeasure experience

Smith J.T., Kudelsky A.V., Ryabov I.N., Hadderingh R.H., Bulgakov A.A. (2003) *The Science of the Total Environment* 305, 217-227.

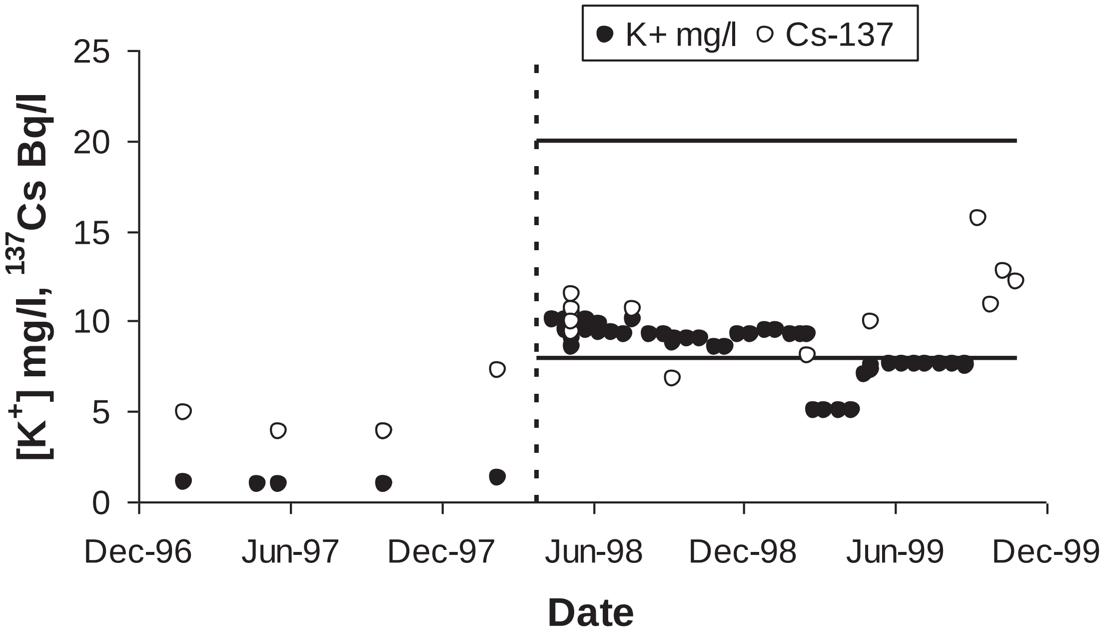
Result of 10 x increase in potassium in L. Svyatoe, Belarus



Model prediction - perch



Changes in water chemistry



Disadvantages of countermeasures

- Often very expensive – is the cost per Person-Sv justifiable ? E.g. if 10-20 psnSv = one averted fatal cancer, and a life is valued at $X Million, cost per psnSv ≤ $X M ÷10-20
- Dose to clean-up workers; waste generation
- Potential unintended consequences to humans (e.g. salting fish can reduce Cs, but excessive salt intake may outweigh health benefit) and ecosystem damage.

Lifestyle changes

- Ban on consumption of fish/aquatic foodstuffs; economic value of commercial and sport fishing, but catch and return possible for sport fishermen;

- Occupancy/Swimming/boating ban ? Unlikely to be needed if area is suitable for re-settlement, but this needs to be assessed.

Applicability/reliability of models for Fukushima conditions

- Need to critically test models, not validate them;
- Indications are that models developed post-Chernobyl will overestimate food chain doses for Cs but underestimate physical redistribution by sediment;
- Need model endpoints at an appropriate spatial scale – if dose limitation, not Bq/kg is the objective, spatial scale is large.

What models/research do we need ?

- Need to critically evaluate countermeasures by economic and dose cost/benefit;
- Very long term Cs-137 trends ? Weapons Test and Chernobyl give us a guide
- Don't try to model less quantifiable impacts (e.g. lifestyle changes; ecosystem services): use subjective judgement supported by informed stakeholder engagement

What models/research?

- Comparative risk analysis as part of integrated dose assessment: put risks in context of more important health risks (e.g. natural/cosmic radiation, stress, poor diet, air pollution, overweight, passive/active smoking);
- Effects on organisms are not necessarily important from an ecological perspective but are very important in public communication.

Social, mental health and economic impacts of Chernobyl

"*The mental health impact of Chernobyl is the largest public health problem unleashed by the accident to date*"

UN/WHO/IAEA Chernobyl Forum Report, 2006

- Dose is not the most important health factor !
- Most important health factor is the sense of control and empowerment in people
- Effort in education and communication needs to equal clean-up effort.

Grigory Mamonin,
Forester