Stable isotopes provide evidence for the biomagnification of radiocesium in a contaminated aquatic environment

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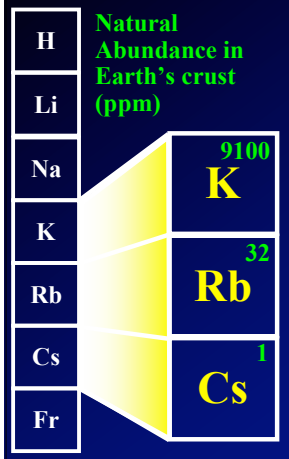
Gone Fission

- Nuclear reactions consume » 56 g of U or Pu/kT (4.186×10^{12} J) of energy released
- Each kT yields ~15 TCi (5.6×10^{23} Bq) of (mostly short-lived) fission and activation radionuclides
- A few of these are either radionuclides of natural nutrients, or are biochemical analogs of them
- Because of the need for coolant water, nuclear facilities are frequently located near aquatic systems. Numerous releases of fission products from these (and fallout from weapons detonations) have shown that aquatic food webs can be major sources of exposure
- Cesium-137 (^{137}Cs) is one of the most important of the radionuclide contaminants: it has a long physical half-life (30.17 y), a high fission yield, and high biological availability

Truckee

15:37 (GMT) 9 June 1962
16 km S of Christmas I.
210 kT

Characteristics of Group IA (Alkali) Metals



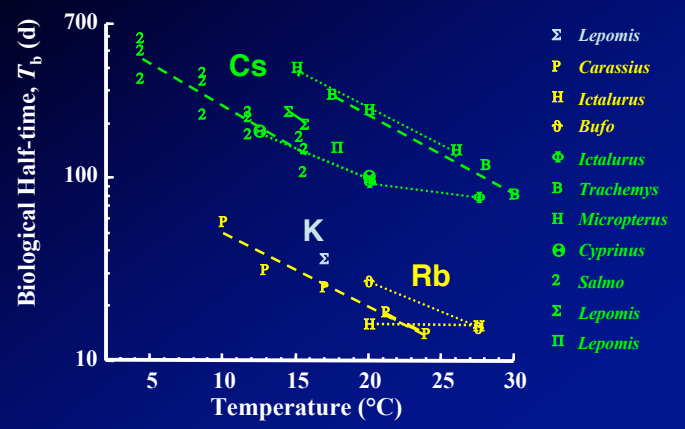
- As with both K and Rb, Cs is *bioaccumulated*, i.e., it is highly concentrated (intracelluarly) in living organisms relative to its concentration in the environment
  - ^{137}Cs concentrations in skeletal muscle of fishes are 100s to 1000s of times greater than in freshwater
  - Consumption of fishes and other animals is therefore an important source of human exposure
- K, Rb, and Cs have similar assimilation efficiencies, but…

Characteristics of Group IA (Alkali) Metals

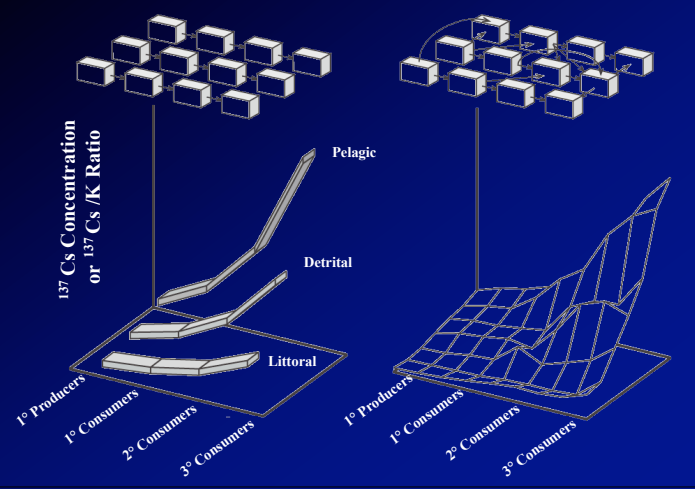
- Unlike K and Rb, Cs appears to *biomagnify*: both Cs concentrations and Cs/K ratios increase with trophic level, but *this is controversial*:
  - In several communities studied, Cs concentrations and Cs/K ratios increased by 2–3× with each increasing trophic level (Reichle and Nelson 1970, Whicker and Schultz 1982)
  - Whicker, et al. (1990)* noted that gizzard shad, which are phytoplanktivorous, had the *highest* ^{137}Cs levels among Pond B fishes
  - In one study (Lidén and Gustafsson 1967), Cs/K ratios increased by 7× with each increasing trophic level
- Cesium biomagnification patterns seem more consistent where trophic structure is more linear, e.g., arctic ecosystems or agroecosystems with forage → livestock → human 'chains'

*Whicker, F.W., J.E. Pinder, III, J.W. Bowling, J.J. Alberts, and I.L. Brisbin, Jr. 1990. Distribution of long-lived radionuclides in an abandoned reactor cooling reservoir. *Ecol Monogr* 60:471-496.

Elimination half-times (T_b's) of Cs are 2-7× longer than those of K and Rb



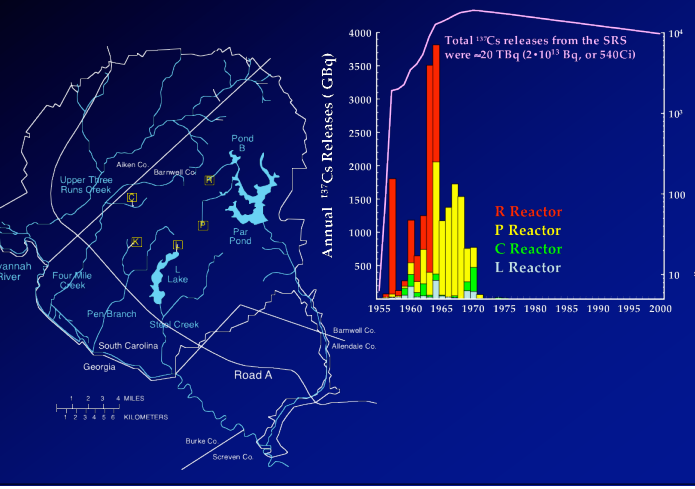
Influence of Trophic Structure on ^{137}Cs Concentration



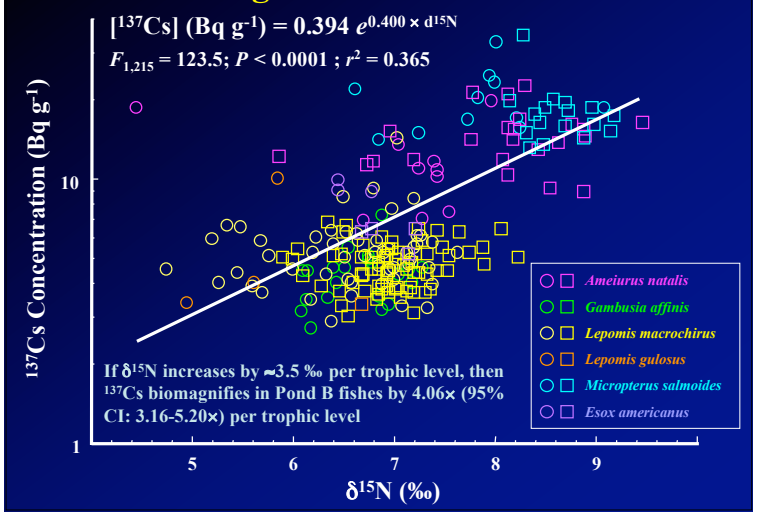
Addressing Potential ^{137}Cs Biomagnification Using Stable Isotopes

- If ^{137}Cs is biomagnified, then there should be a positive correlation between δ^{15}N and ^{137}Cs concentration
- If ^{137}Cs concentrations differ in various producer classes (phytoplankton, periphyton, macrophytes, emergent or upland plants), then the trophic increase in ^{137}Cs may need to be corrected for contributions from these different carbon sources

^{137}Cs Releases at the Savannah River Site



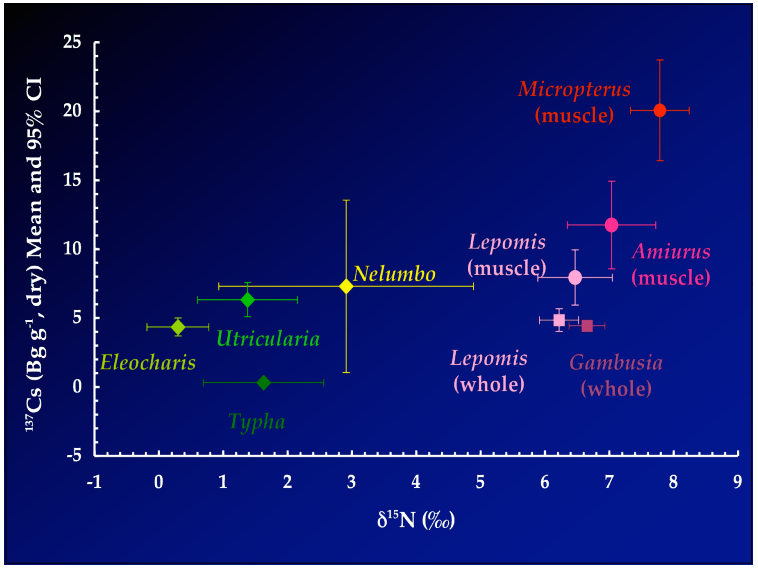
^{137}Cs Biomagnification in Pond B Fishes

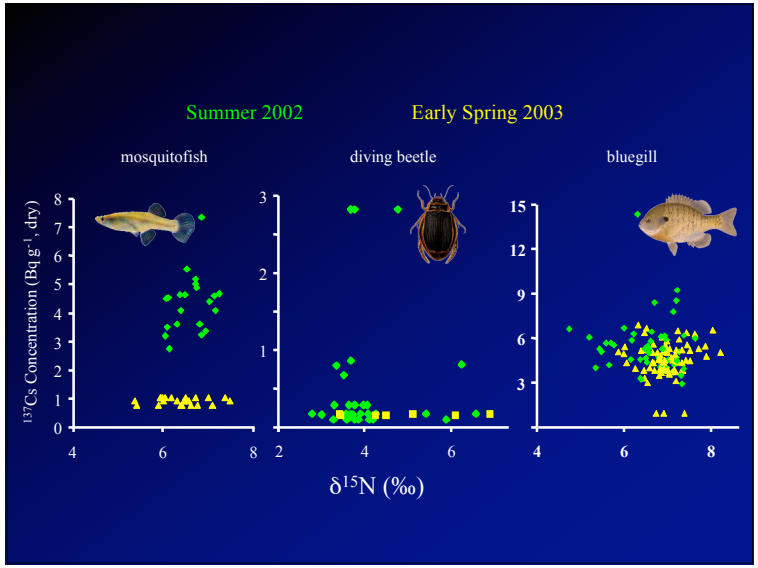


^{137}Cs Biomagnification in Pond B Fishes

Analysis of variance of δ^{15}N and δ^{13}C enrichment (‰) on $\log_e$-transformed ^{137}Cs concentrations (Bq g^{-1}) of Pond B fishes. For the overall model, $F_{3,213} = 56.91$; $P < 0.0001$; and $R^2 = 0.445$.

Source	*df*	*F*	*P*
δ^{15}N	1	15.61	0.0001
δ^{13}C	1	14.39	0.0002
δ^{15}N × δ^{13}C	1	10.94	0.0011
Residual	213		





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