Progress on the Development of Parameter Values for Reference Animals and Plants

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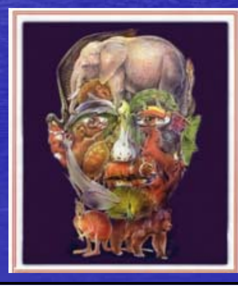
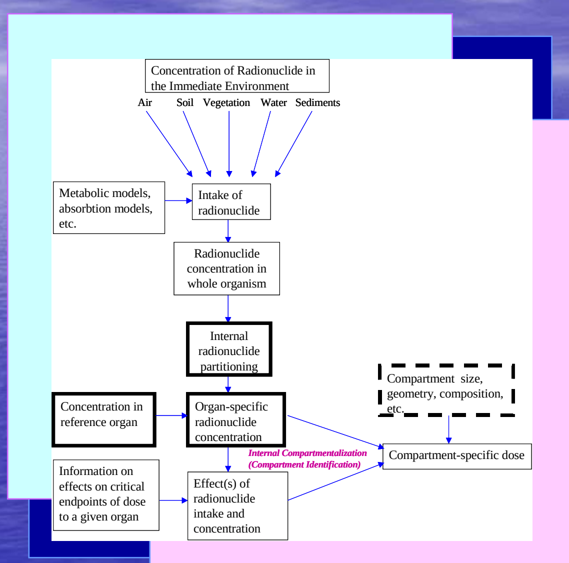


Interactions and Chemical Exchange between Organisms and their Environment



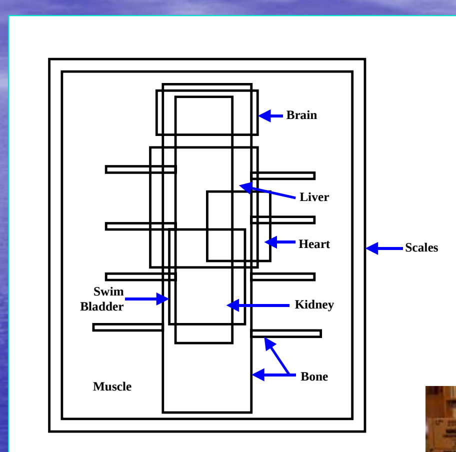
Where . . .

- Doses to non-human biota ("wildlife") are typically predicted on a whole-body basis.
- However, depending on the purpose of a given study, tissue-specific measurements may be taken, as opposed to those for the whole body.

(e.g., those for edible tissues in monitoring programs designed to assess radionuclide transfer to humans).

Specifically,

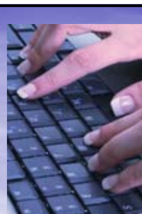
How do we use tissue-specific data to estimate whole-body values given the internal complexity of an organism?



e.g., the potential complexity of a fish

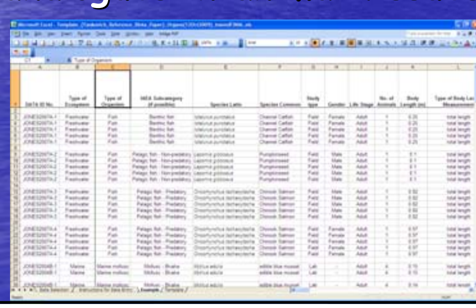
To Address this Question . . .

- An organism can be assessed using a mass balance approach *(e.g., Yankovich, 2009)*.
- In doing so, data on compartment sizes and the internal partitioning of radionuclides in a given tissue relative to a “reference tissue” could be used.



With this in Mind . . .

Efforts have been undertaken to compile available data on internal partitioning of radionuclides and stable analogues in animal tissues.



Where the Purpose was . . .

To estimate whole-body radionuclide concentrations based on measurements taken for specific tissues.



Data Requirements:


- ✓ Measurements taken at under steady state conditions.
- ✓ Realistic exposure conditions for laboratory experiments.
- ✓ Concentration data for at least two tissues or for one tissue plus whole-body.
- ✓ Tissue mass data for at least one tissue plus whole-body.
- ✓ Measurements taken for the same organism or group of organisms.

Scope of Compilation:

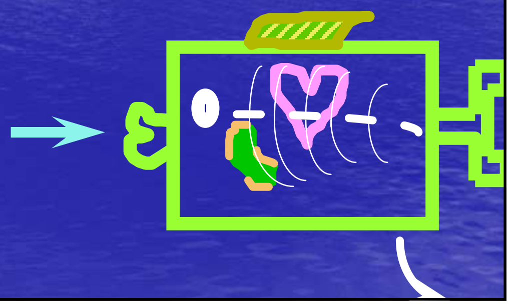
- ✓ Radionuclides of stable elements.
- ✓ Freshwater, marine and terrestrial ecosystems.
- ✓ Wild and domesticated vertebrates and invertebrates.
- ✓ Whole-body, muscle, bone, liver, kidney and gonad tissues.
- ✓ Where possible, animals were categorized by IAEA 'wildlife' category.

Outcome . . .

An estimation of whole-body radionuclide (or stable analogue) concentrations based on measurements taken for specific animal tissues.

To Date…..

Focus has been placed on developing conversion factors for animals, with the intent to switch focus to plants, once complete.



Compilation of Compartment Size

Table 1

Predictive relationships between whole body weight (in kg fresh weight), *X*, and tissue weight (in g fresh weight) for teleost fishes, *Y* (Crile and Quiring, 1940; Muir and Hughes, 1969; Quiring, 1950; Reynolds and Karlotski, 1977; Yankovich, 2002).

Tissue type	Relationship between whole body weight and tissue biomass	Tissue-to-body weight (%) geomean (Min.–Max.) [*n*]
Bone	$Y=40.68X^{1.03}$ ($r^2=0.992$)	4.71 (2.34–9.1) [17]
Gills	n.a.	1.3 (0.7–1.8) [4]
Scales	n.a.	7.0 [1]
Brain	$Y=0.960X^{0.504}$ ($r^2=0.747$)	0.087 (7.02×10^{-5}–2.29) [183]
Eyes	$Y=5.36X^{0.76}$ ($r^2=0.727$)	0.504 (0.034–1.65) [174]
Gizzard	n.a.	1.80 (1.8, 1.8) [2]
Gizzard Contents	n.a.	0.242 (0.03–0.7) [5]
Gonads (female)	$Y=3.67X^{0.729}$ ($r^2=0.340$)	1.53 (0.040–6.41) [39]
Gonads (male)	$Y=2.03X^{1.13}$ ($r^2=0.421$)	0.860 (0.034–1.8) [35]
Heart	$Y=1.92X^{1.00}$ ($r^2=0.915$)	0.192 (0.077–2.71) [180]
Kidney	$Y=5.16X^{1.03}$ ($r^2=0.891$)	0.518 (0.155–1.44) [137]
Liver	$Y=13.42X^{1.08}$ ($r^2=0.899$)	1.43 (0.222–6.23) [216]
Muscle	n.a.	64.3 (55.3–76.7) [5]
Skin	n.a.	7.1 [1]
Skin and scales	n.a.	12.0 (9.3–14.1) [5]
Spleen	$Y=1.12X^{0.98}$ ($r^2=0.856$)	0.112 (0.031–0.413) [77]
Stomach/ intestine	$Y=39.61X+36.76$ ($r^2=0.894$)	5.06 (0.200–12.3) [157]
Thyroid	$Y=0.0131X+8\times10^{-5}$ ($r^2=0.628$)	1.42×10^{-3} (2.03×10^{-6}–0.162) [170]
Viscera	n.a.	10.4 (6.5–16.1) [3]

Compilation of Internal Partitioning Data

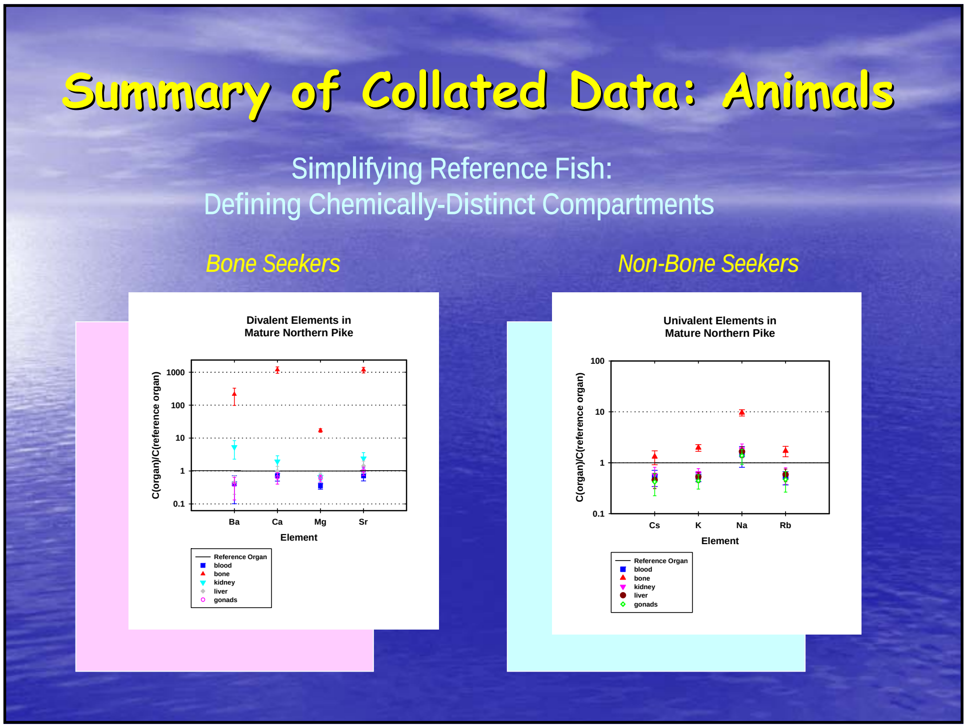
Table 2
Tissue-specific concentration ratios (CR_t) for stable nuclides measured in edible tissues from fishes ($n = 15$) collected in Perch Lake (PL) relative to those reported in the scientific literature (lit.) (as summarized in Yankovich and Beaton, 2000).

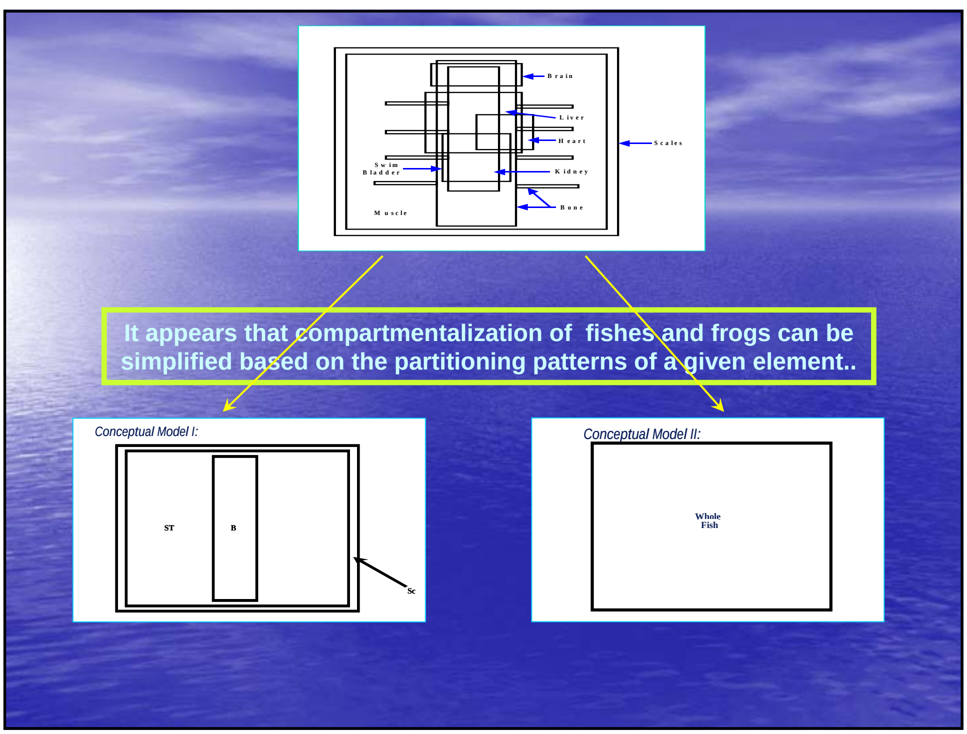
Type of nuclide	Nuclide, *n*	Mean tissue-to-muscle concentration ratio (CR_t) in edible fish tissues ± standard deviation [*n*]			
		Gonads	Liver	Bone	Whole
Alkali metals	Cs	0.578 ± 0.185 (PL)	0.45 ± 0.035 (PL)	2.07 ± 0.62 (PL)	n.m.
	K	0.615 ± 0.205 (PL)	0.56 ± 0.053 (PL)	2.49 ± 0.65 (PL)	n.m.
	Na	2.2 [1] (lit.); 1.29 ± 0.194 (PL)	1.1 [1] (lit.); 1.37 ± 0.31 (PL)	8.0 [1] (lit.); 9.28 ± 2.16 (PL)	n.m.
	Rb	0.659 ± 0.240 (PL)	0.57 ± 0.020 (PL)	2.4 [1] (lit.); 2.42 ± 0.77 (PL)	n.m.
Alkaline earth metals	Ba	0.441 ± 0.154 (PL)	0.41 ± 0.17 (PL)	235 ± 205 (PL)	n.m.
	Ca	0.888 ± 0.670 (PL)	0.87 ± 0.56 (PL)	954 ± 709 [9] (lit.); 938 ± 342 (PL)	n.m.
	Mg	0.701 ± 0.200 (PL)	0.73 ± 0.10 (PL)	14.7 ± 2.53 (PL)	n.m.
	Sr	1.1 [1] (lit.); 1.14 ± 0.638 (PL)	2.9 [1] (lit.); 1.18 ± 0.69 (PL)	291 ± 389 [7] (lit.); 971 ± 217 (PL)	23 ± 27 [2] (lit.)
Basic metals	Al	2.04 ± 2.10 (PL)	2.13 ± 1.96 (PL)	3.08 ± 2.89 (PL)	n.m.
	Tl	1.87 ± 1.92 (PL)	3.97 ± 3.82 (PL)	12.2 ± 3.87 (PL)	n.m.
	Pb	1.9 ± 1.9 [19] (lit.);0.980 ± 0.535 (PL)	3.9 ± 11 [67] (lit.); 16.1 ± 23.5 (PL)	15 ± 9.5 [11] (lit.); 6.26 ± 1.91 (PL)	9.0 ± 15 [14] (lit.)
Rare earth elements (Lanthanides)	Ce	16.8 ± 16.5 (PL)	4.26 ± 0.68 (PL)	6.10 ± 4.79 (PL)	n.m.
	Eu	3.48 ± 3.94 (PL)	2.32 ± 0.57 (PL)	11.8 ± 1.04 (PL)	n.m.
	La	17.3 ± 18.8 (PL)	3.3 [1] (lit.); 3.86 ± 1.38 (PL)	8.0 [1] (lit.); 6.63 ± 6.64 (PL)	13 [1] (lit.)
Rare earth elements (Actinides)	Th	2.89 ± 3.07 (PL)	1.78 ± 1.30 (PL)	11.6 ± 16.4 (PL)	n.m.
	U	4.43 ± 5.69 (PL)	2.8 ± 1.1 [5] (lit.); 1.74 ± 1.51 (PL)	56 ± 72 [12] (lit.); 6.37 ± 3.86 (PL)	14 ± 22 [7] (lit.)
Metalloids	Sb	1.87 ± 0.887 (PL)	2.55 ± 2.63 (PL)	8.95 ± 3.34 (PL)	n.m.
	Te	3.34 ± 2.07 (PL)	2.26 ± 0.98 (PL)	3.51 ± 1.26 (PL)	n.m.
Non metals	P	2.4 [1] (lit.); 1.07 ± 0.306 (PL)	5.5 [1] (lit.); 1.21 ± 0.24 (PL)	16 [1] (lit.); 46.3 ± 8.99 (PL)	n.m.
Transition metals	Cd	2.8 ± 4.1 [22] (lit.); 1.72 ± 1.01 (PL)	23 ± 53 [32] (lit.); 7.85 ± 9.05 (PL)	3.93 ± 4.22 (PL)	n.m.
	Co	4.35 ± 2.33 (PL)	5.7 ± 7.6 [5] (lit.); 3.45 ± 2.34 (PL)	4.1 ± 5.3 [8] (lit.); 23.1 ± 22.6 (PL)	12 ± 22 [4] (lit.)
	Cr	1.69 ± 1.16 (PL)	1.8 [1] (lit.); 1.40 ± 0.40 (PL)	0.27 [1] (lit.); 8.91 ± 9.84 (PL)	3.8 [1] (lit.)
	Cu	2.3 ± 1.4 [14] (lit.); 6.23 ± 5.42 (PL)	30 ± 56 [26] (lit.); 35.0 ± 27.3 (PL)	4.1 [1] (lit.); 2.16 ± 0.355 (PL)	n.m.
	Fe	2.4 ± 2.4 [9] (lit.); 29.0 ± 24.8 (PL)	18 ± 19 [16] (lit.); 203 ± 151 (PL)	1.5 ± 0.91 [5] (lit.); 4.19 ± 1.94 (PL)	5 [1] (lit.)
	Mn	1.6 ± 1.1 [11] (lit.); 13.8 ± 10.9 (PL)	4.6 ± 4.0 [19] (lit.); 6.42 ± 1.85 (PL)	8.9 ± 2.3 [4] (lit.); 325 ± 148 (PL)	9.1 ± 10 [3] (lit.)
	Mo	8.30 ± 7.15 (PL)	31.8 ± 7.75 (PL)	4.97 ± 1.24 (PL)	n.m.
	Ni	0.60 ± 0.011 [2] (lit.); 1.89 ± 0.345 (PL)	2.1 ± 1.1 [11] (lit.); 2.14 ± 1.09 (PL)	11.3 ± 5.03 (PL)	n.m.
	Sc	Not available	3.2 ± 4.6 [2] (lit.)	11 ± 15 [2] (lit.)	30 [1] (lit.)
	V	3.24 ± 3.00 (PL)	3.24 ± 2.01 (PL)	6.18 ± 6.00 (PL)	n.m.
	Y	9.60 ± 14.6 (PL)	5.12 ± 2.94 (PL)	6.37 ± 3.86 (PL)	n.m.
	Zn	7.3 ± 5.1 [21] (lit.); 15.1 ± 9.83 (PL)	5.8 ± 6.6 [39] (lit.); 9.02 ± 5.59 (PL)	7.3 ± 2.1 [6] (lit.); 23.6 ± 12.1 (PL)	99 [1] (lit.)
	Zr	1.82 ± 1.37 (PL)	1.35 ± 0.22 (PL)	1.1 [1] (lit.); 4.57 ± 1.77 (PL)	

n.m. – not measured.

Based on this Analysis:

Similarities between groups of elements have been used to estimate expected internal partitioning patterns within an organism.


Summary of Collated Data: Animals
Simplifying Reference Fish:
Defining Chemically-Distinct Compartments
Bone Seekers
Non-Bone Seekers
Divalent Elements in
Mature Northern Pike
C(organ)/C(reference organ)
1000
100
10
1
0.1
Ba
Ca
Mg
Sr
Element
Reference Organ
blood
bone
kidney
liver
gonads
Univalent Elements in
Mature Northern Pike
C(organ)/C(reference organ)
100
10
1
0.1
Cs
K
Na
Rb
Element
Reference Organ
blood
bone
kidney
liver
gonads


Brain
Liver
Heart
Scales
Swim
Bladder
Kidney
Bone
Muscle
It appears that compartmentalization of fishes and frogs can be simplified based on the partitioning patterns of a given element..
Conceptual Model I:
ST
B
Sc
Conceptual Model II:
Whole
Fish

Work is Available on This . . . . .

Yankovich, 2009. Mass balance approach to estimating radionuclide loads and concentrations in edible fish tissues using stable analogues. Journal of Environmental Radiactivity, doi:10.1016/j.jenvrad.2009.05.001.

(from the EMRAS I update of IAEA TRS 364)

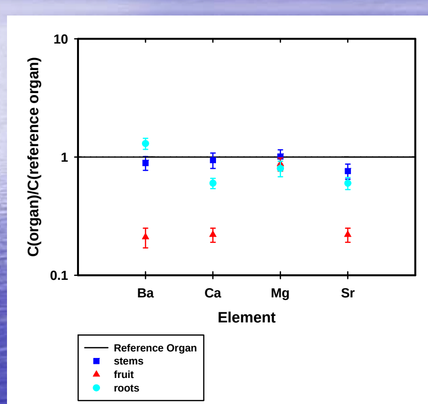
... from a human perspective.

Summary of Outcome: Animals

- ✓ A series of look-up tables with tissue-to-whole body for radionuclides and stable isotopes in the specified animal categories.
- ✓ As context, tables containing the % biomasses of specified tissues with respect to the whole-body biomass have been compiled.
- ✓ Data are also available on tissue water contents, ash contents, % C contents.

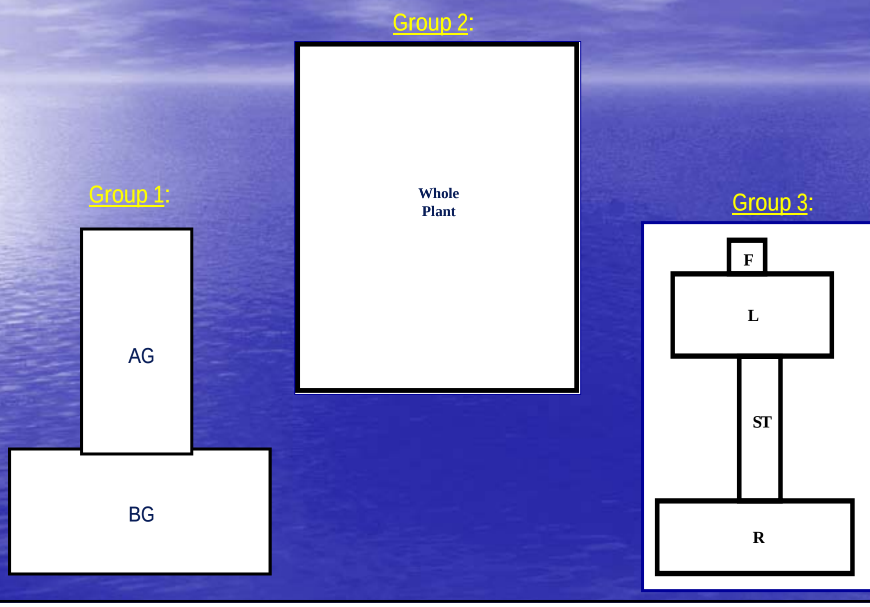
Summary of Findings for Reference Plant

Similar Work is Underway for Plants



- ✓ It seems possible to develop conversion factors for plants, as well.
- ✓ With relatively consistent patterns occurring for similar types of elements.
- ✓ A key question is how to compartmentalize the plant.

Conceptual Models of Reference Plant



Status Summary:

- ✓ Look up tables have been generated for marine fish, mammals, birds reptiles and amphibians (freshwater fish tables to be finalized this week).
- ✓ Based on these data, a paper has been drafted for submission as part of a special edition.
- ✓ Input of data has been received from UK, Japan, Norway, Sweden, Australia and Canada.
- ✓ Work is underway to compile data on plants (participation welcome!)

Applications . . . . .

- Development of Reference Biota
- Use/Standardization of Existing Data
- Sample Processing
- Improvement of Dose Estimates
- Further Understanding

Database QA/QC Document:

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. . . . . Thank YOU!