Characterization of absorbed dose from natural and anthropogenic radionuclides for the purpose of establishing reference points within the marine environment

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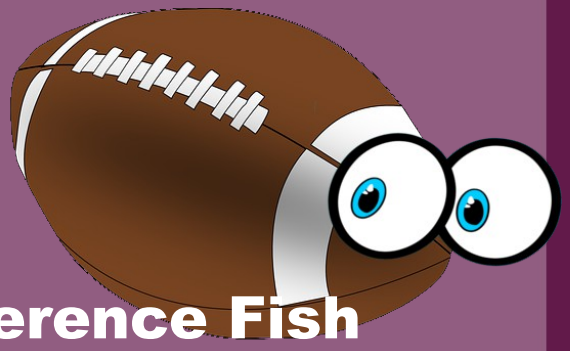
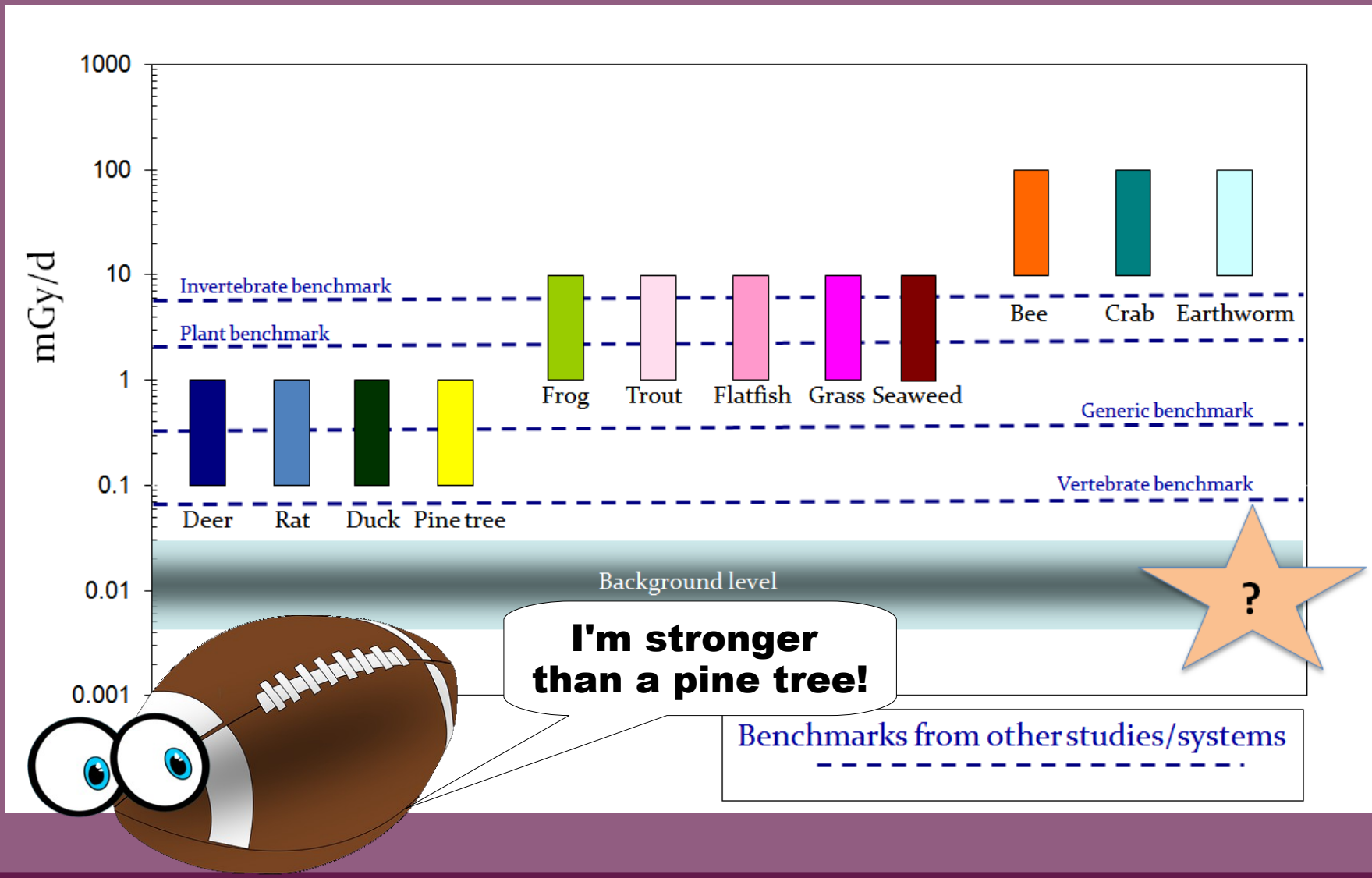
Outline

- Derived Consideration Reference Levels (DCRLs)
- Methodology
- Data Gaps & Challenges
- Northern California Current Estimates



Wilson, the Reference Fish

DCRLs – ICRP 108



DCRLs – Why?

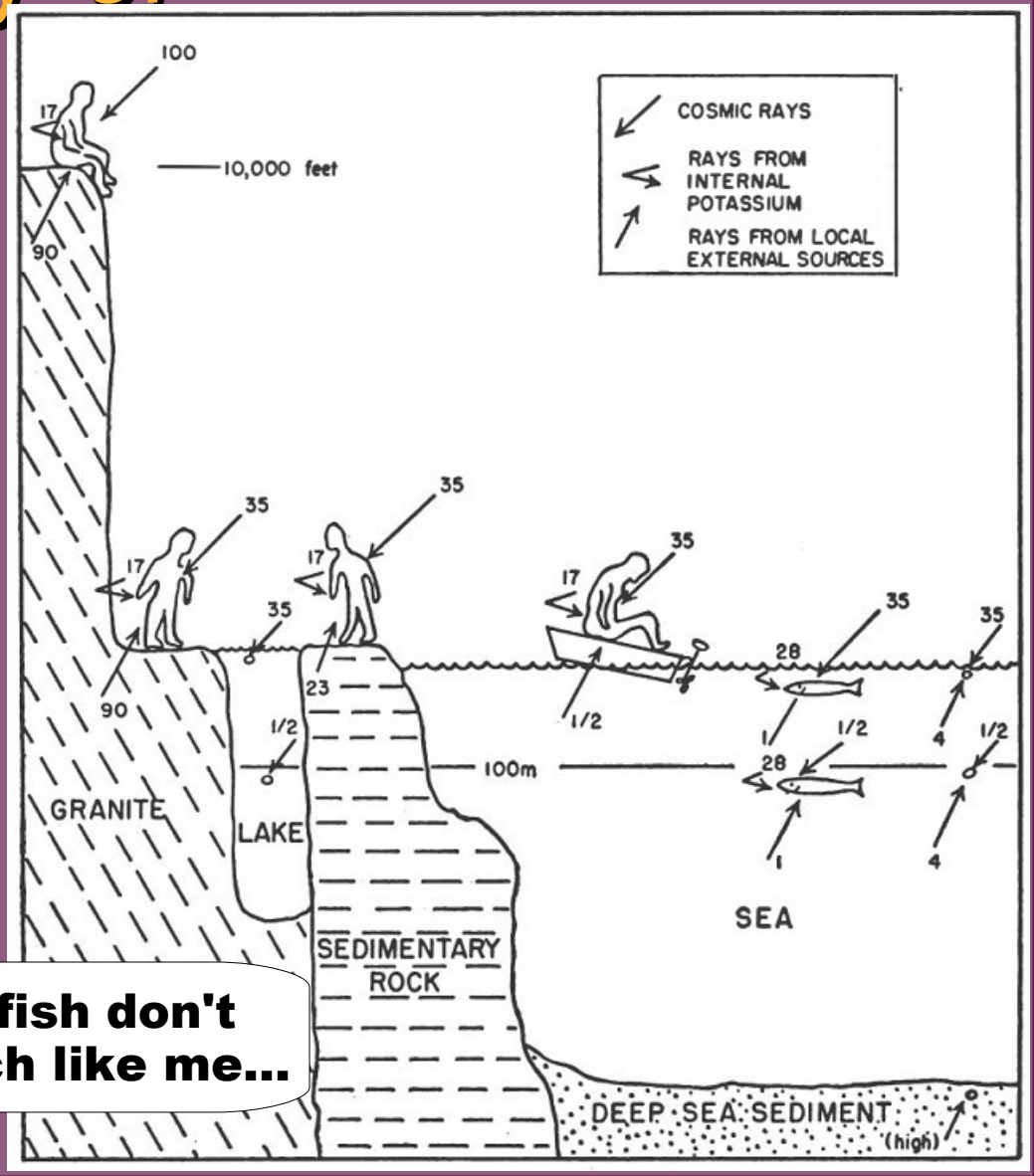
- Animal studies on dose-effect relationships
  - Limited in number
  - Most on mammals (basis for humans)
  - High dose-rates and total doses
  - No other stressors
- Derived Consideration Reference Level
  - Baseline of comparison
  - Define bands where concern may be warranted

Existing Work: NCC Normal Dose

- Folsom & Harley '57
- Holtzman '67
- Woodhead '73
- Brown et al. '04: FASSET
- ICRP 108 '08

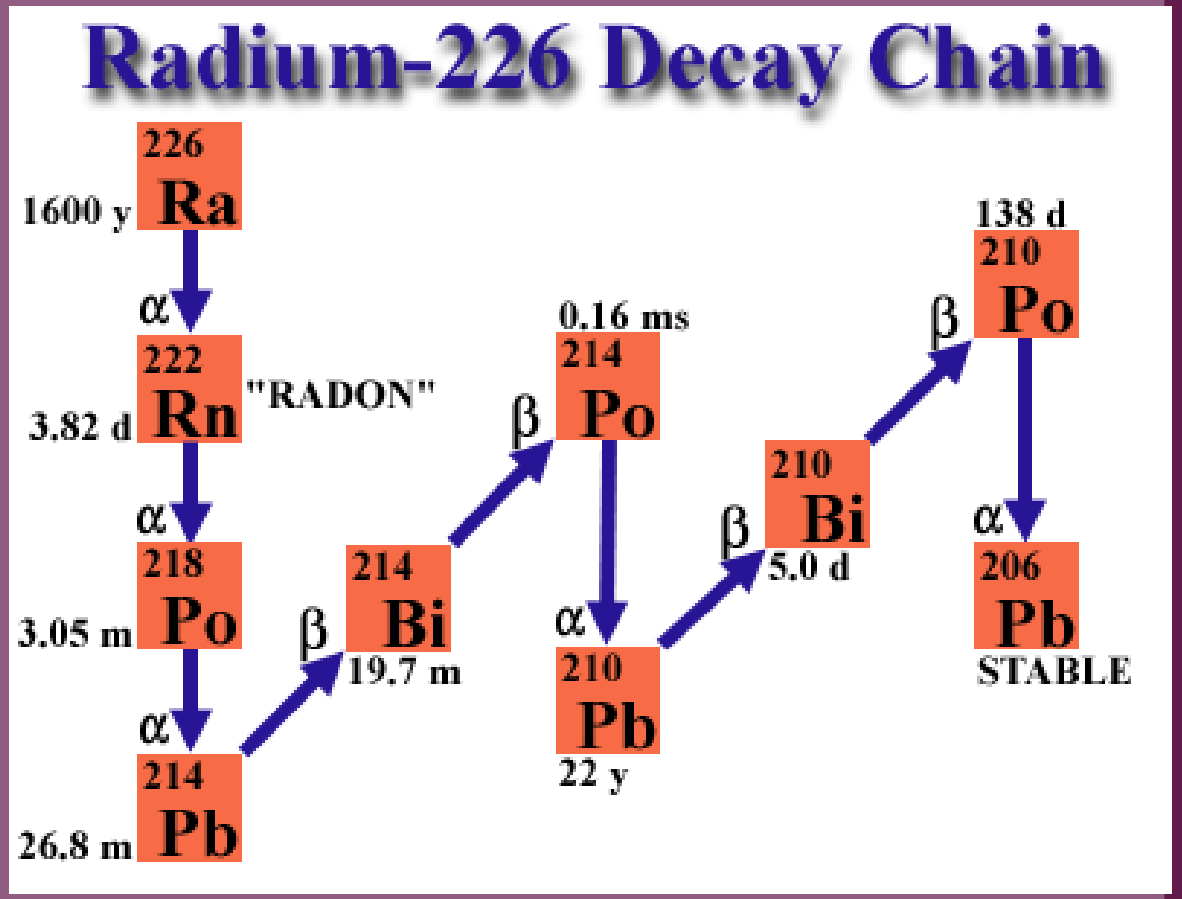
Folsom & Harley '57

- Seawater: K-40
- Cosmic rays
- Organism size
  - Only for betas
    - Discussed
    - Not in calcs



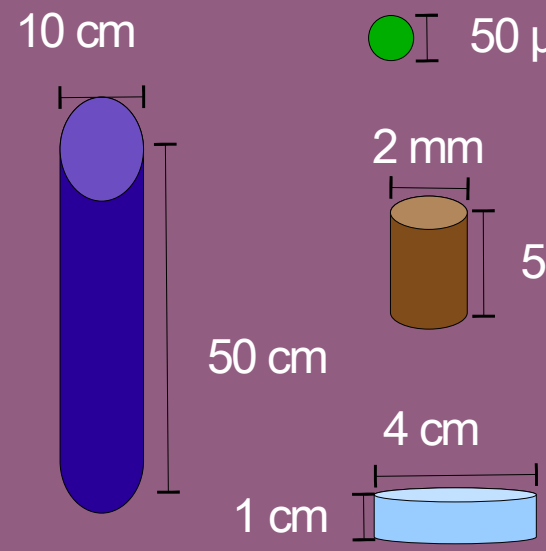
Holtzman '67

- K-40
- Ra-226 series
  - Esp. Po-210!
- Cosmic rays
- Organism size
  - Undefined

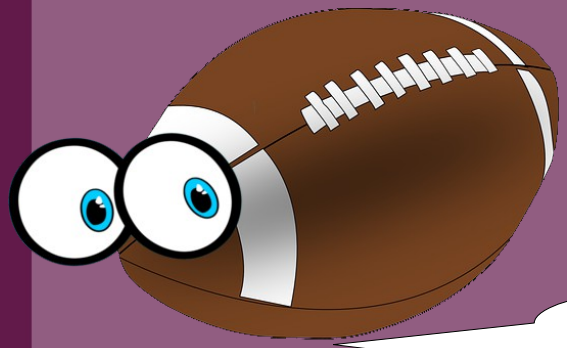


Woodhead '73

- K-40
- C-14
- H-3
- Rb-87
- Actinides



- Ra-226 series
  - Esp. Po-210!
  - Cosmic rays
- Organism size
  - By taxa
  - α/β Penetration
- Concentrations
  - By taxa
  - Global Avg. or UK



Fish in the UK sure look a lot different than me…

Top to bottom, right to left: phytoplankton, zooplankton mollusc, crab, fish

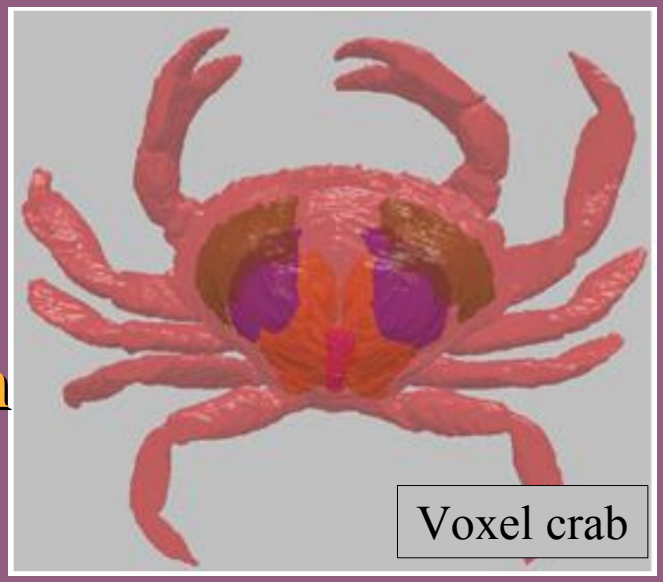
FASSET

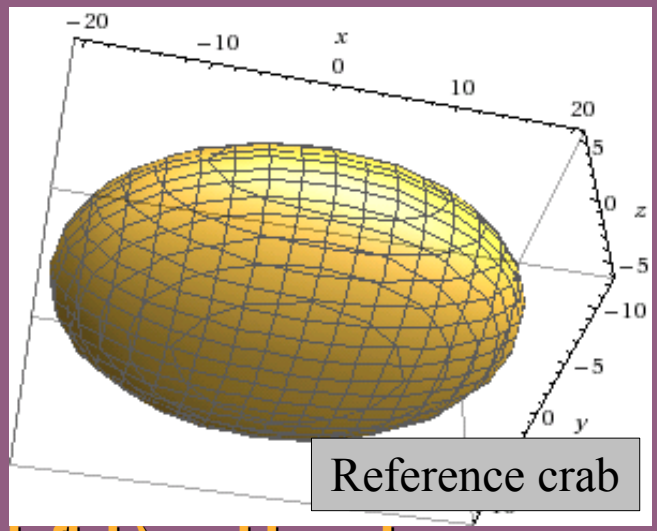
- Radionuclides as in Woodhead
- Explicitly focused on Europe
- Size & Concentrations
  - By taxa as in Woodhead
    - Bacteria, macroalgae, mammals added
  - Uniform concentrations per muscle data
  - Ellipsoid geometry
  - Same geometry used in current ICRP RAPs

Wilson the Reference Flying Fish

ICRP RAPs - Modern

- Reference Animals and Plants
  - 12 RAPs total
  - Ellipsoids, uniform composition
    - Deer has testes & liver
  - Voxels vs. "blobs" underway
    - No general pattern yet
- Marine RAPs
  - Crab
  - Flatfish
  - Brown seaweed
  - Primarily benthic*


Voxel crab

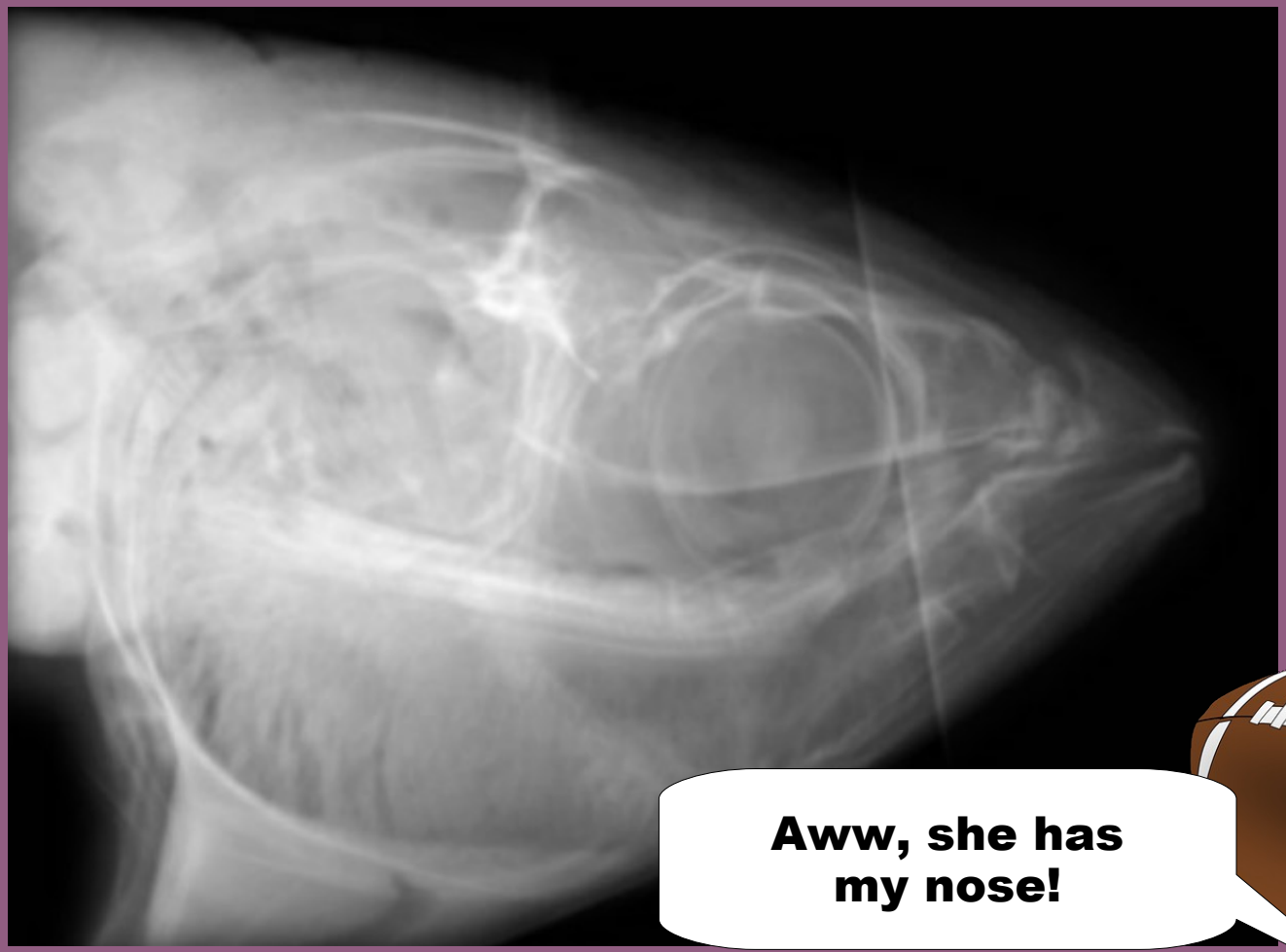


Reference crab

* Several larval flatfish, some juveniles (e.g. sablefish) and larval crabs (Megalopae) are found in the pelagic. The Reference Crab larvae model, however, is identical to a trout egg.

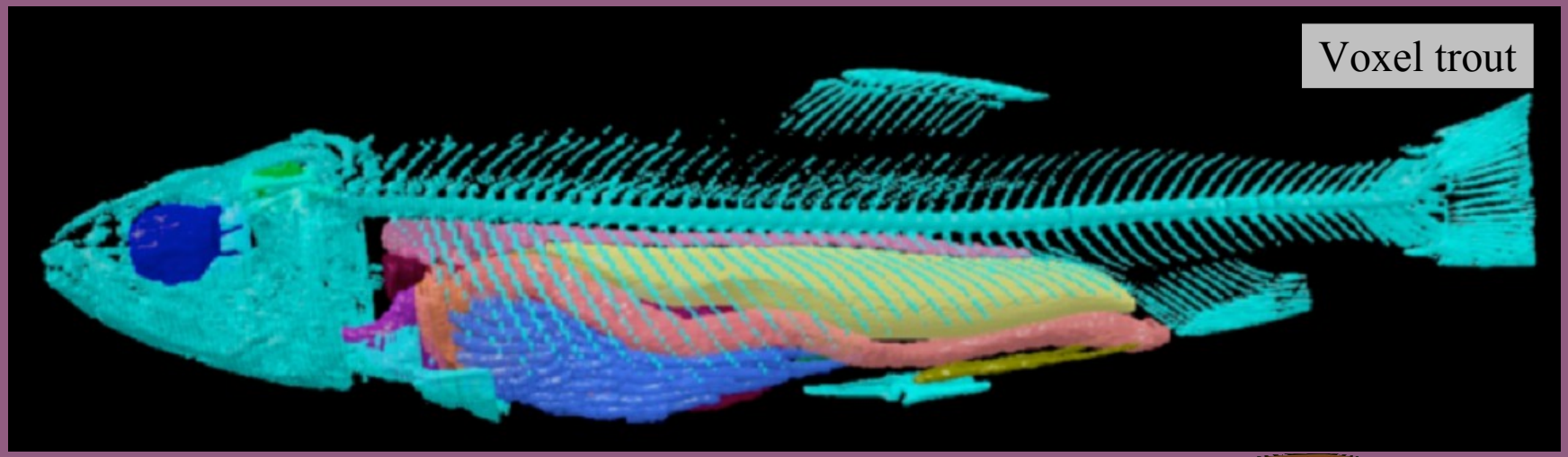
Methodology: Next Step

- **Create voxel model of *Thunnus alalunga***



Methodology – Next Step

- **Compare doses & DCFs for albacore versus:**
  - **Scaled trout voxel model**
  - **Ellipsoid**

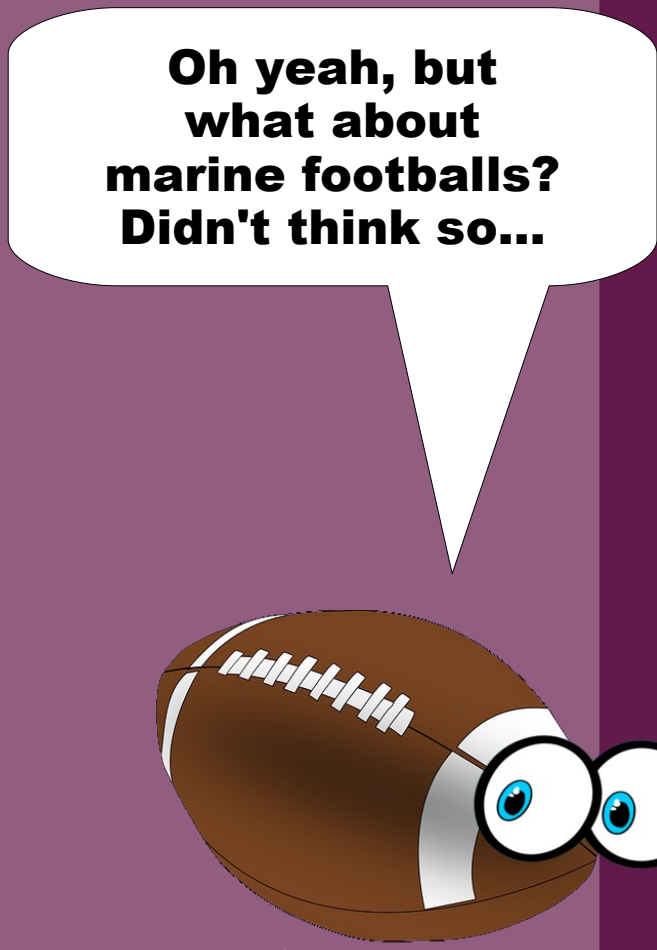


Methodology – Next Step

- Geometry
  - CT or MRI taken of whole albacore
  - Organ systems & tissues slice-by-slice
  - 3D model exported to MCNP
- Composition
  - Density by water displacement
  - Organic content by FAO data and trout RAP
  - Trace metal content by fallout CRs

Data Gaps in NCC – Po-210 & Pb-210

- **Substantial quantity of whole body data**
  - Sea cucumber / *Paleopatides*
  - Mixed zooplankton
  - Benthic *Polychaeta*
  - Lepas barnacles / *Lepas anatifera*
  - Copepods / *Acartia clausii*
  - Pelagic *Polychaeta* / *Tomopteris*
  - Chaetognaths / *Sagita elegans*
  - Shrimp / *Sergestes similis*
  - Medusae / *Atolla bairdii*
  - *And much, much more...*
- **Limited tissue specific**
  - Dolphin, myctophids, albacore



Data Gaps in NCC – K-40

- Previous work assumed isotopic abundance
- Effective for any organism with K concentrations known
  - e.g. Nutrition information for commercial species
- Detectable by gamma spectrometry
  - Most relevant organisms will be directly assayed
    - Sizes range from euphausiids and up

Data Gaps in NCC – Less Prominent

- Limited Ra-226 data for NCC biota
  - Sperm whale, salmon, tuna
  - Expands to include sea urchin & euphausiids from SCC
- Natural actinides wholly lacking in NCC data
- Cs-137
  - Until Fukushima, most recent data decades old
  - Much of the NCC work focused on activation products
- H-3, C-14
  - Plenty of seawater measurements
  - Can infer tissue concentrations by isotopic abundance

Data Gaps: External Sources

- Many differences from human/terrestrial dosimetry
  - No lungs -> Rn-222 essentially external only
  - Diurnal vertical migration
    - Cosmic rays shielded
    - Radionuclide vertical gradients
  - Surrounded by water
    - Electronic equilibrium at skin surface

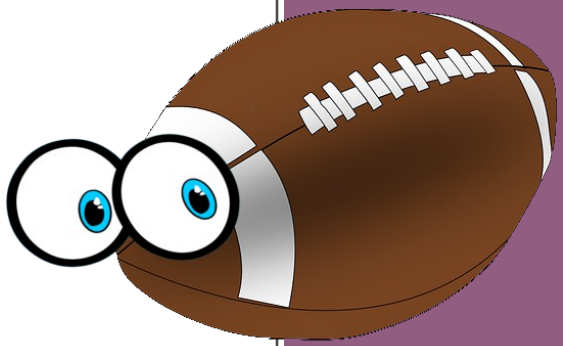
Dose Estimates

- Using ICRP RAP closest match
  - Size differences substantial
  - All other inaccuracies in geometry equal to RAPs
    - Ellipsoids
    - Uniform composition - human tissue
    - Uniform distribution of radionuclides

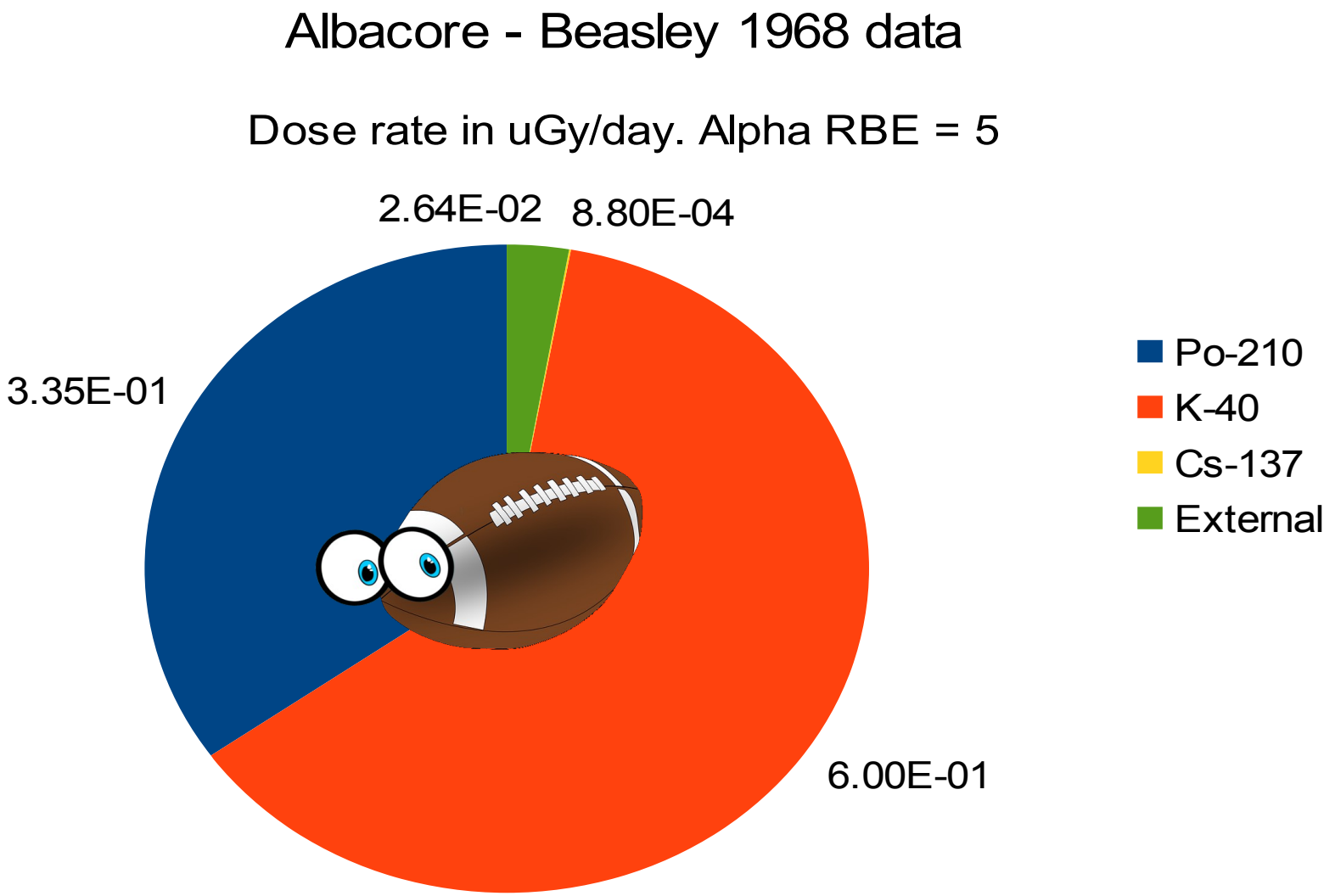
Dose Estimates

Dose rate ($mGy\ d^{-1}$)	Reference Frog	Reference Trout	Re
10-100	No positive 'effect' information.	Some deleterious effects expected on young fish, e.g., reduction in resistance to infections. Reduced reproductive success.	Reduced reproductive success.
1-10	No positive 'effect' information.	Possible reduced reproductive success.	Possible reduced reproductive success due to reduced fertility in males.
0.1-1	No information.	No information.	No information.

Reduced reproductive success? But I was made in the Wilson factory…



Dose Estimates



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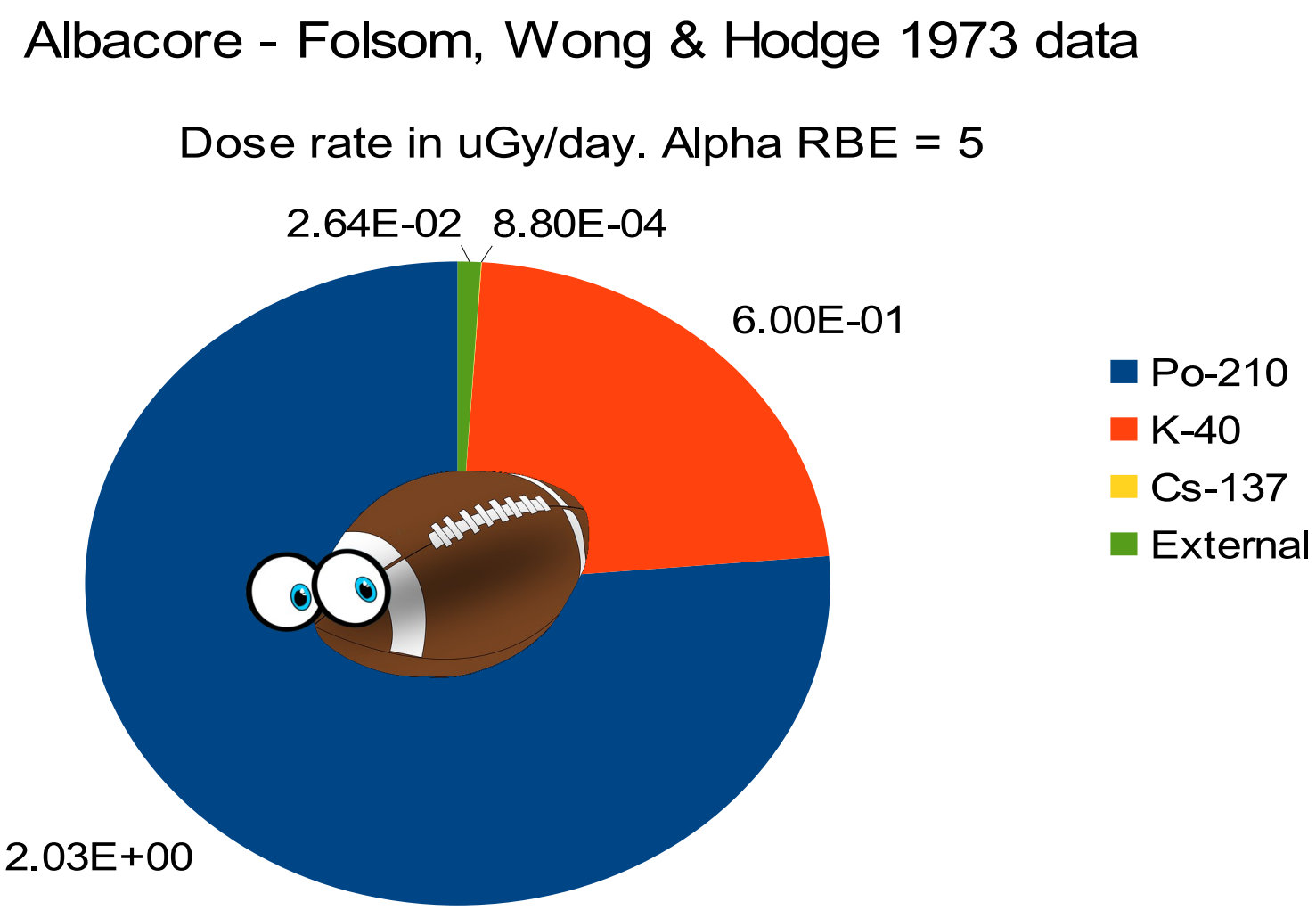

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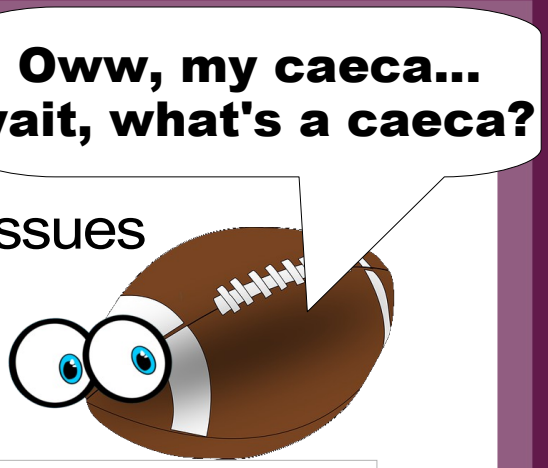
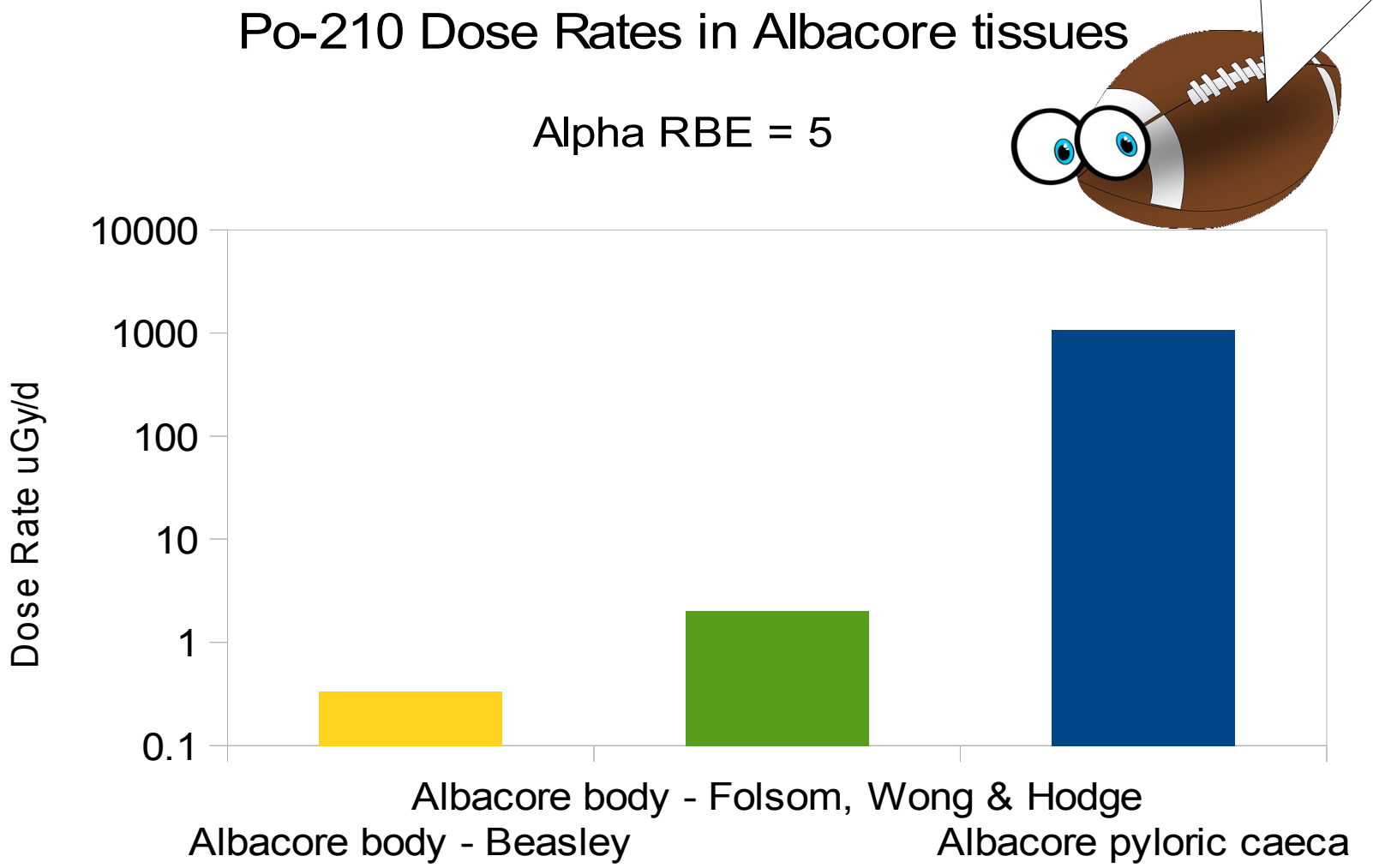
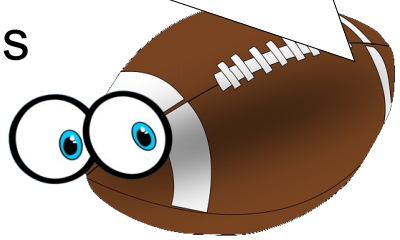
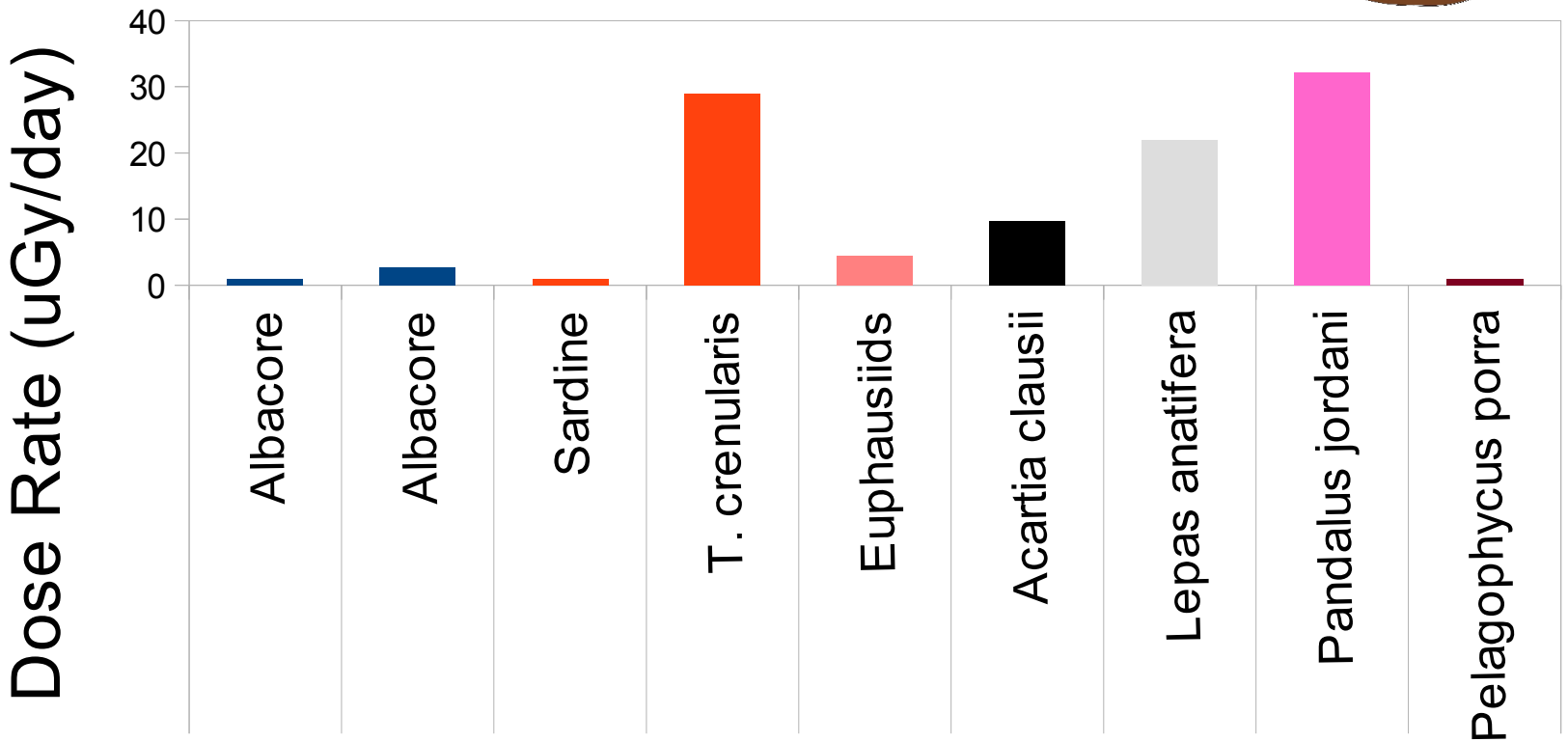




Dose Estimates

Epic battle!
Myctophid vs. Pink Shrimp!
They both look just like me!





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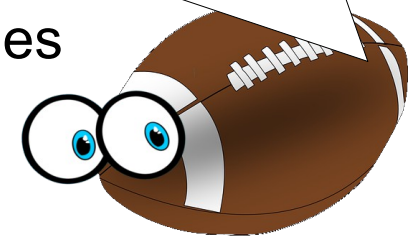
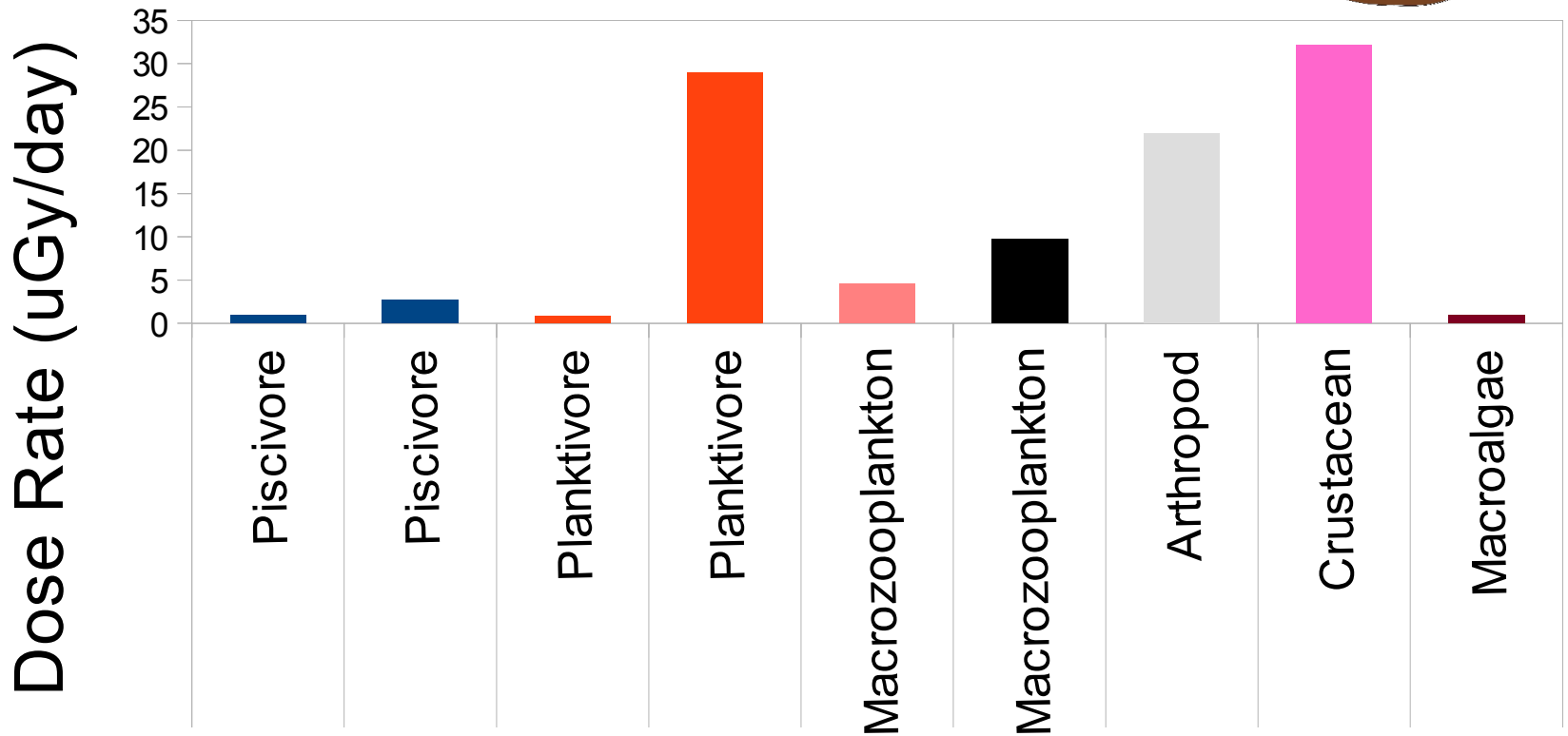
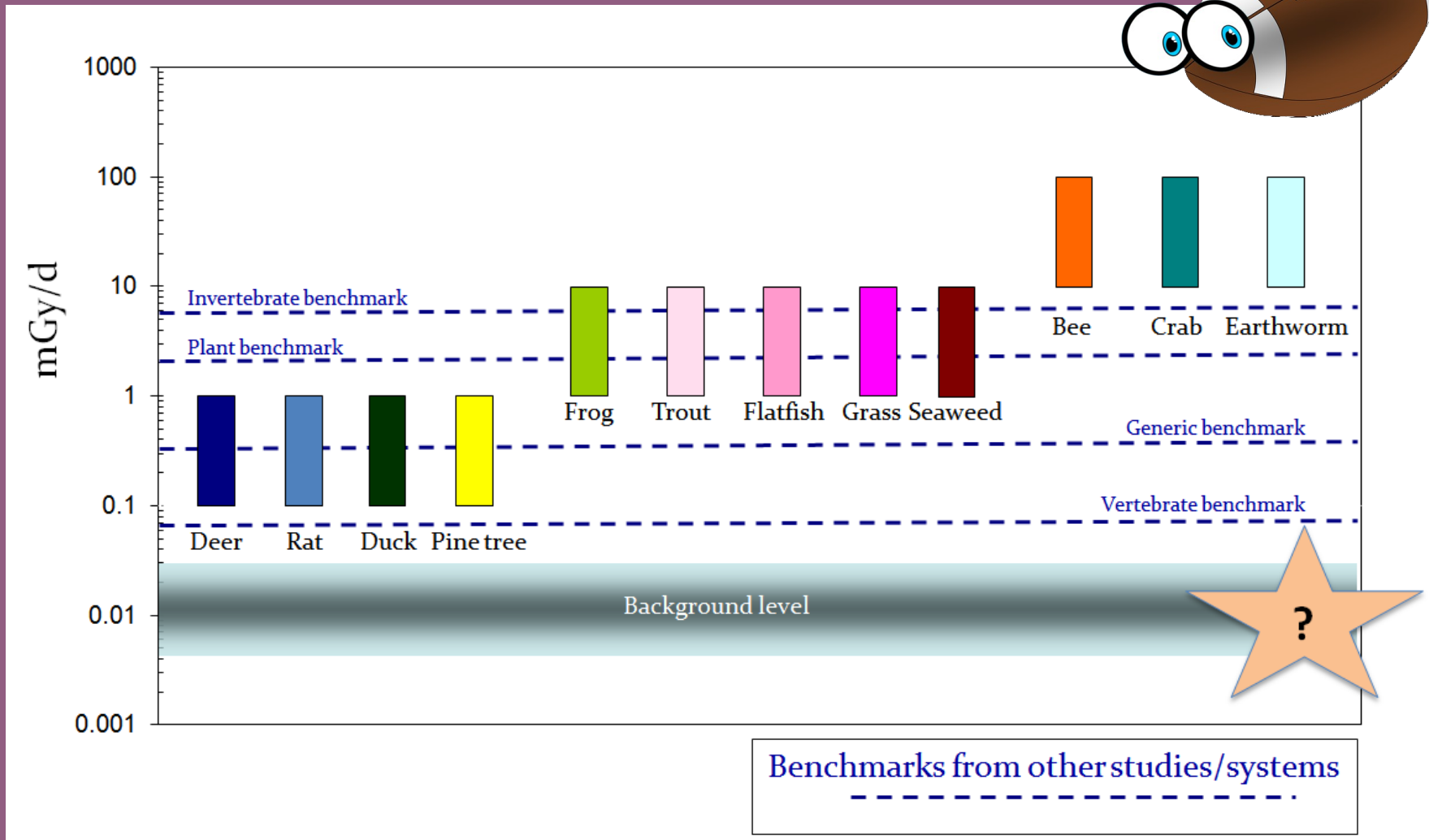


Dose Rates for Selected NCC Species

Homogenous ellipsoids. Alpha RBE=5



DCRLs – ICRP 108



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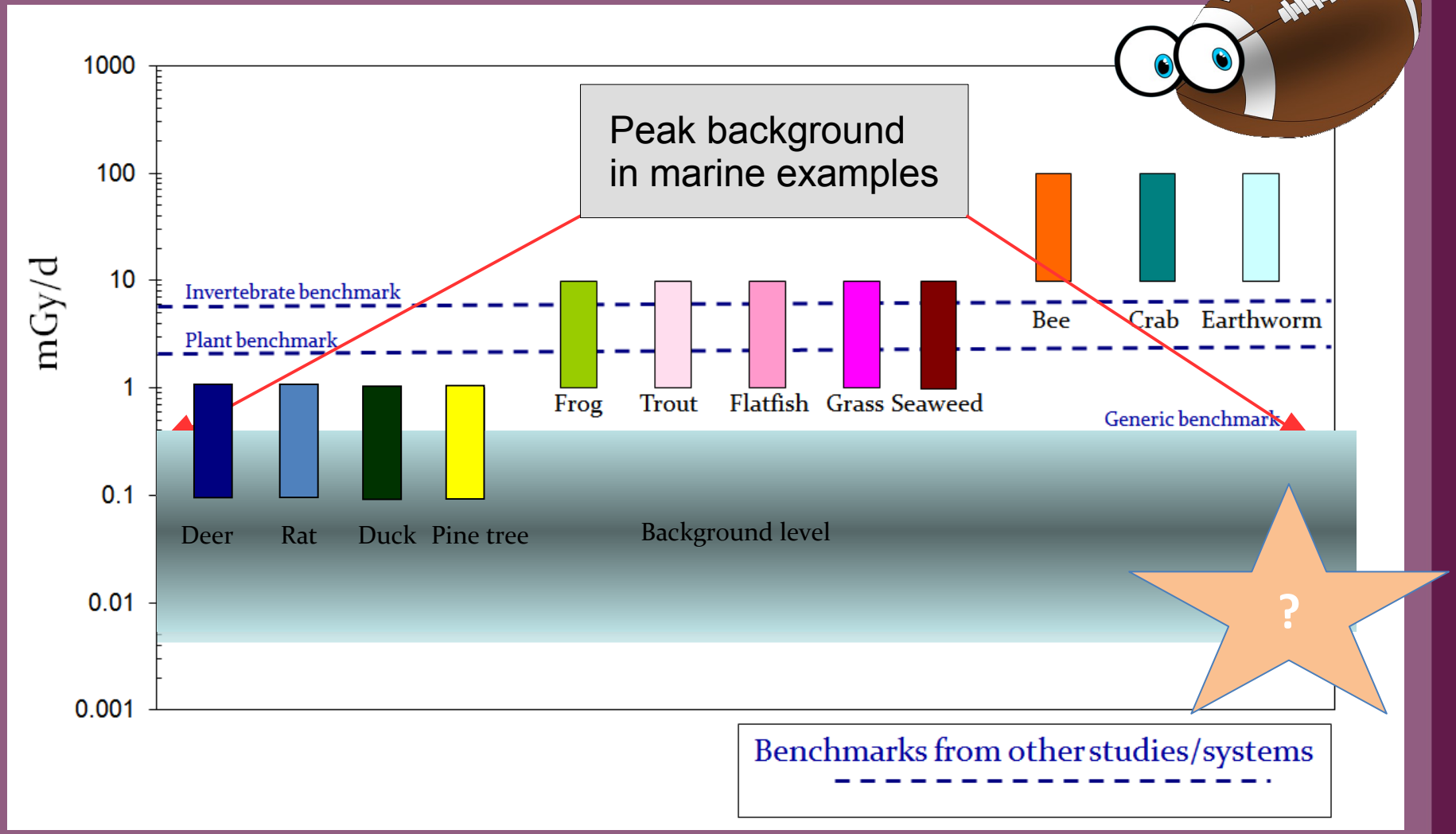

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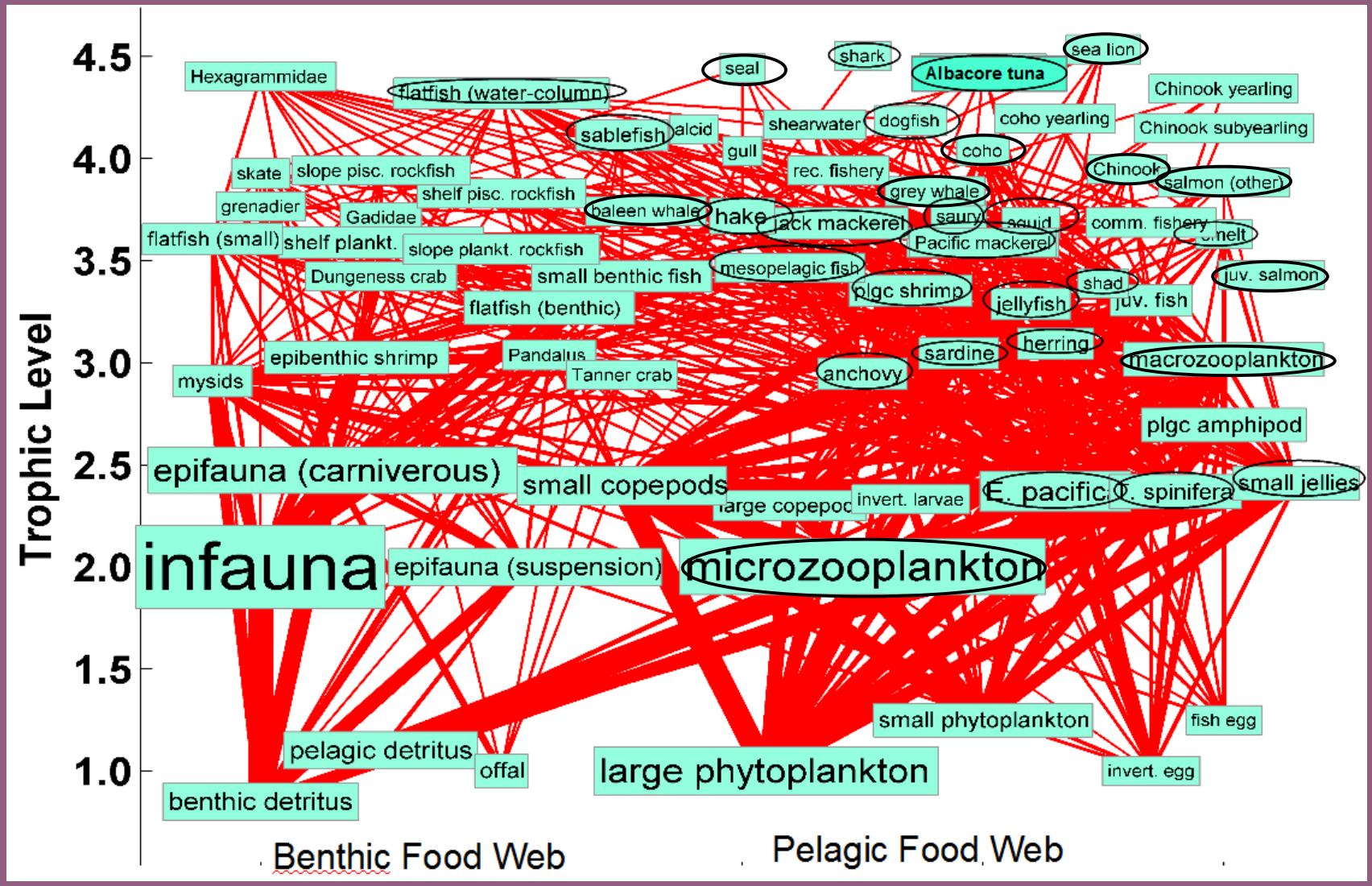
Questions?

Food Web Coverage