# Radiological Levels in North Pacific Seafood Consumption


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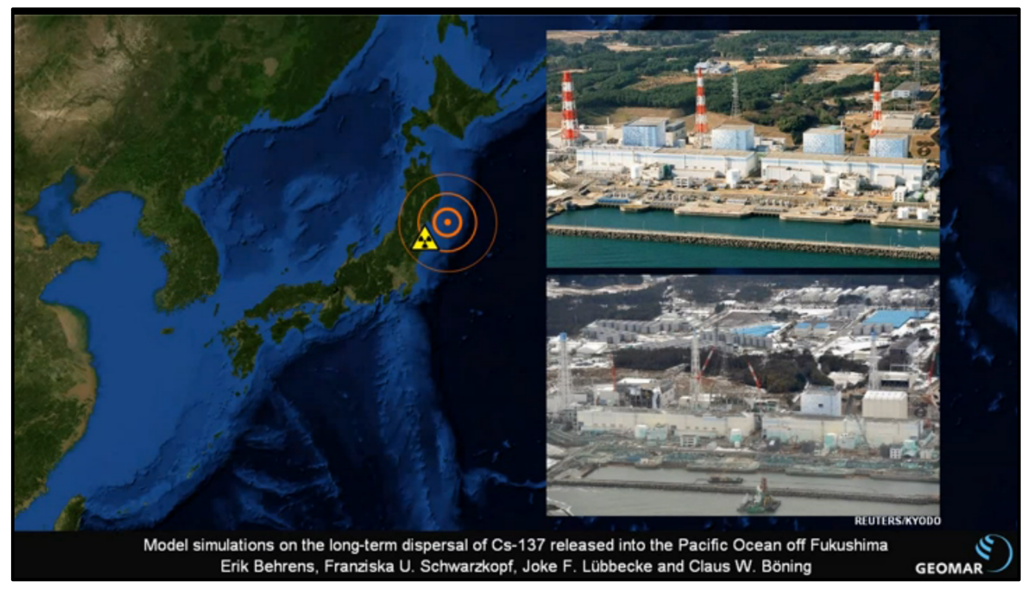
## Introduction

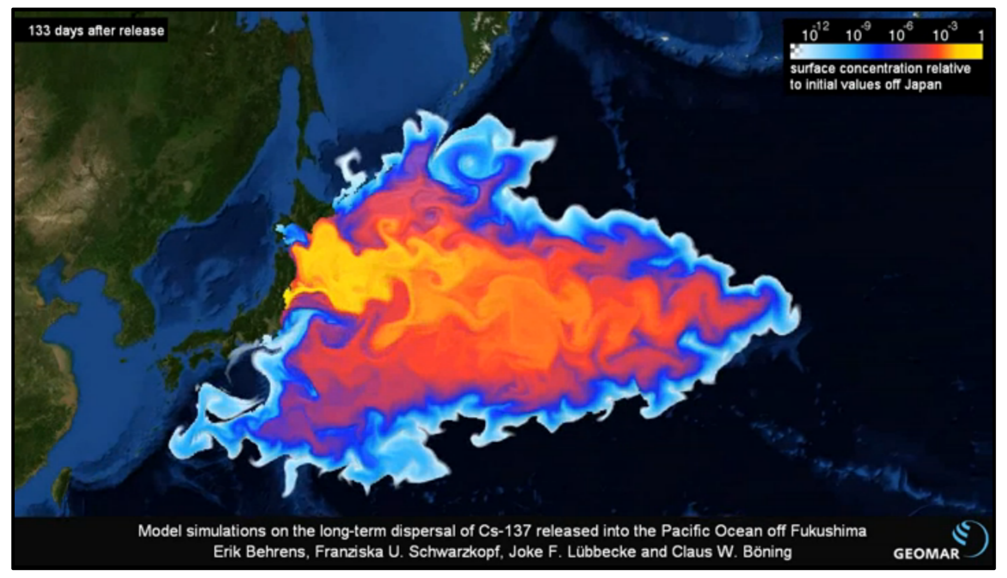
Concerns over the effect of bioaccumulation of toxins in our food webs have been voiced for decades, and the recent release of dangerous nuclear decay products from the Fukushima Daiichi nuclear power plant in Japan into the northern Pacific ocean only amplifies the threat. Many communities around the northern Pacific rim express the reasonable fear that both coastal and deep-sea fisheries may now be contaminated with $^{134}$Cs and $^{137}$Cs, along with a host of other radionuclides that have half-lives long enough to be taken in by a variety of marine organisms, including those we eat ourselves. Determining the measureable levels of ionizing radiation in the seafood sold in Pacific supermarkets is essential to determining whether measures to prevent consumer exposure need to be addressed.




## What is Radioactive?

All atoms possess unstable isotopes, most being exotic and rare, decaying within a matter of seconds or less. Certain isotopes, however, are more common with longer half-lives. $^{222}$Rn in the atmosphere, $^{40}$K in living tissue, and $^{238}$U and $^{235}$U (along with its decay chain daughters like $^{232}$Th) commonly found in terrestrial rocks, are particularly abundant and pose a threat to public health if not managed properly. In addition, many manufactured products like smoke detectors with $^{241}$Am and (now outlawed) glow-in-the-dark watch dials with $^{226}$Ra are common in our modern, post-atomic-age world.

In nuclear fission processes that occur in reactors, there are additional radionuclides that may have shorter half-lives, but higher decay energies, and hence have a more damaging effect on living tissue. The Fukushima incident released large amounts of volatile isotopes like $^{133}$Xe, $^{85}$Kr, $^{131}$I, $^{132}$I, $^{134}$Cs, $^{136}$Cs, $^{137}$Cs, and $^{132}$Te into the Pacific ocean currents and airstreams, that were subsequently distributed all over the northern Pacific basin. These range in half-life from 2.3 hours to 30.2 years, with some gamma ray energies of over 800 keV, certainly enough to damage tissues.



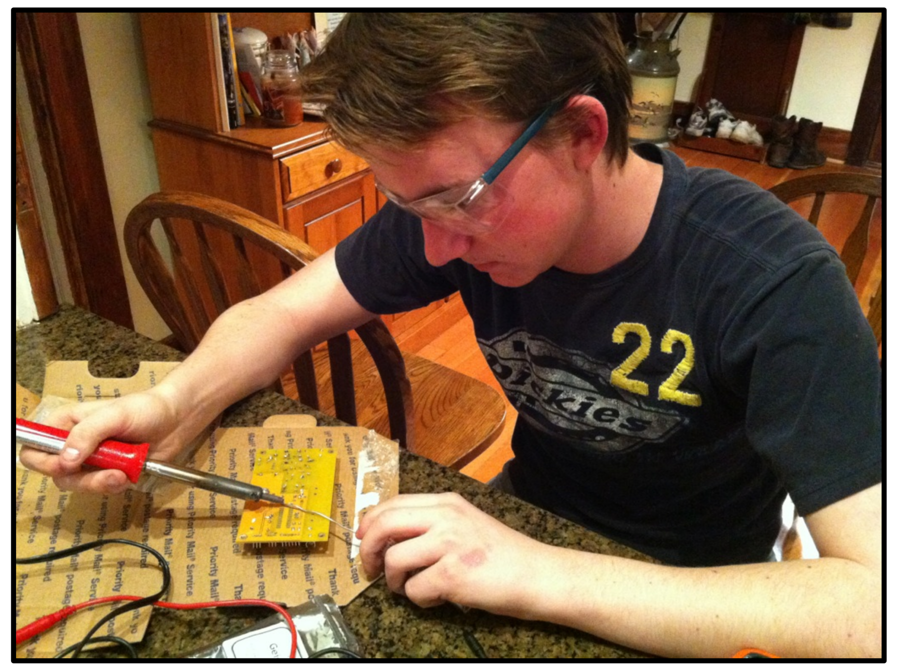

## Trophic Levels

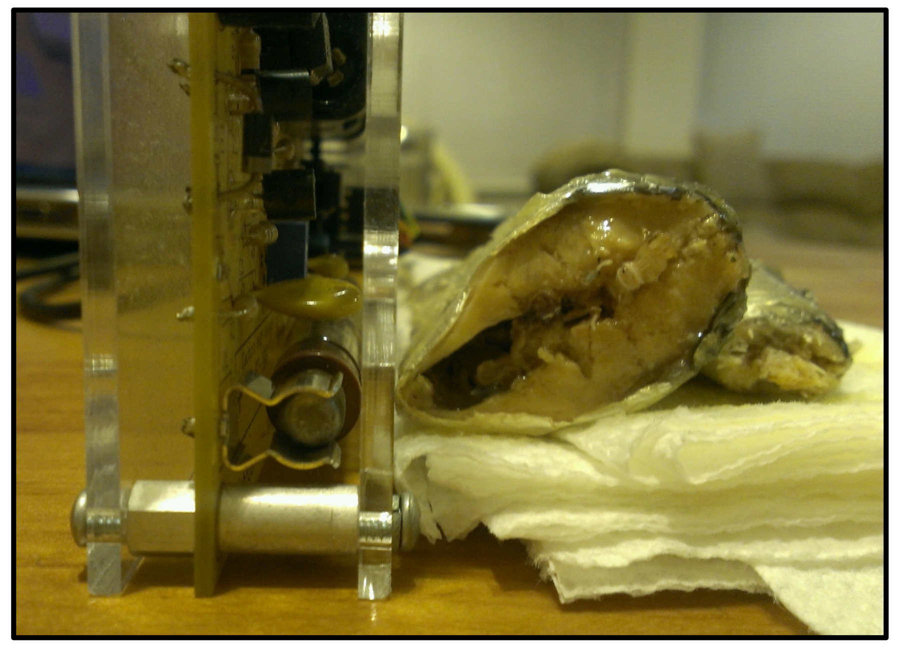
Of particular concern is the irradiation of our fisheries with isotopes of cesium, as it has similar chemical properties to potassium, an easily absorbed nutrient responsible for many biochemical ion channel and metabolic pathways. Also since the excretion coefficient for potassium is about three times higher than that of cesium, we expect the relative ratio of the ions to favour cesium as we progress upwards in the food web, an effect known as *bioaccumulation*. We define the *trophic level* (TL) of the organism to be how many levels above the primary producers (level 1) it is in the food chain. Fractional trophic levels are defined as trophic levels in a food web that are weighted by how much of a given lower trophic level an animal consumes.

## The Experiment

In this experiment, we measured radiation levels of 10 species of marine organisms suitable for human consumption, both from the North Pacific and the North Atlantic, and from varying trophic levels:

- Nori Seaweed 海苔 (Pacific: *Porphyra* sp.) – at the base of the marine food web, likely little irradiation; TL 1
- Sardines (Atlantic: *Sardina pilchardus*, Pacific: *Sardinops sagax*) – low in the food web, but may be elevated by bioaccumulated iodine in the thyroid since eaten whole; TLs 3.05/2.43.
- Herring (Atlantic: *Clupea harengus*) – similar to sardines; may see a difference in Atlantic vs. Pacific; TL 3.19.
- Chub Mackerel (Pacific: *Scomber japonicus*) – again low in trophic level, but occasionally thyroid is eaten; TL 3.09.
- Dover Sole (Pacific: *Microstomus pacificus*) – cesium is strongly absorbed by suspended particles like clays, so this benthic fish may not be as irradiated; TL 3.3.
- Coho Salmon (Pacific: *Oncorhynchus kisutch*) – expect piscivorous fish to have higher radiation levels; TL 4.2.
- Red Snapper (Pacific: *Sebates alutus*) – Pacific pelagic fish with higher trophic level; TL 3.5.
- Cod (Pacific: *Gadus macrocephalus*) – piscivorous Pacific pelagic fish; TL 4.2.
- Yellowfin Tuna (Pacific: *Thunnus albacares*) – near top of food web; TL 4.34.





## Methodology

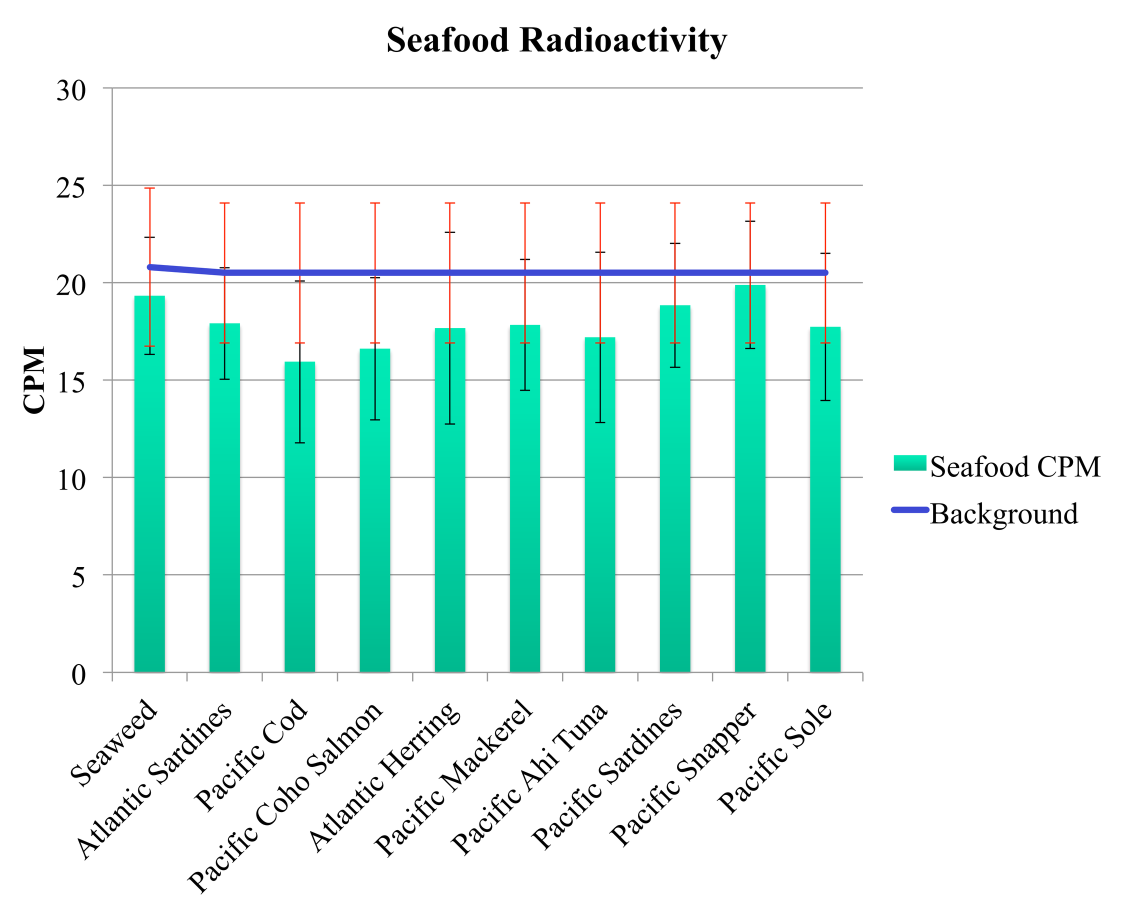
We assembled a MightyOhm Geiger Counter from a kit and maintained a 340V operating voltage. We used a TTL-232R3V3 6-pin serial to USB cable to record count and dosage data in RealTerm for Windows®. An approximately 45 g sample of each seafood product was measured 1 mm from our Geiger tube for between 300 and 400 seconds, then the averaged count-per-minute (CPM) rates and computed errors were plotted as demonstrated below.

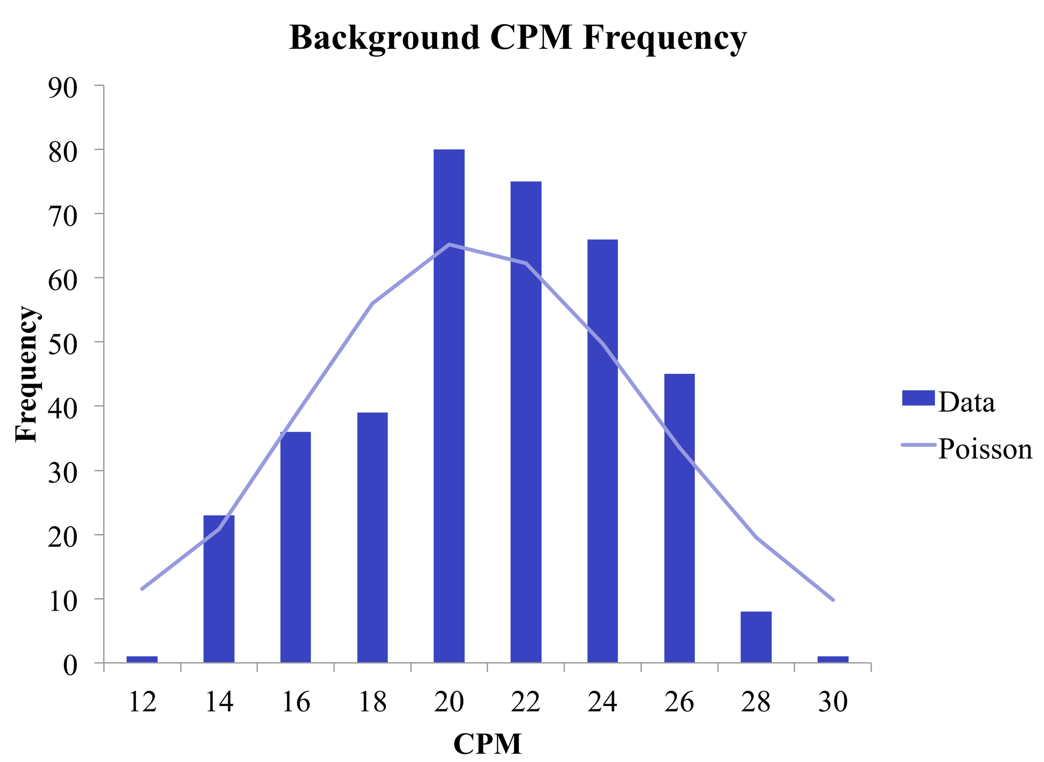
## Results

The average count per minute (CPM) rate is shown below. Since radioactive decay counts independent events with only elapsed time determining probability, it can be modelled as a Poisson process, allowing us to calculate the error in our average, $\sigma\downarrow\mu$ , in terms of the standard deviation $\sigma$ and the total number of counts $N$:

$$\sigma\downarrow\mu = \sigma/\sqrt{N}$$

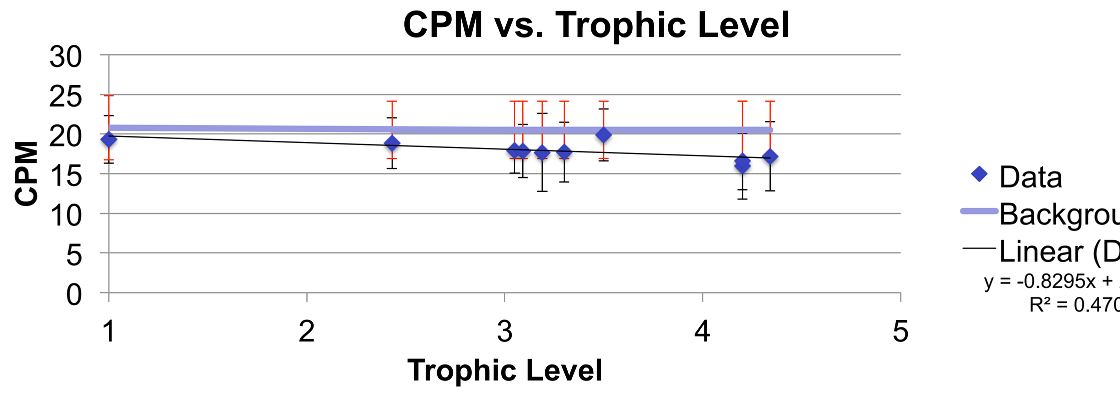
A closer look at the expected distribution of counts in our measured background shows excellent agreement with a Poisson distribution.




## Analysis

We can see from our data that the radiological measurements of all the tested marine seafoods are nearly indistinguishable from the background. Curiously, all measurements indicate a *lower* level of measurable irradiation than the ambient atmosphere of my home, suggesting that in fact these samples actually act as partial shielding from the natural radiometric background. Additionally, a comparison of radioactivity and trophic level shown in the following plot corroborates the near identical levels to background, but suggests a slight *negative* correlation between radioactivity and trophic level.




## Error Analysis

Aside from the background radiometric levels of my house and the inherent triggering energy limitation of our Geiger counter, there were few sources of intrinsic error to consider. One consideration is how fresh the seafood was; this information was nearly impossible to determine, but could have a huge effect on measure radioactivity (indeed, the time since death is the determining factor in $^{14}$C dating, where the half-life is in thousands of years, not around 30 as for $^{137}$Cs).

## Conclusion

Measured radiometric levels for all tested seafoods are commensurate with background levels. There is little cause for concern in consumption of current fishery stocks, at least for radiological reasons (other toxins such as heavy metals may be present). The slight negative correlation of radioactivity with trophic level is likely due to the fact that piscivorous fish need to have high muscle density to catch their prey, and denser muscle tissue may provide a greater shielding effect for the Geiger counter from ambient background radiation.

## Acknowledgements


I chose this project because it is a direct application of nuclear phenomena in the environment. The omnipresent and fundamental nature of physics fascinates me. This experiment was an exciting and engaging opportunity to explore the subatomic phenomena constantly in play around us, as well as address a real environmental concern that affects non-scientist consumers every day. Thank you to MightyOhm for the counter we used in the experiment, to Nugget Market for providing the seafood samples, and to Pia van Benthem and the AggieMentors program for the opportunity to conduct this research.


## Sources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