FUKUSHIMA RADIOACTIVITY IN TUNA: IMPLICATIONS FOR PUBLIC HEALTH AND TRACING MIGRATIONS

N. Fisher [1]*, Z. Baumann [1], D. J Madigan [1], K. Beaugelin-Seiller [2], T. G Hinton [2] and J. Garnier-LaPlace [2]
[1] Stony Brook University, Stony Brook, NY USA - nicholas.fisher@stonybrook.edu
[2] 2. IRSN, Centre de Cadarache, St. Paul lez Durance Cedex, France

Abstract
Bluefin tuna accumulated ^{134}Cs and ^{137}Cs released from the Fukushima nuclear power plant in Japan and transported these isotopes to the eastern Pacific. Radiation doses to the tuna and to human seafood consumers are below doses from natural radiation background, but these isotopes can be used to trace migratory routes and timing in large pelagic animals.

Keywords: Fishes, Radionuclides, Pollution, North-Central Mediterranean

The damage to the Fukushima Da-ichi nuclear power plant in Japan in March 2011 resulted in a the largest accidental release of radioactivity to the oceans in history. The principal radionuclides released into the Pacific were ^{131}I, ^{134}Cs, and ^{137}Cs, but others were also found in biota and marine sediments. Nearly all the short-lived ^{131}I decayed away within a few months, but ^{134}Cs ($t_{1/2}$ = 2 y) and ^{137}Cs ($t_{1/2}$ = 30 y) are detectable in water and biota in coastal regions near Japan. We used gamma spectrometry to analyze biota in Japanese waters in June 2011, 2.5 months after the date of maximal release of radioactivity. We found that zooplankton were contaminated with equal quantities of ^{134}Cs and ^{137}Cs (~15 Bq kg^{-1} each), as well as ^{110m}Ag (~8 Bq kg^{-1}). Small myctophid fish were found to have both Cs isotopes (~10 Bq kg^{-1} each) but no Ag [1]. In August of 2011, we also collected Pacific bluefin tuna from waters off California; this species spawns in the western Pacific and migrates eastward to California, often at the age of 1-2 years.

All 15 bluefin tuna that were new arrivals to California in August 2011 were found to have both Cs isotopes in their muscle, resulting in concentrations that were over ten times the amount of radioactivity from anthropogenic radionuclides prior to the accident [2]. Yellowfin tuna, a residential species, also collected off California had no ^{134}Cs and only "background" ^{137}Cs (from nuclear weapons testing in the 1960s), indicating that the radioactivity in the bluefin tuna off California was accumulated in waters off Japan and transported via migration to the eastern Pacific. The radioactivity in bluefin tuna caught off California that derived from Fukushima was only about 3% above the radioactivity from the naturally occurring ^{40}K.

Using a simple model, we calculated that the radioactivity from ^{134}Cs and ^{137}Cs in these tuna prior to their departure from Japanese waters was about 15 times higher than at the time of capture in California waters [2], matching independent measurements of tuna radioactivity near Japan. The decrease during the migration across the Pacific was attributable to excretion of the Cs, which has an efflux rate constant from marine teleosts of ~2% d^{-1}. We also evaluated the radiation risks to human consumers of the contaminated bluefin tuna in Japan and in the USA. Japanese eat more seafood, on average, than Americans (57 vs. 24 kg y^{-1}). The total estimated annual dose from consumption of these fish in August 2011 from $^{134+137}$Cs would be 0.9 µSv in the US and 33 µSv in Japan in April 2011 [3]. By comparison, the annual dose to tuna eaters from the naturally occurring ^{40}K and ^{210}Po in the same fish would be 570 µSv in the US and 1340 µSv in Japan (Table 1) [3]. Doses from ^{210}Po to the tuna exceed doses from radiocesium by 2-3 orders of magnitude [3].

The radioactivity from the Fukushima reactor to human consumers of Cs-contaminated tuna would thus be well below the natural radiation background to which we are all exposed, and estimated additional cancers from tuna consumption would be ~2 per 10 million people, although this estimate is highly uncertain. Other species of fish in Japanese coastal waters have also been reported to be contaminated with ^{134}Cs and ^{137}Cs, particularly benthic species [4]. As with the tuna, consumption of most other contaminated species would not exceed human safety limits, although some greenlings are extremely contaminated (7400 times the Japanese legal limit for Cs), and although banned, fishermen who ignore regulations and eat them would exceed human safety limits. In 2012, 50 additional bluefin tuna off California had $^{134+137}$Cs concentrations < half the levels found in 2011 [5], reflecting the dilution of the radioactive wastes in the Pacific. By studying the ^{134}Cs:^{137}Cs ratios in the fish, it is possible to discern the timing of migration of these fish and to assess the fraction of total fish in the eastern Pacific that are recent migrants [2, 5]. Such information is vital for proper management of this imperiled fishery. One positive outcome of this accident is that the application of radioactive tracers for evaluating migration routes and timing could be extended to understanding dynamics of other migrating animals, including other fish, turtles, birds, and mammals.

Tab. 1. Radioactivity in biota (Bq kg^{-1} dry wt) and radiation doses to tuna and humans

	Zooplankton	Bluefin tuna-US	Bluefin tuna-Japan	Dose to tuna (nGy h^{-1})	Dose to human tuna eaters (µSv y^{-1})
$^{134+137}$Cs	33	155	10	0.5-1.7	0.9: US; 33 Japan
^{40}K, ^{210}Po	199	347	347	600	570: US; 1340: Japan

This study highlights the possibility of using point sources of contamination, not restricted to radioactivity, to trace migration patterns of animals in any body of water, including the Mediterranean. The Mediterranean and Black Seas have numerous point sources of chemical contaminants whose background concentrations in uncontaminated seawater are negligible; bioavailable contaminants can be used to trace the movement of animals in these waters, as exemplified by tuna transporting Cs. Thus, any future radioactive releases from nuclear installations or accidents could be used to better understand animal migrations in these waters. And, importantly, detectability of contaminants in seafood does not necessarily imply significant risk for consumers.

References
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