Fishing for Answers

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The triple disaster of the March 11, 2011, earthquake, tsunami, and subsequent radiation releases at Fukushima Dai-ichi were, and continue to be, unprecedented events for the ocean and for society. More than 80% of the radioactivity from Fukushima was either blown offshore or directly discharged in to the ocean from waters used to cool the nuclear power plants (*1*). Although offshore waters are safe with respect to international standards for radionuclides in the ocean (2), the nuclear power plants continue to leak radioactive contaminants into the ocean (3), and many near-shore fisheries remain closed.

Public anxieties about seafood safety remain high, in part because Japanese are among the world's highest per capita consumers of seafood. In an effort to bolster confidence in their domestic supply, regulators tightened restrictions for cesium-134 and cesium-137 in seafood on April 1, 2012, from 500 to 100 Becquerels per kilogram wet weight (Bq/kg). In fact, this may have had the opposite effect, as the public now sees more products considered unfit for human consumption because of a lack of rapid decreases in contamination levels.

In fact, the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF) has been monitoring radionuclides in fish and other seafood products since shortly after March 11th. They have been releasing these data on a regular basis, most notably in a single annual compilation of more than 8500 samples of fish, shellfish and seaweeds that were collected at major landing ports and inland freshwater sites, particularly in the most affected coastal areas near Fukushima (*4*).

The MAFF results show total cesium levels (^{137}Cs + ^{134}Cs in Bq/kg) in demersal (bottom-dwelling) fish, including many important commercial species, are highest off Fukushima and lower in four prefectures to the north and south (Fig. 1a). Fishing for these species is currently banned off Fukushima, as 40 percent are shown here to be above the new regulatory limit of 100 Bq/kg.

The data also show that demersal fish have higher cesium levels than other marine fish types, grouped here as epipelagic (near-surface ocean dwellers), pelagic (open ocean), and neuston (surface-dwelling planktonic fish) and are comparable only to freshwater fish (Fig. 1b). Also striking in these data is that cesium levels have not decreased even one year after the accident, except perhaps in neuston.

Cesium accumulates in fish muscle tissues with relatively modest concentration factors ([Cs in fish]/[Cs in sea water]≈ 100 (*5*)), that increase only slightly as one moves up the food chain (*6*). Bioaccumulation is much higher in general in freshwater fish (*7*), as seen here. Uptake of cesium is balanced by loss back to the ocean, which increases with body size and metabolic rate (*6*). The loss rate is on average a few percent per day and has been shown to be faster if the cesium supply is pulsed, rather than a steady source (*8*).

With these high loss rates and the fact that cesium-134 and -137 remain elevated in fish, particularly in bottom-dwelling species, one key conclusion is that there must be a continued source of cesium contamination associated with the seafloor. Reports of Fukushima cesium in marine sediments, though not extensive, support this assumption (*9*). Given the 30-year half-life of ^{137}Cs, this means that that, even if these sources were to be shut off completely, the sediments would remain contaminated for decades to come.

Of equal concern, is the factor of 100 or more difference in total cesium levels for any given date and fish type, making management decisions of when to open or close a particular fishery more difficult. This range may be due to variability in the cesium loss rates from fish, the life stages of each species, and differences in habitat. Of course, many fish move over a wide range of temporal and spatial scales, which will also affect cesium levels in fish caught at a particular location that may have been exposed elsewhere if the sources are patchy and poorly known.

Fortunately, the MAFF data show that the vast majority of fish remain below even the new, stricter regulatory limit for seafood consumption. In addition, it must be remembered that we are surrounded by a sea of radioactivity, in that many naturally occurring radionuclides appear in fish at similar or higher levels and are not considered a health threat. For example in fish we sampled in June 2011 off Japan, natural levels of potassium-40 were more than 10 times greater than Fukushima derived cesium (*2*). Moreover, because cesium is rapidly lost from muscle after exposure stops, fish that migrate to less affected waters will gradually lose much of their Fukushima-derived cesium, as seen in a report of tuna caught off San Diego (*10*).

However, the fact that many fish are just as contaminated today with cesium-134 and -137 as more than one year ago remains troubling and provides the best evidence that cesium is still being released to the food chain. The Japanese government is using these MAFF results to keep fisheries closed off Fukushima and to closely monitor neighboring areas where levels are approaching the regulatory limits. These patterns of contamination and trends over time for different species need to be communicated to the media and the public in order to put these risks in context. But, studies of cesium in fish are not enough. An understanding of sources and sinks of cesium and other radionuclides is also needed to predict long-term trends in fish and other seafood. Such knowledge would support smarter, more targeted decision making, lessen public concern about seafood, and potentially help revive these important fisheries safely, with confidence, and in a timely manner.

References

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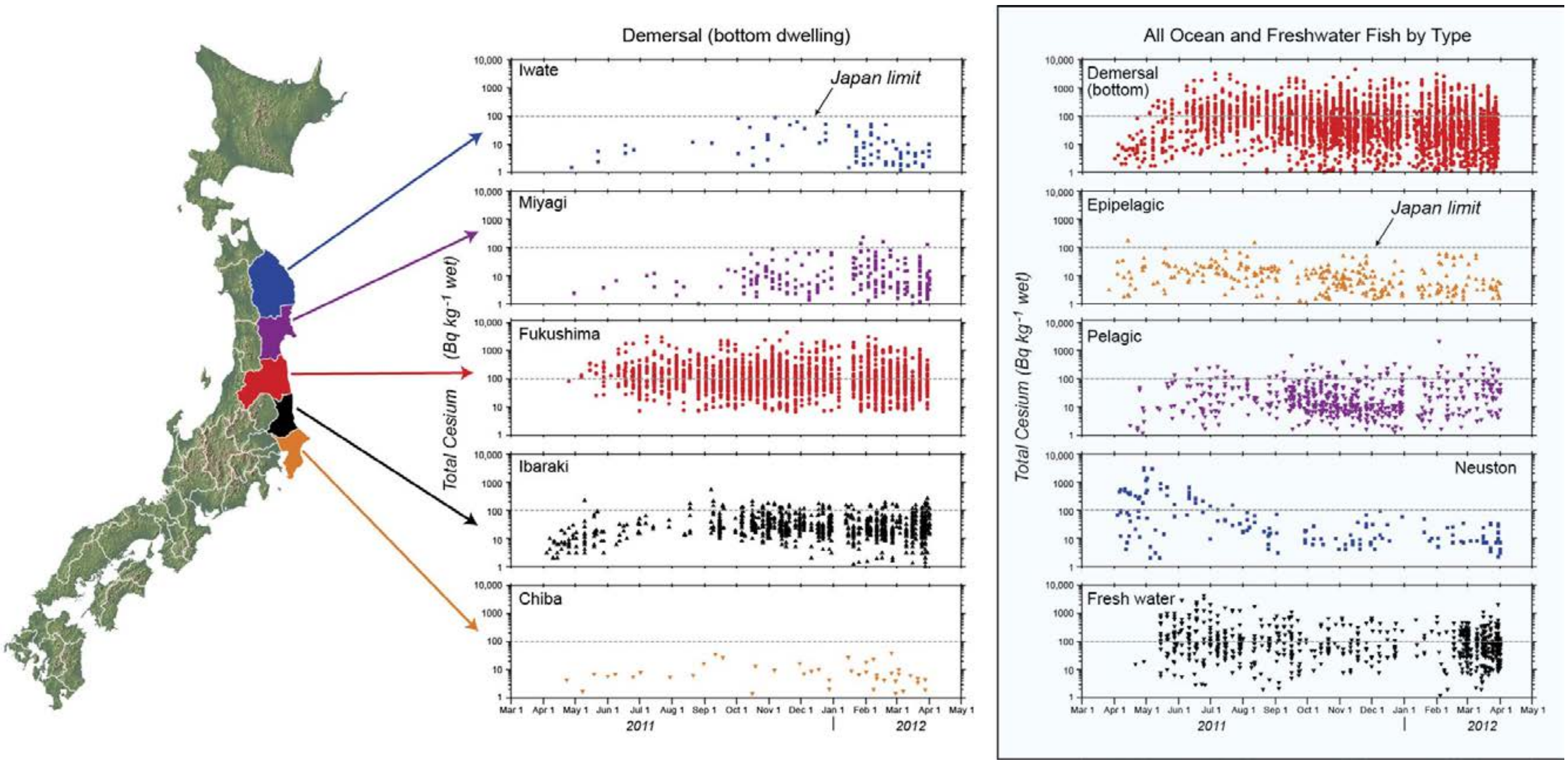
Figure Caption-

Figure 1. MAFF Fisheries data (*4*). 1a. Total cesium (^{137}Cs + ^{134}Cs in Bq/kg) for demersal fish vs. time for five prefectures in East Japan closest to Fukushima. 1b. Total cesium for five different fish types vs. time. Demersal: cod, conger, flounder, halibut, pollock, rockfish, skate and sole; Epipelagic:

saury, sardines, anchovies; Pelagic: amberjack, mackerel, salmon, seabass, tuna; Neuston: Japanese sand lance, ice fish, shirasu; and Freshwater fish: farmed and native.


Demersal (bottom dwelling)
Iwate
Japan limit
Miyagi
Fukushima
Ibaraki
Chiba
Total Cesium (Bq kg-1 wet)
10,000
1000
100
10
1
Mar 1 Apr 1 May 1 Jun 1 Jul 1 Aug 1 Sep 1 Oct 1 Nov 1 Dec 1 Jan 1 Feb 1 Mar 1 Apr 1 May 1
2011
2012
All Ocean and Freshwater Fish by Type
Demersal (bottom)
Epipelagic
Japan limit
Pelagic
Neuston
Fresh water
Total Cesium (Bq kg-1 wet)
2011
2012