Tuna transport of Fukushima-derived radiocesium across the North Pacific, and application to improved understanding of trans-Pacific migration rates

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Introduction

The Fukushima accident released radionuclides directly into the West Pacific Ocean. The dominant long-lived gamma-emitting radionuclides 134Cs (t1/2 = 2.1 yrs) and 137Cs (t1/2 = 30 yrs) were released at a consistent ratio of ~1, and after 2 to 3 months surface concentrations still exceeded prior concentrations by up to 1,000-fold over a 150,000 km² area of the Pacific east of Japan.

The Pacific bluefin tuna (Thunnus orientalis; PBFT) inhabits the West and East North Pacific Ocean. Mature PBFT spawn in the West Pacific, and some juveniles remain in Japanese waters while others migrate eastward to the California Current Large Marine Ecosystem (CCLME) (Fig. 1). PBFT were assessed as a highly depleted species in 2012, making assessment of their migratory cycle and associated regional mortality a priority.

We tested that juvenile PBFT served as biological vectors of radionuclides by analyzing muscle for the presence of Fukushima-derived radiocesium. We then tested the efficacy of the radiocesium tracer by comparing it to stable isotopes of carbon and nitrogen. Finally, we combined these methods to assess migration dynamics in a large sample set of Pacific bluefin tuna in the CCLME (n = 428), and with similar approaches and results from the West Pacific, assess the overall proportion of PBFT that are likely to migrate to the CCLME at some point in their life history.

Materials and methods

In 2011, 15 juvenile (≤70 cm) PBFT were sampled off San Diego, CA, USA. Muscle tissue was collected for the presence of 137Cs and 134Cs using gamma-spectroscopy. Samples of pre-Fukushima (2008; n = 5) PBFT and post-Fukushima yellowfin tuna (2011; n = 5) were also analyzed to validate Fukushima as the source of detected radiocesium.

On a larger dataset of PBFT, we tested for the presence of radiocesium in PBFT collected in 2012 and 2013. We compared results to SIA of δ15N and δ13C to validate the new tracer.

We applied SIA of δ15N and δ13C to PBFT spanning ages 1 – 7 to assess trans-Pacific migration, residency, and migration timing in PBFT in the CCLME.

We combined SIA results with those in the EPO to assess the proportion of PBFT that use the CCLME at some stage of their life.

Results

1. All analyzed (n=15) PBFT carried Fukushima-derived radiocesium across the North Pacific Ocean in 2011 (Figure 1).

2. Detectable 137Cs in all PBFT ≤7.5 years old, and in some age 1.7 to 2.5 years old, suggested that all PBFT migrate across the Pacific in the first years of life. This dataset validated the efficacy of the radiocesium tracer, and that of SIA of δ13C and δ15N.

3. Applying δ13C and δ15N to 428 PBFT, along with radiocesium, demonstrated on a larger scale that no PBFT migrate across the Pacific at ≥2.5 years of age. This indicates that older (≥ 4 – 8 years old) PBFT reside in the CCLME for at least 4 - 5 years, making mortality in the CCLME impactive on growing fish.

4. Combined with δ13C and δ15N results in the West Pacific, we showed that a majority of PBFT use the CCLME. This makes management in the CCLME a priority rather than previous inferences of negligible proportions.

Conclusions

1. A pelagic fish served as a transport vector of Fukushima radionuclides from the West to East Pacific. This presented the possibility of a new chemical tracer of trans-Pacific movements.

2. Radiocesium showed that stable isotopes of C and N can track PBFT migrations ad infinitum as a naturally occurring tracer.

3. All PBFT migrate to the East Pacific in the first 2 years of life. Larger fish face fishing mortality in the East Pacific for years before returning West.

4. Combined with SIA in the West, tracers show that the majority of PBFT uses the East Pacific. Formally considered a minority, this makes management in the East a priority.

Literature cited


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