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Fukushima derived radiocesium in subsistence-consumed northern fur seal and wild celery

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ABSTRACT

In July 2014, our investigative team traveled to St. Paul Island, Alaska to measure concentrations of radiocesium in wild-caught food products, primarily northern fur seal (*Callorhinus ursinus*). The 2011 Fukushima Daiichi Nuclear Power Plant accident released radiocesium into the atmosphere and into the western Pacific Ocean; other investigators have detected Fukushima-derived radionuclides in a variety of marine products harvested off the western coast of North America. We tested two subsistence-consumed food products from St. Paul Island, Alaska for Fukushima-derived radionuclides: 54 northern fur seal, and nine putchki (wild celery, *Angelica lucida*) plants. Individual northern fur seal samples were below minimum detectable activity concentrations of ^{137}Cs and ^{134}Cs, but when composited, northern fur seal tissues tested positive for trace quantities of both isotopes. Radiocesium was detected at an activity concentration of 37.2 mBq ^{134}Cs kg^{-1} f.w. (95% CI: 35.9–38.5) and 141.2 mBq ^{137}Cs kg^{-1} f.w. (95% CI: 135.5–146.8). The measured isotopic ratio, decay-corrected to the date of harvest, was 0.26 (95% CI: 0.25–0.28). The Fukushima nuclear accident released ^{134}Cs and ^{137}Cs in roughly equal quantities, but by the date of harvest in July 2014, this ratio was 0.2774, indicating that this population of seals has been exposed to small quantities of Fukushima-derived radiocesium. Activity concentrations of both ^{134}Cs and ^{137}Cs in putchki were below detection limits, even for composited samples. Northern fur seal is known to migrate between coastal Alaska and Japan and the trace ^{134}Cs in northern fur seal tissue suggests that the population under study had been minimally exposed Fukushima-derived radionuclides. Despite this inference, the radionuclide quantities detected are small and no impact is expected as a result of the measured radiation exposure, either in northern fur seal or human populations consuming this species.

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1. Introduction

The 2011 Tohoku earthquake triggered powerful tsunami waves up to 40 m high that devastated coastal Japan more than 5 km inland (Mori et al., 2011). Nearly 16,000 people died as a result of the earthquake and tsunami, and an additional 3000 people are still listed as missing (Mimura et al., 2011). In the wake of this devastation, the Fukushima nuclear power plant (NPP) lost electric power and the ability to circulate coolant, resulting in overheating of its nuclear reactors. A series of overpressure ventings, combined with the buildup of explosive hydrogen, ultimately led to loss of containment and releases of radionuclides to the atmosphere and the marine environment. While the atmospheric release has been abated, marine releases may be ongoing due to groundwater seepage (WNA, 2015).

The atmospheric plume from the Fukushima Daiichi reactors traveled east and passed over North America days after the initial release. Modeling (Behrens et al., 2012; Rossi et al., 2013), has predicted that the leading edge of the marine plume reached the west coast of North America sometime in 2014. Measurements (Smith et al., 2015) indicate that Fukushima-derived radionuclides

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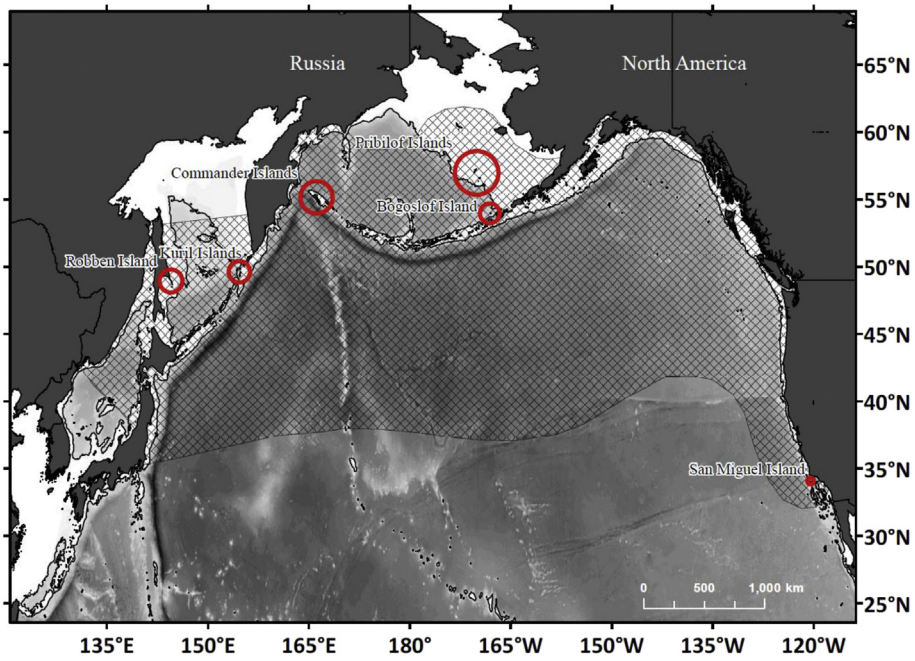

Fig. 1. Range of northern fur seal, with the relative abundance of the breeding areas represented by the relative size of red circles. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

were present in waters above the Canadian continental shelf by June 2013, with concentrations off coastal North America expected to increase through 2015 before declining. Due to Pacific Ocean currents, the Fukushima plume likely arrived on the west coast of North America prior to transport north and east toward our study site (Smith et al., 2015).

The arrival of the Fukushima marine plume has aroused concern for some North American stakeholders, particularly those living near the coast and those who consume seafood from the Pacific Ocean. Additionally, the potential effects of exposure to Fukushima-derived radionuclides on sensitive marine species will need to be studied and understood in the coming years. To date, investigators have primarily focused on exposure in marine fish (Johansen et al., 2015; Madigan et al., 2012; Neville et al., 2014). To complement existing work, this study measured activity concentrations of Fukushima-derived radionuclides in northern fur seal (*Callorhinus ursinus*), both to understand the radiological risk to the animals, as well as the risk associated with human consumption of animal tissues.

Northern fur seal is an eared seal that is widely distributed throughout the North Pacific Ocean and Bering Sea (Fig. 1). These animals spend the majority of their time foraging at sea, returning to land on six island groups across the Bering Sea and North Pacific Ocean (National Marine Fisheries Service, 2007). Individuals may travel great distances, particularly during their seasonal migration. Adult females and juvenile male fur seal from the Pribilof Islands annually migrate from the Bering Sea to the Central North Pacific Ocean, ranging as far west as the Okhotsk, Kurile, and the Japanese Current, returning each spring to the Pribilof Islands (Ream et al., 2005).

Radiocesium biomagnifies through marine foodwebs (Calmet et al., 1991; Carroll et al., 2002; Heldal et al., 2003; Kasamatsu and Ishikawa, 1998; Watson et al., 1999). Thus the northern fur seal, a predator, should be an excellent sentinel of marine radiocesium in the North Pacific. Additionally, due to this biomagnification effect, human exposure to radiocesium via consumption of fur seal meat is of concern. The approximately five hundred Aleuts on the Pribilof Islands of St. Paul and St. George have annually harvested between 323 and 608 (mean = 328 individuals harvested) two-to-four year old male fur seal for subsistence food in the last decade (Zimmerman and Letcher, 1986; Zimmerman and Melividov, 1987). Edible meat per animal ranges from 10.4 to 12.5 kg, with a mean of 11.9 kg animal^{-1}, for a mean total of 3903 kg harvested annually (8.1 kg per person) (Zimmerman and Letcher, 1986; Zimmerman and Melividov, 1987). Finally, the species has been designated as "depleted" under the Marine Mammal Protection Act of 1986 due to the decline of the population by more than 50% since the 1950s (NMFS, 2007). Several stakeholder and government groups are interested in demonstrating protection of the public and of northern fur seal populations exposed to Fukushima-derived radionuclides, and so testing of northern fur seal tissues for radiocesium is warranted.

2. Material and methods

Tissue samples were collected over a two-week period during the subsistence harvest season on St. Paul Island in July 2014. Northern fur seal samples were collected during the community harvest on July 24, 2014 (MMPA permit 14327) from 54 individual sub-adult males. Approximately 500 g of skeletal muscle was collected from the neck of each animal and refrigerated until dehydration. Additional biological samples included nine putchki plants (wild celery, *Angelica lucida*), which is the dominant ground cover on St. Paul Island and is occasionally consumed by residents. Putchki samples were collected from several sites over the harvest period; only the edible stalks of the plant were processed.

All biological samples were field-dried at 60 °C to achieve a stable mass using a commercial food dehydrator. Dehydration occurred within 18–24 h and the stabilized samples were subsequently transported to Colorado State University (CSU), where they were dry-ashed in a muffle furnace at 450 °C for 4–6 h. CSU's muffle furnace does not allow the user to set a temperature ramp, but the furnace generally reached full temperature after about two hours. Ashes were hand-homogenized and counted on a high