STRONTIUM-90 IN CANADA GOOSE EGGSHELLS AND REED CANARY GRASS FROM THE COLUMBIA RIVER, WASHINGTON

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Abstract. Strontium-90 (^{90}Sr) released to the ground near the N Reactor at the U.S. Department of Energy's Hanford Site enters the Columbia River through shoreline seeps. The ^{90}Sr is then potentially available for uptake by plants and animals. The life history and foraging behavior of nesting Canada geese is such that female geese could ingest ^{90}Sr while foraging on shoreline plants. Radiochemical analyses showed that goose eggshells taken from an island, downstream from the N Reactor, contained more ^{90}Sr than did eggshells collected from other downstream islands. Reed canary grass samples taken from shoreline areas immediately downstream from the N Reactor contained higher concentrations of ^{90}Sr than samples from other downstream areas. All goose eggshells did not contain enhanced levels of ^{90}Sr, and all reed canary grass samples did not contain enhanced levels of ^{90}Sr, but a relationship exists between the releases of ^{90}Sr to the Columbia River and the enhanced levels of ^{90}Sr in some of the environmental samples analyzed.

1. Introduction

Strontium-90 is a radioactive nuclide produced during the nuclear fission process. Over the last 40 years ^{90}Sr has become widely distributed in the surface environment because of the deposition of worldwide fallout from aboveground testing of nuclear devices (Bowen, 1966), Strontium-90 has a long half-live (29.1 yr) and behaves in the biological environment much like calcium. In birds, ^{90}Sr would be expected to occur in bone tissue and in the calcium-rich eggshell (Romanoff and Romanoff, 1949).

On the U.S. Department of Energy's Hanford Site located in southeastern Washington, operation of the N Reactor to produce nuclear materials has resulted in the release of aqueous effluents containing ^{90}Sr to a covered trench. Small quantities of ^{90}Sr have percolated to the ground water and then followed the ground water as it flowed into the Columbia River through shoreline seeps (McCormack and Carlile, 1984). Estimates are reported each year of the total amount of ^{90}Sr discharged from the trench to the river through these seeps and the ^{90}Sr concentrations are measured in river water samples collected upstream and downstream of the reactor (Jaquish and Mitchell, 1988).

A series of islands is located in the Columbia River downstream from N Reactor

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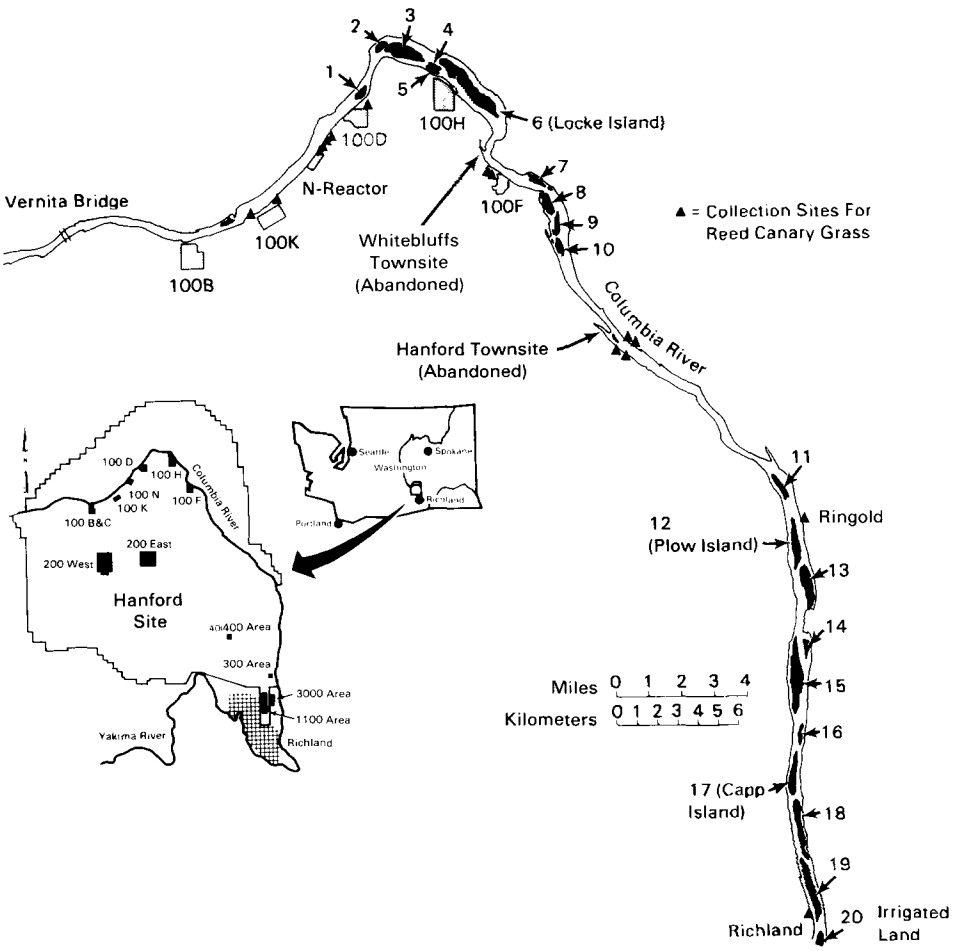

Fig. 1. Map showing the Hanford Reach of the Columbia River, goose nesting islands, collection sites for reed canary grass, and the sites where alfalfa was collected from irrigated land east of Richland, Washington.

(100 N), and these support nesting Canada geese *(Branta canadensis moffitti)* (Ball *et al.*, 1981) (Figure 1). Adult geese begin to nest in March. Young geese, accompanied by adults, forage on shoreline plants throughout the spring and summer months where reed canary grass (*Phalaris arundinacea)* is abundant. By September, the young geese can fly, and they then begin to forage in agricultural fields and rangelands located away from the river (Eberhardt, 1987).

Knowledge of the life history and foraging behavior of nesting geese and their broods suggest that female geese have the potential to ingest ^{90}Sr while foraging on shoreline plants and then pass it on to eggshells. In 1985, a preliminary survey of islands supporting nesting Canada geese in the Hanford Reach of the Columbia River

indicated that goose eggshells taken from Plow Island located downstream of the N Reactor, had slightly elevated levels of ^{90}Sr. The purpose of this study was to test the hypothesis that eggshells taken from the Columbia River goose population near the N Reactor would have higher ^{90}Sr concentrations than eggshells collected from islands upstream from the Hanford Site or from islands in other rivers in eastern Washington. If ^{90}Sr concentrations in the eggshells of Hanford Site islands were enhanced, samples of reed canary grass would be collected from several locations and analyzed to possibly identify the source of ^{90}Sr to geese.

2. Methods

Eggshell fragments were taken from goose nests a few days after the eggs had hatched. The eggshells were washed in tap water to remove external debris (e.g., mucous, blood, and feces). The internal membranes were stripped from the shells. Air-dried shells (10 g or more) were analyzed for ^{90}Sr by chemical separation of strontium followed by beta counting. Analyses for calcium and other stable minerals was by X-ray fluorescence spectrometry.

In the spring of 1986, eggshells were collected from six newly hatched nests on Plow Island located downstream from the N Reactor (Figure 1). Eggshells were also collected from 10 nests on New York Island in the Snake River, a large tributary that enters the Columbia River downstream from the Hanford Reach. In the spring of 1987, eggshells were again collected from 14 newly hatched nests on Plow Island. Eggshells were also collected from 15 nests located near the town of Bridgeport on the Columbia River, about 160 km upstream from the N Reactor. The Bridgeport eggshells were pooled into a single sample for ^{90}Sr analysis.

In the summer of 1987, samples of reed canary grass were collected at 15 locations along the shoreline of the Columbia River both upstream and downstream of the N Reactor (Figure 1). A single sample was collected from the shore of the Yakima River upstream from the city of Richland. The samples were cut from above-ground leafy portions of the plants. The samples were dried at 60 °C and analyzed for ^{90}Sr by chemical separation of the strontium followed by beta counting on a gas-flow proportional counter.

3. Results and Discussion

Goose and domestic chicken eggshells were analyzed for calcium, stable strontium, and other mineral elements to verify the assumption that eggshells were rich in these elements. Goose eggshells contained 38% calcium and 210 ppm stable strontium (Table I). Eggshells from the domestic chicken contained 37% calcium and 190 ppm stable strontium. The calcium concentrations in eggshells were similar to reagent grade calcium carbonate (Table I).

The eggshells taken from Plow Island in 1986 had about twice as much ^{90}Sr as those collected from New York Island in the Snake River (Table II). Eggshells

TABLE I

Concentrations of stable mineral elements in eggshells of Canada goose and domestic chicken compared with reagent grade calcium carbonate

	Ca (%)	Fe (ppm)	Cu (ppm)	Zn (ppm)	Sr (ppm)	Ba (ppm)
Eggshells (goose)	38	40	12	<4.8	210	97
Eggshells (chicken)	37	26	7.9	6.6	190	28
$CaCO_3$	40	23	11	<3.5	71	<16

TABLE II

Concentrations of ^{90}Sr (pCi g^{-1} dry weight) in Canada goose eggshells from islands in the Columbia River (Plow Island) and the Snake River (New York Island)

Location	Year	*n*	Mean ± SE	Mean ln ± SE
Plow Is.	1986	6	1.621 ± 0.273	0.404 ± 0.183
New York Is.	1986	10	0.847 ± 0.115	−0.241 ± 0.129
Plow Is.	1987	14	1.281 ± 0.144	0.187 ± 0.101

TABLE III

A one-factor analysis of variance comparing ^{90}Sr concentrations in goose eggshells from Plow Island and New York Island

Comparison	Mean Difference	Fisher PLSD
Plow Is. 1986 vs Plow Is. 1987	0.217	0.403
Plow Is. 1986 vs New York Is. 1986	0.645	0.426*
Plow Is. 1987 vs New York Is. 1986	0.428	0.342*

* Significant difference, $\alpha = 0.05$.

collected from Plow Island in 1987 had slightly lower concentrations of ^{90}Sr than the shells collected from the same island in 1986. Eggshells from Plow Island contained significantly greater concentrations of ^{90}Sr than those from New York Island (Table III). However, a comparison between eggshells collected from Plow Island in 1986 and in 1987 showed no significant between-year difference. The pooled sample of shells collected near Bridgeport, Washington, upstream from the Hanford Site had a ^{90}Sr concentration of 0.99 ± 0.08 pCi g^{-1} dry weight (result ± 1σ counting error). This value is greater than the mean ^{90}Sr concentration for eggshells from New York Island, but less than either of the two mean values for eggshells from Plow Island.

The eggshell data suggested to us that a source of ^{90}Sr in addition to worldwide fallout was available to the geese nesting on Plow Island. The source could have been

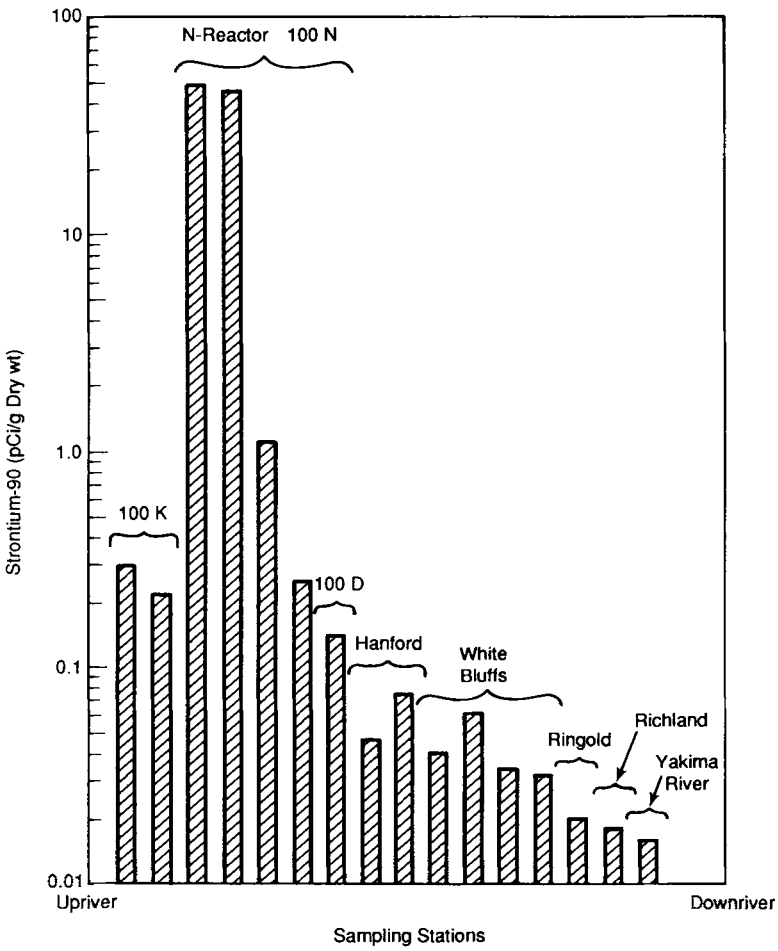

Fig. 2. Concentrations of ^{90}Sr (pCi g^{-1} dry wt) in reed canary grass samples from the Columbia River shoreline upstream and downstream of N Reactor.

shoreline plants such as reed canary grass, or crops such as alfalfa *(Medicago sativa)* irrigated with Columbia River water withdrawn downstream of the N Reactor. The highest concentrations of ^{90}Sr were measured in samples of reed canary grass collected near the N Reactor (100 N) (Figure 2). Concentrations of ^{90}Sr generally decreased with increasing distance either upstream or downstream from N Reactor. The location of the ^{90}Sr associated with the grass samples was not determined, but was assumed to be internal and within the plant tissue. Alfalfa grown on land on the eastern side of the Columbia River opposite the city of Richland is irrigated with water pumped from the Columbia River (Figure 1). Samples of alfalfa collected from this area in 1986 had an average ^{90}Sr concentration of 0.035 ± 0.003 pCi g^{-1} dry weight (mean $\pm$ SE) (Jaquish and Mitchell, 1988). This value is very low when

compared with the reed canary grass samples collected from the banks of the Columbia River near the N Reactor and seems to rule out the possibility of irrigated alfalfa fields as the source of ^{90}Sr to geese. Clearly, all the reed canary grass growing along the Columbia River did not contain enhanced levels of ^{90}Sr, and all goose eggs from Plow Island did not have enhanced levels of ^{90}Sr. However, a relationship seems to exist between the releases of ^{90}Sr to the Columbia River, ^{90}Sr concentrations measured in reed canary grass, and ^{90}Sr measured in goose eggshells from Plow Island. The shoreline seeps from the covered trench at the 100 N Area occur in a rather restricted area (about 400 m), and most of the time the seepage flow would not be available to geese as drinking water because the flows are below the normal water level of the river.

Bird eggshells are especially suited as a biological material for detecting the presence of ^{90}Sr in surface environments. Eggshells from hatched eggs are relatively abundant, and it is not necessary to kill birds to obtain samples for analysis. More detailed sampling of plants, sediments, and eggshells from other wild birds could provide additional information concerning the long-term fate of ^{90}Sr in the shoreline environment of the Columbia River.

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