Modelling of radiocesium transfer in the lichen-reindeer/caribou-wolf food chain

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Abstract: The environmental contaminate radiocesium (cesium-137) has been shown to be of value as a marker in food selection and intake studies. Its greatest potential value as a food marker is in the subarctic/arctic regions, particularly in the lichen to reindeer/caribou to wolf food chain. A kinetic model describing the movement of radiocesium through the food chain has been developed using the SAAM computer program and is presented here. The program has been written so that the various paramenters affecting the transfer of radiocesium in the food chain can be altered more realistically to describe the system being modeled. The values of the parameters as given in this example are realistic for interior Alaska, however caution should be exercised in the application of the present results to regions that may be vastly different from the Alaskan interior without first evaluating the parameters and assumptions of the model.

Key words: Environment, fallout, transfer systems, cesium

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The computer program - SAAM and CONSAM

The computer program SAAM (Simulation, Analysis and Modeling) has been developed over a period of many years, primarily by the U.S. National Institute of Health. The program has been under continuous modification and is now available in a 'user interactive' form called CONSAM (conversational SAAM). SAAM and CONSAM will run on several computer systems including the Vax 11/780, DEC-SYSTEMS 10, UNIVAC, DEC 20 and the AT&T UNIX PC 7300. Information and tapes of the programs are available from:

Resource Facility for Kinetic Analysis
Center for Bioengeneering FL-20
University of Washington
Seattle, Washington 98195
U.S.A.

The computer program, version SAAM-29, was used in this study, however a later version, SAAM-30, is presently available.

In practice, the SAAM user writes a source input file in SAAM language which describes the model, and requests certain output. Output may be in the from of individual values, tabulated data or plots. A copy of the present source input file can be obtained form the authors.

The model - A description and the output

The transfer of radiocesium through the food chain is indicated in Figure 1. Radiocesium enters the reindeer/caribou via ingestion of contaminated forage and is subsequently transferred to the wolf. A two-compartment model is used to describe the kinetics of radiocesium in both

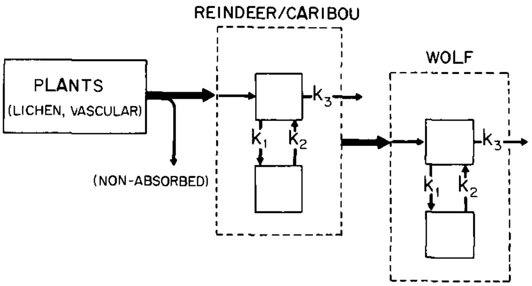

Figure 1. Radiocesium transfer in the lichen- reindeer/caribou-wolf food chain.

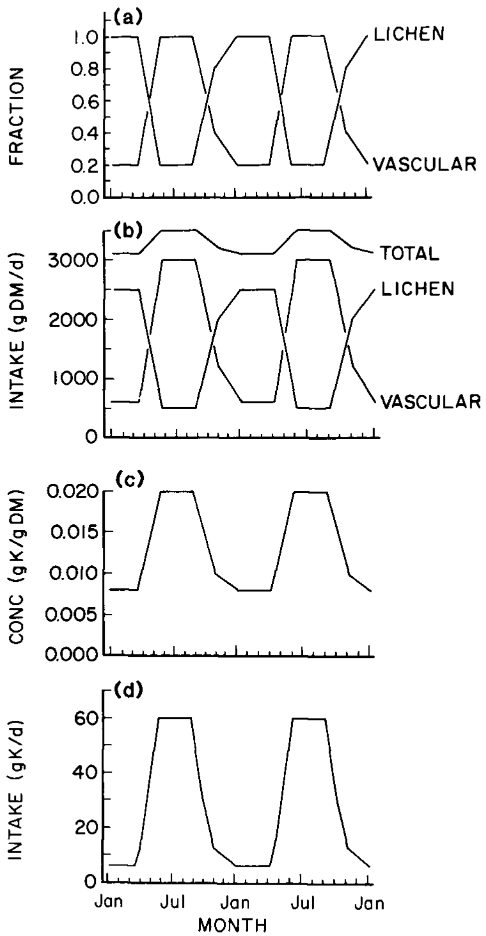

Figure 2. The potassuim intake rate of the reindeer-caribou and the input data that affect the potassium intake rate: (a) the fractional forage intake rate relative to the annual maximum intake for lichens and vascular plants, (b) the forage intake rates, (c) the potassium concentration in vascular plants and (c) the total potassium intake rate.

the reindeer/caribou and the wolf (Holleman *et al.* 1971; Holleman an Luick 1976).

Figures 2 - 5 show both input data and simulated output data of the model over a two year period. Input data can be altered in the program whereas simulated output data are the results from the execution of the program. It should be noted that the radiocesium concentration in the reindeer/caribou and wolf is arbitarily set to one initially (set to one instead of zero to prevent division into zero), which may be unrealistic but necessary since the actual values would be unknown. Therefore the initial part of the simulated output data, i.e., for 2-3 months, does not necesarily reflect what would normally be observed.

For the present simulation, the annual maximum intake rate of lichen and vascular plant by reindeer/caribou was assumed to be 2500 and 3000 g/d dry matter, respectively. The forage intake rate (fig. 2(b)) is the product of the annual maximum intake rate and the fractional intake rate relative to the annual maximum intake

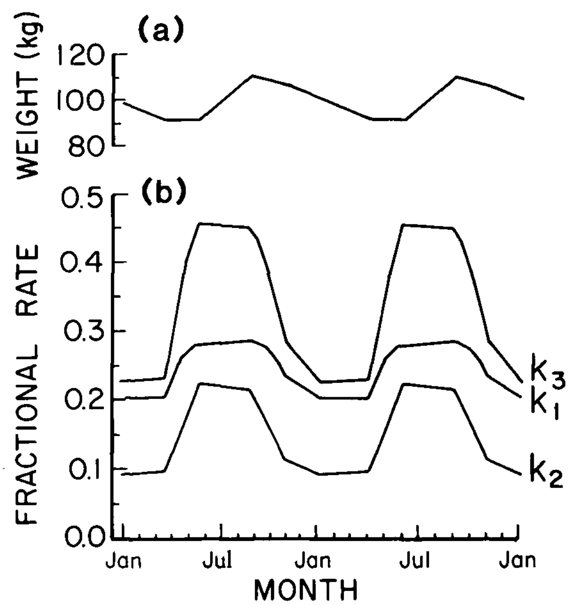

Figure 3. (a) Input data for the seasonal body weights and (b) the simulated output data for the seasonal kinetic parameters in reindeer/caribou.

rate (fig. 2(a)). The total potassium intake rate (fig. 2(d)) is the product of the forage intake rate and the potassium concentration in the respective forage (fig. 2(c) for vascular plants; 0.0005 g potassium per g dry matter for lichens).

In the present model the radiocesium kinetics in reindeer/caribou (fig. 3(b)) are dependent upon potassium intake rate and body weight (fig. 3(a)). The relationship between potassium intake rate and the kinetic parameters for reindeer/caribou (the k's - fractional rate parameters) are given in Allaye-Chan *et al.* (1990). The radiocesium kinetics for the wolf are assumed to be constant during the simulation.

The absorbed radiocesium intake for reindeer/caribou (fig. 4(a)) is the product of radiocesium concentration in the forage, the forage intake rate and the fraction of the radiocesium absorbed. In the present simulation the initial radiocesium concentration in lichen and vascular plants are assumed to be 0.1 and 0.005 Bq/g dry matter, respectively. The effective halftimes of radiocesium in lichens and vascular plants are assumed to be 8.2 and 2.0 years, respectively. It was further assumed that 26% of the ingested radiocesium was absorbed (Holleman *et al.* 1971). Radiocesium concentrations in reindeer/caribou resulting from these assumptions are presented in figure 4(b).

The wolf was assumed to ingest 1000 g/d of

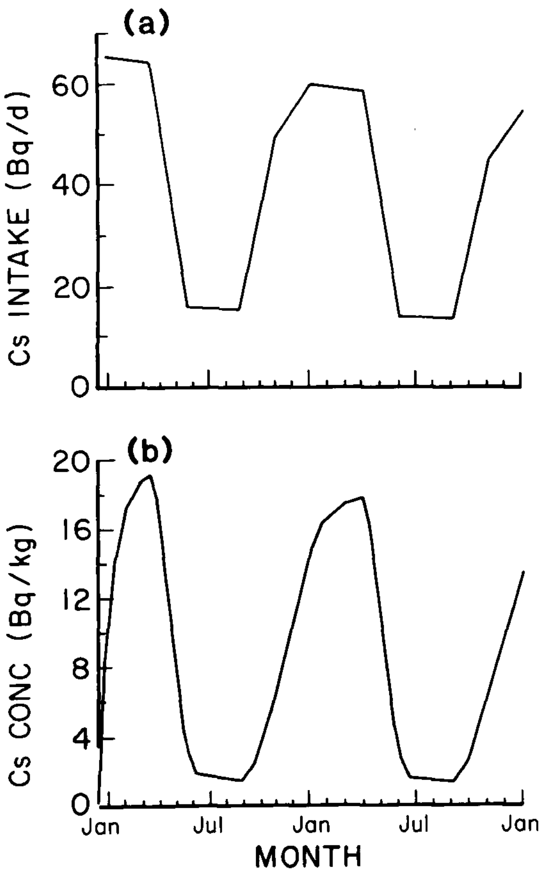

Figure 4. (a) Total radiocesium intake for reindeer/caribou and (b) the resulting radiocesium concentration in skeletal muscle of reindeer/caribou.

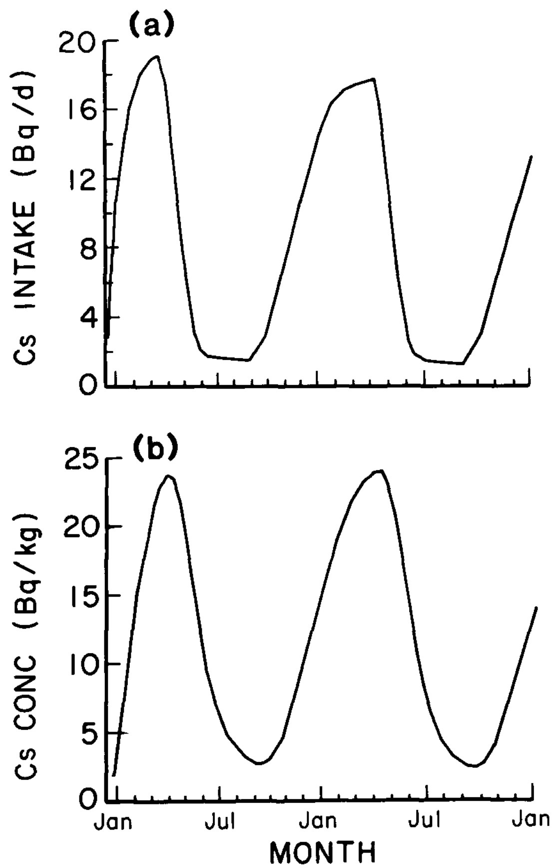

Figure 5. (a) Absorbed radiocesium intake for the wolf and (b) the resulting radiocesium concentration in skeletal muscle of the wolf.

reindeer/caribou muscle at the radiocesium concentration given in figure 4(b). All of the ingested radiocesium be the wolf was assumed to by absorbed. The resulting radiocesium intake rate for the wolf and the radiocesium concentration in the muscle of the wolf are given in figure 5.

Conclusions

The present model can be used to predict radiocesium concentrations in the reindeer/caribou and the wolf from known concentrations of environmental radiocesium. In this application the model could be used to evaluate the potential radiation dose from various levels of radiocesium in the environment. Also the model can be used to estimate food intake rates by reindeer/caribou and wolves from a knowledge of radiocesium concentrations in the study animal and in the respective food sources. In Alaska the model has been used to determine prey selection between caribou and moose for the wolf.

However, application of the model to other systems should include a careful consideration of the model's input data and assumptions to ensure that they are applicable to the system being modeled.

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References

Allaye-Chan, A.C., White R.G., Holleman D.F and Russel, D.E. 1990. Seasonal concentrations of cesium-137 in rumen content, skeletal muscles, and feces of caribou from the Porcupine herd: lichen ingestion rates and implication for human consumption. - *Rangifer Special Issue No 3:* 17-34 (these Proceedings)

Holleman, D.F., Luick, J.R. and Whicker, F.W. 1971. Transfer of radiocesium from lichen to reindeer. - *Health Physics* 21:657-666

Holleman, D.F. and Luick, J.R. 1976. Radiocesium kinetics in arctic carnivores. - *Health Physics* - 30:241-243.