CESIUM-134 AND STRONTIUM-85 TURNOVER RATES
IN THE CENTIPEDE Scolopocryptops nigridia MCNEILL

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Date Published - July 1979

PREPARED FOR THE
DEPARTMENT OF ENERGY
UNDER CONTRACT DE-AS09-76EV00641

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1. Introduction

Radioactive tracers are providing significant information about the ecology of food chains, including such phenomena as accumulation of radioactive fission products, movement of materials along food chains, assimilation and ingestion rates, and nutrient accumulation and turnover (Cushing 1976).

Most of the studies concerning the metabolic rates of radioactive isotopes have used herbivore or saprovore organisms as experimental subjects. Very few studies have attempted to analyze elemental turnover in predators, except for spiders (Moulder et al 1971; Van Hook 1971; Nabholz and Crossley 1978). Yates (1977) stated that centipedes appeared as important predators as spiders in a mixed hardwood forest when their energy requirements were compared.

In this study the ingestion, assimilation and turnover to two radioactive tracers were investigated for Scolopocryptops nigridia, an abundant species in forests of the southeastern United States (Yates 1977). The two tracers utilized, cesium-134 and strontium-85, are metabolic analogs of potassium and calcium, respectively. The research was performed as part of a larger investigation on the population ecology of the centipede species, emphasizing its relations to nutrient cycling and energy flow in a forest floor system (Yates 1977).

2. Materials and Methods

Centipedes were collected from a mixed hardwood forest stand of the Botanical Garden of the University of Georgia, Athens (Clarke County), Georgia.

A description of the site is given by Yates (1977). Parameters describing radiotracer excretion were measured for three different age-classes of the centipede population. Age-classes could be distinguished by body length (Yates 1977), and were designated as follows: Age-class 0 (less than one year old), age-class 1 (one year old), and age-class 2 (two years old or older).

Animals were kept in the laboratory in individual glass containers. The bottom of each container was covered by moist filter paper and the top of each was sealed with plastic film, to maintain humidity close to saturation. Scolopocryptops nigridia individuals readily accepted whole Tenebrio molitor pupae or fresh pieces of them. Radiotracer tagged food for centipedes was prepared by dipping Tenebrio pupae in an aqueous radioactive solution containing about 4 $\mu\text{Ci/ml}$ of radioactivity. After the tagged food was dry, it was offered to centipedes for time periods up to four hours. Centipedes containing radioactive tracers were then fed on fresh untagged food and kept in a temperature controlled environment chamber at 20°C . Centipedes were transferred to uncontaminated containers daily, to minimize external body contamination from radioisotopes associated with feces.

Radiocesium and radiostrontium radioactivity was measured every 1 or 2 days with a Tracerlab Model 132 M Scaler connected to a Tracerlab Model Sc-46 NaI (TI) well crystal and shield. Individual centipedes were placed in glass test tubes and counted for 2 minutes. All measurements were corrected for background radioactivity and radioactive decay and were then normalized to a percentage of the initial count rate. The non-linear least-squares method of Marquart yielded estimates of biological elimination coefficients.

3. Results

3.1 General Retention Model

The Cs-134 and Sr-85 bioelimination curves for the different age-classes of S. nigridia corresponded to general two component exponential model which is described by the equation:

$$Q_t = Q_0 (p_1 e^{-b_1 t} + p_2 e^{-b_2 t})$$

where: Q_t is body radioactivity at any time (t), Q_0 is the initial radioactivity ($t=0$), p_2 and p_1 are the proportions of input either assimilated (p_2) or remaining unassimilated with food residues in the gut (p_1), b_1 represents the rate of loss of non-assimilated radioactivity from the gut, and b_2 represents the rate of excretion of assimilated radioactivity. Webster and Crossley (1978) recently discussed the use of two-component models of radioisotope retention and the identification of assimilated versus non-assimilated pools of radiotracers. In a two component system, counts of radioactivity when plotted on semilogarithmic axes do not form a straight line. Instead, a rapid decrease in radioactivity is followed by a slower linear portion. The rapid loss of the first component is due primarily to voidance of unassimilated radioisotope in the feces. The slower linear portion which follows then represents loss of the assimilated portion of the initial radioactivity. The fitting of these curves to the model with the Marquart iterative method was highly significant with a correlation coefficient (r) of 0.99.

The bioelimination rates of radionuclides can be expressed in terms of biological half-lives (T_b) (Crossley 1963), the time required to eliminate 50% of an ingested dose. The biological half-life is calculated as:

$$T_{b_2} = \frac{0.693}{b_2}$$

Similarly, the half-time for gut clearance can be calculated as:

$$T_{b_1} = \frac{0.693}{b_1}$$

Following a single feeding, the fraction of radioisotope assimilated can be estimated from the Y- intercept of the slower linear portion of the regression line (Van Hook and Crossley 1969). To separate such a composite curve, the linear part of the slower component is extrapolated to time zero and subtraction of this portion from the total apparent activity gives the first component.

3.2 Cesium-134 Retention

Radiocesium retention curves for the different age-classes of centipedes are shown in Figures 1, 2, and 3. Radiocesium values for parameters of the general retention model are shown in Table 1. Rates for gut clearance (b_1) were much higher than rates for elimination of assimilated tracer (b_2). Assimilation fractions (P_2) exceeded 60% of ingested radiotracer. Rates for both gut clearance (b_1) and excretion of assimilated tracer (b_2) decreased in older age-classes. Consequently, biological half-lives for radiocesium increased directly with age. Crossley (1963) showed a direct relationship between sizes of arthropod species and biological half-lives for radiocesium. Since the size of centipedes increases with age, it seems likely that the relationship we observed here is size dependent rather than age dependent.

Statistical analysis of both rate components of the model showed that the turnover rate for the first component (b_1) of age-class 0 centipedes was significantly different (1% level) from the values of b_1 for age-class 1 and 2

centipedes. However, there was no significant difference between the b_1 values of age-classes 1 and 2. A significant difference (1% level) was found between the turnover rates of the second component (b_2) of age-classes 0 and 1; and between age-classes 0 and 3. The b_2 values calculated for age-class 1 and 2 centipedes were also significantly different but only at the 5% level. Assimilation efficiency, as measured by the fraction P_2 , was higher in age-class 0 centipedes as opposed to older ages ($p < .01$ Table 1).

3.3 Strontium-85 Retention

Figures 4 through 6 illustrate the behavior of radiostrontium retention by the different age-classes of centipedes. Table 2 gives values for radiostrontium parameters of the general retention model. Again, rates of gut clearance (b_1) were much more rapid than rates of excretion (b_2) for each age-class. The fraction of radiostrontium assimilated ranged from 50% to 60% of the ingested amount. The rates again generally decreased in the older (= longer) age-classes.

The differences between the b_1 values in age-classes 0 and 1 were not significant, but the value exhibited by age-class 2 centipedes differed significantly (5% level) from the values in the other age-classes. The excretion rate of Sr-85 (b_2) for age-class 0 centipedes was significantly different from those shown by the other age centipedes at the 1% level. However, the comparison among the b_2 values for age-classes 1 and 2 showed no significant difference.

4. Discussion

The excretion rates (b_2) of both Cs-134 and Sr-85 of younger than one year old centipedes were significantly different from the respective values

shown by 1 year old or older centipedes. A decrease in the excretion rate of tracers for increasing body size has been reported previously by Crossley (1966) for the different life stages of a leaf-beetle species. This higher excretion rate of young centipedes could be associated with a higher metabolic rate and the intensive activity they normally showed in laboratory cultures or in the field (Yates 1977). It is not clear whether size and developmental stage, or size alone, would account for the higher rates for centipedes in the 0 age-class. The pattern of radiocesium retention by Scolopocryptops nigridia generally resembles experimental results reported for other species of cryptozoans (Table 3). A high fraction of ingested tracer may be assimilated, and excretion of assimilated tracer has been reported to be much slower than the turnover of non-assimilated radiocesium. Biological half-lives for assimilated radiocesium (T_{b_2}) for non-insectan cryptozoans fall into the range of 20-40 days. (Temperatures at which authors carried out experiments varied, but were in the range of 15-20° C).

Little information is available on radiostrontium turnover by cryptozoans, and most experimentation concerns arthropods with a calcareous exoskeleton. Long biological half-lives have been reported for radiostrontium in isopods (Hubbel et al 1965), diplopods (Gist and Crossley 1974), and oribatid mites (Gist and Crossley 1975). Generally those arthropods had higher assimilation fractions and slower turnover rates than we found for radiostrontium in S. nigridia.

The biological interpretation of the general two-component retention model depends upon the identification of P_2 with assimilation and b_1 with gut turnover rate. Webster and Crossley (1978) presented arguments for these identifications, and demonstrated that the more complex model of Goldstein and Elwood (1971) yields identical results. A strong argument for the interpretation of b_1 as gut turnover

rate includes the observation that, for a given arthropod species, radiotracers, with widely varying P_2 and b_2 , exhibit similar b_1 rates (Van Hook and Crossley 1969). Thus we would expect that the rates b_1 for radiostrontium and radiocesium in S. nigridia would be similar, at least within age classes. Table 1 and 2 show that this apparently is not the case. The rates b_1 seem more characteristic of radiotracer element than of age-class. It would appear that unassimilated radiotracer is being voided with feces at rates which differ for the two types of tracers. Alternatively, assimilation mechanisms or internal physiological properties may differ for these materials, enough that the two-component turnover model is less adequate.

Radiocesium has been considered as a radioactive analog of potassium in arthropods. The high assimilation rate and low elimination rate of radiocesium suggest that centipedes accumulate potassium throughout their life-time. The retention of the element is further enhanced by the low mortality and the extended longevity of the adult centipedes (Yate 1977). It is suggested accordingly, that the role played by centipedes in the cycle of potassium is represented by 1) an active mobilization of the element in the spring by the newborn centipedes which are characterized by a high elimination rate of the element, a high metabolic activity and a high mortality; and 2) a retention of the element in the tissue of the older centipedes of the population.

On the other hand, centipedes show very low body concentrations (0.6 mg/gmashfree) of Calcium (Reichle et al 1969). The elimination rates determined for radiostrontium, which is considered to be homologous to Calcium, suggest that this element is not heavily utilized by centipedes and it is returned to the system fairly rapidly through digestive and excretory waste products.

Table 1. Radiocesium values for parameters of the general two-component retention model for three age classes of Scolopocryptops nigridia. Means $\pm$ standard errors. (Symbols explained in text).

	AGE-CLASS 0	AGE-CLASS 1	AGE-CLASS 2
b_1 (hrs ⁻¹)	0.047 $\pm$ 0.0120	0.0156 $\pm$ 0.0020	0.0155 $\pm$ 0.0010
p_1 (%)	20.4 $\pm$ 2.07	32.5 $\pm$ 2.11	34.0 $\pm$ 1.02
T_{b_1} (hrs)	14.63	44.4	44.6
b_2 (hrs ⁻¹)	0.0016 $\pm$ 0.000046	0.00081 $\pm$ 0.000055	0.00059 $\pm$ 0.000025
p_2 (%)	79.6 $\pm$ 1.234	65.5 $\pm$ 1.90	65.3 $\pm$ 0.91
T_{b_2} (hrs)	596.4	851.5	1176.3
r^2	0.99	0.99	0.99

Table 2. Radiostrontium values for parameters of the general two-component retention model for three age classes of Scolopocryptops nigridia. Means $\pm$ standard error. (Symbols explained in text).

	AGE-CLASS 0	AGE-CLASS 1	AGE-CLASS 2
b_1 (hrs ⁻¹)	0.026 $\pm$ 0.00278	0.027 $\pm$ 0.0018	0.019 $\pm$ 0.0016
p_1 (%)	46.0 $\pm$ 2.97	49.5 $\pm$ 1.88	39.6 $\pm$ 2.01
T_{b_1} (hrs)	26.2	26.00	35.50
b_2 (hrs ⁻¹)	0.0033 $\pm$ 0.00021	0.0022 $\pm$ 0.00014	0.0018 $\pm$ 0.00011
p_2 (%)	53.9 $\pm$ 2.94	50.4 $\pm$ 1.81	60.9 $\pm$ 2.04
T_{b_2} (hrs)	208.2	319.5	386.9
r^2	0.99	0.99	0.99

Table 3. Comparisons between radiocesium retention curve parameters of cryptozoan arthropod species selected from the literature and the values calculated for the centipedes in this study.

	p_1	T_{b_1} (days)	p_2	T_{b_2} (days)	Authority
ISOPODA					
<u>Armadillidium vulgare</u>	0.14	1.04	0.86	26.5	REICHLE 1967
<u>Cylisticus convexus</u>	0.30	0.96	0.70	26.5	REICHLE 1967
<u>Armadillidium nasatum</u>	0.07	0.81	0.93	30.8	REICHLE 1967
<u>Metanoporthus pruinosus</u>	0.06	0.42	0.94	14.8	REICHLE 1967
DIPLOPODA					
<u>Cambala annulata</u>	0.38	1.50	0.62	12.4	REICHLE AND CROSSLEY 1965
<u>Ptyoiulus impressus</u>	0.35	0.80	0.65	20.0	REICHLE AND CROSSLEY 1965
INSECTA					
<u>Parcoblatta</u> sp.	0.47	0.60	0.53	5.5	REICHLE AND CROSSLEY 1965
CHILOPODA					
<u>S. nigridia</u> , class 0	0.20	0.60	0.80	24.9	Present study
<u>S. nigridia</u> , class 1	0.32	1.90	0.68	35.5	" "
<u>S. nigridia</u> , class 2	0.34	1.90	0.66	49.0	" "
<u>S. nigridia</u> , average	0.29	1.40	0.71	36.4	" "
ARANEAE					
Lycosidae	0.15	1.20	0.85	33.6	MOULDER et al 1970
Gnaphosidae	0.12	0.80	0.88	33.0	MOULDER et al 1970
<u>Pardosa lapidicina</u>	--	--	1.00	44.7	NABHOLZ AND CROSSLEY 1978

5. Acknowledgements

We thank Dr. Frank B. Golley for suggestions and interesting discussions. The manuscript was commented upon by several of our colleagues, including Dr. David T. Abbott and Dr. Timothy R. Seastedt. Research was supported in part by a contract between the U. S. Department of Energy and the University of Georgia Department of Entomology (D. A. Crossley, Jr.).

6. Summary

Cesium-134 and Strontium-85 turnover rates of the centipede Scolopocryptops nigridia McNeill were estimated under laboratory conditions. Both tracers' behavior exhibited a two-component retention pattern. A direct relationship between assimilation of either radioisotope and mean body weight was observed. It is postulated that 1) calcium is not heavily utilized by centipedes and it is returned to the system fairly rapidly through digestive and excretory waste products, and 2) an active mobilization by juveniles and a retention of the element in the tissue of the adults characterized the transient behavior of potassium through the centipede population.

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FIGURE LEGENDS

- Figure 1. Cesium-134 retention curve for age-class 0 (less than one year old) Scolopocryptops nigridia centipedes. Points are means $\pm$ two S. E. (n=6).
- Figure 2. Cesium-134 retention curve for age-class 1 (one year old) S. nigridia. Points are means $\pm$ two S. E. (n=6).
- Figure 3. Cesium-134 retention curve for age-class 2 (two years or older) S. nigridia. Points are means $\pm$ two S. E. (n=6).
- Figure 4. Strontium-85 retention curve for age-class 0 (less than one year old) S. nigridia. Points are means $\pm$ two S. E. (n=6).
- Figure 5. Strontium-85 retention curve for age-class 1 (one year old) S. nigridia. Points are means $\pm$ two S. E. (n=6).
- Figure 6. Strontium-85 retention curve for age-class 2 (two years or older) S. nigridia. Points are means $\pm$ two S. E. (n=6).

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