Chapter 9

Resource utilization and energy balance of Earthworm *Pheretima* sp. (Oligochaeta : Megascolecidae) in old grass field

Introduction

The number, the biomass, the metabolism and the distribution pattern of *Pheretima* sp. (H-1) (Oligochaeta: Megascolecidae) in grass field was studied in previous chapters. Three process of the resource utilization of *Pheretima* sp. (H-1) through a life span can be estimated by using the results, which has been shown in previous chapters. First estimation is the feeding process that animal demonstrates his own food demand in field. Secondary estimation is the feeding process that animal divides the resource which exists in field with companions. Third process is obtained by synthesizing the result concerning the quantity and quality of the resource comsumed by the population.

1. First estimation of the resource utilization

The feeding process of earthworms in first estimation is represented by the litter consumption rate of cultivated earthworms. In this case, the following is assumed. In field, there is no food shortage, and is not competitor either. The intrinsic food requirement of population is the product of the density, the weight frequency of population and the litter consumption rate of cultivated earthworms, assuming Q_{10} law. The food requirement of *Pheretima* sp. (H-1) in area D 1972 was presumed 2963.66 g dry wt m^{-2} of litter (Chapter 4). Otherwise, the amount of fecal pellet produced by this population was presumed to be 13247.09 g dry wt m^{-2} (Chapter 4). These values mean that the population of *Pheretima* sp. (H-1) in area D 1972 requires 2963.66 g dry wt m^{-2} of litter and 10283.4 g dry wt of soil m^{-2}. The energy content of materials per unit weight was 17.983 KJ g^{-1} dry wt of leaf litter and 0.887 KJ g^{-1} dry wt of the soil (chapter 4). Then, the total energy quantity of the resource consumed was estimated as 62416.494 KJ m^{-2} (2963.66 × 17.983 + 10283.43 × 0.887). The average assimilation efficiency of cultivated earthworms was 8.124 % (Chapter 5). These values mean that the population of *Pheretima* sp. (H-1) in area D 1972 would absorb 5070.715 KJ m^{-2}. This estimated value is amount to 609.32 % of the energy consumption of A=P+R (832.198 KJ m^{-2}) (Chapter 3).

2. Secondary estimation of the resource utilization

The second guess process is an amount of the energy supply from the environment. It is synonymous with the amount of energy which animal can use. Some preparations are necessary for this estimation. Figure 9-1 shows the procedure of secondary estimation. The content of each items in the figure are represented as follow

(a) The different vegetation area (area G) adjoined study area (area D). *Pheretima* sp. (H-1) distributed mainly in area D but rarely in area G (chapter 2). The estimation of the available energy was made on the population distributed within area D.

(b) The litter fall of the above ground vegetation is the main food resource for *Pheretima* sp. (H-1). Annual net production of the above ground vegetation in area D 1972 has been presumed to be 1176.45 g dry wt m^{-2} (Chapter 1).

(c) The maximum thickness of the wormcast was 1.835 cm on June 30, 1972. The soil density of the wormcast in June 1973 was 0.4055 g dry wt cm^{-2} (Chapter 8). The maximum thickness 1.834 cm of the wormcast was equivalent to 7441 g dry wt m^{-2} (Chapter 8). Otherwise, total quantity of fecal pellet produced by two litter dwellers: *Pheretima* sp. (H-1) and *Pheretima vittata* (Goto et hatai) were amount to 13247.09 g dry wt m^{-2} and 1766.5 g dry wt m^{-2}, respectively (Chapter 4). The figure was far larger than the maximum weight of wormcast actually obtained in the field (7441 g dry wt m^{-2} on July 30, 1972). These results show that soil and litter pass through earthworm intestine more than once in a year. wormcast decayed after pellet production at 38.7 % per a month (Chapter 8). Earthworms might consume the decaying wormcast as alternatively food resource. Its turn over rate was given by the ratio of the pellet production of earthworms to the maximum quantity of wormcast. The rate was estimated at 2.0177. This value mean that soils and litter passed twice per a year through the earthworm intestine.

(d) The maximum quantity of wormcast was 7441.45 g dry wt m^{-2}. This means that earthworm blend 1176 g dry wt of litter fall with 6264 g dry wt of soil. Then, wormcast contained litter at a ratio of 15.81 %. The value of 15.81 % of the litter to total weight was equivalent to 25.088 % of the food used for cultivation to total weight consumed. The latter value was estimated by following equation

$0.887 (1 - X) + 12.125 X = 0.887 \times 0.1581 + 17.983 \times (1 - 0.1581)$

$X = 0.25088$

Where, 0.887 is the energy equivalent of the soil used for cultivation, 12.125 is the energy equivalent of the food used for cultivation, and 17.983 is the energy equivalent of newly litter (Golley 1961). Also, X is the ratio of the food to total weight. The digestive efficiency of *Pheretima* sp. (H-1) fed on the resource containing the litter at 15.81 % was presumed 2.080 % by extrapolating the value of 25.88 to the regression of the digestive efficiency on the ratio of the food to total weight (Chapter 5).

(e) The primary litter consumer were only *Pheretima* sp. (H-1) and *Ph. vittata* in area D. The amount of the fecal pellet production of two primary litter feeders in area D 1972, is presumed like 13247.09 g dry wt m^{-2} as for *Pheretima* sp. (H-1) and 1766.5g dry wt m^{-2} as for *Pheretima vittata* (chapter 4). These figures mean, 11.766 % among all food resource was divided for *Ph. vittata* and 88.234 % was divided for *Pheretima* sp. (H-1). *Ph. vittata* showed a higher food consumption rate than that of *Pheretima* sp. (H-1) (Chapter 4). Then, the actual division of resource among litter feeders might be slightly different from the above mentioned dividing rate.

After these preparations, the amount of energy which the earthworm can absorb from these materials is presumed as follows. The consumable resource of earthworm was 1176.45 g dry wt of litter and 6264 g dry wt m^{-2} of soil. The caloric equivalent of litter is 17.983 KJ g^{-1} dry wt (Golley

1961). Also that of the soil was 0.887 KJ g^{-1} dry wt (Chapter 4). Then, the total energy of the resource consumed by earthworm was 26713.459 KJ m^{-2} (1176.45 × 17.983 + 6264 × 0.887). Then, the available energy of *Pheretima* sp. (H-1) could be estimated as 490.365 (26713.459 × 0.88234 × 0.02080) in first pass and 479.905 {(26713.459 × 0.88234 - 490.365) × 0.02080} in second pass, and 8.326 {(26713.459 × 0.88234 - 490.365 - 479.905) × 0.02080 × 0.0177} in third pass. This calculation means that *Pheretima* sp. (H-1) could absorb 978.638 KJ m^{-2} in total. This value equivalent to 117.6 % of total assimilation (A = P + R). Still, in this case, the quantity of the litter consumed by the population of *Pheretima* sp. (H-1) was estimated as 2094.52 g dry wt m^{-2} (1176.5 × 0.88234 × 2.0177)).

There were the not inhabitable wormcast layer above than B cm depth (Chapter 8). If the wormcast had the thicker layer than B cm, Layer of wormcast which cannot be inhabited for earthworms might be available as food for earthworm. Because, earthworm puts self's body on deeper layer than B cm and piles up new pellet on the surface of wormcast. However, the thinner wormcast than B cm in dry period might be not available as food for earthworm. Because, earthworm could not inhabit to the thinner wormcast than B cm. The percentage of the not available wormcast to total quantity of the wormcast was only 4.08 % in average after June (Fig. 9-2). Then, the not available wormcast might be insignificant for this estimation.

3. Third estimation of the resource utilization

Third feeding process was estimated basing on the nutrient contents of the gut materials of earthworms. The nutrient analysis showed that earthworms ingested litter at 15.61 % (Chapter 4). The field population of *Pheretima* sp. (H-1) in area D 1972 eject 13247.09 g dry wt of fecal pellet (Chapter 4). This means that the field population consumed 2067.71 g dry wt litter and 11179.38 g dry wt of soil. The energy equivalent of litter was 17.983 (Golley 1963) and that of soils 0.887 KJ g^{-1} (chapter 4). The assimilation efficiency of the earthworms in field was 1.895 % (Chapter 5). Then, the absorbed energy was calculated as 892.531 KJ {(2067.71 × 17.983 + 11179.38 × 0.887) × 0.01895}. This value exceed only 7.25 % than the energy consumption for respiration and production.

Discussion

1. Do the absorbed energy satisfy the energy consumption?

Ups to now, three processes on the feeding activity of earthworm population were estimated. First process was related to the required energy, second process was related to the absorbable energy and third process was related to the absorbed energy.

If population require resource as the cultivated earthworm (First estimation), the required energy would attain to 6.08 times of the energy consumption (A=P+R). The weight of field earthworms was smaller than that of the cultivated earthworms. The weight of the field earthworms decreased after maturation. Otherwise, the cultivated earthworms gained the more weight growth

after maturation. The difference in the growth pattern between field and cultivation mean that first estimation did not reflect the true process of the resource utilization of the population in field.

The absorbable energy (second estimation) exceed 17.6 % than the energy consumption (A=P+R). The absorbed energy (third estimation) exceed only 7.25 % of the energy consumption of field population (A=P+R). Then, the second and third process on feeding activity of earthworm population may reflect the true process of the resource utilization in field. This mean that the assumption in the second estimation and the third estimation were reasonable. Namely, animals share the available resource from litter and other thing with members and the available resource pass through the earthworm intestine more than twice per a year.

The respiration rate in field is higher than that of resting individuals in respiration chamber (Satchell 1967). The excess energy (digestion minus assimilation) were far larger in younger than elder (Chapter 5). The growth rate of the cultivated earthworms was far larger in younger than in elder (Chapter 4). Younger earthworm consumes the more quantity of energy for their higher growth rate than elder earthworms in culture (Chapter 5). Then, the difference between the 'absorbed energy' and the ' consumed energy' might be used for detecting the resource and for obtaining the higher growth rate.

2. Three aims of ecological feeding studies

Petrusewicz and Macfadyen (1970) said there were two aims of ecological feeding studies. One aim is to clarify the effect of a population on subsequent food chains in the community. Secondary aim is the another check of the energy consumption estimated from the data on respiration and net production. However, there is a large difference in feeding activities between field and cultivation. It is quite probable that the population densities and the density of food competitor besides the quantity and the nature of food resource effect on the feeding activities of earthworms in field. Inversely, the feeding activity of field populations seems to relate to the dispersion of individuals and the mortality of population (Chapter 4). Thus, third aims of the study on the feeding activities of field population may be another check of the population study. This aim will be discussed in next paper.

Summary

1) Three process of the resource utilization of animal were concerned for the population of *Pheretima* sp. (H-1) in area D. And the energy balance of this population was discussed.

2) If animal can exhibit owns ability of intrinsic food requirement also in field, the energy required was estimated as 609.32 % of the energy consumption (P + R). Then, this assumption might not reflect the true process of feeding activity in field.

3) If animal share the available resource from litter supply and other thing among members, the available energy was 117.6 % of the energy consumption.

4) The absorbed energy was estimated by integrating the data on the fecal pellet production rate

of field population and on the nutrient content of gut content of the earthworm in field. The absorbed energy was attained to 107.3 % of the energy consumption.

5) The comparison on three process for feeding activity show that the available energy and the absorbed energy, both would reflect the true process of the resource utilization of animals under the field.