Chapter 4
Feeding ecology of *Pheretima* sp. (H-1) (Oligochaeta: Megascolecidae)

Introduction

Knowledge of food consumption is necessary for productivity studies for two reasons. 1) The measurement of assimilation from consumption minus rejection provides an independent check on production plus respiration, 2) Any natural population constitute a place of division in the flow of energy through an ecosystem. Two quantities: assimilated and rejecta food is thus an important index of the effect of a population on subsequent food chain in the community (Petrusewicz and Macfadyen 1970).

The above studies need the knowledge of the quantitative and qualitative feeding characteristic of animal as they occur under natural conditions. However, such direct measurement has never yet been made in the field. To arrive at the possible estimates, the field data must be combined with laboratory data.

In this paper, some metabolic rates of *Pheretima* sp. (H-1) (Oligochaeta: Megascolecidae) are determined with a culture method under controlled temperature conditions. Secondly, the quality of the materials consumed by the earthworms in field is investigated. By combining the field data with the laboratory feeding work, some metabolic rates of the earthworms in field is discussed.

Method

1. Cultivation of earthworm

The cultivation of earthworm was carried out during the period from March 3, 1973 to June 20, 1973. *Pheretima* sp. (H-1) was cultivated. The specimens were collected in the experimental field of the department of biology of Kyushu University on late Feb. 1973. Test specimens were cultivated in a plastic container, 4.5 cm in diameter and 8.0 cm in length. To measure the amount of the food feeding, a fixed amount of food and soil was put in the container. The container consists of three parts: food, soil as substrate and cotton.

Food: The food used for the cultivation was made from the old straw matting of *Oryza sativa* L.. The old straw matting was weathered for six months in field and the rotting part was dried under room temperature for a week. The decaying straw matting was placed in vessel with fluid nitrogen and grind down into powder with pestle of iron. The powder filtered through 1 mm mesh was used as the food for cultivation.

Soil: When earthworm was bred only with food, earthworm did not reach maturity. However, the earthworms fed on soil besides the powder of the decaying straw mats could get sexual maturity. Then, earthworms were cultivated with soil as filler besides the powder of the decaying straw matting as food. Soil was collected in the experimental field of the department of biology of Kyushu University on late Feb. 1973. Soil was dried under room temperature. The soil which had passed mesh of 1mm was used as substratum for culture.

Cotton: Cotton of 5 cm^2 was adopted for controlling the humidity of soil and of food in container. Test specimens utilized the cotton as shelter. 40 g dry wt of the soil and 4 g dry wt of the food were placed in a containers. The weight of the soil and the food were the values after drying at 60 ºC for a day. A piece of cotton (5 x 5 cm^2) and 15 ml water was added into a containers. The schema of the culture container is shown in Fig. 4-1.

The culture experiments were carried out under three temperatures, 15, 20 and 25 ºC controlled by thermo-regulator. Ten individuals were cultivated under each temperature, putting by one individual per one container. However, one individual per one temperature condition has been dying for the experiment period. Besides, two individuals of *Pheretima vittata* (Goto et Hatai) were cultivated under 22.5 ºC and at 15 ºC. The additional data on the feeding of *Ph. vittata* is necessary for the comparative consideration of the feeding ecology between two Pheretima species.

The interval of the observation is as follows. On the following two days from the beginning of cultivation, the residual food and the fecal pellets in containers were removed. The earthworm is left in the container, and new food and new soil are added to the container. Two days later, earthworm's fresh weight is measured. The earthworm is moved to a new container. The removed residual food and the removed fecal pellets were dried at 60 ºC for a day, and weighed. The food consumption is shown by **FC = SF - RF**, where, FC is the food consumption, SF is the supplied food, and RF is the residual food. The soil consumption (SC) is given by the fecal pellet production (FP) minus the food consumption (FC).

2. Nutrient content and energy equivalent of the material used for the cultivation

To presume various amounts of metabolizing of the field population from the result of the cultivation, Information on Nirogen content and Carbon content and energy equivalent in the material used for cultivation is necessary. Carbon and Nitrogen contents of materials were determined with C-N corder (YANAGIMOTO). The energy equivalents of materials were determined with Bon caloric meter (YANAGIMOTO). The measurement results were settled in Table 4-1.

3. Nutrient contents of the materials contained in alimental canal of the earthworms collected in field

The information on the quality of the materials contained in alimental canal of the earthworms collected in field were also essential to estimate some metabolic rates of the earthworms in field. It was difficult to quantify the resource consumption rate of earthworm under the field condition. Alternatively, Nitrogen and Carbon contents of the materials contained in alimental canal were determined. Forty pre-mature specimens of *Pheretima* sp. (H-1) and 3 pre-mature specimens of *Ph. vittata* were used for this determination. The specimens used for these measurements are individuals that is collected for population study, and preserved in 70% alcohol. The intestines of earthworms were dissected with a surgical knife and opened. The materials in the alimental canal

were taken out, and kept in 100 % alcohol for a day. After that, the materials were placed on glass funnel with filter papers. Then, alcohol was excluded from these materials. The materials were dried at 60 ºC for a day before determination. Carbon and Nitrogen contents in the materials were determined with C.N corder (YANAGIMOTO).

Result

1. Growth rate

The growth curves of the cultivated individuals are shown in Fig. 4-2. The growth rate of the cultivated individuals (average in each culture temperature) can be represented as follow

$W(t) = 4515.2 / \{1 + \exp(-0.1233t + 4.4028)\}$ at 25 ºC (4-1)

$W(t) = 4513.2 / \{1 + \exp(-0.1170t + 4.4171)\}$ at 20 ºC (4-2)

$W(t) = 3908.9 / \{1 + \exp(-0.0733t + 4.4861)\}$ at 15 ºC (4-3)

where, W(t) is the weight of earthworms at time t (day). Whether earthworm attained to a sexual maturity or not was judged with the presence of the clitellum on the body surface. The earthworms cultivated under same temperature required same days for sexual maturation. The earthworms cultivated with 25ºC required 34 days to mature. The earthworms cultivated with 20ºC required 38 days to mature. The earthworms cultivated with 15ºC required 58-67 days to mature. The average weights of earthworm cultivated with 25 ºC were 2.35 g fresh wt at the time of maturation. The average weights of earthworm cultivated with 20 ºC were 2.39 g fresh wt at the time of maturation and the average weights of earthworm cultivated with 15 ºC were 2.11-2.72 g fresh wt. After the maturation, the cultivated earthworm gained the more weight growth but decreased its growth rate.

The variance (S^2/x) for the weight of the earthworms of the different ages in days is shown also in Fig. 4-2. The deviation decreased with the passage of the day. When the earthworm reached maturity, it was minimized. The deviation increased again after the earthworm was mature.

The literature contains only scarce data on the growth rate of Pheretima species. The growth curve of *Pheretima communissimus* have a similar pattern to those of *Pheretima* sp. (H-1), *Ph. vittata* and *Pheretima irregularis* (Goto et Hatai) (Ohfuchi 1947). Hino (1929) reported that *A. communissimus* cultivated with fresh soil need 100 days to gain a sexual maturity. Ogawa (1934) reported that *A. communissimus* cultivated with moses besides soil need 70 days for maturation (2.45 g fresh wt) at 15.8 ºC. The growth speed of *A. communissima* is extremely near the growth speed of *Pheretima* sp. (H-1) under the breeding condition of 15 ºC. The development of Lumbricidae species: *Lumbricus terrestris* L., *Allolobophora caliginosa* (Savigny) and *Allolobophora rosea* (Savigny), take many years (Lakhani and Satchell 1970, Nowak 1975 and Phillipson et al 1978). The developments of many Lumbricidae species are far low than those of Pheretima species.

Earthworm's cocoons were found in the containers breeding with 25 ºC and 20 ºC, showing the parthenogenesis of earthworms. The cocoons gained were a boll like shape having a short projection and were yellow brown in color. The cocoons were 3-4 mm in diameter and ranged

from 10 - 30 mg in fresh wt. The cocoons were produced on days from 51 to 67 days after the beginning of cultivation at 25 ºC, and on days from 51 to 78 days after the beginning of cultivation at 20 ºC. Total numbers of the cocoons produced were 20 per 9 earthworms at 25 ºC and 16 per 9 earthworms at 20 ºC. These rates were slightly lower than the rates observed in area D 1971 and 1972 (Chapter 1). However, the fertility of the cocoon gained in parthenogenesis was uncertain.

2. Food consumption and fecal pellet production

Daily change of food consumption and of fecal pellet production are shown in Fig. 4-3, 4-4 and 4-5 respectively. The food consumption rate at 25 ºC attained to the maximum of 1159 mg dry wt d^{-1} on 34 days after the beginning of culture. On that day, the weight was 2.35 g fresh wt in average. After this maximum, the food consumption rate decreased gradually. Otherwise, the fecal pellet production rate increased with the weight increase (Fig. 4-5). The food consumption rate at 20 ºC attained to the maximum of 1075 mg dry wt d^{-1} on 38 days after the beginning of culture. On that day, the weight was 2.39 g fresh wt in average. After this maximum, the food consumption rate decreased also in this temperature condition. The fecal pellet production rate at 20 ºC increased with the weight increase (Fig. 4-4). The food consumption rate at 15 ºC attained to the maximum of 792 mg dry wt d^{-1} on 58 days after the beginning of culture. After, it once decreased as seen in another temperature. The fecal pellet production rate increased with the weight increase also in this temperature condition (Fig. 4-3).

The relation between weight and food consumption rate can be expressed by following equations

$Y = 545.15\ W^{0.4382}$ r=0.8589 at 25 ºC (4-4)

$Y = 481.55\ W^{0.5280}$ r=0.8777 at 20 ºC (4-5)

$Y = 338.13\ W^{0.8764}$ r=0.8764 at 15 ºC (4-6)

where, Y is the food consumption rate (g dry wt d^{-1}) and W is the body fresh weight in gram. The relation between weight and fecal pellet production rate can be expressed by following equations

$F = 1419.12\ W^{0.7015}$ r=0.92642 at 25 ºC (4-7)

$F = 1405.93\ W^{0.9594}$ r=0.9594 at 20 ºC (4-8)

$F = 986.86\ W^{0.92840}$ r=0.9409 at 15 ºC (4-9)

where, F is the fecal pellet production rate (g dry wt d^{-1}) and W is the fresh weight in gram.

As mentioned in above, the food consumption rate increased till the day when the earthworms attained to a sexual maturity. After the maturation, the food consumption rate once decreased and fluctuated. This result shows that the food consumption rate must be distinguished between the immature individual and the matured individual. Then, the relations of immature earthworms can be represented as follow

$Y = 679.57\ W^{0.6040}$ r=0.8589 at 25 ºC (4-10)

$Y = 604.18\ W^{0.6957}$ r=0.9454 at 20 ºC (4-11)

$Y = 403.97\ W^{0.9749}$ r=0.8699 at 15 ºC (4-12)

Also, the relation of mature earthworms can be represented as follow

$Y = 562.75\ W^{0.2588}$ r=0.1451 at 25 ºC (4-13)

$Y = 301.48\ W^{0.7136}$ r=0.3142 at 20 ºC (4-14)

$Y = 552.05\ W^{0.1359}$ r=0.1759 at 15 ºC (4-15)

The regression coefficient for matured earthworms showed the unreliability of the relations (r = 0.145 - 0.312). This low reliability mean that the food consumption rate of matured earthworms was not proportional to their weight. Then, the use of formula 4-13, 4-14 and 4-15 is unsuitable for the estimation of the food consumption of matured earthworms. The formula: 4-4, 4-5 and 4-6 are containing the relation of matured earthworms. These showed a relatively high value of the regression coefficient. The observed food consumption of the matured earthworms are equal to 75.94 % at 15 ºC, 82.00 % at 20 and 86.12 % at 25 ºC, to the quantities calculated by using the formula 4-4, 4-5 and 4-6. Then, the food consumption rate of matured earthworms can be approximated by the following equations

$Y = 469.51\ W^{0.4382}$ at 25 ºC (4-16)

$Y = 394.85\ W^{0.5283}$ at 20 ºC (4-17)

$Y = 256.78\ W^{0.8359}$ at 15 ºC (4-18)

The formulas: 4-10, 4-11 and 4-12 will be used to estimate the amount of the food consumption of immature individual. And, the formulas 4-16, 4-17 and 4-18 will be used to estimate the amount of the food consumption of mature individual.

The energy equivalents of the food and of the soil were 11.661 KJ and 0.887 KJ, respectively (Table 4-1). The energy of the food (11.661 KJ) is only 64.8 % of the energy equivalent of newly litter (Golley 1969). The lower energy equivalent of the food may be due to microbial activity in weathering of older straw mats.

Because the earthworms in field could get new litter, the earthworms in field would gain same quantity of energy with the lower rate of the litter consumption than the rate of the food consumption of the cultivated earthworms fed on the powder of the decayed straw mats. The food consumption and the fecal pellet production, of *Pheretima* sp. (H-1) in area D 1972 were estimated at 4702.504 g dry wt m^{-2} (=powder of the decaying straw mats) and 3247.09 g dry wt, respectively by integrating the cultivation data (Formula 4-10, 4-11, 4-12, 4-16, 4-17 and 4-18, and 4-7, 4-8 and 4-9) and the field data (Weight distribution and field temperature), assuming the Q_{10} formula. These values mean that the consumed powder of the decaying straw mats was equivalent to 35.5 % of total material consumed. Under the assumption that the cultivated earthworms consume the food (=the powder of decayed straw mats) at the ratio of 35.5 % and the soil at the ratio of 64.5 % in average, The litter consumption rate of the earthworm cultivated with new litter is presumed as follows.

$17.983\ X + 0.887\ (1-X) = 11.661 \times 0.355 + 0.887 \times 0.645$

$$X = 0.224$$

Where, the value 11.661 is the energy equivalent of the food (the powder of the decayed straw mats) in KJ, the value 0.887, the energy equivalent of the soil in KJ, the value 17.983, the energy equivalent of newly litter in KJ (Golley 1969), and X, the ratio of Litter consumption to total material consumed. Namely, the earthworms fed on newly litter can gain same quantity of energy with the rate of 63.02 % of the food consumption of the cultivated earthworms. Then, the litter consumption rate of immature earthworms fed on newly litter should be expressed as follow

$Y' = 428.27\ W^{0.6040}$ at 25 ºC (4-10')

$Y' = 380.75\ W^{0.6957}$ at 20 ºC (4-11')

$Y' = 254.58\ W^{0.9749}$ at 15 ºC (4-12')

Also, the litter consumption rate of mature earthworms fed on newly litter should be expressed as follow

$Y' = 295.89\ W^{0.4382}$ at 25 ºC (4-16')

$Y' = 248.83\ W^{0.5283}$ at 20 ºC (4-17')

$Y' = 161.82\ W^{0.8359}$ at 15 ºC (4-18')

Where, W is the weight of earthworm (g fresh wt), and Y', the litter consumption rate (mg dry wt per a day).

There are no comparable data on the litter consumption rate of Pheretima species. It had been recorded that the resource consumption of Lumbricid per body wet weight per day were 27 mg in *L. terrestris* fed on elm leaves (Needham 1957), 27 mg dry wt in *Lumbricus rubellus* Hoffmeister fed on hazel litter (Franz and Leitenberger 1948), 27 mg dry wt in average of 6 species of Lumbricid fed on alder leaves (Rhee 1963) and 80 mg dry wt in immature specimens of *Allolobophora caliginosa* (Savigny) fed on cow dung (Barley 1959). (Satchell (1967) cited these data.) The litter consumption rate of *Pheretima* sp. (H-1) with the weight of 1g at 15 ºC was calculated at 254.58 mg dry wt in immature earthworms and at 161.82 mg dry wt in mature earthworms. These values show the far higher litter consumption rate of *Pheretima* sp. (H-1) than the rate of Lumbricidae species.

Watanabe (1975) observed the cast production of casting species *Pheretima hupeiensis* (Michaelsen) under the field condition. He reported that the rate of cast production of this species was represented as $2.21 - 5.1\ W^{0.91}$ (13 ºC - 22 ºC), where W is the weight mg fresh wt. This rate is higher than that of *Pheretima* sp. (H-1). He noted that total cast production was two or three time of the cast deposited on the soil surface, in culture condition. Then, the true rate of casting species and soil feeder species may be several time of the rate of litter feeder species. Otherwise, the egestion rate of *A. caliginosa* in field was 200-420 mg dry wt g^{-1} fresh wt d^{-1} (Barley and Jennings 1959). Piearce (1972) reported that *A. caliginosa* and *L. rubellus* fed on soil from deciduous wood land, produced 40-80 mg dry wt of feces and 25-50 mg dry wt of feces g^{-1} d^{-1}. He said that the low rate of *A. caliginosa* in deciduous reflects the relatively high humus contents of the soil. Bolton and

Phillipson (1976) reported that *Allolobophora rosea* (Savigny) fed on bramble soil produced about 2200 mg dry wt of feces g^{-1} fresh wt d^{-1} in average of size, at 14.8 ºC. Crossley et al (1971) estimated the gut turn over rate of *Octolasium* fed on forest soil were at 288 mg $g^{-1}d^{-1}$. The feces production rate of Lumbricidae species, except the rate of *E. rosea* fed on bramble soil, are lower than that of *Pheretima* sp. (H-1). Lavelle et al (1980) reported 6-30 g g^{-1} of daily soil consumption of five geophagous species of the Lamto Savanna. Lavelle (1983) cited 3-6 g g^{-1} for the glossoscolecid of Laguna Verde. The daily soil consumption of tropical species was far higher than that of *Pheretima* sp. (H-1).

3. Nutrient contents of the material contained in alimental canal of field population

Figure 4-6 shows the frequencies of Carbon content and Nitrogen content of the materials in alimental canal of the field earthworms, respectively. In the materials contained in the alimental canal of the field earthworms, Carbon content ranged from 13.1 mg to 110 mg g^{-1} and nitrogen content ranged from 1.64 mg g^{-1} to 30 mg g^{-1}. The average content of Carbon was 72.15 ± 35.39 mg g^{-1} (N=40) and the average content of Nitrogen was 6.42 ± 2.43 mg (N=40). The earthworms in culture consume the food (the powder of the decaying mats) at 35.5 % and Soil at 64.5 %. These values were estimated from the field data (Weight distribution of the population in area D 1972 and the field temperature in 1972, in Chapter 1) with the laboratory work assuming the Q_{10} formula. These values mean 93.6591 mg Carbon (222.93 mg × 0.35 + 22.51 mg × 0.645) and 6.0065 mg Nitrogen (13.94 mg × 0.355 + 1.64 mg × 0.645).

Otherwise, the average content of Nitrogen in the gut material of the field earthworms was higher than that estimated from the cultivation. This difference is due to the difference in the C/N ratio of food resource between field and cultivation. The C/N ratio in the gut material of the field earthworms was 11.238 and the C/N ratio in the cultivation was 15.593.

4. Feeding ecology of *Pheretima vittata*

The main food competitor of *Pheretima* sp. (H-1) in field may be *Ph. vittata* which consume same food resource and consume the more quantity of resource than *Pheretima* sp. (H-1). *Ph. vittata* have four fold of weight of *Pheretima* sp. (H-1) in spite of lower density of earlier species. Then, the knowledge of feeding ecology of *Ph. vittata* is very important for the study of feeding activity of *Pheretima* sp. (H-1) in field, although the data on feeding ecology of earlier species was rare.

Two individuals of *Ph. vittata* were cultivated. One was cultivated at 22.5 ºC and other was cultivated at 15 ºC. Moreover, The amount of C, N in the gut content of *A.vittata* of three individuals was measured. The growth curve of *Ph. vittata* can be represented as follow

$W(t) = 7374.2/\{1+\exp(-0.1269t+5.5285)\}$ at 22.5 ºC (4-19)

$W(t) = 5807.2/\{1+\exp(-0.0627t+3.56\ )\}$ at 15.0 ºC (4-20)

where, w(t) is the body wet weight of the earthworms at time t (day). The food consumption rate of

Ph. vittata could be expressed by following equations

$Y = 770.5\ W^{0.7249}$ at 22.5 ºC (4-21)

$Y = 469.0\ W^{0.8033}$ at 15.0 ºC (4-22)

The fecal pellet production rate of *Ph. vittata* can be expressed by following equation

$F = 840.7\ W^{0.79952}$ at 15.0 ºC (4-23)

Where, W is the body wet weight (g fresh wt), and F, the fecal pellet production (g dry wt d^{-1}). The data on fecal pellet production of the individual cultivated at 22.5 ºC was unavailable.

Maximum weight and food consumption rates of *Ph. vittata* were 1.4 - 1.6 fold of those of *Pheretima* sp. (H-1) cultivated at similar temperature condition. However, the fecal pellet production rate was slightly lower in earlier species than in later species. Nutrient content (Carbon and Nitrogen) in gut material of *Ph. vittata* was 1.618 fold of that *Pheretima* sp. (H-1) (116.8 ± 44.91 mg Carbon and 9.9 ± 3.36 mg Nitrogen, for *Ph. vittata*). Total quantity of food consumption of field population of *Ph. vittata* in area D 1972 was estimated at 924.5 mg dry wt of powder of the decayed straw mats), by integrating the cultivation data (the food consumption rate of the cultured earthworms of this species under two temperature) and the field data (Weight frequency and field temperature, in Chapter 1), assuming Q_{10} formula. Also, total quantity of fecal pellet production of same population was approximated at 1766.5 g dry wt m^{-2} with same method, but by using the data on the fecal pellet production rate of *Pheretima* sp. (H-1) (Formula 4-7, 4-8 and 4-9). These values mean that the cultivated individual of *Ph. vittata* consumed the food in the ratio of 52.33 % and consumed the soil in the ratio of 47.67 %. And the nutrient content in the materials required by the cultivated earthworm of *Ph. vittata* can be calculated at 127.39 mg Carbon g^{-1} dry wt and 8.08 mg Nitrogen g^{-1} dry wt with same method for *Pheretima* sp. (H-1). This calculation show that Carbon content in gut content of field earthworms of *Ph. vittata* is equivalent to 91.7 % of the estimated value, but the determined Nitrogen content is higher than the estimated content. This difference depends on the difference of the C/N ratio of the food of the field individual and the food of the breeding individual.

Discussion

The necessary period of the cultivated earthworms for maturation were 34 days at 25 ºC, 38 days at 20 ºC and 58-67 days at 15 ºC. These were far shorter than the maturation period of field population of *Pheretima* sp. (H-1). This species need about 100 days in grass field for maturation (Chapter 1). The weight of the cultivated earthworms increased even after maturation and attained to 6-7 g fresh wt. However, the weight of the earthworms in field decreased after maturation. Its maximum weight were 2.7 g fresh wt in area H 1968 except the irregular value on 2 Sept. 1968, 1.84 g, area D 1971 and 1.80 g, area D 1972. The difference in the growth pattern of *Pheretima* sp. (H-1) between field and cultivation may be caused by the difference in quantity of food resource. Namely, the cultivated earthworms were fed on nutrient rich material with fully quantity but the earthworms

in field consumed the poor and limited resource.

It is very difficult to estimate the food resource consumption rate by direct method in field. Then, the rate in field is estimated from the data of the nutrient analysis of gut content. As mentioned in earlier, C/N ratios of food resource were different between field and cultivation. The food resource with high nitrogen content also has a high sugar content. Because earthworm are capable of detecting sweet tasting substance (Mangold 1955, Laverack 1960, quoted by Satchell 1967), this explain the selection of Nitrogen rich litter in field. Then, the carbon content in material is the more fundamental indicator.

The carbon content in gut material of the field individuals was 72.15 mg g^{-1} dry wt in *Pheretima* sp. (H-1) and 116.83 mg g^{-1} dry wt in *Ph. vittata*. These were equivalent to 77.03 % in *Pheretima* sp. (H-1), and 91.71 % in *Ph. vittata*, of the estimated carbon contents of the cultivated earthworms, respectively. The litter feeding ratio of the *Pheretima* sp. (H-1) field populations can be presumed from the data of the content of the carbon of the field population by the next expression.

$$72.15 \text{ C mg} = 222.93 \text{ C mg } X + 22.51 \text{ C mg } (1-X)$$

$$X = 0.2477$$

Where the value 222.93 mg is the carbon content of the food used for cultivation, and the value 22.51 mg, the carbon content of the soil used. This calculation mean that *Pheretima* sp. (H-1) in area D 1972 consume the food at 24.77 %. The ratio of the food consumed to total material consumed by the cultivated individuals having the same weight frequency of the area D 1972 population was estimated as 35.5 %. Namely, the true rate of the food resource consumption of the field earthworms is 69.78 % of the rate of the cultivated earthworms. These results explained the low growth rate, the smaller weight and the weight loses after maturation, of the field individuals. Dividing the limited food resource among members and between competitor might cause the decrease of the food resource consumption rate of *Pheretima* sp. (H-1) in field. Against this, there were no food shortage, no food competitor and no food conditioning under the cultivation. In *Ph. vittata*, the ratio of the food consumed to total quantity consumed is estimated as 47.06 %: $116.83 = 222.93 x + 22.51 (1 - X)$. This value was attained to 89.93 % of that of the cultivated earthworms (47.06/52.33). These may mean that the metabolic rate of *A.vittata* does not receive the influence so much by the change in an environmental factor.

It is also very difficult to estimate the fecal pellet production rate in field. This estimation can be done by the indirect method. The weight of earthworm cast in area D attained to the peak of 7441 g dry wt m^{-2} on 30 June 1972 (Chapter 8). The total weight of the fecal pellets produced by *Pheretima* sp. (H-1) and *Ph. vittata* in area D 1972 between Feb. and August was estimated at 15013.6 g dry wt m^{-2} (13247.09 g dry wt + 1766.51 g dry wt, respectively). The decaying rate of earthworm cast was estimated at 38.715 % per a month (Chapter 8). Bi-monthly production of earthworm cast can be estimated from the data of fecal pellet production with the decaying rate of

wormcast. The wormcast at 30 June and 15 July 1972 in area D was estimated as 6491 g dry wt m^{-2} and 6929.4 g dry wt m^{-2}, respectively (Chapter 8). The estimated value was slightly smaller that the observed maximum (7441 g dry wt m^{-2}, in chapter 8). This result may mean that the earthworms consuming a poor resource material produced a more quantity of fecal pellets. However, the estimation value is approximated enough to the observation value.

The metabolic rate of *Pheretima* sp. (H-1) in field or in cultivation, with those of *Ph. vittata*, were summarized in Table 4-2. The feeding activity in field is effected by the life of animal in field (Such as inter and or intra species relation etc). The difference in some metabolic rate between field and cultivation will be the useful indicator for the study on the natural life of animal in field. Then, the measurement of the metabolic rate in field besides that in cultivation is useful for the study of inter or intra species relation ship in field in addition to two bio economical aims mentioned by K. Petrusewicz and A. Macfadyen (1970). {1) An independent check on production plus respiration, 2) The flow of energy through an ecosystem. } The more detail comparison on metabolic rate between field and culture will be discussed, in later paper.

Summary

1) *Pheretima* sp. (H-1) were cultivated under three temperature condition, and fecal pellet production, food consumption rate growth rate were determined.

2) The cultivated earthworms required 34 - 64 days for their maturation against to 100 days of maturation period for the field earthworms. Also, the maximum weight of the cultivated earthworms was attained to 4 - 4.5 g fresh wt against 1.7 - 2.5 g fresh wt of the field earthworm.

3) Fecal pellet production of the cultivated earthworms were 1054 - 1540 mg dry wt for an individuals having one gram body wet weight.

4) Litter consumption of the cultivated earthworms were 374 - 590 mg dry wt for an individuals having one gram body wet weight. Still, the litter consumption rate of mature earthworms was smaller than the rate of immature earthworms.

5) The quality of the material consumed by the field earthworms were investigated with determining Carbon and Nitrogen content in the gut content of the field earthworms. The carbon content in material was regarded as the more fundamental indicator for the consideration on the metabolic rate of field earthworms. Carbon content in the gut content of the field earthworm was 72.15 mg g^{-1} dry wt in average. On the other hand, Carbon content in the materials consumed by the cultivated earthworm was estimated at 89.91 mg g^{-1} dry wt. From these results, it was estimated that the food consumption of the field earthworm was attained to 73.64 % of the rate of the cultivated earthworms.

6) It was thought that the lower growth rate and the lower weight of the field earthworms than those of the cultivated earthworms might be due to the lower resource consumption rate of the field earthworm than that of the cultivated earthworms.

Reference

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