Memoirs of the College of Science, University of Kyoto, Series B,
Vol. XXXIII No. 3 (Biology), March 1967

Defication Ratio of a Young Crucian Carp, *Carassius carassius*, in Relation to its Ingestion Rate* ** ***

by

Hiroya Kawanabe

Department of Zoology, Faculty of Science. Kyoto University

Abstract

The defication rate of a young crucian carp, *Carassius carassius*, was measured directly and was calculated from the ingestion, respiration and growth rates in laboratory aquaria. It was clearly observed from the investigation that the defication ratio increased as the ingestion rate increased.

Introduction

Few investigations have been carried out on the defication rate of animals, which is one of the most fundamental values of production ecology. Fishes are relatively well studied animals on this point, most papers of which were simply described the defication ratio itself or were focussed only upon the relation of the ratio to quality of food materials. The present paper, however, deals with the effect of ingestion rate upon the defication ratio in fish.

Before going further, I wish to express my hearty thanks to Miss Junko Kitamura, now Mrs. J. Yamanoue, for her kind assistance and to Mr. Norio Suzuki for his suggestions from the physiological point of view.

Methods

Individuals of a young crucian carp, *Carassius carassius*, collected from the north-eastern part of Lake Biwa and of an aquatic oligochaete, *Tubifex*, as food of crucian carp, were used for the present study.

Two kinds of experiment were planned and carried out. Five large aquaria,

---

* Contribution from the Laboratory of Animal Ecology, Department of Zoology, Kyoto University.

** Contribution from the Otsu Hydrobiological Station, Kyoto University, Foreign Language Series, No. 184.

*** Contribution from the B. S. T. (Biological Research Group of Organic Resources in Lake Biwa), No. 73.

being 59 cm in length, 29 cm in breadth and a water depth of 28 cm, were used for the first experiment; in each of which five individuals of fish were kept and tubificids were put for their foods at a definite time every day. The remains of food were picked up at the same time of the following day, and the difference between given amounts and remains of tubificid indicated the amount of food intake of the five fish per day. The control experiment was made without fish, but no differences were observed between amounts of given and remained tubificid. Body weight of fish was measured every week. Water temperature was maintained at 15°C or 25°C.

Fifteen small bottles, being 9 cm in diametre and a water depth of 18 cm, were used for the second experiment. A fish was kept in each bottle and tubificids were put in and picked up as same as the first experiment. Deficated materials were filtered every day by Toyo No. 5c filter-paper with aid of aspirator, and filtering residue were weighed. The control experiment was also done without fish, where practically no filtering residue were measured. Water temperature was maintained at 25°C during the experiment.

Results

Relation between the ingestion rate (I) and the growth rate (G) of the fish observed in the first and second experiments is shown in Fig. 1. Each number

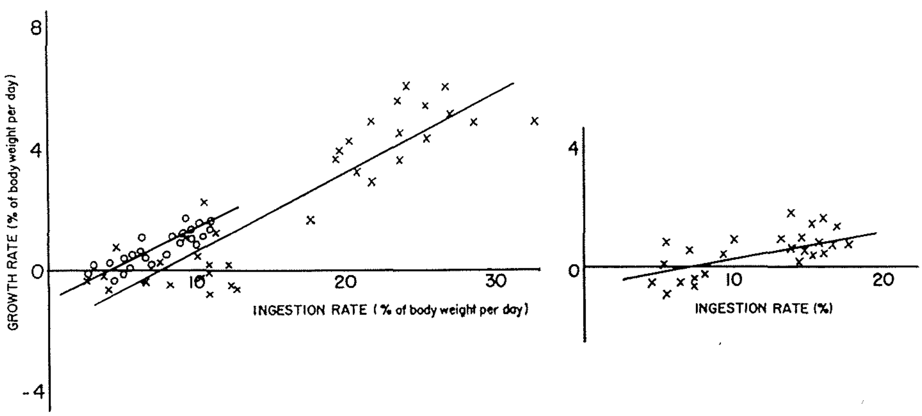

Fig. 1. Relation between the ingestion rate and the growth rate of young crucian carp in aquarium and small bottle. The scales are shown as percentage values of the rate per day to individual weight both in caloric value. Left one shows the case of 3 to 6 grammes fish in body wet weight, while right one shows the case of 10 to 20 grammes fish. Symbols ○ and × indicate the result in water temperature of 15°C and 25°C respectively.

is shown as the ratio of the rate per day to individual weight both in caloric value. Caloric conversion ratios measured by SUZUKI and YANAGISHIMA (unpublished) by using bomb calorimetre are as follows: 1.02 kcal/g(wet weight) for the crucian carp, 1.08 kcal/g(wet weight) for the tubificid and 5.10 kcal/g(dry weight) for the deficated material by the fish.

Linear relations are observed between the ingestion and growth rates in every cases, and two coefficients of the formula

$$G = aI - b$$

and related values can be calculated as shown in Table 1.

Table 1. Two coefficients of linear relation (G=aI+b) and related values between the ingestion rate (I) and the growth rate (G) of young crucian carp in aquarium and small bottle. I_0 means I at G = 0, namely so-called maintenance ration.

body wet weight	water temperature	a	b	I_0	correlation coefficient
3- 6 g	15°C	0.229±0.062	0.935	4.09(3.87-4.35)	0.872
3- 6 g	25°C	0.263±0.025	2.00	7.62(6.98-5.48)	0.923
10-20 g	25°C	0.133±0.088	0.991	8.05(4.82-9.96)	0.826

In general, the growth efficiency increases as the coefficient "a" increases or as maintenance ration (I_0 : I at G=0) decreases. As shown in Table 1, the coefficient "a" is clearly larger in small individuals than in large ones, but no difference of "a" is observed according to water temperature. Whereas, I_0 varies with water temperature, and the ratio of I at 25°C divided by I at 15°C is about 1.86, which is agreed with the general value of Q_{10} in the respiration rate shown in most fishes.

From Fig. 1 the ingestion and growth rates of the fish, when it was given sufficient amounts of food, can be seen as shown in Table 2. From these

Table 2. The ingestion rate and the growth rate of young crucian carp in aquarium when sufficient amounts of tubificid were given for its food.

body wet weight	water temperature	mean ingestion rate	maximum ingestion rate	mean growth rate	maximum growth rate
3- 6 g	15°C	9.5%	10.3%	1.3%	1.7%
3- 6 g	25°C	24 %	33 %	4.5%	6.5%
10-20 g	25°C	15 %	18 %	0.8%	1.1%

values Q_{10} of the ingestion and growth rates can be calculated as 2.52 and 3.46 respectively.

Relation between the ingestion rate (I) and the defication ratio (F/I) obtained from the second experiment is shown in Fig. 2. Linear relation is also

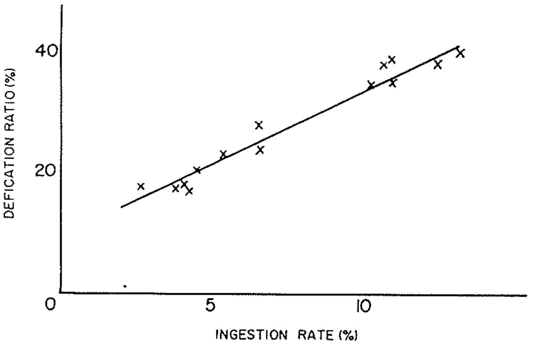

Fig. 2. Relation between the ingestion rate and the defication ratio of the fish in body weight of 3 to 6 grammes measured in small bottle. Water temperature was maintained at 25°C.

observed between I and F/I as the following formula:

$$F/I=2.40\, I + 9.22 \qquad \text{(correlation coefficient: 0.954)}$$

Defication ratio is about 17 to 38 per cent, and it is clear that the higher the ingestion rate, the larger the defication ratio.

Direct measurement of the defication ratio was made onlyi n very small bottle as mentioned above, but the defication ratio may be calculated also from the results of the first experiment if the respiration rate can be measured or estimated. For this purpose, the relation between swimming speed and active metabolism of the fish was investigated by using rotating cylindrical bottle, and swmming movement of the fish individuals was observed in the aquarium all day long. Then the both results were combined and active respiration rate per day was

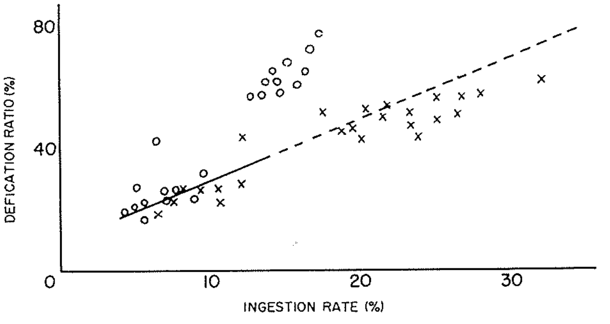

Fig. 3. Relation between the ingestion rate and the defication ratio of the fish calculated from the respiration and growth rates measured in aquarium. Symbols ○ and × indicate the fish in body weight of 10 to 20 and 3 to 6 grammes respectively. Solid line shows the regression calculated from the result in small bottle as shown in Fig. 2, and broken fine is its extension.

calculated. These results will be reported separately, but it is found that the active respiration per day in the aquarium was about two times of standard respiration. The defication rate is, then, calculated as the difference between the ingestion rate and the respiration rate plus the growth rate. These results agree with the direct observation mentioned above as shown in Fig. 3. When the ingestion rate is considerably high, however, the defication ratio seems to be slightly lower than that expected from the latter formula mentioned above. It may be related to "specific dynamic action". Much higher defication ratio is calculated in the case of larger individuals, 10 to 30 grammes in body weight.

Discussion and Conclusion

The defication ratio of fish has been investigated for a rather long time. In 1930s, KARZINKIN and his colleagues devoted their efforts to measuring production rates of various fishes, in which the defication ratio was obtained. They also noticed the effect of external and internal conditions upon the defication ratio, i. e., KARZINKIN (1935) and ALNOLDI and FORTUNATOVA (1937) pointed out the temperature effect and KARZINKIN (1935) did also the effect of ingestion rate. Technically developing studies being carried out since that time, however, most studies of them were focussed only on the relation between defication ratio and quality of food materials or on defication ratio of each nutritive element, such as protein, amino acid, starch, mono- and poly-saccharide, fat, fatty acid, etc. (e.g., TUNISON, et al., 1942; GERKING, 1955; NOSE, 1960; INABA, et al., 1963; MUSACCHIA, et al., 1964; SIVADAS, 1965). No further informations have been given upon the effects of other external or internal conditions.

On the other hand, it is well known in plankton animals that the defication ratio is greatly affected by the ingestion rate. They filtrate small algae from water much more than enough for their food when density of algae is high, and most of filtering algae simply pass through their gut and are deficated. It is termed "superfluous feeding" (e.g., RICHMAN, 1958; MONAKOV and SOROKIN, 1959; BEKLEMISHEW, 1962; MARSHALL and ORR, 1962).

In the case of fish, such a excess feeding has not been observed, but the defication ratio is greatly differ according to the change of the ingestion rate as shown in the present study. On the reason of such phenomenon, KARZINKIN (1935) already supposed that food material remained in the gut a shorter time when a lot of food was ingested. Following investigators, however, have not proved yet his speculation.

As was mentioned in the introduction, the defication rate is one of the most fundamental values of production ecology. If it is a general phenomenon that the defication ratio is greatly affected by the rate of ingestion, most of past studies on trophic relation may need to be re-examined from this point of view.

References

ALMOLDI, L. V. and K. R. FORTUNATOVA, 1937. A contribution to the experimental study of the nutrition of Black Sea fishes. Compt. Rend. Acad. Sci. USSR., 15: 513-516. (cited from RICKER, 1946)

BEKLEMISHEW, C. W., 1962. Superfluous feeding of marine herbivorous zooplankton. Rapp. Proc.-Verb. Réun. Expl. Mer, 153: 108-113.

CUSHING, D. H., 1964. The work of grazing in the sea. "Grazing in terrestrial and marine environments" (ed. D. J. CRISP), 207-225.

GERKING, S. D., 1955. Production and food utilization in a population of bluegill sunfish. Ecol. Monogr., 32: 31-78.

INABA, D., C. OGINO, C. TAKAMATSU, T. UEDA and K. KUROKAWA, 1963. Digestibility of dietary components in fishes. II. Digestibility of dietary protein and starch in rainbow trout. Bull. Jap. Soc. Sci. Fish., 29: 242-244. (in Japanese with English summary)

KARZINKIN, G. S., 1935. Zur Kenntniss der Fischproduktivität der Gewässer. II. Mitteilung. Erforschung der Physiologie der Ernährung der Spiegelkarpens. Arb. Limnol. Stat. Kossino Hydrometeorol. Admin. USSR., 19 : 21-66. (in Russian with German summary)

MARSHALL, S. M. and A. O. ORR, 1962. Food and feeding in copepods. Rapp. Proc.-Verb. Réun. Expl. Mer, 153: 92-98.

MONAKOV, A. V. and I. I. SOROKIN, 1959. Experimental studies of the carnivorous feeding of cyclops by means of an isotope method. Dokl. Akad. Nauk SSSR., 125: 319-321. (cited from CUSHING, 1964)

MUSACCHIA, X. J., S. S. NEFF and D. D. WESTHOFF, 1964. Active transport of d-glucose by intestinal segments, in vitro, of *Ictalurus nebulosns*. Biol. Bull., 126: 291-306.

NOSE, T., 1960. On the digestion of food protein by gold-fish (*Carassius auratus* L.) and rainbow trout (*Salmo irideus* G.). Bull. Freshw. Fish. Res. Lab. (Japan), 10: 11-22. (in Japanese with English summary)

RICHMAN, S., 1958. The transformation of energy by *Daphnia pulex*. Ecol. Monogr., 28: 273-291.

RICKER, W. E., 1946. Production and utilization of fish populations. Ibid., 16 : 373-391.

SIVADAS, P., 1965. Absorption of fat in the alimental canal of *Tilapia mossambica* (PETERS) (Teleostei). J. Cell. Comp. Physiol., 65 : 249-254.

TUNISON, A. V., D. R. BROCKWAY, J. M. MAXWELL, A. L. DORR and C. M. MCCAY, 1942. The nutrition of trout. Protein utilization by brook trout. Cortland Hatchery Rep., 11 : 24-42. (cited from NOSE, 1960)