UTILIZATION OF FOOD BY MACKEREL, PNEUMATOPHORUS JAPONICUS (HOUTTUYN)

UTILIZATION OF FOOD BY MACKEREL, *PNEUMATOPHORUS JAPONICUS* (*HOUTTUYN*)

By

Masayoshi HATANAKA and Masao TAKAHASHI

Department of Fisheries, Faculty of Agriculture, Tohoku University, Sendai, Japan

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Materials and Methods

During the seasons of summer and autumn of 1955, a feeding experiment was undertaken for the purpose to determine the relation between growth and food consumption among mackerel (*Pneumatophorus japonicus*), one of the most important food fish of the Country.

Specimens were caught by a trap-net settled on the shore in the Bay of Onagawa, Miyagi Prefecture. The fish used in this experiment ranged between 68 and 130 mm long (to the end of the urostyle), weighing 3.8 to 23.4 g, during the period of July and August, and between 153 and 157 mm long, weighing 45.3 to 58.2 g, in October, and all were 0 year of age. They were held at first in the indoor concrete aquaria measuring 1.5×0.5 m and 0.5 m deep and later in the outdoor aquaria measuring 4×3 m and 1 m deep, both in running sea water. The number of fish admitted at a time in the aquaria was from 3 to 6 individuals, which were distinguished with each other by size and dermal spots.

It was revealed from the results of observations made on the stomach contents of the young mackerels in natural that the main food item in summer and autumn was the anchovy (*Engraulis japonicus*). For food in this experiment, anchovies, weighing 1 to 2 g each, were used and fed five to six times a day. The weight of food eaten by individual fish per day was recorded and any unused food were removed immediately.

The mackerel were weighed and measured once per 10 days after slightly narcotized by 1% urethan solution, whose effects on the fish were neglegible. The water temperature taken daily ranged between 19° and 25°C in summer and between 15° and 16°C in autumn.

Before proceeding further we express our hearty thanks to the staff of Onagawa Fisheries Experimental Station, Tohoku University, for their kind co-operation made during the experiment. This study was supported financially by a grant from the Agency of Fisheries, the Ministry of Agriculture.

Table 1. Rations and growth of 14 mackerel fed with anchovy (1955, Onagawa).

Fish No.	Date	July 22	Aug. 1	,, 11	,, 21	,, 31	Sept. 10	,, 20
	Water temp. °C		22~23	23~25	24~25	23~25	19~22	19~20
1	Body length mm	83.1	109.4	126.0	138.8	149.6	157.0	164.0
	Body weight g	7.5	14.2	24.3	33.0	42.4	55.2	57.9
	Food eaten g		25.3	36.1	34.3	43.2	50.1	26.0
2	l.	80.2	106.5	125.4	133.8			
	w.	5.9	13.5	24.5	28.8	died		
	f.		20.2	39.3	25.4			
3	l.	68.1	97.6	115.8	128.2	140.1	147.0	152.7
	w.	3.8	10.7	19.7	26.8	34.2	43.9	48.5
	f.		17.6	26.4	23.1	31.4	35.7	21.0
4	l.			82.4	109.5	122.0	127.1	134.8
	w.			7.2	15.6	22.0	25.4	30.2
	f.				26.7	15.4	14.7	20.8
5	l.			74.6	98.2	101.0	113.1	123.8
	w.			4.1	9.2	12.3	18.6	23.6
	f.				15.8	11.2	14.0	18.7

Fish No.	Date	Aug. 24	Sept. 3	,, 13	,, 23
	Water temp. °C		23~25	19~22	19~20
6	Body length mm	130.8	143.1	146.4	
	Body weight g	23.4	32.1	35.5	died
	Food eaten g		37.2	15.1	
7	l.	126.5	133.8	145.7	150.8
	w.	21.0	28.6	36.2	40.5
	f.		21.7	39.9	24.0
8	l.	83.4	100.0	120.9	120.1
	w.	6.0	11.0	22.0	19.8
	f.		13.6	27.4	7.7
9	l.	90.1	103.2	114.7	122.1
	w.	8.0	12.6	17.3	20.7
	f.		16.1	18.1	19.9
10	l.	86.1	89.4	101.6	114.0
	w.	6.5	7.6	11.9	15.9
	f.		5.6	15.8	14.6

Fish No.	Date	Oct. 22	Nov. 1
	Water temp. °C		15~16
11	Body length mm	153.	159.
	Body weight g	45.3	56.4
	Food eater g		52.0
12	l.	153.	158.
	w.	48.5	58.7
	f.		60.7
13	l.	154.	164.
	w.	53.9	63.1
	f.		58.8
14	l.	157.	165.
	w.	58.2	64.1
	f.		61.4

Results

The increases in weight and length of the mackerel and the amount of food eaten, for each 10 days during the experiment were shown in Table 1, separately for the individual fish. The growth in length of the mackerel were plotted in Fig. 1. Fish No. 1 and No. 3, which were reared for the period of 60 days between July 22nd and September 20th, grew nearly twice the size and eightfold the weight of the beginning. Consulting on the result of our preliminary experiment of mackerel rearing made in autumn of 1954, and on the growth of *Scomber scombrus* in the larval period by O. E. Sette (8), it may be presumed by extrapolation on these growth curves of the reared mackerel that the fish were to be born about the time of May and will be grown up to nearly 20 cm in length at the end of the year. The rate of growth coincides well with the seasonal variation in body length of the samples collected from the various localities along the Pacific coast of Japan throughout the year (M. Hatanaka et al (3)). Hence the mackerel, as they were held in an artificial environment, seems to be grown up in a fairly good condition.

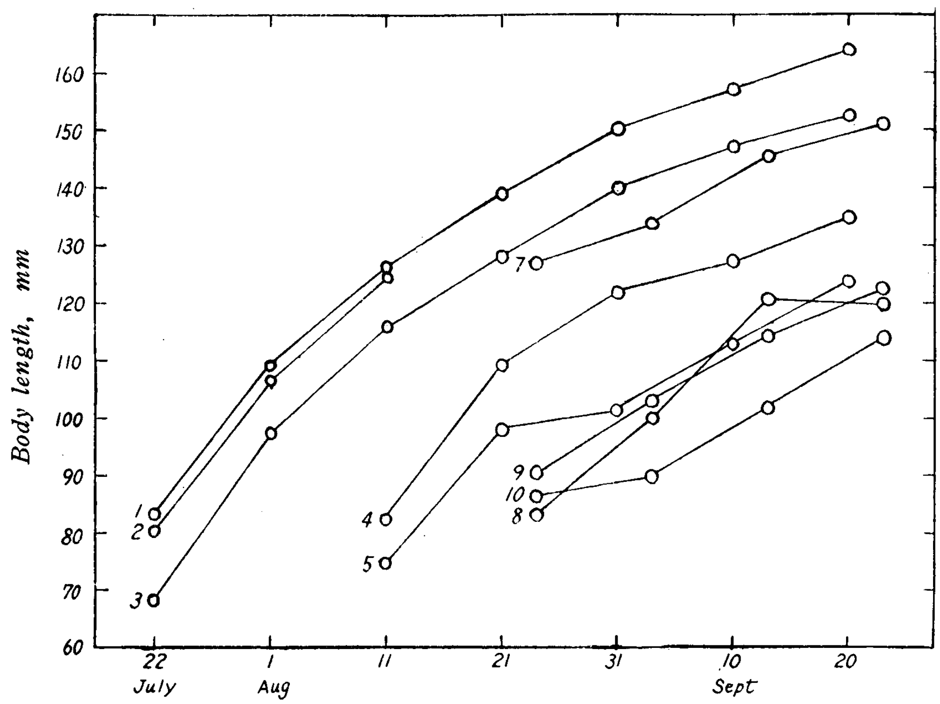

Fig. 1. Growth curves of the mackerel fed with anchovy.

The details of the feeding and the growth for each 10 days throughout the individual fish were shown in Table 2, separately for the different conditions, namely starvations, shortages of feeding days and lower temperatures. The results were also expressed by the calorie equivalence, in which 1 g of

Table 2. Rations and growth of mackerel fed with anchovy for each 10 days, separately for the rearing conditions.

Fish No.	Mean water temp. °C	Initial body weight g	Final body weight g	Average body weight g	Daily ration g	Ration ÷ body weight %	" Cal %	Daily growth g	Growth ÷ body weight %	Growth ÷ ration %	" Cal %	Note
5	24.5	4.1	9.2	6.65	1.58	23.8	13.4	0.51	7.6	32.3	57.5	
3	22.0	3.8	10.7	7.25	1.76	24.3	13.7	0.69	9.5	39.2	70.1	
2	22.0	5.9	13.5	9.70	2.02	20.8	11.7	0.76	7.8	37.6	66.7	
1	22.0	7.5	14.2	10.85	2.53	23.3	13.1	0.67	5.9	26.5	47.1	
4	24.5	7.2	15.6	11.40	2.67	23.4	13.2	0.84	7.4	31.5	55.9	
3	24.0	10.7	19.7	15.20	2.64	17.4	9.8	0.90	5.9	34.1	60.5	
2	24.0	13.5	24.5	19.00	3.93	20.9	11.8	1.10	5.8	28.2	49.8	
1	24.0	14.2	24.3	19.25	3.61	18.8	10.6	1.01	5.2	28.0	49.6	
3	24.5	19.7	26.8	23.25	2.31	9.9	5.6	0.71	3.0	30.7	54.8	
1	24.5	24.3	33.0	28.65	3.43	12.0	6.8	0.87	2.3	25.4	45.2	
3	24.0	26.8	34.2	30.55	3.14	10.3	5.8	0.74	2.4	23.6	41.9	
1	24.0	33.0	42.4	37.70	4.32	11.5	6.5	0.94	2.5	21.8	38.8	
3	20.8	34.2	43.9	39.05	3.57	9.1	5.1	0.97	2.5	27.2	48.1	
1	20.8	42.4	55.2	48.80	5.01	10.8	6.1	1.28	2.6	25.5	45.2	
10	23.0	6.5	7.6	7.05	0.56	7.9	4.5	0.11	1.6	27.9	34.2	fed for 6 days
8	23.0	6.0	11.0	8.50	1.36	16.0	9.0	0.50	5.9	36.8	65.9	starved for 2 days
10	20.5	7.6	11.9	9.75	1.58	16.2	9.1	0.43	4.4	27.2	48.1	low temp. involved
9	23.0	8.0	12.6	10.30	1.61	15.6	8.8	0.46	4.5	28.6	50.9	fed for 6 days
5	24.0	9.2	12.3	10.75	1.12	10.4	5.9	0.31	2.9	27.7	49.3	starved for 2 days
10	20.0	11.9	15.9	13.90	1.46	10.5	5.9	0.40	2.9	27.4	49.0	fed for 5 days
9	20.5	12.6	17.3	14.95	1.81	12.1	6.8	0.47	3.1	26.0	46.3	low temp. involved
5	20.8	12.3	18.6	15.45	1.40	9.1	5.1	0.63	4.1	45.0	79.8	starved for 2 days
8	20.5	11.0	22.0	16.60	2.74	16.5	9.3	1.12	6.7	40.9	72.3	low temp. involved
4	24.0	15.6	22.0	18.80	1.54	8.2	4.6	0.64	3.4	41.6	73.8	starved for 2 days
9	20.0	17.3	20.7	19.00	1.99	10.5	5.9	0.34	1.8	17.1	30.8	fed for 5 days
8	20.0	22.2	19.8	21.00	0.77	3.7	2.1	−0.24	−1.1			fed for 4 days
5	20.0	18.6	23.6	21.10	1.87	8.9	5.0	0.50	2.4	26.7	48.0	fed for 4 days
4	20.8	22.0	25.4	23.70	1.47	6.2	3.5	0.34	1.4	23.1	41.8	starved for 2 days
7	23.0	21.0	28.6	24.80	2.17	8.8	5.0	0.76	3.1	35.0	62.1	starved for 2 days
6	23.0	23.4	32.1	27.75	3.72	13.4	7.5	0.87	3.1	23.4	41.8	starved for 2 days
4	20.0	25.4	30.2	27.80	2.08	7.5	4.2	0.48	1.7	23.1	41.0	fed for 4 days
7	20.5	28.6	36.2	32.40	3.99	12.3	6.9	0.76	2.3	19.0	33.7	low temp. involved
7	20.0	36.2	40.5	38.35	2.40	6.3	3.6	0.43	1.1	17.9	31.7	fed for 4 days
3	20.0	43.9	48.5	46.20	2.10	4.6	2.6	0.46	1.0	21.9	39.0	fed for 4 days
1	20.0	55.2	57.9	56.50	2.60	4.6	2.6	0.27	0.5	10.4	18.4	fed for 4 days
11	16.0	45.3	56.4	50.85	5.20	10.2	5.7	1.11	2.2	21.3	37.9	low temp.
12	16.0	48.5	58.7	53.60	6.07	11.3	6.4	1.02	1.9	16.8	29.7	low temp.
13	16.0	53.9	63.1	58.50	5.88	10.1	5.7	0.92	1.6	15.6	27.7	low temp.
14	16.0	58.2	64.1	61.15	6.14	10.0	5.6	0.59	1.0	9.6	17.0	low temp.

the mackerel was 1.19 kcal and 1 g of the anchovy was 0.67 kcal in the mean.

Under the conditions that the food was given as much as the fish would eat and in the temperature range between 20.8° and 24.5°C, the daily rations, the daily growth and the efficiency of food conversion in the mean for each 10 days were plotted against the body weight in Figs. 2, 3 and 4 respectively. The rate of food consumed per day reached up to 24 per cent of the body weight (13.5 per cent in calorie equivalence) for the fish of about 7 g but the rate diminished gradually as the fish grow larger and secured the stability at 10 per cent level of the body weight (6.0 per cent in calorie equivalence) at least between 20 g and 50 g. The daily growth reached up to 9 per cent of the body weight for the smaller fish but it kept stably at nearly 2.4 per cent for the larger fish. The efficiency of food conversion showed 39 per cent (70 per cent in calorie equivalence) ever attained, however the rate diminished also as the fish grow larger and remained at about 25 per cent (45 per cent in calorie equivalence) for the fish above 20 g in weight. In short, the utilization of food by mackerels below 20 g in weight (12 cm in length) varied

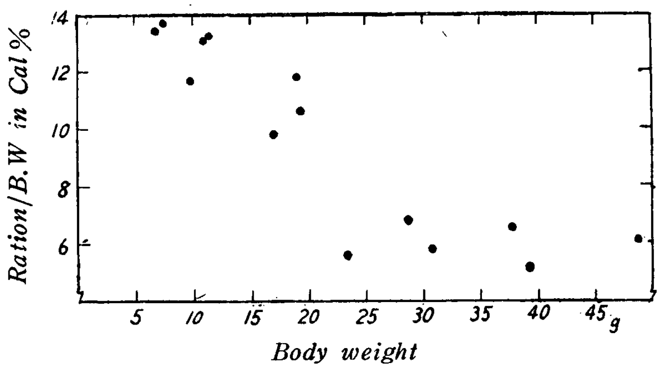

Fig. 2. Daily rates of ration in calorie equivalence plotted against body weight of mackerel.

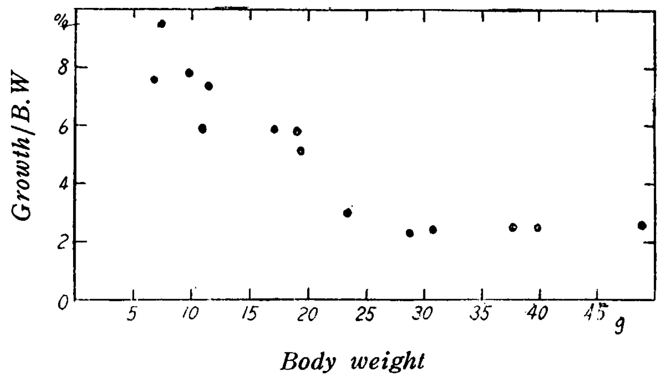

Fig. 3. Daily rates of growth plotted against body weight of mackerel.

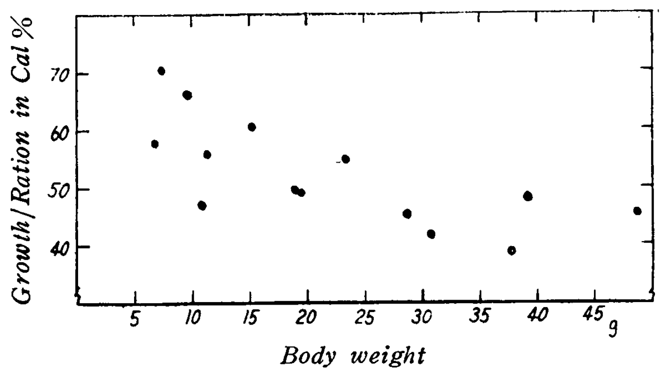

Fig. 4. Efficiency of food conversion in calorie equivalence plotted against body weight of mackerel.

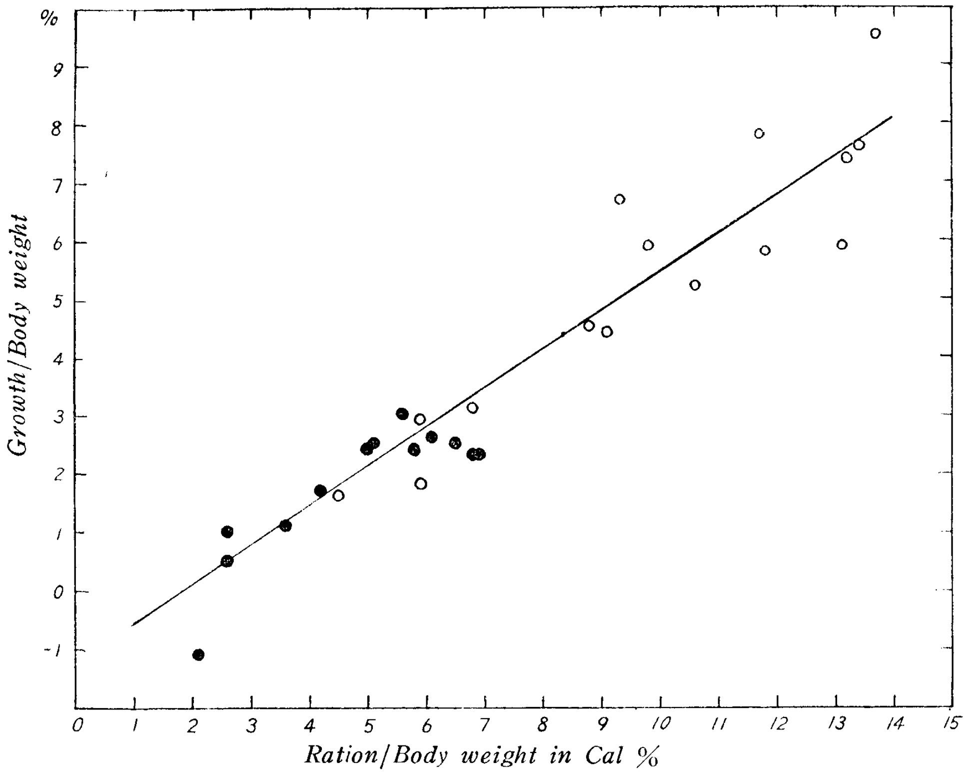

Fig. 5. Daily rates of growth plotted against daily rates of ration in calorie equivalence. Solid circles represent fish above 20g in weight, open circles those below 20g.

considerably but for the fish above this size little change according to size was observable.

The relation between food consumed and growth were shown in Fig. 4 under the temperature ranging between 20.0° and 24.5°C. Here the case of the starvation for 2 days among 10 days rearing was omitted, because no stabilization of the effect by the starvation was observed. From this figure it was indicated that the mackerel could barely maintain their weight on a daily ration on nearly 3.5 per cent of their body weight (1.8 per cent in calorie equivalence).

In the range of daily ration between 8 and 10 per cent, the best efficiency of food conversion was obtained for the fish beyond 20 g in weight, but there was no increase in efficiency over the rations of about 10 per cent.

At the temperature of 16.0°C, the food was consumed as well as in the case of the higher temperature, while the efficiency of utilization of food for growth was worse (20.5 per cent) and the daily growth remained at 2.2 per cent of the body weight.

Discussion

The food cousumed per day in this experiment is liable to be higher on account of the food given in most cases as much as they would eat. However, according to the investigation on the young mackerel in natural in summer and autumn, the standing amounts of the stomach contents was mostly between 2 and 5 per cent of the body weight and in one case it showed 12.4 per cent. Hence, the daily ration here obtained is not necessarily considered to be much different from the natural state. As the results of experiment show, the higher rations of the smaller fish compared with the larger fish coincide with the results obtained by Hathaway (4) in the case of the pumpkinseed and by Arnoldi and Fortunatova (1) in *Scorpaena porcus*.

The higher maintenance ration of the mackerel compared with the case of the plaice (1~2 per cent) seems to be caused from the habit of the fish always swimming actively and from the higher temperature held. However, in the case of the artificial feeding, the food is restricted on one kind and also the movement of the fish may become lower, so that the maintenance ration appears to be less or the efficiency of the food conversion to be higher than those in natural.

The habitat temperature of the young mackerel is said to be higher than that of the adult, hence the temperature in this experiment is not necessarily improper for the rearing. But it is needed to perform experiments under the lower temperatures. The result of the experiment made in autumn of 1954 in this line, showed that at the temperature of 12°C, the daily ration was 2~3 per cent of the body weight (for the fish of about 50 g in weight) and the efficiency showed 20 per cent. In these lower temperatures, the ration becomes obviously lower, however the relation between efficiency and temperature is complicated by the effect of the amount of food consumed. It is possible that the growth of the fish in the lower temperatures becomes very slow.

The main food of the mackerel during the seasons of winter and spring is constituted by *Euphauseaceae*, hence it is necessary to investigate the effect of the kinds of food upon the growth of the fish. In addition, more detailed experiments are wanted for the effect of crowding and for the larger size of the fish.

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