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GASTRIC EVACUATION RATE IN MACKEREL (Scomber scombrus L.)

by

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Abstract

About 1500 mackerel, 25-45 cm in length, were kept in a net for 10 days. In two experiments the fish were fed frozen euphausiids ad libitum, and the wet weight of the stomach content determined every second hour for 20-30 hours. The stomachs were then almost empty. Independent of fish size, the rate of digestion was related to the water temperature (14.5 - 17.0°C): $f(T) = 0.005 \cdot \exp(0.2 \cdot T)$. The maximum stomach capacity (wet weight, grams) was a function of fish size (total length, cm): $w = 0.0087 \cdot L^{2,21}$.

Introduction

The present paper is a contribution to the International Stomach Sampling Project 1981 in the North Sea. The project aims at producing data for a multispecies virtual population analysis (VPA) for the commercial fish stocks in the North Sea (Anon., 1980). Such an analysis requires data on the consumption of each age group of the fish stocks included in the model by the other fish stocks/age groups included.

Estimates of this consumption can be made from the rate of gastric evacuation and the stomach content as a function of time (e.g. Bajkov, 1935, Elliot and Persson, 1978 and Jobling, 1981). Data on the rate of gastric evacuation in mackerel, Scomber scombrus are to our knowledge not reported in the literature. For this reason, we conducted a preliminary field experiment in July 1982 by feeding euphausiids to encaged mackerel.

Materials and Methods

In July 1982 about 500 kg of mackerel was caught in a shore seine outside Bergen, Norway. The length distribution of the fish is shown in Fig.1. 8 days after capture the fish were transfered to a keep net 4x4x4 m in size anchored in a small bay.

The fish were fed frozen Antarctic euphausiids. Euphausiids is an important part of the diet in mackerel (Walsh and Rankine 1979, Mehl and Westgård, 1983).
The euphausiids were melted and spread over the surface and eaten by the fish while sinking. Krill was offered until the fish refused to take it, which took about 2.5 hours. One sample was taken immediately and then from 19-44 fish were sampled every second hour until all or most of the stomachs in the sample were empty.

The estimates of the gastric evacuation rate were based on the wet weight of the stomach contents. The fish were separated into four length groups (25-29, 30-34, 35-39 and 40-45 cm).

If in the first sample after the fish were fed some individuals in a length group for some reason had empty stomachs they were disregarded in the calculations. In later samples the same proportion of fish with empty stomachs was subtracted.

Results

Gastric emptying

In Figs 2 and 4 the changes in the mean stomach content in grams, for the fish in each length group as a function of time is shown. Figs 3 and 5 show the same, but now relative to the mean stomach contents just after the fish were fed. The number of fish sampled at each point of time in each length group and experiment is given in Tables I and II. In the first experiment the temperature varied between 16.6°and 17.0°C, and in the second between 14.4° and 15.2°C.

Maximum stomach capacity

A preliminary investigation of maximum stomach capacity in grams wet weight was carried out. In each length group the heaviest stomach was picked out and weighted from the sample taken just after the fish were fed to satisfaction. A total of ten fish were picked out and measured. We fitted an ordinary power function to the data.

$$W_{max} = 0.0087 \cdot L^{2.21} \qquad (1)$$

where

W_{max} = maximum stomach capacity in grams

L = total length in cm

r = 0.86, n = 10

Mathematical model of gastric emptying

A mathematical description of the balance of mass in a fish stomach can take various forms. An exponential decrease in stomach content as a function of time has commonly been found (Tyler, 1970, Elliot and Persson, 1978). Other authors reported the rate of evacuation to be proportional to the stomach content raised to a power between 0 and 1 (Fänge and Grove, 1979, Jobling, 1981). For the time being we have adopted the exponential model as a good fit to our mackerel data. The balance equation of the stomach contents is therefore:

$$\frac{dW}{dt} = - f(T) \cdot W + i(t) \qquad (2)$$

where,

t = time in hours

$W(t)$ = wet weight of stomach contents in grams at time t

$i(t)$ = Instantaneous rate of food uptake in grams/hour

$f(T)$ = The rate of digestion (Function of temperature)

T = Temperature in ^{o}C

As is seen in Figs. 3 and 5 there seems to be a time lag before the exponential decrease of stomach content sets in. This might be an artifact since the krill was colder than the ambient water temperature when offered to the fish. The rate of digestion seems to be similar for all size groups of fish. Prey species and sizeclasses may have an effect on the rate of digestion, but we do not have any data to confirm or enfeeble this. Its possible effect is therefore left out in equation 2.

To reach 10% of the mean stomach contents at the outset of the experiment took 16 hours in the first experiment and 26 hours in the seond (Figs 3 and 5). The temperature difference was about $2^{o}C$.

Fabian et al (1963) argued that an enzymatic kinetic reaction of the Arrhenius type should be used for the dependence of the rate of evacuation on temperature. This equation could be approximated by an ordinary exponential function. Such a function is found to describe the effect of temperature on the rate digestion quite well in brown trout (Elliot, 1972). We have two measurements seperated only by a $2^{o}C$ temperature difference. Therefore the confidence we can put into the result is limited. We got the result:

$$f(T) = -0.005 \cdot \exp(0.2 \cdot T) \qquad (3)$$

Discussion and conclusions

The present results are to our knowledge the first to describe the gastric evacuation rate of mackerel. This may be due to the difficulties in keeping mackerel in ordinary aquaria over extended time periods. Due to this we were able to carry out two experiments only and the water temperatures were too close to describe the temperature's effect on digestion in any detail. Unfortunately, we were unable to investigate the effect of food type and particle size on the rate of digestion. The fish had only small damages at the end of the experiment, mostly wounds on the snout, and there was a low mortality in the keep net. Most of the fish were willing to eat at once when food were offered in both experiments. This indicates that the fish were in good condition. The experiments should therefore give a fairly good description of the mackerel's rate of digestion of krill.

Aknowledgements

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Table 1. Number of fish sampled (in each 5 cm length group at each point of time) 4-5 August 1982.

Time \ Length (cm)	25-29	30-34	35-39	40-45	Sum
20.00	4	10	7	3	24
22.00	9	10	2	3	24
24.00	4	11	4	0	19
04.00	5	11	2	0	18
08.00	8	11	4	5	28
11.00	7	10	6	2	25
14.00	7	10	4	0	21
17.00	4	10	3	5	22
19.00	6	10	3	4	23
Sum	54	93	35	22	204

Table 2. Number of fish sampled (in each length group at each point of time) 11-12 August 1982.

Time \ Length (cm)	25-29	30-34	35-39	40-45	Sum
12.00	10	22	6	3	41
14.00	14	21	6	1	42
16.00	7	23	5	6	41
18.00	9	22	6	4	41
20.00	9	20	10	3	42
22.00	8	23	5	3	39
00.20	8	28	6	1	43
02.00	12	23	3	3	41
04.00	6	25	8	3	42
07.00	11	23	3	5	42
09.00	8	25	4	4	41
11.00	8	26	5	2	41
13.00	7	27	5	4	43
15.00	9	26	6	3	44
17.00	9	21	7	6	43
Sum	135	355	85	51	626

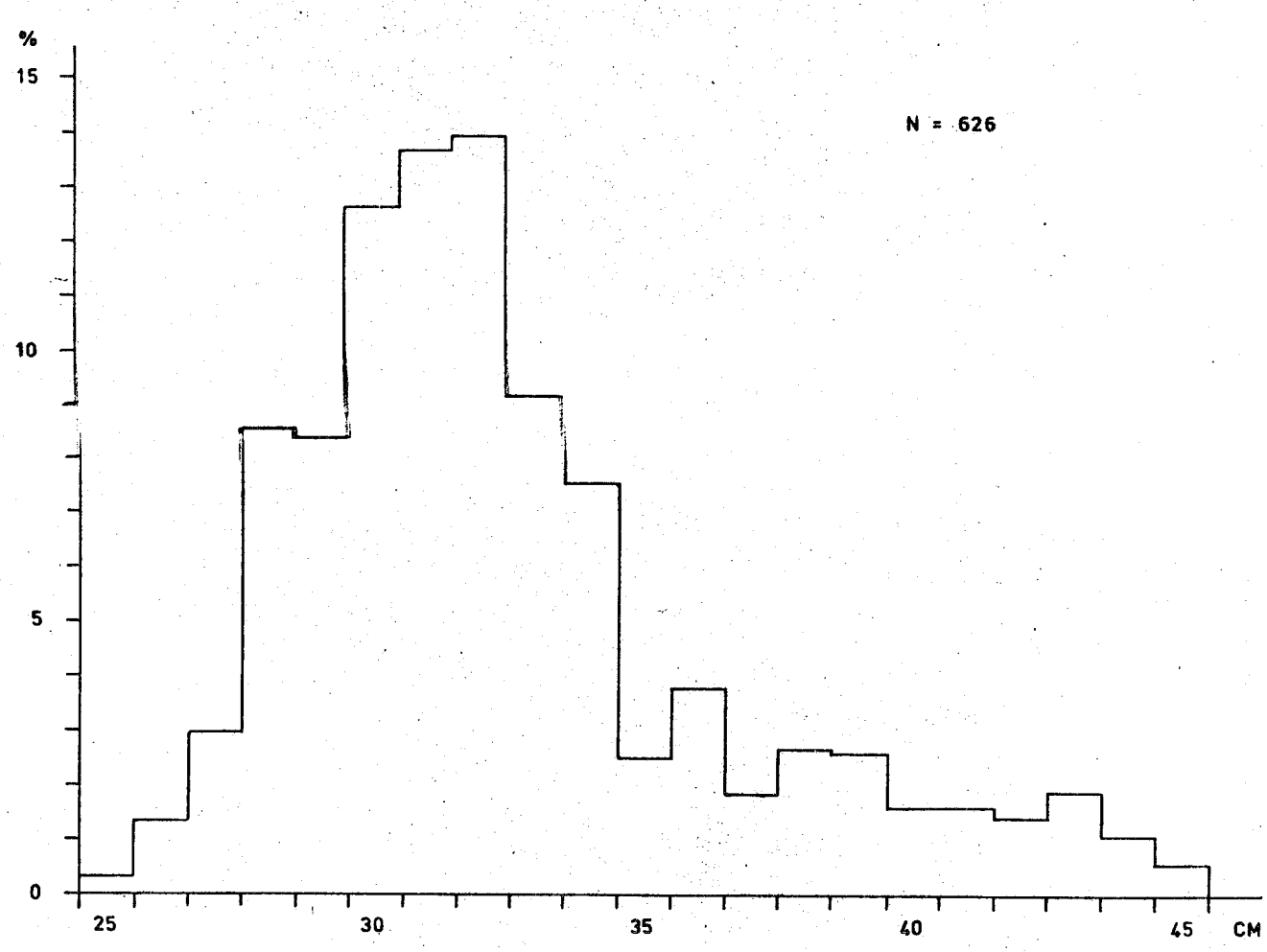

Fig. 1. The length frequency distribution of the mackerel used in the gastric evacuation experiments in August 1982.

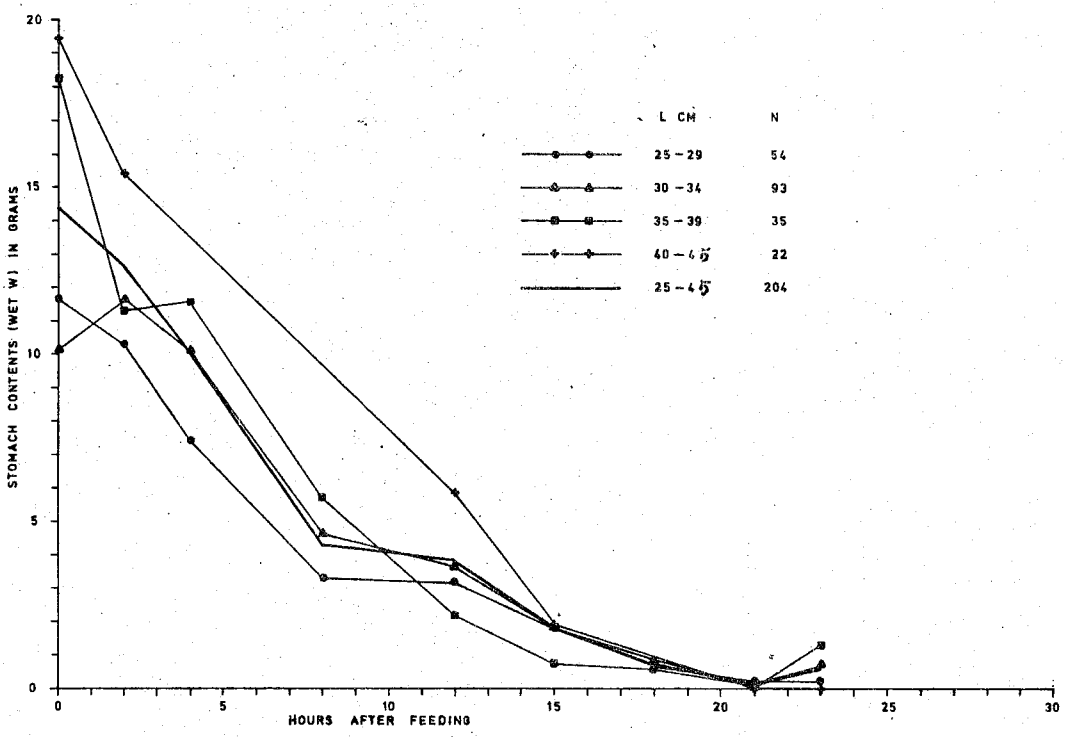

Fig. 2. The stomach contents in grams wet weight for the length groups 25-29 cm, 30-34 cm, 35-39 cm, 40-45 cm and 25-45 cm as a function of time in hours after the fish were fed. 4-5 August 1982.

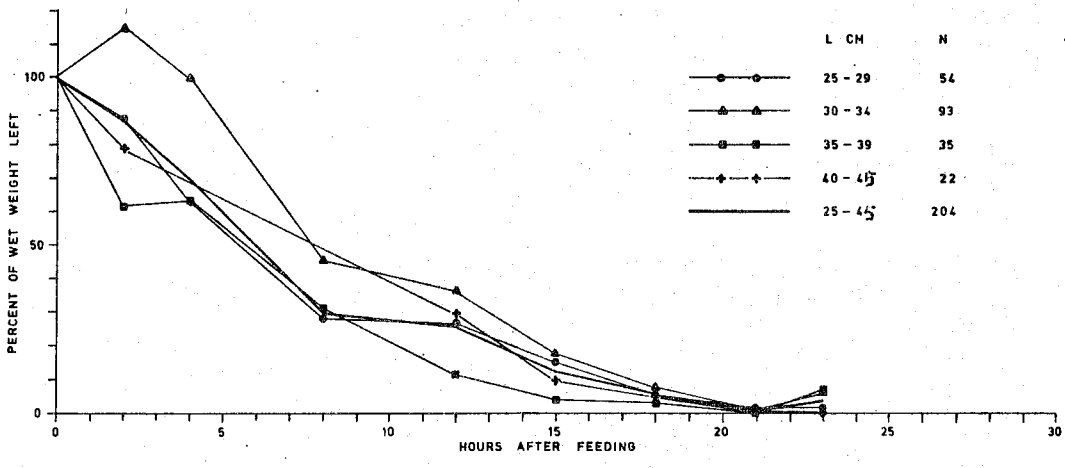

Fig. 3. The weight of stomach contents measured relative to the stomach contents just after the fish were fed as a function of time in hours after the fish were fed. The length groups were 25-29 cm, 30-34 cm, 35-39 cm, 40-45 cm and 25-45 cm. 4-5 August 1982.

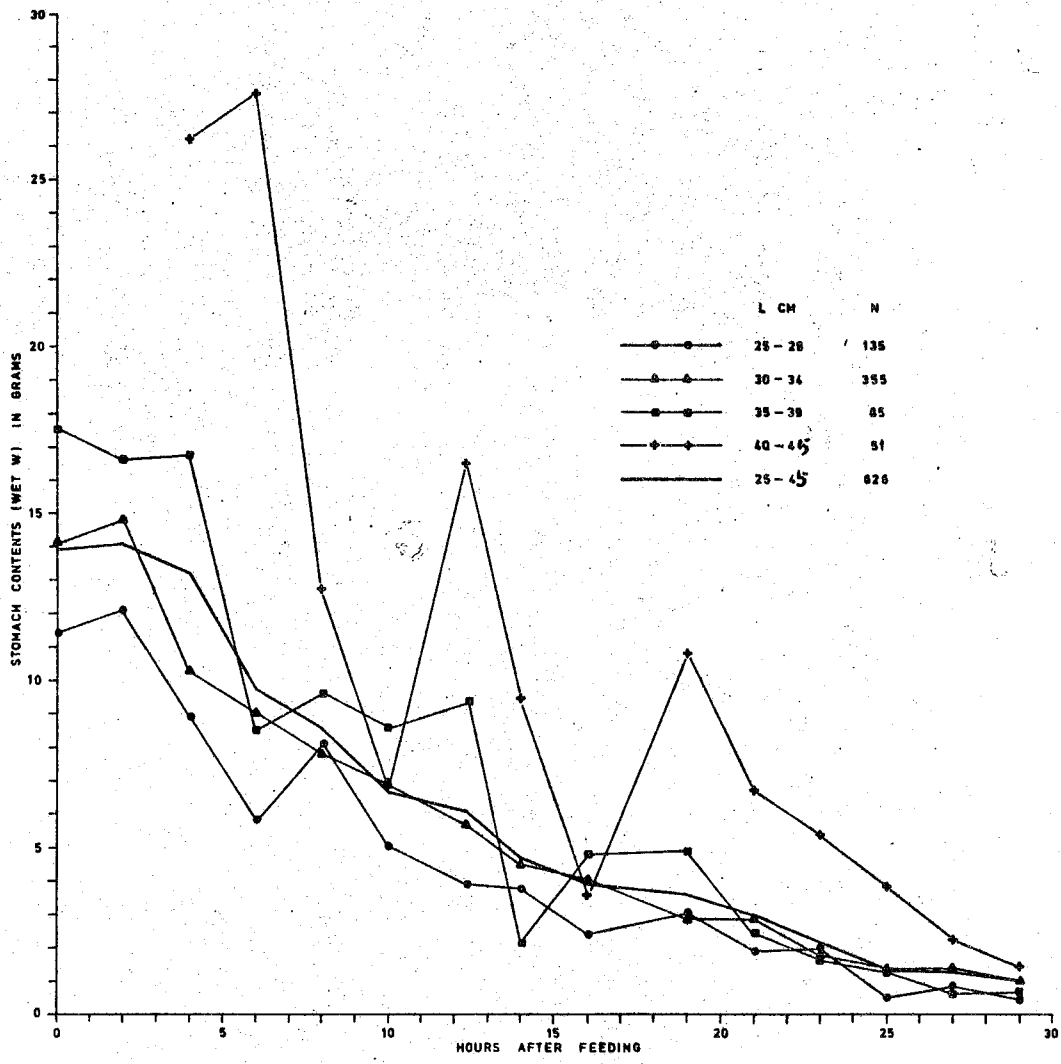

Fig. 4. The stomach contents in grams wet weight for the length groups 25-29 cm, 30-34 cm, 35-39 cm, 40-45 cm and 25-45 cm as a function of time in hours after the fish were fed. 11-12 August 1982.

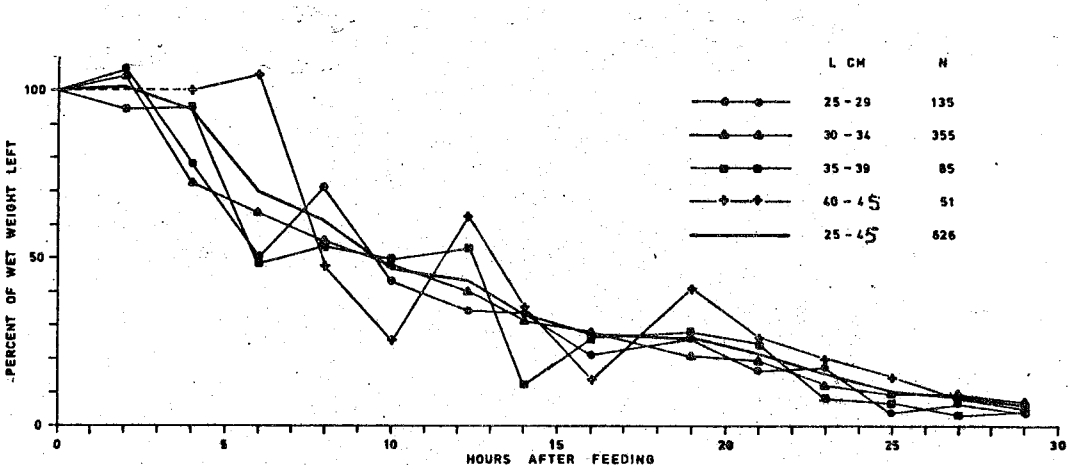

Fig. 5. The weight of stomach contents measured relative to the stomach contents just after the fish were fed as a function of time in hours after the fish were fed. The length groups were 25-29 cm, 30-34 cm, 35-39 cm, 40-45 cm and 25-45 cm. 11-12 August 1982.