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Meal Size and Digestion in Cod (Gadus morrhua L) and Sea Scorpion (Myoxocephalus scorpius L)

by

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Abstract:

Cod (Gadus morrhua) and Sea Scorpion (Myoxocephalus scorpius) have been fed with known amounts of food under aquarium conditions. The emptying of the stomachs on time has been estimated by opening the stomachs of the fish with intervals of 24 hours.

It was found that for cod the emptying lasted 115.3 - 1o4.9 hours and for sea scorpion 132.3 - 126.9 hours at 14.o - 15.o°C, and that the emptying was delayed 44.8 - 47 hours for sea scorpions at 8.2 - 1o.4°C.

It was found that the rate of emptying of the stomachs in sea scorpions increased with the meal size during the total period of emptying, but not during the first 24 hours period, during which the rate of emptying decreased. It was further found that the amount of food digested per unit of time is not related to the weight of the fish when equal meal sizes are given.

Introduction

Knowledge about the rate of gastric emptying on time, meal size and temperature in predators is important when it is wanted to assess their total consumption.

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This work has been carried out in relation to an attempt to estimate the yearly quantitative and qualitative consumption by cod (Gadus morrhua) which is the dominating predator in the Kattegat, the Belt and the Baltic.

As the aquarium capacities did not allow to store a sufficient large number of cod for longer periods at different temperatures sea scorpion (Myoxocephalus scorpius) being smaller and showing no tendency to cannibalism were used instead. Preliminary experiments indicated that the rate of gastric emptying at 14-15°C was not much different from that of cod.

Material and Methods

The experiments were carried out in January and February 1966 and 1967. The cod were caught by trawl in the Sound by the research cutter "Havkatten" and brought to the harbour of Humlebæk in 500 liter boxes to which a pump continously carried water. From the harbour the cod were transported by car in 50 liter plastic containers to the aquarium in Charlottenlund (30 miles), where they were transferred to tanks (93 x 79 x 7o cm). The temperature in the tanks was 14-15°C, the salinity about 30‰. Each tank held 15 individuals.

The fish were acclimatized during 14 days in the tank, the dead individuals being removed. After 24 hours in the tank the cod were offered food (pieces of the greater weever)(Trachinus draco), which in most cases was accepted. Fish which still refused to eat after one week were removed.

The sea scorpions were caught in stake nets in Køge Bugt off Mosede, kept in the well of a fishing boat and transported to Charlottenlund in 50 liter plastic containers.

The same procedure as described above with cod was used.

Each of the experiments with cod comprised 7 individuals which were held in a tank 93 x 79 x 7o cm. The fish were starved 5 days in order to secure that the stomachs were empty.

Then they were fed with pieces of greater weever (only the part from anus to the tail fin was used). The pieces were cut in right angles to the backbone so that each piece of food contained a piece of backbone. Each piece was weighed (wet weight, 2-3 grammes) and a label of red plastic with a number was inserted along the backbone.

From the labels found in the stomachs the amount of food eaten could be estimated. The cod were allowed to eat as much as they wanted. Food lumps not eaten were collected and registered.

The experiments with sea scorpions were carried out in the same way except that instead of using plastic labels in the food the food was cut into pieces of 5.0 grammes each (wet weight). It was easy to detect afterwards the total amount of food eaten from the number of pieces of backbone in the stomachs.

This technique was chosen because after 3 days of digestion the labels were vomited.

Further the tanks used were smaller being 80 x 25 x 30 cm containing about 40 liter water. Three individuals were kept in each tank.

The experiments at 10°C were carried out in two 44 x 80 x 47 cm tanks placed in the open air and packed in insulating matting. For temperature regulation and oxidation air was led in.

All the experiments were carried out under conditions of natural photoperiods.

After the meal the stomachs of 1-3 cod or scorpion fish were opened with time intervals of 24 hours and the total stomach content weighed (wet weight).

The total length and weight of the fish were taken at the same time. It was preferred to have several individuals together in the same tank, because the competition seemed to stimulate the appetite of the fish.

The length frequencies and the mean weight of the cod and sea scorpions used in the experiments are shown below.

Table 1.

Cod: 14-15°C.

cm	21	23	24	25	26	27	28	29	3o	31	33	34
number	2	1	1	2	8	1	1	2	1	2	3	2
mean weight	67	91	1o5	153	154	144	174	181	248	272	287	332

cm	35	36	37	38	4o	total
number	3	1	2	1	1	34
mean weight	33o	465	396	43o	54o	

Table 1 (cont.)

Sea Scorpions: 14-15°C.

cm	11	15	16	17	18	19	2o	21	22	23	24	25	26	total
number	1	1	1	11	13	19	22	12	7	4	4	2	1	98
mean weight	2o	56	61	74	88	1o8	13o	141	162	184	223	233	3o2	

Sea Scorpions 10°C.

cm	15	16	17	18	19	2o	21	22	23	24	25	26	total
number	2	2	5	11	11	3	6	4	2	5	2	1	54
mean weight	53	74	75	84	1o1	119	141	154	192	2o8	244	215	

Results:

Rate of Gastric Emptying.

Cod: Tyler (197o) found that the relation between the quantity remaining in the stomach and time after feeding was not linear. Daan (1973) mentions that the emptying of stomachs of cod roughly is described by a linear function.

The result of the present experiment is shown in fig. 1, where the wet weights as percentage of the initial stomach contents are plotted against time and fitted to a rectilinear regression which is considered being a usable description ($F = 2.24$, F_{9o} (3.29) = 2.28). The y intercept is 77.6% indicating that the depletion rate is higher during the first 24 hours. A rectilinear fit forced through (o.1oo) is made, too.

A curvilinear fit described by the expression $W_t = W_o \times e^{-bt}$, where W_o is the weight of the food at time 0 and t the time after feeding resulted in b = -o.69 and y intercept 137.7%, which seems to be less realistic than the rectilinear fit.

In the experiments of Tyler (1971) the stomachs of cod (23-35 cm, 15o-375 g) were empty or almost empty after 2o - 55 hours de-

pending on the temperature. At 15°C and a salinity of 28-30‰ they were emptied in the course of 15 - 20 hours using shrimp tails (Pandalus montagui) as food. The weight of the food given was 8% of the weight of the fish (wet weight). In the experiments of Daan (1973) who fed cod (44-56 cm, 700-1450 g) with 2-10 whole sprat (Clupea sprattus) (mean weight 14 g), at approximately 12°C (the salinity is not mentioned, but possibly about 30‰) the stomachs were empty after 72 hours. From fig. 1 it appears that when feeding with greater weever at 14-15°C the total emptying lasted not less than 115.3 - 104.9 hours when putting y = 0 in the equation describing the depletion.

The temperatures and the salinities in the 3 experiments were almost identical. The only differences seem to be that the fish used by Daan were not starved before the beginning of the experiment, and that the food given was different in all the experiments. As the total depletion time found by Daan was intermediate between that found by Tyler and in the present work where the same starving technique was used, it seems that the different food or environmental factors caused by the aquaria conditions must explain the differences between the depletion rates. According to Quigley and Meschan (1941) high fat content delays the gastric evacuation. Fat content of greater weever is lower than that of sprat and shrimps, the different environmental factors are the most possible reasons.

Sea Scorpions: In figs. 2 and 3 the depletion rates in sea scorpions (Myoxocephalus scorpius) are plotted against time after feeding at 14.0 - 15.0°C and 8.2 - 10.4°C. A rectilinear fit is made, and a rectilinear fit is further forced through (0.100). At 14.0 - 15.0°C, $F = 1.36$ ($F_{97.5}(4.93) = 2.93$) and the y intercept is 85.6%; at 8.2 - 10.4°C, $F = 0.50$, the y intercept being 97.7%. It appears from the figures that the variances within sets are large, especially at the highest temperature; putting y = 0 the time for total gastric emptying is found to be 132.3 -126.9 hours at 14.0 - 15.0°C, and 177.1 - 173.9 hours at 8.2 - 10.4°C. The effect of change in temperature from 14.0 - 15.0°C to 8.2 - 10.4°C has then delayed the time of total emptying of the stomachs with 44.8 - 47 hours or 34-37%.

In fig. 4 is shown the emptying of stomachs on time at the 2 intervals of temperature mentioned above. The difference between the slopes is not significant, as t = o.58 (f = 148).

The Effect of Meal Size.

In the experiments with sea scorpion at 14-15°C it is possible to divide the material between 3 groups according to meal size 5, lo and 15 g. In the experiments at 8.2 - lo.4°C all the fish except some few have eaten only 5 g each.

In fig. 5 grammes recovered are plotted against time for the 3 initial meal sizes, and rectilinear fits are made.

Table 2.

Initial meal size	N		SSD	SPDx$\bar{y}$	s^2	f	SSD$\bar{y}$/x	y-intercept	x-intercept.	
15 g	2o	36.2o	-2.57	-93.o3	4.14	18	74.52	14.88	5.79	139.o hrs.
lo g	22	37.85	-1.54	-58.29	2.o5	lo	41.oo	9.o8	5.9o	141.6 "
5 g	43	81.16	-o.66	-53.57	o.78	41	31.98	3.39	5.14	123.3 "
	85	155.21	-1.32	-2o4.88	1.87	79	24.93	147.5o		

variation about the lines

$s_1^2 = 1.87 \sum f_1 = f_1 = 79$

$s_2^2 = 46.87 \quad f_2 = m - 1 = 2$

Bartlett's test:

$\chi^2 = 19.31892$

$\chi^2_{.95} = 5.99$

Reject identity of variances.

variation between slopes

$F = 25.o6$

$F_{.95} = 3.11$

Reject identity of slopes

$s^2_{1-2} = 2.98 \quad f_{1-2} = 81$

$s_b^2 = o.o197$

$t_{.95} = 1.99$

$b = -1.32$

$\bar{b} + ts_b = -1.o4$

$\bar{b} - ts_b = -1.6o$

It appears that the larger the meal size the bigger the rate of emptying the stomach (the slopes of the lines, b) making the time for the total emptying (x-intercept) almost equal when the meal

size is 1o and 15 g, and about 17 hours less for meal size 5 g. This means that regardless the meal size the percentages of initial meal size removed per unit of time are almost equal. Windell (1966), Kitchell and Windell (1968) who worked with sunfish, and Tyler (197o) came to the same conclusion. Tyler (197o) mentions that the intestinal absorbtion may be coupled to the gastric volume. A simple relationship between the surface area of the food and the possibility to gastric juice to work may be involved.

The regression lines are compared in table 1, from which it is seen that the variances cannot be considered identical (Bartlett's test). The analysis was carried through nevertheless.

To illustrate that the different meal sizes represent different fillings of the stomach the weight of the meal is expressed as percentage of the weight of the consumer (mean) together with the corresponding rate of digestion and intercepts (Table 2).

Table 3.

Weight of meal g.	$\frac{\text{Weight of meal}}{\text{Weight of fish}} \times 100\%$	n	g digested per 24 hours	y-intercept.
5	5.49	43	o.66	3.39
1o	9.32	22	1.54	9.o8
15	11.I4	2o	2.57	14.88

From the y intercept it seems that in the first 24 hours the depletion is relatively larger than in the following and related to the initial meal size, so that the smaller the meal size the larger the depletion rate the first 24 hours.

In this connection the amounts of food recovered after 24 hours expressed as percentage of the initial meal size are plotted against initial meal size (Fig. 6). To estimate the upper limit of percentage food recovered after 24 hours the differences between mean percentage food recovered at initial food intake x and (x + 5) grammes have been plotted against mean percentage recovered at food intake x. Putting y = 0 the upper limit is found to be 87.56%, the slope of the fit being - o.64.

The percentage recovered in relation to initial meal size after 24 hours can then be described by the equation:

$P_v = P\infty(1 - e^{-kv})$,
where P_v = percentage recovered at initial meal size v,
$P\infty$ = 87.56 being the percentage food recovered of an infinitely large initial meal size,
k = o.2; (o.64 = 1 - e^{-5k})
v = initial meal size.

The Effect of the Weight of the Consumer.

In the computations above dealing with the emptying of stomachs in relation to time and initial meal size it is not taken into account that there may be a relation between the rate of digestion and the size (weight) of the consumers.

Table 4.

Temp.°C	Meal size	n	b	SSDx	s^2	S_b	t	f
14.o-15.o	15 g	22	-o.oo25o	3o4oo.oo	1.o2	o.oo579	o.43	2o
14.o-15.o	1o g	22	o.oo37o	86oo.oo	o.26	o.o1423	o.26	2o
14.o-15.o	5 g	42	o.oo195	69544.19	o.32	o.oo291	o.67	4o
8.6-1o.4	5 g	4o	o.ooo36	12364o.oo	o.o9	o.ooo99	o.37	38

Therefore grammes digested per 24 hours are plotted on the weight of the fish for meal size 5, 1o and 15 g separately, and rectilinear fits are made. The results are shown in fig. 7 and table 4. It is seen that the slopes of all the fits are very small. t-tests show that the slopes do not deviate significantly from zero. This means that when equal meal sizes are given the amount of food digested per unit of time is not related to the weight of the fish (sea scorpion) in the intervals of weight shown.

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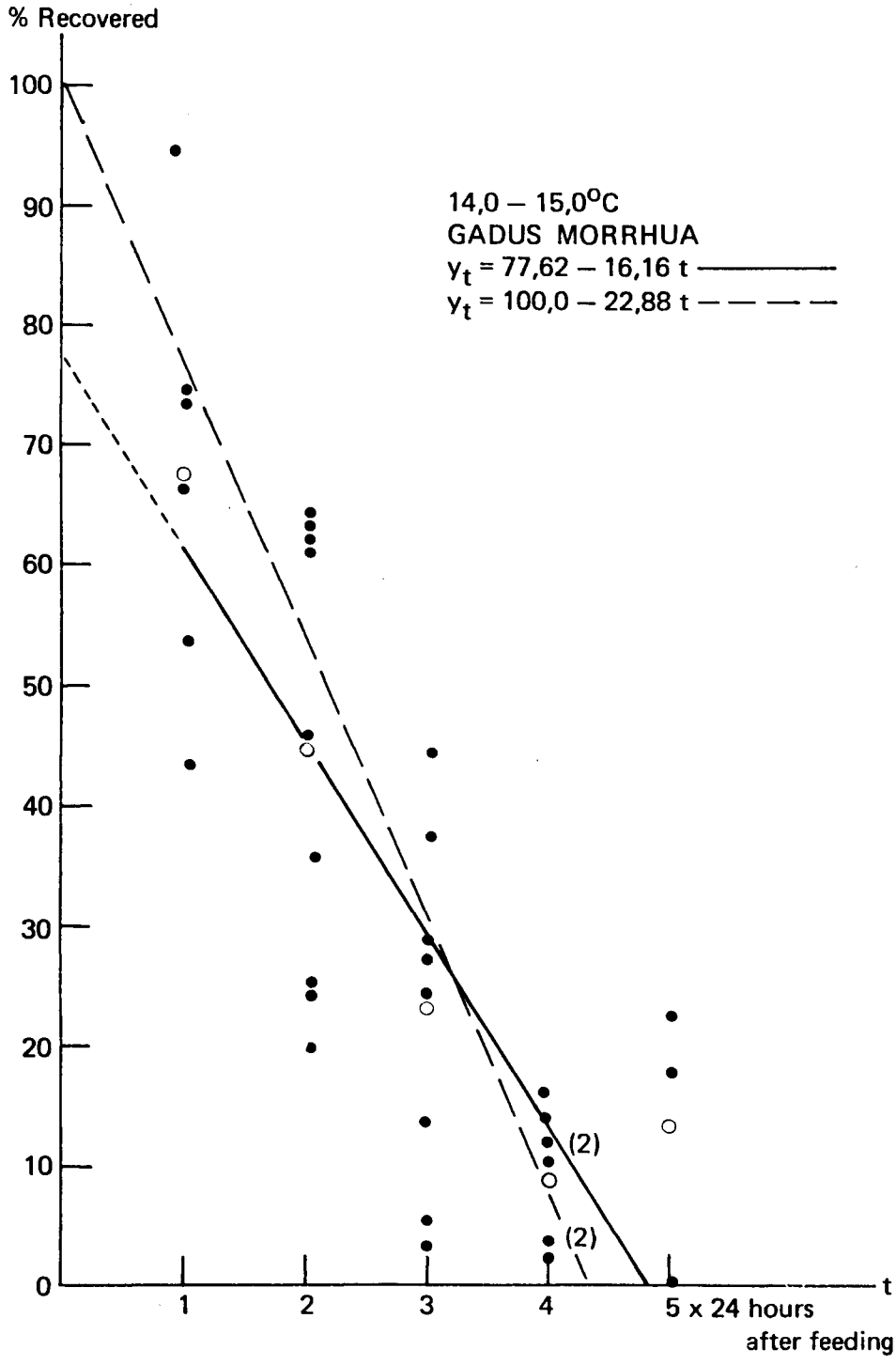

Fig. 1. Cod - Percentage recovered per 24 hours at 14.0-15.0°C.
Stippled line forced through (0.100).
Each dot indicates a fish, the figure in bracket indicates numbers of fish.

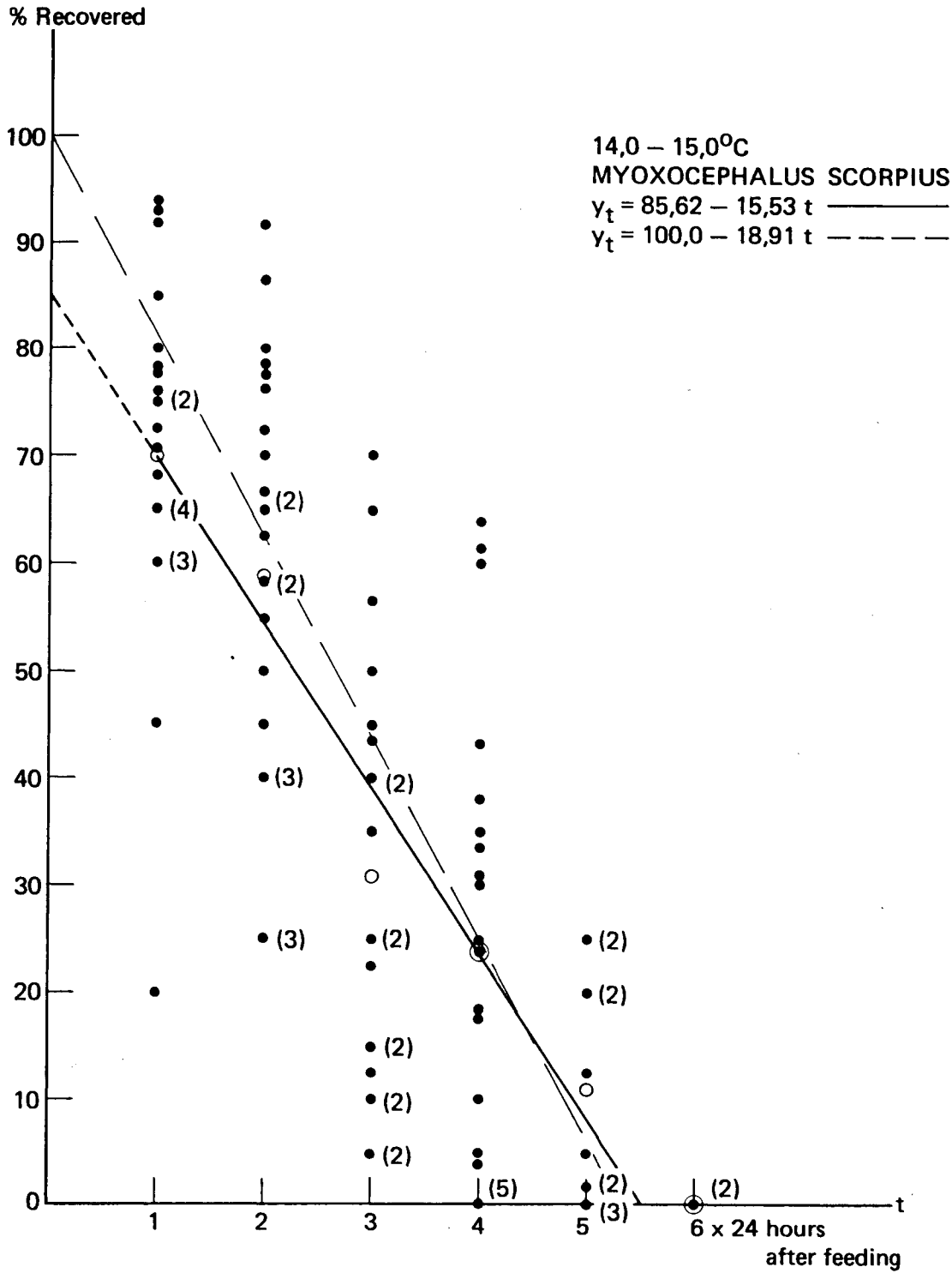

Fig. 2. Sea Scorpion. Percentage recovered per 24 hours at 14.0-15.0°C. Stippled line forced through (0.100). Each dot indicates a fish, the figure in bracket indicates numbers of fish.

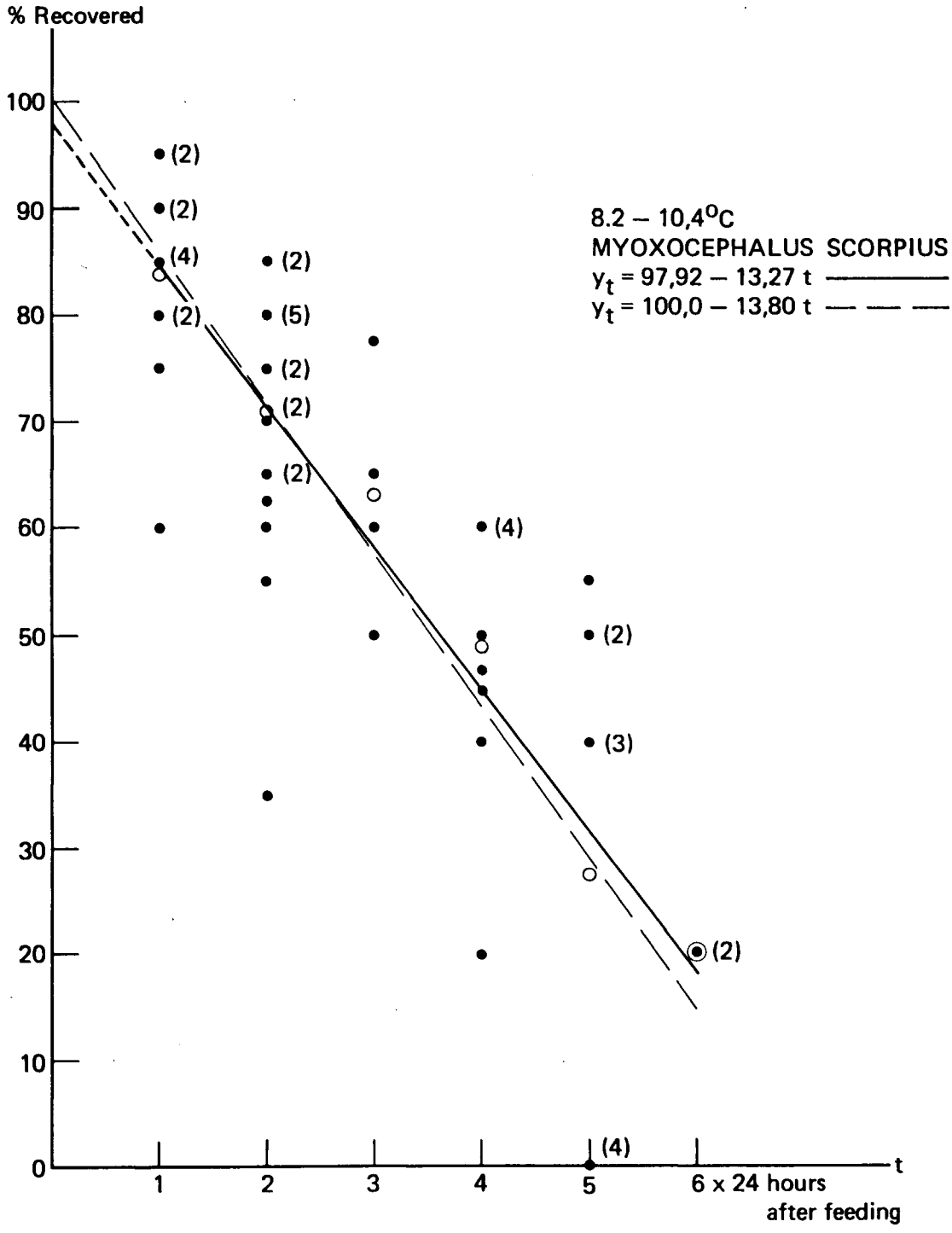

Fig. 3. Sea Scorpion. Percentage recovered per 24 hours at 8.2-10.4°C. Stippled line forced through (0.100). Each dot indicates a fish, the figure in bracket indicates numbers of fish.

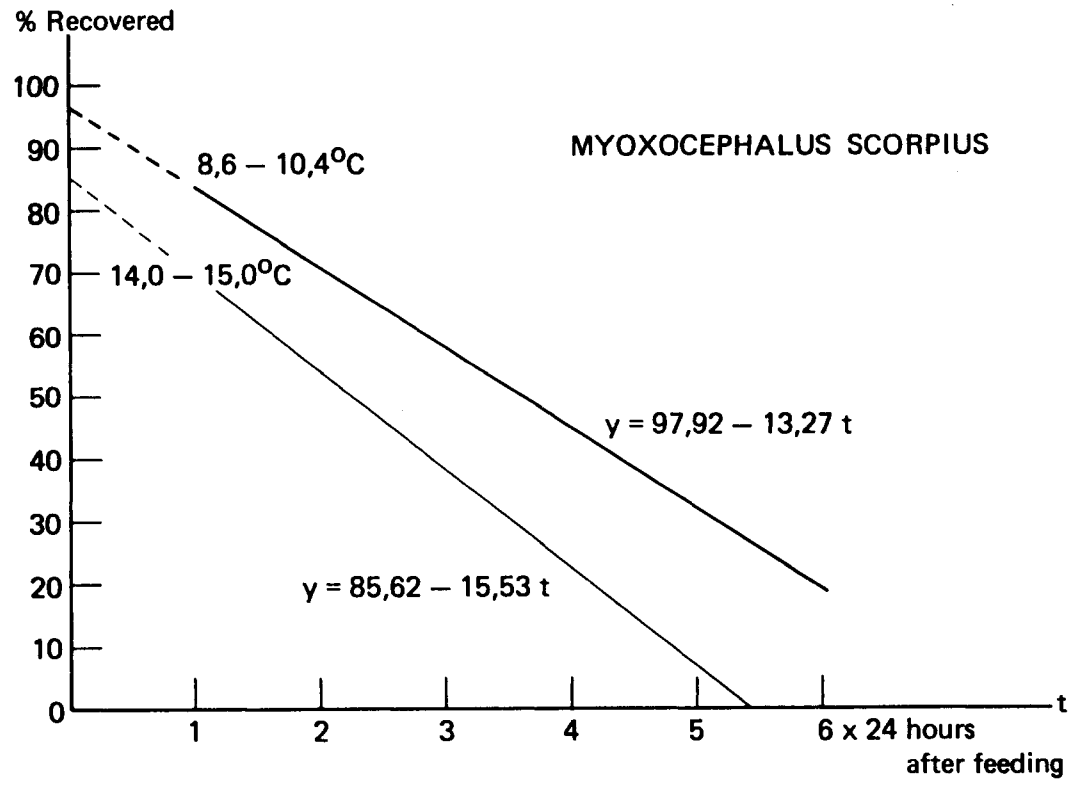

Fig. 4. Sea Scorpion. Percentage recovered per 24 hours at 14.0-15.0°C and 8.1-10.4°C.

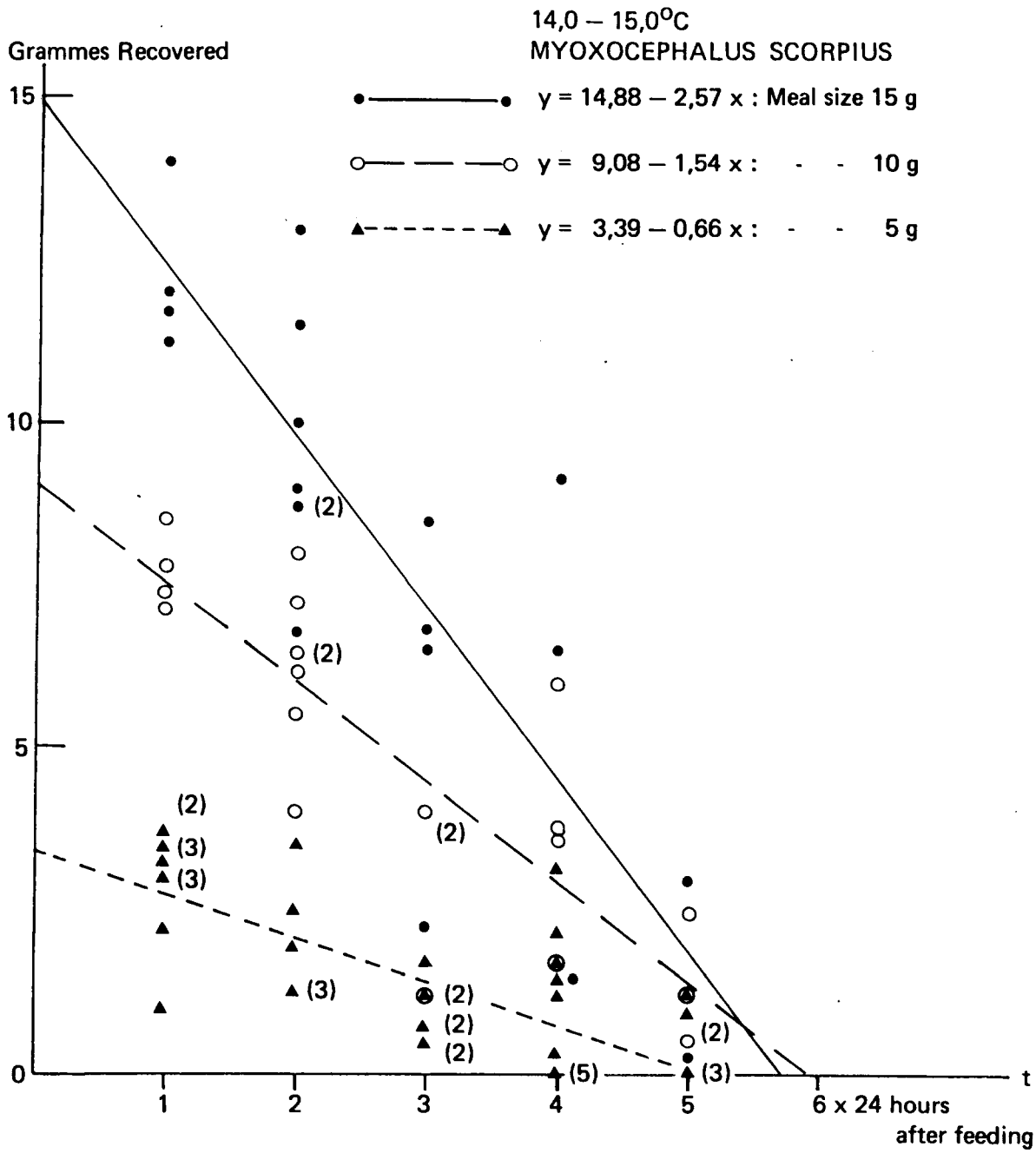

Fig. 5. Sea Scorpion. Grammes recovered per 24 hours according to meal size at 14.0-15.0°C. Each dot indicates a fish, the figure in bracket indicates numbers of fish.

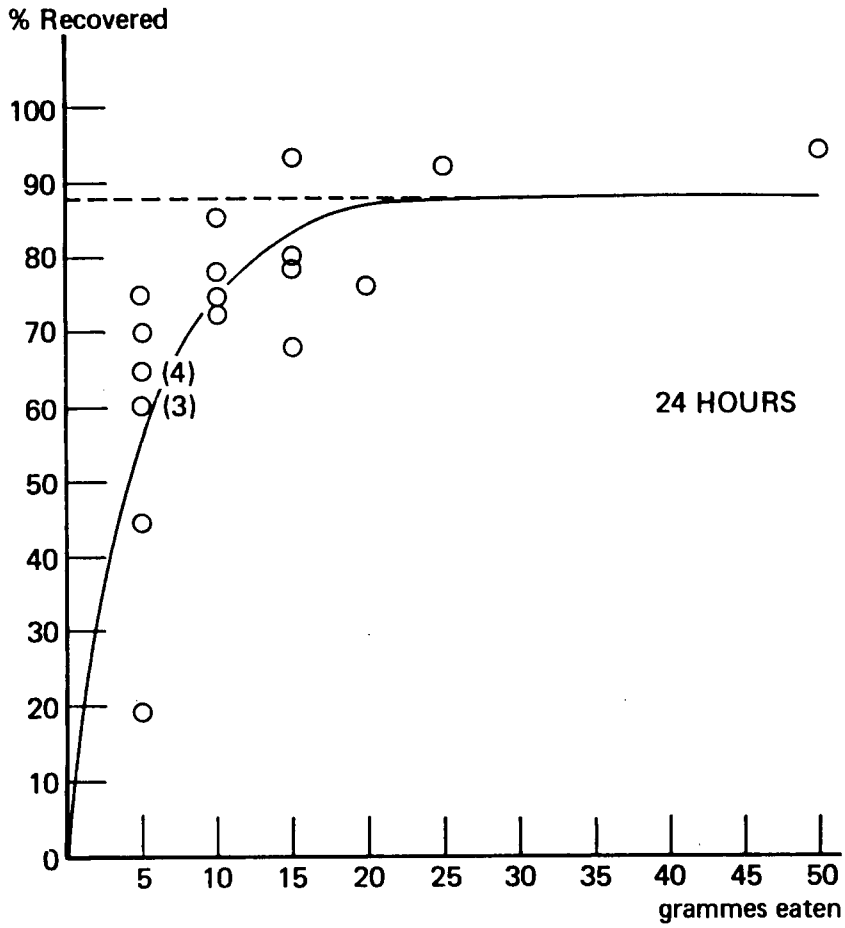

Fig. 6. Sea Scorpion. Grammes recovered according to meal size the first 24 hours. Each circle indicates a fish, the figure in bracket indicates numbers of fish.

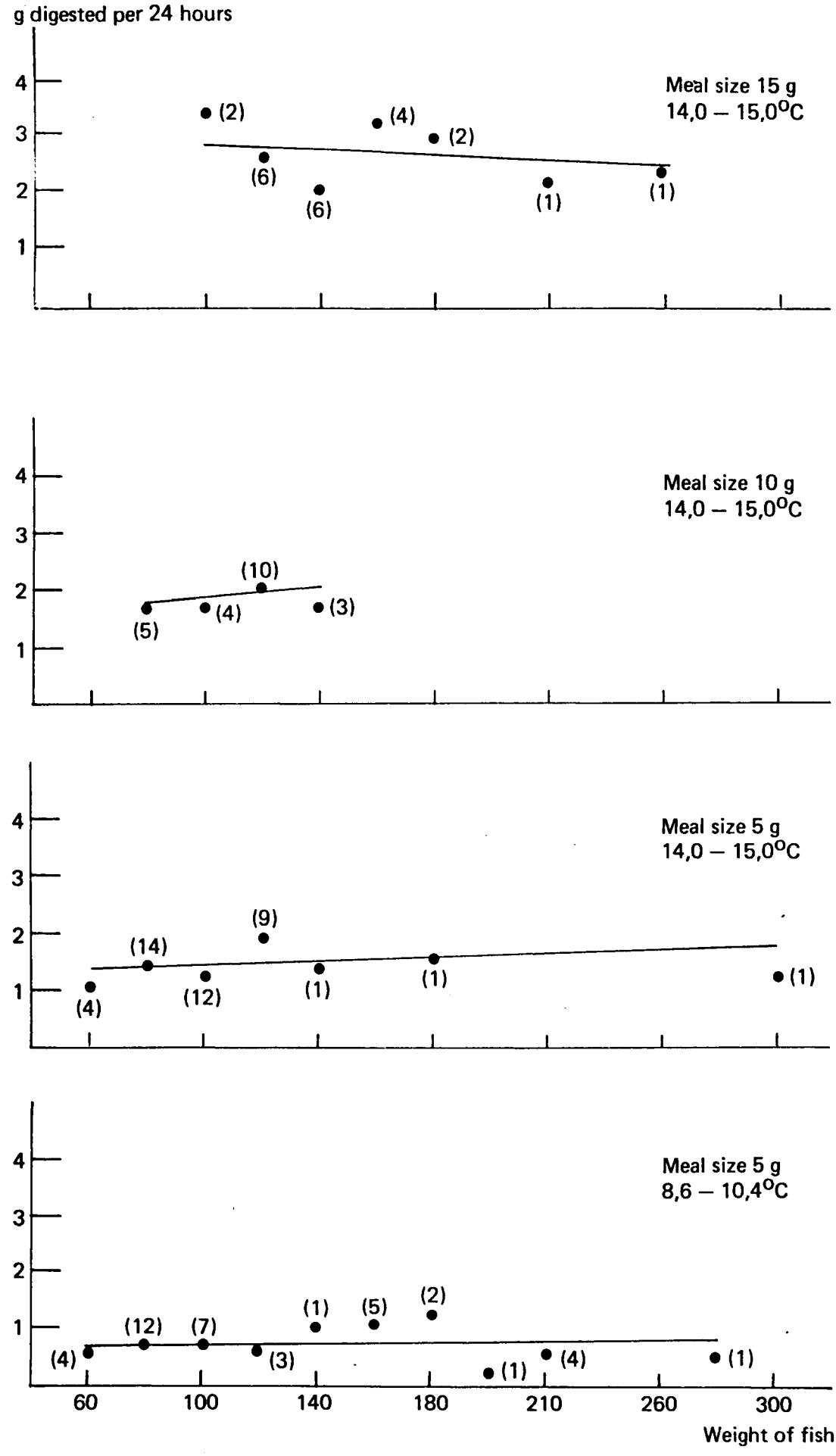

Fig. 7. Sea Scorpion. Grammes digested per 24 hours in relation to the weight of the fish at different initial meal sizes. Each dot indicates a fish, the figure in bracket indicates numbers of fish.