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"Reactions of cod (Gadus morhua L.) to smell stimuli from bait"

by

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Introduction

The cod is a gregarious fish with a wide selection of prey. Its food changes with age, (Wiborg 1948., 1949., Powles 1958., Destadli 1972) and also varies throughout its distribution area (Zatspin and Petrova 1939). Also it seems that the cod can detect its prey by odour produced by intact invertebrates (Brawn 1969b).

The moment the cod takes some prey into its mouth, it registers the taste. As the sense of smell and taste are closely related in aquatic organisms (Bieck and Zippel 1973) and as fish have a well developed memory, (Hasler 1968) we suggest the following working hypotheses:

1) Cod are able to differentiate between varied prey organisms by smell;
2) From experience cod will develope smell and taste preferences for one or more prey organisms.

Long line fishing shows that the sense of smell is an important factor in the cod's ability to detect the bait. Long line is stationary equipment used in deep water, by day and night. It is therefore unlikely that cod use their sight to locate the bait.

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In the past, lugworms and squid were considered to be good bait. Nowadays, herring, mackerel and prawns are used most. It has always been under discussion which is the best bait to use. Many long line trials have been made in an effort to resolve this problem. Unfortunately these trials were of little value to us because some of the types of bait came off the hook more easily than others. Also, some bait types were more frequently eaten by bottom-living invertebrates.

We have therefore found it necessary to make experimental investigations in the laboratory to test the above mentioned hypotheses

The range of bait has, until now, been restricted to that which can be hung on the hook. The aim of this continuing investigation is to find the best suited marine organism for the extraction of a smell stimulant to be placed in a carrier substance on the hook. If this succeeds, the mechanisation of the long line fishery can be simplified. At the same time, the large amounts of commercial fish previously used for bait would then become available for human consumption.

Materials and methods

1. Experimental fish.

75 cod (Gadus morhua L.) from the coastal population of the Smøla-Helgeland coast, 40-75 cm in length, were collected in the beginning of November 1973. These were divided into three groups of 25 individuals, and fed on herring, (Clupea harrengus L), squid (Illex illhosus, Lesueur) and capelin (Mallotus villosus, Müller).
In the beginning of November 1973 fifty "I group" cod were collected at Vikenes in the vicinity of Bergen. These were divided into five groups of ten individuals and were fed on herring, capelin, squid, mackerel and mussel, respectively.

2. Experimental equipment

a Feeding tanks.

The coastal cod were placed for feeding in three concrete tanks of 2 x 4 x 2.5 m.

The small cod were fed in five P.V.C. aquaria of 1 x 1 x 0.5 m.

b Experimental tanks

The preference experiments with the coastal cod were undertaken in the circular tank at the Institute of Marine Research, Bergen. This tank is a circular concrete through 2 m deep, with an inner circumferance of 31 m. It holds approximately 200 m^3 of water. Three television cameras were mounted on the tank at equal distances apart. A pole was placed across the tank beside each TV-camera, and a bait bag was hung from each to a depth of 1 m. (see fig. 1). The cameras were placed so that each covered an identical observation field in relation to each bait bag. Each camera was connected to a monitor. The tank was screened to prevent visual disturbance of the fish.

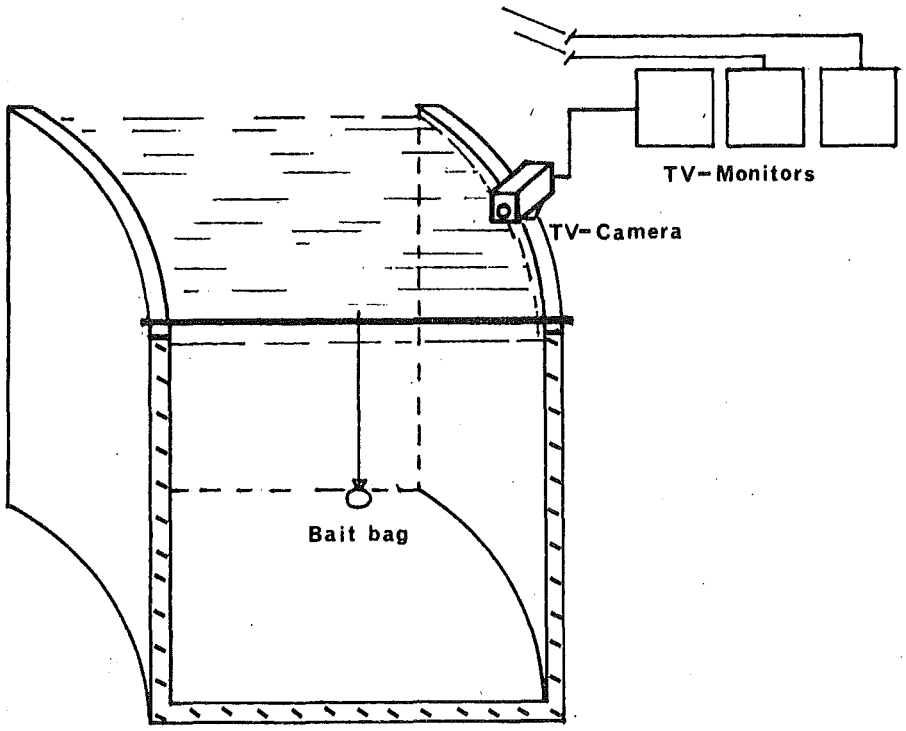

Fig. 1. Section of the large concrete circular tank, with bait bag and observation equipment.

The preference tests on the small cod were conducted in a cylindrical P.V.C. tank 2 m across, 50cm deep. A 60 cm high P.V.C. cylinder, 1 m across, was placed in the center of the tank, and three bait bags placed at equal distances apart, as in the large tank experiment. The tank was supplied with water from pipes mounted on the walls, and a central pipe at the surface removed the exess. Thin black plastic sheeting totally shaded the tank. The behaviour of the cod could be ovserved with the aid of the TV-camera + monitor or through small aperatures in the plastic.

c Bait bags.

The bait bags were made of double gauze (Tubinette H 56) placed in fine meshed seine netting for extra support. In the large circular tank they were filled with 100 gr. bait, while in the P.V.C. tank they contained 40 gr. The bait was cut into small pieces.

3. Experimental methods

a Behaviour description.

During the preference trials in the circular tank the behaviour of the cod towards the bait bags was observed for 10 seconds every half minute for an hour.

In order to gain a quantitative measurement of the behaviour, the fish were placed in the three following categories:

I. Fish crossing the observation field of the TV-camera and eventually coming near to the bait bag without showing any interest in it.

II. Fish approaching to touch the bait bag with their snouts or barbles.

III. Fish biting the bait bag. This behaviour was registered continually.

In the P.V.C. tank the behaviour of the fish was registered continually over 30 minute periods. For practical reasons, only behaviour types II and III were noted.

b Preference tests.

In these tests the cod were given a choice of three bait bags,

one of which contained the bait organism on which they had been fed. The positions of the bags were changed for each test. Two groups of ten fishes were tagged so that the behaviour of each fish could be studied.

The fish were not fed for the duration of the preference tests. 10 cod were used in the large tank experiments, while five were used in the P. V. C. tank.

Results and discussion

Three groups of coastal cod were fed on herring, squid and capelin, respectively, and were tested separately for smell preferance in the large circular tank. One test was undertaken per day. Figs. 2 and 3 show that cod fed upon herring and squid developed strong smell preferences for these particular foods. The responses increased within the 1 week test period. There was also good correlation in the progression of behaviour patterns II and III. Behaviour pattern I describes the distributions of fish in the tank. As can be seen from the figures, the fish were distributed throughout the tank during the test series. This showes that the fish were in a situation where they could actively choose between the three baits.

Cod fed on capelin (fig. 4) did not seem to prefer the smell of the food to the extent shown by the herring- and squid-fed groups for their foods. During feeding, before the tests started, this group ate capelin as willingly as the other groups ate herring and squid, respectively.

Earlier investigations into feeding in relation to the significance of smell preferences have given conflicting results. Tester *et al.*, (1955) recorded a positive smell response to their foods from the little tunny (*Euthynnus affinis*) and the yellowfin (*Neothynnus macropterus*). McBride *et al.*, (1962) found the same in relation to the sockeye salmon (*Oncorhyncus nerka*). However, Steven (1959) could not report a smell preference for food from the silverside (*Hepsitia stipes*) and the tomtate (*Bathystoma rimator*).

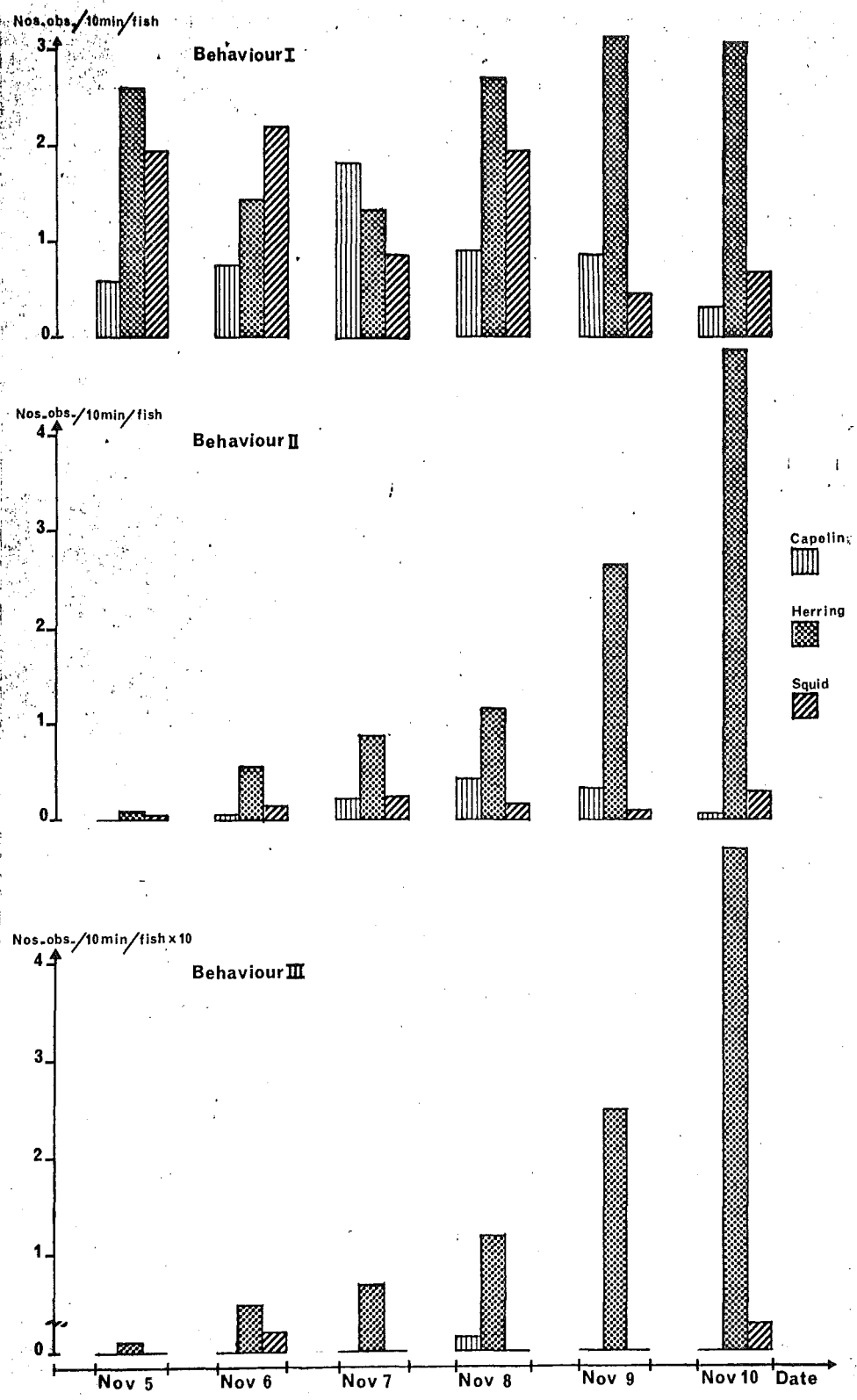

Fig. 2. Preference tests. Data from 10 coastal cod fed for 14 days on herring and tested for 6 days in the circular tank. They were given the choice of three bait bags containing herring, squid and capelin.

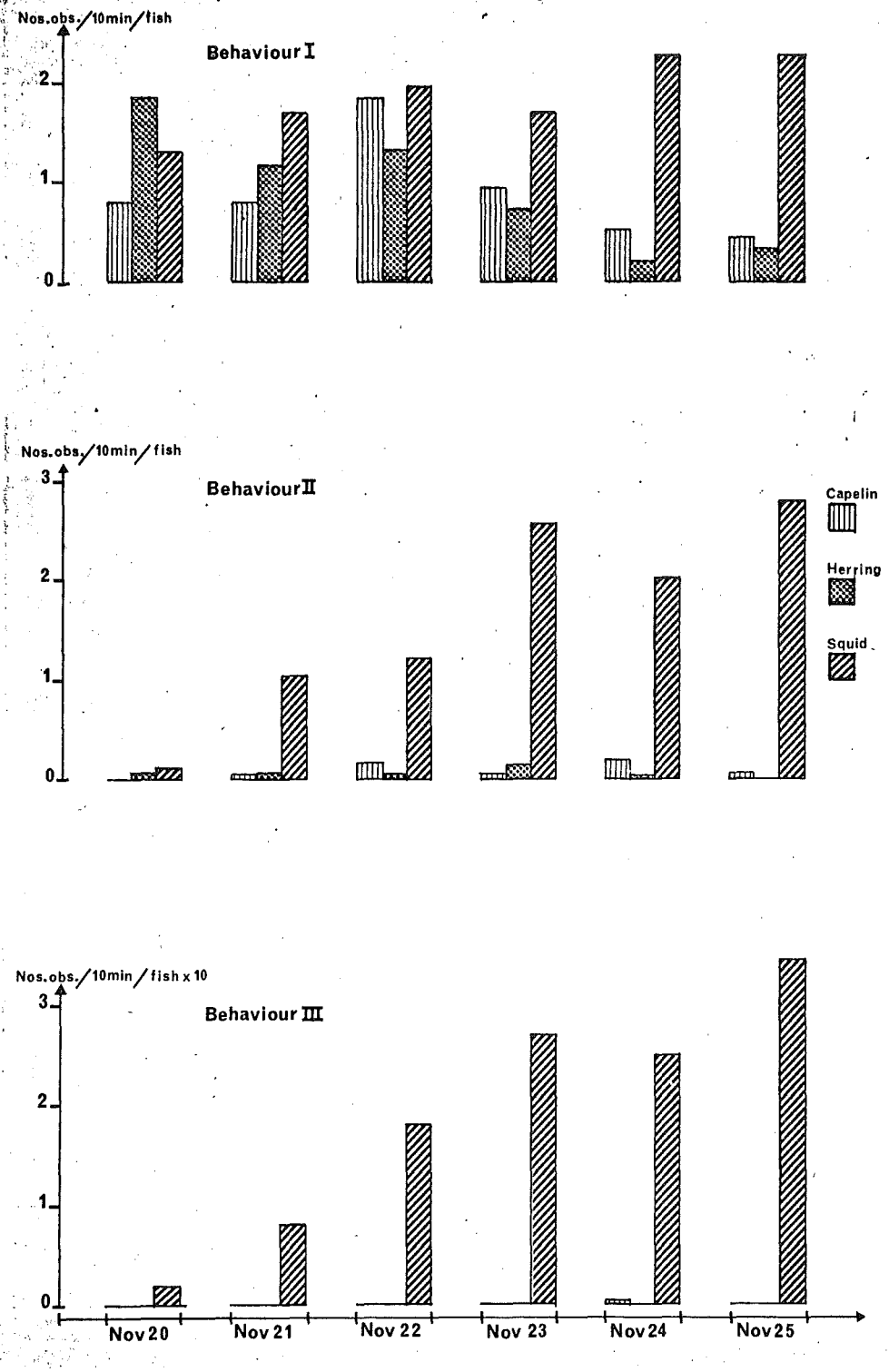

Fig. 3. Preference tests. Data from 10 coastal cod fed for 14 days on squid and tested for 6 days in the circular tank. They were given the choice of three bait bags containing herring, squid and capelin.

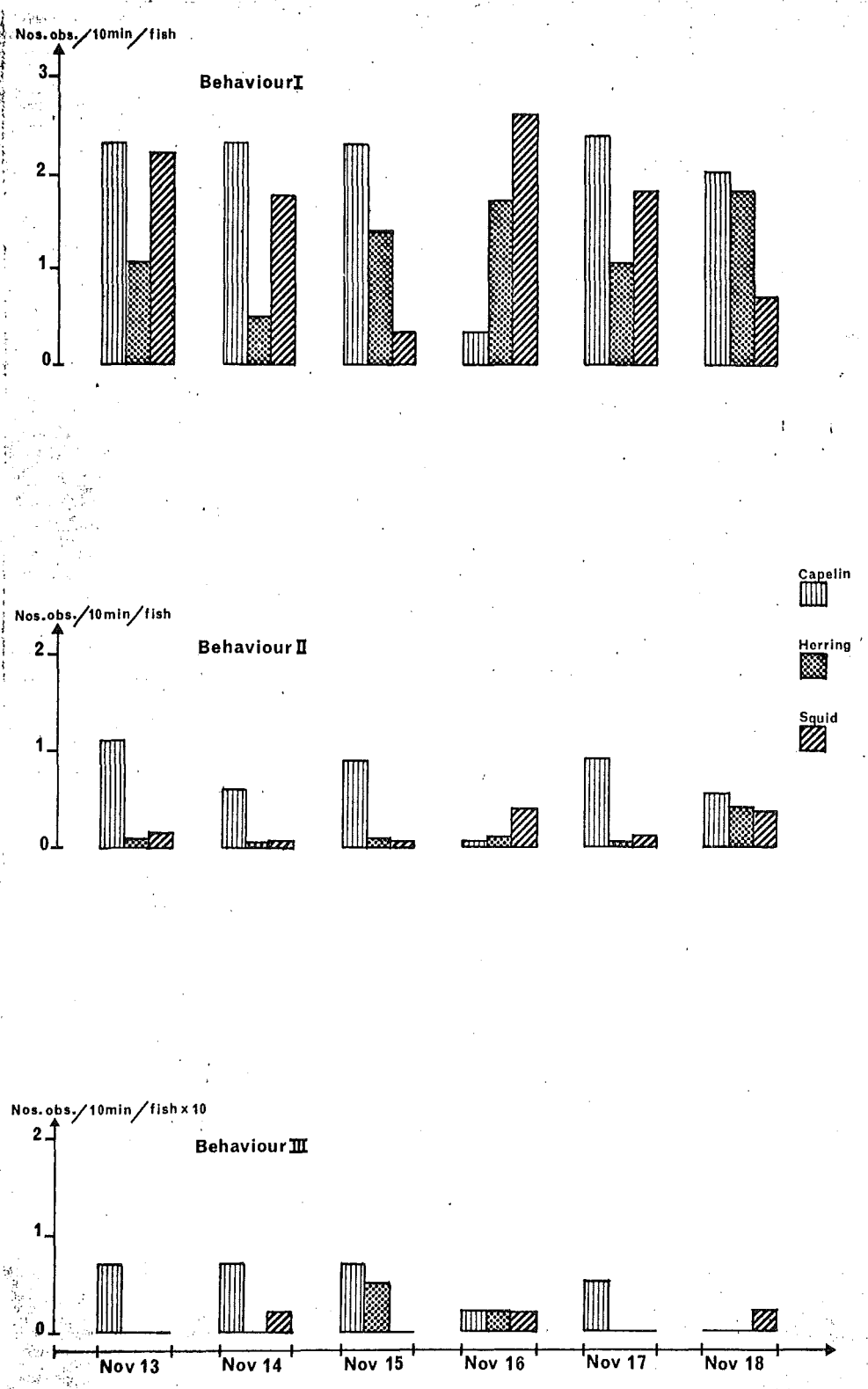

Fig. 4. Preference tests. Data from 10 coastal cod fed for 14 days on capelin and tested for 6 days in the circular tank. They were given the choice of three bait bags containing herring, squid and capelin.

Haynes et al., (1967) repeated the experiments with the tomtate, but could not demonstrate a difference in the fishes' response to either whole organism extract of parts of organisms extract of ten species from five different phyla. His test fish, fed on mollusc meat did not show any preference for this food either. As a consequence of these results, the authors suppose that the response is caused by substances generally found in marine organisms. However a common factor in these experiments was that the test fish were only exposed to one stimulus at a time. Besides, the observation method gave the fish no possibility to show their complete feeding reactions. We consider the most important thing to be whether or not the smell stimulates a biting response from the fish.

A corresponding series of experiments was carried out after 8 weeks of feeding. The results from each group are shown in table 1. This time, the cod were kept in the circular tank for fourteen days without food. Data taken in the first week is shown separately from that recorded in the second. Cod fed on squid and herring continued to show a strong preference for the smell of these foods.

Table 1. Results of preferance tests.
3 groups of coastal cod, 40-75cm, fed for 8 weeks on squid, herring and capelin, respectively. 12 experiments were carried out on each group over two week periods. The results for the first and second week are given seperately. The figures are given in observations/hour/10 fish.
S = Squid, H = Herring, C = Capelin.

	Cod fed on squid				Cod fed on herring				Cod fed on capelin			
Behaviour	II		III		II		III		II		III	
Bait Bag	S	H+C	S	H+C	H	S+C	H	S+C	C	S+H	C	S+H
1st Week	114	22	11,4	1.4	30	8	4.7	0.9	17	28	0	1.3
2nd Week	151	39	11,6	3.6	157	25	18.1	2.9	16	61	0.5	3.8

The data in table 1 also shows how the response to the smell developes over longer time periods. Comparison of the bite response in the first week to that of the second week in all the cod groups shows an increased interest in bait bags other than those containing the food that the cod had been fed upon. This may be an effect of starvation. Squid-fed cod did not show an increased response for the smell of squid from the first to second week. Herring-fed cod gave a very low response at the beginning of the tests. In the middle of the test series with this group we noticed that there was a quality difference in the herring we were using as bait. The latter half of the test series was therefore continued with the herring bait which stimulated the best responses. This is the cause of the high bite response in the last part of the test series.

The herring bait initiating the best response had more fatty tissue and softer musculature than the poor quality herring which was meagre and hard. The response of the cod group to these two herring baits was systematically investigated. The results are given in table 2. Here the cod clearly show the quality difference of the bait.

Table 2. The smell response of coastal cod to the two different qualities of herring.

Bait Bag	"Good herring"			"Bad herring:"			
Behaviour	I	II	III		I	II	III
Date: Dec. 11	3.28	2.68	0.46	Date: Dec. 10	0.97	0.43	0.03
" 13	4.00	1.39	1.00	" 12	1.20	0.90	0.03
" 18	4.77	4.81	0.30	" 12	1.20	0.90	0.03
" 19	4.75	4.80	0.80	" 13	2.47	0.27	0.00

With reference to the capelin fed cod, their weak preference for the smell of capelin in the first test series (fig. 4) developed into a stronger preference for herring and especially squid in the second series, table 1. The response is genrally low for this group in both test series; The reason why this group did not developed a smell preference for capelin may be due to the fact that capelin is not a prey organism for coastal cod.

In connection with the series presented in table 1, the cod fed on squid and herring were individually tagged. Observations of behaviour from individual cod were obtained at the bait bag containing the food.

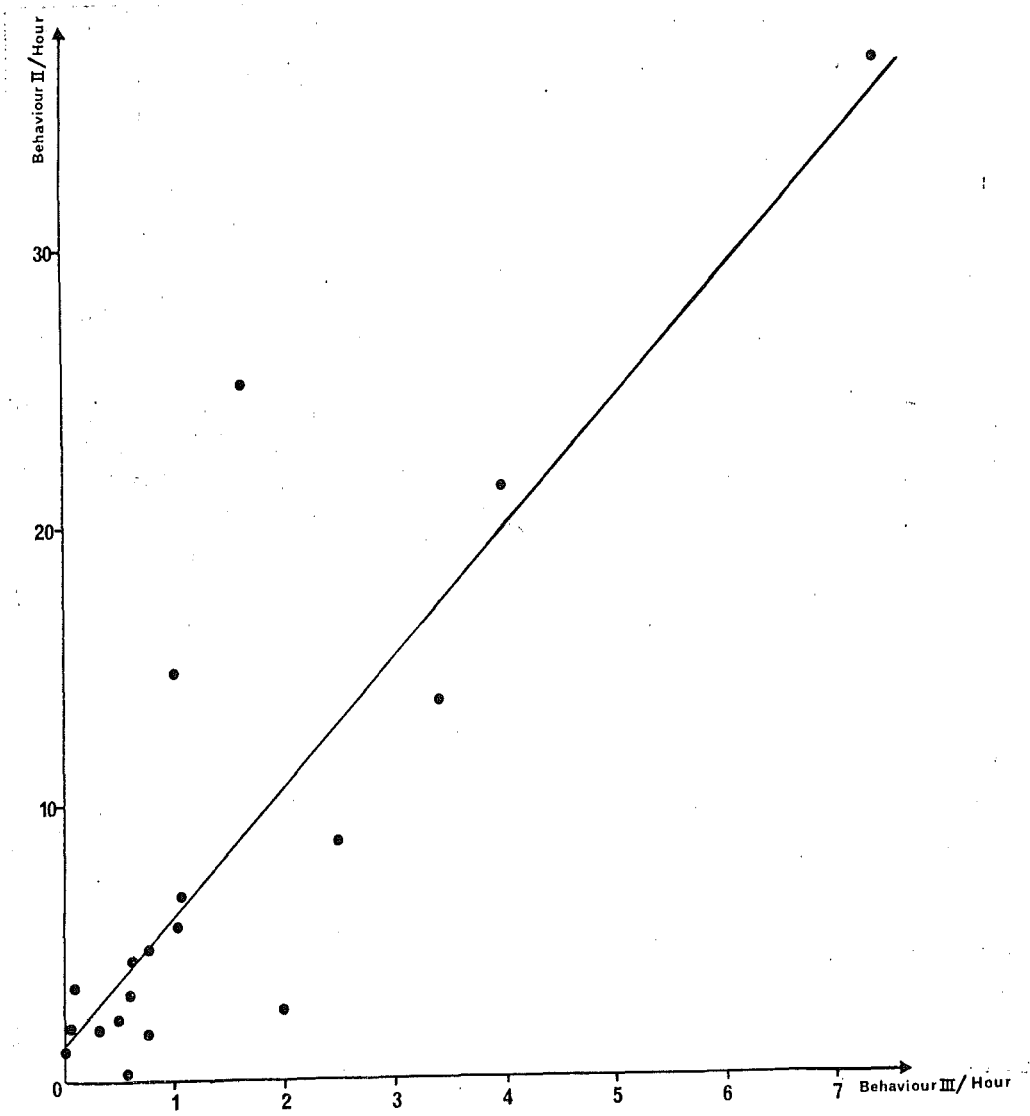

Fig. 5. Relation between behaviour patterns II and III, from individually tagged fish. The regressionline: $y = 4,7048x + 1,3146$.

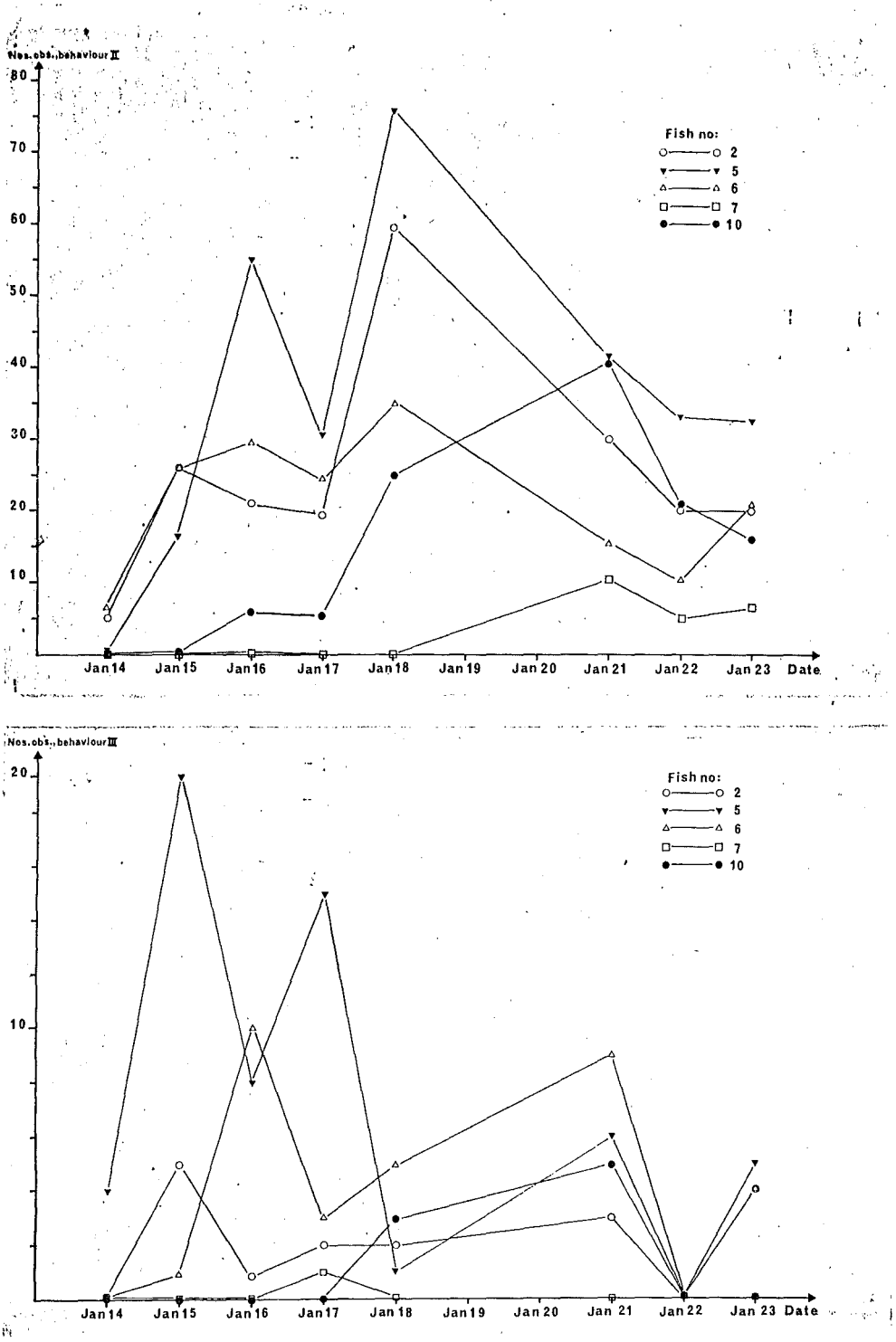

Fig. 6. Coastal cod, individualy tagged, fed on squid. Observation on behaviour patterns II and III at the squid bait bag. The figures are given in numbers of observations pr. hour.

Fig. 5 shows the data for behaviour patterns II and III plotted against each other from all the fish in both groups. The correlationcoefficient 0,8529 is significant at the 0,001 level. Data from some individually tagged cod with different response activities is given in fig. 6 to show how the responses in behaviour pattern II and III develop during the test period. The figure shows wide variation in the responses, both in strength and time. These results show the need to work with groups of fish. It also appears from the figure that the responses of the individual fish reach a maximum and then decline. This extinction is a natural consequence of the fish not being rewarded during the test period. The results from the two preference test series have clearly shown that a test period of one week is enough to give reproduceable results.

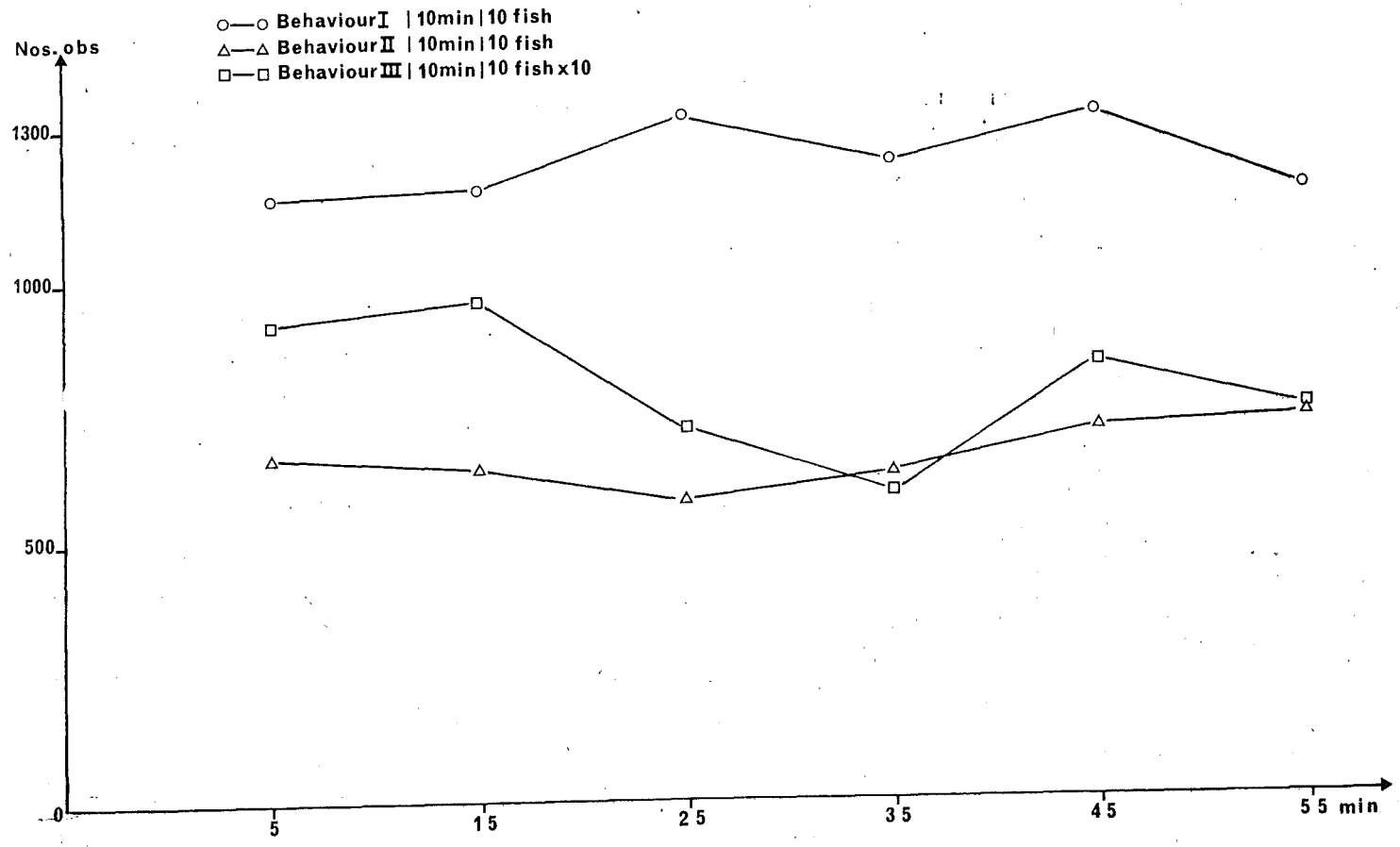

Fig. 7. Response of coastal cod during 1 hour of observation. The figures are the mean values of 34 experiments.

Fig. 7 shows the group responses in the 3 behaviour categories over ten minutes intervals from 34 1-hour tests. The response tendency is stable throughout the whole test period for both behaviour patterns I and II. We cannot at this moment give any definite explanation for the low behaviour pattern III response occurring in the middle of the test period. Group data does not give any information on the number of fish responding.

Table 3. Response of individually tagged cod from a series of 1 hour experiments. The fish are numbered from 1 to 10 and the data is split into 30 minute periods.

Behaviour	II		III	
Obs. period	1 - 30 min.	31 - 60 min	1 - 30min	31 - 60 min.
Date	Fish no.	Fish no.	Fish no.	Fish no.
Jan 14	6,	2, 5, 6,	5,	5,
" 15	2, 5, 6,	2, 5, 6, 10,	5,	2, 5, 6,
" 16	2, 5, 6, 7, 8, 10,	2, 3, 5, 6, 7, 8, 10,	2, 5, 6,	2, 5, 6,
" 17	1, 2, 4, 5, 6, 10,	1, 2, 4, 5, 6, 7, 10,	2, 5, 6,	2, 5, 6, 7,
" 18	1, 2, 5, 6, 10	2, 4, 5, 6, 9, 10	2, 5, 6, 9	10
Sum	1, 2, 4, 5, 6, 7, 8, 9	1, 2, 3, 4, 5, 6, 7, 8, 9, 10,	2, 5, 6, 9	2, 5, 6, 7, 10

Table 3 shows the number of different fish responding in the first and last 30 minutes from a series of tests. The table shows that the number of fish which responded, increased during the latter half of the test. Therefore we decided to conduct our experiments over 1 hour periods.

Tester et al., (1955) found that the response to the smell stimuli failed to occur when the number of tests per day was too high. In the large circular tank we carried out 2 tests per day with an interval of 4 hours. The water exchange during this interval was approximately 15%. Experiments showed that there was no reduction in the response during the second test, table 4.

Table 4. The cod's smell response from two test series with 4 hours interval. The figures are the mean of 13 test days.

Behaviour	I	II	III
1st test	3,98	0,87	0,11
2nd test	3,58	0,92	0,12

In order to investigatigate the effect of a new food on the smell preference, the food was changed for the cod groups fed on squid and herring. Table 5 A and B shows that the cod originally fed on squid retained their smell preference for this food even after a long feeding period on herring. On the other hand, cod orginally fed on herring changed their smell preference from herring to squid.

Tests with small coastal cod

The results from the preference tests of the small cod, 20-30 cm, are shown in table 6. The test series lasted 6 days. The table shows again the significance of the food on the smell responses. One exception is that of the capelin-fed cod. This reaction was similar to that of the big cod, as discussed previously. The table shows also that when young cod showed a response to the smell of food other than that they had been fed on, they seem to prefer the smell of squid.

Table 5. A Preferance tests at different intervals after changing the food from squid to herring, for the squid-fed-group

B and from herring to squid for the herring-fed-group. The figures are the mean values from the test series, and given in obs./10min/fish.

A

Smell stimuli		Herring			Squid			Mackerel		
Days after food change	No. of tests.	I	II	III	I	II	III	I	II	III
6	4	0, 65	0, 03	0, 00	1, 66	0, 49	0, 03	0, 72	0, 05	0, 00
14	5	1, 68	0, 09	0, 00	0, 95	0, 21	0, 01	0, 84	0, 04	0, 00
21	5	0, 33	0, 03	0, 00	1, 06	0, 42	0, 03	Capelin 0, 60	0, 04	0, 00
84	6	0, 74	0, 01	0, 00	1, 05	0, 58	0, 10	0, 38	0, 01	0, 00

B

Smell stimuli		Herring			Squid			Capelin		
Days after food change	No. of tests.	I	II	III	I	II	III	I	II	III
6	6	0, 74	0, 00	0, 00	0, 76	0, 09	0, 00	1, 24	0, 00	0, 00
14	5	1, 31	0, 55	0, 05	1, 18	0, 30	0, 03	0, 52	0, 03	0, 00
124	4	1, 13	0, 17	0, 00	1, 25	0, 25	0, 06	1, 09	0, 10	0, 00

Table 6. Preferance tests of five groups of small coastal cod, fed on herring, mackerel, capelin, squid and mussel. The figures are the mean values from the test series given in obs/10min/fish.

Smell stimuli	Herring		Mackerel		Capelin		Squid		Mussel	
Behaviour	II	III	II	III	II	III	II	III	II	III
Cod group:										
Herring-fed	4, 54	0, 41	-	-	0, 47	0, 02	1, 41	0, 08	-	-
Mackerel-fed	0, 53	0, 01	1, 97	0, 05	-	-	0, 40	0, 00	-	-
Capelin-fed	0, 35	0, 00	-	-	0, 17	0, 00	0, 64	0, 02	-	-
Squid-fed	0, 25	0, 00	0, 24	0, 00	-	-	1, 82	0, 09	-	-
Mussel-fed	0, 43	0, 02	-	-	-	-	0, 86	0, 11	0, 90	0, 18

Table 7. Preference tests from small coastal cod fed on capelin for 11 and 27 weeks, respectively. The figures are given obs./10min/fish.

	11 Weeks						27 Weeks					
Smell stimuli	Capelin		Squid		Herring		Capelin		Squid		Herring	
Behaviour	II	III	II	III	II	III	II	III	II	III	II	III
Early exps.	0, 13	0, 00	0, 39	0, 00	0, 33	0, 00	0, 23	0, 00	0, 30	0, 03	0, 10	0, 00
Late exps.	0, 21	0, 00	0, 90	0, 03	0, 36	0, 00	1, 73	0, 29	1, 40	0, 05	0, 88	0, 03

Table 7 shows that young capelin-fed cod will prefer this smell after 27 weeks of feeding. This shows that cod can, after a sufficiently long period of being fed on one food type, develope a smell preference for a bait in which they previously had little interest. As seen from table 7 it is necessary to continue each test series for at least one week.

Summary

1. The coastal cod is able to discriminate between different bait organism smells in a situation of choice. Usually the cod prefer the smell of what they have been fed upon.

2. However, the results of capelin-fed cod have shown that they also have the ability to prefer certain smells, irrespective of previous feeding. The same was also found in the experiments where the food was changed.

3. The 3 bait types can bee listed in the order of the cod's smell preferences-first squid, then herring and finelly capelin.

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