FOOD SELECTION IN COD (*GADUS MORHUA*): REACTIONS TO COLOUR AND SMELL

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ABSTRACT

Gjøsæter, J. 1990. Food selection in cod (*Gadus morhua*): Reactions to colour and smell. Flødevigen rapportser. 1, 1990: 1-10.

Cod were offered food and food imitations with various colours and smells. When offered crabs with natural colour and with the carapace painted in red, yellow or green, they showed no significant preference. Neither did they react differently to pieces of shrimps with natural colours or pieces coloured red or green. In a series of lures, those giving the best contrast to the water surface were usually selected first. When food and artificial imitations were offered simultaneously, the food was normally taken first. Cod reacted similarly to pieces of shrimps soaked in alcohol and to natural shrimps. They also had the same response when offered shrimps and a paste made of fish and shrimps simultaneously. When offered a paste made of crabs and one made of mackerel, they preferred the one made of crabs.

INTRODUCTION

Cod is an opportunistic feeder. In nature it takes a wide variety of food items depending on what is available and what is easily caught (e.g. Daan 1973, Klemetsen 1982). Studies have shown that in captivity cod also eat many types of food and readily switch to new types.

Cod is primarily a visual feeder, although smell and taste have been shown to be of some importance too (Brawn 1969, Pawson 1977, Ellingsen and Døving 1986). Although it is known that vision is very important, little is known about which visual cues stimulate feeding behaviour in cod. Studies on other species have shown that form, colour, and contrast to the background can be important (Keenleyside 1979).

Several studies have been conducted to find which chemical cues start feeding behaviour in adult cod (Brawn 1969, Pawson 1977, Bjordal and Fernö 1983), and cod larvae (Wennberg in prep, Wennberg and Gjøsæter in prep). These studies have shown that various amino acids start feeding

behaviour, and so do extracts from various food items as shrimps, crab, blue mussels and fish.

In the present paper food of different colours and smells were offered to cod to see which they preferred. Lures of different colour were also used.

MATERIALS AND METHODS

Reactions to coloured crabs

In the first group of experiments described, 12 crabs (*Carcinus maenas*) were painted on their carapace, using nail polish. 4 were painted red, 4 yellow and 4 green respectively. These and 4 unpainted crabs were offered to cod. Two groups of cod, one caught in fish pots near the Biological Station, and one reared from eggs at the station were used. The reared cod were fed pieces of fish before the experiments started. Two experiments were run with two reared cod, 35 and 40 cm long, and two experiments with 9 wild cod, 20-40 cm long (Table 1). All sixteen crabs were given at the beginning of each experiment, and each day the number of crabs eaten by cod were recorded. The cod got no other food during these experiments. The experiments were run in 500 litre tanks made of dark greyish fibre glass. The temperature during the experiments was about 10-12°C.

Experiments with coloured lures

In the experiments with coloured lures 4 groups of reared and wild cod, mostly of length 35-45 cm were used. Each group contained from 2 to 20 fishes, and were kept in 500 to 2500 litre tanks made of dark greyish fibre glass. The wild fish were not fed before the experiments started, while the reared fish received pieces of fish. The lures were presented to the fish in groups of three, and each presentation lasted for 5 min. During the presentation the lures were hung side by side about 20 cm apart. They were not moved during the presentation. The number of bites towards the lures were recorded. In this experiment a bite was recorded when the fish took the lure into the mouth, even when the mouth was not shut.

Table 1

Number and size of fish used in the experiments.

Exp.	No of fish	Type of fish	Size cm
I Reactions to coloured crabs	2	reared	35,40
	9	wild	20 - 40
II Exp. with coloured lures	2	wild	35
	10	wild	35 - 45
	10	reared	35 - 40
	20	reared	35 - 45
III Exp. with food items and other couloured objects	10 (one at a time)	wild	13.5 - 16
IV Fod with different smell and colour	same fish as above		
V Various types of food.	6	reared	15 - 20

The lures used were Sølvkroken Spesial 12 g without hooks, painted on both sides in the following colours: red, brown, black, or non-painted in the colours silver, gold and copper. The temperature during the experiments was about 10-12°C.

Experiments with food items and other couloured objects

In the third experiment pieces of shrimp with a diameter of about 0.8 cm were presented to fish together with white, green, yellow, red, blue and black plastic beads of similar size. In each presentation one piece of food and two plastic beads were offered. They were placed on needles keeping them on a line with distance about 10 cm between them and about 3 cm from the bottom of the aquarium. The relative position of the food and the plastic beads were random. The food and plastic beads were presented to one fish at a time, and the order in which the fish touched or bit the items were recorded. To avoid learning each fish was only used a few times.

The experiments were carried out in a glass aquarium, 85x48x47 cm (l x b x h), the walls of which were covered with white paper. The fish used in the experiments were caught in a beach seine and their size was 13.5-16 cm. The temperature during the experiment was about 15°C.

Food with different smell and colour

The fourth experiment was similar to the third one, except that the fish were offered red, green and natural pieces of shrimp in the first part of the experiment, and red, natural and pieces soaked in alcohol in the second part. The shrimps were coloured with dyes used in the human food industry.

Various types of food

In the first part of the fifth group of experiments, six reared cod (15-20 cm.) were offered a paste of fish (mainly coalfish) and a piece of shrimp. Five items were placed simultaneously along a line at the bottom of the aquarium, and their order was chosen randomly. The distance between the pieces was about 5 cm. In each presentation the order in which the food items were taken was recorded. The 500 l aquarium with black walls was used for this experiment. The temperature during the experiment was about 10-12°C.

In the second part of these experiments three cod were offered one piece of a paste made of crabs (*Carcinus maenas*) and one made of mackerel (*Scomber scombrus*). Both also contained binder and vitamins, and both had the same colour. One piece of each kind was dropped from the surface simultaneously, and the one taken first was recorded. New pieces were given till the fish stopped eating. This experiment was conducted in the same aquarium as experiment III and IV. The temperature was about 10-12°C.

The statistical methods used in the present report are described by Siegel (1956).

RESULTS

Reactions to coloured crabs

When wild cod were offered crabs with different colours, the yellow ones were taken first (Fig. 1) followed by natural, green and red. The mean rank was 2.13, 2.50, 2.58 and 2.87 respectively. The differences were, however, not significant (Friedman two-way analysis of variance, Chi-square =0.849, v=3, $p>0.05$).

The reared cod also took the yellow crabs first (Fig. 1). The second choice was green then came red, and finally natural. The mean rank was 1.88, 2.44, 2.44 and 3.25 respectively. As in the case with wild cod the differences were not statistically significant. (Friedman two-way analysis of variance, Chi-square= 5.197 , v=3, p>0.05).

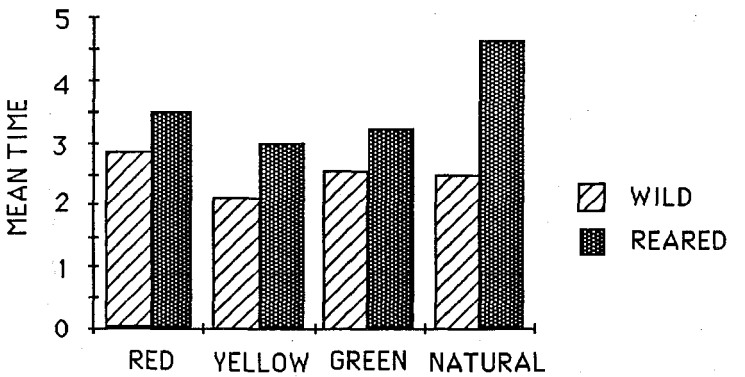

Fig. 1. Mean time in days for crabs with the dorsal shield painted in different colours to be eaten by wild and reared cod.

Experiments with coloured lures

Three experiments were conducted. First fluorescent red, brown and black were tried. Of these black was usually taken first, followed by red and brown (Table 2). The hypothesis that all colours were taken equally frequently, was however not rejected. (Log-likelihood ratio test, G=3.33, v=2, p>0.05).

In the second experiment the colours silver, gold and copper were used. Of these copper was usually taken first, followed by silver and gold (Table 2). In this case the hypothesis that all colours were taken equally frequently, was rejected (G=6.04 , v=2, p<0.05).

In the final experiment the preferred colour from the two first experiments were combined. In this case copper was preferred before black (Table 2). In this case too, the hypothesis that both colours were taken equally frequently, was rejected (G=7.64 , v=1, p<0.01).

Table 2

Number of "bites" and number of "bites" per five minutes towards lures with different colours. The G values from the log-likelihood ratio test are also given.

Exp. no.	Colour	Bites	Bites/ 5 min.	G
1	Red	30	1.88	
	Brown	27	1.69	3.33
	Black	41	2.56	
2	Silver	66	3.67	
	Gold	46	2.56	6.04
	Copper	72	4.00	
3	Black	48	4.00	
	Copper	79	6.50	7.64

Experiments with food items and coloured objects

Juvenile cod were offered small pieces of shrimps and plastic pieces of similar size, but of different colours. In each experiment the cod were offered one piece of shrimp and two plastic items. The cod clearly preferred the food items (Table 3). It is not possible to assess the relative preference for the plastic beads, as the number of experiments with each colour was too low. The difference between food on one side and plastic beads on the other was, however, significant (Log-likelihood ratio test, $G=22.19$, $v=1$, $p<0.01$).

Table 3

Experiments with food and plastic beads. Number of observations indicate the number of trials in which each item was included.

Food	Plastic beads						
	White	Green	Yellow		Red	Black	Blue
First bit	11	1	0	0	0	0	2
Second bit	2	1	1	1	4	0	1
Third bit	0	1	2	1	0	1	2
No bit	1	0	0	1	3	3	3
Number of observ.	14	3	3	3	7	4	8

Food with different smell and colour

Small cod were offered natural pieces of shrimps and coloured shrimps. In the first series of experiment shrimps soaked in alcohol were also offered.

In 45 experiments where the small cod were offered natural, red and green pieces of shrimps the natural pieces were taken first while red and green were taken later (Fig. 2). The difference was small, and non-significant (Friedman two-way analysis of variance, Chi-square=1.73, v=2, p>0.05).

In 20 experiments where natural pieces, red pieces and pieces soaked in alcohol were offered, the red ones were usually taken first and the natural ones were taken last, but the difference was not statistically significant (Fig. 3) (Chi-square=2.70, v=2, p>0.05).

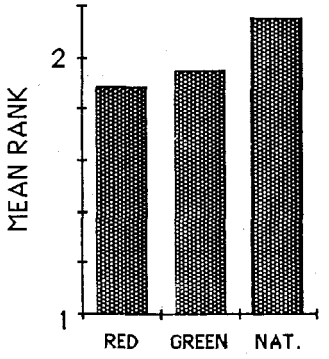

Fig. 2. Mean rank of removal of natural food and food coloured red and green.

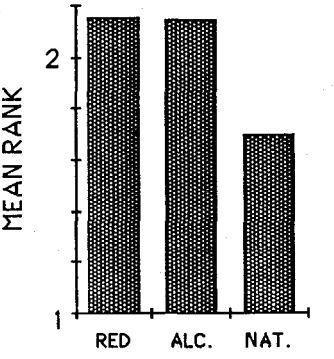

Fig. 3. Mean rank of removal of natural food, food soaked in alcohol and coloured red.

Various types of food

In a series of 15 experiments the juvenile cod were offered pieces of shrimps and a paste made of fish and shrimps. The fish showed no difference in preference (Table 4) (Log-likelihood ratio test, G=1.00, v=4, p>0.05, Rank 5 and not eaten combined).

Table 4

Order in which pieces of shrimps and a paste of fish and shrimps were eaten by small cod.

	Removed as no.					Not
Food type	1	2	3	4	5	eaten
Shrimp	6	8	8	7	9	0
Paste	9	7	6	7	5	3

In another series of experiments, juvenile cod were offered a paste made of crabs and another one made of mackerel. They both looked the same. When one piece of each paste was offered simultaneously, the paste made of crabs was taken first 63 times and the one made of mackerel 12 times. The difference was significant ($G=38.02$, $v=1$, $p<0.01$).

DISCUSSION

The experiments with food items and other objects of different colours all suggest that other factors are more important than colour in determining food selection in cod.

The experiments with natural and coloured pieces of shrimps, and with shrimps and plastic beads (Experiment III and IV) were carried out in an aquarium with glass walls covered with white paper, and the natural shrimps offered obviously had a much lower contrast to the background than the coloured shrimps and plastic beads. Even so, the natural shrimps were taken equally often as coloured shrimps, and more often than plastic beads of various colours.

The experiment with crabs (Experiment I) was conducted in a dark greenish tank, where the natural crabs were most similar to the background, and the yellow ones made the best contrast, at least to the human eye. Again, the cod showed no difference in its preference for the different colours.

Two hypotheses could be presented; that cod should prefer food with colours similar to what they usually eat, or that they should prefer food showing good contrast to the background (e.g. Keenleyside 1979). The reason for the lack of support to any of these hypotheses, could be that those colours which were most natural gave least contrast in the present experiments. Therefore, the tendency to take the most natural colour and to take the most contrasting colour could neutralize each other.

In the experiments with lures (Experiment II), no natural food items were offered and most of the fish used in this experiment were recently caught, and were not used to artificial food of any particular colour. The cod took the darkest alternative both when offered silver, gold and copper, and when offered red, brown and black. When offered black and copper, however the lightest alternative was chosen. In the two first trials the contrast to the surface might have been decisive. The choice of copper before black, needs however, another explanation.

The experiments with two similarly looking types of food (Experiment V) show that smell can be decisive for the choice of food, and the food made of crabs were highly preferred to that made of fish. On the other hand, no difference was found in the reaction to shrimps and to a paste of fish. The preference of shrimps over plastic beads (Experiment III) may also support the importance of smell. Other experiments have shown that extracts of crabs and other invertebrates are attractive to cod (Brawn 1969, Wennberg and Gjøsæter in prep.). It is difficult to explain why cod showed the same preference to natural shrimps and shrimps soaked in alcohol in experiment IV. Observations that cod will eat shrimps soaked in petrol also seem to contrast the importance of smell (Gjøsæter, unpubl.), particularly as it is known that cod can react even to low concentrations of petrol (Bøhle 1985). Neither of these observations were made with particularly hungry cod.

ACKNOWLEDGMENTS

I am grateful to K. Lønnhaug and A. Wennberg for technical assistance and to Dr. P. Dalpadado, Dr. A. Fernö, H. Gjøsæter and T. Johannessen for helpful comments to the manuscript. These studies were supported by the Norwegian Council of Fisheries Research.

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