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COMPETITION FOR FOOD AND PREDATOR-PREY RELATIONSHIPS AMONG YOUNG COD (*GADUS MORHUA*) AND SOME OTHER FISH FROM SHALLOW WATERS

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ABSTRACT

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Experiments were conducted to study food competition between young cod (20-30 cm) and some other fish from shallow waters. When food was dropped from the surface the cod took much more than the other species, but goldsinny-wrasse, *Ctenolabrus rupestris*, and flounder, *Platichthys flesus*, also took considerable quantities.

Competition between small (15-17 cm) and larger (22-26 cm) cod was generally in favour of the larger fish. The first piece of food offered was often taken by the smallest fish. After that the big fish took most of the food till it was satisfied. Then the small fish could feed again.

Experiments in aquaria and in large outdoor basins showed that cod of 20-50 cm length will eat small cod and whiting, *Merlangius merlangus* (7-20 cm) even if other, natural or artificial, food is available. Small cod apparently have a better chance of survival in basins with macroalgae.

INTRODUCTION

For considerable parts of the year, cod of the two youngest year classes occur in shallow waters, together with several other species of fish (Tveite 1971, Riley et al. 1981, Riley and Parnell 1984, Gjøsæter and Danielssen in prep.). Experiments have indicated that they, at least to some extent, chose different habitats (Gjøsæter 1987a, b), but still some competition and predation is expected to take place. It is well known that cod prey on smaller cod and other gadoids (Daan 1973, 1983), while less is known about its predation on typical littoral fish.

Intraspecific food competition and predation are also important problems in the rearing of cod (Kvenseth 1985) and for releasing young cod in the sea (Gjøsæter 1986).

The present paper reports a series of experiments conducted to study feeding interaction and predator-prey relationships between cod of different size and between cod and some littoral fish. In the first experiments, cod and some littoral fish were kept in an aquarium to study their feeding interaction. In the second group of experiments, cod of the two youngest age groups were kept together in one aquarium, and their competition for food was studied. In the third series of experiments, fish naturally occurring together in shallow waters off the south coast of Norway were kept in aquaria and in outdoor basins to study their predator-prey relationships.

MATERIALS AND METHODS

Most of the fish used in the experiments were caught in beach seines in the Arendal area of the Norwegian Skagerrak coast. Some of the fish were caught in pots in shallow waters. A list of the fish species used in the experiments is given in Table 1.

Table 1

Fish used in the experiments

Cod	*Gadus morhua* L.
Whiting	*Merlangius merlangus* (L)
Pollack	*Pollachius pollachius* (L)
Poor-cod	*Trisopterus minutus* (Mull.)
Sea scorpion	*Taurulus bubalis* (Euphrasen)
Eelpout	*Zoarces viviparus* (L.)
Butter-fish	*Pholis gunnellus* (L.)
Black goby	*Gobius niger* L.
Goldsinny-wrasse	*Ctenolabrus rupestris* (L.)
Ballan wrasse	*Labrus bergylta* Ascanius
Plaice	*Pleuronectes platessa* (L.)
Brill	*Scophthalmus rhombus* (L.)
Flounder	*Platichthys flesus* (L.)
Dragonet	*Callionymus lyra* L.
Deep-snouted pipefish	*Syngnathus typhle* L.
Sprat	*Sprattus sprattus* (L.)

In some of the experiments the fish were used immediately after capture. In the others, they were kept for some time in storage tanks (2500 l) until the experiments started. In the tanks, the fish were fed to satiation with shrimps or a paste of minced fish and shrimps with vitamins added. During all the experiments the water temperature was about 8-10°C.

Experiment series 1 was conducted to study food competition between cod and some littoral fish. The fish species used are listed in Table 1. The fish were transferred to an aquarium 180x60x80 cm (l x w x h). During an initial period of about one month the fish were fed to satiation once a day to get used to the artificial food. During the experiment, they were fed once a day, except Saturdays and Sundays, with pieces of shrimp 0.5 to 1.5 cm long. The pieces were dropped from above the surface, and the time from hitting the surface to capture was recorded. It was also recorded if the food was lost and subsequently taken by other fish, or was stolen by other fish. A new piece was only offerred when the previous one had been eaten. Feeding was continued until no more pieces were taken.

Experiment series 2 was conducted to study how small and big cod reacted to food when they were kept together. One small cod (15-17 cm) and one big cod (22-26 cm) were kept together in one aquarium 180x60x80 cm (l x w x h). Pieces of shrimp 0.5 to 1.5 cm long were given once every 30 sec. using an automatic feeding device which dropped them above the surface. The fish were kept in a separate room and watched using a video system. No observer was present in the aquarium room during the experiments. Each pair of fish was only used in five or less of the 29 experiments carried out.

Experiment series 3 was conducted to investigate predation when fish naturally occurring together in the littoral zone were kept in aquaria and in outdoor basins.

Experiment 4a was conducted in an aquarium 180x60x80 cm (l x w x h). The fish used in the experiment are listed in Table 1.

Experiment 4b was conducted in an approximately 45 m^3 large outdoor basin of 2 m greatest depth. The bottom was fairly smooth and there were no stones or vegetation where the fish could hide. The fish used in the experiment are listed in Table 1.

Experiment 4c was conducted in the same basin as experiment 4b, but in this experiment parts of the bottom (about 5 m^2) were covered

with stones with algae. The algae used were *Ascophyllum nodosum* and *Fucus serratus*.. They formed a fairly dense mat of vegetation about 30-60 cm high. The fish used in the experiment are listed in Table 1.

Experiment 4d was conducted in an approximately 2000 m^3 large basin with a surface area of 660 m^2 and greatest depth of 5 m. The bottom was partly covered with rocks of various sizes and partly with gravel and mud. The fish used in the experiment are listed in Table 1.

RESULTS

Food competition between cod and littoral fish in aquaria

In 14 experiments conducted over a 20 day period, a total of 316 pieces of food were offerred. Of these 129 were first taken by cod, 82 by goldsinny-wrasse, 41 by flounder and 38 by butter-fish (Table 2). Some of the species lost most of the food items they caught after fighting with other specimens or because they were too large to handle for the fish in question (Table 2). Coldsinny-wrasse lost 78 pieces and butter-fish 40, while cod lost only three. The number of food items finally eaten by the different species ranged from 151 for cod to 1 for plaice (Table 2).

Table 2

Results of feeding experiment with cod and some littoral fish. Number of pieces of food first taken, finally swallowed and lost to other fish are shown. It is also indicated to whom the food pieces were lost. Number of fish and approximate mean size is given for each species.

Spec.	No.	Mean size (cm)	Food pieces taken First	Final	Lost	Cod	Sea sc.	Golds.	Flound.	Butterf.	Ball.wr.	Eelp	Pla.	Bl.gob.
Cod	4	25	129	151	3			1		1				
Golds.	5	12	82	59	78	15	2	33	2	5	12	2	1	6
Flound.	2	16	41	37	7	2	1			1				2
Black g.	5	18	13	22	6			2				1		2
Eelp.	3		1	4	2	1		1						
Sea sc.	3	17	8	17	1			1						
Butterf.	1		38	9	40	6	6	18		2	1	2		8
Ball wr.	1	22	4	17	0									
Plaice	1	16	0	1	0									

The average number of food pieces first taken by each fish species over the experimental period varied from more than 30 for cod and butter-fish to less than 1 for eelpout (Fig. 1). The number of pieces finally eaten ranged from about 38 for each cod to 1 for plaice and eelpout (Fig. 1). Only cod ate more than an average of one piece of food per fish per day.

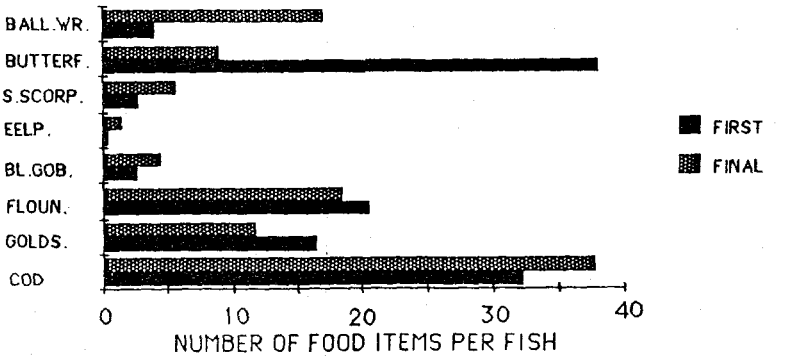

Fig. 1. Average number of food items per fish first taken and finally eaten by various fish spesies.

The cod, after eating intensively one day, often had one or more days with little feeding (Fig. 2). No similar effect was observed among the other fish.

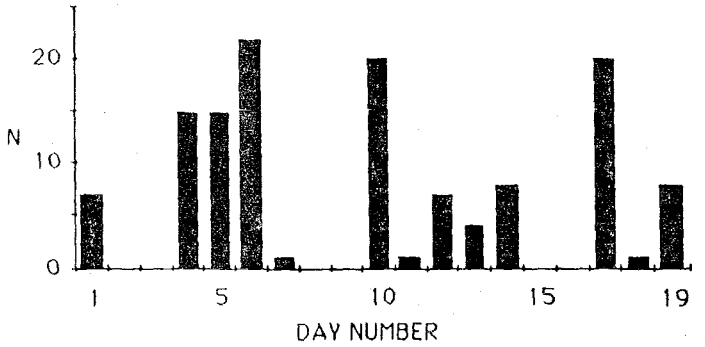

Fig. 2. Average number of food items per day first taken by cod.

The time from a food item reaching the water until it was first taken varied from less than 1 to 20 sec. The average time taken for the different species varied from 2.5 sec for ballan wrasse to 7.1 sec for black goby (Fig. 3). The daily average increased only slightly within each experiment (Fig. 4).

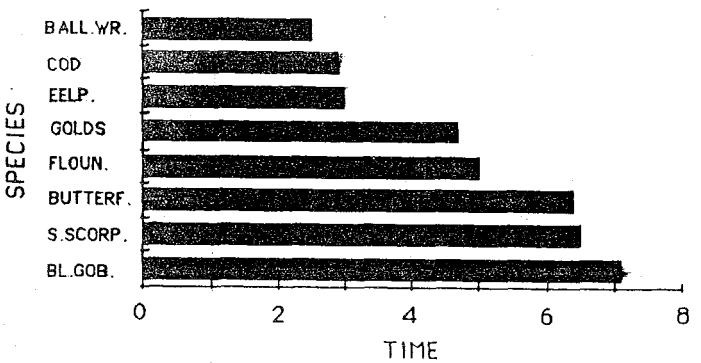

Fig. 3. Average time in seconds from a food item is dropped till it is caught by various fish species.

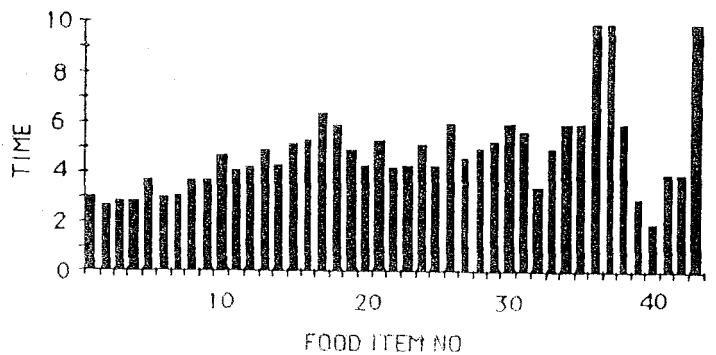

Fig. 4. Average time in seconds from a food item is dropped till it is caught by a fish.

Both cod and goldsinny wrasse reached about 90% of their total consumption after the addition of about 20 and 25 pieces respectively (Fig. 5). The two species ranking third and fourth in food consumption,

flounder and butter-fish, took less than 20% of their food among the first 10 pieces. They reached 90% only after 30 more pieces had been

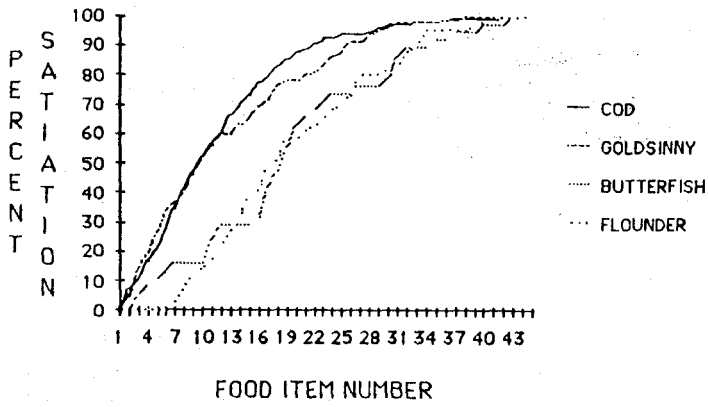

Fig. 5. Cumulative frequency of number of food items eaten for some species given as percentage of the total number eaten by each species.

offerred. Apparently some fish took little or no food. Sometimes, however, small pieces of food were torn off, and fell to the bottom, and these pieces may have provided food for some of the fish.

Competition for food between small and big cod

The first food item offerred was taken by the biggest fish in 16 of the 29 experiments carried out (55%). For food items 4 to 9 this proportion increased to about 22 of 28 (79%) (Fig. 6). The proportion taken by the big fish stayed high until about 25 food items had been offerred, then the proportion taken by the biggest fish decreased.

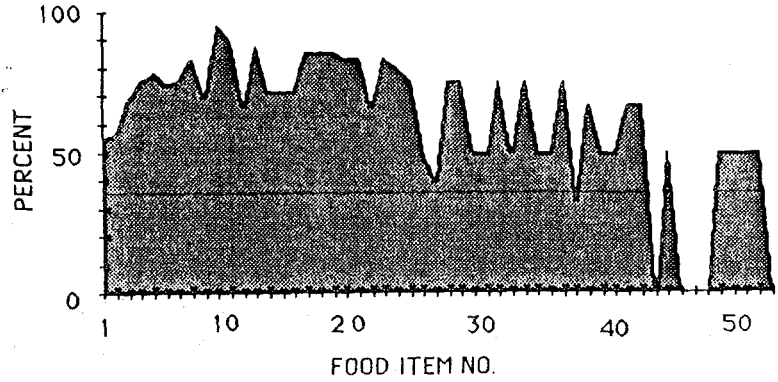

Fig. 6. Proportion of food items eaten by big cod as a function of the number of food items given. The remaining proportion was eaten by small cod.

Of the total number of food items eaten, the biggest fish took about 70% and the smallest 80%. This was in fairly good accordance with the proportion between their body weights (about 3:1)

Both small and big fish took about 55% of their total food consumption from the 10 first food items offerred (Fig. 7). From then the biggest fish ate most intensively, and reached 90% of its total food intake after 30 food items had been given. The smallest fish reached this percentage after about 45 items.

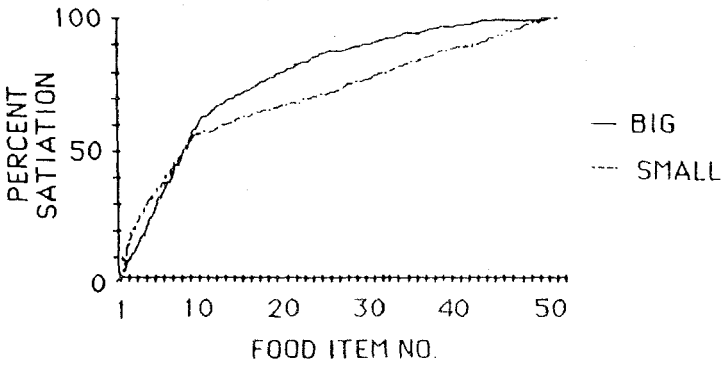

Fig. 7. Cumulative frequency of number of food items eaten by small and big cod given as percentage of the total number eaten by each category.

The first food items given were often taken by the small fish, which apparently noticed the presence of food more quickly than the big fish. When the big fish noticed that food was coming, they took most of the food, and often chased the small fish away if they tried to eat. When the big fish were satisfied, the small fish again got a chance to eat.

Predator-prey reltationships in aquaria and outdoor basins

The fish listed in Table 3 were caught in a beach seine on 22 August and put in an aquarium 180x60x80 cm (l x w x h). They were kept there and fed to satiation with shrimps and a paste of minced fish and shrimp until 12 September. During this period 16 of the whiting were eaten by the cod. The other whiting (4) died from other causes. Four flounders and one black goby were also eaten during this period. All the fish except the ballan wrasse were seen eating the artificial food offerred regularly.

Table 3

Fish present at start and end of experiment 4a with littoral fish kept in an aquarium. Length range is given in cm.

Species	Start		End	Lost
	No.	Length range	No.	No.
Cod	4	20 - 31	4	20
Whiting	20	9 - 12	0	
Sea scorpion	3	15 - 22	3	
Eelpout	3		3	
Butter-fish	1		1	
Black goby	6	12 - 15	5	1
Flounder	6	14 - 21	2	4
Goldsinny-wrasse	5	10 - 14	5	
Ballan wrasse	1	22	1	
Plaice	6	15 - 17	5	1
Brill	2	22	2	
Total	57		31	26

During the first week of September, 11 large cod caught in fish pots were released into a 45 m^3 basin. They were fed daily with a paste of minced fish and shrimps. In the middle of September the rest of the fish listed in Table 4 were added. In the following period the fish were also

offerred artificial food, but there were few natural food organisms in the water.

Tabell 4

Fish present at start and end of experiment 4b with littoral fish kept in a small outdoor basin without algae. Length range of the fish is given in cm.

Species	Start		End		Lost
	No.	Length range	No.	Length range	No.
Cod (big)	11	30 - 50	11	30 - 50	0
Cod (small)	17	7 - 20	1	20	16
Whiting	47	11 - 16	0		47
Pollack	2	37 - 38	2	37 - 38	0
Goldsinny-wrasse	14	6 - 10	0		14
Flounder	11	7 - 25	4	15 - 28	7
Sprat	4	12	0		4
Black goby	8	8 - 13	0		8
Ballan wrasse	1	20	1	20	0
Butter-fish	2	12 - 20	0		2
Plaice	2	20	2	21 - 22	0
Total	119		21		98

The experiments were terminated in the beginning of October and the fish surviving at that time are listed in Table 4. Only 21 fish survived the 18 days when small and big fish were together. 98 fish were apparently eaten. Only one of the gadoids smaller than 30 cm survived. All goldsinny-wrasses (14), black gobys (8), sprats (4) and butter-fish (2) were eaten, and so were most of the flounders (7).

In October, a similar experiment was conducted in the same basin, but this time parts of the bottom were covered with stones and algae. The fish listed in Table 5 were released and the experiment lasted for one month. During this period the fish were fed with a paste of minced fish and shrimp.

In this experiment 28 fish survived and 24 were eaten. Among the fish eaten were 8 small cod and 10 whiting, while 12 small cod survived (Table 5).

Table 5

Fish present at start and end of experiment 4c with littoral fish kept in a small outdoor basin with algae. Length range of the fish is given in cm.

Species	Start		End		Lost
	No.	Length range	No.	Length range	No.
Cod (large)	3	30 - 42	3	32 - 43	0
Cod (small)	20	7 - 13	12	7.5 - 13.5	8
Whiting	10	9.5 - 14	0		10
Goldsinny-wrasse	5	6.5 - 14.5	3	7 - 13.5	2
Founder	7	15 - 23	7	15 - 22	0
Black goby	4	7.5 - 14	1	11	3
Deep-sn. pipefish	1	27	1	27	0
Butter-fish	1	?	0		1
Plaice	1	18	1	18	0
Total	52		28		24

The fourth experiment, conducted in a 2000 m^3 basin, was started in September, and the fish listed in Table 6 were released in batches during a period of about two weeks. During the whole experiment the fish were offered artificial food, and the large fish were regularly observed eating. There were also natural food organisms in the water, mainly crab (*Carcinus maenas*) and sand goby (*Pomatoschistus minutus*).

Table 6

Fish present at start and end of experiment 4d with littoral fish kept in a large outdoor basin. Length range of the fish is given in cm.

Species	Start		End		Lost
	No.	Length range	No.	Length range	No.
Cod (large)	19	20 - 35	10	22.5 - 38	9
Cod (small)	6	11 - 14	0		6
Goldsinny-wrasse	9	10.5 - 14.5	7	10.5 - 14.5	2
Poor-cod	5	16 - 23	0		5
Ballan wrasse	2	22 - 24	2	22 - 24	0
Dragonet	1	21	1	21	0
Sea scorpion	7	15 - 22	5	15 - 22	2
Saithe	1	33	1	33	0
Deep-sn. pipefish	1	21	1	21	0
Brill	2	22	2	22	0
Plaice	5	-	2	15.5 - 17	3
Black goby	5	-	1	13	4
Founder	2	20 - 21	2	20 - 21	0
Eelpout	5	-	3	-	2
Butter-fish	1	-	0		1
Total	71		35		36

The experiment was terminated in the middle of November. The surviving fish are listed in Table 6. 35 fish survived the experiment while 34 were lost, and probably eaten. All cod smaller than 20 cm were eaten (6) and so were nine of the larger cod. All poor-cod (3) were also eaten, but there were survivors among most other species.

At the termination of the experiment the stomachs of the surviving fish were opened and the contents recorded. Among the ten cod, six had eaten crabs, four had remains of the artificial food, one had eaten sand gobys and one had eaden hermit crabs. Among the other species sand goby, crabs and artificial food were found.

DISCUSSION

When fed artificial food dropped from the surface, cod took the food more quickly than most other species. Goldsinny-wrasse sometimes took food before the cod, but very often lost it and it was then taken by cod. Butter-fish also took many food items, but mainly those falling to the

bottom, and although the butter-fish took many of these food items first, most of them had been lost to other fish (Table 1). Ballan wrasse had the opposite feeding strategy; they were seldom first to take a food item, but they never lost those food items taken. In these experiments, cod were the larger fish. Therefore, they do not indicate the level of competition between cod and littoral species of the same size.

When the littoral fish used in these experiments occurred with cod, they mainly took the surplus food after the cod had fed. From these experiments it is difficult to draw any conclusions on how these species would compete for food given at the bottom, which would probably be a more natural situation. However, other experiments have shown that giving food at the bottom, instead of at the surface, favours 0-group cod in competition with 0-group whiting (Gjøsæter, in prep.).

When a small and a big cod were kept together, the small fish often seemed to notice the presence of food quicker than the big fish. The relatively higher proportion of the first food items taken by the small cod (Fig. 6) could, however, also indicate that when the small cod are hungry they are less afraid of the big cod. When the big fish started eating, the small ones were usually frightened and did not eat until the big ones had finished. Sometimes the big fish approached the small fish quckly, and the small ones fled.

When small cod and whiting (less than 20 cm) were kept together with larger cod they were eaten, even if the cod were offerred unlimited artificial food and had access to large quantities of crabs and sand gobys, which are among the most important food items in the habitat where they were caught (Hop et al. in prep.). Therefore, it seems that feeding to satiation is not sufficient to avoid cannibalism and predation. The small cod and whiting were eaten both in aquaria and in basins. However, when algae were placed in the basin, some of the small cod survived.

The experiments also show that cod may take other fish from the littoral zone, although they seem to be less preferred than cod and whiting. In the large basin where the small fish could hide among stones and other objects, the littoral fish apparently had a much higher chance of survival than in the aquaria and the smaller basin. Apparently, the structures in the larger basin did not help the cod to survive, while the algae placed in the small basin did. The observation that the algae helped the survival of small cod supports previous experiments indicating that small cod tend to hide among algae when a big cod is present (Gjøsæter 1987b).

Field studies have also led to the assumption that small fish use algae and other struc-tures in the littoral to hide (Cooper and Growder 1979, Keats et al. 1987).

Although the experiments indicate that cod prefer to eat small cod and whiting, field studies on the Skagerrak coast have shown that black goby and goldsinny-wrasse are much more frequently recorded in the stomachs of older cod from the littoral zone than are small cod and whiting (Hop et al., in prep.). This suggests that those species are more easily obtained, either because they are more abundant in the habitat where cod seek food, or because they are more easy to catch.

Cannibalism is a serious problem in the rearing of cod. It has been suggested that the problem can be overcome by giving the cod plenty of food. The present studies suggest that even a cod that has access to all the artificial and natural food it needs will still act cannibalistic, if large and small cod are kept together.

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