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HABITAT SELECTION OF JUVENILE COD (*Gadus morhua*), WHITING (*Merlangus merlangius*) AND SOME LITTORAL FISH IN AN AQUARIUM

Jakob Gjøsæter

Flødevigen Biological Station, N-4000 Arendal, Norway

ABSTRACT

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Experiments were conducted to study the habitat selection of juvenile cod Gadus morhua, juvenile whiting *Merlangus merlangius*, black goby *Gobius niger*, great pipefish *Syngnathus acus*, sand eel *Ammodytes tobianus*, butterfish *Pholis gunnellus*, three-spined stickleback *Gasterosteus acculeatus*, sea stickleback *Spinachia spinachia*, goldsinny *Ctenolabrus rupestris*, and flounder *Plathichthys flesus*. Aquaria with compartments with algae, with sand and with no substratum were used.

Cod, whiting and great pipefish preferred the empty compartments followed by the compartments with sand. For the other species no significant differences were observed although butterfish, three-spined stickleback, and sea stickleback were most frequently found in compartments with algae, and black goby and sand eel were most frequently found in the compartments with sand.

The experiments also showed that cod and whiting had a significant attraction to each other.

INTRODUCTION

Beach seine and trawl samples have shown that 0-group cod often co-occur with 0-group whiting and several species of littoral fish (Riley et al. 1981, Riley and Parnell 1984, Tveite 1971, 1984). Although they are caught simultaneously it is not known whether they occur in the same habitats. Therefore, it is not known if the other species compete with cod for space or food, or if there are other types of interaction.

In nature fish will choose their habitat according to natural conditions, food supply, occurrence of other individuals of the same or other species etc.

One approach to the study of habitat selection is to keep fish in aquaria with different types of environment and to see where the fish prefer to stay. Keeping several species in the aquaria simultaneously can also give information about interspecific relationships.

In the present study a number of species, often occurring together in the beach seine catches at the Norwegian Skagerrak coast, were tested. The fish were kept in an aquarium where they could choose between six compartments, two with sand as the substratum, two with stones and algae and two empty compartments. The present paper intends to analyse their habitat selection and their affinity to each other.

MATERIALS AND METHODS

The fish were caught with beach seine in mid August and kept in large tanks (2500 l) until the experiments started on 30 August (Experiment 1) and 15 September (Experiment 2). In the store tanks, the fish were fed a paste of minced fish and shrimps with added vitamins.

The experimental aquarium is shown in Fig. 1. The aquarium had six compartments. The sides of the compartments were about 60 cm and the water depth 45 cm, giving a volume of about 80 l in each compartment. From each compartment there was an opening about 11 x 8 cm. Through these openings the fish could move from compartment to compartment via a central compartment. The walls between the compartments and the outer walls were blackened to prevent the fish from seeing through them. A more detailed description of the aquarium is given by Bøhle (1986). The aquaria were kept in separate rooms and care was taken that the observer should not disturb the fish.

In two compartments (No. 1 and 3) there was an approximately 1 cm thick layer of fine sand taken freshly from the sea, and in two other compartments (No. 2 and 5) three tufts of

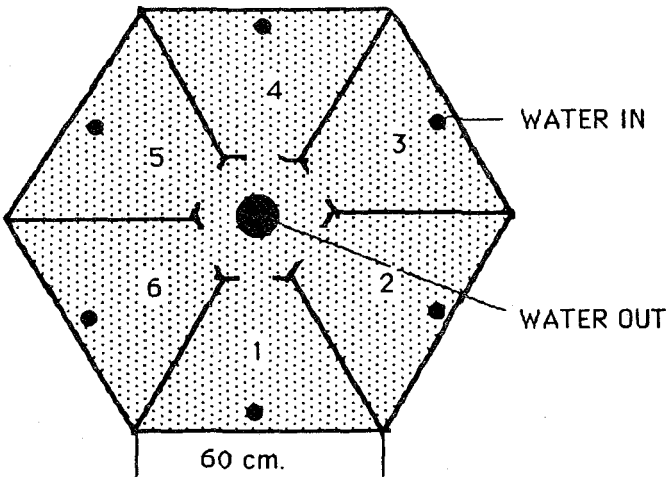

Fig. 1. The aquarium used in the experiments seen from above.

knotted wrack (*Ascophyllum nodosum*) rooted on stones. The size of the stones was about 5x10x15 cm and the height of the algae tufts about 25 cm. The two remaining compartments (No. 3 and 6) had no substratum or algae. Fish were sometimes observed passing through the central section of the aquarium, but they were never observed staying there.

A 60 W bulb was placed over the center of the aquarium, approximately 80 cm over the water surface. This light was automatically regulated to give cycles of 15 h light and 9 h darkness.

In the first experiment the following fish (sizes in parentheses) were simultaneously introduced to the aquarium:

Cod *Gadus morhua* (≈ 10 cm)
Whiting *Merlangus merlangius* (≈ 12 cm)
Black goby *Gobius niger* (≈ 11 cm)
Great pipefish *Syngnathus acus* (≈ 25 cm)
Sand eel *Ammodytes tobianus* (≈ 12 cm)
Butterfish *Pholis gunnellus* (≈ 15 cm)
Three-spined stickleback *Gasterosteus acculeatus* (≈ 6 cm)
Sea stickleback *Spinachia spinachia* (≈ 10 cm)

In the second experiment two cod (≈ 10 cm), two whiting (≈ 12 cm), one sand eel (≈ 12 cm), one flounder *Plathichthys flesus* (≈ 15 cm), and one goldsinny *Ctenolabrus rupestris* (9 cm) were used. The fish species and the sizes used, were typical for the catches in a beach-seine taken at the Skagerrak coast during autumn. Cod and whiting which are the most important species from a fisheries point of view, were used in two experiments, the others in one only.

The fish were placed in the experimental aquarium 1 h before the experiments started, and they were observed at irregular intervals one to five times a day. In the first experiment the fish were observed 25 times over a period of two weeks. In the second experiment the fish were observed 13 times over one week. In both experiments the position of the fish was recorded. In the first experiment it was also recorded how many times the fish had changed compartment between consecutive observations.

The fish were not fed during the experiments.

RESULTS

Experiment 1

Two species, cod and whiting, were most frequently observed in the empty compartments (Table 1). Three species, pipefish, sand eel and black goby, were most frequently observed in the compartments with sand. The other species, sea stickleback, three-spined stickleback and butterfish were most frequently observed in the compartments with algae. For all species the hypothesis that the fish occurred equally in each compartment type could be rejected (Table 2, Log-likelihood ratio test (Zar 1974)). For whiting the number observed in the empty compartment was significantly higher than that observed on sand ($G = 7.8$, $v = 1$, $0.01 > p > 0.005$), but for cod and pipefish the difference between sand and empty was not significant ($G = 1.52$, $v = 1$, $p > 0.10$ and $G = 0.14$, $v = 1$, $p > 0.75$ respectively). Sea stickleback and butterfish were both more frequently found in the compartments with algae than in the others. ($G = 6.28$, $v =$

Table 1

Distribution of fish in a six-compartment aquarium

Species	Sand 1	4	Tot	Algae 2	5	Tot	Empty 3	6	Tot	Total
Cod	8	1	9	1	0	1	2	13	15	25
Whiting	4	1	5	2	0	2	8	10	18	25
Great pipefish	11	1	15	0	0	0	1	12	13	25
Black goby	8	8	16	1	5	6	2	1	3	25
Sand eel	7	4	11	0	3	3	3	0	3	17
Three-spined stickleback	2	7	9	0	10	10	0	0	0	19
Butterfish	1	1	2	4	13	17	2	1	3	22
Sea stickleback	0	1	1	2	16	18	6	0	6	25

Table 2

Log-likelihood ratio tests of distribution of fish in experiment 1

Species	Number of observations on Sand	Algae	Empty	G	P
Cod	9	1	15	14.78	<0.001
Whiting	5	2	18	16.91	"
Great pipefish	15	0	13	29.20	"
Black goby	16	6	3	10.80	<0.005
Sand eel	11	3	3	6.96	0.05-0.025
Three-spined stickleback	9	10	0	15.46	<0.001
Butterfish	2	17	3	18.03	"
Sea stickleback	1	18	6	19.54	"

1, $0.02 > p > 0.01$ and $G = 13.6$, $v = 1$, $p < 0.001$ respectively). Black goby and sand eel were not significantly more frequent in the compartments with sand than in the other compartments ($G = 4.7$ and 4.2 respectively, giving $p \approx 0.10$). Neither was there a difference between sand and algae for the three-spined stickleback.

Examining the total number of observations in the six compartments it seems that 1, 5 and 6 were most frequently visited. Comparing the two compartments with sand (1 and 4), and

the two with no substratum (3 and 6) the difference between each pair of duplicate compartments was not significant (one sample t-test testing the hypothesis that the mean difference were not different from zero. (Zar 1974) $t = 1.27$ and 0.74 respectively, $v = 7$, $p > 0.1$). Among the two compartments with sand, compartment no. 5 had significantly more observations than no. 2 ($t = 2.26$, $v = 7$, $0.05 > p > 0.025$).

The number of times a fish had changed compartment between two consecutive observations were recorded (Table 3). With the exception of great pipefish, which changed 4 times and black

Table 3

Number of changes of compartment between consecutive observations

Species	No.
Black goby	16
Butterfish	11
Three-spined stickleback	11
Sand eel	11
Cod	10
Whiting	10
Sea stickleback	8
Great pipefish	4

goby which changed 16 times, all the others changed between 7 and 11 times. It was also recorded how often two species were observed in the same compartment (Table 4). Cod and whiting were observed together 17 times and sea stickleback and butterfish 14 times. All others were found together 0 to 5 times. If all the fish were distributed independently and randomly, each pair of species should occur together about 4 times.

Assuming that cod and whiting had the preference for substrata as given in Table 2, and no positive or negative relation to each other, they should occur together about 7 times. There is therefore little doubt that a co-occurrence of 17 times indicates a positive affinity between the two species.

Table 4

Association between species kept in a six compartment aquarium

	Cod	Whiting	Sand-eel	Three-spined stickl.	Black goby	Pipe-fish	Butter fish	Sea-stickl.
Cod	-							
Whiting	17	-						
Sand eel	4	2	-					
Three-spined stickleback	0	0	3	-				
Black goby	5	2	4	3	-			
Pipe fish	3	1	1	0	3	-		
Butter fish	1	1	4	5	3	1	-	
Sea stickleback	1	1	3	7	2	0	14	-
N. observed	25	25	17	19	25	25	22	25

For sea stickleback and butterfish the theoretical number of co-occurrences would be about 9 and the observed frequency was 14. Similarly cod and stickleback should occur together slightly less than once and cod and butterfish 3 or 4 times.

Experiment 2

Cod and whiting were still most frequently observed in one of the empty compartments (Table 5), and so was the flounder, while goldsinny seemed to prefer compartments with algae. Sand

Table 5

Distribution of fish in a six-compartment aquarium. Experiment 2

	Sand			Algae			Empty			Total
Species	1	4	Tot	2	5	Tot	3	6	Tot	
Cod	1	0	1	5	0	5	0	20	20	26
Whiting	0	2	2	2	1	3	0	21	21	26
Flounder	1	0	1	1	0	1	0	10	10	12
Sand eel	3	2	5	0	1	1	1	2	3	9
Goldsinny	0	3	3	3	7	10	0	0	0	13

eel showed no clear preference. Out of 13 observations, all the gadoids were found together in one compartment 8 times, in the five other cases three were found together and one alone. This supports the observation that there is a positive affinity between cod and whiting.

DISCUSSION

The distribution of fish in the experiment may depend on substratum and the presence of other fish in addition to light, current, noise and other disturbances.

The intention was to keep light, noise and current similar in all compartments. It is, however, difficult to judge how successful it was, and the difference between compartments with similar substratum may be due to difference in one of these factors.

Cod and whiting seem to prefer empty compartments. For cod this does not agree with observations in larger aquaria, where young cod seem to prefer to stay among algae (Gjøsæter unpubl.). The compartments used in the present experiment were, however, very small, and it could be that the cod found those compartments with algae too crowded. It could also be that they just followed the whiting. Pipefish also preferred the compartments without algae. In nature it is commonly found on sandy bottoms, among eel-grass (Zostera) or seaweed (Muus 1967, Wheeler 1969).

The affinity of the sea stickleback and butterfish to compartments with algae fits well with their natural habitat (Wheeler 1969). The preference for sand showed by the black goby and sand eel is also expected (Muus 1967, Vaas et al. 1975).

The black goby had changed compartment more often than average and great pipefish less often. This is probably a relative measure of the mobility of the fish, although a fish could move several times between the observations and it would be recorded as one if it ended in a different compartment, and it would not be recorded at all if it ended in the same compartment as it started.

The cod and the whiting occurred together much more often

than should be expected from their habitat selection alone. Other observations also indicate that the juveniles of these species often occur together in aquaria (Gjøsæter unpubl.). There are insufficient observations to trace any positive or negative relationship between the other species.

Due to the small size of the aquarium, only one or two fish of each species was used. This might influence the behaviour of fish that normally occur together in schools or other groups. Three-spined stickleback often seem to be schooling, particularly to protect themselves against predators (Keenleyside 1979). Cod and whiting might to some extent be occurring in groups too, but few data are available on the natural behavior of the age groups used in the present experiments.

As only one fish of each species was used in each experiment (except cod and whiting in exp. 2), individual differences within a species could influence the results. For those species used in both experiments, the results were, however, similar, although the specimens used were not the same.

The experiments suggest that the juvenile cod and whiting have the same habitat preference, and that they are positively attracted to each other. The feeding habits of the two species at the Skagerrak Coast is not known in detail, but there are indications that cod eat more crabs and hermit crabs and less fish than the small whiting do (Danielssen and Gjøsæter, unpubl.). Data from the North Sea also suggest that whiting is more piscivorous than the cod (Gislason and Helgason 1985).

Further studies should be done both in aquaria and in the field to assess the niche overlap between juveniles of cod and whiting.

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