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by

G.A. Malyukina

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CHEMORECEPTION AND SCHOOLING BEHAVIOR OF FISHES

By G. A. Malyukina

The high development and the great functional significance of the chemical sense organs -- olfaction and taste -- in the life of fishes have made it possible to assume that a definite role should be ascribed to these types of reception in schooling behavior. The present work is devoted to an examination of this question.

The schooling way of life, as is known, has a significant effect upon the physiology of the individual. The intensity of feeding and oxygen consumption, motor activity, the growth rate and sensitivity to toxic substances vary for fishes in a school and in isolated individuals. The reduction in the intensity of oxygen consumption and motor activity in the school is called the "group" or "school effect." The "group effect" which is one of the most objective manifestations of schooling behavior has been used by us as the criterion of the propensity for schooling.

The research objects were: minnows, crucian carp, and carp. The rate of oxygen consumption was determined by using the covered vessel method. As respirators we used containers made from plexiglass which were separated by a nontransparent barrier into two uneven sections: a small one where a single fish was kept and a large one where a group of several fish was (from 4 to 9). During the time of the experiment, the respirators were hermetically sealed. The water samples were taken before and after an hour-long exposure; the intensity of oxygen consumption was calculated (in mg per hour figured per gram of live weight). The measurement of the oxygen content in the water was done by a polarographic method (a stationary platinum electrode), and in a number of experiments, using Winkler iodometric titration.

In the preliminary series of experiments, it was established that the "group effect" is endemic to all of the tested fishes, with the isolated specimen always consuming more oxygen than a fish in the group. The greatest "group effect" was found in the minnows with 48 percent, and for the crucian carp and carp it equaled 36.3 and 38.4 percent respectively.

The first task of the research was to establish whether or not the fish were capable of detecting a school by using solely chemoreception.

For this purpose, in the compartment of the respirator where the solitary specimen was kept, a certain quantity of water was added in which the fish school of the same species had been kept for a certain period of time (the so-called "school" water). The oxygen content and the temperature of this water were brought up to the level of the indices of the pure water used for the control. It might be expected that if the test fish were capable of perceiving the "odor" of the school, the level of their gas metabolism in the "school" water should drop.

The experiments indicated that both the minnows, the crucian carp and the carp reacted clearly to the "odor" of a school of their own species. However, the intensity of oxygen consumption did not drop, but on the contrary, rose sharply. Thus, while in pure water the minnows consumed an average of 0.448 mg/Ghr of oxygen, in the "school" water, their consumption increased up to 0.820 mg/Ghr, while the "group effect" here rose to 72.5 percent (from 49.6 percent in the control). For the crucian carp and the carp, the reactions were equal in terms of intensity with the rise of the "group effect" being around 10 percent.

Along with the increase in gas exchange, in the experiments there was also a rise in the motor activity, with the fish swimming excitedly and making characteristic "search" movements.

Thus, it was shown that all of the test fish are using only chemoreception, without the participation of other sensory systems, were capable of detecting the school.

However, a chemical signal of the school in none of the fish species evoked the indications of schooling behavior -- a drop in the intensity of gas exchange and motor activity.

When visual reception was excluded by an operation on the test fishes, and here information from visual reception on the absence of the school could influence the examined reaction, there was no change either in the sign or the strength of the reaction, as the fishes which had been deprived of vision reacted to the "odor" of fishes of their own species just as strongly as did fish with their vision intact.

The differences in the reaction of the seeing and blind fishes were manifested in experiments involving the protracted keeping of the fish in the "school" water. In the blind fish, the reduction in the intensity of gas exchange over time occurred much more slowly than in the seeing fishes.

The data obtained have shown that the chemical action of the school is for the fish a strong physiological stimulus which significantly changes the conduct of the individual fish and the intensity of metabolism, however, its isolated action, in the absence of signals from the other sensory systems, evidently is not sufficient for manifesting the reactions which are characteristic for fishes in a school.

Which of the systems of chemical reception causes the reaction of the fishes to the "odor"?

As is known, olfaction in fishes is an extremely developed sensory system, and according to the existing notion, holds second place after vision in the life functions of fishes. Taste reception in fishes is also very developed; in contrast to the terrestrial vertebrates, the taste buds in fishes are located not only in the mouth cavity, but also on the lips, barbs, fins and in some fishes, over the entire body surface. In coming to the surface, the taste receptors acquire exteroreceptive functions and become related to the locomotive activity of the animal.

The participation of olfactory reception in the schooling reactions has been investigated in experiments on crucian carp.

Previously we discovered that with a loss of vision, these fishes do not lose their propensity for schooling. The "group effect" in the blind fishes was maintained, although markedly dropping in amount, in comparison with the seeing fishes.

The surgical chronic excision of olfaction in these fishes by severing the olfactory tracts did not cause the scattering of the school. However, the oxygen consumption by the fishes in the group rose, and this led to a drop in the "group effect" of 12 percent (38 percent in the seeing fishes, 19 percent after enucleation).

The drop in the amount of the "group effect" after eliminating olfactory reception shows that olfactory stimulation plays a definite role in the schooling reactions of these fishes.

Due to the complexity and inaccessibility of innervation, it was not possible to eliminate taste reception. The role of this type of sensitivity has been examined in experiments where the elimination of olfaction was combined with the action of the "school" water. It was shown that minnows, crucian carp and carp which were deprived of olfaction did not lose the reaction to the school "odor." The intensity of oxygen consumption in the "school" water markedly exceeded consumption in the control after the exclusion of olfaction.

When olfaction was left intact, and all reception on the body surface, including taste, was eliminated by cocaine (a 5% solution), the fish also maintained the ability to react to the "odor" of the school.

Thus, the experiments showed that both olfactory and taste reception participate in the perception of the chemical effect of the school by the fishes.

However, is the chemical signal from the school of the fish's own species specific for this fish, or does the "odor" of other fish species cause a similar reaction?

In order to answer this question, experiments were undertaken in which as the stimuli we used water from fishes of other species in the same family as the test fishes as well as from fishes in other families which were taxonomically far removed from the test fishes. Thus, for the minnows we added water from carp and crucian carp (in the family Cyprinidae) and water from the cisco (the Salmonidae family), and for the carp we added the water from crucian carp and ciscos, and for the crucian carp, water from carp and the cisco.

The experiments indicated that all the test fishes reacted to the "odors" of fishes from their own families with a clear change in gas exchange. Thus, the intensity of oxygen consumption by the minnows in the "school" water from the carp rose to 0.520 mg/Ghr, and in water from the crucian carp up to 0.500 mg/Ghr (from 0.430 mg/Ghr in the control). Here the "group effect" increased by 12 and 10 percent respectively. In the crucian carp, the intensity of gas exchange rose from 0.234 mg/Ghr in pure water up to 0.282 mg/Ghr for the carp "odors" (a "group effect" of 13 percent) and for carp in the water of crucian carp from 0.230 to 0.278 mg/Ghr (the "group effect" of 12 percent).

Thus, it was shown that aside from the "odor" of their own species, the fishes are capable of clearly reacting to the "odor" of fishes which are taxonomically close to the test fishes.

However, the test fishes differed significantly in terms of the force of the reactions to these effects.

While considerable differences were not observed in the reactions of the crucian carp and the carp with the effect of the "school" water from both their own and another species, in the minnows the reactions to the "school" water of the crucian carp and carp were significantly less than to the "odor" of their own species, and evidently this is explained by the different biological significance of both types of actions for the minnows.

Experiments with the water from the cisco showed that this stimulus does not cause any marked changes in gas exchange for either the minnows, the crucian carp or the carp.

Thus, it may be felt that the chemical effect of fishes of a taxonomically remote species which do not represent any interest for the species being tested is a physiologically indifferent stimulus.

Among the adaptive purposes of the school, its protective role holds one of the main places. In line with this, we examined the participation of chemoreception in the perception of a danger signal by the fishes. As the stimuli in these experiments we used water in which predatory fishes -- the pike (Esox lucius L.) and the rotan (Percottus glenis L.) -- had been kept for a certain period of time.

It was shown that all the test fishes -- minnows, crucian carp, carp and perch -- reacted intensely to the "odors" of predatory fishes. Thus, while in the control the "group effect" for the minnows was an average of 47 percent, in the pike water it increased to 73 percent and in the rotan water to 68 percent. In the carp and crucian carp, the "odor" of the pike caused an increase of the "group effect" by 19.8 percent and 15.6 percent respectively. In the perch, this reaction was the most intense, with the "group effect" rising by 37.8 percent to the "odor" of the pike.

In literature there are data that a damaged skin of fish has a characteristic repellent action on the school. In line with this, we were interested in comparing the chemical effects of skin extracts taken from fishes which were close and remote taxonomically to the test specimens. As the stimuli we used skin extracts from the minnows, crucian carp, carp and ciscos. In experiments on the minnows, it was shown that the strongest effect is produced by skin extracts from their own species; here oxygen consumption increased sharply, and the group effect rose by 30.3 percent. The reaction to the skin extracts of the carp and crucian carp was markedly less: the "group effect" rose by 20.6 and 19.7 percent respectively.

In the crucian carp and carp, with the effect of skin extracts from their own species as well as in cross effects, the reaction intensity did not differ considerably.

The skin extracts of the cisco did not have any effect at all.

The skin extracts from the predatory fishes evoked as strong a reaction as did the water in which they had been kept.

The results of the experiments with the "odor" of a predator and the skin extracts make it possible to assume that chemoreception plays a significant role in the defensive reactions of the school for these fishes.

Significant specific differences in the intensity of the examined reactions make it possible to assume a different ecological-physiological significance of chemoreception and chemical signals in the schooling behavior of these fishes.

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13. ABSTRACT

This translation describes tests performed on the chemical sense organs, olfaction and taste, of certain fishes, specifically minnows, crucian carp, and carp. The high development and the great functional significance of these chemical sense organs in the life of fishes have made it possible to assume that a definite role should be ascribed to these types of reception in schooling behavior. The article includes the experiments and their results which help to describe the "group" or "school effect" life which is readily observable in many fishes.

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