Fish can determine their social rank by observation alone, study finds

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A male fish can size up potential rivals, and even rank them from strongest to weakest, simply by watching how they perform in territorial fights with other males, according to a new study by Stanford University scientists. The researchers say their discovery provides the first direct evidence that fish, like people, can use logical reasoning to figure out their place in the pecking order.

The study, published in the Jan. 25 edition of the journal *Nature*, is based on a unique experiment with cichlids (SIK-lids), small territorial fish from Africa.

"In their natural habitat, male cichlids are constantly trying to ascend socially by beating each other up," said study co-author Russell D. Fernald, professor of biological sciences at Stanford. "It would be really valuable for them to know in advance who to pick a fight with."

The Nature experiment was designed by lead author Logan Grosenick, a graduate student in statistics at Stanford, and Tricia S. Clement, a former postdoctoral fellow. Their goal was to determine whether territorial fish use a type of reasoning called "transitive inference," in which known relationships serve as the basis for understanding unfamiliar ones.

"Transitive inference is essential to logical reasoning," Fernald explained. "It's something that kids generally figure out by age 4 or 5--Mary is taller than Fred, Fred is taller than Pete, therefore Mary is taller than Pete. It's been demonstrated in primates, rats and some bird

species, but how and why it evolved in animals is a matter of debate."

Aggressive bouts

In the experiment, the Stanford team used a popular laboratory fish called Astatotilapia burtoni, one of many cichlid species that inhabit Lake Tanganyika in eastern Africa. A. burtoni males are extremely territorial and regularly engage in aggressive fights, the outcome of which determines who gets access to food and mates.

"Males that repeatedly lose fights are unable to hold territories and consequently descend in social status," the authors wrote. "Success in aggressive bouts is therefore crucial to male reproductive fitness, and the ability to infer the relative strength of rivals before engaging them in potentially costly fights should be highly adaptive."

When A. burtoni males fight, it's easy to spot the winner. Mature males have a menacing black stripe, or eyebar, on their face. After a fight, the winner retains his showy appearance, but the loser's eyebar temporarily disappears as he tries to flee his more aggressive opponent.

To test for transitive inference, the Stanford team took advantage of this reversible change in appearance by staging a series of short fights between male cichlids of equal size. In the experiment, fish that lost their eyebar during one-on-one combat were declared the loser.

After each bout, the loser was separated from his opponent and put back in his original tank. Within minutes, his eyebar returned, and he looked like all the other dominant males again.

Bystanders and rivals

The fights were staged in a square tank divided into several compartments. A lone male observer--the "bystander"--was placed in a cubicle in the center of the tank. Surrounding him were five smaller compartments, each with a solitary male rival identified simply as A, B, C, D and E. Researchers made sure that the bystander had never met any of his five potential rivals.

Although the bystander remained alone in his cubicle and never swam with the others, he was allowed to observe a series of fights between rival pairs--A vs. B, B vs. C, C vs. D, and D vs. E. Researchers manipulated the fights so that A would dominate B, B would dominate C, and so forth down the line.

"These fights, taken together, imply the dominance hierarchy A>B>C>D>E," the authors wrote. But did the bystander really comprehend this intricate pecking order, and if so, would he use that knowledge to make logical decisions about the same fish paired in new relationships?

To find out, eight different bystanders were tested in the familiar square tank and in a new setting--a rectangular aquarium with three adjacent compartments. In each test, a bystander was placed in the middle compartment between two sets of rivals that he had never seen together--A and E (AE), and B and D (BD). At this point in the experiment, all the rivals had recovered from earlier losses, so their physical appearance was similar, right down to the eyebar. From the point of view of the bystander, therefore, each rival looked like a winner.

Using a video camera, researchers recorded which rival the bystander approached first, and the overall time he spent next to each of them. "Previous experiments in A. burtoni and other fish have shown that time spent in tank quadrants adjacent to a particular male indicates bystander

'preference,' and that bystanders spend more time near the rival they perceive to be weaker," the authors explained.

Losers and winners

The results were dramatic. Virtually all of the bystanders swam to the weaker rival first and stayed near him for a significantly longer period of time. In the AE tests, bystanders preferred E, the wimpiest of all the losers, over A, the top fish in the tank. In the more subtle BD tests, most bystanders chose D over B, even though these two rivals were ranked very close together on the dominance hierarchy.

"These results show that fish do, in fact, use transitive inference to figure out where they rank in the social order," Fernald said. "I was amazed that they could do this through vicarious experience, just by watching other males fight. In Lake Tanganyika, where conditions change all the time, it would be advantageous for a male to know who the new boss is going to be and who his weakest rivals are. Our experiment shows that male cichlids can actually figure out their odds of success by observation alone. From an evolutionary standpoint, transitive inference saves them valuable time and energy."

The results raise the possibility that fish brains might contain the rudimentary neuronal circuitry for transitive inference that appeared later in birds and mammals.

"Any animal that has evolved a social system that requires combat among males will have some kind of eavesdropping capability allowing them to surreptitiously draw inferences about their social rank," Fernald said. "Cognitive capacities that evolved in fish may contribute to human transitive inference, or perhaps this capacity evolved independently. The question remains unresolved."

Source: Stanford University