WHAT KIND OF SCHOOL DO FISH PREFER?

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Many animals like to live in groups. Typical examples include large herds of hoofed mammals, flocks of migrating birds, and, of course, large schools of coral reef fish moving in synchrony. (In accordance with current convention, I use the word "school" to indicate highly synchronized groups of fish, and the word "shoal" to indicate any fish aggregations, synchronized or not; I should have used the word shoal in the title, because I will talk about fish groups in general.) For a long time, behavioral ecologists have wondered about the reasons why animals live in groups. What could be advantageous about group living? And, are the advantages mitigated by possible disadvantages?

One way to get a handle on these questions is by determining the types of groups that animals prefer to join. Through experimentation, one can "ask" an animal directly by giving it a choice and noting which of two different groups it spends more time with. This is rather hard to do with herds of mammals and flocks of birds, as they require too much space. But groups of fish are easy to maintain in moderate-size aquaria. Three aquaria can be placed end to end, one aquarium housing a "test" fish between two aquaria with shoals in them. A vertical line is drawn along the middle of the front glass on the center tank, and the percentage of time spent by the test fish on either side is taken as an indicator of shoal preference. Such ease of manipulation has enabled fish behaviorists to contribute greatly to our understanding of group living and behavioral ecology. The same ease of manipulation can enable you to duplicate the scientists' findings with your favorite species. Take a look at the following experiments and their underlying rationale, and see if you can add to the results with your own experimentation.

One possible advantage of belonging to a group is protection against predators. When many fish are present, predators have more difficulty concentrating on one specific prey (a confusion effect), and each prey has a statistically smaller chance of being caught (a dilution effect). These advantages should increase as the group gets larger, and so we would expect fish to prefer larger groups, especially when predators are present. This is exactly what Mary Hager and Gene Helfman, of the University of Georgia in Athens, have found (Hager and Helfman, 1991). These researchers gave fathead minnows a choice between two shoals of various sizes (anywhere between 1 and 28, in many different combinations). Minnows spent more time close to the larger groups, especially when the difference in shoal size was pronounced. Hager and Helfman then introduced a fourth aquarium, containing a predator (a largemouth bass), behind the middle aquarium so that the test fish could see it. Under these new conditions, the test fish chose the larger groups more rapidly and spent even less time than before close to the very small groups.

When a predator attacks a shoal, it can minimize confusion by concentrating on an individual prey that looks different from the rest of the shoal (an oddity effect — see one example in Landeau and Terborgh, 1986). Prey should counteract this by joining shoals composed of individuals that look similar to them, or at least the same size as them. Esa Ranta and co-workers at the University of Helsinki have tested this idea with the brook, ten-spined, and three-spined sticklebacks (Ranta, *et al.* 1992a, 1992b, and check the title of this last reference). When given a choice, small test fish spent more time close to similar sized conspecifics, especially when a predator (a rainbow trout) was shown to them. Large fish also preferred similar sized conspecifics, although this preference was not always increased in the presence of a predator. Other examples of size segregation under predatory threat have come from studies on minnows (for example, see Pitcher, *et al.* 1986, Theodorakis, 1989).

This preference for similar conspecifics is obvious in multi-species shoals. Various species of minnows can become mingled in the course of their normal activities, but when a model of a predatory pike is dragged through the water, the fish form big groups in which each individual tends to be closer to members of its own species. This behavior was videotaped by John Allan and Tony Pitcher from the University of Wales at Bangor (Allan and Pitcher, 1986). Such species segregation may not, however, happen in all situations: Jens Krause and Jean-Guy Godin, from Mount Allison University in Sackville, Canada, have shown how banded killifish, *Fundulus diaphanus*, when exposed to the model of a heron, prefer to shoal with similar sized golden shiners, *Notemigonus crysoleucas*, rather than with larger members of their own species (Krause and Godin, 1994). In this case, similarity in size seemed more important than species similarity.

Another possible advantage to group living is the presence of more food finders who can share their discoveries. Indeed, several studies have shown that fish in large shoals find food faster (Pitcher, *et al.* 1982) or hesitate less before starting to eat (Olla et Samet, 1974; Ranta and Kaitala, 1991). However, there is

another side to this coin: If there are too many fish in a group, then competition for food may become a limiting factor. So how would we expect a hungry fish to behave when given a choice of shoals? Would it rather be part of a big shoal in the hope of increasing the chance of food discovery, or should it go for the smaller shoal, hoping to decrease competition? Nathalie Van Havre and the late Gerry FitzGerald, from Laval University in Quebec City, have offered female three-spined sticklebacks a choice between a group of 15 or 45 conspecifics. They observed that satiated females preferred the large group, while females starved for 24 hours were more attracted to the smaller group (Van Havre and FitzGerald, 1988). Working with the same species, Jens Krause found different, but not necessarily contradictory, results: In test choices of 5 versus 3, 10 versus 3, or 20 versus 3 individuals, hungry and satiated fish always preferred the larger group, but the preference was less marked in the case of the hungry fish (Krause, 1993). Compared to 3 or 45, a shoal size of 15-20 fish may be ideal for a hungry stickleback who wants to both increase the chance of finding food and decrease competition.

Competitive abilities depend on size. Within the same species, larger fish outcompete smaller ones. So, we might expect hungry fish to join groups of smaller fish, even though they would risk the oddity effect, while satiated fish would seek similarly sized partners. Nancy Saulnier, working in my laboratory with golden shiners, has recently confirmed this prediction. When given a choice between five small and five large individuals, small shiners stayed on the side of the small fish, whether they were hungry or satiated (in either case, food competition and the oddity effect were minimized). In contrast, large fish preferred other large fish when satiated, but chose to be with small fish when hungry. Large hungry shiners appeared willing to risk the oddity effect in order to gain a competitive edge for food.

Questions about shoal choice can include more subtle parameters than

just shoal size or fish size. For example, recent studies have shown that bluegill sunfish and European minnows can recognize specific individuals and prefer to associate with those that are either good food finders (Dugatkin and Wilson, 1992) or poor competitors (Metcalfe and Thomson, 1995). Guppies prefer to be with "familiar" individuals rather than with strangers they have never seen (Magurran *et al.*, 1994). The same is true of fathead minnows except that in this case recognition is based on chemical rather than visual cues. When Grant Brown and Jan Smith, from the University of Saskatchewan, used clear Plexiglas partitions between the test fish and the stimulus groups, they noted that test fish did not display a clear choice. But when they used double partitions, 1.5cm apart, with the first one opaque on the left side and screened on the right, and the second one opaque on the right and screened on the left, their minnows showed a definite preference for the side where the familiar shoalmates were, even though they could not see them (they could still smell them because water could pass through the staggered screens: Brown and Smith, 1994).

Other questions could be asked. Can fish recognize and associate with healthy looking conspecifics? Would they avoid parasitized or hungry looking fish? Do they prefer to associate with their brothers and sisters? To answer such questions, all that is required are three aquaria arranged end to end, a stopwatch, and a large stock of fish! Care must be taken to alternate the various shoals between the right and left tanks, in case one side of the middle tank is more attractive to the test fish for some unknown reason that has nothing to do with the shoals near that side. One more thing is to habituate the fish to their tanks for a few minutes or hours between the time you put them in and the time you start the test. Then you think up a question, you make up your shoals accordingly, you take good notes, and there you are!

Who says science is hard to do? Try it ... it's fun.

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