FISH EYES

by

Manly W. Mumford

It is well known that fishing lures are designed not to catch fish, but to catch fishermen. Let me read to you some of the claims made in advertising various artifical lures in a magazine published for fishermen. Apparently the advertisers intended them to be taken seriously.

"New hopping, swimming action. Three years in designing and testing.....World's first bait developed for walleyes." "A top favorite for fishermen throughout the world for life-like action -- extra sport -- and results" "Genuine ABALONE MOTHER OF PEAL lures. Nickel silver back. Minnow shaped. Deadly for all game fish." "Here is one of the most popular lures on the market today. A TOP-QUALITY fish killer" "Tested in quiet brooks, flood torrents, rapids, pools, there's something about each of these great lures that moving water turns into a killer. These easy-to-use fish murderers are stream fishermen's connoisseurs lures for any stream situation." "Strange...humming, clicking, vibration draws fish before they see lure....veteran Wisconsin woodsman's secret developed from 40 years fishing. Trout can't resist it." "I tested the fish-catching discovery Illegal in six states!....Like a motr to flame...fish couldn't resist it.." (This discovery appears to be luminescent powder to be sprinkled on bait, allegedly illegal in states whose laws prohibit using lights to attract fish.) "Day Old 'Duckling' Slaughters Big Fish....When big fish see helpless action of little day-old duckling lure they go wild."

The magazine contained 152 pages, but the foregoing seems adequate to give a sample of the prose which is used as bait to catch fishermen.

I wonder if any advertising agency, seeking clients among the sellers of fishing lures ever ran an ad saying: "New type ads get results fast! Over 10,000 lures sold in one week after first publication of improved advertisement based on tested formula of Idio English Prose. Secret layout process drives fishermen wild. Specially exaggerated photos trap even veteran worm users."

In addition to lures, one can see advertisements for fish calendars which are supposed to tell, based on the phases of the moon or the calendar maker's rheumatism, which days, and at what times on those days, fishing will be best. I understand that a fishery scientist once determined that if enough of these fishing calendars were consulted one could reach the conclusion that whatever day he had in mind would be a good day for fishing.

My purpose, however, is not to poke fun (or at least not to poke any more fun) at the poor fellows who have to sit at their typewriters thinking up new ways to say the same thing about each of hundreds of different fishing lures; rather it is to present some of the available evidence on certain aspects of the nature of game fish.

Many people seem to believe that fish think or have and use limited powers of reason. **Another** belief is the exact opposite; that because a fish lacks the power of reason, it is capable of acting only by instinct. In refutation of both beliefs let me quote J. A. Colin Nicol, Zoologist at the Plymouth Laboratory of the Marine Biological Association in England. In his book, The Biology of Marine Animals he declares: "Animals are not mere automatons, passive machines pulled this way and that by each external stimulus to which they are sensitive. Their responsiveness is variable, and changes during development, and over shorter periods according to their more immediate past history. There are recognizable behaviour patterns characteristic of each species; these patterns are modified by experience and, to the observer, appear directed towards goals, which may be attained in various ways."

There are at least two fairly recent books which attempt to apply the results of scientific investigation to the sport of angling. One is <u>Why Fish Bite and Why They Don't</u> by James Westman; the other is <u>New Angles for the Angler</u> by Barry Atkinson. The latter, which was published in 1966, seems the better, yet neither managed to do what I suspect the publishers hoped; to formulate rules for fishermen based on scientific discoveries arising from the research that many scientists have been doing for many years, but have hidden away in scientific publications where the public can neither find nor understand them. But science has not led to any such formulation of rules; the evidence which scientists have uncovered seems to lead in the opposite direction. At this time practical fishing experience will lead to better rules for the fisherman to follow than all the scientific work done to date, even though the people who formulate and apply those rules may be completely wrong if they try to explain why they work. The ~~academic~~ scientific community has, however, come up with much information worth knowing, not only in helping one to understand what he has learned by experience, but also to make better use of his experience in the future.

To receive information about its surroundings, a fish, like any other animal, depends on its senses. But these senses are radically different from those of land mammals and they operate under radically different conditions.

Under water, eyesight is neither so useful nor so necessary as in air; light does not travel far through even the clearest of water, and often water is muddy or turbid. However, sight is peculiarly useful in perceiving objects above the surface of water as sounds and other vibrations, smells and tastes penetrate the surface little if at all. Yet from beneath the surface can be seen only those light rays which approach at a relatively steep angle, because the surface reflects those rays which approach at an angle of ten degrees or less. Further, refraction distorts the appearances of the distance and the height above the surface of an object seen from below. If you look down at an angle into smooth water and see a rock, then aim a stick at the rock, then push the stick along the path which it is pointing, as it enters the water the stick will appear to bend away from you and, if you keep it pointed and moving in the same direction, it will pass beyond the place at which you were aiming it. From under the surface a corresponding distortion occurs. A smooth water surface provides a submerged observer with a mirrored ceiling having a circular window directly above him. The diameter of this window varies with the depth from which it is viewed, as the circle equals in size the base of an inverted cone having a ninety degree angle at the observer's eye. Objects less than ten degrees above the surface of the water, as measured from the closest edge of that circle, can not be seen, but higher objects will appear to be closer to the underwater observer than they really are. Beyond the circumference of this window the surface reflects underwater objects and permits a fish to see an additional image of its surroundings. In case the fish is near a rock or other underwater object which blocks its direct vision in one direction, it may nevertheless see the reflected image of, say, a fisherman's legs on the other side of that rock. If a solid object touches or penetrates the surface, it destroys the mirror effect; a fishing line lying on the surface may thus be much more noticeable than one which is submerged because the floating line both cracks the mirror formed by the surface, and casts a shadow on the bottom to be reflected by another part of the surface.

The eyes of fish are significantly different from those of human beings, not only because of the larger field of vision, but also because of the mechanical apparatus inside. Our eyes have a lens which focuses the light rays on the retina at the back of the eyeball, and in order to adjust and focus correctly, the lens itself is made flatter or rounder by muscles in the eye. In most fish, however, the shape of the lens stays the same, and it is pulled toward or pushed away from the retina to focus on objects at various distances. At rest the fish's eye focuses on objects about an inch away; muscles draw the lens toward the retina to focus on objects further away. To adjust for different light intensities, our eyes have irises which cause the pupils to enlarge in darkness and contract in bright light. In many fish, the retina has certain projections between the visual cells and in bright light these projections fill with pigment which protects the cells from some of the light rays; in dim light the pigment goes elsewhere. Also, in many fish, the rods (which are highly sensitive) move out of a pigmented area when the light is dim and go into the area where the light is, while the cones (which are less sensitive) alone are exposed to the light when it is bright. This procedure takes some time, and so the fish which is suddenly exposed to different light conditions from what it is used to may try to find a darker or lighter place to go until its eyes adjust to the new conditions. On a day that is alternately sunny and cloudy, therefor, you may expect to find fish at different places when the sun is hidden than when its rays are falling on the water.

Apparently some if not all fish are capable of discriminating among various colors. One pertinent experiment involved associating an electric shock with a visual stimulus from which it was learned that the fish which took part in the experiment could tell blue, green and red from grey, but could not distinguish between different shades of grey. One writer claims that small and large mouth black bass usually show a preference for red and for yellow, but he does not say how he came by this information.

Many functions which human beings regard as being in the province of sight, however, are performed by other methods of perception in fish. Water, although it conducts light less well than air, conducts vibrations far better; and most fish have three methods of perceiving vibrations. One set of organs in the head, which correspond to the ears of mammals, pick up relatively high vibrations - between 32 and 6,000 vibrations per second in one species of minnow for instance. This is roughly the equivalent of the hearing range of a man who doesn't hear [redacted] high or low notes very well. Very low frequency vibrations and changes in the pressure of the water are perceived by receptor mechanisms in the skin. This corresponds to a sense of touch, more or less. The third device, and the one which does not correspond to any sense which human beings have, is the lateral line. This lateral line is a series of openings in the skin and scales, behind each of which a nerve branch extends to a nerve running along either side of the fish in a tube or canal. Fluid moves slowly through this tube and an interruption in the flow of this fluid causes the nerve to produce an electric discharge. This mechanism is so sensitive that the vibrations from the footsteps of people walking into the laboratory in which a prepared fish was lying on a board on a table were sufficient to produce responses.

Professor Parker of the Oceanographic Institute at Woods Hole has conducted a number of experiments on the function of the lateral line, and has determined that it does not respond to light, heat, salinity of the water, food, oxygen dissolved in the water, carbon dioxide, foulness of water, and hydrostatic pressure. But when the water in an aquarium was made to vibrate certain reactions always appeared except when the lateral line was cut. So Parker concluded that the purpose of the lateral line is to perceive vibrations intermediate between those perceived by the skin and those perceived by the ears. Parker's experiments have been criticized on the ground that he may have cut the nerves to the skin of the head of the fish when he cut the lateral lines; I am in no position to judge the worth of this criticism, but there does seem to be pretty general agreement that the lateral line acts, in part, as a sort of "distant touch" allowing the fish to perceive changes in water currents, ripples in the water, the effect on the water of the fish's own movements and the movements of other bodies in the water nearby. Also, perhaps, the water movements made by the fish in swimming may be reflected back from solid objects in the water and picked up by the lateral line. This would, in effect, amount to something like the sonar that bats use --- emitting high-pitched sounds which bounce against solid objects and warn the bat, in flight, where he might bump into something.

An experiment performed in the Caribbean involved recording, on tape, the sounds made by a school of small fish as they were being attacked by larger fish. When the same sounds were played back in another school of the same species, the fish cleared out faster than they had at the time of the real attack.

Experimenters also recorded the noises made by a species of predatory fish when eating; on replaying the noises to other fish of that species, the fish became excited for several minutes and even nibbled at the rubber surface of the machine which was producing the noise.

In another experiment, one member of a school of fish in a tank was blinded yet swam and veered with the rest of the school when they were startled by hand movements near the aquarium; this same member resumed random movements when the school came to rest while the others maintained approximately equal intervals from fish to fish. Presumably the pressure waves made by the rest of the school while all swimming in the same direction guided the blinded one.

As to the senses of taste and smell -- strictly speaking, the words can apply only to animals that live in the air, for smell is the detection of airborn molecules and taste is the detection of particles which are proceeding into solution. An animal in the water finds that the molecules it detects are already in solution. Yet fish have devices which perform similar functions or rather other functions serving similar purposes. So we can use the terms "taste" and "smell", according to the purpose of the sense rather than the method of perception. In other words, we'll call a sense "smell" if it detects small concentrations of a substance, the source of which is probably at some distance, and we'll call it "taste" if it detects only relatively high concentrations of the substance, the source of which is near or in physical contact with the pertinent organ.

Professor Parker did some experimenting on lampreys and catfish and found that their entire body surfaces were more or less sensitive to salt, acid and alkali, and that the lampreys but not the catfish showed such sensitivity to quinine. Cutting the nerves to the lateral line, the olfactory organs and the taste buds of the fish did not eliminate the sensitivity, so he concluded that certain free nerve endings in the skin were responsible.

The olfactory organs, which govern the sense of smell, are located back of the nostrils, and plugging the nostrils eliminates the effectiveness of these organs. However, the taste buds are not confined to the mouth, but appear in various parts of the body of the fish, depending in part on the species of fish and how it feeds. Tom Cod, for instance, have taste buds in the ventral fins which are sensitive to animal food on the bottom of the sea.

Much of the research on the operation of various perceptory organs has been done by the use of conditioned reflexes. In order to see whether a fish perceives something the experimenter will associate the thing to be perceived with a pleasant or unpleasant experience several times in succession, thus giving the fish the habit of reacting one way or another whenever the stimulus (the thing to be perceived) is present.

I'll have more to say about conditioned reflexes a little later, but mention it now telling you about an experiment in which several fish were given pieces of meat which had been sweetened along with pieces of cotton soaked in meat juice and in either salt, sour or bitter solutions. In three or four weeks they learned not to take the cotton. Thereupon they were offered cotton soaked in a sugar solution and took it promptly. Eliminating the olfactory nerves did not change the conduct of the fish, so the experimenter reached the conclusion that the sense of taste was involved.

In other experiments it was determined that catfish would strike at bags holding pieces of earthworm, beef liver or clotted blood, and would cease to do so when the olfactory organs were eliminated. Blinding and loss of the barbells (the whiskers that catfish and some others have near their mouths) did not affect the result. The experimenter came up with the conclusion that the stimulus involved was not a fat nor an oil, but proteins in quantities too small to be detected in ordinary tests.

The senses of smell and taste are not all the same in the various species, nor are they equally important from species to species. Catfish, which are likely to be in muddy water and eat food which does not move rapidly if at all, depend far more on taste and smell and less on eyesight than the trout which live in clear water and eat live insects and small fish. Among various kinds of fish, the size of the portion of the brain which receives the signals from each of the various sensory organs varies according to the degree of reliance upon the sense involved.

If we take for example the brains of a dog, a shark and a trout, the largest part of the dog's brain is used for reasoning; the largest part of a shark's is that which reacts to the sense of smell, and the part involved with sight is largest in the trout. Although fish do not have a faculty for reason, they do have a complex series of reflexes both instinctive and conditioned. It is the latter which enables a fish to avoid making the same mistake time after time. The instinctive reaction is the one which is programmed into the fish at conception, one example of which is that the presence of food substances in the water will stir a fish to action, but not necessarily direct his movements.

The following experiment was made with a pike and then repeated with a perch. The fish was kept in one half of an aquarium separated by a glass screen from the other half in which some minnows were swimming about. The pike dashed at them and bumped its nose on the glass partition. After a considerable period of this sort of experience the pike quit. Then the glass was removed and the minnows were allowed to swim freely around the pike. The larger fish' instinct to take the minnows had been suppressed, and it left them alone. However, the pike did proceed to bump its nose against the glass several more times when some worms were lowered into the water in the far half of the aquarium. The pike learned not the truth about glass, but rather a falsehood about minnows.

As fishes' body temperatures are controlled by the water surrounding them, fish have certain temperature ranges in which their bodies perform best. If the water is too cold, they don't move around much and don't each much; in warmer water they move about more and eat more until the temperature reaches an optimum. If the water is more than a few degrees above the optimum, the fish will not eat at all except in unusual circumstances. Part of the reason for this is that as water increases its temperature, the amount of oxygen it can make available to the fish diminishes. However, sometimes fish will continue to feed when the temperature has risen about the normal maximum -- an example is that when a school of fish have started to feed, they may continue even though the water temperature rises above the point at which each would quit feeding if alone. No one seems to know what starts fish feeding and keeps them feeding and in large numbers at the same time. Perhaps they all respond at the same time to some stimlus that reaches them all simultaneously, or perhaps they have a form of involuntary communication.

I've previously mentioned the conditioned reflex as means of testing what and how a fish perceives. The word "conditioned" is used in distinction to "instinctive:" It is an instinctive reflex to remove your hand from a flame. It is a conditioned reflex to intentionally keep your hand out of a flame. Fish act differently from one another under the same circumstances because of the different experiences which condition their individual behaviours.

One writer tells of training seventeen largemouth bassnot to take artificial lures, and then stocking these bass in a pond and offering a five dollar reward to anyone who took one of these bass on an artificial lure. For two summers no one was able to catch even one of these bass on such a lure. He also tells of bass which, after one or two experiences, would not take a live minnow attached to a hook and visible leader, but would strike at a free minnow. Unfortunately the writer did not describe the methods used in conditioning the fish, nor in the former experiment did he mention whether anyone had managed to catch all of the anti-artificial bass on worms within the first week of the two-year experiment. Also it is not clear that it was the visibility of the leader that kept the fish from striking the hooked minnow instead of the unnatural actions of the minnows due to the hook and leader being attached to them.

Although the ability of fish to learn -- that is, to condition their behaviour according to various stimuli, -- varies from species to species, a certain amount of knowledge about one species will be helpful in understanding other species. One interesting experiment was performed with gold fish to illustrate a second order conditioned reflex. An aquarium was arranged with a compartment at one end, separated from the main body of the aquarium by a wall having a hole through which a fish could swim. At the beginning of the experiment it was determined how long it would take any of the fish to swim through the hole on a purely random basis. Then a light would be turned on in the main body of the aquarium and as soon thereafter as a fish swam through the hole it would be fed. After a few days the time it took the fish to swim through the hole after the light was turned on diminished as to every fish used, even though some individuals appeared to learn faster than others. In the second part of the experiment, the fish were put in a new compartment which also had a hole leading into the main body of the aquarium. A record of time was kept to see how long it took for the fish to swim from the new compartment to the main aquarium and then into the old compartment after a chemical with a distinctive smell was put in the new compartment and the light turned on in the main body of the aquarium. After the fish learned to respond, it was determined that the absence of either of these stimuli lengthened the time before the fish would swim from the new compartment to the old one. Also, when the experimenters quit giving food to the fish when they went to the old compartment, the time increased. However, in another experiment with fish that had been trained the same way, there was a significant reduction in the time it took the fish to swim from the new compartment to the old one when these fish never got any food during the second part of the experiment. The experimenters reached the conclusion that the fish now looked on the light, which had been the stimulus, as the reward. Thus the fish learned first to associate the light with the food, but then to associate the chemical smell with the light.

Another, far older, illustration of the conditioned reflex in fish is described by Isaac Walton in The Compleat Angler. He cites Sir Francis Bacon as authority "that he knew

Carps come to a certain place in a pond, to be fed, at the ringing of a bell or the beating of a drum." Walton, however, avers that despite this information he intends to continue making as little noise as possible when fishing. As a personal note, I, too, would avoid beating drums or ringing bells when fishing unless I knew that the fish in that particular body of water had regularly been fed to the beating of drums or ringing of bells.

In laboratory experiments ~~it has been found that~~ the fish Ameiurus (a catfish) was trained to associate the experimenter's whistle with food, and even to distinguish between the spoken words "Adam" and "Eve". Other fish were trained to distinguish between large representations of certain different letters of the alphabet, and between groups of two or four letters.

The number of times it takes a fish to condition its behaviour to a certain stimulus is quite variable. In some types of experiments, it is likely to take not more than 80 nor less than ten. If no response is shown after 200 tries, scientists are likely to conclude that no response will occur.

One writer states that the level of most fish behaviour is about equal to that of rats from which the cortex of the brain has been removed, and roughly similar to that of similarly treated dogs or men. I don't know how he got hold of a man so treated. He suggests that the cortex of the mammals "has taken over and elaborated from subcortical centers in the thalamus and mid-brain and at present unknown kind of functional control of higher behaviour whose importance increases rather more than a linear relation to its structural increase in either size or complexity." I'm not completely sure what this means, but it has a grand sound to it.

It is important to note that the power of a fish to condition its reflexes does not inevitably lead to the right answer. I've already mentioned the pike which reached the wrong conclusion about minnows. There is also a story about a perch which lost an eye because of foul hooking; a very few minutes later that same perch was caught by the fisherman using the lost eye for bait.

One suggested practical application of our knowledge on this subject is to put a chemical having a definite smell in some streams in which salmon spawn, so that the fry will associate that smell with the stream in which they were hatched. Then when it is time for the adult fish to return to their native streams to spawn, the same chemical will be put in other streams where the fish are wanted.

A less pleasing possibility for the fishermen, if not for the fish, is that the use of echo sounding devices by large commercial trawlers may associate the noises of these machines with near capture in the minds of the fish, resulting in a behaviour that will cause the fish to leave quickly whenever the telltale noises approach.

One experiment or series of experiments which I would like to see performed involves the association in the mind of one fish of a stimulus which produces a demonstrable effect in another fish. In other words, it would be interesting to find out whether one fish can learn not to take a baited hook by being in the vicinity of another fish which does so. If such an association does exist, it is probably not based on seeing the other fish hauled bodily out of the water, but rather on the disturbances made in the water by the struggling comrade. Anyone who has come across a school of perch or mackerel which are in a mood to bite knows that many individuals pay not the least attention to what happens to others of the school for they crowd one another to be first at the bait. However, those are the fish that get caught. I wonder if there are others of the same school who do learn something and don't get caught. It would also be interesting to find out whether the sense by which a stimulus is perceived affects the nature, intensity or duration of the reflex which is conditioned to it.

There is one more experiment which I should like to have performed, and that is to determine whether fishermen who rely on their powers of reason catch more fish than those who rely on their own conditioned reflexes. The impertinent might suggest that if a man relies on his reason at all, he is not a fisherman; he will go to the store and buy his fish. Such, of course, is a conclusion which I reject instinctively. In human behaviour, a conditioned reflex is but a habit based on experience, and will probably turn up with the same result in most situations as the use of reason. Under either method of procedure, the fisherman will probably stick with a bait that is catching fish, and change baits if the one he is using is unsuccessful. The fisherman with the conditioned reflex will be more likely to try baits that have been successful in the past, whereas the one relying on reason will tend more to analyze the circumstances and use baits which seem more pertinent to the situation of the hour. The experiment can be completely fouled up, of course, by a fisherman who has conditioned his reflexes to rely on his powers of reason.

As to the practical application of the foregoing discussion, about all that can be said is "Beware of those who wish to catch fishermen, expecially if they purport to rely on science."

The word "magic" is more nearly appropriate, as it assumes a certain result through an ~~unknown~~ unknowable process rather than the scientific assumption of theoretical results through a process which is knowable but not yet known.

I have set out some evidence as to what a fish can perceive, and some evidence as to what principles govern their behaviour. You will note that I did not mention hunger or anger or fear as a motive for a fish striking a hook or failing to do so. Fish have no emotions or feelings in any form which would fit customary definitions of those terms. As to hunger, fish never get all the food they could use, and the only apparent damage it does is to keep them from growing as large as soon as they would if they had more food. Should you look at the specimen of rainbow trout at the Shedd Aquarium here in Chicago, you would see not the trim, active fish of our mountain streams and lakes, but a gross, obese creature so fat it can hardly move. Such is a fish which gets all it will eat. An examination of the contents of the stomach of a freshly caught fish will often reveal that hunger was not pressing the animal to take risks it would otherwise leave.

There is, then, evidence that fish perceive things not only by sight, which is not comparable to sight in air, but also by touch and by sensations which resemble taste and smell, and by reception of water vibrations of frequencies which we call sound, and lower frequencies as well; it appears that, in addition to certain instinctive behaviour patterns, fish have the power to make fairly complex associations of what they perceive and to alter their behaviour accordingly. Perhaps by taking advantage of this information we can manouver fish into acting more in accordance with our wishes that they usually do.

My own modest contribution in this direction is to be a succession of experiments, one of which was performed with considerable satisfaction at the end of the trout season in Wisconsin last summer. Having read of the reaction of fish to meat juices in the water, I tossed a bouillon cube into the stream above where I was about to fish. I also pressed bits of bouillon into a piece of cloth on a fishhook. The result, as I say, was satisfying and gratifying, but because only one day's fishing was involved, and because I did not try other combinations of stimuli, and absence of stimuli, no conclusion can yet be reached. It may be that the presence of the bouillon cubes set up an instinctive reaction which offset a behaviour pattern which would otherwise have caused the fish not to strike. It may also be that after a while, if I catch enough fish in this manner, the presence of bouillon in the water will stimulate a conditioned reflex which will keep the remaining fish from striking at anything at all.

In any event, I consider the matter a fit subject for experimentation which I intend to conduct personally, even at the sacrifice of a few hours now and then which might otherwise be available for family and clients.