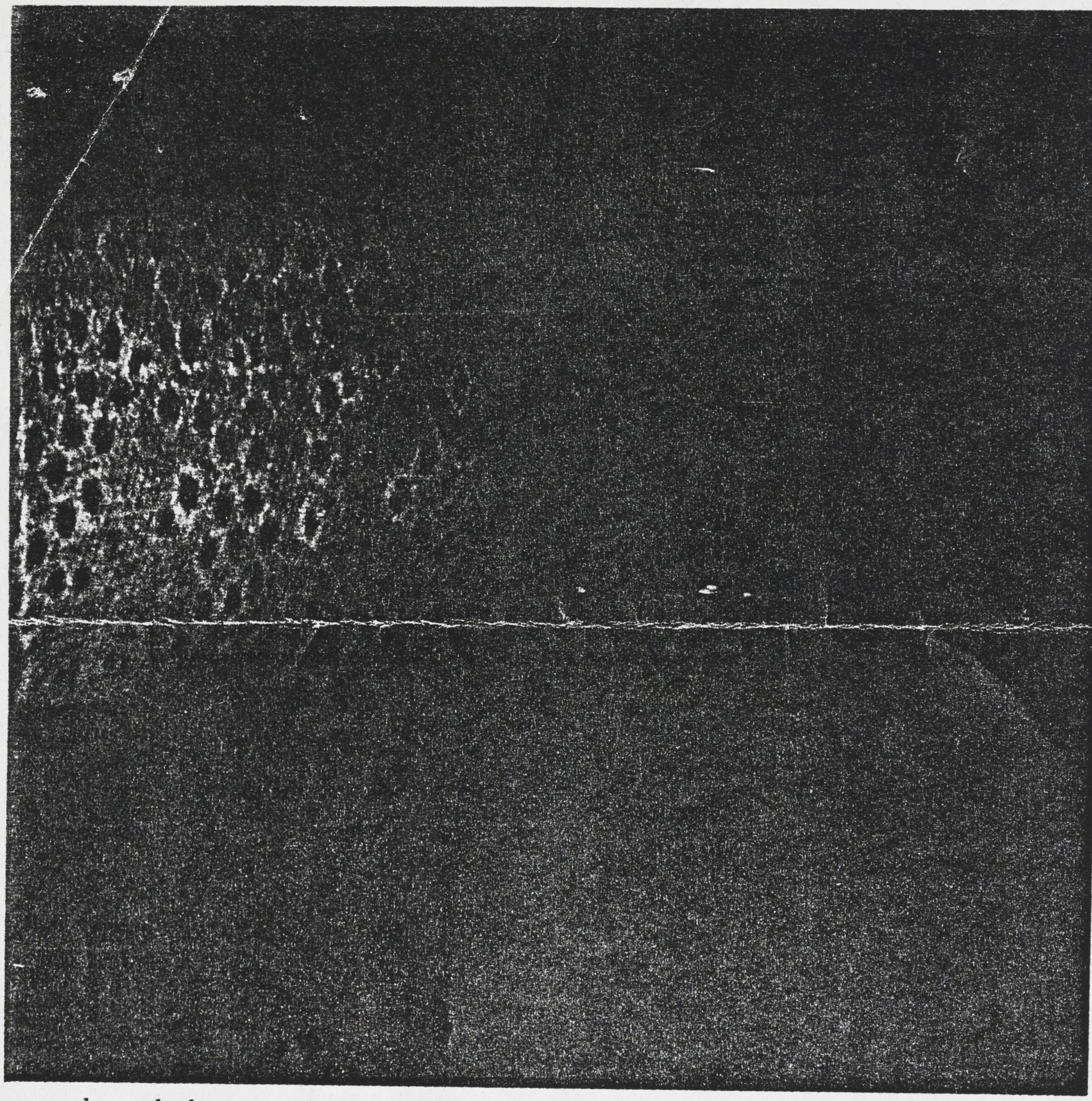

through the eyes of a trout. Poppies are coloured ultraviolet with an admixture of red and this is how trout — and birds — see them. Because we see only the red light reflected from the petals of the poppy and are blind to the ultraviolet light reflected at the same time, we are deceived into the mistaken notion that poppies are red.

More to the point, the trout sees an underwater world in which there are objects coloured ultraviolet, far violet, far purple (a term coined for a mixture of far violet and red), and so on.

The facts of trout vision outlined make biological sense. Light rays are absorbed and scattered as they pass through water but low energy, long wavelength rays at the red end of the spectrum are absorbed, scattered, dissipated and lost more rapidly than high-energy short wavelength rays towards the blue-green end of the spectrum.

In shallow water, when a great deal of the sun's energy lies in red, as it does on bright sunny days, yellows, oranges and reds are almost as clearly visible underwater as on land, so the trout needs a reasonably good ability to discriminate colours towards the red end of the spectrum. But towards dawn and dusk and on overcast wintry days when the sun's rays have less energy in the red (and what little red light there is is rapidly absorbed and lost as it enters the water), strange underwater transformations take place as objects which were coloured yellow, orange and red change colour and become various shades of green, blue, violet and far violet.

In deep water, where natural red light never penetrates, everything is coloured green, blue, violet, far violet or black (divers who cut themselves underwater are sometimes perturbed so see dark green blood welling from their wounds).

The fisherman, concerned at exact imitation of natural flies, should take note. Except in bright light, colour is less important than shape, and shape less important than the pattern's movement. In overcast conditions or deep water the trout sees as green to far violet a fly which, to the angler, is red to yellow. In all lights the trout has periscopic vision. Sometimes, therefore, a fisherman can be seen by a trout which he himself is in no position to see.

ANDREW ALLEN

fishing to Bristol's lakes

David M. Beanland traces the development of Chew Valley and Blagdon where bird-watchers and naturalists are as well catered for as anglers

TURN TO almost any book on stil water trout fishing and you will fin mention of Blagdon and Chew reservoir. They lie to the north of the Mendips about ten miles from the heart of Bristo Beneath a net of hedgerows and dar patches of woodland, the small limeston hills of this area swell up, subsiding as the reach the lakes.

Of these, Blagdon is the older. It wa created at the beginning of this century b the Bristol Waterworks Company t supply unpolluted water to an area whicl was becoming increasingly populous. Th idea of fishing it seems first to have oc curred to the general manager at that time a Mr Alexander, who angled in its waters with a roach pole.

Finding the fish were smashing hi light tackle, he turned to stronger gear anc soon realised that the reservoir containec superb brown trout. Blagdon Lodge became a shrine for fly fishermen and their aquarian gods can be seen in glass cases round the walls. As the early fishing records reveal, these fish were hard to catch, but well worth the effort, for they averaged over 4 lbs each.

Chew Valley Lake is a later creation and a larger one, its shoreline roughly a third longer than Blagdon's seven miles. Whilst it lacks the sedate, established intimacy of Blagdon, it offers a more open aspect, inviting admiration for the way in which the Waterworks Company has blended the provision of recreational facilities with an enlightened policy of conservation.

Fishing began at Chew in the 1950s and reflects the increasing popularity of stillwater angling for trout. The telephone is warm with bookings months before the season opens in April. At the Ubley hatchery and Blagdon pumping station trout are reared to stock the lakes. Each year 90,000 fish are released at irregular inter-

Call Bachman re
Behnke's article on
Trout vision in
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One mistake (?)
Trout ~~slow~~ cease
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HOW TROUT

See

GORDON BYRNES, M.D.

HAVE YOU EVER WONDERED why a trout will sometimes approach within inches of your artificial fly, pause, then carefully inspect your offering before deciding to strike or refuse it and leave? Certainly we can tell the difference between a standard dry fly and a real fly, even at quite a distance. Why then would a trout waste valuable energy to leave a holding position and scrutinize an artificial fly so closely if its vision were comparable to our own? You might also be inclined to wonder how it is that a fragile insect such as a mayfly can be so easily imitated with bits of fur and feathers tied on a hook. The answers to these questions lie in understanding the visual perceptions of the trout.

With poor visual acuity, they must get close to make the decision—eat or don't eat.

Many of the trout's behaviors are adaptations to its visual perception of the world. It is well reported that trout must rely on visual cues for their survival, especially in food gathering, danger avoidance, and reproduction. Until relatively recently, fishermen could only speculate on what a trout is actually able to see. Fortunately, scientific investigation has provided a much more insightful and accurate analysis of the trout's visual abilities. These abilities are very different from our own.

Most fly fishermen may find this discussion of trout behavior startling; much of the rationale presented for the behavior will be contradictory to many well-accepted notions. Unfortunately, these widely accepted notions are the result of misconceptions presented by other authors on the subject of trout vision. Knowing and using the facts presented in this article on vision in trout should lead to a better understanding of fundamental methods in developing and tying effective and realistic fly patterns and in developing effective fishing techniques.

The Trout Eye

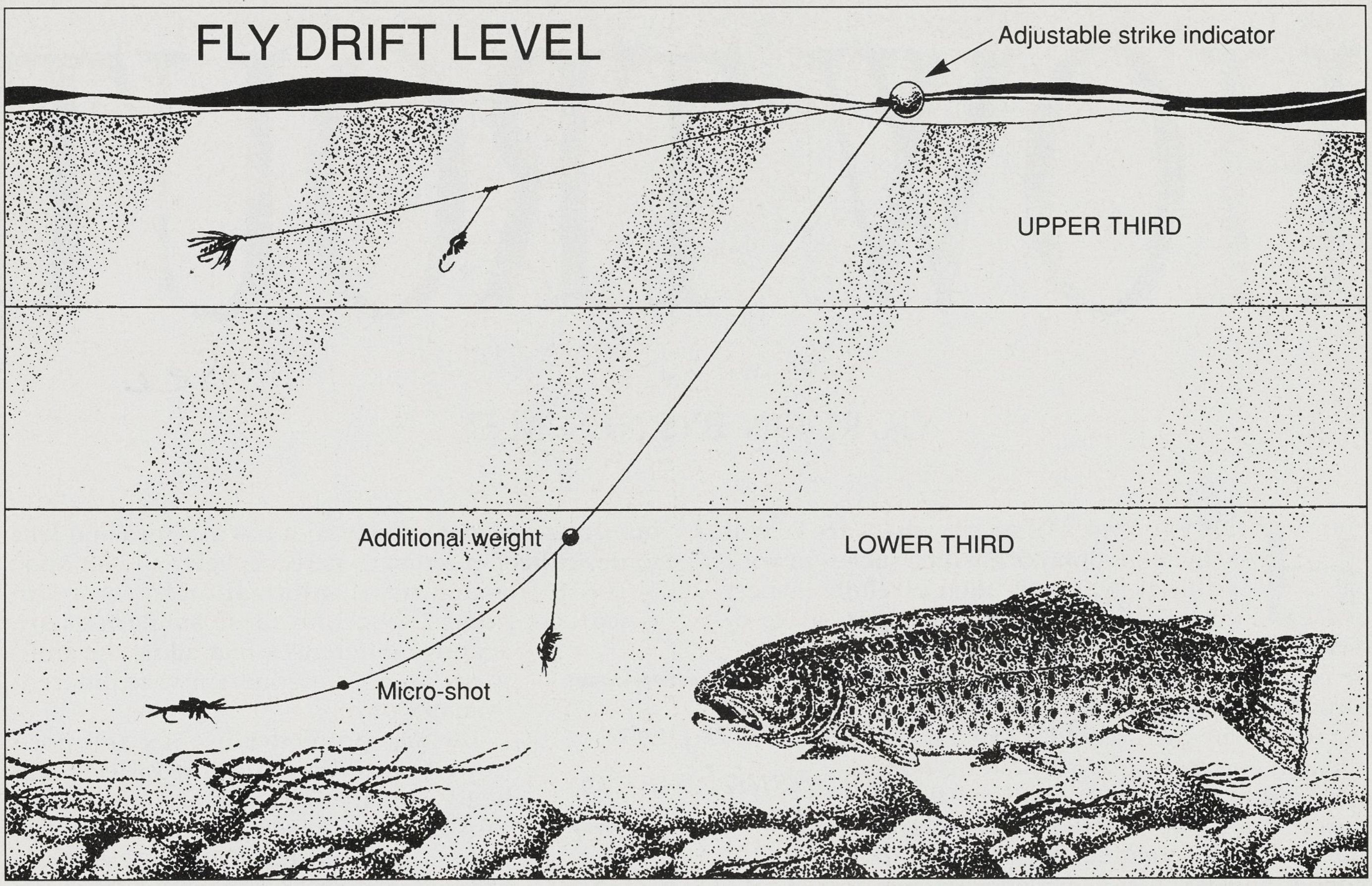
TO UNDERSTAND THE TROUT'S VISUAL SYSTEM, it helps to compare the anatomical makeup of their system to our own. Outwardly the trout eye resembles the human eye in many respects; it has a cornea and lens to direct light, a retina to perceive light, and an optic nerve to transfer visual information to the brain (Diagrams 1 and 2). Beyond these similarities are adaptive differences that allow the trout to see in an environment very different from our own.

Lacking protective eyelids and positioned laterally along the side of the head, the trout's eyes are located to provide an extensive peripheral field of vision. The cornea of the eye actually protrudes slightly from the side of the fish's head and renders it vulnerable to injury. The trout is able to move its eyes in a coordinated fashion by use of several muscles attached to the outside portion of each eye. By experimentally moving the eye with tweezers, scientists have demonstrated that the trout has a range of ocular motion comparable to that of the human eye.

The Visual System

A DISCUSSION ABOUT VISION in any visual system is incomplete without a fundamental understanding of how light moves through space and how visual images are formed. Light travels through a vacuum at a constant speed. When light enters a medium with a different optical density, the speed of the light changes, and at the interface between the two materials the light bends. This bending of light is called refraction. Understanding refraction is an essential part of understanding how visual systems bend light in order to focus light on the retina to form a clear visual image.

Because of the large disparity in optical density between air and cornea, the human eye bends incoming light primarily at the air/cornea interface through the process mentioned above, refraction. The relatively weak lens of the human eye fine-tunes the focus of incoming light onto the retina to provide us a clear image. In trout eyes the opposite is true, as light is bent very little from water through the cornea, because both of these substances have similar optical



ROD WALINCHUS ILLUSTRATION

The fly drift level is important to nymphing success. Nymphs and crustaceans work best if dead-drifted in the lower third of the stream's depth. Emergers and pupa imitations should drift naturally in the upper third of the stream.

especially in shallow riffles. Trout in shallow water can be approached closely because their cone of vision becomes smaller the closer to the surface they are.

The Lower Third Rule

THE FLY DRIFT LEVEL is the most commonly overlooked presentation factor and is what separates the men from the boys when it comes to nymphing success. The fly drift level is controlled by the amount of weight used on the fly or leader and by how far upstream of your target you cast to allow the fly to sink to the proper level. For most conditions, you should try to achieve a natural dead-drift of the fly in the lower third of a stream's depth. For example: If a section of riffle is 18 inches deep, try to keep the fly in the six inches of water closest to the stream bottom.

To know if you are achieving the proper drift level, carefully watch the strike indicator to see if it goes slightly slower than the surface currents or bubbles. Also, the fly should occasionally catch the bottom rocks or vegetation. If the fly hangs on the bottom too often, reduce the weight, and if you never get the bottom, then add weight or cast a little farther upstream to give the fly more time to sink. The smallest removable split-shot available (size B) and a selection of micro-split-shot work well together. Place the larger split-shot 18 to 24 inches above the fly to help the leader sink, and the micro-split-shot three to five inches above the fly to ensure that it will stay at the proper drift level. In very shallow water the fly weight or one micro-split-shot is all you need.

In addition to changing the weight, adjust the strike indicator in relation to the speed and depth of the water. Too long a distance will create more slack, reducing your reaction time, and too little distance won't allow the nymph to sink properly and may distract the fish.

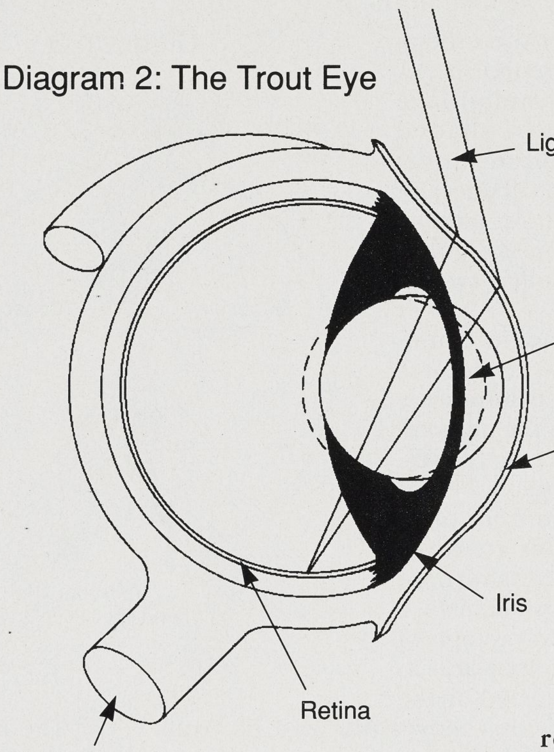
The exception to the lower third rule is, of course, when pupae or emerger imitations should be used. When fish are breaching in shallow water but normal dry flies don't produce well, try one or two larvae imitations in the surface film or just a few inches below. A small strike indicator and little or no weight should do the trick. Although the dead-drift works great, pupae often are good swimmers, so letting the fly swing and rise below you can bring an eager take that you should feel. This is the only time in shallow-water nymphing that you should strike by feel rather than sight.

Once I observed a nearby trout take then spit out a fly, and the strike indicator two feet away showed only the slightest sign of an aberration in the natural drift. Since then I've set the hook fast and sufficiently hard on any slight deviation in the natural drift. Never assume that a hesitating indicator is just dragging on the bottom or stuck on weeds. Always set the hook

Continued on page 64

SEE

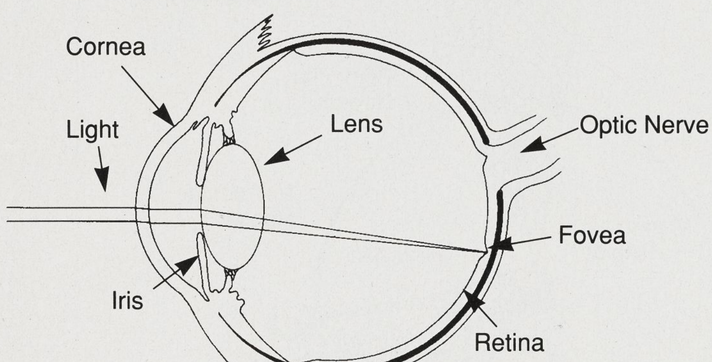
Diagram 2: The Trout Eye



densities, hence refraction of light is minimal. A powerful lens is then necessary to focus incoming light onto the retina of the trout. The lens of the trout's eye is so powerful that it is roughly spherical and actually protrudes through the pupil. Despite the high power of this lens, it is remarkably free of visual distortions, another miracle of evolution.

In order for the human eye to focus on both near and far objects, the lens must change shape to increase or decrease its power. While at rest, our eyes are focused at infinity, allowing us to see distant objects effortlessly. To read something up close, our lens power increases until the material focuses correctly. As we reach the age of forty-five and older, our lens loses much of its ability to change shape, hence the need for bifocals or reading glasses for close work.

Diagram 1: The Human Eye



ROD WALINCHUS ILLUSTRATIONS

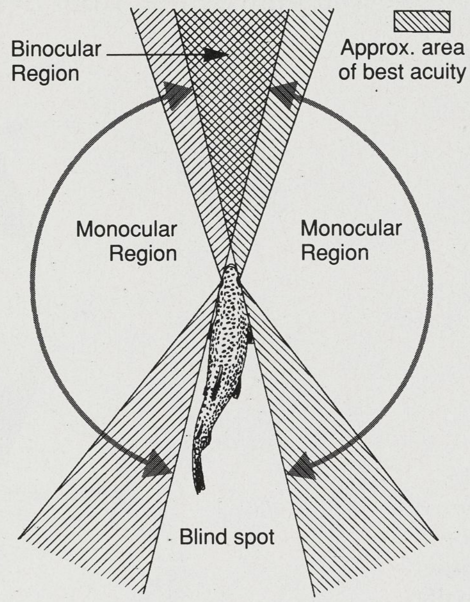
In contrast, the lens of the trout does not change shape to focus as it does in the human. Rather, the entire lens moves in a plane forward and backward to focus an image in the back of the eye (Diagram 2). While at rest, the trout's eye is focused at approximately three to four inches forward and slightly upward. The eye always remains focused at infinity, looking laterally, backward, down, and straight up. When the trout's lens is retracted in a focusing effort, the fish is able to see forward to infinity while the focus of other positions of gaze remains essentially unchanged. In this way the trout may actively focus its eyes only looking forward, while the remainder of its visual field is focused in the distance. Because the lens of the trout eye is very powerful, objects from approximately six feet and beyond are all in focus on the retina at the same time when the fish gazes at distant objects.

It may seem confusing how so much information about the peripheral environment could possibly be perceived at the same time by the trout. As with humans, the trout probably has an area of conscious awareness in its most developed field of gaze looking forward. The peripheral fields of gaze are probably subconsciously perceived until movement or contrast is detected and draws the conscious attention of the fish. Carrying this analogy to the human visual system, we commonly perform tasks with our central vision without being continuously aware of the details in all of our 180 degrees of peripheral vision. Typically we do not notice objects in our peripheral fields until changes occur in color or movement to draw our attention to these areas.

Contrast in color and hue between objects helps us discriminate them more clearly, particularly at low levels of light or at the limits of resolution. This becomes particularly important for the trout. Although the trout cannot sharply see an overhead predator or the silhouette of a fisherman in its peripheral vision, the movement of these objects against a contrasting background draws its attention and the trout flees for cover. Many fishermen through trial and error—mostly error—are well aware of this fact and have learned to reduce contrast between themselves and their environment through the use of camouflage clothing or fishing in shaded areas. Avoiding sudden movements also reduces the chances of detection by the trout. An emphasis should be placed on slow, careful wading and controlled casting motions.

Although trout have an extensive field of peripheral vision, it is worth mentioning their four areas of blind spots. Due to the anatomical positioning of the trout's eyes, it is unable to see directly below, directly behind, just in front of its snout, and just above its head (Diagrams 3 and 4). Fishermen who cast directly upstream to a fish attempt to take advantage of the trout's rear blind spot and in this way remain undetected by the fish. In reality, a trout that moves the least bit from side to side shifts is peripheral vision enough to detect a threat at its rear. In this way the trout will most likely see the fisherman if he draws attention to himself.

Diagram 3



While the trout's eyes are well positioned to view the surface of the water from a relatively horizontal position, it is unable to focus below to the bottom of a stream from this position. In searching for food items near the bottom, the trout must position itself with its tail elevated and head pointed downward. Only in this position can it focus to see the bottom with both eyes.

The ability to adjust the amount of incoming light into the eyes is important for optimum viewing and preventing overexposure of the retina to sunlight. Our eyes may adjust the amount of incoming light by constricting or relaxing the iris, which in turn changes the size of the pupil. Because the trout's lens extends through the center of the pupil, it is unable to adjust the pupil diameter as humans do. Rather, the trout's retina has an associated, specialized layer of pigment granules that actually moves in response to light and is able to protect one variety of very sensitive retinal cells from overexposure to sunlight. This process is aided by the additional movement of the photoreceptive cells. Unlike the pupil response in humans, which occurs in a fraction of a second, the migration of pigment granules in the trout's retina requires several minutes to occur once it is stimulated by bright light.

The retina is a specialized tissue that lines the back of the internal eye. It is capable of sensing a wide spectrum of light wavelengths and intensities through a photochemical reaction that in turn produces signals that are transmitted via the optic nerve to the visual centers of the brain. The brain reconstructs the signals to perceive an image.

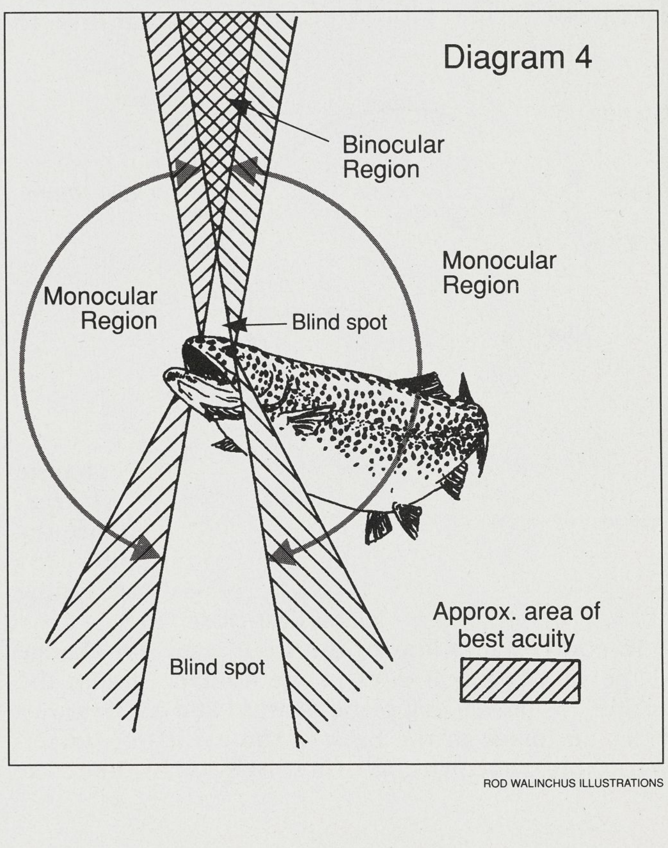
The photoreceptive units of the retina may be divided into cell types known as cones and rods. Cones perceive colors in normal daylight viewing. The rods, which are unable to discern color, are approximately one thousand times more sensitive to light than cones and allow vision at very low levels of light (starlight). The human eye possesses three types of cones that allow us to see in the blue through red color visual spectrum.

Young trout possess four types of cones with color vision extending from the ultraviolet range through red. As the trout gets older, the cones responsible for ultraviolet perception regress, and the retina reverts to a three-cone system similar to that of the human. The cones responsible for vision into the ultraviolet range may allow young trout to better feed on small aquatic life. If true, this represents yet another adaptation of the trout's visual system designed to enhance survival.

The rods found in the retinas of both humans and fish are only useful for vision at low levels of light. In order to see with our rods, the retina must adapt from a daylight system to a night-vision system, a process that usually takes from 20 to 30 minutes. This period of adaptation of the retina explains why fish stop feeding for about half an hour just after dusk as their eyes adjust from seeing with cones to seeing with their very light-sensitive rods.

Interestingly, the trout's eyes are not the only organ of its body to possess vision receptors. The

Diagram 4



ROD WALINCHUS ILLUSTRATIONS

Diagram 3 shows the horizontal visual field of the trout. Diagram 4 shows the vertical visual field. The trout has monocular vision to its sides. The single-hatched area shows the area of best acuity. The double-hatched area shows the area of binocular vision, where both eyes see with good acuity. Blind spots occur behind, below, above, and in front of the fish.

The trout's brain contains a small pineal gland that responds to input of light and dark signals from overhead. The gland is thought to help the fish regulate daily and seasonal body cycles based on changes in the light perceived.

MICHEL ROGGO PHOTO

brain of the trout contains a small center called the pineal gland, located just beneath a portion of the relatively translucent skull, and it responds to input of light and dark signals from overhead. The pineal gland is thought to function as a calendar for the fish which helps regulate body cycles based on daily and seasonal variations.

How and what we see of our environment is directly related to the arrangement of rods and cones of the retina. The human retina possesses a central, small area that is highly specialized, known as the fovea (Diagram 1). This region consists solely of numerous tightly packed cones and provides us our best daylight visual acuity. The adjacent retina consists of a diffuse mixture of cones and rods with rods predominating. Because of this array, humans possess excellent central daylight acuity for approximately five degrees, but our acuity drops off dramatically in our peripheral vision. The correlation to this arrangement is that at very low levels of light, starlight for example, we are unable to look directly at something and see it accurately. This is because our cones lack sufficient sensitivity at these low levels of light. By looking slightly to the side of what we want to see, we place a focused image in a region of retina concentrated with rods, and the image is perceived, although no color is detected.

The trout retina is organized much differently from our own. Having no central fovea, it rather has a ring-shaped area of peripheral retina that is concentrated in cones. Because the concentration of cones in this region is substantially less than that of the fovea in the human eye, the resolving power or acuity of the trout eye is only a fraction of the acuity of a human eye. The location of this specialized ring of retina in the trout affords the best daylight vision peripherally, exactly the opposite of the human. This means that a trout sees best forward, backward, up, and down but has poor acuity laterally because the corresponding central retina has relatively few cones (Diagrams 3 and 4).

It should be noted that the regions of greatest visual acuity overlap forward and above the fish, providing the trout a long but narrow arc where it sees best binocularly, using both eyes together. Given this fact, it is not surprising that trout tend to feed in lanes, often ignoring flies just a few inches laterally, simply because they do not see well in this direction. To cover a larger area for feeding, the trout would have to swim back and forth, scanning the above water surface and wasting a tremendous amount of energy against the current, something no wild fish can afford to do.

Because the trout's peripheral specialized region of retina retains the presence of very light-sensitive rods, it is able to see at night by simply looking directly at its quarry. In this regard the trout's eye is better adapted than a human eye for hunting at night. However, due to the way the rods collect visual information and transmit it to the brain, the fish's nocturnal visual acuity is probably less than its daylight acuity.

What the Trout Actually Sees

THE DAYLIGHT VISUAL ACUITY of the trout has been measured experimentally in a laboratory study by three

MICHEL ROGGO PHOTO

German scientists using a particular behavioral pattern of the trout combined with an experimental apparatus to accurately measure acuity. Their results correlate closely with the calculated visual resolution based on the optical properties of the trout eye and the measured distance between cones. The scientists found that the visual acuity of the trout was 14 times less than that of a human.

The fact that trout only see a fraction as well as humans do explains a characteristic feeding pattern of the fish. Most fishermen have seen trout move from a holding position near the bottom of a stream to approach within inches of a fly to closely observe it before feeding. At a few feet away the trout is only able to see a fuzzy silhouette of the fly, which initiates its interest in the object. As the trout gets closer to the fly, its image projected onto the retina proportionally enlarges until the fish can discriminate it conclusively from other surface objects that might resemble a fly. Once the trout decides if the object is on its menu that day, it either strikes the fly or returns to its holding position.

Through the Trout's Eye

THE VISUAL ACUITY OF THE TROUT can be closely approximated by taking a picture and altering the focus a calculated amount. Photo 1A shows what a human might see of a standard dry fly from directly underwater. Photo 1B is what a trout sees of the same fly at a distance of one foot. Photos 1C and 1D are what a trout sees at six inches and three inches from the fly, respectively. Notice that as the fish gets closer to the fly, it is able to resolve more details, although the acuity remains unchanged. At approximately three inches from the fly, the trout reaches maximum visual discrimination.

Photographs 2A and 2B, modified from a photo provided by Dr. Carl Richards, demonstrate what a trout sees of the mayfly *Baetis hiemalis* at a distance of six inches and three inches, respectively.

Previous authors and researchers on vision in fish have attempted to refract various species of fish both in and out of the water. Refraction is basically a method to determine if spectacles are needed for the eye to achieve its best vision, a procedure that anyone who wears glasses is familiar with. Initially, trout were thought to be nearsighted. Later, researchers using measurements of light reflected from the fish's eyes felt that the trout was farsighted. Most recently, studies using sophisticated electronic recording devices from the fish's brain have proven that most fish have little refractive error and that the previous methods for testing refraction were inaccurate. The significance of this to the fly fisherman is only to clarify this topic which appears in other material on vision in trout.

Binocular and Stereo Vision

ONE MAJOR CONSIDERATION NOW REMAINS concerning vision in trout. Do trout have binocular vision as most humans possess, or are they essentially monocular, using input from one eye at a time? Binocular vision is an ability of the brain to take visual information from two eyes and form a single image. For this system to exist the eyes must be able to both "lock on" to a target and maintain coordinated tracking. Although research has not proven the trout to be binocular, observations of the fish demonstrate a consistent pattern of moving the eyes together in small tracking motions. For this and other reasons most researchers speculate that trout do possess binocular vision.

Binocular vision can only exist in fields of vision shared by the two eyes. As was mentioned previously, this correlates to a common area forward and above the trout (Diagrams 3 and 4). This region of binocular vision is ideally suited to a creature that holds near the bottom of a river and must scan both forward and above for food that washes downstream.

Stereovision, or the ability to see in three dimensions, is a higher-level function of the brain that requires the presence of binocular vision. Most people with binocular vision can see in three dimensions, although some cannot. If we assume that a trout does have binocular vision, it is possible to make speculations about its stereoacuity.

Experimentally blurring the vision of a human to the level of a trout reduces stereoacuity by approximately 100 times to a very rudimentary level. It is essentially impossible for a creature with the visual acuity of a trout to possess high-grade stereoacuity. How then are trout able to feed on moving insects without this ability?

Actually, most of our clues to depth perception have little to do with stereovision. Many people with poor or nonexistent stereoacuity have little difficulty driving cars or performing manual tasks. They are accustomed to using clues of size, shape, and shad-

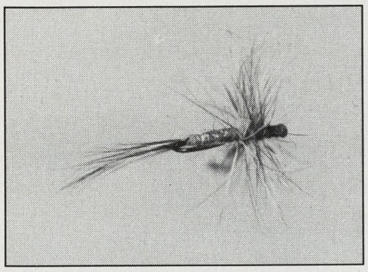


Photo 1A. Depicts how the human eye sees a standard dry fly from underwater.

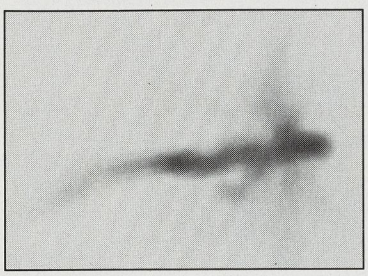
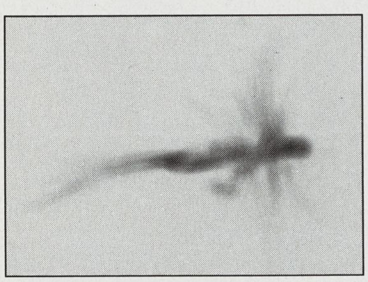


Photo 1B. How the trout sees the same dry fly at a distance of one foot. The fly's details are lost.



GORDON BYRNES PHOTOS

Photo 1C. How the trout sees the same fly at a distance of six inches.

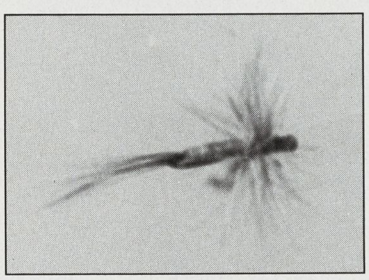


Photo 1D. The trout reaches maximum visual discrimination at three inches from the fly. The fly's details become visible.

ows to help judge distance and direction. The fact that trout not infrequently miss the fly during a strike points to a certain lack of stereoacuity. Certainly the fish is successful most of the time. Proving that stereoacuity is not necessary for trout to feed or survive are the numbers of hook-injured monocular fish that survive and feed

Continued on page 62

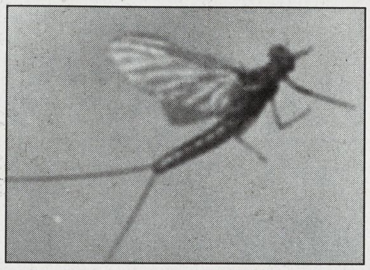
How Trout See . . .

Continued from page 61

despite their visual handicap.

In summary, trout possess a visual system which is adapted for underwater viewing and is quite unlike our own. Although we surpass the trout in visual acuity, the trout has a much larger area of visual surveillance and is better adapted to hunting at night. Much of the trout's behavior is governed by its visual abilities and limitations. This is most apparent in observations of the trout's close scrutiny of flies and use of feeding lanes. Comprehending the visual capabilities of the trout provides a better understanding of why this creature has gained the reputation as a wary, yet selective, predator.

Photo 2A (above) depicts how a trout sees a mayfly at a distance of six inches. Photo 2B (below) shows how a trout sees the same mayfly at a distance of three inches.



DR. CARL RICHARDS PHOTOS

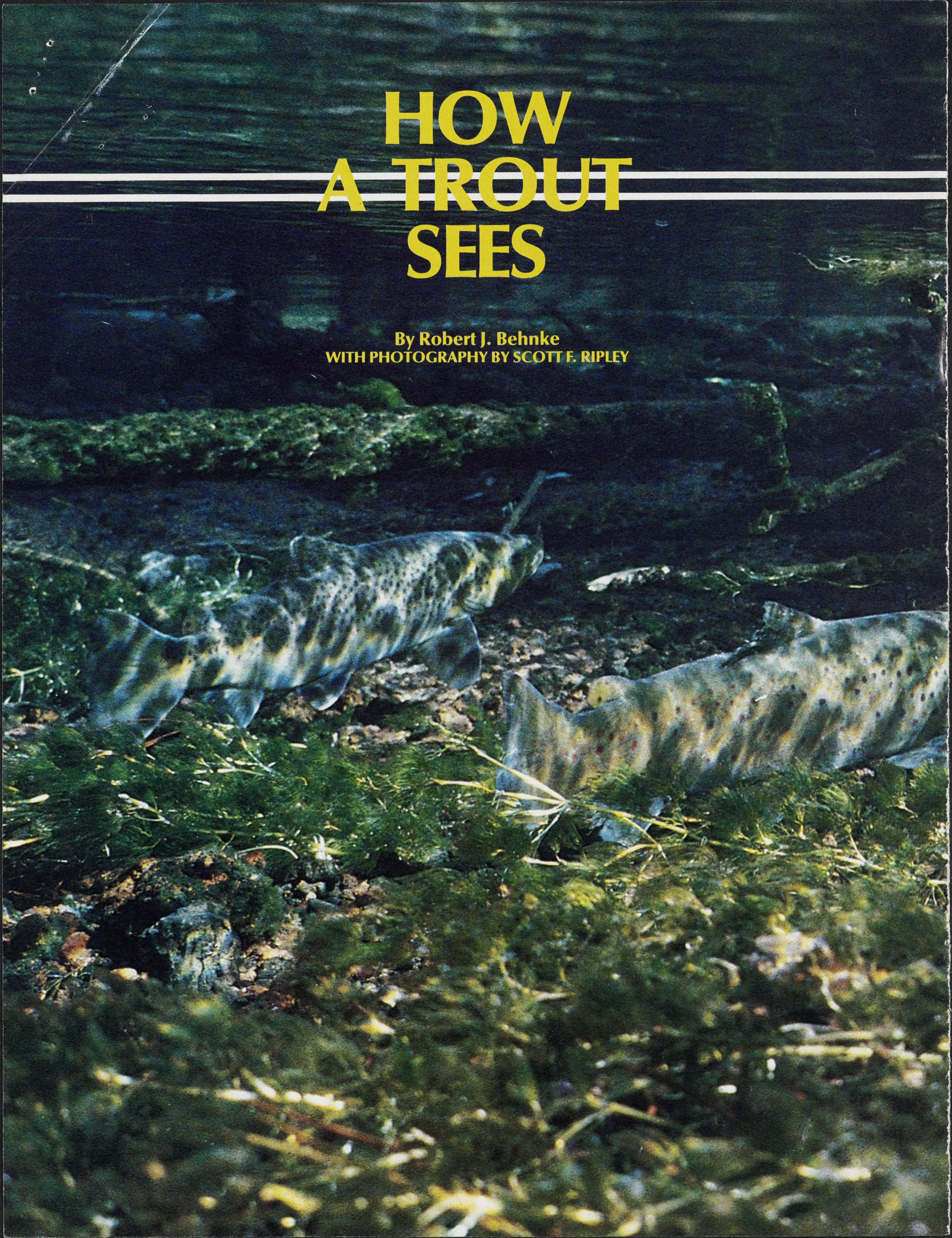
Fly Design

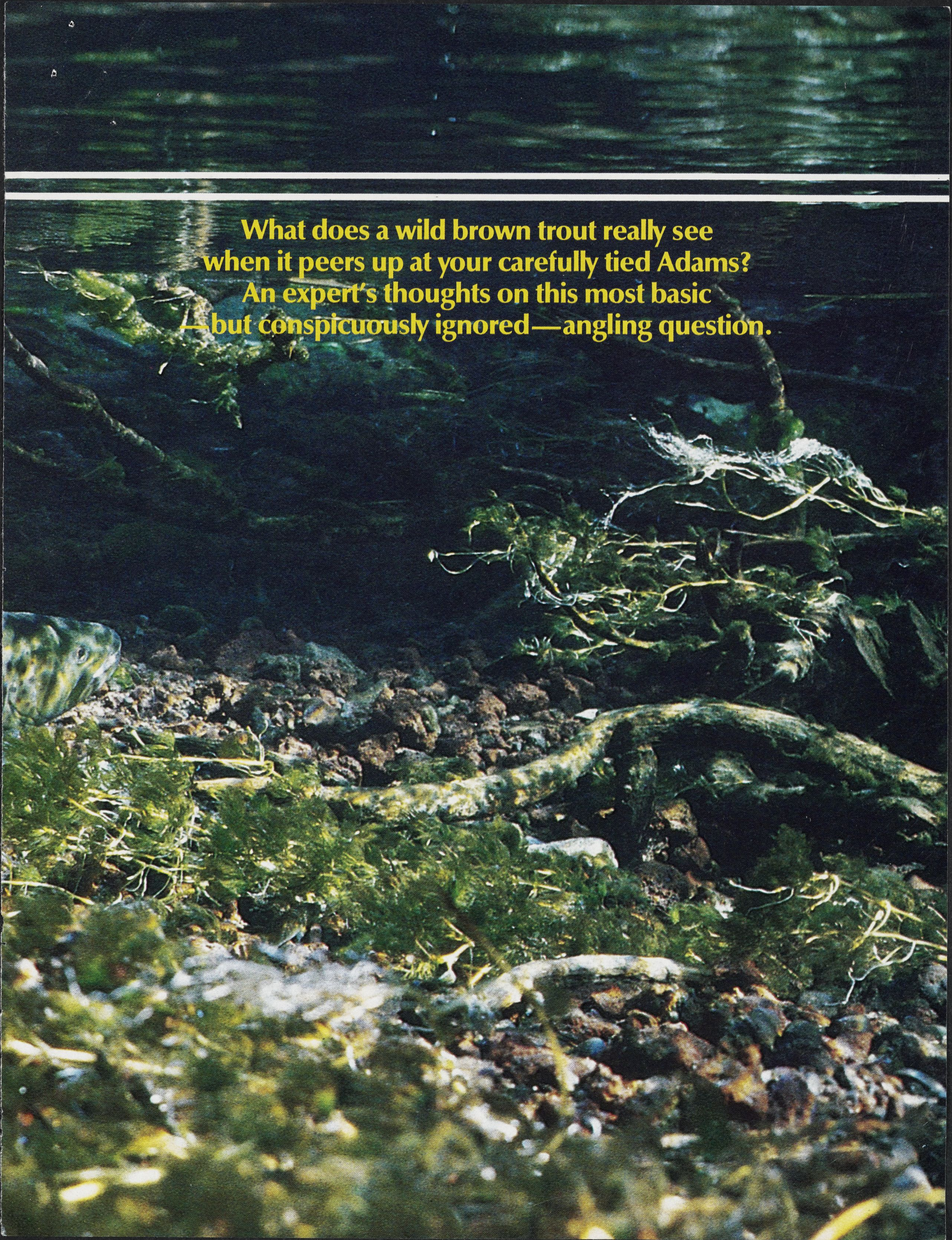
FUNDAMENTAL TO THE DESIGN of artificial flies and fishing technique is a clear understanding of how and what a trout sees. Using information presented here as a foundation, I am currently investigating questions that I have found puzzling for years. Specifically, how can artificial flies be modified to make them appear more realistic to a selective trout? How small must a tippet be before it becomes invisible to the trout? Can the hook be modified to make it less conspicuous? Which methods of fishing are least likely to disturb a wary fish? Perhaps these and other questions can be answered by further visual investigation.

GORDON BYRNES, M.D., a fly fisherman and a Navy physician in residency training as an ophthalmologist, lives in Gaithersburg, Maryland.

HOW A TROUT SEES

By Robert J. Behnke
WITH PHOTOGRAPHY BY SCOTT F. RIPLEY





What does a wild brown trout really see
when it peers up at your carefully tied Adams?
An expert's thoughts on this most basic
—but conspicuously ignored—angling question.

SEEING IS SUCH A NATURAL and instinctive phenomenon that we take vision for granted. Mechanically interpreting the world around us through our eyes is a constant activity of "photoreception." We rarely give much thought to such questions as how and why we see what we see; how do other animals perceive what we see; and how can some animals — for example, trout — see things we cannot see?

I first must admit that many of the complexities of the physics and chemistry of vision are beyond my understanding. My interest in fish vision concerns adaptations of the eyes of fishes to different conditions such as shallow water, deep water, nocturnal activity, etc. Several years ago I wrote an article on salmoniform fishes for the *Encyclopaedia Britannica.* It was a fascinating experience to learn about some of the extreme adaptations of the eye in some of the bizarre deepsea salmoniforms to function under light intensities most animals cannot perceive.

The eyes of all vertebrate animals, from fish to mammal, follow a similar basic plan to function as a photoreceptor organ. The major differences between the eye of a typical fish and the eye of a typical mammal concern the differences between life underwater and life on land.

The first obvious difference one might notice in comparing the eye of a trout with the human eye is the absence of eyelids on trout. The cornea or outer surface of the eye must be kept continually moist and clean. Eyelids and tear glands serve no useful purpose to the underwater eye, but they became necessary additions to the eye when vertebrates evolved to live on land more than 300 million years ago. Another obvious difference is the position of the eyes. Trout, and most fishes, have the eyes positioned laterally, on the sides of the head. This position results in more limited binocular vision (the area where the fields of vision of the left and right eye overlap), but a much greater total field of vision. A trout can take in much more of the surrounding world without turning its head. This is an adaptive trait in view of the fact that fish lack necks with which to turn their heads.

Other differences, found within the eye, relate to optimizing vision underwater and on land.

When light passes from air into water, the difference in density between the two media slows the light waves and bends or refracts them. The image of a fish or any object we see from above the surface is actually not where it appears to be due to the reflected light we see from the object being refracted when it leaves the water into air. This same phenomenon of refraction occurs when light enters our eyes and passes from air through the denser medium of our cornea and eye fluid. Thus, the cornea and lens of the terrestrial eye is structured to re-refract or "straighten out" the light waves so we can see straight. Because the density of the fish eye is similar to water, and light underwater is already refracted, there is no need to re-refract the light within the eye. Thus, in fishes' eyes, the cornea is typically thin and the lens more spherical. We adjust our depth of focus by changing the shape of our lens. The lens of a fish eye cannot change its shape, but some accommodation is possible by back-and-forth movement of the lens. Because of the shape of its lens, and the position of its retinal receptor cells, a trout can focus simultaneously on both near and far objects. Such a sensation is difficult for us to "envision."

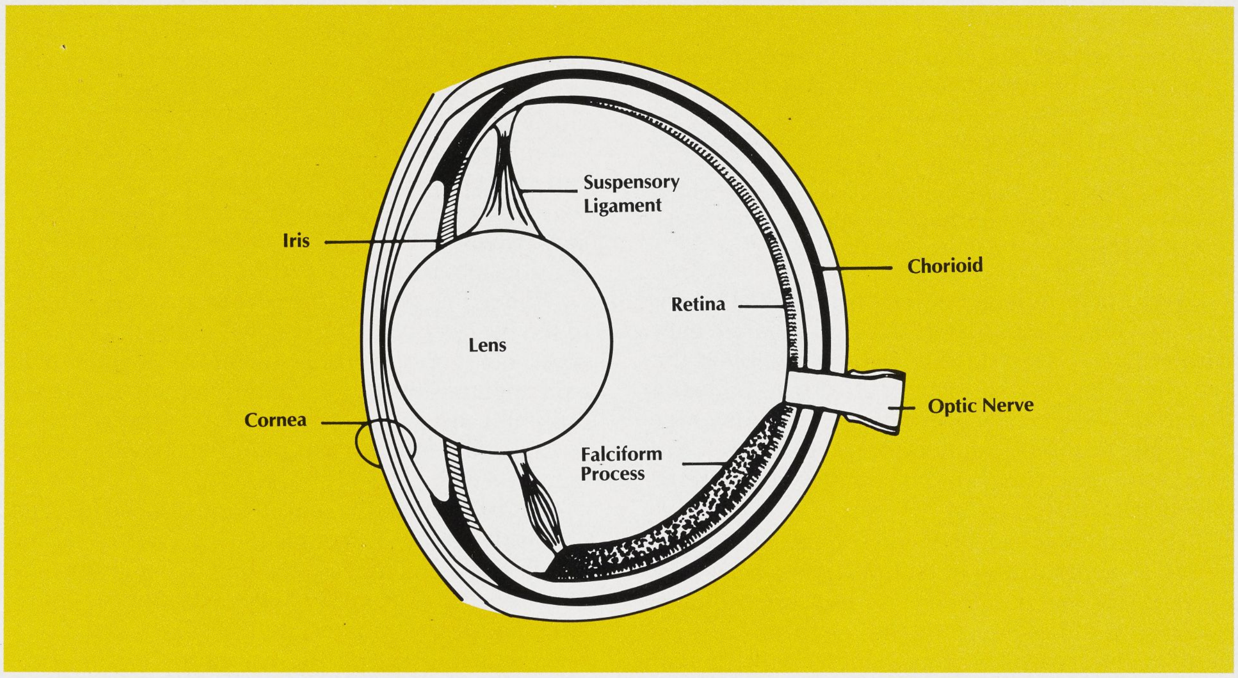
A trout can focus simultaneously on both near and far objects.

Our iris diaphragm expands and contracts to regulate the amount of light falling on the retina in relation to the intensity of illumination. We can also "squint" with our eyelids to shield our eyes from intense light. The iris in the fish eye is fixed. The pupil (the opening in the iris) of a fish eye cannot dilate or contract. This is no big problem for a fish's vision because light intensity is greatly reduced when light passes into water due to scattering and absorption. In clear, calm water about 99 percent of the light intensity is lost by about 25 feet in depth. When the water contains suspended particles (turbidity) or has turbulence such as in a riffle area of a stream, the reduction of illumination by scattering and absorption is greatly increased and visual acuity decreased. Most anglers quickly learn that trout are typically less wary and less selective when fished in a turbulent section of a river in comparison to trout in a calm, clear pool.

An understanding of light attenuation (loss of intensity) when light is transmitted through water in relation to the wavelengths (colors) best transmitted at certain depths (what colors are most readily perceived) is more important for lake fishing than for stream angling. In clear water, the shorter (blue) wavelengths of light penetrate deeper than longer (red) wavelengths. This relationship between the intensity of transmission of various wavelengths of light and depth is distorted in turbid waters and optimum wavelength transmission can be shifted toward the yellow-orange side of the light spectrum. In any event, for serious anglers, a gadget is now marketed that will indicate what wavelengths are optimally transmitted (what color is most readily perceived) at any given depth.

In stream fishing, where the presentation of the fly to the trout typically occurs at depths of less than three feet, I doubt that there is any problem concerning what is most readily perceived — all colors will be perceived; if you're matching the hatch, try to match the colors.

Fluorescent colors are more intense and result from stimulation of "fluorescent" material by ultraviolet light (invisible to our eyes) so that the "stimulated" material glows in its own color. Fluorescent



The eye of all vertebrate animals, trout included, follows a basic plan: light reflected off an object enters the eye through the cornea and the lens focuses light on the retina, which responds by relaying the signal to the optic lobe of the brain. The retina is made up of more than 100 million cells. Two basic types of retinal cells are rods and cones. Rods function after dusk and before dawn in very dim light. Specific types of cones respond only to specific wavelengths (colors) of light. Three types of cones are needed for full color vision — trout have them all, and perhaps a fourth allowing perception of ultraviolets.

colors are more readily perceived and perceived at a greater distance than ordinary colors. Just how a fish perceives fluorescence, I cannot say. I would point out, however, that the introduction of fluorescent flies and lures has not resulted in any revolutionary new influence on the art of angling. The main use of fluorescent flies and lures is for steelhead and salmon angling where fish on the spawning run typically are not actively feeding. The attractor, curiosity, or agitation effect may be of more importance to entice a nonfeeding fish to strike.

I suspect that trout can perceive light in the near ultraviolet spectrum (light that we cannot perceive) — several species of minnows that feed near the surface, similar to trout, have been demonstrated to possess ultraviolet vision. If this proves to be fact, as with fluorescence, I do not forsee any significant implications for new "revolutionary" flies and lures, but be alerted for some stories in the popular press about "sensational new scientific discoveries" on trout vision.

4th cone

Anglers, especially fly fishers, historically have been interested in learning more about trout vision for an obvious reason — so they can create and present artificial flies more effectively to catch more fish.

The first serious treatment that I know of in the angling literature of light and vision in relation to fly fishing was the 1836 classic work of Alfred Ronald, *The Fly-Fisher's Entomology.* Many books on fly fishing since have contained some discussion on vision: what a trout sees, the trout's "window," et cetera.

Generally recognized in the angling literature as a landmark work on trout vision is Colonel E.W. Harding's 1931 book, *The Fly-Fisher and the Trout's Point of View.* The pioneer American scientific angler Edward R. Hewitt devoted considerable thought and effort to better understanding trout vision. Hewitt constructed special tanks for underwater photography to see for himself how a trout perceives a fly. But, in my opinion, the angling book that displays the most impressive in-depth understanding of trout vision is Eugene Connett's last book, *My Friend the Trout,* published in 1961. For many years, Connett had collaborated with an eye specialist, Dr. E.B. Gresser, to conduct experiments on trout vision.

I am most impressed with Connett's book because he did not rely on previous authority. He understood that the literature on trout vision at that time contained errors and considerable gaps of knowledge. Instead of simply repeating previous errors and fabrications to fill in the unknown gaps of knowledge, he sought out the most expert opinion and participated in original research. Be particularly suspicious of the validity of statements made by authors who introduce a technical discourse with "scientists say."

At the other extreme, my nomination for the shallowest, most simplistic, and most erroneous treatment of trout vision would go to Charles Zibeon Southard's 1931 book, *A Treatise on Trout for the Progressive Angler.* I rest my case by quoting Southard's explanation of how trout can see in the dark:

> I have no hesitancy in saying that all fishes have, to a greater or lesser extent and according to their requirements, the power to produce light for themselves, by their eyes, whereby to see when natural light does not exist. Trout have the ability of emitting or radiating light and their eyes have the power of luminosity which enables them to do the things at night and other times that in the past went unexplained.

Besides being completely erroneous, what Southard failed to realize is that if fish could generate light within the eye such internal light would blind the eye to anything outside of the eye! It is true, however, that trout — especially brown trout, whose eyes are especially adapted to function in dim light — can continue to see when our own eyes would perceive only blackness.

To better understand light intensity thresholds for vision, a quantification of illumination is necessary for comparison. The "lumen" is a measure of illumination. One lumen equals all the light from one candle concentrated on one square meter with the candle at one meter distance from the illuminated surface. On land, bright sunlight equals about 100,000 lumens of light intensity. Illumination during an overcast day without direct sunlight would equal about 1000 lumens. A night with moderate moonlight would have about .1 lumen of illumination and a moonless night (starlight) only .001 lumen (at such illumination we might have trouble seeing our hand in front of our face).

A few years ago, an experiment was conducted in Arizona to gain some insight into the mechanisms of how brown trout might outcompete and replace the native Apache trout. The experiment was designed to test the lowest light intensity at which brown trout continued to feed. The fish were maintained in tanks and fed brine shrimp (an adult brine shrimp is comparable to a size 28 fly). Brown trout continued to feed with illumination of only about .001 lumen (starlight). Considering that the illumination was recorded above the water, I do not believe my eyes could have seen a whale underwater at such illumination, much less a brine shrimp!

The ability to see at extremely low levels of illumination is dependent on the retinal cells responding to low intensity photon reception. Photons are "bundles" of light energy which are received by the retinal cells. A certain threshold of photon reception is necessary before the retinal cell responds by triggering its nerve fibers to send the message via the optic nerve to the optic lobes of the brain for interpretation. The retinal cells in the eyes of trout, especially brown trout, respond to lower thresholds of photo reception than do our retinal cells.

Because of the great daily range of illumination from day to night, the retina of the eye of trout and man is composed of two basic types of receptor cells: cones for vision in bright light and rods for vision in dim light. Cones give color vision and visual acuity. Three types of cones are needed for full color vision (color blindness is the result of only one or two types of cones functioning in the retina). Trout have all three types of cone cells and essentially see the same colors we do — except, as discussed, trout may have a fourth type of cone that allows perception of ultraviolet light.

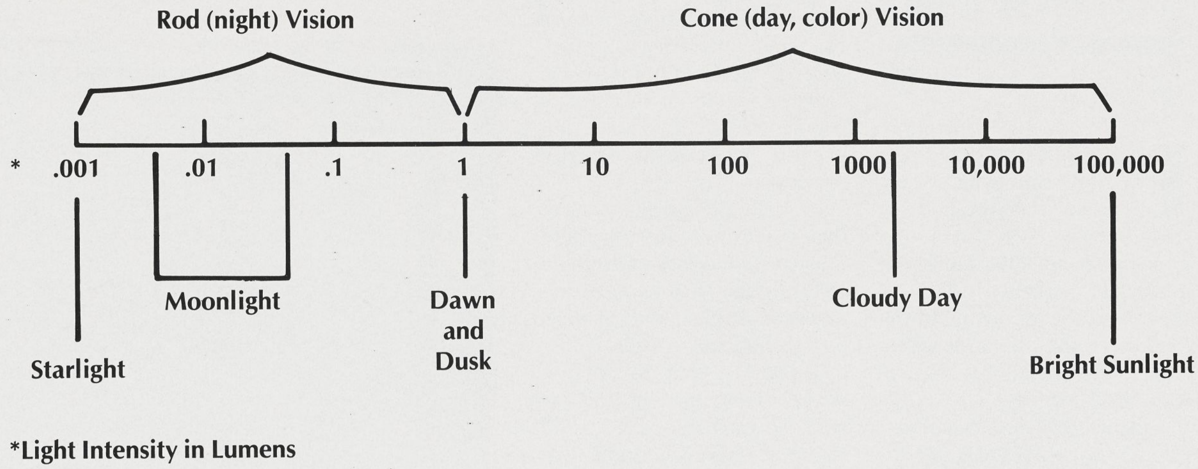
As illumination decreases, cone cells are retracted and rod cells extended as the trout's eye changes its adaptation from day to night vision. This occurs at late twilight. The process of complete adaptation to night vision takes about 20 to 30 minutes, during which feeding ceases. The reverse process of night to day vision occurs near dawn. Anglers fishing at night might notice this day-night-day adaptation in trout and bass by lulls in feeding activity right after dusk and just before dawn followed by spurts in feeding after darkness sets in and again with the first light of dawn.

In most streams, the bulk of food utilized by trout is provided by the drift of aquatic insects. Depending on numerous influences, drift may occur at any time but, typically, peak rates of insect drift occur at low illumination of .1 lumen and less (dawn and dusk). Thus, to make available the major source of food in a stream, the trout's vision must be well adapted to function at low levels of illumination.

Brown trout are especially adapted to function in dim light, and can continue to see when our eyes perceive only blackness.

As all fly fishers know, trout do, indeed, have excellent visual acuity which is responsible for selective feeding. Precisely why a trout will take a certain artificial fly or a natural insect while ignoring others is not fully understood. Long-term studies on brown trout feeding by Professor Neil Ringler, however, provide some insights on the subject. When fed a certain organism, such as brine shrimp or meal worms, for a prolonged period, the trout's eye-brain connection evidently becomes "programmed" to respond to the specific image of the constant food item. When other food, such as crickets, are introduced in the tank or raceway, most trout ignore them for some time even though crickets may have been the preferred food if brine shrimp, meal worms, and crickets were all introduced together at the beginning of the experiment. After an adjustment period of exposure to a new food item, the trout will begin to feed on them.

Typically, the natural drift of aquatic insect larvae in a stream consists predominantly or entirely of one species for a long period. In rivers where the flow



The light intensity scale is expressed in lumens, approximately 10 lumens equaling one foot-candle of light. Between dawn and dusk, the cone cells of the retina are used for vision. At dusk the retina changes from cone to rod vision. During the period of adaption, trout feeding ceases.

and temperature regimes have been modified by a large dam and reservoir, the total abundance and biomass of insects may increase, but the species diversity decreases, and the species that typically exhibit great increases are very small — midge larvae, mayflies, and caddisflies (sizes 18–22). Under such circumstances, extreme selectivity of feeding trout may be encountered. Trout are least selective when they are feeding on a broad spectrum of invertebrates in relation to size, shape, and color. In a productive lake or reservoir with a great diversity of insects and crustaceans, the diet of trout can be expected to be highly varied; stomach contents show a wide range of invertebrate species of different sizes, shapes, and colors. When this is the case, trout can be taken on a wide variety of flies and lures — they are not selective. In unproductive high mountain lakes, the total food supply for trout, for long periods of time, might consist of a single species of invertebrate organism such as water fleas, tiny midge larvae, or a minute species of backswimmer bug. Under these conditions, extreme feeding selectivity can be expected. Even cutthroat trout, the species of trout most vulnerable to angler catch, when exposed to a single species of invertebrate for a long period, can become as "selective" as an old brown trout in a roadside pool.

To answer the question: what exactly does a trout see? I would advise the reader to put on a face mask and go underwater and see for himself. A face mask is necessary to have a layer of air between our terrestrial-adapted eye and the water, to make our underwater vision more comparable to what a fish sees. Yet anything we can see a trout will see better, and the trout will see things our eyes do not see. Besides the ability to function at lower light intensities, the trout's eye is more specialized than our eye to detect movement and contrast. The first phenomenon that a human might be aware of when first viewing the underwater world from a fish-eye point of view is the great reduction in illumination, even in the clearest water, and the limited range of accurate vision. Another phenomenon that is quite striking underwater is how much better and farther one can see when positioned in a shaded area and looking out into a sunlit area compared to the reverse situation. This phenomenon makes it understandable why fish seek cover in shallow water.

It takes 20 to 30 minutes for a trout to completely adapt to night vision, during which feeding ceases.

Obviously, no one knows the precise sensory impressions a trout experiences from its sense of vision compared to our interpretation of optical images. Certainly, there are vast subjective differences in the complex interactions between vision, physiology, and behavior. For example, in relation to visual signals from the opposite sex, a trout would effect a behavioral response for only a brief period each year during the spawning season. How do the other parts of the trout's brain respond to the sight of a grasshopper or a plump stonefly in comparison to our brain's interpretation of a perfectly grilled T-bone steak? One obvious difference would be the absence of the mouth-watering response, because there is no need

Eyesight of Trout

by Eugene V. Connett III

I HAVE LEFT THE PROBLEM of the trout's eyesight for a chapter of its own, because it is a very important one and one that is not generally understood. Furthermore, the matter of how a trout sees the angler and the angler's fly can be the crux of successful fishing.

Early in 1937 I was fortunate enough to obtain the assistance of the well-known New York opthalmologist, the late Dr. Edward Bellamy Gresser, in my investigations of the eyesight of trout. In February we went to the Hackettstown Hatchery, in New Jersey, and the superintendent, Mr. Charles Hayford, kindly made the facilities of the hatchery available to us.

Observations of the eyes of brown, rainbow and native brook trout were made above and *beneath* the surface of the water with an opthalmoscope. There was a marked difference in the appearance of the retina of the rainbow trout as compared with those of the other two varieties; but to the angler this is not important. Another, and much more practical result of the observations, was that while the readings of the instrument showed six degrees of short-sightedness when the fishes' eyes were examined above the surface, it showed perfectly normal results with the eyes beneath the surface. This indicates that previous investigators have made their observations with the eyes above the surface only, as it is usually stated that trout are decidedly short-sighted.

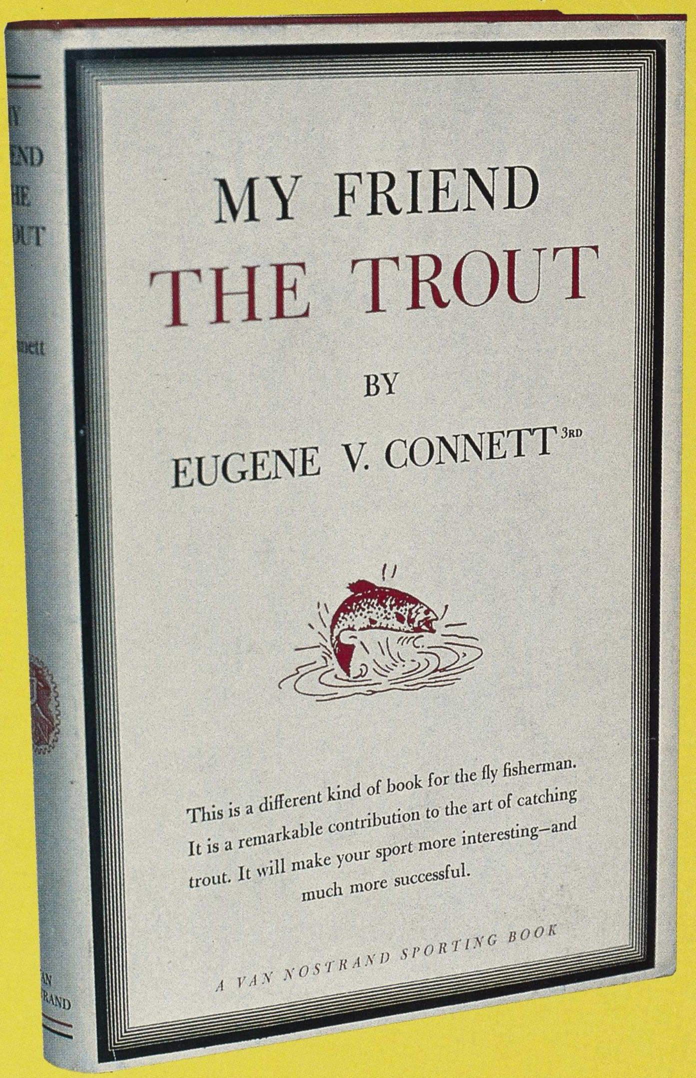
Specimens of the three varieties of trout were selected from a number of two-year-old fish, and were taken alive to Dr. Gresser's office in New York, where a complete range of optical instruments was available for various measurements and observations. First the fish were examined alive and later their eyes were dissected. A further supply of eyes was taken to the eye laboratories of the New York University College of Medicine, where Dr. Gresser taught. In due time a report on the eyes was completed, with microscopic sections.

. . . It is interesting to note that the brown and the rainbow trout have the same angle of binocular vision of 36 degrees, while the native char has but 30 degrees. All three species have the same field of binocular vision upward, and upward toward the rear, i.e. 10 degrees. There is a slight variation in the field of monocular vision in each species.

. . . the field of monocular vision . . . in the case of the brown trout is 122 degrees for each eye. A relatively slight movement of the eyeball enables the fish to make a complete survey of its surroundings in a field above its head. Just what the lower extent of this vision would be, could probably be computed from a combination of the vertical, horizontal and sagittal vision, but such knowledge would be of very little importance to the angler, and the work involved would be very laborious.

The information I have just given was developed by Dr. Gresser and his students at the New York University College of Medicine. It is therefore accurate and may be accepted by future students of the subject.

In making our examinations of trout under the surface, Dr. Gresser and I noted that the fish can and do move their eyeballs, sometimes in unison, and sometimes independently, which of course may extend their fields of monocular vision when the latter occurs. Merely for the record, the surface of the corneal surface protrudes between two and three mm. beyond the surface of the wall of the body. The vertical plane of the orbital cavities form an angle of 60 degrees anteriorly, whereas the sagittal planes converge above to an angle of about 40 degrees. (Practical anglers will forgive this digression in the interest of science!)



The field of binocular vision is important. To the best of my knowledge, no angling writer has stressed it before. Trout obviously take a fly within that field. In other words, when a trout sees a fly with one eye only, in order to take it he must turn toward it which brings it within his field of binocular vision. I have often observed that when a trout is watching a drifting fly, it will back downstream under it, rather than to one side of it as would be the case if he had only monocular vision; i.e., could only see an object with one eye at a time, as most investigators have intimated. It should be noted that the pupil of the trout's eye is not round, but extends toward the front, which aids its binocular vision.

I do not believe that a trout can place an object accurately in space when viewing it with one eye — any more than we can, although we are so accustomed to stereoscopic binocular vision and the relative position of familiar objects that even when closing one eye we can closely approximate the position of familiar objects in space. But the trout, looking through open water at a drifting nymph with one eye only, with no intervening objects to help it relate its position, cannot accurately determine its exact position or distance away. But it can and does turn toward the nymph if it wishes to take it, and this automatically brings it within its field of binocular vision. It can then accurately determine its exact position. However, the trout can be aware of a nymph in its field of monocular vision.

Dr. Gresser says: "Much of the belief that fish were myopic (short-sighted) is based upon the mechanics of the human eye in water. However, the physical structure of the fish eye, the length of the axis of retina from lens and the spherical character of the latter, bespeak a hyperopic (far-sighted) refraction even in the medium of water." This in fact repudiates the long-held conviction on the part of angling writers that trout are short-sighted.

A few more facts that may be of interest: the trout has a very efficient mechanism for focusing the eye, not through altering the shape of the lens as is the case in the human eye, but by an actual movement of the lens in relation to the retina — somewhat as a camera is focused by moving the lens back and forth. The cornea of the trout's eye, that front section which acts merely as a protection to the pupil and lens, is flatter than ours, which tends to make the eye far-sighted. The lens, however, is more convex than ours and has a greater index of refraction (in order to overcome the index of refraction of the water that surrounds it), but this in fact, does not make the trout's eye short-sighted.

When the trout's eye is at rest, it is focused for short vision. If it wishes to extend the length of focus a muscle attached to the back of the lens contracts and moves the lens closer to the retina. Generally speaking, however, the focus of the lens in a trout's eye is for close vision compared to our eye, but the fish is actually what we, referring to the human eye, call "far-sighted."

Now, from all this we see that a trout under normal conditions (with its eye at rest) will not see a fly until it is quite near — how near, no one knows unfortunately, but somewhere in the neighborhood of 40 inches. However, when something about the fly attracts the trout's attention at a longer distance from the eye — such as a bright flash of light reflected from the fly, or a decided "unnatural" movement of the fly — the eye can assume a longer focus and it will see such a fly at a greater distance than it would with its eye at rest.

At how great a distance I can only surmise from actual experiences on the stream. If a trout is not in a feeding mood, and therefore not on the lookout for flies, it has often been necessary to drift a wet fly within a foot or less of his eye before he has paid any attention to it. On the other hand, when a trout is hungry, I have seen him come five or six feet for a submerged fly. Note that I am referring to *submerged* flies only; if they are on the surface an entirely different problem is involved — that of light sparkles in the surface film caused by the tiny depressions made by the hackle points of the fly in the surface film.

I asked Dr. Gresser how clearly a trout can see. He replied: "According to the retina I think comparatively well. In the human eye it has been established beyond doubt that the particular elements of the retina, the rods and cones, have distinct and separate properties. The former have to do with the perception of movement, and the latter for sharpness and color. The fish's retina possesses both elements. In the human eye the area of sharpest direct vision is almost entirely made up of cones, whereas as one proceeds toward the periphery the rods increase in frequency. Verrier, amongst other researchers, has determined that in the trout's eye there is an area richer in cones, hence predicating a particularized area for sharper vision." All I can add to that is, that trout have sufficiently sharp vision for their purposes, or there wouldn't be many trout in the world!

From *My Friend the Trout* by Eugene V. Connett III, copyright 1961 by D. Van Nostrand Company, Inc.

Does a trout respond to a grasshopper or plump stonefly the same way we do to a perfectly grilled T-bone?

for saliva to assist underwater feeding.

For those who wish to go beyond the superficial aspects of learning about vision I would suggest the book *Vision in Vertebrates* by M.A. Ali and M.A. Klyne, 1985, Plenum Press. Be aware, however, that much is yet unknown concerning the anatomical basis for subtle differences in selective visual discrimination in different species. For example, see the article, "The Functional Architecture of the Retina," in the December 1986 issue of *Scientific American* for a review of the latest research on the complexity of the retina and its functioning.

Besides the obvious advantage of aquatic respiration, the lateral line system of fishes gives them a tremendous advantage over us for interpreting what's going on in the underwater world. The lateral line has often been considered as an extension of the sense of hearing. This is not accurate; the lateral line is more of a remote sense of touch. A trout can detect and locate a one-millimeter water flea swimming nearby through its lateral line sensing the pressure waves from the water flea's movement. I have observed well fed trout in excellent condition suffering from parasite-induced eye cataracts to such a degree that their corneas were completely opaque. Eyes with such cataracts could detect light and perhaps some movement, but probably not much more. I assume that the lateral line becomes the major sensory system used for feeding in blind trout.

The angling literature on trout vision typically makes a special case for surface feeding or dry fly fishing. The fly is on the surface of the water and the trout is viewing it from below. What is perceived in the way of shape and color? Again, I would suggest putting on a face mask, going underwater and seeing for yourself under different light conditions.

It is perhaps instructive to consider the most specialized surface feeding fish in the world, the famous four-eyed fish of the genus *Anableps.* The eye of *Anableps* is divided into two halves. The upper half is above the water surface and functions as a terrestrially specialized eye. The lower half is below the surface and functions as a typical fish eye. In the famous Halford-Skues controversy of nearly a century ago over dry fly versus wet fly fishing as proper angling protocol, it occurs to me that Skues missed an opportunity to score for his position by failing to make the point that if God had intended trout to be strictly surface feeders, He would have given them four eyes like *Anableps.*

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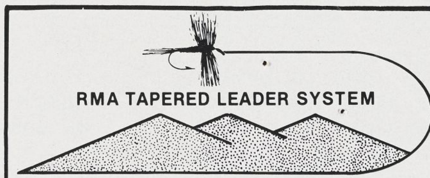

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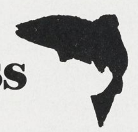

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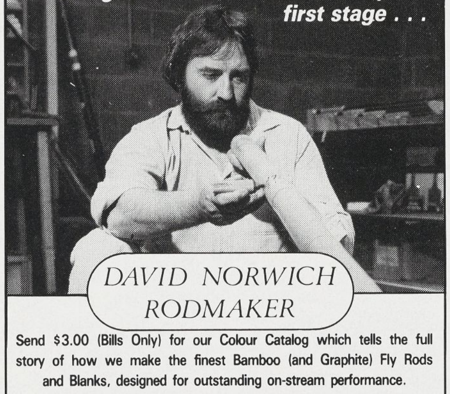

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Twenty-twenty vision?

*The eyesight of trout is a subject of intense speculation, but, after lengthy research and practical experience, **JOHN GODDARD** comes up with some startling new facts*

THIS IS A subject that has fascinated me for many years as our knowledge of how a fish sees and what he sees is sketchy to say the least. While we may make educated guesses, one thing no one can say is how the brain of a fish interprets the message transmitted from the eyes. However, when it comes to *how* a fish sees we should be able to make some pretty accurate assessments, by combining known scientific facts with carefully controlled experiments and/or observations.

During the late '70s when Brian Clarke and I were working on our book *The Trout and the Fly,* we were both involved in a tremendous amount of research and also carried out a lot of most interesting experiments, many on various aspects of fish vision.

After publication of our book I decided personally to pursue some of these aspects and, as a result, have now reached certain conclusions which I hope in the fullness of time will prove to be correct.

One of the most intriguing aspects of a trout's vision is the fish's ability to scan an arc of 180 degrees or more on each side of its body while at the same time being able also to observe objects immediately ahead with binocular vision where the arc of the eyes overlap.

Obviously this area of binocular vision must be very important, particularly to a brown trout that spends a large percentage of its time searching for food on or near the surface. Would it not therefore be interesting from a fishing point of view, I asked myself, to find out the precise area that was covered by the fish's binocular vision?

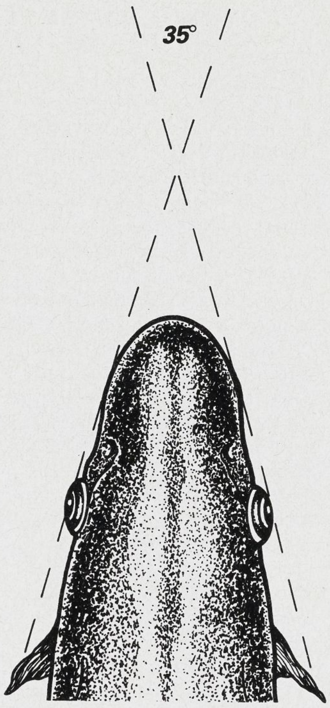
On referring to all the books in my library that cover the vision of fish, little seems to have been written about this aspect. The only reference, which most of them repeat, is that a trout has a narrow arc or band of binocular vision some 45 degrees dead ahead, where the arc of the eyes overlap.

Now it seemed strange to me that a trout which spends much of its time searching the undersurface or mirror overhead would only have binocular vision immediately ahead. I therefore decided to study the structure and position of the eye in the head of the trout. The first point I noticed — and one which seems to have escaped the attention of other researchers — was that not only do the eyes slope inward slightly towards the nose, but they also slope inward to the top of the head. In effect this means that not only does the arc of the eyes overlap immediately ahead but also over the top of the trout's head, so surely this should mean that the range of binocular vision would be very much more extensive than previously suspected?

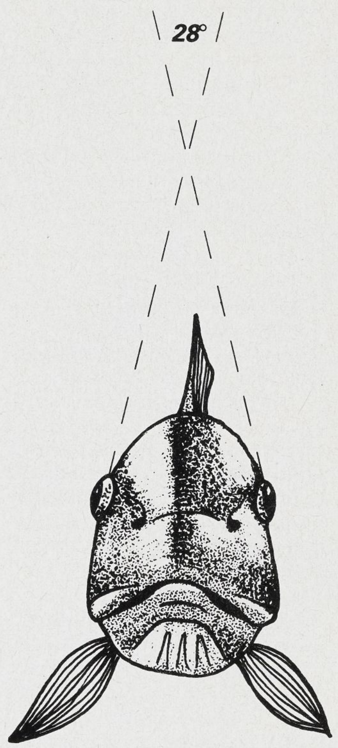
To find out what area this covered I took a series of close-up photographs of the heads of many trout — both from directly in front and also from overhead. I then measured the angles of the arcs formed by the inward angles of the eyes in front and overhead. While it was not possible with the equipment available to me to measure these angles precisely, I am confident that they are probably accurate to within at least a couple of degrees.

To start with, I found that the arc immediately in front was about 35 degrees, and not, as previously supposed, 45 degrees. The arc overhead was a little less and seemed to be about 28 degrees. Due to the fact that the two arcs (or more probably elongated cones) of binocular vision overlap considerably because of the two inwardly converging angles of the eyes, I assume that the overall area covered by binocular vision is about 100 degrees from in front to overhead. I also assume that the trout's binocular vision at each end of this arc would be less acute, and that its most acute vision would occur where the cones overlap — which would probably be at an angle of about 30 degrees from the horizontal in front of the trout's head.

From many hundreds of subsequent personal observations of trout in their feeding lies I noticed that most trout seem to lie at a slight angle with their head up. This in effect means that this optimum angle of acute binocular vision is probably nearer to 45 degrees from the horizontal, which would enable the trout to observe not only the mirror above but also into the edge of its



The arc of vision immediately in front of a trout is 35 degrees and not, as commonly supposed, 45 degrees.



The arc of vision overhead is about 28 degrees.

window. During the latter stages of my research into the above I once again contacted Professor W.R.A. Muntz in the department of biology at Stirling University. Professor Muntz is one of the world's leading authorities on fish vision and had been of considerable help to me when I was researching the fish-vision section of our book.

Binocular vision

This time I asked him if he could provide some detailed information on the structure of a trout's eye with particular reference to its binocular vision and focusing ability. The information he provided was most interesting, as he was able to provide accurate details of how a trout moves the lens in its eye by means of a large retractor lentis muscle to adjust its focus. When at rest in the retina, the lens is so positioned that anything in front and overhead is in close focus, which to some degree seems to confirm my research. This lentis muscle when retracted moves the lens both inwards and towards the back of the retina in a straight line away from the nose, thereby providing focus to infinity directly in front and to some degree above.

As a matter of interest, during the vision research for our book we had established with the help of Professor Muntz that infinity occurred at about two feet. Having, I hope, established the approximate area of a trout's binocular vision I now wanted to establish, if possible, the width of water overhead and in front that this would cover. First of all we must take the two arcs first discussed: the one in front at 35 degrees and the one overhead at 28 degrees. A rough average would then be 32 degrees. This means that if the trout's eyes were focused at less than infinity he would be aware only of approaching food within a narrow arc no more than 13 inches wide at most. Even with its eyes focused to infinity and concentrating on approaching food within its area of binocular vision, the band of water above and in front covered would be less than 30 inches wide at the maximum distance.

Seldom is one able to confirm theories by practical tests or observations in the field, but early last season I was most fortunate to find a co-operative trout in a perfect lie in such a position that, with dense cover behind and partly over me, I was able to lower a dry-fly from directly above him and place it very accurately on the water a few feet in front of the spot where he was rising. To start with I was drifting the fly down to him at predetermined distances to each side, and by this method I quickly established that my theory seemed reasonably accurate, as with the trout lying only about 12 inches below the surface he completely ignored my fly if it were more than 18 inches to either side of his lie. I was about to retire and leave the trout in peace when

TIME FOR ACTION

*The number of salmon netted in the Tay is nothing short of horrendous, says **MICHAEL SMITH**, who recommends some urgent steps to save this once-prolific river*

THE TAY is Scotland's greatest river in terms of water volume, width, length (117 miles), major tributaries (11), large lochs (10) and huge catchment area of almost 3,000 square miles. As a salmon rod fishery it should have no equal and few rivals, but sadly this is not so. Ten years of living on its lovely banks, and much of this time spent investigating its history and mystery, have led to my penning these observations.

Throughout the 1800s the river's salmon were heavily exploited by man, using almost every netting means available. Late that century, and early into the next, a few men emerged who had remarkable vision and dedication. The first of these was Sir Robert Menzies, of Castle Menzies by Aberfeldy. In 1893 he called a meeting of all proprietors upstream of Campsie Linn. In December of that year agreement was reached and river netting ceased above the Linn. There was an immediate improvement in salmon stocks throughout.

In 1898, the legendary Peter Donald Malloch laid a scheme before the Earl of Ancaster and Mr Archibald Coats. It pleased them and this was how the Tay Salmon Fisheries Co was formed. With an initial capital of £70,000 they leased or bought out nets on the river and in the estuary. Peter Malloch managed the company wisely and their profits flourished in symbiosis with the river's salmon stocks. They were unable to lease Scone Palace river nets, and I quote Malloch: "I have no hestitation in stating that if we had got the Earl of Mansfield's fishings, then we could more than double the supply of fish!" Peter Malloch died in 1921 but his company and the Tay prospered for many more years.

In recent times the management of TSF changed. They stopped leasing the Barony fishings around Newburgh and netting intensified there. Then, without statute, netting cobles were powered by engines instead of oars, and winches were likewise powered instead of being worked by hand. Salmon stocks faltered under this deadly and efficient onslaught. Rod fishing increased in popularity and salmon numbers wilted. The crunch came in 1980.

The Tay Salmon Fisheries Co (TSF) disagreed with the Perth City Council, and lost their lease on the Perth fishings. These six netting stations are intensively fished by a Mr Clements and annually remove around 12,000 salmon and grilse from the angling and spawning stock.

Today the situation is this. Salmon leaving the North Sea and entering the Tay estuary as far as the River Earn have to swim through water of almost zero visibility due to tidal action on the mudflats. They have to pass the nets of the Dundee, Birkhall, Balmerino, Barony and TSF stations. From the confluence of the Earn upstream to Perth they find up to 13 netting stations operated by Mr Clements and Mr Mitchell (TSF) competing to catch them. The few salmon that survive to swim past Perth are unlikely to pass Lord Mansfield's nets at Scone. Collectively, these stations killed over 20,000 salmon and grilse last July while some rod beats "enjoyed" their worst season on record.

In 1985 (a year of high rainfall) catch returns show that the rod:net catch ratios on Dee and Spey were 50:50 or better. Here on Tayside, the ratio was 20:80 overall; grilse 4:96. The manager of Tay Salmon Fisheries has stated to the press that "if nets are so damaging then the upper owners should put their money where their mouths are, and buy the nets out."

In the anglers' defence I would point out that due to so few fish getting into the river, poor beats are useless, while good beats are poor and TSF own many of the best beats. Many owners receive barely enough revenue to pay their rates, and certainly not enough to employ a gillie. A lot of us feel that our only function is to finance and protect the spawning and nursery areas for the profit of netsmen.

Spinning for salmon on the Tay at Benchill.

While we often hear of netsmen claiming compensation, I wonder whether the reverse should be applied. Surely it is the netsmen who are the proven parasites and it is the angling/tourist concerns who suffer loss of stock, revenue and employment.

The salmon is a magnificent and resilient creature. If the following steps are taken then Tayside will once again be the mecca for anglers seeking big Atlantic salmon.

- Lord Mansfield should cease river netting immediately. To continue would be in utter contempt of his 120-plus upstream neighbours.
- The Tay Salmon Fisheries Co shareholders should act against their company's intransigent management.
- The Secretary of State should extend the weekly close period for nets to 60 hours immediately and for longer if deemed necessary.
- It is economic and genetic folly to net dwindling spring salmon stocks. Professor Dunnett's salmon advisory committee should advise accordingly.

These four steps would at a stroke conserve salmon and improve rural Perthshire's prosperity and employment prospects. I would not dream of asking the Crown Estate Commissioners to consider campaignig for a levy on netted wild salmon, but on reflection it's not a bad idea!

Charles McLaren

ON February 27 a congregation gathered from many parts of Scotland, representatives from Kinlochewe and Altnaharra; as well as those who had known him from early childhood, to celebrate the life of Charles McLaren, who died very suddenly in this country while returning from holiday in Portugal.

The following is part of the address given at Perth Crematorium by his great friend, the Rev Graeme Longmuir:

Charles was a husband, father, friend, hotelier, author and fisherman *par excellence,* holding a fly-casting distance championship. I wonder how many of the guests at the Culag Hotel in Lochinver or the Altnaharra Hotel were regular guests just *because* it was Charles who was there? Or was it because of the very genuine interest he and Barbara took in all their guests whether they were there just to enjoy the scenery or, getting their priorities right, there for the fishing?

It was one mark of his sincerity that when guests left, he waved them off, though — with that characteristic humour which formed the backbone of his life — with the words, "It's only to make sure that you haven't taken the silver!"

In *Trout and Salmon* some years ago I wrote about two fishermen to whom I owe an unpayable debt. One was an old gillie in North Uist, the other was Charles. It happened like this.

I'd been holidaying at Altnaharra for two, maybe three years, and I hadn't caught a fish — not a real one, that is. I guess that Charles must have sensed that if something weren't done soon, I'd give up. Consequently, he said to me on my return to the hotel one evening: "Are you tired?" "Yes," I replied. "Oh, that's a pity. We're running out of salmon for the hotel and I wondered if you'd like to come with me."

What teenager could resist that offer? The fly was cast, as expertly as always, and I rose!

So we went, and, on the banks of a Sutherland river he cast and then, with a shrug, said: "I don't think there's anything here. Hold the rod and I'll walk further down."

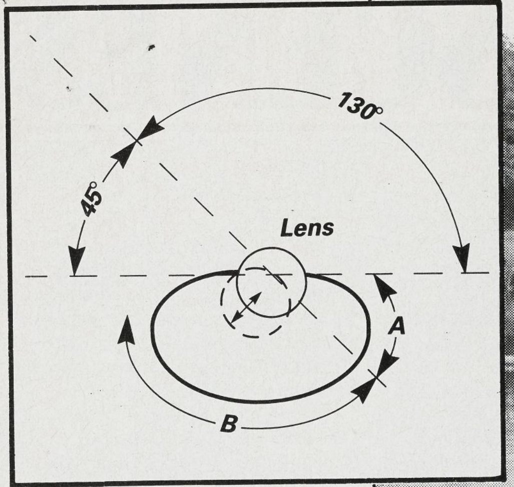
I did, and although it was some little time before I realised that the rod was behaving in a strange way, that magic evening we took back five salmon. He sent me back the following day, when I took my first salmon, unassisted. That exemplifies the sterling quality and insight of the man.

Charles knew the desolation of tragedy which shook him to the very core of his being and many of us who knew him in those grief-filled days felt helpless. Two things saved him: one was his faith he had learned in his childhood and the other was love — the love of and for his two daughters — but latterly and importantly, the very evident love he and his second wife, Lily, had for each other.

I have some flies he sent me from his shop at Invermudale last summer, in response to a letter I wrote him about fishing the Uist sea pools. One was separately packed and on it was written the telling phrase: "Try it!" That, in essence, was how he lived his life.

The sympathy of many is extended to his wife Lily and to his daughters Lorna and Baba.

Graeme Longmuir



Eye seen from above with the nostril to the right. In "A" the lens remains equidistant from the retina at all times to give an arc of about 45 degrees of vision focused to infinity at the rear. In "B" with the lens extended and at rest, everything in front over an arc of about 130 degrees is in close focus. With the lens retracted for forward infinity vision it appears that the trout's arc of binocular vision immediately ahead would be far less than 35 degrees.

Got him! Presenting a fly accurately to a deep-lying trout is not crucial, but great care must be taken in your approach.

to my astonishment he broke through the surface in the most perfect arc and took my fly in the air as it was hanging about 15 inches above the surface and about 20 inches upstream of his lie.

Fly in the air

Now the only way he could have seen this fly in the air was over the edge and in front of his window, and as I was reasonably sure that he had not tilted upwards before jumping I realised that if I could persuade him to jump and accept the fly a few more times I might also be able to prove, or disprove, my first theory that they may indeed have cones of binocular vision to some extent overhead as well as in front. Never have I met such a co-operative trout as during the next 15 minutes or so is I persuaded him to launch himself into the air 17 times!

His reactions were absolutely fascinating as each time I lowered the fly and swung it down towards him I was in no doubt at all as to whether he had seen it. When he did, all his fins — particularly his tail — would start vibrating, and these vibrations would increase in intensity as I swung the fly closer until it was in range of his lie, when he would jump and try to take it in mid-air. I quickly established that he would first see the fly in the air if I swung it to within three or four feet directly upstream of his lie. Now of course what I wished to establish was whether or not the trout was observing this fly over the edge of his window through his ordinary vision, or through his binocular vision.

If my theory were to be confirmed, he would be unaware of the fly if I positioned it in the air between three to four feet upstream and more than 18 inches off-centre, and so it proved to be. If I swung the fly down to him anywhere near that centre-line he would see it every time, but I could swing it down right past him repeatedly if it were more than about two feet off-centre and not once did he seem to be aware of it.

Now what conclusions can we draw from the above — and how will this help the fly-fisher improve his chances of success? 1, A trout lying and feeding within, say, 18 inches or so of the surface will probably be concentrating through his binocular vision and therefore the approaching fly-fisher would probably not register unless he made any sudden movements. 2, A trout lying very close to the surface will probably be focused below infinity so any approaching objects, including the fly-fisher, will be even less likely to be seen. In both cases, however, accurate casting will be necessary, as the fish is unlikely to be aware of any fly drifting down to him either on or below the surface either side of his narrow arc of binocular vision. In view of this I am now beginning to wonder whether this may explain our difficulty in tempting trout during those infuriating evening rises on stillwater when every trout in the lake seems to be rising and yet any pattern we offer is ignored. At this time the trout are usually cruising along almost in the surface so would be unlikely to see any fly less than about 24 inches immediately in front or 12 inches on either side of them. Maybe during this evening rise we would increase our chances if we fished our team of flies much closer together. I certainly intend to try this during the coming season.

Finally, what about those trout that are lying and feeding at a much deeper level? All the angling books that contain a section on trout vision tell us that the deeper a trout is lying the further off he can see the angler as of course the deeper he lies the larger his window overhead.

While this is certainly true, the additional distance he will be able to see is at best marginal, so I am now inclined to think that the more likely explanation for his increased awareness of our presence is due to the fact that at this depth he is unlikely to be concentrating through his binocular vision so everything on each side of his head within the whole 180-degree arc of his vision will be clearly seen. This also means that when presenting a fly to such a trout even more care will have to be taken with your approach but at the same time accurate presentation of your fly will not be crucial as the fish will be aware of approaching food over a much wider area.

In conclusion, I would add that the detailed information provided to me by Professor Muntz on the structure of a trout's eye and exactly how he moves his lens to provide his focusing ability has thrown up a most interesting new fact. The lentis muscle is apparently so positioned that when it expands or contracts to provide the necessary focusing adjustment to the lens, it moves in and out at such an angle that it leaves the front section of the lens equidistant at all times from the front section of the retina. This means that even when a trout is focusing at very short range on food immediately ahead of it, an arc of about 45 degrees on each side and to the rear of the fish is still focused to infinity.

Close to the surface

This would indicate that a trout feeding very close to the surface and focused at short range would be less likely to see you if you were either opposite him or even upstream, rather than well downstream, where you would come within the range of this 45-degree arc at his rear.

In confirmation of this point I am sure everyone has experienced evenings on a river when there has been a heavy fall of spinner and the trout are all lying so close to the surface that their dorsal fins are often protruding. During this period you can often approach a trout so closely that you are almost casting down on to him and yet more often than not he appears to be completely oblivious of your presence.

Sudden movements

This season when the opportunity arises, try positioning yourself opposite or even slightly upstream of any trout rising very close to the surface and cast to him from this position as I think he will be less likely to see you, but do remember to avoid any sudden movements and where possible cast with a wrist movement to avoid moving your arms.

Finally one other most interesting aspect of a trout's vision, which I do not think anyone has seriously considered, is whether a trout is able to focus one eye independently of the other. This is extremely difficult to prove or disprove, but while I think it is quite likely, I don't think that this facility would be of very great value to a trout, as most of the time when he is focusing on close-up objects he is utilising his binocular vision, when both lenses would have to be focused together. As I have already suggested, it would appear that his vision on each side and to the rear is permanently adjusted to infinity so this would leave only a relatively narrow arc towards the front on each side where he could use such a facility — and I really cannot visualise many circumstances in which this would be required.

BEHIND THE SCENES

Salmon close-time shock

The Association of Scottish District Salmon Fishery Boards (ASDFB), the body which claims to represent the views of Scottish district fishery boards, has rejected the recent Dept of Agriculture and Fisheries for Scotland exploratory proposal, issued by DAFS assistant secretary Iain M. Whitelaw, for a 12-hour increase in the national (Scottish) weekly close-time (WCT) from 42 to 54 hours. (So far as anglers are concerned a 72-hour WCT is the minimum needed; but 54 hours was at least a start). In an amendment to the minutes of the ASDFB Council meeting held on January 23, issued from ASDFB offices by its secretary, John Proudlock, it is stated that:

The department (DAFS) sought the views of the Association on whether the weekly close time should be increased by 12 hours from midnight on Friday to noon on Saturday. The Department's letter was before the Council and the chairman (Neil Graesser), invited comment. Mr Sellar stressed that there was no need to extend the weekly close time. Both Mr Clerk and James Mitchell agreed and said that both the Spey and Dee boards had already rejected the proposal. Mr Smart said that although it was a complex matter, he questioned the wisdom of the proposed extension because in his view the effect would be minimal. Ian Mitchell agreed. During discussion it was thought that illegal fishing would increase because of the absence of netting crews during the extended period. Council concluded that there was no merit to the proposal and agreed that the Association should write to the Department advising against any action to alter the existing weekly close time.

Vital decision

As anglers will appreciate, this was an extremely important decision. It is of equal significance that this decision was taken in the name of the ASDFB, a body which DAFS and Government chooses to recognise as the sole authoritative voice of fishery owners (net *and* rod) in Scotland. It is therefore perhaps worth noting who these ASDFB Council members were, who endorsed this action.

Patrick Sellar is a director of the Moray Firth netting firm J. and D. R. Sellar, of Macduff; a director of the Findhorn Salmon Fishing Co; and a shareholder in the Moray Firth/NE Scotland salmon and whitefish marketing company, Scotsal. He is also an executive member and former chairman of the Salmon Net Fishing Association of Scotland (SNFAS). It was Mr Sellar who in 1982 sought a two-week extension of the netting season in the Deveron district where his firm carries out its principal operations. Following the now historic "Deveron Inquiry" in July 1983, Mr Sellar's application — which was regarded as a test case for netsmen anxious to secure seasonal extensions elsewhere in Scotland — was rejected by the then Scottish secretary George Younger.

The chairman (Neil Graesser) is the owner of net and (River Cassley) rod fishings in the Kyle of Sutherland district. He is also chairman of the Kyle of Sutherland District Salmon Fishery Board (which inludes the rivers Shin, Oykel, Cassley and Carron). Among anglers he is perhaps best remembered in support of Mr Sellar's application at the 1983 Deveron Inquiry. Mr Graesser is a member of the management committee of the Atlantic Salmon Trust (AST), and a member of the current government salmon advisory committee.

Robert Clerk is employed by the estate management firm, Smiths-Gore, at Fochabers, mouth of Spey. Smiths-Gore manages and operates the river and estuary nets on the Spey owned by the Crown Estate Commissioners (CEC). Mr Clerk, who is responsible for these operations is perhaps best known to anglers for his leading role in the renowned "1981 Spey Dispute". This concerned complaints that bulldozed alterations to certain netting pools effectively blocked upstream movement of salmon. These complaints were never satisfactorily answered. Mr Clerk, however, who at the time was chairman of the Spey BoarJ and hence was responsible also for dealing with these complaints, survived. On January 19 this year, Mr Clerk was re-elected (under the new provisions of the 1986 UK Salmon Act) as chairman of the Spey District Salmon Fishery Board.

James Mitchell is a netsman, an Aberdeen fish-dealer, and a member of the Dee District Board.

Noel Smart is a director of the Montrose netting firm Joseph Johnston and Sons, which carries out its principal operations on the foreshores, and in the estuaries and rivers of the North Esk and South Esk. Johnston's "unofficial 1982 total catch was estimated at 83,600 — perhaps 60,000 of these being fish bound for other rivers; or about 25 per cent of the total Scottish reported catch", (See May 1986 *Scenes*). Its total "fish turnover" for 1982 was valued at about £1m. Mr Smart is also an executive member and former chairman of SNFAS, and a member of the Joint Esks/Bervie Area Salmon Fishery Board.

Ian Mitchell is managing director of the netting firm, Tay Salmon Fisheries Co. TSF, a long-established multi-million pound business, regularly extracts in excess of 40,000 salmon each season from its principal netting stations on the Tay below Perth. Mr Mitchell is current chairman of SNFAS, a member of the Tay Board, a member of the Joint Esks/Bervie Board, and a management committee member of the Atlantic Salmon Trust (AST) — a body of which the TSF Chairman, Lord Lansdowne, is a founder and one of AST's seven-only members. He is also a member of the new governmental salmon advisory committee.

One might also note that it was puzzling indeed that the Atlantic Salmon Conservation Trust's leading spokesman, Moray-based Hon James Stuart, though present at the meeting allegedly supported the Council's consensus that there "was no merit" in the DAFS proposal. Mr Stuart, who is general manager of the Moray Firth Salmon (Net) Fishing Co, and the Findhorn Salmon (Net) Fishing Co, is ASDFB council representative for the River Conon.

There are but two relevant questions regarding this most revealing ASDFB position and the persons who formulated it. First, were upper (rod) proprietorial representatives on the above and other Scottish district boards consulted on this vital issue? Second, if so, did these rods' representatives support *rejection* of an increased weekly close-time?

Official salmon secrets

Did you know that salmon matters are vital to the "defence and security of the realm"? Well, Government says they are. So, believe it or not, when the new salmon advisory committee met on February 26 at MAFF's Whitehall offices for its inaugural gathering, each of the 20 committee members was required to sign an oath of silence under the Official Secrets Act! How on earth the "salmon (civil) servants" and Government sought to justify this undertaking is not readily understood. By the same token — though, to be fair, many members were "ambushed" by this requirement — it is a little disappointing that members did not rise as one in righteous wrath and let it be known that such a requirement was "not on"!

After all, the committee is "advisory" only; it has neither statutory nor even quasi-judicial standing — indeed readers may recall that Government fought shy of any provision that either the Committee should have statutory powers, or that ministers should have "enabling powers"; each member is the nominee of a prominent representative group, hence obviously each group will need to de-brief and then re-brief its nominees for subsequent Committee gatherings.

Netsmen favourites

As for the formal issues to be considered — the effects of predators and fishing at low-water levels — the serious sparring has yet to commence. And as the odds are about 16:4 in favour of our principal *human* predators, one doesn't need to be a genius to recognise that the unfortunate grey seals will be in for a rough time; and indeed that the problems in "establishing the influence of low water on salmon stocks" will be shown to be so many, complex and judiciously convoluted that inevitably a "definite conclusion" stands only an outside chance.

All good fun

At any rate, it should all be good fun — and indeed ensure further sizeable waste of the taxpayers' money. All the many conflicting interests will at least have the oppportunity of sorting things out face-to-face. Lively and therapeutic stuff. It should also serve as a further — perhaps final? — opportunity for the still-dominant commercial interests to engage in yet more stalling. With a little luck this should mean they may not have to face the music for another few years yet.

And who knows; by then our Scottish netting friends (who through their representatives and "tame" clients on the committee can easily retain a majority on any key vote), may have been able to scratch up sufficient of their customary pseudo-scientific evidence of "salmon savings" via Atlantic Salmon Conservation Trust coastal net reductions etc, that they will be able to sustain the ASDFB case that the key "true conservation" provisions — a sizeably increased WCT and ACT (annual close time), together with much-tightened monitoring, regulation and inspection — are "irrelevant and unnecessary".

David Shaw

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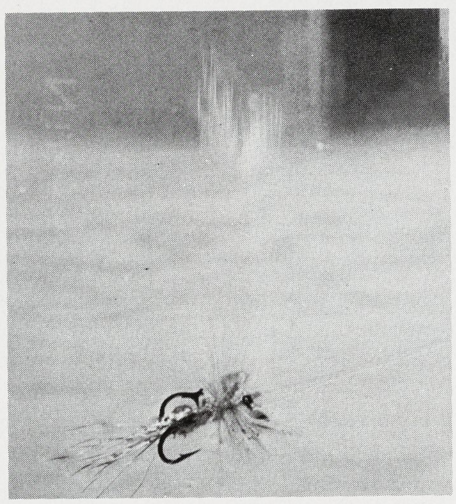
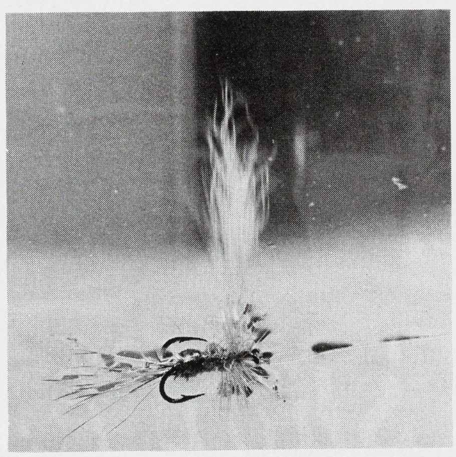
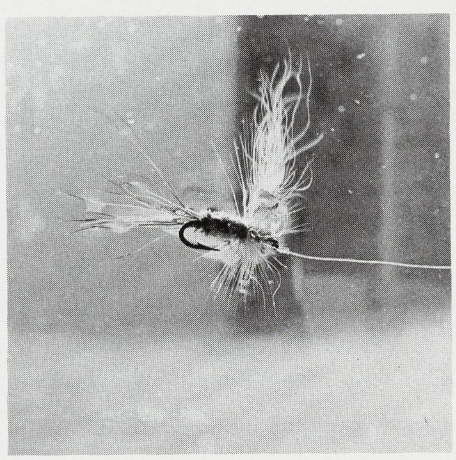
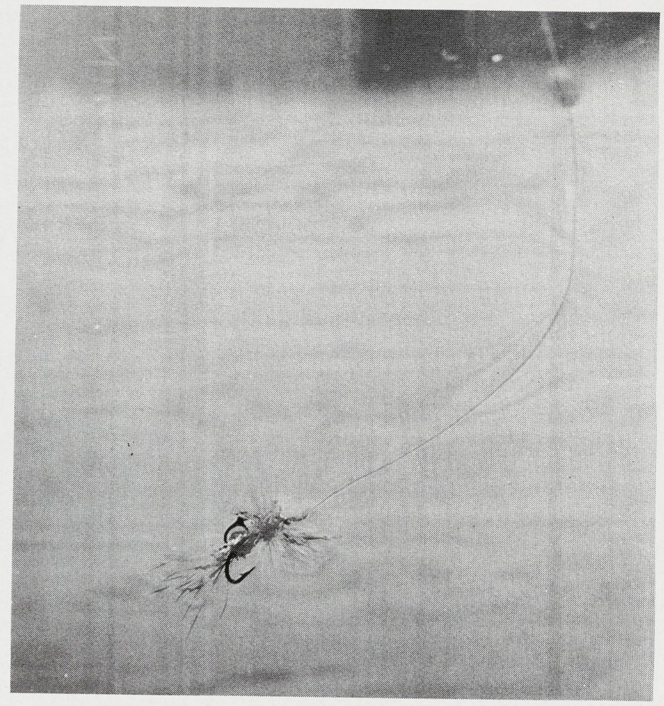
by pulling the fly to the edge of the window, photographing as it came closer. Note that whatever is *below* the surface is reflected *on* the surface and that the wings are the first thing visible above the surface at the window's edge.







The fly is now entirely within the window and those portions of it above the surface are now completely visible for the first time. A valuable lesson through the fish's eye—with thanks to Mr. Hewitt.



view this phenomenon, and I recently duplicated his experiment by working from an illustration in his 1948 book, A TROUT AND SALMON FISHERMAN FOR 75 YEARS. In the above picture, I am photographing a floating fly through the glass end of the tank, which is designed to simulate the trout's visual cone.

My tank is one foot square by three feet long. The end is angled at 48½ degrees, which is the angle of one side of the fish's window. Since light is distorted very little when going through the surface at right angles, I made certain the lens was square to the glass to get a distortion free picture.

This second photograph is the picture I took. A White-Wing Rat-Faced McDougal on a 1X tippet is visible only where it touches or breaks the surface. It is surrounded by the reflection of the tank bottom. The edge of the trout's (my) window is at the upper portion of the photo. I produced the following series of photos

Mottram

THOUGHTS ON ANGLING

CHAPTER I

SOME REFLECTIONS ON DRY FLIES

WHEN a point of gut stained sky-blue or grey, is looked at against the sky its appearance varies greatly according to the lighting conditions and the background. On a cloudless day when the sun is not very high, say at 10 a.m., stand with your back to the sun and hold the gut against various parts of the sky, held overhead it will appear darker than the sky, held low down near the horizon it will be lighter, and somewhere in between it will be invisible; now turn round and repeat the observations facing the sun, the gut will appear darker than the sky in all positions; with the sun on one's shoulder, it will be mostly darker than the sky, but a small region of invisibility will probably be found. The gut is invisible when the amount of sunlight reflected from the gut to the eye matches the amount of light coming from the sky.

On a day of alternating sun and cloud, the gut will be seen to vary widely in appearance according to whether it is viewed against white or grey cloud or against blue sky and as to whether it is in or out of direct sunlight.

On a grey day, especially when the sky is evenly grey, the gut will always appear conspicuously dark, in all conditions, against the sky.

Evening rise, early?

These variations in the visibility of gut have, I am convinced, a bearing upon fishing. They account for the great difficulty in catching trout on days of dull grey skies, why it is that sunny days are better than dull days and why days of alternating cloud and sun are by far the most favourable days.

This specially applies to gut-shy trout such as are found in public, hotel and society waters; in private fisheries where trout are little educated, the state of the sky is of less importance.

It is obvious that the appearance of the gut, its visibility, will be quite different according to whether it is seen by the trout in front, on its right or its left side, and according to whether the sun is in or out and whether the background is a white or grey cloud or blue sky.

After many casts in all of which the gut was conspicuous to the fish, one may occur when the conditions make for invisibility, therefore it pays, as long as the trout keeps rising, to go on casting in the hope of such an event. Experience shows that though a trout will refuse time after time and without hesitation, it will often, at last, rise boldly to the fly.

Some anglers keep changing the fly, trying many patterns and when at last the fish takes they conclude that success was due to the change of fly: I do not think this is a sound conclusion since exactly the same happens when the fly is not changed.

This leads one to ask, if the gut changes in appearance according to lighting and background, surely the fly must also change?

If one picks up an olive dun on the point of the finger, kills it by squeezing the thorax and then examines it against the sky and against surrounding trees, meadows and hills with the sun shining on it from different sides, a set of bewildering differences are seen, very wide differences: different parts of the fly behave differently, for instance the semi-transparent setæ, legs and wings do not tally in appearance with the opaque body and thorax, further, end-on views do not behave like side ones, colour varies very widely according to whether the sun is in front, behind or at the side of the fly, likewise any background tends to shine through the transparent parts. If, now, you place upon the top of another finger an artificial fly, considered to be a good imitation of an olive, such as

Halford's pattern, and examine this *vis-à-vis* with the natural, it will be seen that the artificial fly also varies widely in appearance according to the conditions, but to a much smaller extent than does the natural fly. It follows that under most circumstances the artificial will appear quite unlike the natural, but that occasionally there will be very considerable resemblance. This is to be expected because one is comparing a living fly with one made of entirely different materials, feather, fur, silk, etc., which will absorb, reflect and transmit light very differently to the living insect.

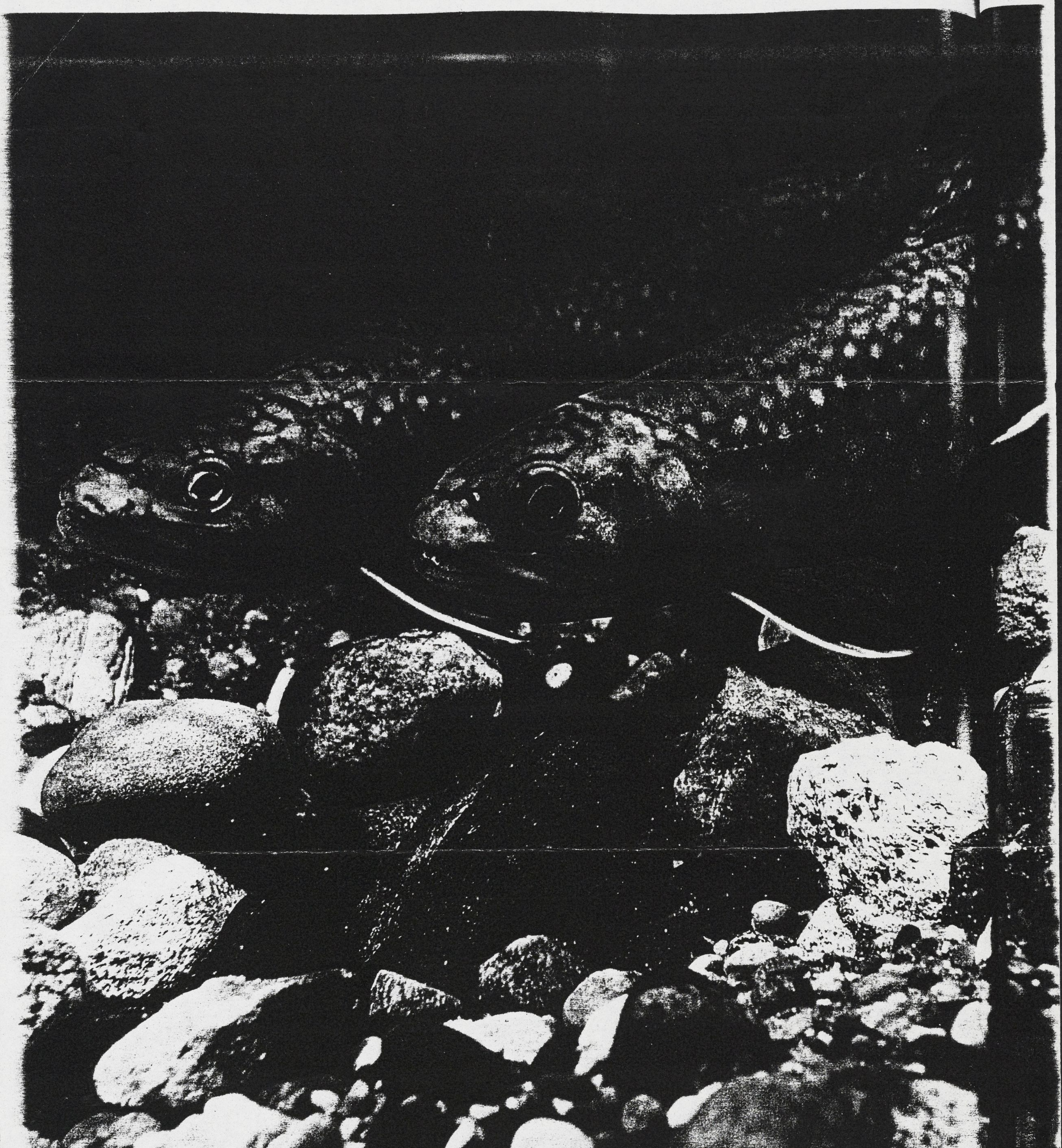
If one takes another pattern of olive, one again generally finds poor resemblance though occasionally considerable likeness and with this second pattern, the conditions for likeness are not those which hold for the first pattern. It is for this reason that one can have a number of artificial patterns of different colour and made of different materials, all of which will, at some time, resemble the natural and catch fish.

What has been said about the value of repeatedly casting over a feeding fish, now this side, now that, now in front, now behind, from the point of view of the visibility of gut, applies with much greater force when the fly is considered. It may be that at the very first cast, the fly happens to be so lit and so backgrounded that it appears as a good imitation of the natural, or, this may not happen until many casts have been made. There is no advantage in changing the fly because it has been refused, not at any rate until it has been refused many times.

It is evident that these facts about the appearance of artificial flies must be taken into account when one sets out to copy a natural fly. The best copy would be the one which, under varying conditions of lighting and background, most often happens to closely resemble the natural fly : success in catching trout is the best test, not the fly-tier's judgment in the unnatural lighting conditions of a room. Further it follows that several quite different dressings may all be successful imitations of say, the olive dun, one being a specially good imitation when the sun is shining on it, another when the sun is behind it, or when seen against the sky or against an overhanging bank; whilst in the hand these artificials look entirely different and none perhaps much like the natural fly.

It is not to be wondered at that some fishermen have confidence in one fly and others, in a widely different pattern; it is probable that of the many patterns designed to represent the olive dun, did one but know it, one is best to use on a grey day, another on a cloudless one, another close under the river bank and another under a canopy of trees, etc.; I feel sure that this is the case, though I am not able to say with confidence, which type of fly is best to use under each condition. On a bright sunny day, with the sun behind the fish, I personally like a dark wingless fly; light winged patterns with the sun on them appear to be much too light. If the sun is in front of the fish, I am not particular about the colour of the fly, but it must be a very sparsely hackled wingless fly, with a well-shaped body—a silhouette fly. I like a light coloured winged fly, say a Halford pattern, on very dull days or when fishing under trees or close under the bank, throwing between the fish and the bank. These preferences seem to me reasonable, at any rate they breed confidence and that makes for success. If the same fly is fished all day long, as many anglers do, a time will come as the sun goes round or clouds appear or disappear when the fish will take; I do not think this represents a change in the fish but a change in lighting conditions, the fly only being taken when they make it closely resemble the natural fly.

These effects of lighting on artificial flies clearly indicate that precise instructions for tying flies as regards the materials to be used rather than colour, etc., with the view of making the best possible imitation of the natural, are useless. By all means have precise instructions for patterns of flies, but do not expect that they will be the best fly to use under all conditions.



Check reference to Ward as
giving first ref to the "Window."

GONE FISH-WATCHING

(There's a sign upon your door)

article by BRUCE BROWN
photography by STEPHEN ROSS

IT WAS A DUSTY TREK from Hoodoo Pass down to Boiling Lake and up over Horsehead Pass into the Eagle Lakes Basin that August afternoon. Packhorses, trail bikes, and the thousands of sheep that are driven through the area had pulverized the soil to the consistency of fine face powder.

For much of the exposed climb to 7,600-foot Horsehead Pass in Washington's North Cascades, the wind kept us walking in our own dust, even though we were the only ones on the trail at the time. We paused long enough on the summit to study a forest fire burning out of control several thousand feet below and dozens of miles to the east, and then hurried on down toward the Eagle Lakes chain.

Because a Forest Service trail crew had warned us that Eagle Creek was the only local source of drinking water free of the parasite *Giardia,* my companions and I pulled out our poly bottles when we arrived at the inconspicuous little creek that connects the lower two Eagle Lakes. Heading upstream forty or fifty feet to get away from the trail and its contaminants, I bent down at the edge of a small pond at the base of a plashing waterfall, and was nearly as startled as the trout with whom I found myself face to face at a distance of perhaps a foot.

Retiring discreetly to a vantage point behind a log, I realized that this little pond, which measured perhaps ten feet by twenty feet and was no more than calf-deep, contained a dozen trout. Although small, ranging from four to an honest ten inches in length, they were handsome fish and unusually marked: a warm golden color with a faint flush of red on the gill covers, and as heavily spotted as an African leopard. These black spots, which occurred both above and below the lateral line, seemed to form a larger snakeskin-like pattern of chevrons that pulsated along their flanks as they swam.

A waterfall at the head of the pool and boulders at its tail prevented the fish from fleeing to another part of the stream. Within a few minutes they had calmed down and returned to their seemingly casual circling in search of food. Most followed the bits of sunken drift that tumbled over the falls, but I also saw one jump straight up out of the water after an insect and bend double in midair like a jackknife, whose size it closely approximated.

The Eagle Lakes are a great fishing mecca, but fishermen who hike and ride past by the hundreds every summer show no interest in these fish, which I guessed were some kind of a

Spawning begins when a male brook trout sidles alongside a female (foreground) and shivers, inducing her to dig the nest area, or redd.

Using her writhing body to fan away sediment, the female digs a depression in a Michigan streambed.

rainbow–cutthroat hybrid. Fishing for them would be like fishing in your bathtub, and even if you caught the whole mess of them there wouldn't be enough to make a decent meal for one person. There was no challenge here, and so the sportsmen sped on to bigger water and the ever-more-distant lakes.

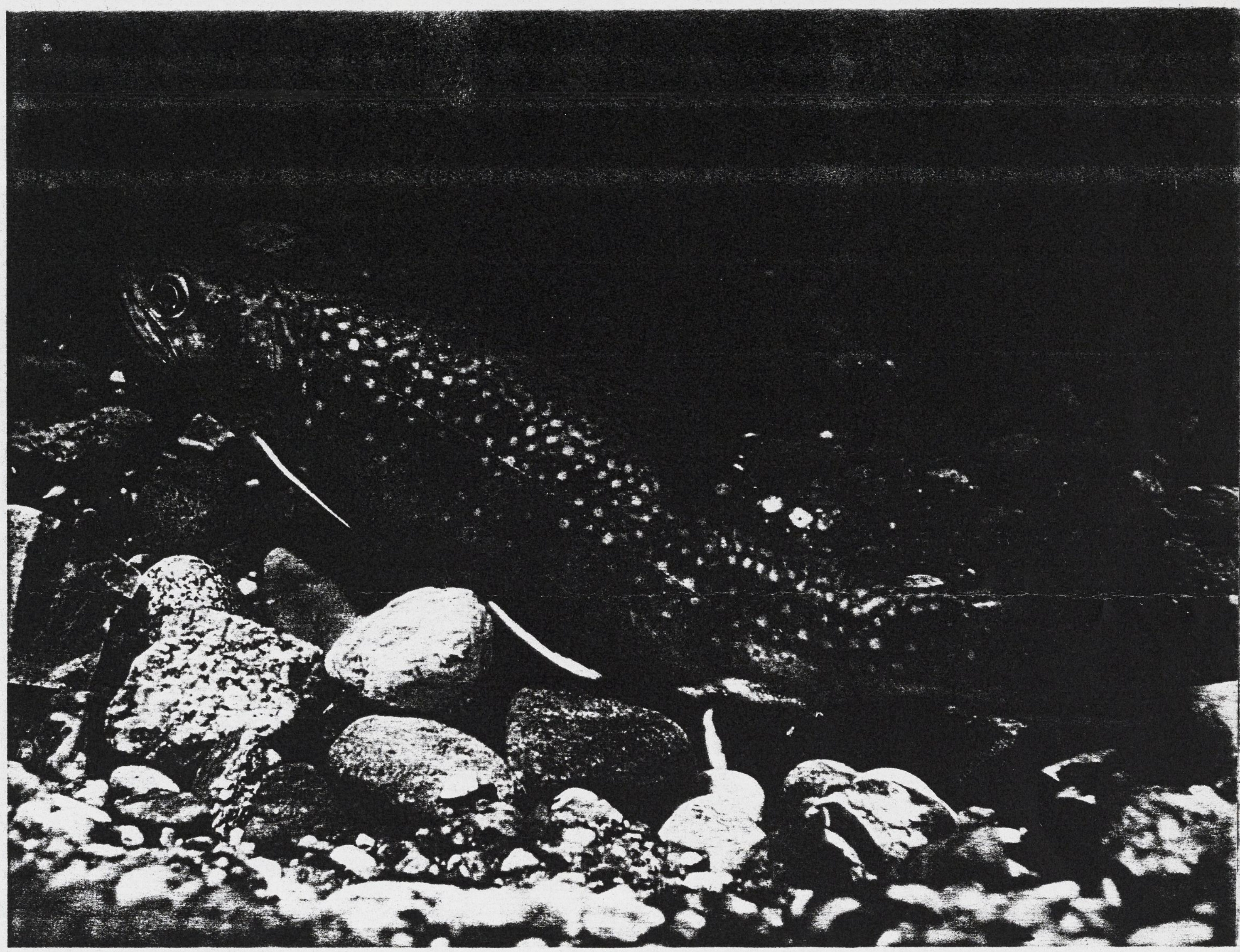
For us, however, this tiny pool provided a fascinating microcosm, a place where the ways of fish and water could be studied with clarity from a reclining position. I remember thinking at the time, too, that these fish showed how traditional fishing differs from the sport that has been quietly rising in its shadow for the better part of a century, namely fish-watching.

ACTUALLY, FISH CAN BE SEEN in many more situations than people suspect, from deep in the wilderness to the heart of some cities, from both coasts to the many rivers and lakes of the American Midwest. I myself have observed salmon, trout, char, and other choice cold-water game fish everywhere from the remote wilds of Alaska to the dock off the back of one of Seattle's fanciest lakeside watering holes, where the gunmetal-blue silhouettes of sockeye salmon slide through the reflections of the mercury vapor lights.

It is obviously impossible to see fish where there are none, but a knowledgeable observer can often see and identify more fish than an equally experienced fisherman can catch in the same place during the same period of time. And unlike the scuba-diving expeditions of saltwater fish-watchers like Jacques Cousteau, the sport of freshwater fish-watchers requires no exceptional bravery, foreign travel, expensive gear, or macho skills. Freshwater fish-watching is something you can do when you just want an excuse to go sit by a stream or lake for an hour. Because the equipment needs are minimal, the freshwater fish-watcher is both ready for the unexpected encounter and free from the frustrations of broken leaders and snarled reels.

Certain aspects of fish behavior can only be investigated completely by fishing in its various and storied forms, but fishing does not (and in fact cannot) reveal the complete piscine mystery. Fishing is an artificial test of response under stress which, if successful, removes the fish entirely from its natural surroundings and behavior. Despite the great sense of rapport and appreciative understanding that characterizes the best fishermen, fishing per se is blind to the undisturbed world of fish. The instant the hook is set, all normal affairs on both ends of the line are abandoned.

Fish-watching, by contrast, is almost exclusively concerned with the natural



Backing into the nest, the female trout senses its shape, depth, and the stones into which eggs will be laid.

air is Not closed to humans. Just flight.

creature, darting and dashing, lolling in the depths of a pool or hiding under a root ball. Its quarry is the one that got away; its aim, to keep it that way.

THE OBVIOUS ANALOG of fish-watching is birdwatching. Each is devoted to the appreciation of often beautiful creatures that are capable of movement in a medium that is closed to humans, and each is the outgrowth of subsistence, commercial, and sport killing of the same.

Just as John James Audubon was an accomplished shooter of birds for table and study, many pioneering fish-watchers have been fishermen who came to linger longer and longer in the presence of their supposed prey. Fly-fishermen in particular must spend time studying fish to be effective, and in certain parts of England "fishing ethics require the fisherman to see his fish before he casts for it," according to Nick Lyons, the noted fisherman, author, and publisher of fishing books. To observe salmon and trout from their own perspective, one fly-fisherman, the late Roderick Haig-Brown, even snorkeled in the same Vancouver Island rivers he fished. Most fish-watchers, however, are content with watching from the shore, or as far from it as hip boots will take them.

Fish-watching shares certain fundamental principles with birdwatching (for example, it is generally most effective in either case to wait for the creatures to come to you, rather than to pursue them); but, because of the special visual qualities of water, there are also a number of differences. For the sake of observation and concealment, one must realize that the fish sees the world outside the stream as a circle of light shimmering overhead, the objects closest to the fish drawn into distorted relief against the sky at the center. Originally described and photographed just before World War I by pioneer English fish-watcher Francis Ward, this circle of light resembles the aptly named "fish-eye" effect produced with an extremely wide-angle lens in photography.

For the fish-watcher, there are other limits to vision that must be considered. Surface opacity is almost always a problem to one degree or another. It can be reduced by putting the sun at your back, by wearing polarized sunglasses of the sort used by many fishermen, and by attempting, wherever possible, to get at least ten feet above the water, as on bridges or climbable trees along the shore. One dedicated fish-watcher, Pennsylvania State University researcher Robert Bachman, has even gone to the trouble of erecting aluminum scaffolding along the bank of Pennsylvania's Spruce Creek to create a permanent elevated fish-watching

Fierce fighting may erupt if an intruding male (rear) attempts to steal the female during nest-building.

blind in a place where none presented itself naturally.

Itinerant fish-watchers generally find the natural terrain to be both obstacle and ally, often frustrating their efforts but also occasionally presenting exceptional vistas. Last summer a friend and I found such a fish-watching vista in the cliffs above a mountain lake in Olympic National Park. Although we had come to do some climbing around Mount Deception, we spent the better part of the day watching more than a thousand red-finned brook trout cruising the waters of Royal Lake, and taking dozens of photographs which did not turn out (unlike Stephen Ross' exceptional photographs of spawning Michigan brookies).

Another method of fish-watching used on lakes and saltwater is the so-called glass-bottomed bucket, which can be anything from commercial products like the Aquascope to home-made combinations of pipe and glass to a simple swimming mask laid on the water. Here the idea is to cut the reflective interference by providing the human viewer with a vantage point just under the surface of the water. Despite the limitations of a relatively narrow field of vision, glass-bottomed buckets can open up the underwater world better than anything short of a swim when conditions are right.

As an outdoor sport, fish-watching may not be as popular as birdwatching or fishing, but it has more adherents than many people might think. In Yellowstone National Park in 1978, for instance, 130,000 people used Fishing Bridge as a vantage point to watch trout in the Yellowstone River, according to Paul Schullery, a writer and a former Yellowstone naturalist and ranger. "In August of that year," says Schullery, "more people watched fish from the bridge than fished in the whole park."

Thousands of spectators line the high banks of British Columbia's Adams River to watch the large runs of sockeye salmon that flood that tributary of the Fraser River every four years. People also congregate at spots like northern Vermont's Willoughby River to watch rainbow trout leap at impassable falls, according to Tom Rosenbauer, editor of *Orvis News*.

IF YOU SPEND enough time watching fish—and an afternoon in the right place can be enough time—you become aware that there is considerable variety and drama in fish behavior. Far from being cold and alien, as many people think of them, fish can be heatedly emotional and express themselves through a variety of physical displays.

In spawning season, for instance, Pacific salmon characteristically put on a

Mouths agape, the mated trout deposit eggs and milt in a two-second burst; the male is in the foreground.

prolonged dance of prowess that illustrates their mastery over moving water. They chase, parry, circle, and dash, and become progressively consumed by procreative frenzy as they near the death that claims virtually all of them after they spawn. Some even have the ability to change their elaborate mating colors almost instantaneously to reflect a change in their position in the nest hierarchy. In a matter of seconds, the fish that looked at first glance like a plain female chum salmon reveals itself to be a boldly hued male.

Eventually, the fish-watcher may get the feeling that he himself is being watched. The feeling first came over me one November afternoon I spent on a stream near my home in western Washington. The weather had just turned cold and clear after a week of rain, and I suspected the wild run of coho salmon might be in. I'd waded barely a half-mile from the bridge when I came around a bend to the sight of two coho males thrashing their way up out of the water in desperate combat fifteen yards ahead of me. Each was about two feet long and had a rich flash of burgundy on its flanks. The slender females nearby occasionally chased each other when one dug too close to the nest of another, but most of the action came from the brightly colored bucks, who drove at each other repeatedly, attempting to rake their opponents with their wicked canines.

The dominant male of the bunch was a six-pounder with red-hot-iron sides, a blue-black head, white moustache-like markings on his upper lip, and a white stripe down the crest of his back, which was out of the water often as he defended his turf. From the bleached, knife-edge look of his back, I guessed he was nearing the end and would probably spawn that night.

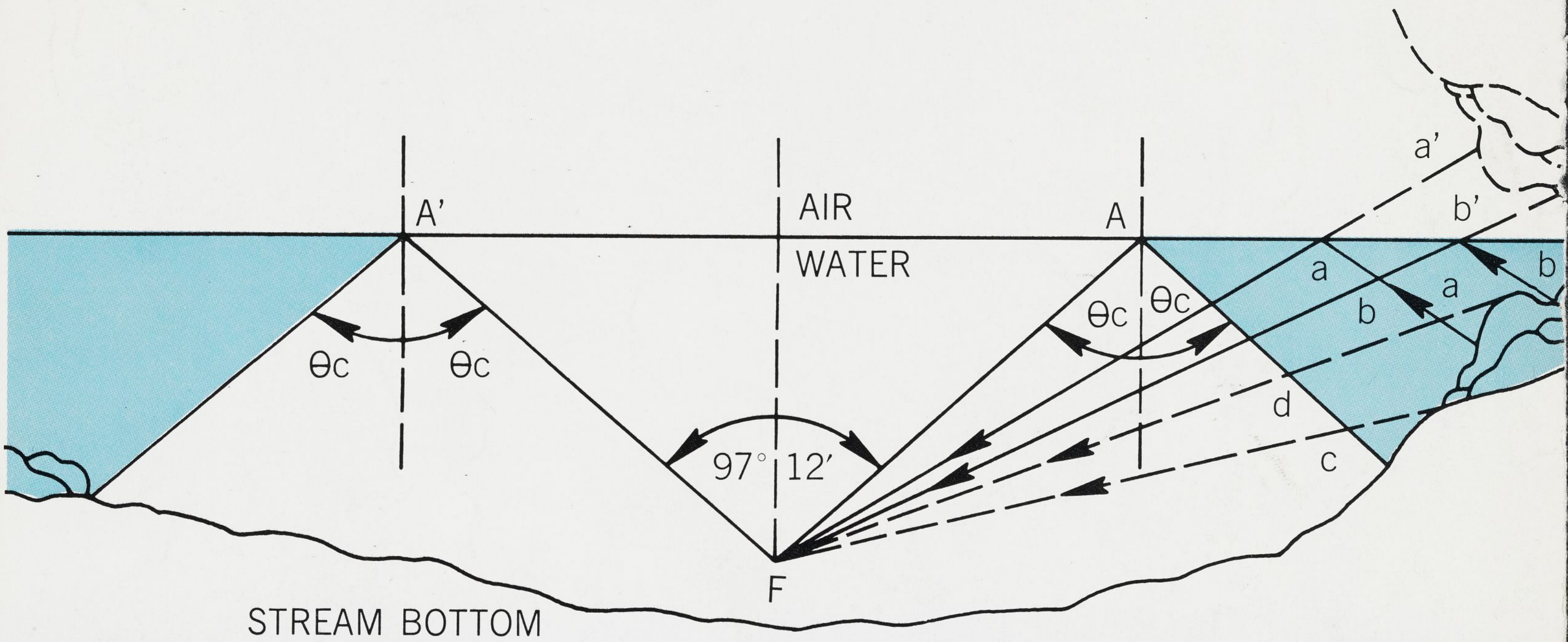
I tried to creep closer, but when I came to within a dozen yards he suddenly rushed straight up the twisting rope of fast water and across the stream to a point directly even with me. Less than five feet separated us as he rode the current as easily as a hawk on the wind, and he was plainly scrutinizing me with his unblinking eye.

I expected the terrified explosion of water that usually comes when a salmon sees or smells a man, but this fish did not seem to be afraid. He hung before me for several seconds, as if we were connected by something much finer even than 8X tippet, and then slowly fell off on the current, letting it carry him back toward his mate, tail first.

After waiting long enough to see that he did not sound the alarm to the other fish, I headed the other way, pondering the possibility that I had been seen by a salmon and recognized as a friend.

WHAT A FISH & WHAT THE ANGLER

Figure 3.



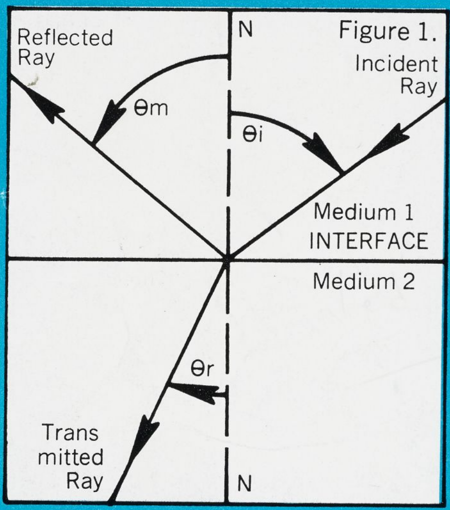


Figure 1. Diagram of a ray of light passing from the air through the air-water interface.

Figure 3. Cross-sectional diagram of fish's view (from position F) of objects seen within the water and outside the cone of vision.

By Robert L. Butler[1]
and Robert D. McCammon[2]

In examining a few books on the subject of fish vision, we have found discrepancies on measurements of the fish's window. The arc subtending the window is most often given as 97.6°. Diagrams to illustrate this point are remarkably similar to those noted in Nikolsky's book, *The Ecology of Fishes*, 1963; Wall's book, *The Vertebrate Eye and Its Adaptive Radiation,* 1942; and in a recent book entitled, *The Life of the Pond, 1967,* by William H. Amos. In *Rising Trout,* by Charles K. Fox, 1967, the window is described as being 83°. On the other hand, in a recent book edited by David Ingle, *The Central Nervous System and Fish Behavior,* 1968, it is diagramed as being 98°.

Most of these authors allude to the unique features of water through such terms as reflection, refraction, angle of incidence, etc. The diagrams are simplistic, lacking detail and devoid of equations which incorporate the physical principles of the above terms.

We are sufficiently pragmatic to accept the fact that a window does exist. Furthermore, we think the window is a function of water and air properties rather than optical properties of the fish and human eyes. Any diver not using a face mask has witnessed the window and its decrease in diameter when he approaches the surface. It is true, however, that we do not know what the fish truly sees. What and how his brain interprets the image on his retina is unknown. Light, however, that comes through his window is the same light that comes through our window when we are underwater at the fish's eye-level position.

As reference to a college text on optics will show, when a ray of light in one medium strikes the interface of a second medium, generally a portion is reflected and a portion is transmitted (Figure 1). According to Snell's Law the transmitted or refracted portion is bent as described by the equation

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Illustrated by George Gaadt

complete it. However, it is very important to note that less than $6,000,000.00 has gone into construction of the dam itself. Aside from salaries which would have been paid anyway, the bulk of expenditures has been for land acquisition and for roads and for bridges which are usable. Thus, the $6,000,000.00 cost of abandonment is small in comparison to the cost and tragic waste of completion..

On June 18, 1971, TVA filed an extremely poor environmental-impact statement on the Tellico project. In August, the Environmental Defense Fund, which was joined by the Association for the Preservation of the Little Tennessee River, National TU, and others, brought suit against TVA in the Federal District Court in Washington. The suit was moved to Birmingham in December, and later to Knoxville where the court placed a temporary injunction against the dam construction portion of the project pending its determination that TVA had filed an acceptable environmental-impact statement.

In early August, Walter L. Criley, director of Planning and Development for the Tennessee Department of Conservation, blasted the TVA environmental statement which, he said, "was one sided, biased, used semantics to prove preconceived points, and did not provide alternatives." TVA ignored his well-documented charges. Later in the month, the Tennessee Game and Fish Commission officially opposed the project.

In December, Tennessee's Governor Winfield Dunn, in a letter to TVA Chairman Aubrey Wagner, said that he would seek legislative action to protect the river and that the interests of the State would best be served if TVA were to discontinue plans to im-

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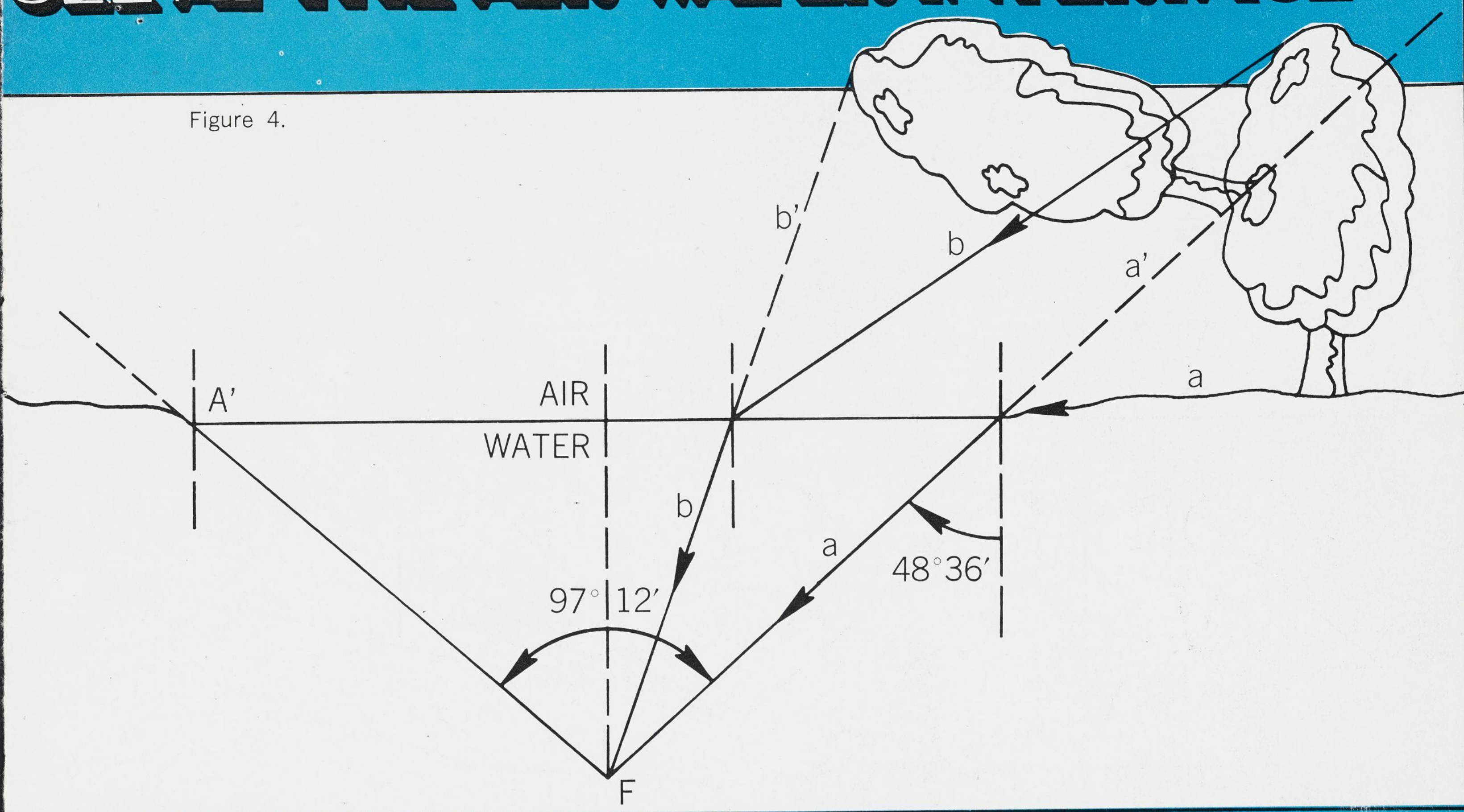
SEE AT THE AIR-WATER INTERFACE

Figure 4.



$n_1 \sin \theta_i = n_2 \sin \theta_r$, where n_1 and n_2 are the indices of refraction of medium 1 and medium 2, respectively. Further, if we assume that neither medium absorbs or scatters light significantly, the sum of the intensities of the transmitted and reflected rays must equal the intensity of the incident ray. Usually as the angle of incidence increases from 0 to 90°, the intensity of the reflected ray increases while correspondingly that of the transmitted ray decreases. The rate of change is not linear.

Light Emanating from Objects Underwater

The application of Snell's Law to the situation where light emanates from objects underwater (Figure 2) is described by the equation $1.33 \sin \theta_i = 1.0 \sin \theta_r$, hence $\sin \theta_i = 1/1.33 \sin \theta_r$. If a transmitted ray is to occur, the angle of refraction must lie between 0 and 90°; that is, $0 \leqq \sin \theta_r \leqq 1$, then $0 \leqq \sin \theta_i \leqq 1/1.33$ or $0 \leqq \sin \theta_i \leqq 48° 36'$. If the angle of incidence exceeds the actual value $\theta_i = 48° 36'$, then the incident ray is totally reflected. Consequently, to a fish at F, those objects lying in the shaded areas of Figure 3, unless they are observed directly via rays c and d, appear to the fish to lie above the surface and inverted as indicated by the dashed lines a' and b'.

Light Entering the Water from the Air

Snell's Law also applies to the situation where light enters water from the air, the fish's view of a fisherman or tree. In Figure 1, if medium 1 is air and medium 2 is water, then $1.0 \sin \theta_i = 1.33 \sin \theta_r$. Hence $\sin \theta_r = 1/1.33 \sin \theta_i$. Since the incident rays may enter the water with any angle of incidence between 0 and 90°, then $0 \leqq \sin \theta_i \leqq 1$. Hence $0 \leqq \sin \theta_r \leqq 1/1.33$, or $0 \leqq \theta_r \leqq 48° 36'$.

The fish at F presumably can perceive any object situated above the plane of the water surface (Figure 4), but such objects appear to the fish to lie within a cone of vision, AFA' having a total angle of $2\theta_c = 97° 12'$. The maximum refraction of a ray from air to water with 90° angle of incidence is 48° 36', the critical angle (θ_c). Since the intensity of the transmitted rays in this case diminishes sharply toward 0

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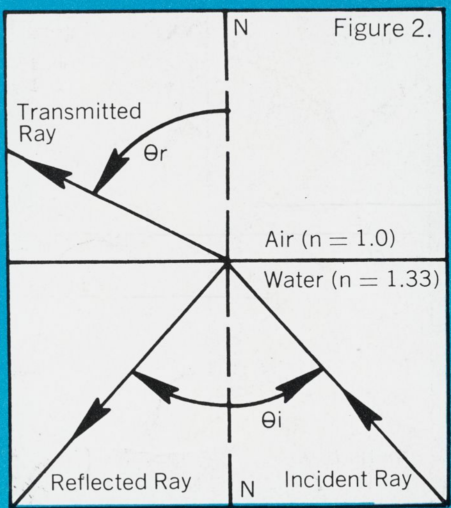
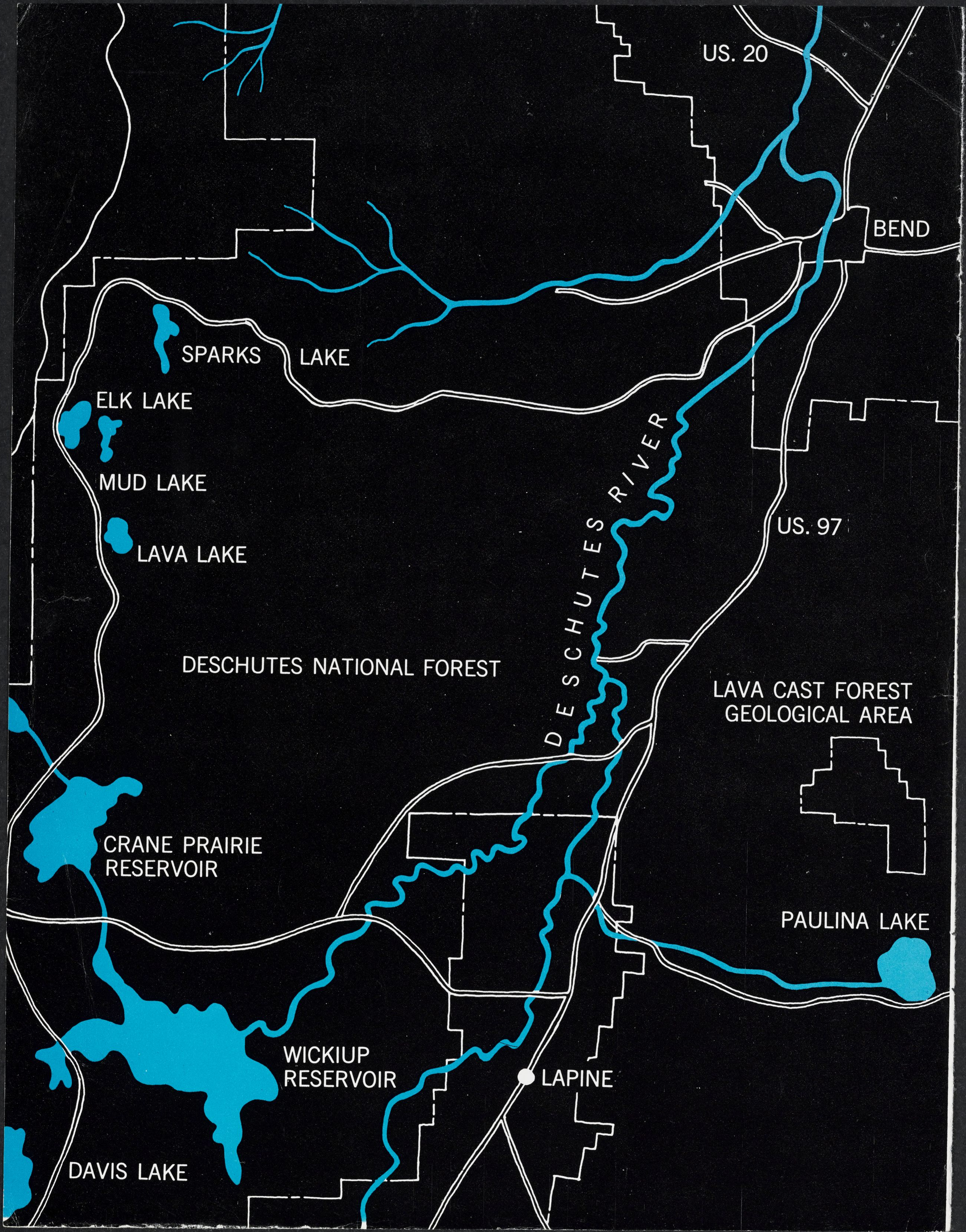


Figure 2. Diagram of a ray of light passing from the water through the water-air interface.

Figure 4. Cross-sectional diagram of fish's view (from position F) of terrestrial objects seen through the cone of vision.


US. 20
BEND
SPARKS
LAKE
ELK LAKE
MUD LAKE
LAVA LAKE
DESCHUTES RIVER
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LAVA CAST FOREST
GEOLOGICAL AREA
CRANE PRAIRIE
RESERVOIR
PAULINA LAKE
WICKIUP
RESERVOIR
LAPINE
DAVIS LAKE

to be used by industries.

Industry came to Tennessee because of cheap labor and cheap power—not for lakefront views. New industry should and obviously will locate in already industrialized areas, such as Maryville and Knoxville, where railroad sidings, airports, population, and other attributes already exist.

The power of non-elected TVA planners to actually decree life styles by condemnation is terrifying. The Cherokee farmed the Little Tennessee Valley, and for over 500 years it has been farmland. Many of the present owners have held their land for several generations. Suddenly, TVA plans "a transition from farmland to a wide range of industrial uses" and says that it is even developing plans for a town of 50,000 people where "housing will vary in price, density and type serving all income and social groups." TVA obviously has no authority to build towns, but with new dams impossible to justify, it would undoubtedly like nothing better. If this authority were ever granted, the problems of empire building, economic and political power, and competition with private industry inherent in the dam-building era would seem small in comparison.

In conjunction with the industrial claims, it is interesting to note that in its panic to justify this project, TVA has resorted to listing (but not submitting to Congress) "Secondary Benefits" for "Enhanced Employment." This figure is now at $3,650,000.00 annually and to support it TVA has conveniently escalated the number of expected jobs to be created from 6,000 early in the project, later to 9,000, and recently to 25,000. In this respect, TVA should think of the many vacant industrial sites on the existing reservoirs.

In looking into the semantics used in the TVA environmental-impact statement of June 18, 1971, we find that TVA says the project ". . . will result in a very minor reduction in the total trout waters of the area . . ." However, the Tennessee Game and Fish Commission says, "The total 650 miles of natural trout streams in the Tennessee Appalachian and Smoky Mountain ranges average less than two surface acres per mile. The Little Tennessee averages 125 yards wide and 45 surface acres per mile . . . having a surface area equivalent to all the natural cold-water stream resources in eastern Tennessee."

TVA says the valley "is of some historical interest." "Some" should have read "priceless" both to historians and archaeologists. It is the site of eight historic Cherokee villages including Tenase from which the State derived its name; Tuskegee, the birthplace of Sequoyah, who made the Cherokee alphabet; and Echota—Sacred City of Refuge. Fort Loudoun, the Tellico Blockhouse site, Toqua Mound, the Virginian Fort site, the McGhee mansion, and the Coyatee Treaty site are also in the valley.

TVA says, "Terrestrial wildlife will be reduced," but . . . "the impact of the losses as a proportion of the land in the region devoted to similar use is insignificant." The same is said for raft and canoe trips. This is like saying it is all right to burn one forest because others exist.

TVA says that 275 families will have to be relocated, and the project will also result in the loss of five churches, four schools, seventy-seven miles of roads, thirteen bridges, and three miles of railroad. In addition, 38,000 acres of land will be condemned and 16,000 acres of farmland and 2,400 acres of timber will be flooded and lost forever. This is not the aftermath of war or another tragic disaster in West Virginia. It is a catastrophe planned by TVA administrators for "the purpose of improving the quality of life in the region." The environmental statement goes on to say, "The modest losses of land in the area for timber and agricultural use will be offset many times over by gains in beneficial use for recreation, residential and industrial development." Obviously, this also infers the modest loss of the Little Tennessee River, which, in my opinion, is the finest public trout water left in eastern America.

T. Henry Wilson, Jr., is a member of the N.W. North Carolina Chapter of TU and of the Advisory Board to the North Carolina Council. He was active in the early efforts to obtain native and trophy regulations on North Carolina streams and has been active in the fight to stop the trans-mountain road in the Great Smokies.

as the angle of incidence approaches 90°, the base of the tree in the figure would be very dimly seen by the fish, whereas the upper parts of the tree would be clearly visible.

From the fish's point of view, therefore, Figures 3 and 4 are complementary in that underwater objects lying in the shaded area of Figure 3 appear when viewed indirectly on the air-water interface to lie in the air outside the cone AFA' while all objects above the water surface appear to lie in the air within the cone AFA'.

When the surface of the water is perfectly smooth a fish can see any object that protrudes above the surface. If an angler can see the water, he can be seen by the fish. Although in theory, both angler and fish can see each other equally well, the angler is most often at a disadvantage.

As the fish's and the angler's viewing of each other approaches the plane of the air-water interface, much of the light from either fish or angler is reflected rather than transmitted. The ease with which each can be seen by the other is further reduced by glare from extraneous light. Anglers attempt to ameliorate this difficuly by using polarizing sunglasses which partially attenuate the glare without critically affecting the transmitted light. At the same time, however, skylight provides maximum lighting of the fisherman. Under these circumstances the fish may see without being seen, particularly as the angler is often in strong contrast against a bright sky, whereas the fish is usually in poor contrast against the bottom.

It should also be noted that the angler is being viewed in his greatest height dimension. The portion of his body that is most active intrudes from the perimeter toward the center of the cone of vision and is made more obvious to the fish. On the other hand, the fish's lesser dimension, body depth, is reduced by refraction. For example, his white belly may show just as a white line. Of course, there is no change in the fish's length, if the angler views the fish broadside. However, if the fish is viewed head on, refraction causes an apparent shortening. These factors explain the common observation that fish look smaller when in the water than when out of it.

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claimed benefits is in order.

Power: TVA admits it is not economically feasible to install turbines at Tellico and that the Little T's flow will be diverted through Fort Loudoun Dam to generate additional power there. However, Kirk Johnson, vice-president of APLTR, puts this in perspective by showing the additional power will amount to only 0.2 of 1 percent of TVA's present annual system generation.

Navigation: Kirk Johnson of APLTR writes, "An economics class at the University of Tennessee found that TVA estimated annual navigation benefits for Melton Hill Reservoir (located just eight miles from Tellico Dam site) at $729,000.00 with a savings rate of of $0.54 per ton of barge freight. Only 16,000 actual tons passed through Melton Hill's locks in the period from 1963 to 1970 resulting in savings of less than $10,000.00 compared to the $5,832,000.00 TVA claimed would be saved in this period." Would you call this an overestimation?

Flood Control: TVA says Chattanooga still has a flood problem. There are twenty-five dams above it already. Tellico-controlled flood storage is claimed at 126,000 acre-feet, but in September, 1971, TVA announced it was raising minimum drawdown levels upward on eight reservoirs upstream of Chattanooga reducing flood storage by 1,700,000 acre-feet. Again, a credibility gap is suspected.

Recreation and Fish and Wildlife: Tellico would result in 16,500 additional surface acres for lake-oriented recreation and warm-water fishing. The Tennessee Game and Fish Commission points out that there are already nineteen major reservoirs with 213,000 acres within a 50-mile radius of the Tellico project. It also says that the Little Tennessee "lies in an area of strategic zoogeographical interest for rare and undescribed fishes and aquatic invertebrates" and it cites the probability of three endangered fish species and forty-nine invertebrate, bottom-dwelling forms classified to date.

In summarizing its statement in opposition to the dam, the Commission says, "Stable habitat conditions allow each level of the aquatic food chain to produce at maximum efficiency. This fortuitous combination of size, setting (natural beauty), watershed protection, and productivity sets the Little Tennessee apart as the most unique cold-water fishery habitat in the eastern United States." Since TVA talks about money, the Tennessee Game and Fish Commission also points out that "the White River below Bull Shoals Dam, the only comparable fishery in in the East, generates over $3,000,000.00 annually to boat-dock operators alone."

In addition to aquatic life, this beautiful valley abounds in small game, especially quail, and the endangered osprey fishes the river.

Shoreline Development: TVA recently stated that only 900 acres of waterfront industrial sites are available in east Tennessee, but Kirk Johnson of APLTR uncovered a 1960 report by the Tennessee State Planning Commission which states . . . "26,593 acres in the valley counties (Loudoun, Blount, Anderson, Roane, and Knox) have been identified as potential industrial sites. Reservoir sites identified by TVA total about 25,000 acres. Needless to say, most of these sites are yet

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WHAT A FISH SEES

When the water is rippled all *stationary* objects viewed through the surface by either fish or angler appear to be not only distorted but also trembling or fluctuating in synchrony with the ripples. It is the unusual asynchronous movement that becomes noticeable to the angler or to the fish. The rippled surface is a condition for a constantly changing normal (NN of Figure 1) that provides for both angler and fish a partial escape from the glare and reduction in the intensity of transmitted light.

Insects on the surface and within the cone of vision are seen in distorted detail with binocular vision (a subject to be developed in a subsequent issue of *Trout*). The image of the dry insect supported on the surface film is distorted by the pattern of refraction formed at each point touched by any part of the insect's anatomy. Insects on the surface and outside the cone of vision are noted as dimples formed on the surface at all points touched by the anatomy. The insect body cannot be seen through the film by the fish.

The *Umwelt* of the fish (the world as perceived by the fish) will be explored in future issues.

Dr. Robert L. Butler is Unit Leader of the Pennsylvania Cooperative Fishery Unit, a position he has held since 1963. He completed his doctoral work in the aquatic sciences at the University of Minnesota and while there he was a research assistant on the commercial fisheries investigations of the Red Lakes. Following his graduate work, he spent eight years with the California Department of Fish and Game in charge of the largest catchable trout study ever attempted. Methodology developed in that study is now applied throughout California and has been used by other states.

In 1962, Bob became field director of the University of California's Sagehen Creek Project on the east side of the Sierra Nevada Mountains. Here he taught fisheries and studied the behavior of trout with respect to artificial cover.

Dr. R. D. McCammon was born in northern Ireland and was educated at Queen's University, Belfast, and at the University of Oxford, England. His main interests, apart from low-temperature physics, are fly-fishing for trout and Atlantic salmon, hunting, and gardening. During a recent leave he savored the superlative trout fishing to be found in Australia and New Zealand.

THE UPPER DESCHUTES

of these home for dinner." In twenty minutes we had four nice brooks for the table, and fresh brook trout is the best in the West as far as I'm concerned.

The top mile of the river is spring fed, and with its 49° to 50° water, it is ideal for brook trout. This stretch of river has some riffles and big pools with three of these about a quarter-mile long. One of these pools, the Blue Lagoon, holds several nice big brooks weighing up to four pounds.

A couple of years back, I tried several times, unsuccessfully, to interest these big brooks in wet flies, nymphs, and bucktails. Later in the season, a friend fished the Blue Lagoon at dusk with night crawlers, and by fishing the banks he hooked and landed several 2½- to 3-pound brookies. I just never caught this stretch of the river with a good hatch of flies or when these big fish were biting. This is a bit unusual because the river contains lots of caddis flies, mayflies, stoneflies and their nymphs. Most of the streams tributary to the Deschutes are blessed with many caddis nymphs. These nymphs start to hatch early in the spring and continue through August; consequently, they make up a large part of the brook trout's diet.

One of the best flies for brooks or rainbows on the Deschutes or its tributaries at this time is the bucktail caddis, or the tied-down bucktail caddis in sizes, 8, 10, or 12.

This upper mile of river has some pretty good spawning gravel and it is used by brooks and rainbows. These big brooks and bows come upriver from Crane Prairie Reservoir, spawn, and then drift back.

Water temperature of the river above Crane Prairie in August may be about 58°or 59°, just right for rainbows which move up into the colder water of the Deschutes and Cultus channels when the reservoir water warms in July and August.

Crane Prairie Reservoir was developed in the early 1920s when an irrigation company built an earth-timber dam across the river. The water backed up and flooded about 4,000 acres, over half of which contained a lodgepole-pine forest which was flooded out. Today, over 1,200 acres of this relic forest still stand as a gaunt reminder of the lack of clearing and cleanup.

The snags may be ugly to some people; however, they furnish excellent cover for trout, waterfowl, swallows, and songbirds, as well as perfect nesting sites for the American osprey and roosting poles for bald eagles.

The dam was rebuilt in 1940 by the Bureau of Reclamation and the reservoir was closed to fishing until about 1949. At this time I've heard there was some of the most fabulous fly-fishing for rainbows that one could dream of. Anglers took strings of big rainbows from 17 to 30 inches. Today the fly-fishing, though not as spectacular, is still good because the snags are offering the protective cover needed by the big fish.

A Game Commission study of the food production on the snags compared to the mud bottom indicated that the underwater portion of the snags was producing about four times as much aquatic insect life as the equivalent mud-bottom area.

Fly-fishing in Crane Prairie is good from the middle of May to the end of October. Caddis flies are the first to hatch, so most local fishermen prefer fishing a size 8 or 10 bucktail caddis or tied-down bucktail caddis, wet, with a sinking line, using a jerky, slow retrieve which moves the fly three or four inches at a time. Later on, hatches of small blue duns will cover the water in June and July. At this time the dry-fly man has his turn with the rainbows and brooks.

Later in July some trollers have discovered that a big 2/0, or 2/0 tandem, streamer fly, known locally as a Crane Prairie Special, will take big rainbows. This fly, tied with bunches of shoulder hackle, either brown or gray, tied back to back, when pulled through the water causes the hackle to close and open, giving the fly a lifelike action. These flies are skipped or jerked over the surface or just under the surface, and they really excite the big rainbows. My theory is that these big fish are watching the surface where smaller fish are feeding on the small blue duns. When

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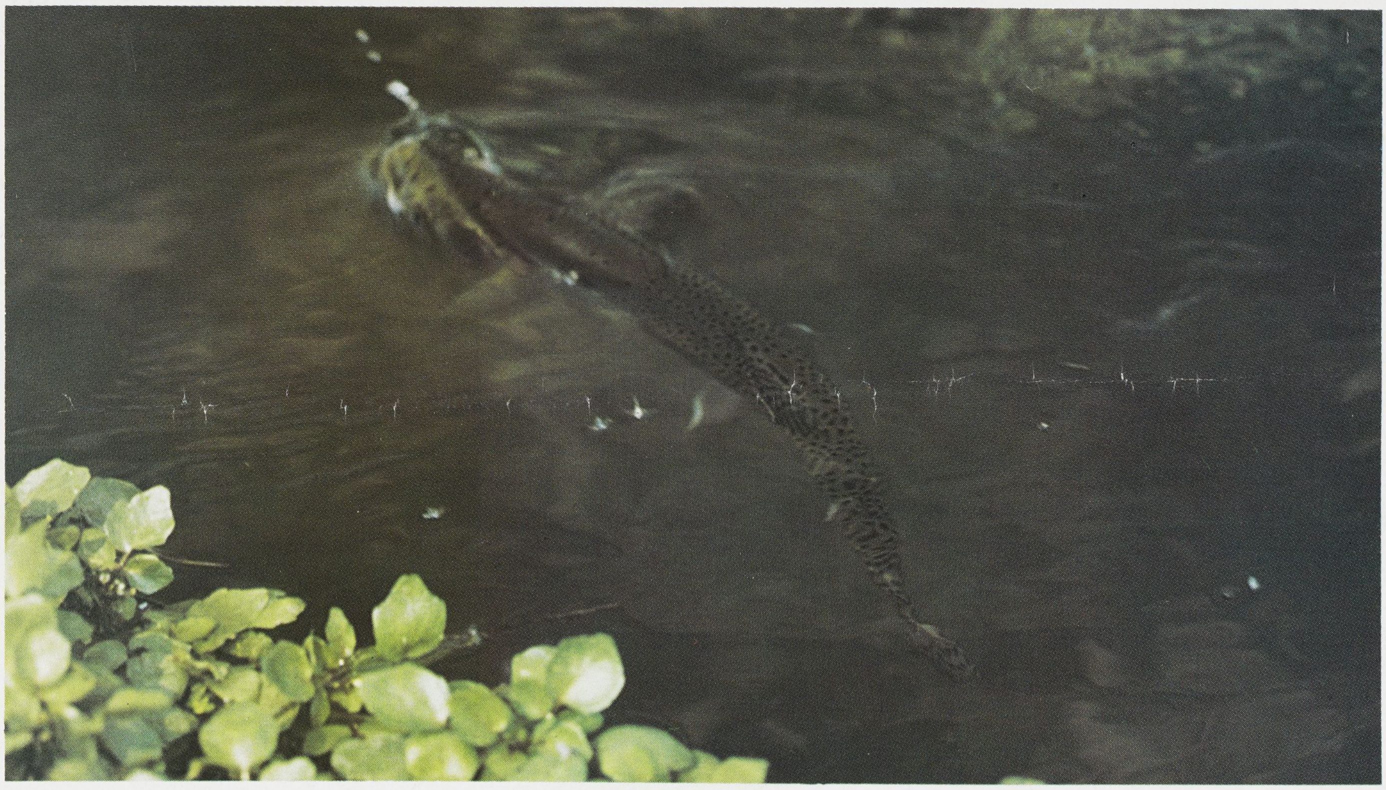


Why this rainbow trout, photographed by Paul Zimmerman in a Pennsylvania spring creek, took one fly instead of the several others around it may be in part answered by some new observations on the fish's window, as described in the text.

At the Edge of the Window

ROBERT HARMON AND JOHN CLINE

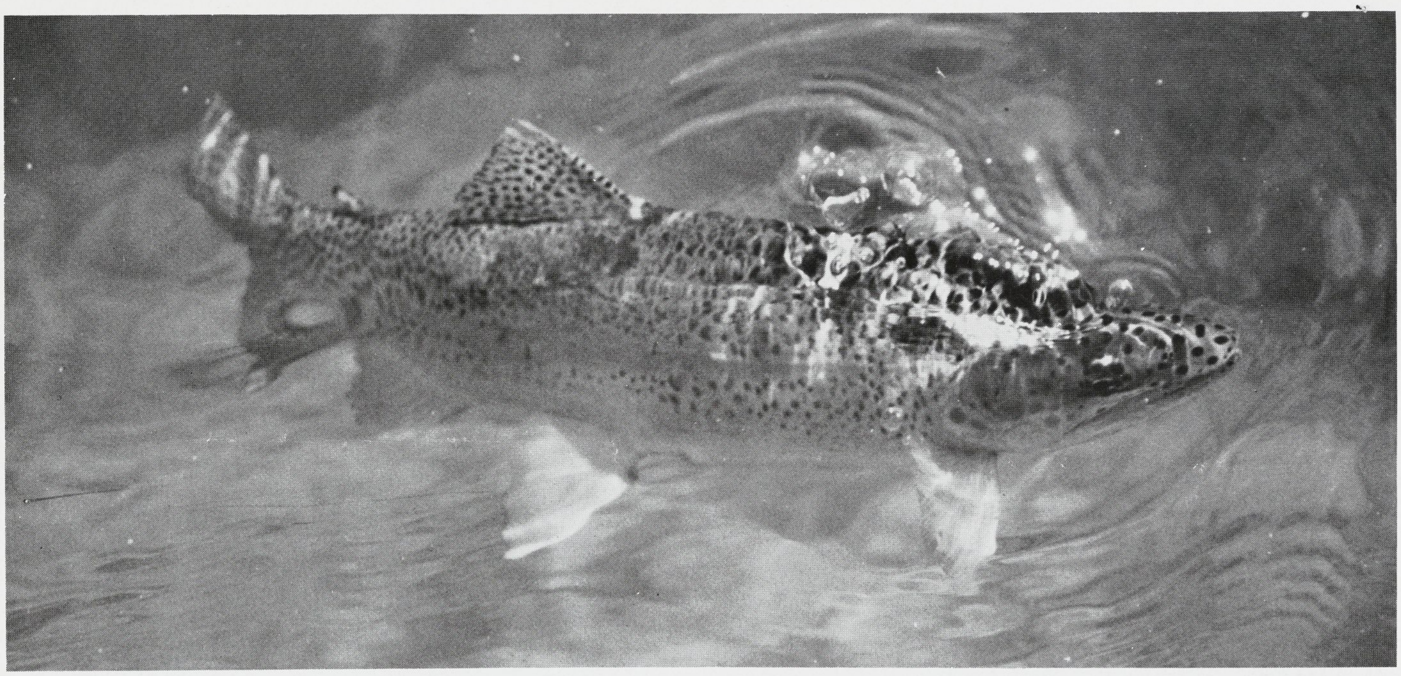
The fish's window has been an occasional topic of angling writers ever since Alfred Ronalds first related the phenomenon of light refraction to fishing in his book, The Fly-Fisher's Entomology *(1836). The following discussion does offer some significant and new observations on that topic; it is also rather technical. If you don't read it for that reason, we'll mention here one of the most significant new points: That a dry fly (or natural insect) on the surface and close to a fish's eye may be magnified as much as three times by a combination of refraction phenomena. The implications of this for a trout's fly pattern selectivity are substantial.*

The authors submitted with this article a twelve-page series of mathematical derivations used as a basis for the conclusions presented here. We had those derivations verified independently at a local university before publishing this material. Through the cooperation of the authors, interested readers may obtain copies of the background material by writing to John Cline at Hume, Clement; Suite 4100; One IBM Plaza; Chicago, IL 60611. R&R.

It is early evening in mid-June. The light is still good, and there is no breeze to ruffle the surface of the smoothly flowing, clear water. A good hatch is in progress, and you watch the lovely little sulphur mayflies float placidly on the current.

A fish begins to rise thirty feet upstream. You tie on a size-sixteen mayfly imitation, with traditional hackle and wings. The fish continues to feed. You cast carefully and well; your imitation passes within a foot of the fish. He ignores it. You cast again and again, your best shots placing the fly in a drift line that is never more than a foot or two to the right or left of the

ROBERT HARMON AND JOHN CLINE are both trial attorneys in Chicago, and both specialize in patent law. They obtained engineering degrees before entering the legal field. They are both members of the Anglers Club of Chicago and do most of their trout fishing in Wisconsin and Michigan.



Cruising fish take their "window" along as they move, which compounds the problems of casting accuracy and selectivity. Photo by Frank Martin.

fish. But he continues to rise, unmoved by your imitation. Finally, you get lucky and hit him right on the nose, your fly dropping not three inches above him. He takes.

As you net the fish, you think the situation is ridiculous, that no human being can cast like that consistently. But you've read all the right books, and you know just what to do. You tie on another fly of precisely the same size and color, but this time a no-hackle version with well-defined wings. You locate another fish and go to work. And now your same fine casts produce results. Not every time, to be sure, but often enough.

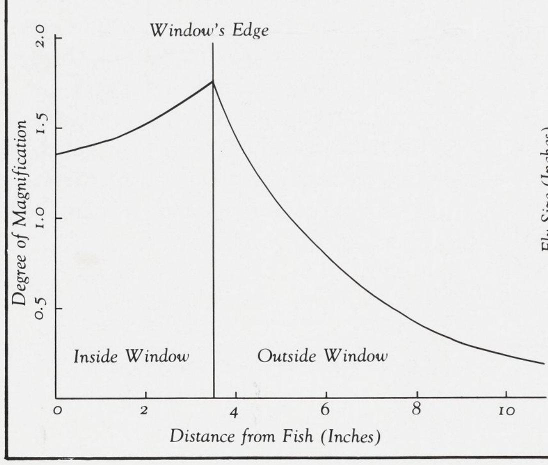
Later, comparing notes with your partner, you find that he experienced the same troubles. His solution, equally successful, was to continue with the same traditional imitation that you started with, but to give it an occasional twitch or flutter.

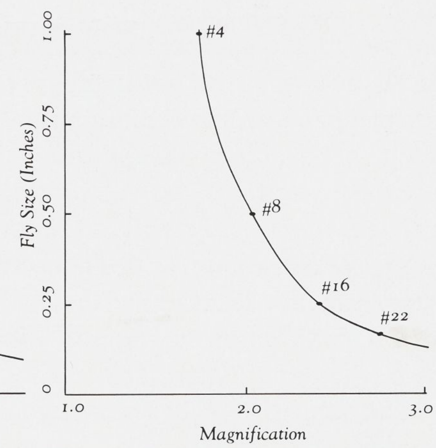
We know that a fish does not respond only to those floating objects that are very close to him, for we have all seen a fish rocket from three or more feet away to take a floating artificial. But what, then, is the characteristic that triggers the fish's attack circuitry? Movement? Is it the first sight of wings? Or a glimpse of a fly body that has broken through the surface film?

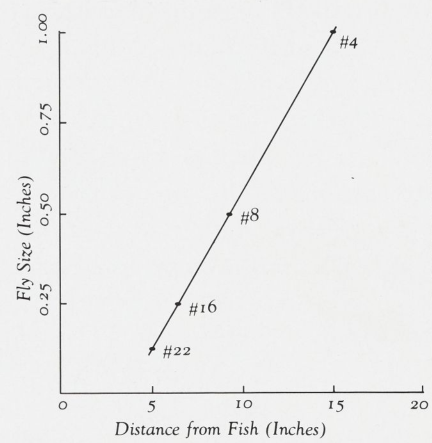
We had long pondered these questions and had made attempts to find the answers in existing books, but it was not until the appearance of Vincent Marinaro's *In The Ring of the Rise* (Crown Publishers, 1976) that we were motivated to do some work of

A Graphic Representation of Window Phenomena

The graph at lower left depicts what happens to the apparent size of a one-inch-high dry fly as it approaches and enters the window of a three-inch-deep fish. The graph in the middle shows the degree to which various size dries are magnified at the edge of the window for a three-inch-deep fish. The third graph shows the maximum distance from a three-inch-deep fish at which that fish can perceive the wingtips of various size flies. The data on which these graphs are based were derived mathematically by the authors and deal only with what is available for a fish to see. They have nothing to do with the physiology of a trout's eye or how an image is registered by its brain.







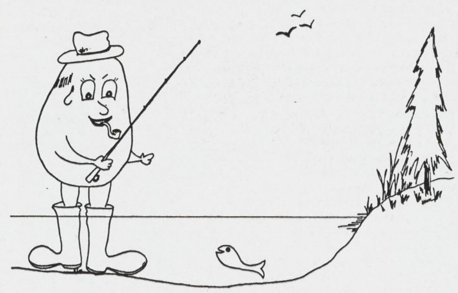
our own. That magnificent book, like any classical work, provides more questions than answers. Marinaro's stunning photography so enchanted us that we were at first distracted, unable to recognize the significant questions that it posed. However, as we read and reread his discussion of the fish's window, we began to wonder whether there was perhaps a little too much intuition involved and not enough hard mathematical analysis.

Being engineers by training, we were not afraid of the mathematics, so we took the plunge. We are glad we did, for we feel that we may now be able, at the very least, to ask the right questions. In the process we have made observations that we have not seen reported previously and have mathematically confirmed those observations with the laws of optics.

Our efforts convinced us that a true understanding of the window phenomenon requires a blend of both observation and theoretical analysis. The effects produced by the refraction of light between water and air are so complex that, without the correct theory, past observers have apparently misinterpreted what they saw and also have not seen all that was there to see. Since the theory is crucial both to a complete understanding of the window and as a foundation for future work in this field, we conducted an extensive mathematical analysis. However, for those who have never heard of sines and cosines (and for those who have, but don't care to become reacquainted with them), we present our results here without the technical calculations.

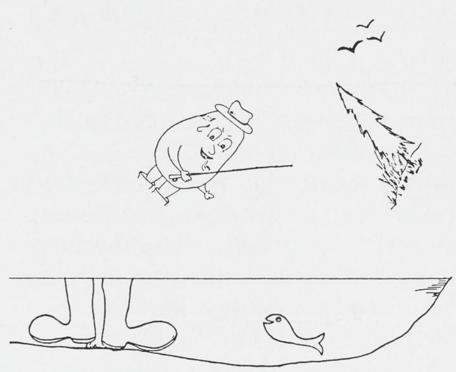
Fundamental to the subject is an appreciation for just what is the so-called window. As has been stated many times previously, the window is defined by a cone having an angle of about 97 degrees, with its apex (point) at the fish's eye and its circular base at the surface of the water. The window is the fish's periscope through which it sees, theoretically at least, all of the objects that are visible to it above the surface. The sides of the cone appear to the fish as the horizon, visible to the fish as a fuzzy band around the circular perimeter of its window. Outside the window's perimeter, all the fish can see is the reflection of the bottom on the surface overhead, plus the underside of whatever floating objects happen to be in contact with the surface.

This is the scene as you might see it. A towering pine, a flight of geese, and you, the mighty hunter of trout, preparing to hook the stately pine. Such is the nature of our sport.



Now let's see how all this appears to our quarry.

The fish also sees it all. However, it all appears within the fish's 97-degree window instead of the 180 degrees that we are used to. Indeed, both the pine and you (from the knees up) have shrunk and joined the geese in soaring



above the surface as far as the fish is concerned. From the knees down, the fish views you directly, and your lower and upper portions appear to be different objects. Now this apparent elevation is only true of objects above the surface that are outside of the circle the window forms on the surface of the stream. Inside that window, objects above the surface appear to the fish *somewhat* the same as they might to you.

So simply lay the fly within the window, and you have him. Not so simple! The window at the surface is very small for fish at normal surface-feeding depths. Surface-feeding trout typically hold only a few inches deep, and at that distance, the area intersected at the surface by the fish's cone of vision is quite small.

Thus the window for a fish three inches deep (a normal surface-feeding depth) has a diameter of less than seven inches. Now you might be able to tell your girlfriend that you can hit a seven-inch circle at thirty feet (with a nine-foot leader, yet), but don't tell us. We might be able to hit the seven-foot window of a three-foot-deep fish with some consistency; but in flat water, such a fish may not be a consistent riser. Obviously, it will take a good cast to hit the two-foot window of a one-foot-deep fish at any decent distance. If you want to go practice your casting, fine. We are neither accurate nor lucky, and yet we do catch an occasional fish on a dry fly. We wanted to find out why, and in order to do that we determined, at least in part and partly as others have done, how a fish sees an object on the surface outside and inside his window, and what it is that he sees.

When well outside the window, the portion of a dry fly's body that is above the surface is—in the fish's view—separated from the subsurface underbody and hook by a large distance. The upper body, being above the surface, appears to be positioned on the edge of the window, as with the upper half of the fisherman in the previous diagram. The hook and underbody are not affected dimensionally by the window at all, because they are subsurface. The entire upper body is compressed, optically, to a point at which it is barely visible and certainly does not resemble a fly. It's important to note here that the shapeless blob seen at this position is a greatly compressed image of the *entire* above-surface portion of the fly, not just its upper tip.

As the fly floats closer to the edge of the window, the separation becomes progressively less, and the upper body appears larger and more distinct. When the fly is at the very edge of the window, the upper body has joined the underbody and hook. Well inside the window, the fly appears reasonably normal.

As the fly approaches the window, the upper body and wings become vertically elongated. This magnification occurs both inside the window and outside it close to its edge, and is the very opposite of the compressive effect observed when the fly is well outside the window. Despite the appearance of an indistinct band or zone at the edge of the window at all positions, the fly itself does not appear fuzzy or indistinct when it is physically at the edge of the window, nor are its colors impaired in any way. This is directly contrary to the conclusions of prior observers.

Mysterious things happen to the portion of the fly affected by the window as the fly is delivered to the waiting fish. While the fly is in the window and to a point just outside of it, it is

Color of this fly is much affected by the prism effect.

The view from the bottom of a tank looking upward. The blue area is what's visible through the "window"; the olive area is the reflection of the tank bottom. At left: The subsurface portion of the fly is clearly visible while only its wingtips, which are above the surface, can be seen at the window's edge. Middle photo: The fly is closer to the window's edge, more of the above-surface portion is visible, and the two images are starting to merge. Above right: The fly is at the window's edge, is at its maximum vertical elongation, and all other parts are clearly visible. Photos by the authors.

vertically magnified. Farther out from the window's edge, it is vertically compressed.

One of the accompanying graphs shows magnification (or apparent size) versus horizontal distance for a one-inch-high (size 4) dry fly as viewed by a fish three inches deep. Note that the *minimum* magnification inside the window is about 1.33, and the magnification outside the window rapidly approaches zero. Note also that when the magnification is less than 1 the image is *smaller* than life size. The same holds true regardless of the size of the fly or depth of the fish. The magnification will go from 1.33 directly overhead to a maximum at the edge of the window, and will then drop off toward zero as the fly moves out past the window. The fly need not be very far beyond the window to be greatly foreshortened in the fish's eye.

The second graph shows the degree of magnification at the edge of the window versus fly size, again for a three-inch-deep fish. Thus a one-inch-high dry fly (size 4) would appear to be almost 1.75 inches tall when it's at the window edge, while a 0.16-inch-high fly (size 22) would look about 0.44 inches tall.

To put it another way, at the edge of the window, a size 22 fly *appears* to the fish to be almost three times as large as it really is. A size 4 fly *appears* almost two times as large as you see it. To those of you who persist in the notion that exactness in imitation is wasted effort, consider this: Not only does the fish see your fly very clearly, he sees it under a magnifying glass. For us, this disposes of the controversy.

Our observations have shown that under ideal conditions a wing tip on a floating dry fly can first be perceived (by the fish) as a wing tip when it subtends a surface angle of about five degrees. This angle determines how close your fly must be to the fish before the surface portion is visible at all. Our third graph gives those values for a three-inch-deep fish.

If a fish can't see your fly, he is not going to be interested in it. For a traditional size 16 dry fly, a fish at normal feeding depth (about three inches) won't see any of the above-surface portion until the fly is within six inches of the fish. You are thirty feet away and have to put your fly withing six inches of the perfect line of drift. A larger fly helps some, but not much; a size 8 fly must be within nine inches of the perfect position. We think the average caster is incapable of that accuracy. We also think it explains a lot of the trout's "selectivity," about which volumes have been written. Selectivity maybe, but we now know that there is at least an equally good chance that you didn't get close enough. The fish simply has not seen enough of the fly.

(This is particularly true for fish that are locked into a rhythmic, surface-feeding pattern during a heavy hatch, at which time thay may be less likely to respond to and chase the subsurface portion of the fly, which they can see at greater distances. R&R)

Not only would the caster be often incapable of the required accuracy if the target were fixed, but the situation is dynamic, not fixed. Generally, the position of the fish is not known exactly. In addition, the fish usually moves after it takes a fly. Frankly, our new understanding of the difficulty inherent in putting a fly where it can be totally seen by the fish has done a great deal to soothe our wounded egos.

Why bother?

To review and perhaps clarify what we have covered so far, here's another example: a size 4 dry fly drifting downstream toward a fish holding at a three-inch-depth, starting about three feet upstream of the fish. This particular fly has well-defined vertical wings about one inch high, and is tied parachute-style so that its underbody and hook break the surface. The water is clear and the light good.

Assuming that the fish has the visual acuity to see that far in the water, he will see the underbody and hook even when the fly is three feet away. He will also see the "condenser" effect as described by Marinaro and others, a pattern of light on the overhead surface caused by the dimpling of the hackle in the surface tension. Indeed, the condenser effect may be the *first* thing he sees, especially if the fly is twitched. He will continue to see these things, clearly and distinctly, without distortion, as the fly moves toward him.

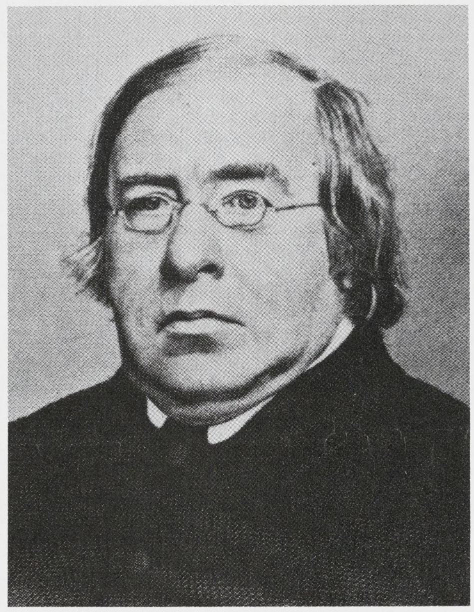
What he sees of the portion of the fly that is above the surface is an entirely different matter. He will see nothing at all when the fly is three feet distant. As the fly moves toward him, he will first perceive a tiny, shapeless blob, floating in air, at a distance of about twenty-five inches. By the time the fly is fifteen inches away, that blob will look like the tip of a wing. As the fly continues to approach, the fish will begin to see more and more of the wing, but still no body. The wing will still seem to be floating in air, high above the underbody (on the water surface); indeed, the disembodied image of the wing will appear to be sliding down a 48.5-degree line from the sky, with the underbody proceeding horizontally below.

At some point, perhaps four or five inches away, some of the body (above the surface) may become discernible, and the wing will appear to elongate. Suddenly, precisely at the edge of the window and only 3.4 inches from the fish, the "floating" image will merge with the underbody, and the fly will appear to be about 1.75 inches tall. Finally, as the fly moves within the window, its above-surface image will continue to be attached to its underbody, and it will gradually reduce in apparent size until it appears, almost directly overhead, to be about 1.35 inches tall.

We now have a much better understanding of the complexities inherent in the fish's window. That is useful in and of itself and should make our fishing more satisfying. We have learned that strange things happen to the portion of the fly above the surface. Its apparent size grows to be much larger than life when at the window's edge. The subsurface portion is visible at a much greater distance than that above the surface and is seen without those strange optical effects caused by the window. The condenser or dimpling effect is highly visible.

We think these observations dictate that we design flies to get the best of both worlds. For visibility, flies should be tied so that a portion of the body breaks the surface, so that at least the fish will see something even if you are an average caster. The portion of the fly that is above the surface should be as distinct and representative as possible. For ourselves, the parachute or no-hackle types with cut wings best satisfy the optical requirements. We think we have brought undeniable logic to their support. ◆

This is also visible w/ high-floating flies



George Washington Bethune; photo courtesy of the Museum of American Fly Fishing.

The Americanization of Walton

LISA CROSBY

Born in 1805, six years after the death of his namesake, George Washington Bethune is remembered as "The American Editor" of the first American edition of Isaac Walton's *The Complete Angler*. Bethune's edition was first printed and published in America in 1847.

One current critic wrote of Bethune's edition: "Notable features of the American Edition . . . (include) the erudite bibliographical preface. . . which traces angling and angling books from antiquity to the time of Walton; the . . . notes accompanying the text; and an appendix containing probably the most complete list of angling books published before 1847." Bethune's copious notes clarify and expand Walton's references to people and places, and "Americanize" Walton's English angling. American angling authorities give Bethune's edition significance because in it he reveals so much of American angling in the 1800's. In the appendix, Bethune included two essays by American anglers on fishing in this country. John Major, who edited and published an 1823 edition of *The Complete Angler* in England, implied in a letter to the American publishers that Bethune's notes were "'hindrances instead of helps' to the understanding and true relish of his (Walton's) beauties." A comment made by "C. A. P." in a January, 1848, review appearing in the *Knickerbocker* serves as a direct rebuttal to Major: "There is detail, certainly; but it is so curious, that any mind of a contemplative turn will find amusement in it."

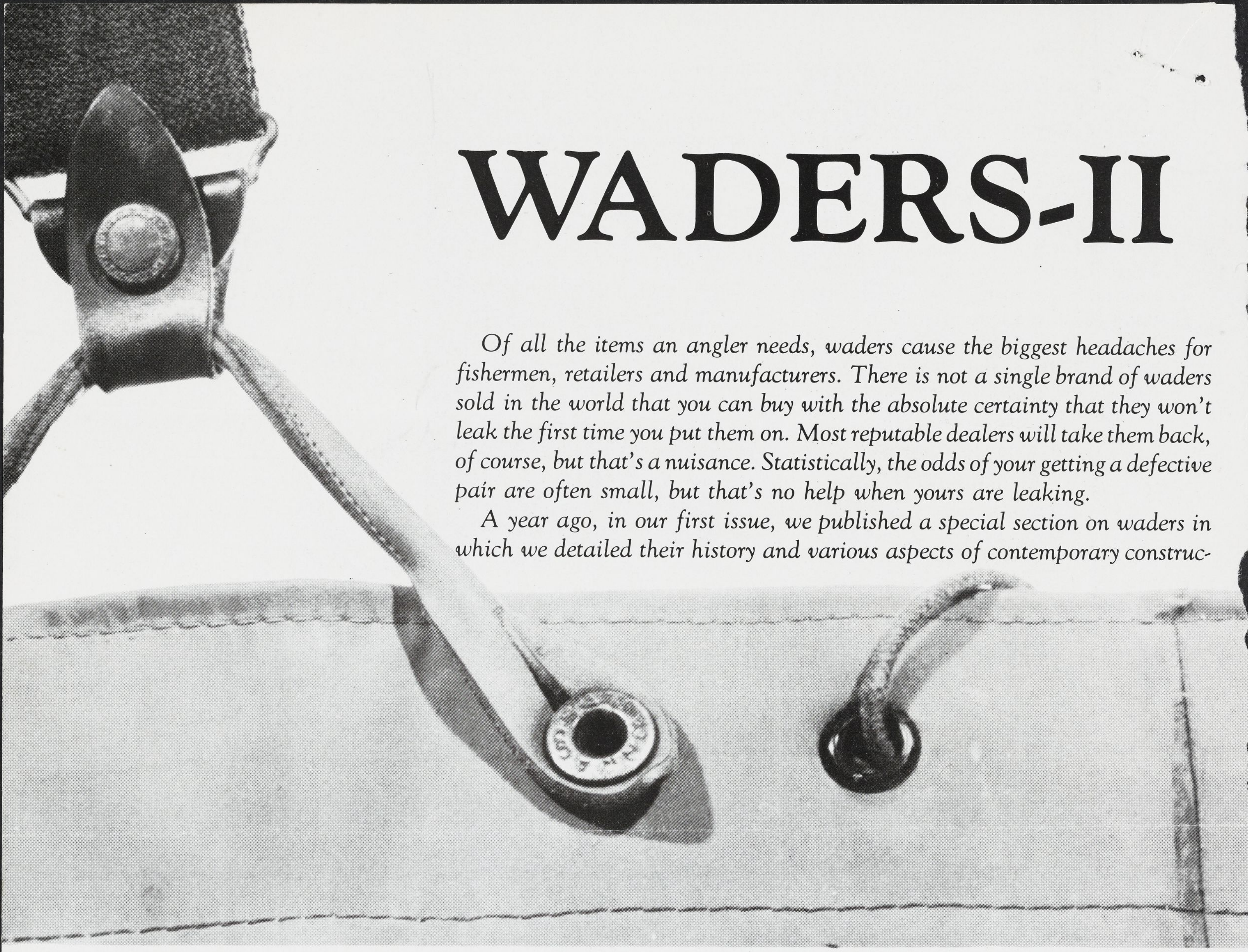
Bethune apparently developed his angling interest as a schoolboy in Salem, N.Y. Angling author Charles Goodspeed reports that it was there that Bethune met "Fishing Billy, . . an improvident addict of the rod (and, to his downfall, of the bottle, also)," and the two probably spent many hours together fishing on the nearby Battenkill. Bethune went on in his schooling and was ordained in 1827 by the Second Presbytery of New York.

Bethune's name doesn't appear in the 1847 edition of *The Complete Angler*; instead he refers to himself as "The American Editor." Goodspeed, in his book, *Angling in America* (1939), suggests that Bethune feared public opinion and the reaction of "narrow-minded churchmen (who) looked askance on recreational indulgences by clergymen." Bethune, a skilled orator, did much traveling and lecturing, at times speaking on the value of "recreational indulgences" such as fishing. Bethune also collected books and had a substantial Waltonian library that included most of the books referred to or quoted from in *The Complete Angler*, in addition to many books on Walton himself.

In the Bibliographical Notes at the end of his 1880 edition, Bethune wrote, "The stream side is ever dear to me, and I love to think of the times when I have trudged merrily along it, finding again in the fresh air and moderate exercise and devout looks upon nature, the strength of nerve, the buoyancy of heart and health of mind, which I had lost in my pent library and town duties."

One hopes that Bethune was able to indulge in this pleasure up to the time of his death in 1862.

LISA CROSBY is a Skidmore College English major who worked at ROD AND REEL as an intern.



WADERS-II

Of all the items an angler needs, waders cause the biggest headaches for fishermen, retailers and manufacturers. There is not a single brand of waders sold in the world that you can buy with the absolute certainty that they won't leak the first time you put them on. Most reputable dealers will take them back, of course, but that's a nuisance. Statistically, the odds of your getting a defective pair are often small, but that's no help when yours are leaking.

A year ago, in our first issue, we published a special section on waders in which we detailed their history and various aspects of contemporary construc-

The Other Side of the Counter

SILVIO CALABI

Think about the tackle shop's side of returns and complaints. If your waders leak because of a manufacturing defect, the chances are that some other customers' waders also leaked and that still others will leak in the near future. To you, this represents a small headache; the shop will help you out somehow. To the retailer, although the supplier will probably help, this may turn into a major headache for his cash flow, his reputation and certainly for his personal peace of mind.

To get a retailer's view of wader sales, we interviewed people at six tackle shops around the country that are known as established businesses owned and operated by people who are also extremely knowlegeable fishermen. As it turned out, the six of them sell a combined total of about 4,000 waders annually. We guess that to be about eight percent of the national annual total (excluding discount chains). That may not sound like a lot, but remember that many of those 4,000 waders are sold with perhaps thirty minutes to an hour's free advice and fitting thrown in. These folks know their waders.

The most popular wader sold—the average, if you wish—is a men's size 10 or 11, bootfoot model in the $50-$60 range. Preference in soles is toward felt, but regional demands vary and some dealers report mainly lug-sole sales. Many fishermen seem to prefer a canvas-type upper, perhaps because this material is generally accepted as both traditional and fairly rugged.

Our informal survey pointed out the increasing popularity of stockingfoot waders. As recently as five to ten years ago, it seemed that only more experienced anglers knew about and preferred separate lace-up wading shoes and soft-foot uppers. Today, those dealers report their sales are split half and half between bootfoot and stock-

AT THE EDGE OF THE WINDOW

ROBERT HARMON/JOHN CLINE

Illustrated By Arleen Nelson

It is early evening in mid-June. The light is still good, and there is no breeze to ruffle the surface of the smoothly-flowing, crystalline water. A good hatch of E. dorothea is in progress, and you watch the lovely little sulphur mayflies float placidly toward you, like tiny sailboats.

A fish begins to rise thirty feet upstream. You tie on a size 16 imitation, with traditional hackle and wings. The fish continues to feed. You cast carefully and well - your imitation passes within a foot of the fish. He ignores it. You cast again and again, your best shots placing the fly in a drift line which is never more than a foot or two to the right or left of the fish. But he continues to rise, unmoved by your imitiation. Finally, you get lucky and hit him "right on the nose", your fly dropping not three inches above him. He takes.

As you net the miserable creature, you think "This is ridiculous. No human being can cast like that consistently." But you are no rookie. You know the score. You have read Swisher & Richards and Caucci & Nastasi, and you know just what to do. You tie on another fly, of precisely the same size and color, but this time a no-hackle version with well-defined wings. You locate another fish and go to work. And now, mirabile dictu, your same fine casts produce results. Not every time, to be sure, but often enough to make you happy.

Later, comparing notes with your partner, you find that he experienced the same troubles. His solution, equally successful, was to continue to use the identical traditional imitation you started with, but to give it an occasional twitch or flutter.

ROBERT HARMON and JOHN CLINE are Chicago based patent attorneys. They have extensive experience on the streams of Michigan and Wisconson.

What's going on here? It appears that the modern demi-gods of the dry fly are right, but why? We know that a fish does not respond only to those floating objects which are very, very close to him, for we have all seen a fish rocket from three feet or more away to take an artificial. But what, then, is the characteristic that triggers the fish's attack circuitry? Is it movement? Is it the first sight of wings? Is it a glimpse of a fly body which has broken through the surface film?

We had long pondered these questions, and had made attempts to find the answers in the existing literature. But it was not until the appearance of Vincent J. Marinaro's In The Ring of the Rise in 1976 that we were motivated to do some work of our own. That magnificent book, like any classical work, provides more questions than answers. Indeed, Marinaro's stunning photography so enchanted us that we were at first distracted, unable to recognize the significant questions which it posed. However, as we read and re-read his discussion of the fish's window (Chapter Two, entitled "What the Fish Sees and Does Not See"), we began to wonder whether there was perhaps a little too much intuition involved, and not enough hard mathematical analysis.

Being engineers by training, we were not afraid of the mathematics. And being patent lawyers by profession, and thus habitually skeptical, we were not inclined to accept, without question, someone else's conclusions. (Although we must confess that doubting Marinaro is akin to asking a Supreme Court Justice whether he is sure of the law.) So we took the plunge. And we are glad we did, for we feel that we may now be able, at the very least, to ask the right questions. In the process we have made observations that we have not seen reported previously and have confirmed those observations with the laws of optics.

Our efforts convinced us that a true understanding of the "window" requires a delicate blend of both observation and theoretical analysis. The effects produced by refraction are so complex that, without the correct theory, past observers have misinterpreted what they saw and also have not seen all that was there to see. Since the theory is crucial both to a complete understanding of the window and as a foundation for future work in this field, we will discuss it in depth later. However, for those that have never heard of sines and cosines (and for those who have, but don't care to become reacquainted with them), we will first present our results without the technical analysis.

Fundamental to the subject is an appreciation for just what the window is. First, it only affects objects, or portions of objects, which are above the surface. Second, as has been stated many times previously, the window is defined by a cone having an angle of about 97°, with its apex at the fish's eye and its circular base at the surface of the water. Third, the window is the fish's periscope through which it sees, theoretically at least, all of the objects that are visible above the surface. (How well he can see them is another matter.) Finally, the sides of the cone appear to the fish as the horizon. These last two points are best understood with the aid of diagram.

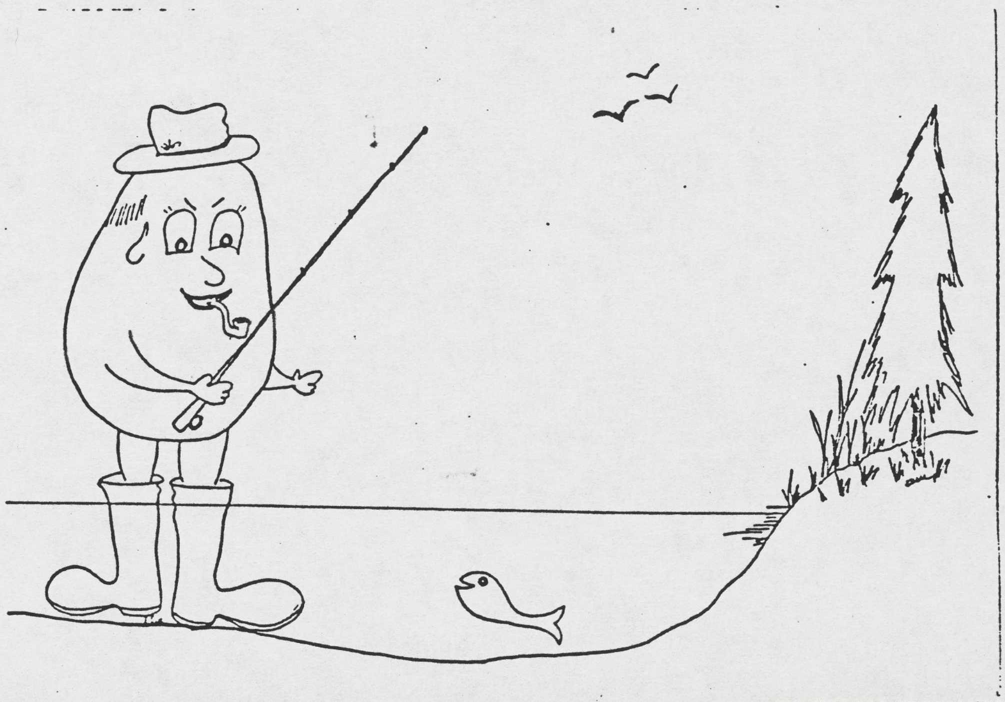


Figure 1 shows a streamside scene as you would see it. A towering pine, a flight of geese, and you the mighty hunter of the trout preparing to hook the stately pine. Such is the nature of our sport. Now let us see how all this appears to our quarry.

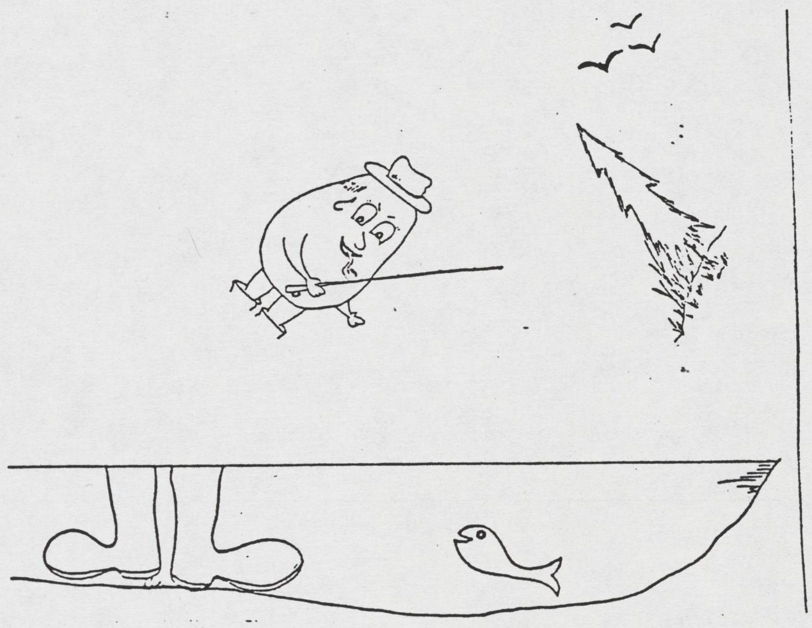
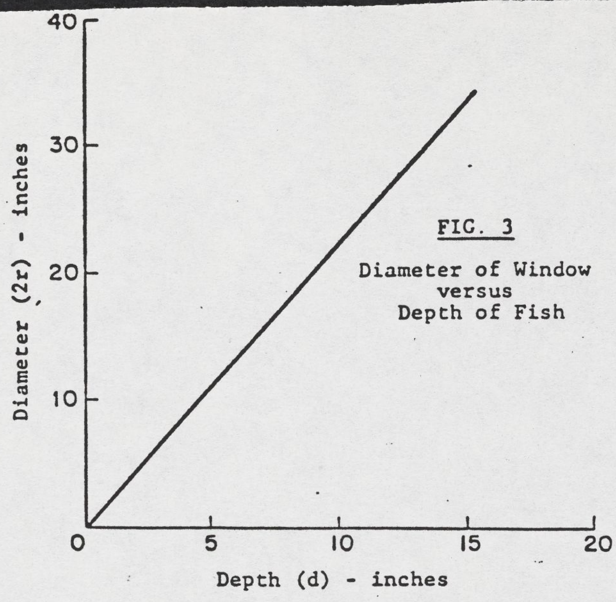


FIG. 2

The fish in Figure 2 sees it all also. However, it all appears within the fish's 97° window instead of the 180° that you and I are used to. Indeed, both the pine and you (from the waist up) have shrunk and joined the geese in soaring above the surface as far as our friend the fish is concerned. From the knees down, the fish views you directly and your lower and upper portions appear to be different objects. Now this apparent elevation is only true of objects that fall outside of the circle the window forms on the surface of the stream. Inside that window, objects appear to the fish somewhat the same as they do to you.

So you say "simply lay the fly within the window and you have him." Not so simple. The window at the surface is very, very small for fish at normal depths. Figure 3 shows the diameter of the window for fish up to 18" deep.



Thus, the window for a fish 3" deep (normal feeding depth) has a diameter of less than 7". Now you might be able to tell your girl friend or your Aunt Nellie that you can hit a 7-inch circle at 30 feet (with a 9-foot leader yet), but don't tell us. We might be able to hit the 7-foot window of a 3-foot deep fish with some consistency, but we wouldn't catch anything. Obviously, it would take a tournament quality cast to hit the 2-foot window of a 1-foot deep fish at any decent distance.

If you want to go practice your casting, fine. We are neither accurate nor lucky, and yet we do catch an occasional fish on a dry fly. We want to find out why, and in order to do that we shall have to determine how a fish sees an object on the surface outside his window, and what it is that he sees.

The pictures at page 44 of Rod and Reel photographically depict how a fly appears to a fish as it enters the window. The fly in the pictures is a size 12, Light Cahill. A portion of the lower body has broken the surface. Like the lower half of our fisherman in Figure 2 it is seen directly through the water and is not affected by the window. It is important to realize that this would not be true for a traditional, heavily-hackled fly which is entirely above the surface.

In the left photo, well outside the window, the portion of the fly's body which is above the surface is separated from the subsurface underbody and hook by a large distance. The upper body, being above the surface, appears to be positioned on the edge of the window, as with the upper half of the fisherman in Figure 2. The hook and underbody are not affected by the window at all, because they are subsurface. The entire upper body is compressed, optically, to a point where it is barely visible, and certainly does not resemble a fly. It is important to note here that the practically shapeless yellow blob you are seeing in the left photo is in fact a greatly compressed image of the entire above-surface portion of the fly, not just its upper tip.

In the center photo, just outside the window, the separation is less, and the upper body appears larger and more distinct. In the right photo, the fly is at the very edge of the window, and the upper body has joined the underbody and hook.

Note, however, that in the center and right photos, the upper body is vertically elongated. This magnification occurs both inside the window and close outside it, and is the very opposite of the compressive effect observed well outside the window, as in the left photo. Note also that, despite the appearance of our indistinct band or zone at the edge of the window at all positions, the fly itself does not appear fuzzy or indistinct when it is at the edge of the window (right) nor are its colors impaired in any way. This is directly contrary to the conclusion of prior observers and we are at a loss to explain the apparent conflict.

Clearly, then, mysterious things happen to the portion of the fly affected by the window as it is delivered to the waiting fish. While the fly is in the window and to a point just outside of it, it is vertically magnified. Further out from the window it is vertically compressed. And these effects are not minor, as the photographs clearly demonstrate.

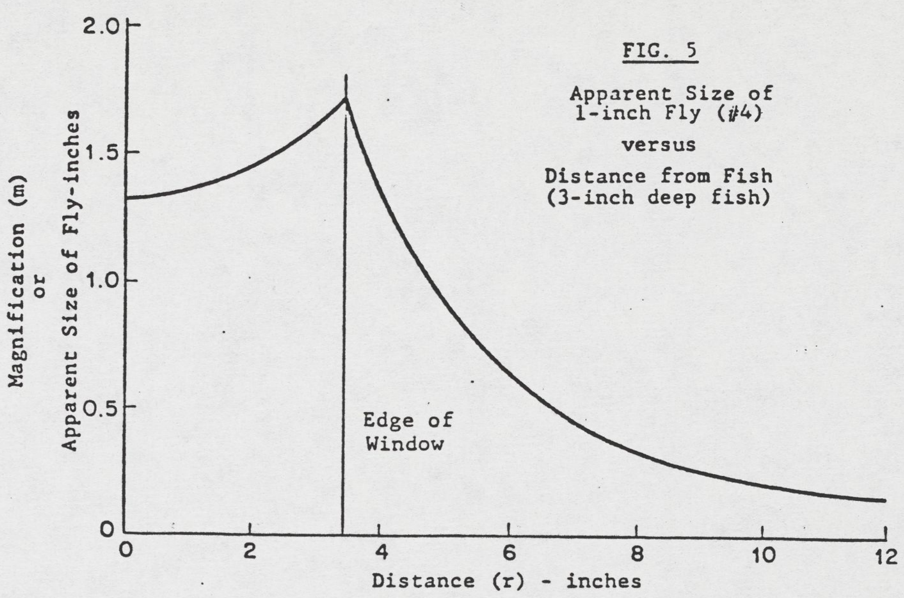


Figure 5 plots magnification (or apparent size) versus horizontal distance for a 1-inch (size 4) fly as viewed by a fish 3" deep. Note that the minimum magnification inside the window is about m = 1.33, and the magnification outside the window rapidly approaches zero. Note also that when the magnification is less than 1, the image is smaller than life size. The same holds true regardless of the size of the fly or the depth of the fish. The magnification will go from 1.33 directly overhead to a maximum at the edge of the window, and will then drop off toward zero as the fly moves out past the window. The fly need not be very far beyond the window to be greatly foreshortened, in the fish's eye.

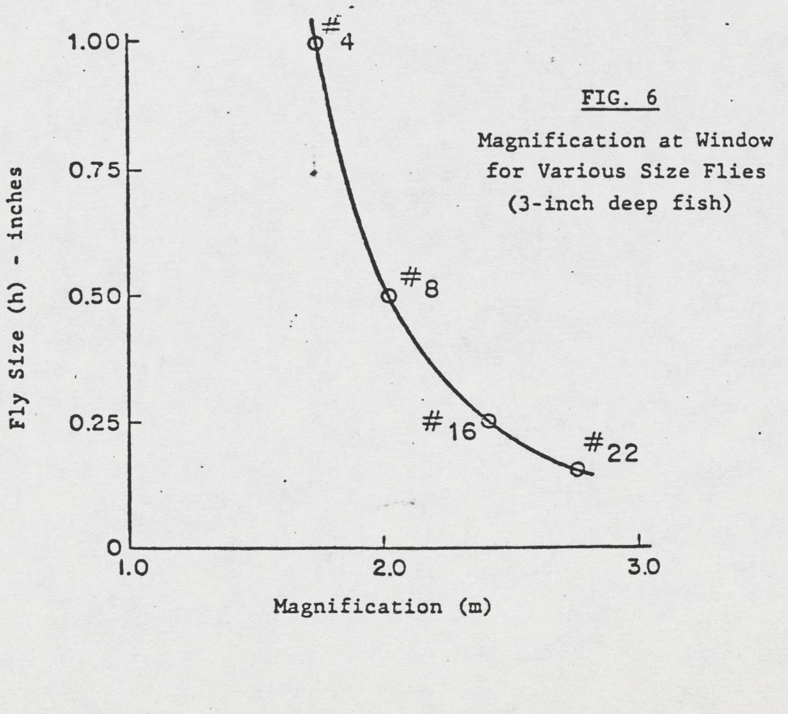


Figure 6 plots magnification at the edge of window versus fly size, again for a 3-inch deep fish. Thus a 1- inch fly (size 4) would appear to be almost 1.75" tall when it is at the window edge, while a 0.16" fly (size 22) would look about 0.44" tall.

To put it another way, at the edge of the window, a size 22 fly appears to a fish almost 3 times as large as it really is. A size 4 fly appears almost 2 times as large as you see it. To those of you who persist in the notion that exactness in duplication is wasted effort, consider this. Not only does the fish see your fly very clearly, he sees it under a magnifying glass. For us, this disposes of the controversy. Henceforth our bivisibles and other impressionisti flies will serve as decoration for our hats not our leaders.

Further from the window, the portion of the fly above the water appears compressed. Even at distances fairly near the window, this compression is so severe that the image is not resolvable. Returning to the photos, at a point further out from the window than the left photo the above-surface portion of the fly would not be visible at all, but the underbody and hook, which are subsurface, would be. This is important for all of us, but is particularly important for those that use traditional dry flies. Since a properly dressed traditional dry fly does not break the surface, nothing will be visible until the fly gets quite close to the window. How close is the significant question.

Our observations have shown that under ideal conditions a wing tip can first be perceived as a wing tip when it subtends a surface angle of about 5°. This angle determines how close your fly must be to the fish before the surface portion is visible at all. Figure 7 gives those values for a 3-inch deep fish.

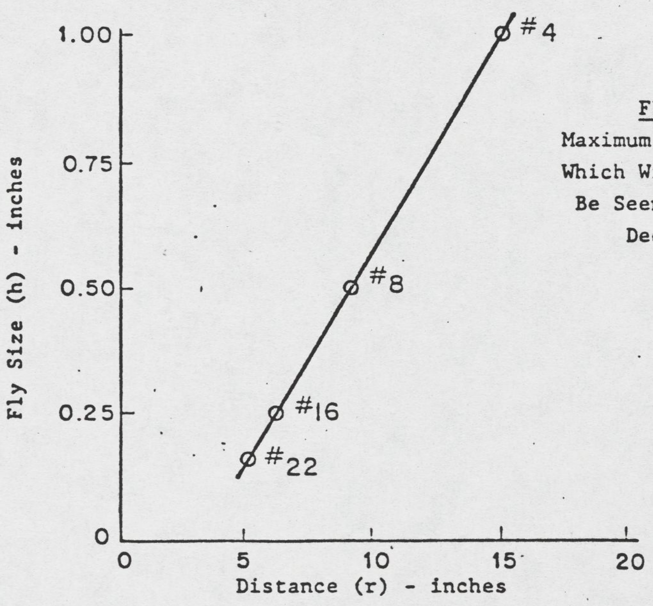


FIG. 7
Maximum Distance at Which Wing Tips Can Be Seen By 3-inch Deep Fish

If a fish can't see your fly, he is not going to be interested in it. As can be seen from Figure 7, for a traditional size 16 fly, a fish at normal feeding depth (about 3") won't see a thing until the fly is within 6" of the fish. Now think about that for a minute. You are 30 feet away and have to put your fly within 6" of the perfect line of drift. That gives you less than a ± 2% margin of casting error. A larger fly helps some, but not much. A size 8 fly must be within 9" of the perfect position. We think the average caster is incapable of that accuracy. We also think it explains a lot of the trout's "selectivity" about which volumes have been written. Selectivity? Maybe, but we now know that there is at least an equally good chance that you didn't get close enough. The fish simply has not seen the fly.

Not only would the caster be incapable of the required accuracy if the target were fixed, but the situation is dynamic, not fixed. Generally, the position of the fish is not known exactly. In addition, the fish usually moves after it takes a fly. Frankly, our new understanding of the difficulty inherent in putting a fly where it can be seen had done a great deal to soothe our wounded egos.

It would seem logical that if the fly must be so close to the fish to be seen, the fisherman need not be concerned about the trout seeing him. Not so! A wading fisherman only 3' above the surface can be seen by a 3" deep fish at 34'. Give him a fly rod which he waves 4' above his head and the moving rod is visible at 80'. We regret to say that you still have to be most careful in approaching your quarry. We wish it were not true.

Let us review what we have learned so far, and let us do it in the context of a size 4 artificial dry fly drifting downstream toward a fish holding at a 3-inch depth, starting about 3 feet upstream of the fish. This particular fly has well-defined vertical wings about 1" high, and is tied parachute-style so that its underbody and hook break the surface film. The water is clear and the light good.

Assuming that the fish has the visual acuity to see that far in the water, he will see the underbody and hook even when the fly is 3 feet away. He will also see the "condenser" effect, described by Marinaro, caused by the "dimpling" of the hackle in the surface film. Indeed, the condenser effect may be the <u>first</u> thing he sees, especially if the fly twitched. He will continue to see these things, clearly and distinctly, without distortion, as the fly moves toward him.

What he sees of the portion of the fly which is above the surface is an entirely different matter. He will see nothing at all when the fly is at 3 feet. As the fly moves toward him, he will first perceive a tiny, shapeless blob, floating in air, at about 25". By the time the fly is 15" away, that blob will look like the tip of a wing. As the fly continues to approach, the fish will begin to see more and more of the wing, but still no body. The wing will still seem to be floating in air, high above the underbody; indeed, the disembodied image of the wing will appear to be "sliding" down a 48.5° line from the sky, with the underbody proceeding horizontally below.

At some point, perhaps 4 or 5 inches away, some of the body may become discernible, and the wing will appear to elongate. Suddenly, precisely at the edge of the window, only 3.4" from the fish, the "floating" image will merge with the underbody, and the fly will appear to be about 1.75" tall. Finally, as the fly moves within the window, its image will continue to be attached to its underbody, and it will gradually reduce in size until it appears, almost directly overhead, to be about 1.35" tall.

We now have a much better understanding of the complexities inherent in the fish's window. That is useful in and of itself and should make our art more satisfying. We have learned that strange things happen to the portion of the fly above the surface. It grows to be much larger than life when at the window's edge. The subsurface portion is visible at a much greater distance than that above the surface and is seen without those strange optical effects caused by the window. The condenser or dimpling effect is highly visible.

We think these observations dictate that we design flies to get the best of both worlds. For visibility, flies should be tied so that a portion of the body breaks the surface. At least the fish will see something even if you are a human caster. The portion of the fly which is above the surface should be as distinct and representativ as possible. For ourselves, the parachute or no hackle types with cut wings best satisfy the optical requirements. We think we have brought undeniable logic to their support.

A TECHNICAL DISCUSSION

Background

Before diving headfirst into the murky underwater world of the fish, we should like to offer a word or two of reassurance.

The fundamental physical laws upon which we have relied may be found in any optics textbook. The equations which we have derived from those laws require only a knowledge of high-school trigonometry and a pencil and paper. The specific numbers which those equations can yield, however, do necessitate a good calculator. We emphasize the word good, meaning especially that it should have built-in trigonometric functions. Indeed, we are convinced that the work we have done, particularly the specific numerical examples, could not reasonably have been done by any simple fishermen prior to the recent availability of relatively cheap, powerful computing devices. The calculations we performed in a matter of 30 or 40 hours would have required several man-months to do using logarithms. Perhaps this may explain why the work was never done, despite ages of interest in the subject.

Our assumptions regarding fly sizes are taken from what we regard as unimpeachable sources: Hatches by Caucci & Nastasi and Selective Trout by Swisher & Richards. From these we calculated that a size 4 mayfly dun, e.g. a Giant Michigan Mayfly (H. limbata), would measure about 1.0" tall from waterline to wing tip; a size 8, e.g. a Brown Drake (E. simulans), about 0.50"; a size 16, e.g. a Sulphur Dun (E. dorothea), about 0.25"; and a size 22 or 24 White-wing Black (Tricorythodes), about 0.16".

Perfect Dun has 3/4" wings in True size 17/14 (Henderson)

Our assumption of a 3-inch depth as normal for a typical surface-feeding fish is taken from Ring of the Rise. If there lives a man who knows how deep a trout is in its feeding station, that man is Vincent C. Marinaro. Besides, his peerless photographs prove it.

highly variable

For our visual and photographic observations we constructed a "slant tank" along the lines of the one described by Marinaro (Ring, p. 15) and highly recommend that you utilize this tool in making your own observations.

Snell's Law

The first thing one encounters in any optics textbook is an equation, usually written

$$n \sin \phi = n' \sin \phi'$$

where ϕ and ϕ' are, respectively, the angles that an incident and refracted ray of light make with a line perpendicular to the interface of the media through which the light travels. The constants n and n' are the respective indices of refraction of the two media. This mathematical relationship is called Snell's Law after its Dutch discoverer, Willebrord Snell, circa 1621. It governs the workings of lenses and prisms, telescopes and microscopes, rainbows and - yes - dry fly fishing. It causes your rod tip to appear to bend where it enters the water. It causes a deep pool to appear (oops!) shallow. And it causes a fish to see a fly in a strange and distorted way.

Figure 8 shows how it works. For our purposes it is much more convenient to think of the incident ray in terms of the angle it makes with the surface of the water. We shall call this incident or surface angle a (for air) and the refracted or subsurface angle w (for water). Taking the index of refraction for air as n = 1.000 and for water as n' = 1.334, Snell's Law becomes

$$\cos a = 1.334 \sin w. \quad \text{(Eq. 1)}$$

From this basic equation, and a little elementary trigonometry, we are able to derive all necessary relationships.

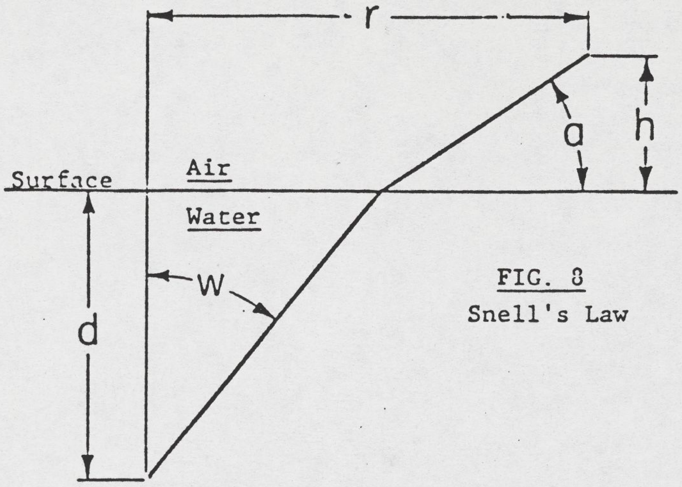


FIG. 8
Snell's Law

Thus, from Figure 8, where d is the depth of the observer (fish), h is the height of the object (fly), and r is the horizontal distance from fish to fly, we have

$$r = d \tan w + \frac{h}{\tan a}. \qquad \text{(Eq. 2)}$$

Note that a ray entering the water is always bent, or refracted, to a more vertical angle. By the same token, a ray leaving the water is bent or refracted toward the horizontal. Also, a ray will trace the same path, be it headed from fish to fly or fly to fish.

Internal Reflection - The Fish's "Window"

When a ray of light in an optically rarer medium, such as air, strikes the surface of a denser medium, such as water, only a portion of the ray penetrates the water; the remainder is reflected. Intuitively, one would feel that the smaller the incident angle a, the larger the reflected fraction, and this is exactly right. From standard optics texts, the reflected fraction f is given by the formula

$$f = \frac{(1.334 \cos w - \sin a)^2}{(1.344 \cos w + \sin a)^2}. \qquad \text{(Eq. 3)}$$

Thus, at $\underline{a}$ = 89° (nearly vertical) only about 2% of the light is reflected, while at $\underline{a}$ = 1° (nearly horizontal) about 92% of the light is reflected. Only when $\underline{a}$ = 0 (sin a = 0) is all of the light reflected.

However, when the light passes from a denser medium (water) to a rarer medium (air), a significant phenomenon occurs. This is known as the principle of total internal reflection, and is illustrated in Figure 9.

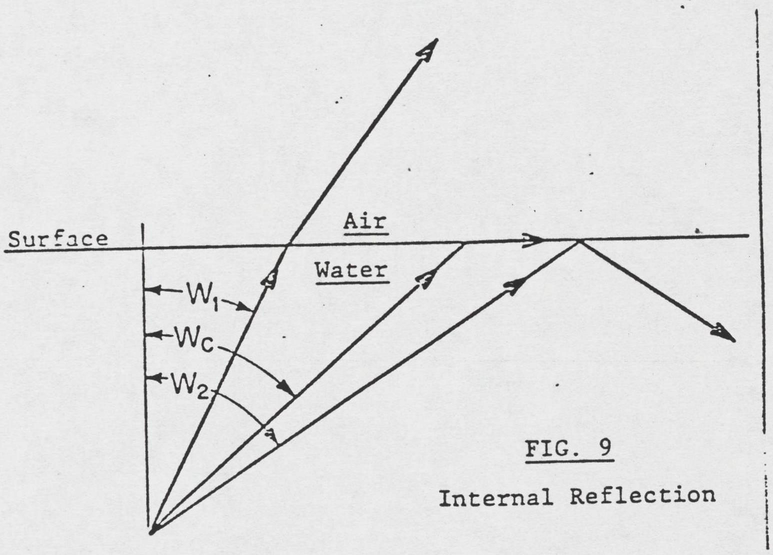


FIG. 9

Internal Reflection

As can be seen, a light ray in the water at angle $\underline{w}_1$ is refracted in air at some positive angle $\underline{a}_1$ defined by Snell's Law (Eq. 1). As the angle $\underline{a}$ approaches zero, angle $\underline{w}$ approaches a critical angle $\underline{w}_c$. At $\underline{a}$ = 0, cos a = 1, and from Snell's Law

$$\sin w_c = \frac{1}{1.334}$$

$$w_c = 48.55792089°.$$

At any angle $\underline{w}$ greater that $\underline{w}_c$, the light is <u>totally reflected</u>. Thus, in Figure 9, at $\underline{w} = \underline{w}_2$ the surface of the water acts as a perfect internal mirror.

The implications of this principle are far-reaching. It means that all light entering the water is refracted or "focused" into a cone having an angle of 2 $\underline{w}_c$, with the apex of the cone at the fish's eye. As the fish goes deeper, the cone will become larger, and as he approaches the surface, it will become smaller, but it will <u>always</u> subtend the same angle of 2 $\underline{w}_c$, or about 97.12°.

The size of the window at the surface is easy to calculate. From Figure 8 and Equations 1 and 2 we can see that when an object is at the edge of the window

$$r = d \tan w_c = 1.13d. \qquad \text{(Eq. 4)}$$

Thus, the diameter of the window (2r) can be readily calculated for any depth of fish. Figure 3 presents those calculations graphically.

This, then, defines the fish's "window". If the fish looks beyond the window (i.e., if he sights along a line at an angle $\underline{w}$ greater than $\underline{w}_c$) he will see only the bottom of the stream mirrored at the surface. Only if he looks within the cone forming his window can he see any surface objects. It should be understood, of course, that if an object such as a fly breaks the surface film so that a portion of its body is <u>below</u> the water line, the fish will be able to see that portion directly (within the limit of his visual acuity); no refraction occurs, and he can see the submerged underbody of the fly along a straight line of vision, regardless of the angle $\underline{w}$.

Alfred Ronalds, the 19-century author of <u>The Fly-Fishers Entomology</u> (1836), did not understand this principle. Marinaro (Ring, p. 12) quotes Ronalds to the effect that, long before an incident ray becomes horizontal, "it will not enter the water at all." Ronalds goes on to say that "light will not pass out of air into water, if the angle of incidence...exceeds 88° [a= 2°], but will be reflected." Of course, we have seen that this is incorrect; as long as $\underline{a}$ is greater than zero degrees, no matter how small, <u>some</u> of the light will enter the water (we saw that a full 8% entered the water at $\underline{a}$ = 1°).

Quite clearly, Ronalds did not understand Snell's Law well enough to know that internal reflection is a one-way street, only working from water to air (denser to rarer) and not in the opposite direction. How he arrived at a figure of 2° for a minimum surface angle $\underline{a}$ is problematical; we doubt that he got there by experiment. More likely, his lack of understanding of internal reflection caused him to fail to appreciate that, when $\underline{w}$ equals the critical angle $\underline{w}_c$, $\underline{a}$ equals 0°. This misunderstanding could cause one to work backwards from a rough figure for $\underline{w}_c$ in an attempt to find a similar critical figure for $\underline{a}$. But the nature of trigonometric functions is such that if one simply uses a figure of $\underline{w}_c$ = 48.5° (rather than 48.55792089°) and plugs that into Snell's Law, one gets $\underline{a}$ = 2.4° rather than zero; similarly, using n = 1.33 (rather than 1.344) results in $\underline{a}$ = 4.40! (See what we mean by a good calculator?) It all depends on the numbers one chooses, and if one fails to understand that $\underline{a}$ = 0° when $\underline{w} = \underline{w}_c$, one can be led to some serious misconceptions.

These misconceptions may well underlie Marinaro's inference (Ring, p. 23) that there is a theoretical minimum value for $\underline{a}$ of 10°. On the other hand, that conclusion may stem from a feeling on Marinaro's part, probably derived from visual and photographic observations, that $\underline{a}$ has a minimum practical value of about 10°, and that light from an object striking the water at smaller angles is somehow so distorted that no meaningful information is conveyed to the observer. Our observations confirm this.

When we observed a less distinct wing, such as the upright deer-hair post of a paradun, or the wings of a conventionally-hakcled fly, we found that we cound not perceive the wing for what it was until it subtended a surface angle of about 10°. But that only means that you have to be more accurate than is shown in Figure 7.

Magnification & Compression

So what <u>does</u> a fish see? The best way to get an understanding of this is to make a diagram, such as Figure 10.

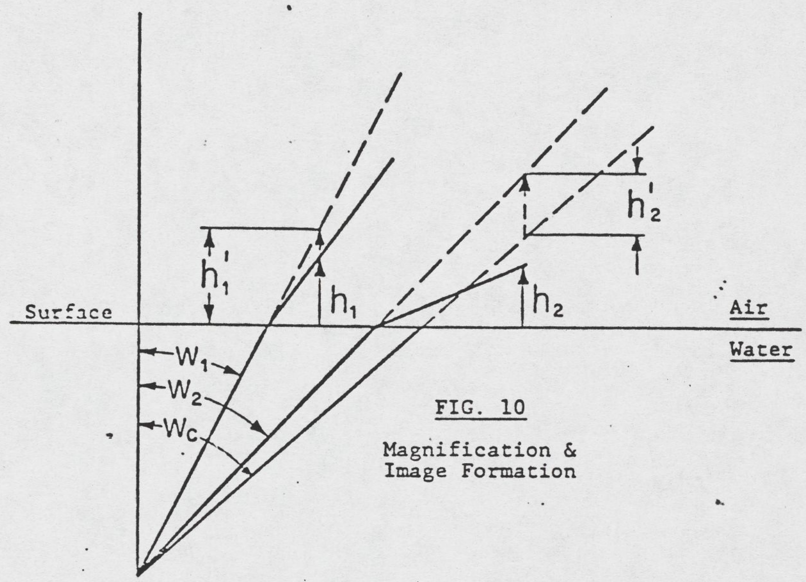


FIG. 10

Magnification & Image Formation

As you can see, we have placed a first object, or fly, of height h_1 well inside the window, and a second fly of identical height h_2 somewhat outside the window. A ray of light coming from a point at the very tip of the first fly h_1 will be refracted down to the fish, according to Snell's Law, at an angle $\underline{w}_1$. To the fish, however, the image of that point will appear to be on the straight-line extension (dashed line) of the refracted underwater ray. By the same token, light from a point infinitesimally close to the bottom of the fly will go virtually straight to the fish. Thus, the image of the fly h_1 will appear to have a height h_1', as shown. Note that h_1' is greater than h_1. Rule 1, then, is that the image of a fly inside or at the window will always appear larger than the fly. This magnification can be expressed as

$$m_i = \frac{h_1'}{h_1}$$

moves toward the window. It may also be responsible for Marinaro's assumption, which we have previously mentioned, that light rays impinging upon the water at a surface angle _a_ of less than 10° are ineffective.

As can be seen from Snell's Law, light rays entering the water at a low angle _a_ tend to be greatly "compressed" as they are refracted toward the underwater observer. Ronalds recognized this when he said (Ring, p. 12) that rays "falling very obliquely upon the surface of the water ...produce very great indistinctness and distortion of the image..." Indeed, Marinaro was really stating the effect of compression in describing (Ring, p. 18) "a fuzzy band that does affect the view of the dun fly. It derives from the fact that the more oblique the rays of the light are, that is, entering the water at a low angle, close to the surface, the more the refraction increases and the image carried by these rays becomes more indistinct."

Where Marinaro erred was in assuming that this compression occurs when the fly is at the edge of the window. In fact, it occurs well outside the window, as we have seen. There is no compression at the window's edge; indeed, it is precisely there that the magnification is at its maximum and the apparent elongation of the fly at its greatest. The "visible fuzziness" which Marinaro (and everyone else who has experimented with a slant tank) observed is simply a greatly compressed image of the horizon and all those objects near it - compressed to the point of indistinctness. And the reason this fuzziness _appears_ to be at the edge of the window is simply that _all_ objects outside the window _appear_ to be at the edge of the window. The photographs provide ample proof of this.

Without a clear understanding of internal and external reflection, Marinaro and his predecessors were unable to take the final step and quantify the distortion caused by Snell's Law. In other words, they were unable to calculate the approximate distance from a particular fly to a particular fish beyond which the fly would be so distorted, by the compression effect, as to be for practical purposes not a fly, but virtually invisible.

It is not difficult to analyze this distortion mathematically. For example, an angle $\underline{a}$ = 10° results in an angle $\underline{w}$ = 47.58°; an angle $\underline{a}$ = 5° produces an angle $\underline{w}$ = 48.31°. Thus, a 5° difference in the air is "compressed" to a difference of only 0.73° in the water. One would naturally expect this compression to produce significant distortion as the angle $\underline{a}$ becomes smaller.

The effect can perhaps be more readily appreciated by considering it in terms of magnification. Consider a fish 3" deep observing a 1-inch tall fly, such as a size 4 limbata. When the fly is 5.75" away from the fish (well outside the window), the lowermost 10% of the fly will have a magnification m = 0.10. That is, a point one-tenth of an inch up from the bottom of the fly (0.10" above the waterline) will appear to the fish to be only one-hundredth of an an inch up.

If this does not impress you as a significant distortion, then consider that same fish observing a quarter-inch fly, such as a size 16 dorothea. At a distance of only 12", a point two-tenths of an inch (80%) up on the fly will look to the fish as if it were less than six one thousandths of an inch (0.006") high. Thus, the lower 80% of that size 16 fly will be compressed by a factor of 35 (m = 0.028). Now there can be little doubt that the effect has a profound impact upon what can and cannot be seen.

One must certainly question whether an image less than 0.006" tall can be perceived by a fish at a distance of one foot. It goes without saying that it cannot be perceived for what it is. A fly compressed that much does not look like a fly.

Using Equations 2 and 5 one may calculate precisely the image size from directly overhead to the window's edge. Equation 6 may be used to calculate image size outside the window. To do so, the fish's depth and the fly size must be assumed. Figure 5 was generated for a 3" deep fish and a size 4 fly. However, the same technique can be used for any combination of fish depth and fly size.

The really significant implications of all this are apparent from Figure 7. There is, in fact, a maximum distance beyond which a fish cannot see the above-surface portion of your fly at all. You must either put your fly within that range, or show him something subsurface. And either way, you must make it as visible and realistic as possible.

Wrong. He sees the light pattern

A REVIEW OF THE LITERATURE

As we have indicated, the problem appeared to us to be most directly concerned with the fly, and how it is presented to the fish. Now there has been a lot said and written about whether and how a fish smells, hears, tastes, feels and otherwise senses external objects. But having isolated the fly itself, and how that fly is revealed to the fish, as the most probable sources of our fishing difficulties, we had to conclude that, of all the fish's sensory inputs, vision is the most significant. If you do not believe this, then read no further dear friend, but go and rub your Royal Coachman with anise oil and attach a sonic beeper thereto.

We therefore decided to attempt to determine, as best we could, how a fish sees. Perhaps we should explain what we mean by that. We do not, in our use of that phrase, mean to embrace the subjects of color perception, binocular/monocular vision, or rod-and-cone systems. Those subjects are far beyond the scope of this work and have been treated accurately and in depth elsewhere. Moreover, they are entirely irrelevant to what we are getting at. It has never been seriously doubted that a trout or a salmon can perceive color, so assume that he can. The divided monocular viewing system of a fish simply makes him more versatile, so assume he has a better range of peripheral vision than we do. Assume anything you like about his night vision.

Nor do we mean to tell you that we know how a fish visually perceives an object. That doesn't matter either. For all we know, a fish perceives a floating mayfly as a banana-shaped object. All that means is that he likes banana-shaped objects.

Perhaps he would perceive a banana as what is to us a mayfly-shaped object. Nor do we particularly care whether he sees it more or less clearly than we do. If he is nearsighted, so be it. None of this matters.

What does matter is how the optical laws of reflection and refraction alter the visual image which reaches the fish's eye. What matters is how that image is formed, not how his brain processes it. What we are trying to determine is whether a fish sees a mayfly floating on the water just as he would if he had wings and could fly in the air like a bird, or whether the fact that he is in the water alters the image of that mayfly.

We think we have the answer, or at least enough of an answer to make us excited about its ramifications. In our work, we have made use of what we regard as fairly elementary principles of optical physics, all of which have been known for more than a century. The mathematics involved is simply high-school trigonometry, nothing more. And yet, in reviewing the work of previous investigators on this subject, we have found what in hindsight appear to be incredible errors and misconceptions. This leads us to suspect that the analysis is not as straightforward as we would like to believe.

Perhaps the best way to begin is by listing a series of facts, some of which were well-known prior to our work, and some of which we uncovered in the course of it. For the present, we shall simply set them forth, and briefly indicate what prior authors have had to say about them, if anything.

1. Reversibility. It is fundamental that a ray of light will take the same path, regardless of which direction it is headed on that path. This means that if you can see a fish's eye, he can see yours, and vice-versa. Try it with a friend and a mirror.

2. Cone of Vision. All light coming to the fish's eye from the air -- that is, all light which enters the water--is focused by refraction into a cone. The apex or tip of the cone is at the fish's eye and its circular base is at the water's surface. The angle of this cone is about 97°.

3. The Window. The circular base of the cone of vision at the surface defines what has become popularly known as the fish's "window". The diameter of the window increases with the depth of the fish, in the ratio of about 2.26 to 1. Thus a fish 3 inches deep has about a 7-inch window and a one-foot deep fish has about a 27-inch window.

4. Light Penetration. At least a portion of the light striking the surface of the water from the air will actually enter the water, regardless of the angle of incidence. Thus 98% of a light ray at an incident angle of 89° (nearly vertical) will enter the water; at an incident angle of 1° (nearly horizontal) 8% of the ray will enter. Only if the angle of incidence is 0° (perfectly horizontal) will all the light be reflected, but then it hardly makes sense to talk in terms of the ray "striking" the water.

5. Internal Reflection. The same does not hold true for light rays attempting to leave the water. Within the cone of vision at least a portion of any ray will leave the water and enter the air. But rays outside the cone of vision (at an angle of greater than 48.5° from the vertical) are totally reflected at the surface. This means that outside the fish's cone of vision,

the surface of the water looks and acts like a perfect mirror; his window can be regarded as a circular hole in the mirror. This mirror produces many interesting effects: he can see the reflection of objects on the stream bottom, and a sunken fly or nymph will be reflected as a mirror image at the surface.

6. The Periscope Effect. Because of the laws governing refraction, which are responsible for light penetration and internal reflection, it is a fact that a fish can see, theoretically at least, everything above the surface of the water. There is no "blind" area. Light rays coming from all objects outside the water, all the way to the horizon, enter the water through his window, are focused in his cone of vision, and reach his eye. How well he sees those objects is entirely another matter, as we shall discover.

but only theoretically

conflict

7. Compression. The "periscope" image of a surface object, such as a fly, floating some distance outside the window, will appear to be compressed. This is because of the refractive focusing action of the cone of vision. The further the fly is away, the greater the distortion, until at last the compression or foreshortening is so great that the fly cannot be resolved at all. Thus the fly will be undiscernible at a much shorter distance than if the fish were viewing it in the air only.

8. Levitation and Tilting. The image of that same fly, floating some distance outside the window, will appear to be floating in midair, or levitated above the surface of the water. It will also appear to be tilted, or coming downhill toward the fish. The angle of that hill is (you guessed it) 48.5° from the vertical (one-half the cone angle). At the same time, any portion of the fly which happens to have broken through the surface film will be directly visible to the fish through the water. Thus the fly will appear to the fish to have split into top and bottom halves.

9. Magnification. As the floating fly approaches the window, its image will become less and less compressed until, at a certain point still outside the window, it appears life-sized. At this point the most curious phenomenon of all begins to occur. The image of the fly appears to get larger, with maximum magnification occuring precisely at the window's edge. This magnification, which varies with the depth of the fish and the height of the object (fly) can be startling: for example, a size 22 fly at the edge of the window of a 3-inch deep fish would appear (in vertical dimension) to be about a size 10! Also precisely at the edge of the window the levitated image, which has been "sliding" downhill, merges with the surface, and the fly appears to be in one piece again. As the floating fly continues to move inside the window, the magnification begins to decrease toward a limit of 1.33 directly overhead. This means that any object, regardless of the fish's depth, will look about one-third larger when it is directly overhead.

We suspect that the foregoing is quite a bite to attempt to digest at one time. Go back and read them a time or two. See if they make any better sense upon rereading. They are, after all, facts. You can, if you have some mathematical training, derive them yourself.

But if you can't make the derivations, don't feel too badly. Ten very highly regarded works of angling literature reflect similar failures, ranging from near misses to outright fumbles. Let's take a look, and see how the experts handled the laws of optics.

Reversibility. Everyone who considered this question at all appears to have gotten it right except, amazingly enough, Edward

R. Hewitt. In his A Trout and Salmon Fisherman For Seventy-five Years, Mr. Hewitt flatly states that under certain circumstances the laws of optics are such that a fish can see the fisherman without the fisherman seeing the fish. And his context is clear: he is postulating a violation of the law of reversibility. This is significant only in that it shows how badly a highly regarded author can be misled.

Cone of Vision. Everyone recognizes the cone of vision, but only about half the authors have the confidence to quantify it. Of these, two got it wrong: Mr. Hewitt, and Charles K. Fox in his Rising Trout, both put it at 83°. This is an easy mistake to make, and results from getting your sines and cosines mixed up, but it creates fatal errors in any further analysis.

The Window. Most everyone understood that there is a relationship between depth and window diameter, but here again Mr. Hewitt got his numbers wrong, undoubtedly because of his cone angle error. Surprisingly, so did Ernest Schwiebert in an article entitled "Why Trout Act That Way", Trout (Spring 1978). Perhaps he used Hewitt's figures.

Light Penetration. The tables are turned. Only Mr. Hewitt got this one right. Another author to clearly express himself on the subject was the dean of them all, Alfred Ronalds in The Fly-Fisher's Entomology (1836); Ronalds said that no light enters the water at an incident angle of less than 2°. The figure was pegged at 10° by Sosin & Clark in Through the Fish's Eye (1973) and by Vincent C. Marinaro in In the Ring of the Rise (1976). Barry Parker in his article "Looking Into The Trout's Window", Fly Fisherman (Spring Special 1976) seemed to put it at 7.5°. They are all wrong.

Internal Reflection. Everybody got this one right. This is probably due to first-hand observation in a lake or swimming pool, or even a bathtub. Try it yourself.

The Periscope Effect. Here the various mathematical errors and optical misconceptions begin to take a toll, with the result that several of the authors are quite vague on whether a fish can in fact see a fly which is floating outside the limits of the window. Two of them got it dead wrong: Schweibert and Parker both indicate that a fly can't be seen outside the window! Parker, Marinaro, Ronalds, Fox and Dan Holland in The Trout Fisherman's Bible (1949), all postulate "blind areas" ranging from 2° to 10°. Whether these errors were the result of mathematical misconceptions or a lack of understanding of either penetration angles or the compression effect (see below) is difficult to say. Only two authors got high marks here: Leslie P. Thompson in Fishing in New England and Cecil E. Heacox in The Compleat Brown Trout (1974). Both seemed to understand that a fish is theoretically capable of seeing everything outside his window.

Compression. Thompson, to his everlasting credit, was able to take this thought one step further and understand that the reason the fish did not see all extra-window objects clearly was compression and its distorting effects. Ronalds, Marinaro and Holland were also on the right track but confused matters with their "blind area" error. Schweibert discussed compression, as did Hewitt, but the latter incorrectly concluded that it occured inside the window.

Levitation and Tilting. Half of the authors recognized these dual effects: Ronalds, Thompson, Fox, Heacox and Marinaro. Ronalds, in particular, deserves special credit due to the remarkable priority of his work (1836).

Magnification. It is here that we feel we have made some small contribution, for it is clear beyond question that none of the authors mentioned above (nor, to our knowledge, anyone else) recognized this phenomenon. And yet the astonishing fact is that, in hindsight, the effect is clearly illustrated in the pioneering photographs of Mr. Hewitt, and the much better and more recent photographic work of Marinaro and John Merwin, "Mr. Hewitt's Window Box", Fly Fisherman (Spring Special 1976). There it was for all to see and yet all failed to see it.

Actually, this is not so astonishing, for we failed to see it at first in our own photographs. It was not until, by chance, a ruled scale was placed in our slant tank that we got a clue that the effect even existed. This prompted a frenzied mathematical analysis which ultimately confirmed our observations and laid open the whole theory.

It does not, we feel, take much cogitation to conclude that the magnification effect is by far the most significant to the fly fisherman. Just how significant remains to be seen.

Evidently did not consult Harding.

<u>CONCLUSIONS AND FOOD FOR THOUGHT</u>

1. An object outside the window is seen as two separate images (split-image). The above-surface portion is seen at the edge of the window and the below-surface portion is seen at its normal position.

2. The above-surface image is vertically compressed or magnified depending upon its location with respect to the window.

3. The degree of magnification is depth dependent. The deeper the fish, the greater the magnification.

4. Magnification is size dependent. Small flies are magnified more greatly than larger objects. Also, the lowermost portion of a fly is magnified more than the upper portions.

5. When a trout inspects and takes a dry fly, the image presented to him through the surface is distinct, colorful, and magnified. Consequently, exactness in duplication should be important. not proven

6. There is a "ring of visibility" outside of which the above-surface portion of the fly cannot be discerned as such. For shallow fish the "ring of visibility" is extremely small and may partially explain "selectivity".

7. The "ring of visibility" can be significantly increased by using a fly design which presents a very distinct wing, such as a no-hackle type. If the fly is more visible, it follows that your chances of catching fish are improved.

8. Refraction causes a larger magnification for small flies than for larger flies. Therefore, the size differences between small and large flies as seen from underwater are less than they appear to the angler. This makes one wonder as to the alleged importance of size.

9. Small flies are greatly magnified at reasonable depths, they should be used with confidence.

10. A sunken fly also presents two images to the fish, real and reflected. They are indistinguishable visually.

11. The double images created by refraction and reflection give the fish a 50-50 chance of attacking the wrong image. This is equally true for both surface and underwater lures, flies or otherwise. This may explain short strikes, misses, and the trout's behavior of "knocking down the dry fly and then taking it".

12. Because magnification changes with depth, a fish attacking the above-surface image will perceive the fly as either getting smaller or moving away from it (the phenomena are visually indistinguishable). However, a fish attacking the below-surface portion will perceive the image as we are used to seeing it. The implications are unclear but suggest a complex process for determining when to "hit" the fly.

13. All of the above is too damn hard.

THE AMATEUR SCIENTIST

What is a fish's view of a fisherman and the fly he has cast on the water?

by Jearl Walker

A fly fisherman who sees a fish in the water confronts the problem of where to cast the fly. The received wisdom is that the best place is just above the fish. Does the cast have to be that accurate? If it misses by a few centimeters, will the fish still see it as a fly? Robert Harmon and John Cline, who are patent attorneys in Chicago, have been looking into the optics of fly fishing. They believe the cast does have to be fairly accurate, otherwise the image seen by the fish might be too distorted by the refraction of the light rays at the surface of the water.

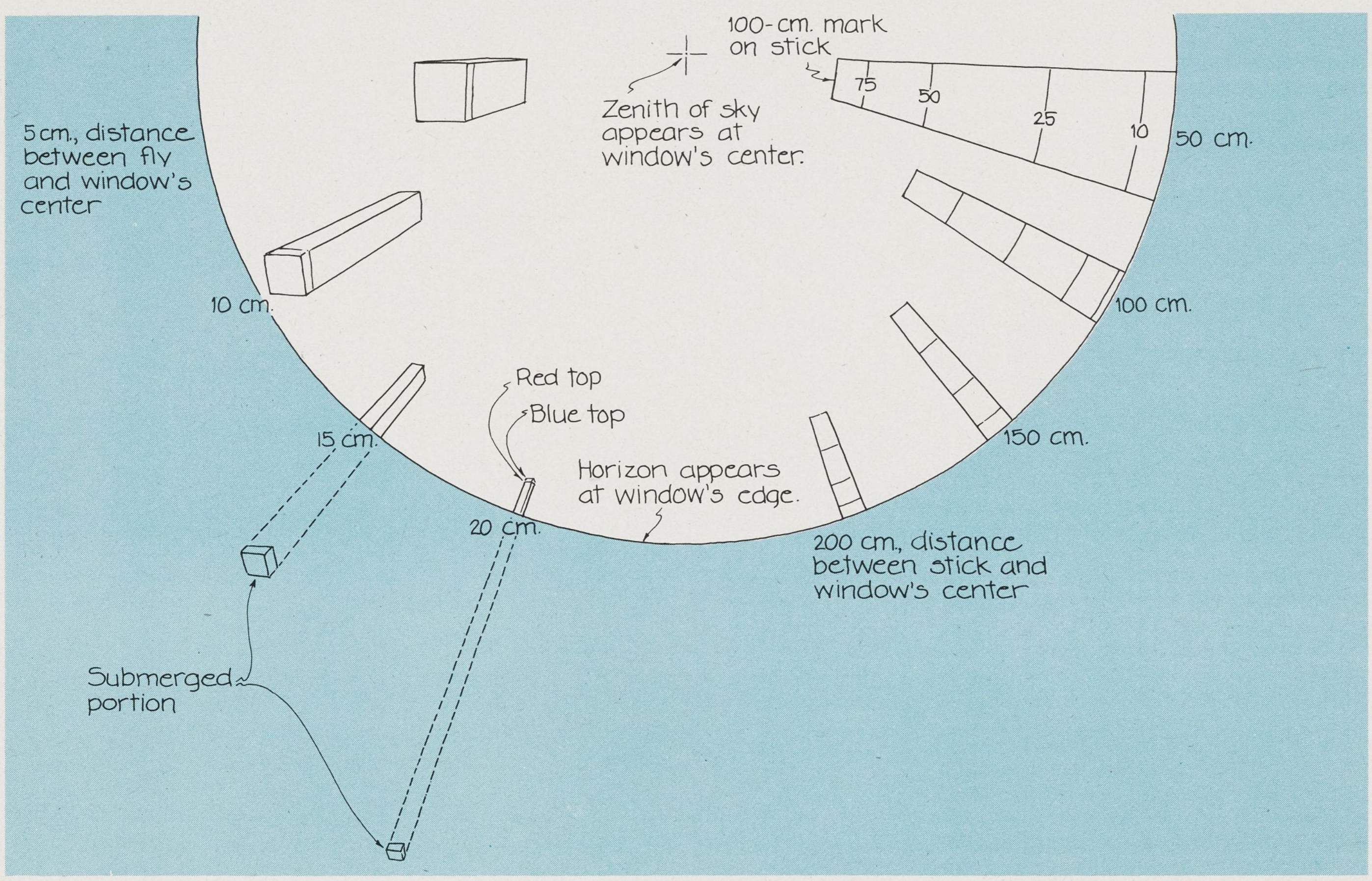
Light in a vacuum travels at only one speed (3×10^8 meters per second). Through any transparent medium, however, its speed is lower because the light interacts with the molecules of the medium. Each interaction can be considered as a brief absorption of the light.

The easiest way to describe the net delay in the passage of the light through the medium is to say the light is moving slower. For this purpose every transparent medium is assigned an index of refraction. The effective speed of light through the medium is equal to the speed of light in a vacuum divided by the index of refraction. The index of refraction of water is approximately 1.331 and of air slightly more than 1. Hence the effective speed of light through air is almost the same as it is through a vacuum, whereas through water the speed is considerably lower.

When a light ray passes through the surface of water, it is refracted (changes its direction) because of the change in its effective speed. By convention the orientation of a ray is measured with respect to a line perpendicular to the surface crossed by the ray. Suppose the ray is incident on the water surface at an angle of 42 degrees with respect to the vertical. Part of the light is reflected from the surface at the same angle from the vertical. The rest of the light refracts into the water as a ray 30 degrees off the vertical.

Other angles of incidence yield other angles of refraction. The relation is set out in the rule named for Willebrord Snell, who proposed it in 1621. According to Snell's rule, the sine of the angle of refraction in the water is equal to a fraction of the sine of the incident angle in the air. The fraction is the ratio of the respective indexes (air : water). In every case except one the angle of refraction is smaller than the angle of incidence. The exception is when the ray is incident along the vertical line; then it goes into the water with no change in direction.

Consider a ray that comes to a fish from an object a short distance above the surface of the water. If the fish can assign a position to the origin of the ray (as a human being can), it interprets the object as lying somewhere along the ray.

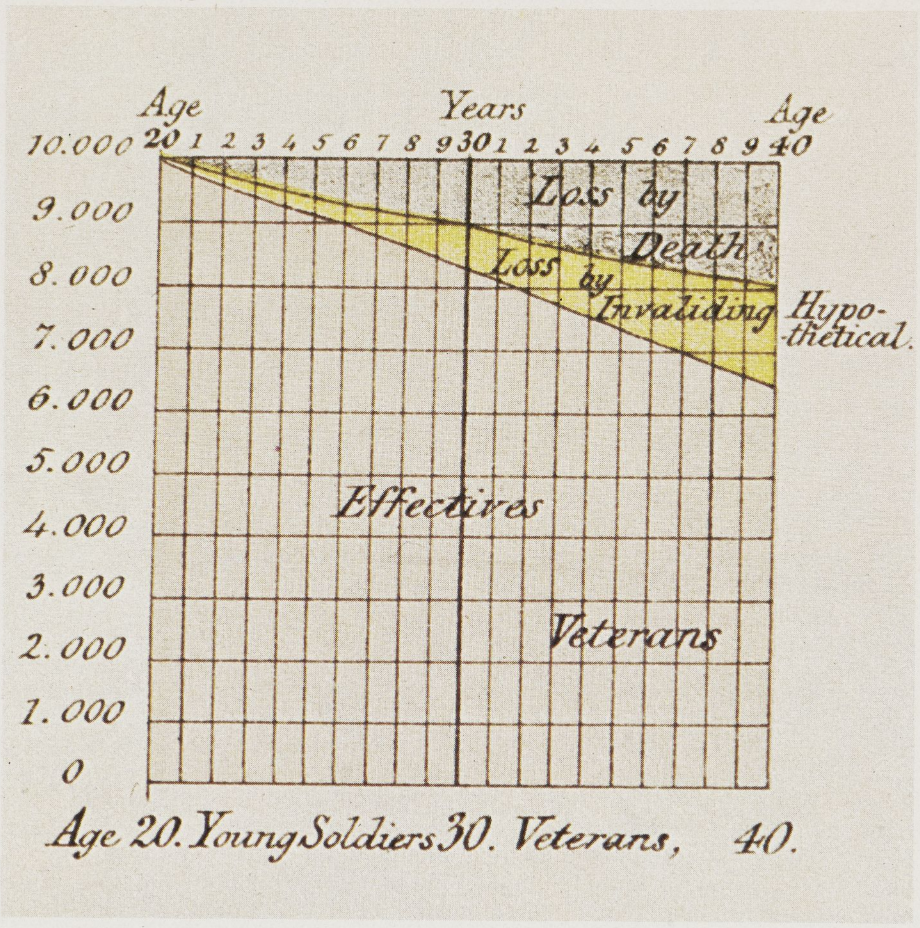


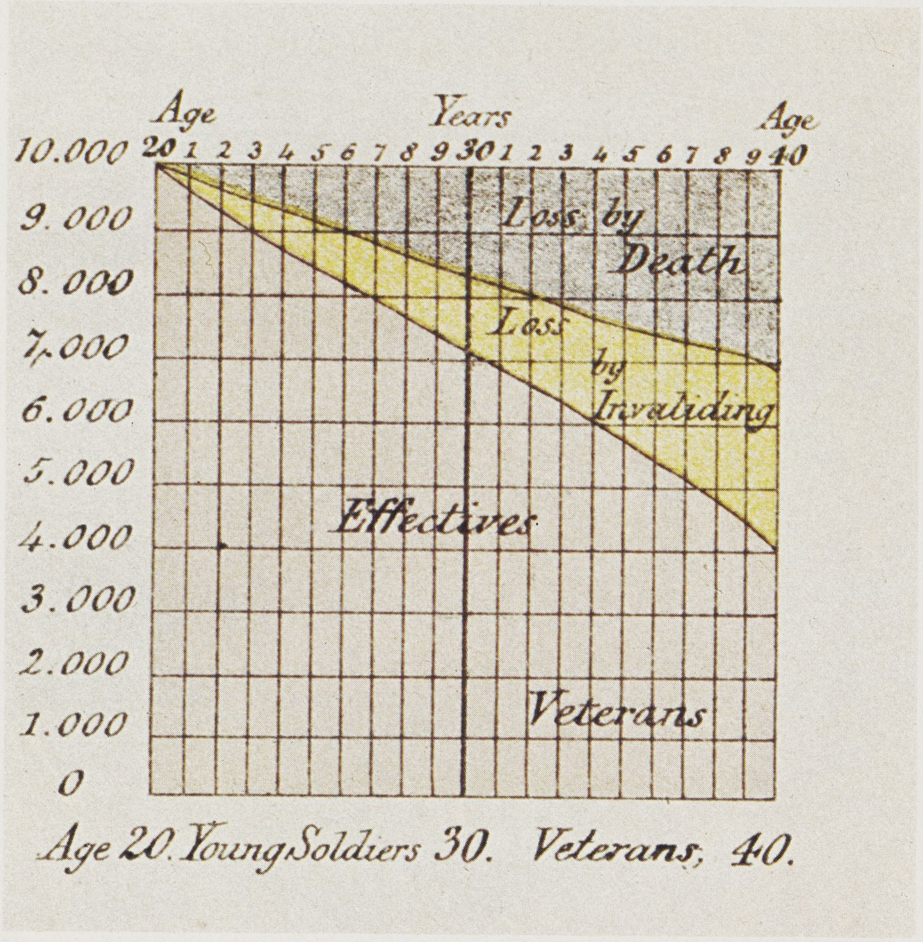
The view through a fish's "window" at the water surface depends the practical application of every other [science]." Judging from their correspondence, the respect seems to have been mutual.

Although statistics were important to Nightingale, during her later years of being "an influential" she by her own account yearned to return to nursing, her chosen profession, her first "call from God." She could not, however, because she lived a good part of her life after her return from the Crimea as an invalid, practically bedridden.

Although Nightingale's poor health may have been related to a fever she contracted while she was in the Crimea, some have suggested that she did not have an organic illness at all, that her invalidism was neurotic or even intentional. In any event confinement to her bedroom, where she received a steady stream of visitors, did not diminish her influence or keep her from establishing the professional status of modern nursing. With money from the Nightingale Fund (almost 50,000 pounds, raised by public subscription to honor "the Popular Heroine") she was able to realize an early goal, founding the Nightingale Training School for Nurses in 1860. She could not, as she had hoped, superintend the school, but it followed her principles: "(1) That nurses should have their technical training in hospitals specially organized for that purpose; (2) That they should live in a home fit to form their moral life and discipline."

Both principles were radical in their time. That they are accepted as commonplace today is testimony to Florence Nightingale's service to nursing, which did as much as any scientific advance to improve the general quality of medical care. In view of her other passion, it is appropriate that another telling indicator of that service is statistical: in 1861 the British census found 27,618 nurses in Britain, and it listed that figure in the tables of occupations under the heading "Domestics"; by 1901 the number had increased to 64,214, and it was listed under "Medicine."





LOSS OF MANPOWER in the British army due to excess mortality and invaliding is illustrated by diagrams from the report of the Royal Commission. Both graphs assume that 10,000 20-year-old recruits are added to the force annually and that a healthy soldier's career lasts for 20 years. Each small rectangle represents 1,000 men. Under the existing unhealthy conditions (*bottom*) death (*brown*) and invaliding (*yellow*) reduce the strength of the army (*beige*) to 141,764 from its maximum size of 200,000, a loss of 29 percent. If mortality were as low as it was in the civilian population and the relation between mortality and the invaliding rate stayed the same, the report concluded, the strength of the army would increase significantly, to 166,910 (*top*).

The object therefore appears to be at an angle in the sky higher than the true angle. The error is small if the angle of the incident ray is small and large if the angle is large.

The ray refracted the most comes from near the horizon; it is incident on the water at an angle of slightly less than 90 degrees. The angle of refraction is approximately 48.7 degrees. (The exact angle depends on the index of refraction of the water.) No ray from above the water can reach the fish at a larger angle of refraction. Hence all the rays reaching the fish from above the water fall within an imaginary cone with its apex centered on the fish's eye and with its sides 48.7 degrees off the vertical.

Harmon and Cline call the intersection of this cone with the surface of the water the "window" through which the fish sees objects above the water. A ray from the horizon passes through the edge of the window and then down the side of the cone. The size of the window varies with the fish's depth in the water. When the fish is at a depth of 10 centimeters, the radius of the window is 11.3 centimeters. A greater depth gives a wider window but cannot alter the angular size of the cone. That size is set by the refraction of the rays from the horizon.

The view of the external world that arrives at the fish is anamorphic: the magnification differs in each of two perpendicular directions. Refraction warps and repositions objects in the fish's view. Perhaps a fish can interpret the anamorphic view, realizing that the objects appearing in the window lie at some distance above the surface of the water. Perhaps instead the fish regards the objects as being on the surface. In either case what does the fisherman look like to the fish?

I investigated the question by computer, calculating what the refraction would be from each of four vertical sticks at several distances from a fish. I programmed my home computer to make the calculation on the basis that each stick extends one meter above the water and 20 centimeters below it, which is about right to simulate a fisherman standing in shallow water. The fish is assumed to be 10 centimeters below the surface, which is a reasonable depth for a feeding fish.

I first considered a stick two meters from the fish horizontally. A ray from the submerged part of the stick is not refracted and is perceived (if the fish can see that far) in its proper place. A ray from just above the waterline on the stick passes through the edge of the window and travels along the side of the imaginary cone that marks the limit of the rays reaching the fish from above the water. The fish might interpret this ray as originating somewhere back along a line making the same angle with the vertical. If it does, the waterline of the stick would seem to lie along a line 48.7 degrees from the vertical.

A ray from the top of the stick passes slightly closer to the center of the window. Its angle of refraction is about 42 degrees. The fish might see the ray as originating along a line that is a rearward extrapolation of the refracted ray. If the fish does, the top of the stick would seem to lie on a line 42 degrees off the vertical. Hence if the fish has depth perception, the stick would seem to lie somewhere in the air between 42 and 48.7 degrees off the vertical.

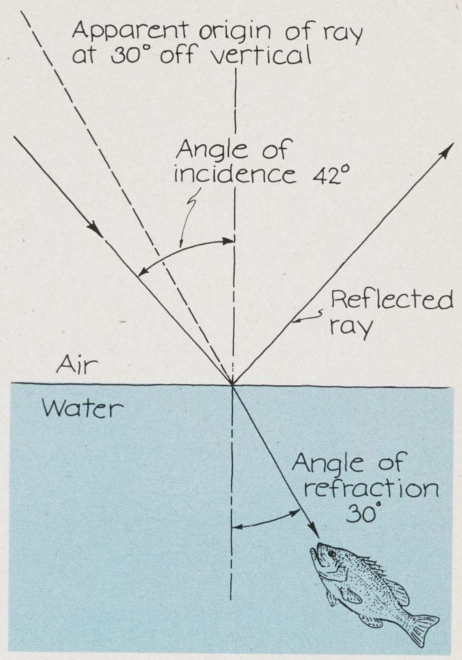
The situation is represented in the bottom illustration on the next page. The image of the stick curves between those angles. In order to leave room for the other components of the illustration the image is shown as being separated from the window by about as much as the stick actually is.

Do not take the drawing literally. I do not know if the fish can mentally extrapolate light rays. I also do not know if it can even recognize a stick for what it is. Surely a fish cannot conclude that the seemingly warped object is a vertical, rigid stick. Much of a human being's ability to assign depth and shape to objects comes from experience with those objects.

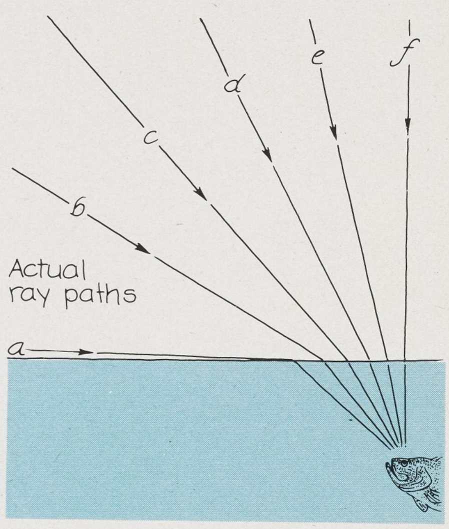
With my computer I calculated angular positions for three other sticks. In all four cases the fish sees two images of the stick. The part above the surface of the water is seen through the window. The submerged part is seen in its true position and is well separated from the image of the part above the surface. As I move a stick closer to the window the images of the two parts get closer to each other, finally merging when the stick reaches the edge of the window.

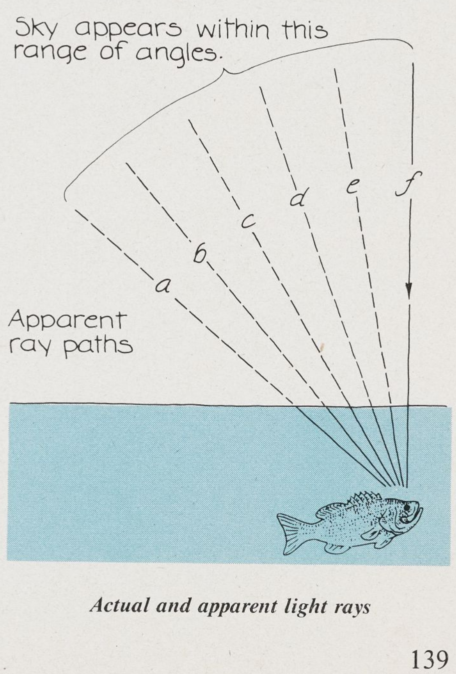
The illustration on the opposite page offers a flat view of the sticks as they are seen through the refraction of the window. A fish without depth perception or any understanding of what it is seeing probably depends on such a flat picture of the external world. To keep the sticks from overlapping in the illustration I have repositioned them so that they lie in a circle around the fish. The sizes of the sticks and the distances from them to the fish are the same as before. The submerged parts are not shown because they are too far away to fit into the illustration. Marks on the sticks indicate several heights above the waterline.

In the illustration the bottom of the part of a stick above the surface appears at the edge of the window and the top appears along a radial line and closer to the center of the window. A stick two meters from the fish is compressed into a small area. The bottom of the part of the stick above the surface is compressed more than the top because of the strong refraction of the rays from the bottom. The image of the stick takes up less than 2.5 centimeters along a radius of

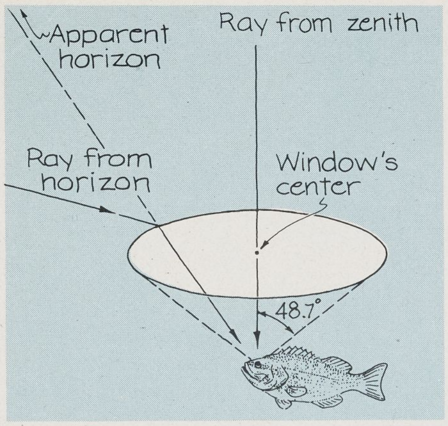


Refraction at a water surface





Actual and apparent light rays



The geometry of the window

the window. Since many other objects around a body of water would show up along the edge of the window, the stick might be lost in the clutter.

Less compression is apparent in the sticks 1.5 meters and one meter from the fish. Since they extend more toward the center of the window, however, they are noticeably tapered. The stick 50 centimeters from the fish is even more tapered and distorted. The full image of the part above the surface takes up about 70 percent of a radial line in the window and therefore must be quite noticeable to a fish.

My stick is equivalent to a short fisherman. Such a fisherman two meters or more from the fish is compressed into a miniature that occupies only a small part of the window and may be lost in the clutter at the edge. As the fisherman moves closer to the fish he takes up more angle in the fish's field of view and occupies more of the window. The submerged part of the fisherman also gets larger in the fish's field of view.

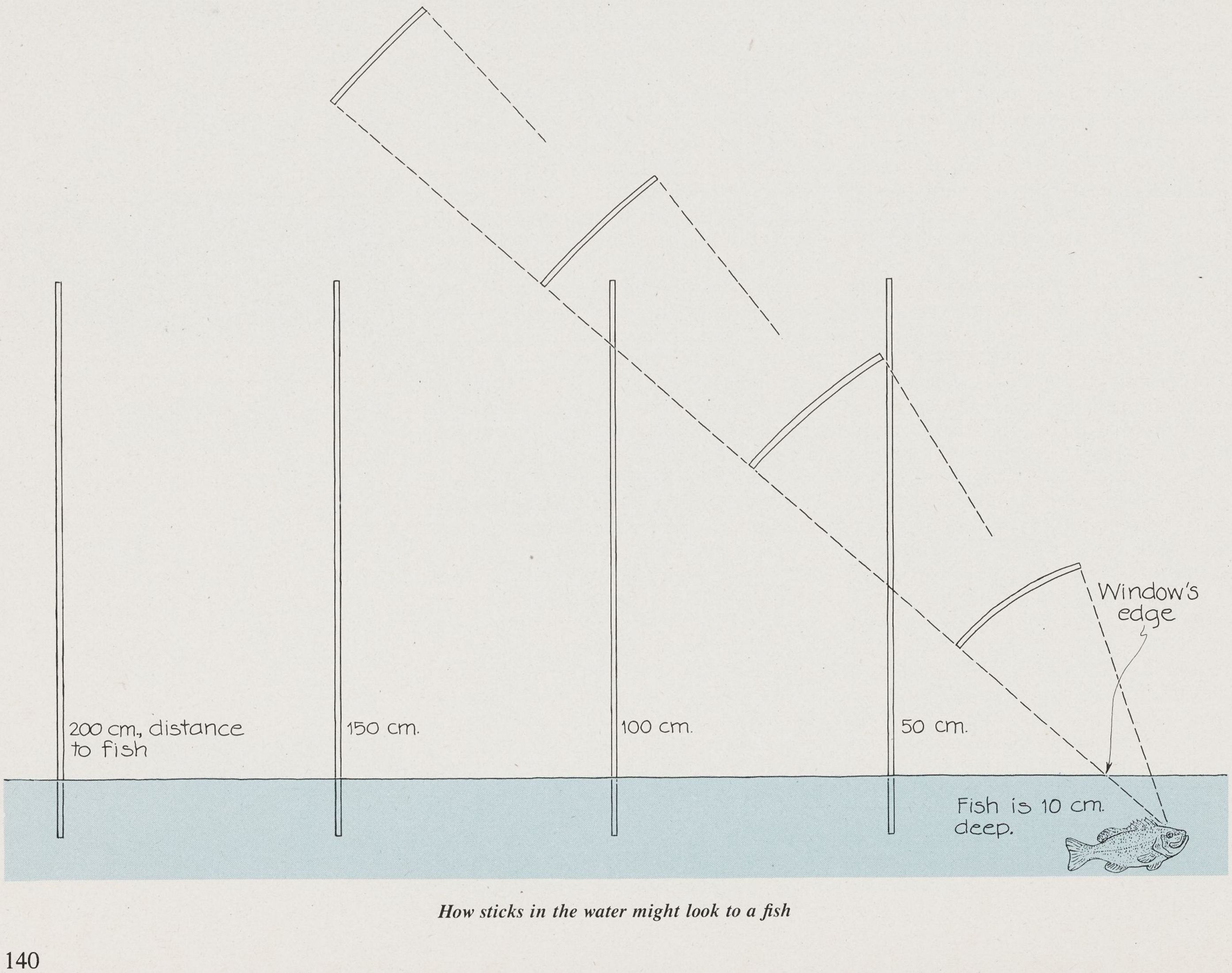
At some point the motion of one of these images warns the fish of possible danger. The motion of the part of the fisherman above the water shows up as an image that starts at the edge of the window and grows radially toward the center. Perhaps the fish watches for motion that looks as though it might cast a full image from the edge to the center.

Similar optics applies to the appearance of a fly cast near a fish. Some possibilities are represented on the left side of the illustration on page 138. For the sake of convenience I have considered a narrow rectangular fly extending 2.5 centimeters above the surface and .2 centimeter below it. (The height is about the same as that of a size 4 dry fly. The width of the fly along the surface is not important.) Although a rectangular fly is not likely to be inviting to a fish, it serves to demonstrate the distortion caused by refraction.

I programmed my computer to find the image the fly makes in the window. If the waterline of the fly is five centimeters from the center of the window, the part of the fly above the surface of the water lies across only 1.3 centimeters of a radial line in the window. The part below the surface, which is compressed, merges into the image of the part above the surface.

As the fly moves closer to the edge its image stretches. For example, when the fly's waterline is 10 centimeters from the center of the window, the image of the part of the fly above the surface takes up three centimeters along a radial line. That is more than the true height of the fly. The image of the part below the surface, still attached to that of the part above the surface, is also stretched slightly, which should make the fly more noticeable to the fish.

When the fly moves past the edge of the window, the image of the part above the surface begins to contract and that of the part below the surface separates from it. The illustration shows the situation when the fly is 15 centimeters from



How sticks in the water might look to a fish the center of the window. The top of the part below the surface is seen at its proper distance from the center. The bottom of the part above the surface appears at the edge. The top of the fly, which is actually 2.5 centimeters above the waterline, shows up only 1.9 centimeters from the edge of the window. The fly is no longer easy to see.

When the fly is moved to 20 centimeters from the center of the window, the apparent contraction of the part above the surface is greater. The bottom of that part still lies at the edge of the window and the top now appears at about .8 centimeter from the edge. This contraction of the image of the part above the surface gives the fish a highly distorted view of the fly. Moreover, the image of the part above the surface may be lost in the clutter at the edge of the window. Recognizing the fly is now more difficult. In addition the image of the part below the surface is well removed from the image in the window. Even if both images are still perceptible, a fish is likely to see two objects, both of them small.

Harmon and Cline say that if you are fishing with a fly and can see the fish, cast the fly as close to it as you can. If you can put the fly within the fish's window, it may be recognizable as a fly. At least the images of the part of the fly above the water and of the part below the water are merged. If the fly lies inside the window near the edge, the image of the part above the water is magnified in the sense that its length along a radial line of the window is larger than the true height of the fly.

If your cast is off by a few centimeters, the fly may be outside the fish's window. The separation of the images of the part below the surface and of the part above makes the fly look less like a fly. The compression of the image of the part above the surface may even make that part so small that it is lost in the clutter at the edge of the window.

The problem is particularly difficult if the fisherman is in the same direction from the fish as the fly is; his image adds to the clutter. In this situation his only chance of attracting the fish is with the image of the part of the fly below the surface, which the fish will see without distortion by refraction. Harmon and Cline suggest it would be well if that part of the fly were brightly colored.

So far I have assumed that the index of refraction of water has a single value. In reality it differs at different wavelengths of light. Red light, at the long-wavelength end of the visible range, has an index of about 1.331. Blue light, at the short-wavelength end, has an index of about 1.343. Suppose a ray of white light, consisting of all the colors, passes into water. Refraction spreads the colors through a small range of angles. The ray with the smallest angle of refraction is blue; the one with the largest angle of refraction is red. The colors at intermediate wavelengths have intermediate angles of refraction. This separation of colors is called dispersion.

Harmon and Cline point out that dispersion plays a minor role in the image a fish sees in its window. To investigate dispersion I considered the rays of white light extending from the top of my imaginary rectangular fly. One ray refracts at the water surface to send a red ray to the fish. Another ray refracts slightly closer to the center of the window to send a blue ray. The fish sees a colored image where the rays cross through the window. Although the blue image is slightly closer to the center of the window, the dispersion of the colored image is weak unless the fly is well outside the window. Even then the spread amounts to no more than about a millimeter in the window.

What the fish sees on the surface of the water outside the window is largely a reflection of rays that have scattered off the bottom. Although any refraction of light through the surface and into the air must obey Snell's rule, for some rays refraction is impossible. Whether or not a ray refracts depends on the angle of incidence. If the angle is less than 48.7 degrees, part of the light refracts through the surface and the rest reflects downward. According to Snell's rule, the angle of refraction (now in the air) must be larger than the angle of incidence. The angle of refraction can be as much as 90 degrees, however, which it is when the refracted ray barely skims over the surface of the water.

If the incident angle is larger than 48.7 degrees, refraction is impossible. The light can only reflect, a situation that is called total internal reflection since the light is unable to escape from the water. Any light that reflects to the fish from the underside of the window must have an angle of incidence smaller than 48.7 degrees. There part of the light also refracts into the air. A ray that reflects just at the window's edge has an angle of incidence of 48.7 degrees, sending a refracted component along the surface of the water. Any light that reflects to the fish from the rest of the surface must have an angle of incidence larger than 48.7 degrees. All this light is internally reflected. The reflections from the window region are likely to be lost in the glare of light from the sky, but the reflections elsewhere might be bright enough to give the fish a mirrorlike picture of the bottom.

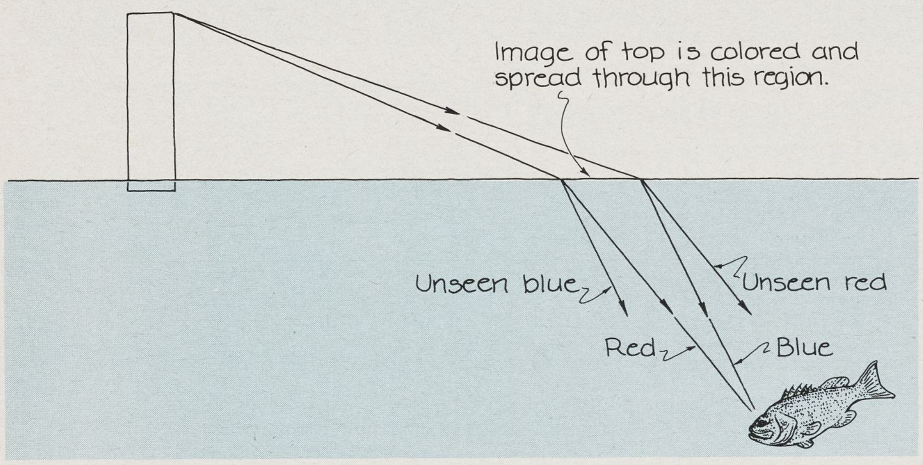
The optics I have been discussing applies to a situation in which a fish looks out through the sides of an aquarium. Here, of course, the window is in a vertical plane. The anamorphic distortion resulting from refraction would change the geometry of objects outside the aquarium. For example, an object that is in fact square would have the shape of a pincushion.

The human eye open in water does not see any of these optical distortions because it is adapted for vision in air. About two-thirds of the refraction necessary for focusing normally takes place at the surface of the eye. Since the eye has almost the same index of refraction as water, a submerged eye loses that refraction. It cannot focus on objects imaged in the window. You can regain focus if you wear a face mask to trap air next to your eye. Is there a window then? There is none if the plane of the mask is parallel to the surface of the water. When the rays pass from the water into the air in the mask, the refraction reinstates their original directions of travel. The cone limiting the rays is eliminated and therefore so is the window. You might want to investigate other orientations of the face mask.

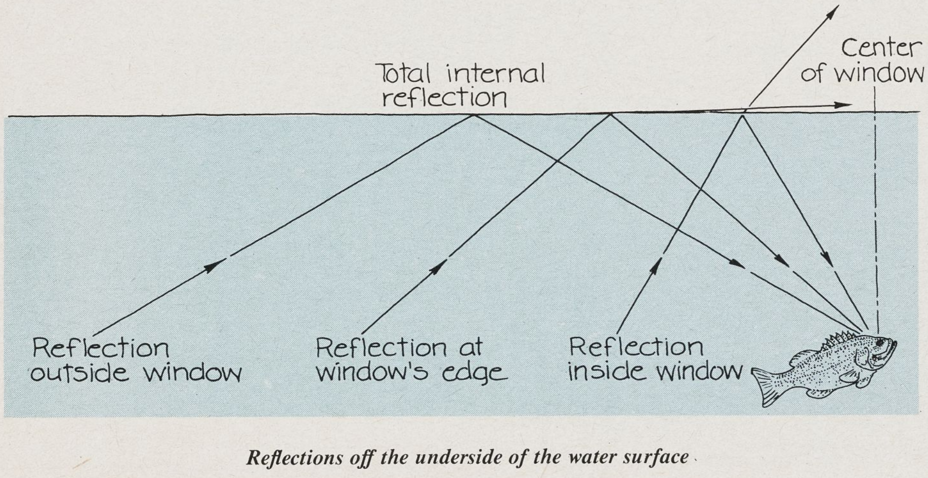
I have briefly considered another refraction problem common to fishing. Can you see a fish in its true location? The problem is crucial if you fish, as a few people do, with a bow and arrow. Should you aim the arrow directly at the fish as you see it? The answer is no. Unless the fish is just below the surface, you should aim lower in your field of view. The rays reaching you from the fish refract according to Snell's rule, ending up with larger angles with respect to the vertical than they had initially. When you receive one of the rays, you mentally extrapolate back along it to find the source, being misled into thinking that the fish is in that direction.

Lawrence E. Kinsler analyzed similar problems about the refraction of rays from a submerged object. He pointed out that the depth of an object is misjudged even when your view is from directly above it. Much of your decision about the distance to the object derives from the angle through which each eye must turn so that the eyes together can converge their lines of sight on the object. Since the rays of light are refracted before they reach the eyes, the point of convergence lies above the object, leaving you with the illusion that the object is not as deep as it actually is.

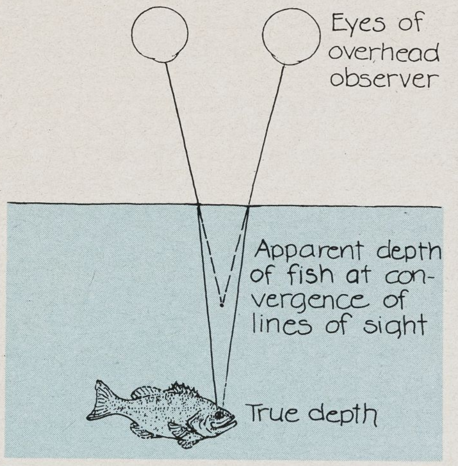
Observations from other angles also involve such an error in the assignment of depth. Kinsler's results (for a fish) are summarized in the lower illustration on the opposite page. One ray is included to represent the light that travels from the fish to the observer. Actually each eye receives a ray from a slightly different direction. The observer believes the fish lies along a rearward extrapolation



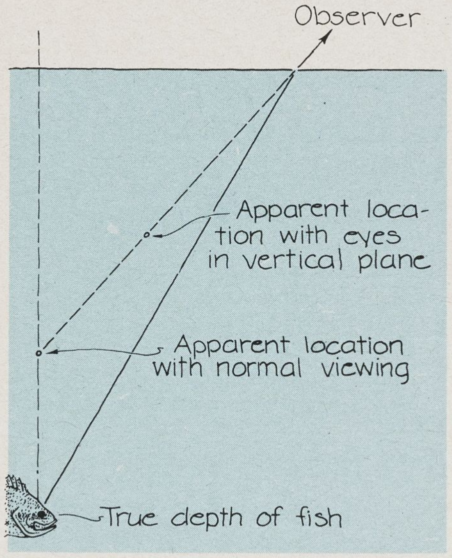
The dispersion of light rays



Reflections off the underside of the water surface



The illusion of depth

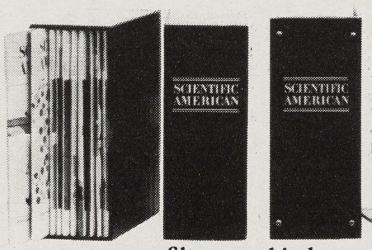


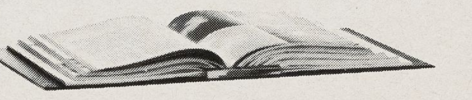
Where a fish is and appears to be

of the rays. In the illustration the extrapolation is indicated for the single representative ray. The convergence of the lines of sight from the eyes determines where along the extrapolation the fish appears to be. The result is that the fish seems to be higher on a vertical line running through its true location.

Such is the illusion for a normal view of a fish. Suppose the observer lies on a dock with his eyes directed downward in a vertical plane. As before the fish seems to be on a rearward extrapolation of the rays reaching the eyes. This time they seem to come from a place higher and closer to the observer.

You can check these illusions with a simple demonstration. Fill a tub with water. Look at a coin on the bottom. When your line of sight is well off the vertical, the apparent depth of the coin is obviously inconsistent with the depth of the tub. When you then move your head so that your eyes are in a vertical plane, the apparent position of the coin immediately shifts so that the coin seems to be higher and closer to you.





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No matter where you live, there's probably a good place to catch catfish nearby. Here's all you need to know to join the action, including a detailed state-by-state guide to the best catfish waters in your region.

The crisp evening held hints of fall as Roy Schwass walked to the water's edge at Lake Warren on September 9, 1980. The small, private Illinois lake, near Monmouth, Schwass' home, offers fine crappie fishing. Schwass flicked out a ⅛-ounce crappie jig. He began a slow retrieve, but the lure hung on bottom. Schwass jerked to free the jig. The "snag" jerked back and, to Schwass' astonishment, began heading toward the center of the lake. Schwass watched 10-pound line peel from his reel until just a few feet of line were left. For the next 45 minutes, angler and fish played give-and-take, Schwass running along the shore to stay close to the fish. Finally, he managed to haul onto shore his prize—60½ pounds of flathead catfish. It set an International Game Fish Association 12-pound line-class record.

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Acting on a hunch, Ron Smith of Oklahoma City snatched pieces of striped bass meat discarded by some Lake Texoma fishermen who were cleaning their fish. Smith had caught some fine blue cats at night from the shore of the lake's Catfish Bay. Some were as large as 10 pounds. He hoped the striper meat would produce on the 1980 Thanksgiving weekend.

He set up shop on shore and, sometime after 3 a.m., a nibble roused him. When he set the hooks, Smith realized that this was no ordinary catfish. He battled in a fish larger than he'd ever imagined catching, a new IGFA line-class-record blue cat weighing 80 pounds.

● ● ●

Claudie Clubb of Heavener, Oklahoma, was tired. It was nearly noon and he'd been making his rounds as a game ranger since early morning, checking turkey hunters. But he knew he should check the trotline he'd set the night before in Wister Lake. As soon as he began picking up the line, he could tell that he'd hooked a *big* fish. To veteran trotliners, "big" is reserved for cats weighing more than 50 pounds. The flathead that Clubb eventually wrestled into his boat weighed 106 pounds.

● ● ●

Bass angler Jack Bishop of Carthage, Texas, worked a Rebel lure against a brushpile at Lake Murvaul. But his retrieve took the

PHOTOGRAPH BY M. TIMOTHY O'KEEFE

I had to be very close to a bear before I could shoot. A cooperative bruin solved that problem, but when he peered right into my blind, I realized he was

TOO CLOSE TO SHOOT

By Rich LaRocco, Senior Editor

Jean-Pierre Elsliger waved his left arm through the driver's window of the station wagon at the slender spruces and white birches that stretched as far as we could see. "This part of the province of Quebec is full of bear, " Jean-Pierre said with an accent that revealed his French-Canadian heritage. "Our biologists say maybe two, three a square mile."

He flashed a big-toothed smile at me and continued. "Canadians don't hunt much bear. They consider them pests. That's why we like American people to come to Quebec for bear."

I was there in May for just that with Jean-Pierre and André-A. Bellemare, both of Quebec City. J-P works for the province's Ministry of Leisure, Fish and Game, and André is the outdoor editor of the Quebec newspaper *le Soleil*. This was to be the first bear hunt for all three of us. André had a scoped Remington 600 bolt-action in .308 Winchester, J-P had an old iron-sighted .303 British bolt-action, and I was hoping to score with my compound bow. Our destination was Richer Lodge on Lac Echouani, about 280 miles northwest of Montreal.

"You really think you can get a bear with bow and arrow?" André asked me.

"I'll have a good chance, if I get close enough to one," I replied. Had I known right then just how close I'd get to a bear, I might have had second thoughts about this hunt.

The miles passed, and soon we arrived at the lodge. Trucks, vans and cars, most of them displaying American license plates, were huddled around the front door, and a string of cabins wound up a dirt road along the lake, which was at least a mile wide and more than 14 miles long.

A wiry man with curly black hair stepped out of the lodge and waved. J-P introduced him to André and me. He was Raymond Richer, the man who leased this 53 square miles of fishing and hunting territory and who had built the camp from scratch.

We spent the night eating and talking and laughing. Jean-Pierre had grown up on the north shore of the St. Lawrence River in an area where there are many bears but few bear hunters. He told us that bears there were wary but not afraid of humans. Each lumber camp in the area has a dump, which attracts bears from long distances. Whenever a camp cook goes to the dump, he must carry a gun for protection. J-P said some lumberjacks even have had to use chain saws to run off bears.

"There's a problem with the crazy bear," he said. "You never know what he's going to do next. One time a bear came in the house. It was maybe 2 o'clock in the morning, and a big noise in the kitchen woke me up. I got my gun and went in there. A bear had knocked the fridge over. I had to shoot him."

The next day Raymond, J-P, André and I went downlake in two 14-foot aluminum skiffs to check out the bear-hunting stand that Raymond had chosen for me. Raymond had put some spoiled chicken parts and fish heads about 50 yards from the mouth of a cove to attract bears. I was supposed to hide next to a 10-foot-high boulder about 40 yards from the bait. That would make for a long shot—too long for me.

"Too bad," Raymond said. "Many bears have been coming here."

André volunteered to hunt there.

We went back to the lodge and drove Raymond's pickup to another bait pile. It was at the end of an overgrown logging road about 10 miles from camp. Bear trails leading from the bush had tracks on them, some made by a very large bear. A rifleman could easily have found a natural blind, but there was no cover within 35 yards, and I didn't want to shoot much more than 20 yards.

"Let's build a ground blind," I said.

In less than half an hour, it was done. Inside the blind was an 18-inch-high rock for me to sit on and a 12-inch hole where I could put my feet when I stood up to shoot so that I wouldn't loom over the blind. The blind itself consisted of two walls made of stumps, brush and limbs. The higher wall was behind me, and the lower one in front. In the front wall was a V-notch so that I could see the bait about 25 yards away and shoot at any bear that might appear there. An approaching bear wouldn't be able to see me.

After putting a face net over my head, I had Raymond use duct tape to close all the openings in my clothing. I'd heard about Canada's bloodthirsty blackflies. Then my companions bid me adieu and left. By dark, hours later, I had seen no bear, so I walked to the main gravel road where I met Raymond in his truck.

"See any bear?" he asked.

"Nope," I said, "but I saw plenty of blackflies. They really got my forehead."

"I see that," he said. "Looks like hamburger."

Back at the lodge, I learned nobody had seen a bear. This was unusual. Raymond said that during the previous spring season, 50 hunters had taken 22 bears on Raymond's lease, but just as many bears had been shot at and missed.

The next day I borrowed a beekeeper's head net from Raymond, and it kept almost all the flies out. I kept myself awake by mashing flies crawling on my gloves. Once, just by closing my hands together slowly, I killed 28. But still no bear came.

At camp I learned that neither André nor J-P had seen a bear, but two of the other hunters had each missed a bear. "Bear hunters get too excited," Raymond said.

The next afternoon we freshened our baits with fish scraps and started the long wait again. Eventually I fell asleep. When I

continued on page 92

The trout's window . . .

BEGINNING with Alfred Ronalds, whose *Flyfisher's Entomology* was published in 1836, a succession of angling writers has described how the laws of reflection and refraction affect what a fish sees. J. W. Dunne and Colonel E. W. Harding amplified, in their books, what Ronalds had said, and now we have a new book by John Goddard and Brian Clarke which will make the whole business much clearer to those angler who lack a scientific or technical background.

I cannot trace with certainty who coined the term "the trout's window", or when it first appeared, but while I cannot offer a better substitute, I think that the term is to some extent misleading. The "window" is of course not exclusive to trout. The effect applies to all kinds of aquatic life.

Refraction has the effect of allowing a fish to see the world above the surface of the water in which it lives through what appears to it as a circular area above its eyes, fringed by a faint narrow rainbow effect. It can see next to nothing below a line making an angle of about 10 degrees to the edge of this circular area.

What writers on this subject have stated, but in my view have failed sufficiently to stress, is that when the fish moves, the circular area through which it sees, moves with it.

The use of the term "window" leads people to think of the circular area as if it were a true window of the sort we are accustomed to look through in our houses. Apart from the distortion produced by refraction, there is another and more fundamental difference; we can move relative to the windows in our houses, but a fish can never move relative to its "window". If it moves, so does its window, so that its eyes are always in the window's centre.

Successive writers have explained how a floating fly outside the trout's "window", moving with the current towards the fish, appears first as a pattern in the reflecting surface, produced by distortion of the surface film where the legs of the fly rest. As the fly approaches the edge of the window, the tips of its wings appear first, then more and more of these wings, until eventually the whole fly becomes visible.

When this happens, it is always at a distance from the trout that is greater than the depth at which the trout is swimming — or "hovering". If the trout stays in the same place, he will have plenty of time to inspect the fly after it has moved into his "window". And in any case he has the option of moving towards the approaching fly so as to bring it into his "window" earlier, or of dropping back, the "window" moving back with him, so as to allow a longer inspection.

Anyone who has watched a rising trout in a clear stream must have seen how, as a fly approaches, the trout will often move forwards by a few inches. One can almost imagine the fish thinking, "Come on, let's get this fly, if it is a fly, through the prismatic margin quickly, so that I can get a proper look at it!" If the fish is unsure, he will drop back with the fly, looking at it carefully before deciding whether or not to take.

We know that at times, trout feed very selectively indeed, eating only insects of a particular species. In rivers, the species are often ephemerids which differ, in many cases, mainly in colour. In my glass-bottomed bowl, I am quite incapable of distinguishing between ephemerid flies of similar size until they are in the "window". They all have the same number of legs and the patterns these

RICHARD WALKER

adds his own theory

legs make in the surface film outside the "window" seem identical. Furthermore, while bodies and legs of various species differ in colour, there is less variation in wing colour, which, as the wings come into view over the edge of the window, is in any case confused by the rainbow or prismatic effect at that point.

I think it highly unlikely that when an ephemerid fly is outside the "window", a trout can know any more about it than its size, and will be as unable as I am to distinguish between ephemerids of different species but of the same size.

If that is so, it means that a trout feeding selectively must see the fly in his "window" before he can decide whether or not it is of the species on which he is feeding selectively; and the fact that trout do, as we know, feed selectively, provides proof that they must wait, at least sometimes, for the fly to pass into the area of the "window" before deciding whether or not to take it. It follows that certain theories that have been advanced in the past are suspect. It is held by some that a trout commits himself to take a fly when he sees the pattern of its legs in the surface outside the "window", or that, following the signal that this pattern provides, comes another, in the appearance of the wings at the edge of the "window", which triggers off the take.

I do not accept this theory. I think the trout waits for the fly to come well into his window before he reaches a decision about it, and that he may often move himself, and his "window" with him, to bring the fly more quickly into a position where he can see what sort it is.

It has been held by some that the floating fly in the "window" appears simply as a black or dark silhouette against the light. I know this is not true; my glass-bottomed bowl tells me so. Once a fly has moved over the rainbow-edge of the "window", it is very brightly illuminated indeed, and while some patterns have opaque bodies, most feathers are translucent to a greater or lesser degree. Bodies of fur, hair or feather-fibre, also have translucency, in addition to which there are effects of diffraction that make colours readily distinguishable.

The very fact that light striking the surface at an angle less than about 10 degrees is totally reflected means that any floating object receives a certain amount of side-lighting, and its amount is not small. Your forehead can, on a bright day, become appreciably sunburned even under a broad-brimmed hat, simply by the light reflected from the surface of the water. So even the opaque fly may be side-lit sufficiently to allow a fish to distinguish its colours. Conditions in which a trout cannot see the colours of a fly floating in his window must be rare indeed, if they ever exist.

I do not mean to infer that the pattern in the surface film produced by the legs of a real fly or the hackles of an artificial are of no importance. On the contrary, I think it likely that they provide an early indication that something that may prove eatable is on its way, and that the appearance of wing-tips over the edge of the "window" may reinforce this warning. The trout is alerted. But I do not believe for a moment that he commits himself to take until he has seen more than these early warnings.

If I am right, it follows that the need for the fly-dresser to do more than supply these preliminary signals remains, for which let us be truly thankful. If it were not so, dry-fly fishing would lose most of its interest.

Contradicts Marinaro.

In the beginning . . .

GRAHAM SWANSON looks back at 'Trout and Salmon' 25 years ago

NOT MANY MONTHS ago, on the way to a piscatorial assignment in the Welsh Marches, my wife and I found ourselves browsing in a bookshop in picturesque Hay-on-Wye. We found little of angling interest until my wife spotted three copies of *Trout and Salmon,* for July, August and September, 1959, Numbers 49 to 51 respectively. At a cover price of 2s they were quite a bargain at 15p each.

Having read them, I proposed to our Editor that an article looking back at the magazine 21 years ago might interest readers. He said "No" — but what he did want was a piece looking at the very first few issues to be included in this Jubilee issue. He also lent me the first six numbers, from July to December, 1955, which in those days cost only 1s 6d each. Although copies of *Trout and Salmon* have a habit of popping up in all sorts of places the world over, these six, in a bound volume, must qualify as the most travelled, having accompanied me several times to the Middle East and once to Singapore.

How do these early issues compare with today's glossy version, which costs the equivalent of 12s? The format was slightly taller, and the rather poor-quality paper used could not do justice to the splendid black-and-white photographs which were used on the covers as well as within. Unfortunately, no photo-credits were given. The cover of Number 1 depicted a fisherman on the Tay, and that on the next issue showed a typical chalk-steam, the Anton in Hampshire.

The *Trout and Salmon* title was in white on a green background, with a logo of a trout and a salmon encircling an artificial fly, as seen until quite recently on our magazine. The Editor was the late Ian Wood, who, with his Scottish connections, worked initially from Glasgow, though the magazine was published, as now, from Peterborough. By December, 1958, the monthly net sales were 16,277 copies, against 38,161 in December, 1979.

Advertisements were not lavish, with quite a lot for fixed-spool spinning tackle, and the editorial of the July 1959 issue was taken up with the threat to traditional sport by the "threadliners". Other advertisements were for traditional gear, with no mention of reservoir tackle as we now know it. Silk lines were still king, though in the very first issue a new unsinkable American bubble-line was mentioned, the reviewer predicting that it was "the answer to the dry-fly fisher's prayer".

Glass rods were seldom featured, but then, a good cane rod could be purchased for £6 2s 6d. The main suppliers of fly-dressing materials were Messeena, of Leamington Spa, and E. Veniard, of Thornton Heath. Perhaps the only advertising more outstanding than today's was Sportex's glamorous mermaid with one of her tresses discreetly covering the really outstanding parts!

☆ ☆ ☆

Howard Marshall, a founder of *Trout and Salmon,* introduced "Our new magazine" in the first issue. "We shall not shun controversy," he said. "We shall, however, discourage belligerent expressions of opinions. There is room in this quiet sport of ours for a wide divergence of views, but not for personal animosity . . . important though the theory of angling may be, our true pleasure derives from the practice of this most fascinating of sports. It is compounded, this pleasure, of excitement and tranquillity, of the perfecting of skill and the study of nature, of swift rivers, hill-encircled lochs and the evening peace of the water meadows. We shall try . . . to evoke for you some of this delight."

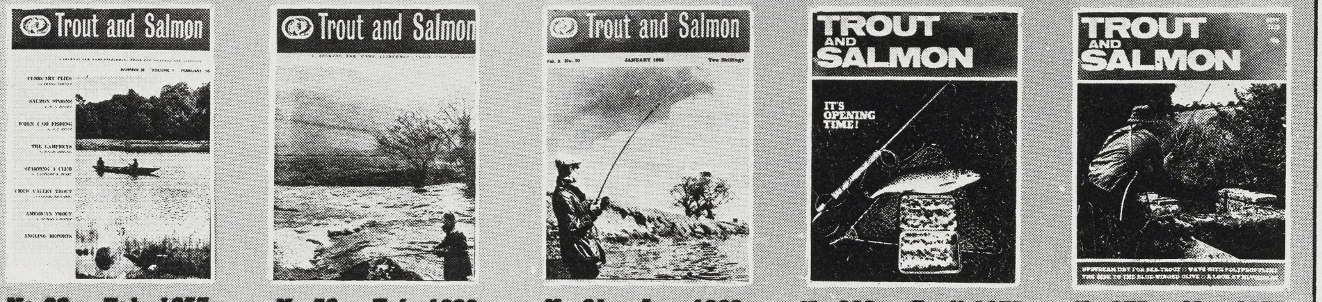
These early issues of *Trout and Salmon* do indeed live up to Marshall's promises, with the gentle but firm editorship of Ian Wood setting the tone of what game-fishing is all about. Longer-established anglers than I would recognise most of the early contributors, but some of those who contributed to the very first issue are still familiar names today. Richard Walker was not among them; no doubt he was still pitting his wits against big carp, but he gets a mention in the advertisement of B. James and Son, "makers of the famous Richard Walker rods".

G. M. Atkinson reported on the Tyne as he does still today, and dear, gentle, late-departed Lionel Sweet reported from South Wales. The prolific Rogie did not make the first issue, but he reported on Alness and Conon in the next, and has been increasing his reportage ever since! Major D. Fleming-Jones gets a mention in Number 1 as a member of the Welsh team which came third to Scotland and England in the International held on Loch Leven in 1955, and Tom Stewart had a mouth-watering report on in the loch. The average annual catch then was 40,000 trout, averaging slightly under the 1lb.

In the fourth issue Tom Stewart started his marathon series Popular Flies, No 1 being the Butcher, with Greenwell's Glory his next choice. In December 1955 Colin Gibson started his long-running commentary on life in the Highlands. Also in December, Roy Eaton, our present Editor, gets a mention as the compiler of that invaluable publication *Where to fish.*

By 1959 the magazine had grown half-an-inch taller, and the price had crept up by sixpence. Apart from the headliners — those other "bogey-men", the lure-flingers, had not been heard of yet — the main topics of the day were the dangers of insecticides, and the ever-with-us problems of water-abstraction and hydro schemes. Fortunately, few of the gloomy predictions seem to have materialised, thanks mainly to the raised voices of anglers, and other sportsmen and conservationists. There was still nothing from Dick Walker, though Commander C. F. Walker was about to publish *A Lake Angler's Entomology,* excerpts from which were published. A young Terry Thomas contributed a regular, informative and very practical "Fishing Diary", and Dermot Wilson, yet to acquire his Mill, was conducting interesting experiments on the Itchen for his series "Dry-fly Laboratory". Oliver Kite had a typical "gutsy" article on trouting in weedy

The changing face of 'T&S'



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Send to Vince

seen for years from a tributary of the Kennet on a fly hackled with a feather casually plucked from his pillow. I forget the weight of the fish, but it was a notable one for the water, where the trout are both large and well educated. Only the strongest protests from my wife restrained me from an orgy of pillow-slashing when I got home that night.

I am well aware of the dangers of generalising from a few particular incidents, but such examples could be multiplied in the experience of most fishermen who are also fly-dressers. One is forced to the conclusion that, so far as the actual catching of fish is concerned, we might well borrow from the example of those old Border anglers, who in a few feathers garnered from the farmyard and a pinch of tweed from cap or jacket, found all the materials they needed to fill their creels with trout.

Lest I be expelled from the Club as a dangerous heretic, or at least publicly de-bagged at the next Annual General Meeting, I make haste to add that I am myself as ardent a collector as any. As a boy I collected everything collectable from stamps to seaweed, and the germ has never left me. (I hope it never will.) Only an innate shyness, coupled with a healthy respect for the Metropolitan Police Force, have so far prevented me from pilfering the headgear of female passers-by since those exotic-looking hat mounts returned to fashion. All the cockerels within a two-mile radius of my home are mentally docketed according to colour against what one owner recently described as their "D-Day." I yield to none—not even to the Member who spends most of his afternoons at the Zoo—in the appreciation of a rare and beautiful feather. *But*, "If we say we catch more fish we deceive ourselves and the truth is not in us."

Let us drop the pretence just for a moment, and admit that we collect fur and feather chiefly because it is very good fun.

EUTYCHUS.

THE TROUT'S POINT OF VIEW

(Some Further Speculations)

It is now some fifteen years since the late Colonel Harding gave us his memorable book "The Fly-fisher and the Trout's Point of View," and during this passage of time remarkably little seems to have been published on the subject of the so called "window" and other allied problems.

As far as I can find out, Alfred Ronalds, in his "Troutfishers' Entomology," first published in 1836, was the first person to set down any ideas on paper concerning how the trout sees objects above the surface of the water. I should have expected F. M. Halford to have had something to say on the subject, but I can find no mention at all of "the trout's point of view" in any of his seven works, written between 1887 and 1913. He seems to have studiously avoided any mention of, or reference to, such matters. In 1911, Dr. Francis Ward published his "Marvels of Fish Life," and followed it up in 1919 with "Animal Life Underwater." Both these books contain a great deal of interesting information concerning Dr. Ward's observation tank, which consisted of a plate glass window built into the side of a pond, as well as a number of photographs, some of them taken underwater.

The American, E. R. Hewitt, seems the next person to probe the matter further, and in "Secrets of Salmon," 1922, he includes a long illustrated chapter entitled "What the fish sees." Whereas Ward used a right angle observation tank, Hewitt had his observation window set at an angle of 48½°, the critical reflecting angle for a ray of light passing from water to air.

J. W. Dunne's "Sunshine and the Dry Fly," 1924, included a chapter "The window in the water," which really throws little additional light on the problem. Some seven years later, 1931 to be precise, Colonel Harding's work saw the light of day, and subsequently, between 1932 and 1934, there were further contributions in the Fly-fishers' Club Journal and the Salmon and Trout Magazine by both Harding and A. C. Kent.

Much of the aforementioned material is well worth reading, but there is one fundamental fact, which has either been glossed over as though it was of small importance or, what is even more surprising, totally ignored, by all the above mentioned writers, and that is that the trout's eye is *in water*, whereas the eye of the observer, or the lens of the camera as far as photo graphs are concerned, is *in air*. Just let us examine the problem from the first principles of elementary optics. Look at Fig. 1.

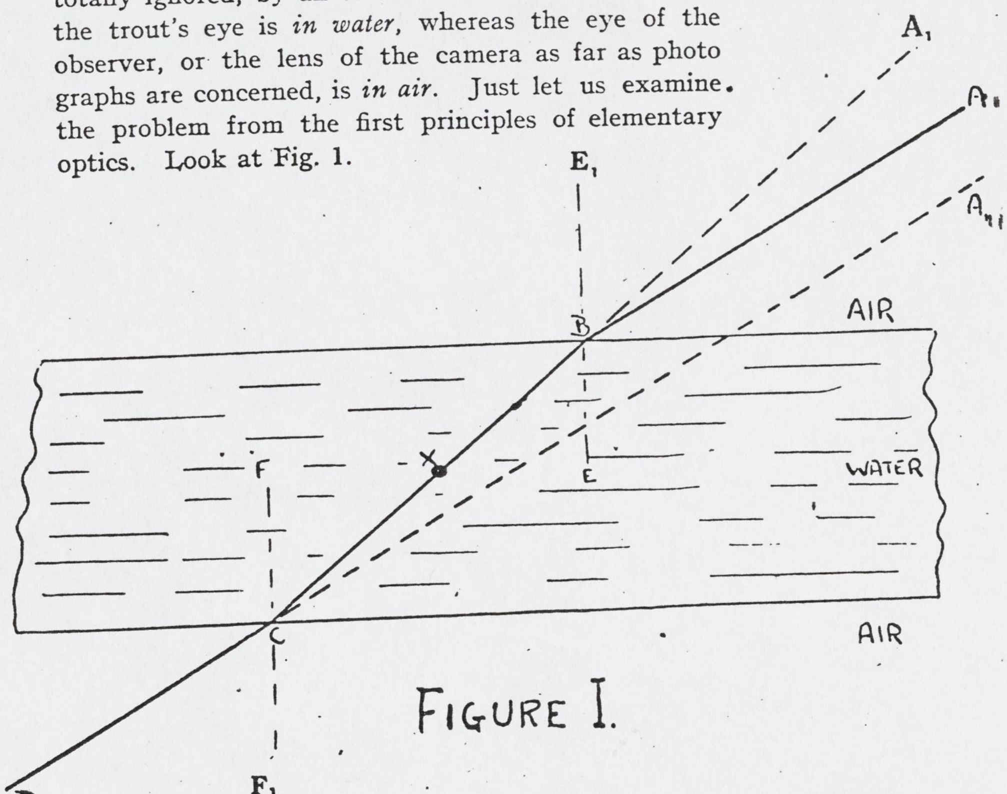


FIGURE I.

An object in air at A will appear to a fish in water at X as though it were at A_1, whereas to an observer in air at D, who is looking through the wedge of water, the object will appear at A_{11}. The reason for this is that a ray of light passing from a rarer to denser medium (in this case air to water) is bent *towards* the normal E_1 E, and on emerging, *away* from the normal F F_1. The normal is a perpendicular to the surface. As the boundary surfaces of the denser medium are parallel, so also will be the incident and emerging ray. The ray trace is therefore AB—BC—CD.

But look at the great displacement of the image A which the fish sees as though it were at A_1 and the observer sees at A_{11} !

In Fig. II (a and b), I have attempted to illustrate what happens in Dr. Francis Ward's tank in which the observation window is at right angles to the water surface. Fig. IIa shows an object at A subtending a fairly small angle with the water surface which will appear to the trout X as though it were at A_1, and to an observer D as though at A_{11}. Again, a false displacement. Under certain conditions, however, see Fig. IIb, the ray falling on the plate glass window may be totally reflected inside the tank, and lost to the observer's view !

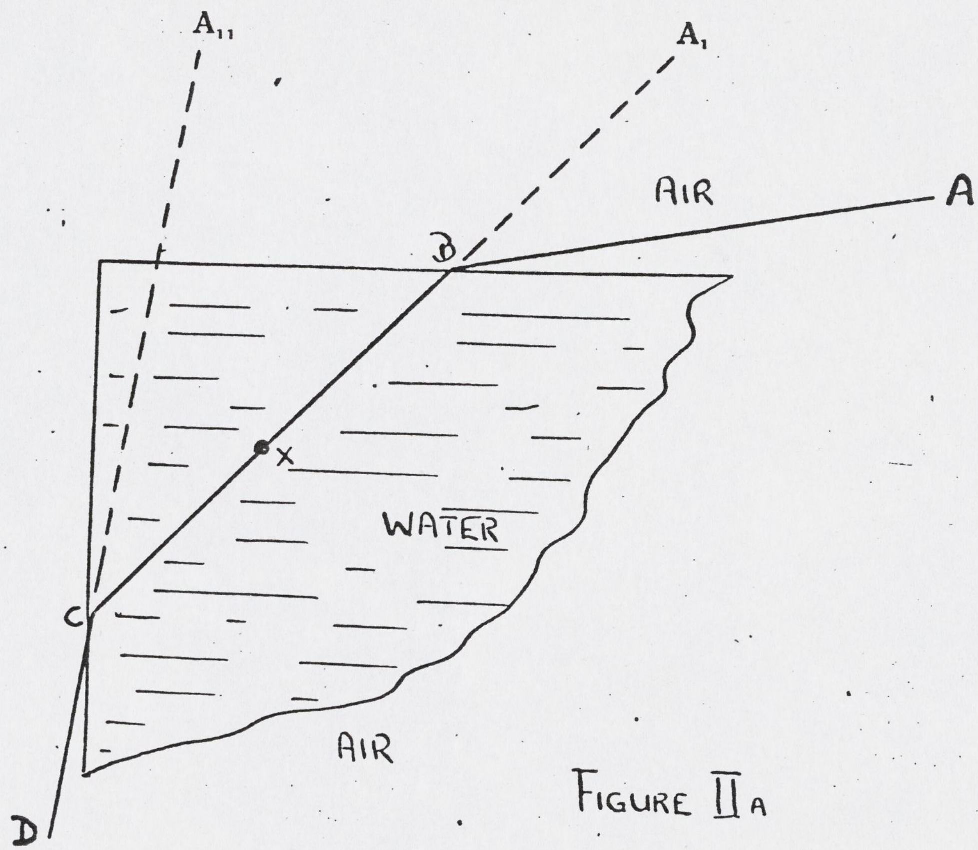
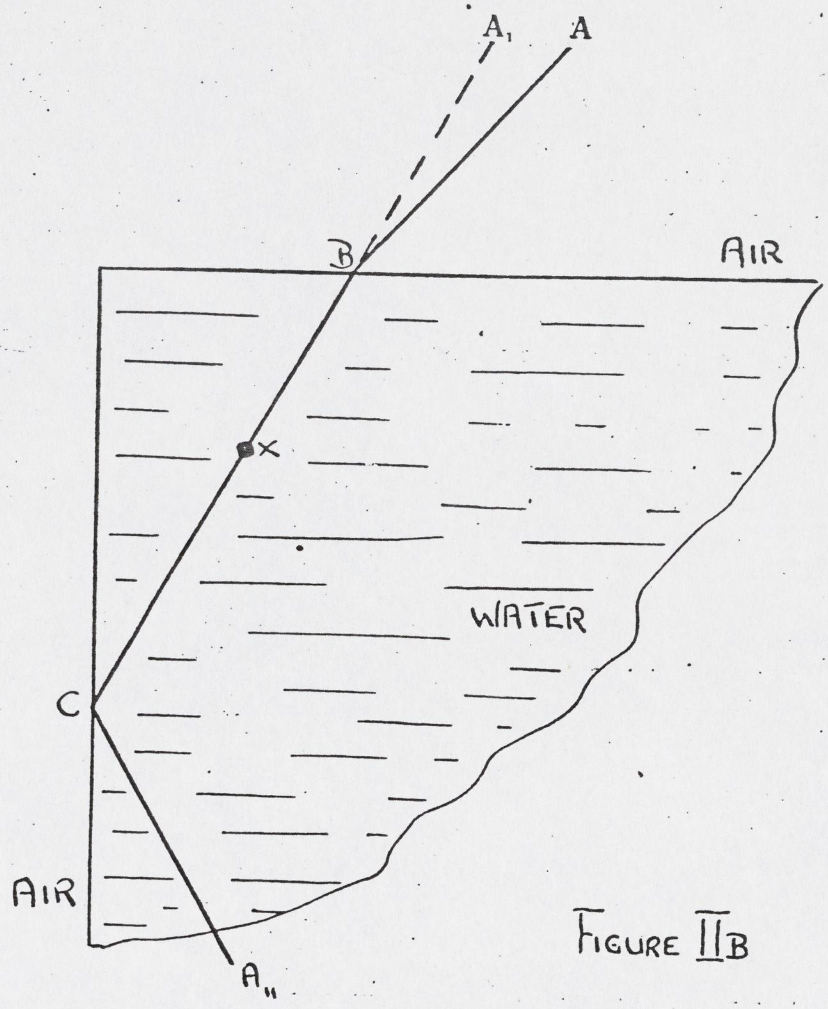
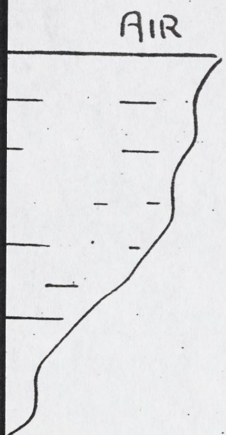


FIGURE II A



As in many other such matters, Mr. G. E. M. Skues, by clear thinking and accurate observation, has got considerably closer to the real solution in Chapter IX, "Looking Upward," of his masterly work "The Way of a Trout with a Fly." Mr. Skues visited Dr. Francis Ward's observation tank, and was puzzled by the fact that when the gardener pushed a broom through the surface of the water, although he could see the head, he was unable to see either the handle or the person holding it, "The rest," as he says, "for all that could be seen of it, might as well not have existed." Small wonder! (See Fig. IIb.) Mr. Skues also tumbled to the fact that he was looking through a prism of water, and, in fact, says, "In the rainbow semi-circles of light we may have been looking through a sort of prism, which perhaps gives the rainbow effects referred to."

Fig. III depicts Harding's and, for that matter, Hewitt's tank, which had the observation window inclined at an angle of 48½° to the water surface.



GURE IIB

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The same story applies as far as the false displacement of the object is concerned, as it does in Ward's tank, shown in Fig. IIa and b, and in both cases the observer, being in air is, as pointed out by Mr. Skues, "*looking through a prism of water.*" In order to see or record what the fish sees, the observer's eye must be *in the water* or, in the case of photography, the water must not only surround the camera lens, but also fill the space between the lens and the photographic plate or film. Unfortunately, both Harding and Ward failed to recognise these facts, and the false displacements of the image were complicated by the dispersion of light into colours because they were looking through a prism. It will be seen, therefore, that any theories or speculations based on such tank observations and/or photographs, fascinating though they may be, are in point of fact most misleading, and have led the aforementioned authors to make wrong deductions.

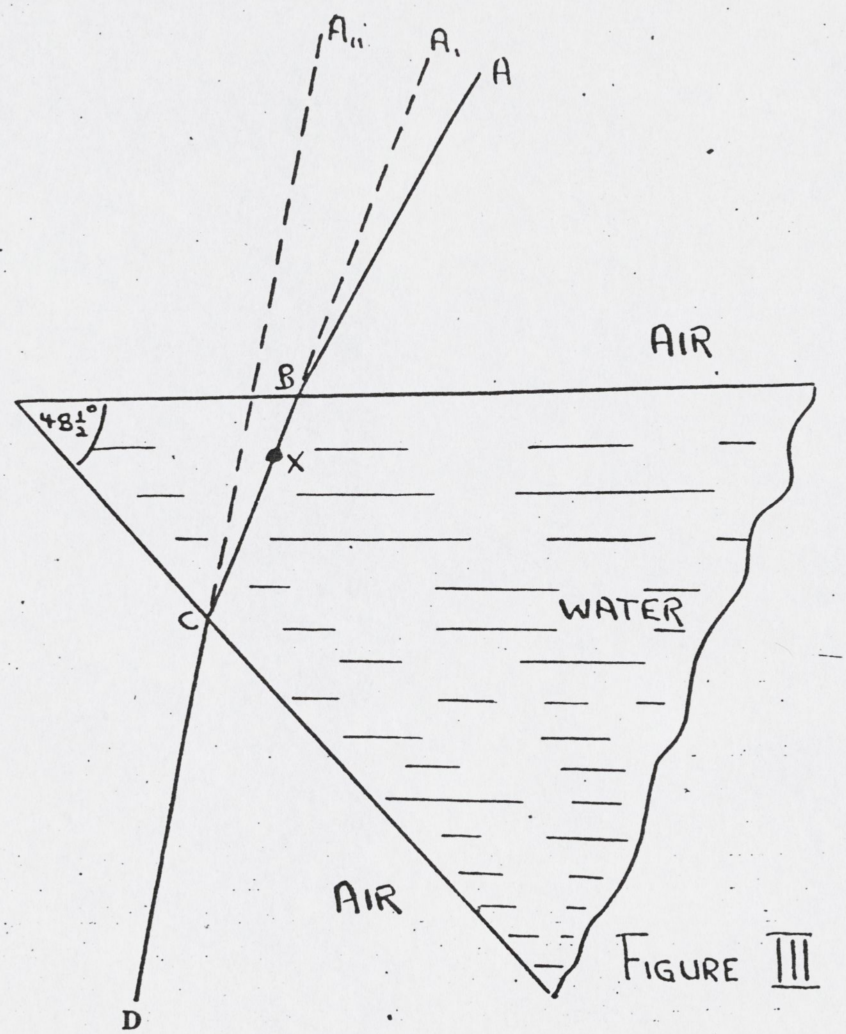


FIGURE III

Contrary to their claims, it should be clearly understood that there cannot be any coloured arcs, fringes or bands at or near to the edge of the trout's " window," neither is the fly at any time similarly coloured. Also it is not correct to say that the edge of the " window " is brilliantly lighted as compared with the central region. Indeed the contrary is the case, the illumination is much stronger in the middle of the window and falls off considerably in the last 10° off the horizon. The reason for this, of course, is that the loss by reflection at 1° from the water surface is about 89%, at 5° about 60%, at 30° about 25%, at 60° about 5%, and at 80° only about 1%.

Perhaps the most strange thing of all is that as far as I can see no previous writer has discovered that as long ago as 1905 there appeared a text book on Physical Optics by R. W. Wood, Professor of Experimental Physics in the John Hopkins University, Baltimore, in which he describes quite clearly, and illustrates with pictures taken with an underwater camera, what the fish really sees. I venture to quote Prof. Wood :—

> " In this connection it is of interest to ascertain how the external world appears to a fish below the surface of smooth water. The objects surrounding or overhanging the pond must all appear within the circle of light previously alluded to. There must be a great deal of distortion of objects which are not very nearly overhead, but we can gain absolutely no idea of their appearance by opening the eyes under water, since the lens of the human eye is only adapted to vision in air, and when submerged is quite unable to distinguish the shape of object. There is, however, no difficulty in photographing the circular window of light and the external world as seen through it. It was found after a little experimenting that better results were obtained with a pin-hole than with a lens, and a small camera was constructed which could be filled with water and pointed in any direction. If pointed vertically it recorded the view seen by a fish in a pond ; if horizontally, the view as seen by a fish looking out through the side of an aquarium. It is obvious that the plate must be immersed in water, as otherwise refraction occurs as in the helmet of diving armour.
>
> " The fish-eye camera can be made of a wooden or metal box measuring about 12 x 12 x 5 cms. (inside measure.) A hole 3 cms. in diameter is bored through the centre of one of the sides, over which is cemented a piece of mirror glass with the silvered and varnished side facing the interior. The glass must be *quite* opaque, i.e. free from pin-holes in the silvered film. A very small hole should be made through the film by scratching it carefully with a needle, before the plate is cemented to the box. This small aperture passes the rays of light which form the image to the photographic plate which lies against the opposite side of the box.

The box must be light-tight, and filled with clean water. A little consideration will show that the part played by the water in the pond is, in this case, played by the glass plate. A number of views secured with the apparatus are reproduced below, Fig. 54. The camera obviously has an aperture of 180°.

" One of the views is of a railroad bridge passing overhead, the other represents the appearance of a crowd of men standing around a pond, to a fish below the surface. The two lower views were taken with the camera pointing in the horizontal direction, i.e. the views correspond to what a fish sees when looking out through the side of an aquarium. One of them shows a view looking both up and down a street, the other a row of men standing in a straight line taken from a point only 50 cms. in front of the central figure. These last two show in a very effective manner that the angle of view embraces 180°."

At this stage, it would perhaps be as well for me to summarise precisely what all the foregoing matter really means and what, if anything, is its effect from the practical aspect of angling. Firstly, the trout can see from bank to bank, although its horizon is actually compressed into an arc of 96°. This is of no consequence whatever to the trout, which has never contemplated the outside world in any other way. Were the trout able to speak, he might venture to suggest that fishermen must have a most difficult time living as they do in air, and seeing things in a most distorted way with a horizon expanded into an arc of 180° ! Secondly, the trout's " window " is more brilliantly illuminated at the centre than it is at the periphery, and finally, neither the edge of the trout's " window," nor the objects or insects which he sees through it, are adorned with coloured fringes. By far the most important point is the illumination of the window, and we must have all noticed the disinclination of trout to surface feed on a bright summer's day, even though there is a big hatch of fly. Between the hours of 11 a.m. and 5 p.m. the sun is very high and consequently there is a concentration of light at the centre of the window, fading off towards the edges. The higher and brighter the sun, the greater is this differential.

It is generally accepted, and with some good reason, that the eye of the trout is sensitive to a low intensity of light, and it is not at all difficult to imagine that he is literally blinded by the almost direct rays of the sun in the centre of his window, but in an area towards the edge of the window, which is not so brightly illuminated, for reasons already explained, he will be able to see fairly well. This area at the edge of the window might be likened to a halo, the width of which alters according to the height and brightness of the sun and, as far as the fish is concerned, is his area of maximum contrast or visibility, in other words, where he can see best. I have noticed on many occasions when fishing on a brilliant day, that a fly cast just above and to one side of a feeding fish will, as often as not, pass apparently unnoticed until it has drifted down just behind the fish, which will suddenly turn round, as though it had only just spotted it, follow the fly downstream, and either accept or reject it.

I suggest that the reason for this is that the fly fell too near the centre of the " window," and in the same way as an attacking aeroplane diving out of the sun is almost invisible to the intended victim, so was the fly almost invisible to the trout until it had drifted into the area of maximum contrast at the rim of the window. On other occasions, I have found that a fly cast considerably above the trout is effective, and I believe the reason for this is that the fish is forewarned of the approach of the fly by its " light pattern " (so excellently depicted by Colonel Harding), and is therefore waiting for it to drift into the halo. In other words, the trout is expecting the fly.

When the sky is bright but overcast, the fish has a larger area of maximum visibility, and although he may surface feed to a greater extent, he is much more easily put down or scared, for the simple reason that he can see much more—floating insects, both real and artificial, gut, waving rods—and fishermen included ! His visibility is further increased just before sunset on a clear summer's evening. Under such conditions he is probably operating under what to him are optimum conditions.

Most of us know only too well how " choosey " the fish are during the B.W.O. hatch, or spinner fall at sunset, and how careful we have to be in approaching and presenting the fly to the fish, and how often our efforts end in failure ! Under such conditions, a trout can see a great deal further and better than is generally thought.

Finally, as regards sub-aqueous feeding, I disagree with Colonel Harding's theory that a trout watches the under water mirror bordering the window to enable him to intercept nymphs ascending to the surface to hatch, or merely drifting downstream towards him. In any case he could only use the under surface of the water as a mirror on an absolutely calm day, and even then it is so much easier for him to watch and intercept the actual insect rather than its mirrored image. It is a pretty thought, but quite unnecessary for a trout earning its livelihood to indulge in such feats of optical gymnastics !

G. C. MONKHOUSE.

A TWEEDSIDE MEMORY

IT is more than 50 years ago since I had the privilege of making the acquaintance—and in a dour, Lowland-Scot fashion—the friendship of Matt Oldham, of Peebles : odd-job man by day, and by night professional trout fisherman on the Tweed.

My meetings with him were all in the evening, when my fishing we have a long way to go before we can rival the success of some other branches, but members can be assured of an enjoyable outing or evening if they accept the invitations they will receive.

Any Wiltshire reader who is not a member and would like information should get in touch with me. It costs less than four gallons of petrol to join the Association; a small enough premium to protect your fishing from the many threats it now faces.

Graham Swanson
Public Relations Officer, Wiltshire Branch,
Salmon and Trout Association
Search Farm House, Stourton,
Warminster, Wiltshire

Latin scholar wanted

CAN ANY reader with enough of his Latin learning still present provide translations of the several Latin names and expressions used by G. E. M. Skues, especially in the delightful *Sidelines, Sidelights and Reflections.* A few examples are "Integer Vitae", "Simplex Mundishes", and "Scelerisque Purus".

P. Kofoed Jensen
Lille Vaerløsevej 72,
DK-3500 Vaerløse, Denmark

Talking about cameras

IT WAS a great pleasure to read Dr Frank Ridell's carefully-reasoned article "Through the Eyes of a Trout" in the January issue of *Trout and Salmon.* As a scientist he presents all his facts in a logical manner and it is quite obvious that a great deal of research has gone into his writing.

He dealt with the questions of focusing and angle of vision, and while these two important subjects are still fresh in our minds, I would like to make a few comments on them, as some clarification and verification appear necessary to the angler's understanding of them.

For instance, the focusing of a fish's eye, comparable with the focusing of a quality camera lens, is highly understandable and logical. What has not been dealt with, or made clear to us anglers, is the acceptance angle or the angle of view of the trout's eye. Dr Riddell states, and I agree with him, that the total vision is almost 360 degrees — practically a full circle, allowing each eye its quota of 180 degrees. That means that a fish can see from horizon to horizon without any movement of eye or body. No camera lens yet made can quite equal that, but it can get fairly near with the introduction of rare-earth glass and a retro-focus system.

So we have a parallel again with the camera, and if the pictures from such a lens are examined, it will be seen that at anything but the closest distances, all images are very small indeed! Even at 100ft on an 8in x 10in print the bricks in a building would tend to disappear, so surely with such a wide-angle lens it would be impossible for a trout to see a 10 pence piece at a distance of 65ft as Dr Riddell states. Some further proof of this is really required.

Furthermore, I do not know from whence he obtains his parallel with the vision of the human eye. The accepted formula for normal human vision is known as the 'six-six axiom' and is accepted in optics and by ophthalmic opticians as a main base from which they work. This means that a 6mm square detail of letter or figure can be recognised at a distance of 6 metres — a far cry from his 10p coin (28mm) at 650ft, about 200 metres!

Now this is where angle-of-view comes into the discussion. Faced with such a problem, the professional photographer

Letters

would whip off his wide-angle lens and substitute a telephoto lens, which has a very narrow angle of acceptance. By this means he would produce a larger and therefore much more visible image. This brings us back to my original thesis; how can we reconcile the wide-angle lens in a trout's eye with its ability to see very small items at long distances, whether in water, or through water into air?

The diagrams on page 43 of the issue concerned confuse the issue and would be optically possible only if the boat and angler on the bank depicted were almost on top of the fish! Take them both away to a distance of, say, 30-50ft and they would, with the trout's wide-angle eyes, be almost invisible specks on the fish's horizon. So, in my lay opinion, coloured as it is by a lifetime of professional photography, I must conclude that Dr Riddell has not given an answer to the basic question, and we are still left with the conundrum.

My original fantasy of a lens deformed aspherically to produce a zoom effect was a possible solution, but without scientific backing. So there must be *some* method by which the fish carry out this amazing function. The introduction of the paragraph on the resolving power of a trout's eye-lens is a red herring and not relevant to the major problem still waiting to be solved: how can an extremely wide-angle lens produce large detail at a considerable distance??

I do hope that Dr Riddell can pin down this one, as, to my mind, it is the most important problem of all, the solving of which would give us anglers a solid base on which to plan our fly-tying and our fishing methods.

I am quite happy for my theory to be completely wrong, so long as another satisfactory and provable theory can be put in its place.

Alec Pearlman
Arkley, Hertfordshire

Easier, stronger 'Parachute' flies

ONE OF THE more tiresome operations in making a 'Parachute' fly is passing the tip of the hackle through the loop prior to securing it. The normally recommended way of doing this is by the use of a small pair of tweezers. However, it will be found that a small crochet hook not only facilitates the operation, but enables you to work with a smaller loop which gives you a longer hackle stalk and loop with which to work.

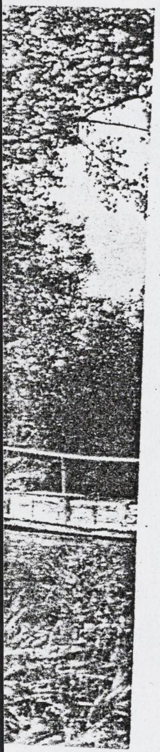
J. W. Booth
Pulborough, West Sussex

Carbon rods do differ

THE IDEA seams to be getting around that the manufacturing costs of carbon blanks are always the same, and that marketing policies account for the wide variation in price. I'm afraid that this isn't the picture. Undoubtedly marketing structures can influence retail prices, but with both glass and carbon, manufacturing processes and raw-material choice vary, giving consequent differences in quality, selection by customers, and eventual retail price.

It would now be possible to give a long list of these technical differences, but the easiest way to demonstrate the differences is by the weave of the cloth from which both glass and carbon rod-blanks are made. It is possible to choose a material with a wide, relatively coarse, weave and then to put fewer turns around the mandrel before cooking the blank. Many would prefer to choose a much closer and finer weave of cloth, and thinner wall, even with more turns around the mandrel.

There is less difference between carbon and glass blank manufacture, but in a glass blank the difference can easily be seen. If, say, you examine a Conoflex glass blank, you can see its fine grain, which explains its higher cost, and many home



SIDE-LINES, SIDE-LIGHTS & REFLECTIONS

FUGITIVE PAPERS OF A
CHALK-STREAM ANGLER

BY

G. E. M. SKUES
(SEAFORTH & SOFORTH)

London
Seeley, Service & Co. Limited
196 Shaftesbury Avenue
1932

long been the object of attention of members of the Club and their guests—and some fish coming yards to take it. Grayling also accepted it freely.

The old angler's patterns were, of course, dressed to sink—and it is only since the dry fly became effective that patterns were evolved, like the quills, whose business it was to float and to suggest surface flies. The older patterns of duns would naturally have been the more effective the more they reproduced the features of the nymph.

S.A.S.

Fly-Fishers' Club Journal, vol. 15, No. 59. Autumn, 1926.

VII

TRANSLUCENCY

I am inclined to think that the argument in favour of translucency or transparency of trout flies has been worked pretty nigh to death. It is assumed for the purpose of the argument that a trout rising to the fly always has the fly between itself and the light—and that therefore the artificial fly always looks black and opaque in strong contrast with the natural fly which looks transparent or translucent. If this thing were as universally sound as its advocates would have us believe, trout would rarely be caught with the artificial fly—and we know well that is not the case. That there is something in the theory cannot in honesty be denied. But it is far from universally true. One constantly finds a trout taking a fly which has covered him several times in vain. Why? Probably because he sees it on the fatal occasion at a different angle with the light upon it in such a way as to give it the appearance of a natural fly. Perhaps the fly has been passing all the time on his

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right side between him and the sun. It is there black and opaque and did not suggest a natural fly. But let it pass down on the opposite or left side and the sun illumines it so that it suggests by reflection the translucency which it has not in nature.

In truth there are more ways in which the fly can reach him looking to him like a natural fly than otherwise. In 1911, when looking up at flies on the surface of Dr. Ward's pond at Ipswich, from the underground glass fronted chamber in the side, I was greatly impressed by the extraordinary clearness of detail in which one saw artificial flies floating in the window of surface vision. There was then no effect of blurring or opacity. No doubt this was because the outlook through "the window" was not into the eye of the sun.

Putting it broadly, I should say that a floating fly delivered to trout will quite as often in a day's fishing be seen in its colours as resembling a natural fly as it will be seen black and opaque against the light. In the case of a wet fly, the odds in favour of the trout seeing it as he is meant to see it are much longer. It will seldom be between his eye and the source of light. So that if the pattern be well devised to give by reflection the appearance or suggestion of translucency, it will be good enough for most practical purposes. Many dubbings and some herls suggest translucency admirably. So does the shiny surface of peacock's quill, so like the bodies of many nymphs.

The argument in favour of translucency is in truth a counsel of almost unobtainable perfection. If it were obtainable it would, I agree be desirable, but in practice it is not obtained very often. And yet trout continue to be killed. I am not forgetting Mr. J. W. Dunne's ingenious invention for obtaining translucency—but I cannot reconcile myself to his methods of wing suggestion, and such success as I have had with flies with bodies of artificial silk tied over white enamelled hook shanks has been obtained by the use of ordinary starling wings or hen blackbird wings and silk of such colours as appeared to me to reproduce the appearance of the natural insect without paying regard to the elaborate combinations and blendings formulated in " Sunshine and the Dry Fly."

S.A.S.

Field. 1929.

VIII

WHEN WEEDS ARE ADRIFT

It is a misfortune of the length of the Itchen on which I spend most of my week-ends during the season, that twice a year, once in the first half of May and once towards the end of July, both that length and the fisheries immediately above are subjected for the miller's sake to a weed-cutting which leaves the bottom of the river practically bare. The masses of weed which come floating down from above must carry with them enormous quantities of trout food in the shape of shrimps and nymphs or larvæ. But it would seem that insects which are content to harbour in the weeds are not so content to remain in the same weeds when they are detached and floating with the stream; and it has been my observation in previous seasons, as in the present one, that they swarm into quiet eddies, where the trout takes heavy toll of them.

This season, after the May weed-cutting on my length was over, I had a week-end and one which was rather instructive in this respect. The general direction of the river is north to south, and during the two days in question there was a strong wind blowing across from the west with a slant towards the easterly, or left bank. For some two hours on the

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and justify, the use of such large and garish flies as are illustrated in these American works, and that such are not to be sneered at or condemned because they are not as our flies.

The moral suggested by the argument here presented for all classes of fishers for trout is that it would be well for them to confine moral indignation and condemnation to breaches on their own waters of the conventions which the conditions of those waters dictate, and to unjust criticism of their methods on the part of outsiders, and to exercise a large charity towards practices on other waters which may be dictated by conditions of which they are not cognisant.

E.O.E.

Salmon and Trout Magazine, No. 57. April, 1928.

XIX

- Re dark wings -

REFLECTION

In the early days of the present century I had a series of holidays in Bavaria on a water where the May fly teemed and trout of fair size were plentiful, and I used to take out with me for these holidays a large selection of May flies in several sizes and of differing colours, ranging from the palest Summer duck to a tint almost as dark as the bronze of Brown Mallard, and, though the fish could not be called difficult, it was a curious fact that each day they appeared to affect one pattern rather than another, and that the size of the score was very much dependent on one's finding out, and finding out as early as possible, the particular pattern which on the day in question suited their vagrom fancy. I never found out the precise reason for the changes of fancy exhibited by the trout, and though I guessed that it was due to variations in the light, or the colour of the sky, I never could formulate any theory which I could apply to the particular conditions of each day so as to deduce what shade of fly would prove most attractive, and I had to go on empirically, changing patterns until I found the most fatal medicine.

My last visit was in 1909, and I had done little May-fly fishing since. It thus happened that in the beginning of the present year (1927) I had still a large collection of unused May flies, and I took down an assortment of several shades for a week-end visit to the Upper Kennet as a precautionary measure, though I sincerely hoped to find that the May fly was over for the season. As it fell out, however, I ran in for an early stage (though not the earliest) of the main hatch, when the trout were beginning to take the fly on the surface, but were still not neglecting the nymph. My supply of Alders and Sedges which I had hoped to use had, therefore, to be put by, and the May flies substituted. For a wonder in this year of storms both days were warm and bright, with an open blue sky, and after trying several patterns and observing how much brighter they looked on the surface than the natural flies, and finding that such trout as rose often came short, I tried a cork-bodied pattern with dark wings of a brown Mallard hue and I found that this appealed to the fish better than any other I had tried, and in the two days' fishing I landed some fifteen brace, putting back most of them. Other rods on the water to whom I gave the same pattern of fly found it attractive, and took fish which had hitherto been coming short. I was not sure of the reason which made this particular fly more attractive than others, and I relegated the experience to the same class as those which I had had in Bavaria. But thinking the question over I recalled an earlier, but recent, experience with the small fly.

Some three or four years since, I had been on Itchen-side one morning early in May, just after the Spring weed-cut, and, as usual, the miller, who maintains his right immemorial to cut the weeds, had cut them to the bone, leaving the bottom almost bare. Nevertheless, there was a fair hatch of pale watery duns of Spring, and the trout soon began to take them or nymphs, not under the banks as one might have expected, but in the open all over the river. There was a faint air from south-west which, though up-stream in trend, was insufficient to create a ruffle. It so happened that I had lately been dressing some flies with bodies of floss silk (of a yellow which goes greenish when oiled) wound over the bare hook from shoulder to tail, under the ginger whisks then over and back to the shoulder again and with a pale ginger cock's hackle. This would have been like enough to No. 1 Whitchurch for all practical purposes, but I had varied the pattern by using the darker-hued hen blackbird for wings and tying it a size larger. So, recollecting that the Dark Spring Olive had still been on in my last week's visit to the water, and thinking there might still be a scattering among the more numerous Pale Watery Duns, I knotted one on to my cast and covered the first rising fish with it. He took it the first time I covered him and proved to be two-and-three-quarter pounds. A few minutes later I was in battle with a second trout which took the same fly and pulled down the scale at exactly three pounds, and I took a brace of smaller fish before the rise, which was a short one, was over. But while it lasted I did not see a single large Dark Spring Olive, and I was not a little puzzled to divine why the dark wing proved so effective.

I recalled, however, that many years ago, when I maintained a long angling correspondence with the only begetter of Tup's Indispensable, the late Mr. R. S. Austin, he had told me that in dressing winged trout flies, most dressers tied them with too pale a wing, and he recommended me always to use as dark a wing as possible. He never explained to me the grounds of his opinion, and it may be that he did not know, or had never put himself to formulate the reason, but had laid down the rule as an outcome of his long and varied experience. So I had put the incident by as one of those many unexplained and often inexplicable things which happen in trout fly-fishing. Nevertheless I had not entirely forgotten it and on several subsequent occasions I had put up the same pattern when Pale Wateries were on, both the Spring and the Autumn kinds, and had at times found it deadly.

Yet I still had the unsolved question in the back of my mind, awaiting a further clue, when in a volume which I picked up and read after the trout fishing season was over, I found some fishing talk which seems to me to present the solution for which I had been seeking for years—from the hand of an author long since dead. I feel, therefore, justified in quoting his *ipsissima verba* and I hope not to be sued for infringement of copyright. The author is J. Arthur Gibbs and I quote from pages 158 and 159 of "A Cotswold Village," second edition. Writing of May-fly fishing he says :—

"As a general rule they cannot be too *dark*.

"Some years ago we caught a live fly, and took it up to London for the shopman to copy. 'At last,' we said to ourselves, 'we have got the right thing.' But not a bit of it. The first cast on to the water showed us that the fly was utterly wrong. It was far too light. The fact is the insect itself appears very much darker on the water than it does in the air. But the artificial fly shows ten times lighter as it floats on the stream than it does in the shop window.

"Dark mottled grey for your wings and a brown hackle, with a dark rather than straw-coloured body, is the fly we find most killing. . . . I suspect there is a tendency to use too light a fly everywhere, save among those who have learnt by experience how to catch trout."

In other words the reflection of light from the water makes the artificial fly much lighter on the surface than it appears in the hand.

This explains why a colleague of mine on my water has had at times a hitherto unexplainable success with some dreadfully tied but quite dark Greenwell's Glories.

I imagine the lesson conveyed by Mr. Gibbs has been learned and forgotten many times—but I record it again in the hope that it may be of service to many a brother angler, not least to those who tie their own flies.

Probably a dark fly may present by reflected light as attractive in appearance as a natural fly by transmitted light. But even if this be so, it does not prejudice the case for Mr. Dunne's flies which get their effects, as do the natural insects by transmitted light.

S.A.S.

Fly-Fishers' Club Journal, vol. 17, No. 65. Spring, 1928.

XX

LIGHT RODS—FINE TACKLE

In his article under the heading in No. 68 of the *Fly-Fishers' Club Journal*, N.F.B. very soundly stresses the desirability of killing a trout in the minimum of time. But when he says that Americans are really the pioneers of the small rod and fine leaders movement and have overdone it, I find it difficult to accept his proposition so far as trout fishing is concerned.

The small rod has undoubtedly been gaining in favour over there but so far as my observation goes the American, using