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REACTIONS OF AQUARIUM CARP TO FOOD AND FLAVORS'

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ABSTRACT

The reactions of carp to 115 flavors and many types of food were observed at the State Fish Laboratory at Livingston Manor. The test fish detected all the oils and a number of water-soluble flavors, but not alcohol and salt. Several water-soluble compounds stimulated feeding activity in blind fish although the fish were unfamiliar with them.

Tests indicated that adult carp will accept almost all foods without regard to color but will not eat those they cannot crush with their pharyngeal teeth. Ability of blind carp to catch some fast-moving animals was demonstrated.

Observations of feeding activities revealed a complicated but stereotyped set of actions, with certain senses dominant over others at times. Sympathetic activity among the senses was also revealed.

As part of efforts to develop an attractive poison bait for carp contrul, a large number of extracts were tested for acceptance. The results provide a good picture of the vagaries of a study of this kind.

It has long been recognized that fish are, like most animals, capable of taste and odor discrimination. As defined by Hasler (1957) odor and taste perception are interpreted here as those chemically induced sensations which are relayed to the central nervous system from the olfactory sacs and the gustatory nerve endings in the mouth or on the barbe!s and other body surfaces. Also accepted here is his view that a smellable substance must pass into solution on the mucous film to be perceived by a terrestrial vertebrate; that smell in all animals is aquatic in the final sense. This is undoubtedly true of taste perception also.

The histology of the taste organs and olfactory sacs has been described in detail for several species of fish, although the location of taste receptors has not been adequately determined. Also, the exact functions of the various taste and odor receptors remain unknown. Evans (1952) showed correlation between the well-developed vagal and facial lobes of the carp and its feeding habits. The vagal lobes receive branches of the 10th cranial nerve from the taste buds in the pharynx and posterior portion of the oral cavity, while the facial lobe receives gustatory fibers of the 7th cranial nerve from the barbels, lips, snout, and body surface. Broad ability to perceive taste is anatomically demonstrated for the carp, and is also borne out by observations in this laboratory.

The entire field of flavor perception suffers from a lack of means of measuring quality and quantity of flavors and the responses of animals to them. Different species show dissimilar reactions to the same flavors. Individuals within species may respond differently as the result of in-

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the relative importance of the senses and their relationships to each other and to the activity of the fish. The work is necessarily incomplete, and many phases may warrant further detailed study.

GENERAL METHODS

Fish used as subjects were all carp from two sources. Those from one source were stunted, 1 to 4 pounds in weight, and good feeders. The others were fat and weighed 5 to 10 pounds; most of these could not be induced to feed even after being starved for several months.

The flavor tests and other studies were carried out in 350 to 550-gallon temperature-controlled aquarium tanks (Loeb, 1959) that permitted observation through plate glass from the side (observation from above panics carp and is deceptive to the observer due to refraction of light). Normal fish were used until it became apparent that visual stimuli (visual detection of food or people) were dominant over senses of taste and smell. Blind fish were generally used thereafter.

Initial tests of different flavors were made only after an interval of at least 24 hours following a previous test.

All fish were in apparent good health. The reader may assume that all were active feeders, unless otherwise stated.

RESPONSE OF CARP TO VARIOUS FLAVORS

The 115 substances tested included a number of the table variety and a large group in the essential oil class. Blind carp weighing from 1 to 3 pounds were used as test fish. At least six fish were used in each test. All flavors were retested; an interval of 24 hours was allowed between tests. None of the fish had previously tasted any of the flavors. The reactions observed are summarized in Tables 1 and 2.

For each water-soluble flavor (Table 1) one eye dropper or teaspoonful was dissolved in a pint of water. This was poured into the inlet stream over the fish and results were noted. Each oil-soluble flavor (Table 2) was tested in two emulsified forms: first, oils were emulsified in a blender; for repeat tests, in a mixture of polyoxyethylene sorbitan monooleate.

Strangely enough, no oil-soluble flavors produced a positive feeding reaction, although all were detected by the fish as evidenced by brief snapping of the jaws. The feeding reaction is defined as the searching portion of the chain of events starting with appetitive behavior (Baerends, 1957) and ending with nonfeeding behavior after eating. The feeding reaction in this case may be described as a horizontal search for food on the tank floor or more rarely on convenient vertical surfaces. It was often preceded by a slow, descending spiral movement from the stratum of flavor-bearing water to the tank floor.

The tests were made in an effort to find exotic substances which would trigger the feeding release mechanism. Several were demondividual experience (very important in the case of adult humans) or varied ability to perceive certain flavors.

Response to water-borne or air-borne flavors has been largely neglected by biologists. However, some analysis of taste perception, i.e., to the extent that the electrical response of individual nerve cells to various flavor stimuli has been measured, has been carried out in a few mammals. Such studies are anything but complete for any species, but they do indicate the extent of the problem.

It has been found that individual receptors are capable of perceiving a variety of flavor qualities, but the extent of this ability has not been determined. Actual physiology of the receptors, concentration of flavor substances and their manner of presentation (size, shape, number, mixture with other flavors, temperature, duration of application, etc.) and other factors are involved.

Testing the effect of flavors on humans is a complicated procedure demanding both trained and untrained (but intelligent) panels of tasters. Results are analyzed statistically, but based on opinion. That this is not a foolproof method was demonstrated during World War II when soldiers spurned food that had been preferred by "experts" (Lockhart, 1958).

Flavor quality itself has not yet been calibrated as have energy frequencies such as visual wave lengths of light. The standard qualities of sweetness, sourness, saltiness and bitterness have been inadequate for explaining human and other animal responses to flavors (Pfaffman, 1958). Rather, it appears that responses are related to an infinite number of combinations which in turn have little relationship to these so-called basic tastes.

Flavor, interpreted as taste or odor, is capable of evoking responses in humans that are more rapid than those from the stimuli of light and sound. If people ignore extremes of bright light and loud sound, it is obvious that they are not attracted to or revolted by certain colors and sounds to the extent that they are by certain tastes and odors.

Although comparison of carp and humans may often be questionable, this last statement may apply to fish also. Varying light intensities appear to evoke little detectable response in carp, but flavors do. None of the 115 flavors tested as water-borne extracts evoked a repelling reaction that could be detected, but certain foods impregnated with some of them were spit out. All extracts, with the possible exception of pure ethyl alcohol and salt, were detected (visual test) by carp. To most flavors, carp were indifferent after tasting. Some evoked vigorous feeding responses.

The thousands of tests involving flavors and foods have permitted observations of the methods by which carp locate food in aquaria. These observations have, in turn, led to the formulation of ideas concerning strated to be positive triggering agents, but their chemical structure is imperfectly known and their physiological effort even less so.

Feeding behavior of carp, as evidenced by fish held in aquaria, consists of stereotyped reactions. These reactions are triggered by various stimuli which release activities that lead to further stimuli and finally eating. A portion of this routine may be classified as appetitive behavior or a search for the stimuli which will release feeding or other activities. Appetitive behavior is sometimes thought to involve reasoning or learning, but in the case of carp at least it does not appear to include the former.

The sequence of feeding activity can be empirically described in somewhat general terms and without the benefit of much physiological fact. At best, the description is inadequate and may not be a true measure of what actually happens.

Normal fish are often moving; blind fish, always. Movement appears to increase in hungry fish. This may be appetitive feeding behavior, or a search for stimuli that will release an active search for food. That this is not always so is evidenced by the continual movement of nonfeeding blind fish. "Aimless" moving in carp probably serves many purposes, one of which is the appetitive search for food stimuli. Regardless of the number of basic instincts to be served, a carp is capable of only limited variation.

The total feeding sequence appears to be as follows: (1) Frequent appetitive movement in normal fish; continuous in blind fish. (2) Triggering by external stimuli such as sight of a person or food, vibrations, touch of food, or a taste or odor. (3) Further appetitive behavior as a result of triggering (this was the criterion of a "natural" flavor) that releases an active search for food. This is direct if the triggering stimuli are visual, but indirect for taste, odor or touch. Carp will attempt to increase the taste or odor stimuli by appetitive snapping. One stimulus may follow another as with vision-touch-taste, or odor-touch-taste. (4) Actual grasping of food and eating. The latter may be interrupted by the addition of more food which starts the sequence again at Stage 2. Grasped food must first be spit out. (5) Eating until satiation occurs. Normal fish will then rest and refuse food in most cases, although a few individuals can be continually stimulated by adding new food.

Addition of a "natural" flavor often causes blind fish to find and eat foods such as snails which are not otherwise detected (unless by chance touch) in the aquaria.

The majority of compounds were ignored after initial detection; ethyl alcohol and salt were not detected, possibly because concentrations were low. Table 1 lists all of the triggering agents found, which include imitation maple flavor and two of its components, tobacco, saliva, brown sugar, white sugar, molasses, saccharin, instant coffee, beef bouillion,

TABLE 1. REACTIONS OF CARP TO WATER-SOLUBLE EXTRACTS *

POSITIVE FEEDING REACTION
- Beef bouillion
- Coffee, instant
- Earthworm extract, filtered
- Foenugreek, solid (component of maple flavor)
- Liver extract, filtered
- Lovage, solid (component of maple flavor)
- Maple flavor, imitation, extra
- Molasses
- Saccharin
- Saliva
- Sugar, brown
  - granulated
- Tobacco juice, filtered (nonaromatic mix)
  - filtered (aromatic plug)
- Tobacco juice & saliva (aromatic plug)
- Tobacco juice & particles (aromatic plug)

VAGUE FEEDING REACTION
- Maple syrup, 15 per cent

INDIFFERENCE AFTER TASTING
- Aromatic mixture, B-48, solubilized §
  - C-48, solubilized §
  - D-48, solubilized §
  - L-48, solubilized §
- Butterscotch flavor, imitation
- Monosodium glutamate
- Raspberry gelatin
- Vanilla extract

NO REACTION DETECTED
- Ethyl alcohol, 200 proof
- Salt, table

* In all cases test fish were blind and unfamiliar with substance being tested.

§ Fruity flavors solubilized with polyoxethylene sorbitan monooleate and manufactured by Magnus, Mabee & Reynard, Inc., New York.

liver extract, and earthworm extract. The physiology of taste and odor involved here is unknown. Blind fish without ability to perceive odors also reacted to all of these substances. Several have a pleasant taste to humans, but extracts of lovage and foenugreek seeds can only be considered as vile tasting. From these data, it may be seen that some of the old standbys, such as spitting on the bait, may have some basis in fact.

Table 2 illustrates the general indifference of carp to a number of substances which have often been thought to have some attractive qualities. Anise is a prime example. Carp ate all these flavors when they were incorporated in fish pellets in small quantities, but whether this was because of or in spite of the flavor ingredient is not known. Fish pellets were definitely a preferred food after a few feedings, although some individuals refused them at first. Dough baits (flour and cornmeal in equal amounts) were readily accepted for several days, after which all fish refused them. When incorporated into dough baits, some flavors, such as oils of clove, thyme, and citronella, were reluctantly eaten after much spitting out.

In dough baits the relative acceptability of most flavors was difficult to measure. It appears that acceptability is also affected by other qualities than flavor. Preferred foods were not made repulsive by any of the flavors tested.

ACCEPTANCE OF VARIOUS FOODS

A number of foods were fed to normal carp during many hundreds of

TABLE 2. REACTIONS OF CARP TO INSOLUBLE EXTRACTS *

POSITIVE FEEDING REACTION

- Olive oil with sardine particles
- Soybean oil with sardine particles

INDIFFERENCE AFTER TASTING

- Allspice oil (oil pimento), N.F.
- Almond oil
- Anethole from pine oil
- Anise oil
- Aromatic mixture B-48 §
  - C-48 §
  - D-48 §
  - L-48 §
- Balsam Peru oil, ext. genuine balsam
- Bay oil
- Bergamont oil
- Bitter almond oil (free from Prussic acid)
- Bois de rose oil, Brazilian
- Cajeput oil, rectified
- Calamus oil
- Camphor oil, water white
- Canada snake root oil
- Cananga oil
- Caraway oil, N.F.
- Castor oil
- Cedarwood oil, American
- Celery seed oil
- Chenopodium oil (American wormseed oil), N.F.
- Cinnamon oil
- Citronella oil
- Cloves oil
- Cocoanut oil
- Cod-liver oil (liver oils of cod percomorph and other fishes)
- Cognac oil, Rhine green
- Copaiba oil, U.S.P., 8th revision
- Coriander oil, U.S.P.
- Corn oil
- Cottonseed oil
- Cubeb oil, U.S.P., 9th revision
- Cumin seed oil
- Dill seed oil
- Eucalyptus oil, N.F.
- Fennel oil, U.S.P.
- Fleabane oil, American
- Geranium oil

INDIFFERENCE AFTER TASTING

- Grapefruit oil, American expressed
- Guaiac wood oil
- Hemlock oil, American
- Laurel oil, expressed
- Lavender oil
- Lemon oil
- Maple flavor, imitation (oil soluble)
- Olive oil
- Olive oil, filtered from sardine can
- Origanum certic oil
- Palm oil
- Patchouly oil
- Peanut oil
- Pennyroyal oil
- Peppermint oil
- Petitgrain oil, South American
- Pine oil
- Pine needle oil, Siberian type
- Rapeseed oil
- Rectified tar oil, N.F.
- Rhodium oil, select
- Rose oil, artificial
- Rosemary oil, N.F.
- Rue oil
- Sage Dalmatian oil
- Sassafrass oil, N.F. (natural)
- Savin oil, U.S.P., 8th imported
- Sesame oil, U.S.P.
- Soybean oil
- Spearmint oil, N.F.
- Sperm oil
- Spike oil, dark
- Spruce oil, American
- Sweet birch oil, U.S.P. (Betula oil, U.S.P.)
- Sweet marjoram oil
- Tangerine oil
- Tansy oil, American
- Thuja (occidentalis) oil, U.S.P.
- Thyme oil
- Ti-tree oil, Australian
- Verbena oil (a compound)
- Vetivert oil, Reunion
- Wine oil (so-called heavy)
- Wintergreen leaf oil, U.S.P. (northern Gaultheria procumbens)
- Wormwood oil, American
- Ylang ylang oil (artificial)

* In all cases test fish were blind and unfamiliar with substance being tested.

§ Fruity oils manufactured by Magnus, Mabee & Reynard, Inc., New York.

tests. These included whole-kernel corn, cracked corn, wheat, oats, buckwheat, soy beans, navy beans, all available livestock feeds, and all available forms of macaroni and noodles. All these foods were presented in original form or coated with food dyes, india ink or shellac. All preferred foods were eaten regardless of color, covering or mixture. Some foods such as beans and split peas usually could not be crushed and, in such cases, were rejected regardless of treatment.

All foods ingested are crushed between the pharyngeal teeth and the basioccipital bone (a skull bone) which is covered with a cartilagenous structure known as the pharyngeal pad. The opening to the esophagus is too small for large particles. The pharyngeal teeth, components of a modified gill arch, are capable of grasping, sorting, rejecting and crushing. Taste buds are present in this area. The efficiency of this grinding mill is evidenced by the ability of the fish to spit out tiny lead shot embedded in corn kernels while eating the corn. The importance of the pharyngeal area with respect to food acceptance is emphasized by the highly developed vagus lobes at the posterior end of the brain.

Carp often fill the mouth with food which is slowly crushed by the teeth. Large meals cannot be eaten because a stomach is lacking. Although the forepart of the intestine is large and somewhat expansive, these fish probably eat often and lightly under natural conditions.

Live, active foods were attractive. A number of aquatic insects were eaten readily by both blind and normal fish. Earthworms were taken at once. Salamanders were quickly seized and swallowed. Blind fish were able to capture crayfish, after chance touching, by a quick movement of the head combined with suction. Normal fish often chased crayfish for a short distance (a foot) but quickly desisted if flight continued.

It appears that carp might be caught most readily in clear water by bait which is occasionally moved in small hops to attract attention. In muddy water, the bait should remain in place, but an attractant such as maple flavor might be added to it and the immediate area.

USE OF SENSES IN FINDING FOOD

The feeding reaction is initiated by a stimulus received through any of the senses. Normal fish feed by sight whenever possible; but blind fish must depend upon other senses. Fish which have neither a sense of sight nor of smell are still able to locate food efficiently by taste, sound, or touch. In certain instances one sense appears to be the guiding force, although another sense may become dominant.

In clear water normal fish are the most efficient at finding food and eat by sight whenever possible. Visual stimuli lead them directly to food in most instances, but coordination is provided by the sense of touch.

Normal carp in an aquarium immediately detect a person (undoubtedly due to conditioning by being fed) and crowd violently toward him. Any small object thrown into the tank is immediately seized (fish learn, after a period of time, not to seize certain foods such as dough baits), and final acceptance or rejection takes place in the mouth. Inedible objects such as tar, putty and pebbles are often carried for several minutes in the mouth. The fish soon show less attraction to inedible objects, but may be restimulated to pick them up by the addition of a preferred flavor or by the sight of additional food, feeding fish or a person.

Flavors sometimes produce a snapping reaction in normal carp, but more often the fish react initially only to visual stimuli. When they do react, the flavor stimulus may be received by the olfactory nerves or taste buds located in the mouth and over much of the body.

Normal carp can locate surface food by sight but usually do not attempt to eat. Occasionally surface food is gulped in an aimless, uncoordinated manner, but most of such food is left uneaten. Falling food is readily seized through sight although coordination is so poor that much is missed. Food which lays on the bottom is located by a combination of vision and touch, and the latter may be dominant. On this two-dimensional plane efficiency and coordination are high. Food which rests on surfaces only an inch above the tank floor is often ignored, even when in sight. Normal adult carp, or those in clear water, are primarily bottom feeders although some food is undoubtedly taken in mid-water or at the surface.

Normal fish (regardless of size) school by sight in aquaria and this may have a relationship to feeding frequency. In at least one tank, a particular, easily stimulated fish was the first to take food, followed always by a second particular fish, and finally by the entire school. These fish were new and unaccustomed to the tank. Nevertheless, the quick stimulation of one fish resulted in more food consumption in this tank than in other tanks of new fish. Among acclimated fish activity of this type was never observed.

Carp fry may be almost completely dependent upon vision for feeding. Fry appear to feed on zooplankton which they obtain mostly during the day, rarely at night (Alikunhi, 1958). This may be a reason for the lack of young carp in many turbid waters where adults are abundant.

Adult fish seldom eat small particles unless the particles are massed. Normal fish will investigate a cloud of colloidal liver, snap at the flavor, and attempt to eat the cloud. As the cloud disperses, the fish are ultimately bathed in a sea of particles which they ignore. Larger introduced particles are seized. It is interesting to note that carp will flee before slowly spreading "black" clouds of malachite green. Some may jump from the tank. Upon envelopment by the cloud, violent activitity ceases. ("Ink" emitted by squids may produce panic rather than a blinding effect.)

In general, it may be said that normal carp feed by sight, but they locate their food by sight and touch. Stimulation to search for food may be provided by any factor which affects any sense.

Blind carp (and possibly normal carp in turbid water) are able to detect as little as one part of liver extract in 180 million parts of water, or a single fish pellet in a tank. Blind fish without olfactory perception are equally sensitive. Thus it becomes obvious that the sense of taste is acute.

The movements of blind carp are continuous, but relatively slow and deliberate as compared with those of normal fish. High speeds are usually avoided and as a result walls are gently contacted. The fish do bounce off of smooth surfaces if other obstructions are lacking and will repeat this maneuver again and again. Smooth surfaces are used for unconventional schooling, the fish continually streaming back and forth along them, often in contact with each other. Food is obtained during high-speed swirling in the center of the tank, but feeding actions are slow and deliberate in corners and at the sides. Logs and branches are actively overturned in search for food.

If a preferred flavor, such as liver extract, is detected with the rear portion of the body, a fish backs up until a tail-down vertical position is reached, after which it often falls over backwards. Snapping is continuous during this maneuver. The fish then circles rapidly to the floor of the tank and searches for food; at this time the sense of touch is dominant. Searching ceases after a few minutes if the fish is not rewarded with food. Addition of more extract forces a repetition of this performance, but continued introduction is ignored as the water becomes "saturated" and the taste and odor receptors fatigued. A new flavor such as maple extract will elicit a response at this point.

Blind fish are not able to follow a "trail" of flavor. Actually, trails do not exist as such except in single-direction currents. Rather, a fish is quickly immersed in a solution of the flavor substance and is stimulated to feed in that vicinity. Most of the fish gather where the flavor is strongest and arrive there by chance. The stronger the flavor, the more violent and efficient the feeding reactions. Apparently reason is not used; the fish remains where the stimulus is most acceptable.

A single trout pellet will cause all blind fish in a tank to search for food. Any fish that crosses the trail of a falling pellet reacts as it would to an extract. Almost immediately the other fish are stimulated by body movements, tooth noises or spreading flavor, and all begin to feed. Attempts, almost always unsuccessful, are made to seize food in mid-water. On the tank floor, the search is quick and efficient, and food is rapidly located by any chance touch. A falling particle will elicit snapping if it touches the body of a carp, but feeding will take place only if it has a flavor component.

Inedible objects are usually avoided, although some may be picked up. If such objects are abundant, feeding is retarded. Under natural conditions location of food is probably slowed by many obstructions.

Liver extract and all other flavors are detected by carp in conjunction with snapping, whether the fish are normal, blind, or without olfactory perception or barbels. Snapping is an apparent attempt by the fish to increase the amount of stimulus caused by the extract. Perception of odor in mammals occurs only when a gas is actually moving over the olfactory nerves. Increased air movement resulting from sniffing increases the stimulus. Odor cannot be detected, even if the originating substance fills the nasal passages, unless the air is moving.

Ordinary movement by fish would appear to enable stimulation of the olfactory and gustatory nerves (pure water causes momentory snapping if squirted directly into the nares), and snapping probably increases perception. In this way a fish ascertains the nature (i.e., pleasant or unpleasant) of a substance very quickly. The continuous movement of blind fish would appear to be efficient in maintaining contact with the environment.

Perception of sound appears to play only a small part in the feeding of normal fish, but it might be important in natural waters at night. Blind fish learn to associate vibration with food and will search if the tank is touched. In fact, blind fish finally learn to search for food regardless of stimulus. Any flavor or vibration will result in a feeding reaction; this is the same as saying that any non-violent change in the environment will cause feeding, if the change is perceived. For example, perception of a person by normal fish will produce feeding reactions in blind fish in the same tank. Blind fish are apparently capable of detecting changes in the movements of the other fish.

Under any condition sight is probably the most efficient locating mechanism, although final choice takes place in the mouth. Various stimuli actually lead the fish involuntarily to food. Other powerful stimuli (internal) may prevent fish from finding food as in the case of non-feeders.

The feeding reaction caused by the presence of a person might appear to be reasoning, but is probably learning. Loss of sight reduces the animal to apparent stupidity until it learns to link a person with vibration.

SYMPATHETIC ACTIVITY AMONG SENSES

It has been demonstrated that olfactory response is increased in rats by any stimulus which may excite the animal (Beidler, 1958). In other words, the ability to perceive odors is enhanced by stimuli received by other senses and transmitted to the autonomic nervous system. Data recorded during limited temperature experiments indicate that carp may be subject to such a relationship between visual and taste perception.

Normal adult fish fed actively at temperatures of 65° to 90 F. In the higher portion of this range, movements were precise, delicate, rapid and efficient. At 90° to 95° F. feeding was less active. Seizing of food at temperatures of 95° to 102° F. occurred, but little attempt was made to actually eat. Discomfort was evident.

Feeding was less active at temperatures below 65° F. A few normal carp fed sluggishly at 45° F. even if held at that temperature for months. Many fish ceased feeding at 45 F. and some fed for only a few days

(8-inch carp netted from natural water at 32° F. have been found filled with plankton).

Feeding carp reacted to a preferred flavor such as liver extract at any temperature at which they still fed. Non-feeding carp did not react regardless of temperature. In reverse it might be stated that any fish which reacted to an extract would feed.

Blind fish followed a pattern which was generally similar to that of normal fish. However, they ceased both feeding and reacting to extracts at approximately 50° to 55° F.

It thus appears that visual stimulation lowers the temperature threshhold at which odors or tastes can be detected. If true, this is a case of sympathetic activity between senses. It is also an indication that perception by various senses does not become more highly developed, as is commonly thought, when another sense is lost. Rather, the reverse is true, i.e., all remaining senses lose some perceptive capacity when one sense is lost.

Incapacitated animals probably learn to use their remaining senses to better advantage than they would have without the destruction of one stimulus-receiving route. This is not the same as an increased development of the remaining senses. In fact this limited evidence suggests that activity resulting from learning by an abnormal animal will never equal that of the same individual in a normal state. This analysis must remain theoretical without further study. However, it is suspected that the same phenomena might occur at extremely high temperatures also.

Sympathetic activity among senses has been amply illustrated by the success of teaching methods employing as many areas of sense perception as possible. Such coordination of senses is probably of great aid to fish in their aquatic environment. Any environmental factor which impedes the use of one sense is bound to reduce the effectiveness of the others, too, and both directly and indirectly to affect the fish's well-being.

Carp would appear to be at a disadvantage in turbid waters at low temperatures.

DISCUSSION

The observations reported here are a small addition to the study of fish behavior. An infinite variety of subjects are available for further original work. Any investigation should reveal new facts which may be useful in fish management. The results of the present work should be helpful in designing a poison bait for carp control. The use of a "natural" attractant, such as imitation maple flavor, which is foreign to the environment may also improve fishing. Other species are probably affected by these or other flavors. Carp are obviously forced to react to certain flavors, but the physiological relationships involved are little understood. There is similar lack of knowledge concerning the chemistry of most of the flavors tested. Why only alcohol and salt should not be detected remains a mystery. Similarly, the reasons for the attractive qualities of certain compounds listed in Table 1 are unknown.

The feeding activities of carp are stereotyped, but they are also complex. The activities noted in aquarium tanks must still be correlated with activity in natural habitats.

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LETHAL OXYGEN CONCENTRATIO FOR THE NORTHERN COMMON SHINER

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ABSTRACT

Mean lethal oxygen levels for the northern common shiner (*Notropis* cornutus frontalis) were determined at several temperatures from 55° to 80° F. The mean values ranged from 0.54 to 1.23 p.p.m. and gave a straight-line curve when plotted on semi-logarithmic paper.

The test procedure involved placing each fish a closed container and obtaining a gradual reduction of the oxygen content of the ambient water by the respiratory activities of the confined fish. Residual oxygen concentrations were determined for the water in each container when the test fish was completely over on its side with barely perceptible gill movements.

On some occasions fish kills in which all or nearly all the fish involved were minnows have resulted from depletion of dissolved oxygen due to organic wastes discharged into streams In such cases, data on lethal oxygen levels for minnows are needed in connection with investigations of the sources of pollution. Very little information for any of the species common to New York streams could be found in the literature. Therefore, tests were made to determine these values for the northern common shiner (Notropis cornutus *frontalis*). This species was chosen because it seemed to be moderately sensitive to reductions in the amount of dissolved oxygen.

The study was begun in 1952 and completed in 1956. All fish used were seined from a short section of lint Creek just north of Gorham in Ontario County. This section of the stream was free from pollution except for a small amount of household wastes. Black spot (Neascus sp.) was present on some of the fish, but no fish noticeably parasitized was used in any of the tests. Nearly all fish were in age group I, although a few of the smallest were young of the year and a few of the largest were possibly in age group II.

The tests were run at five temperatures: 55°, 65°, 70°, 75°, and 80° F. All the fish used in tests at 80° F. and part of those in tests at 75° F. were seined during mid-April or early May when stream temperatures were rising. The remainder used in tests at 75° F. and all of those used in tests at 70°, 65° and 55° F. were seined in late October, November, or in December (a few one year), when stream temperatures were falling. Those used for the 55° F. temperature were seined at a stream temperature only a few degrees lower than the test temperature and thus required a minimum adjustment during the acclimatizing period.

The minimum holding time for acclimatizing the fish to the assay water was 8 days; the maximum, about 30 days. Most fish were acclimatized to the test temperature for more than 7 days, the minimum being 4 days and the maximum, 26 days.