

DEPARTMENT OF COMMERCE AND LABOR

BUREAU OF FISHERIES

GEORGE M. BOWERS, *Commissioner*

EFFECTS OF EXPLOSIVE SOUNDS, SUCH AS
THOSE PRODUCED BY MOTOR BOATS
AND GUNS, UPON FISHES

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BY G. H. PARKER, S. D.
Professor of Zoology, Harvard University

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SENSE OF HEARING IN FISHES.

That sounds affect many fishes has long been recognized by fishermen and naturalists. No less an authority than Izaak Walton declared that it should be a rule with him to make as little noise as possible when he was fishing, lest he be heard and catch no fish. Nevertheless it has been only within the last few years that the sense organs concerned with the reception of sound in fishes have been definitely identified.

Using the term sound to include any vibrations of the water, from such slight movements as result from waves and currents to the vibrations that emanate from the impact of solid bodies under water or from the more violent discharge of explosives, it may be said that sounds affect fishes through three sets of sense organs—the skin, the lateral-line organs, and the ears. Within recent years it has been demonstrated that a fish can feel sounds through its skin in much the same way that a human being can feel the vibrations of a musical instrument when his hand is in contact with it. It has also been demonstrated that certain fishes sense relatively low vibrations, such as trembling movements of the water, by means of the lateral-line organs. And furthermore, though this point has been disputed, it seems clear to the writer through work carried out under the auspices of the Bureau of Fisheries that the internal ears of fishes are not only organs for the adjustment of bodily motions and equilibrium, but also organs of hearing.

THE QUESTION OF MOTOR-BOAT NOISES.

If, then, fishes are sensitive through so many channels to sounds, the question naturally arises as to the effect of the introduction of motor boats and other sound-producing mechanisms on the fishes of

our shores. Are such devices favorable, inert, or prejudicial to our fisheries, and, if prejudicial, in what ways can they be modified to make them least harmful?

Motor boats driven by exploding gasoline are equipped, as a rule, with an escape pipe which is situated close to the level of the water and through which the exploded gas is discharged in violent jets. This pipe is sometimes so arranged that its end may be dropped below the water level or kept in the air. When the gas is delivered into the air each discharge is usually accompanied by a familiar explosive noise of much penetration. When the delivery is into the water the sound is greatly muffled and freed for the most part from its objectionable penetrating character. This method of reducing the noise is so easily applied that in certain communities efforts have been made to require all motor boats to be thus muffled, at least between certain hours. The objection from the standpoint of the motor boats to this form of muffling comes from the fact that when the escape pipe is under water the obstruction to the free outward passage of the gases is so much increased that the efficiency of the motor is considerably reduced, and hence the running of the boat is impaired.

To the human ear under ordinary circumstances most motor boats either with or without mufflers are noisy appliances, generating sounds that are carried a long distance through the air. But in the water these sounds are very much less penetrating. To test this, a 7-horsepower motor boat with an exceptionally loud sound was run in open water and an observer plunged under the surface as the boat passed. When within 10 or 12 feet of the boat, whose escape pipe was in the air, the explosions of the gas could be faintly heard, though they were disagreeably loud to the observer when in the air. With the escape pipe under water and at the same distance as before the noise of the explosions could scarcely be detected at all under water. Thus both methods of running the boat delivered into the water surprisingly little sound as compared with what escaped into the air, and of the two conditions the muffled boat yielded to the water much less sound than the unmuffled boat.

In testing the effect of the motor-boat noises on fishes, a number of kinds of fish known to be sensitive to sounds, such as killifish (*Fundulus heteroclitus*), young scup (*Stenotomus chrysops*), and young kingfish (*Menticirrhus saxatilis*) were placed in a large wooden cage, 4 feet square by about 2 feet deep, whose walls were of strong netting. This cage was fastened in quiet water at the end of a float and a motor boat of $3\frac{1}{2}$ horsepower and with a penetrating noise was started at a distance of some 400 feet from the cage and run at full speed past it.

An observer was stationed on the float to note any response made by the fish. Tests were made with the escape pipe out of water and with it under water, but in neither instance was there any apparent effect upon the fishes. Most of these fishes, and especially the killifish, go down into deeper water when only slightly disturbed, but in these trials they remained playing about on the surface of the water while the boat passed and were in no observable way disturbed until the swash from the boat struck the cage, whereupon they generally dove to the deeper part of the receptacle.

Another test of a like kind was carried out on mackerel (*Scomber scombrus*). About 30 of these fish that had been for one or two days in a large pocket at the end of a pound net about a quarter of a mile from shore were gathered together by having the pocket pursed up into a space about 25 feet square and 10 feet deep. In this space they swam slowly about in a circle near the top of the water.

When an observer stationed in a boat at the edge of the pocket rose in the boat the fish very usually went to the bottom of their inclosure, to return to the surface after the observer had taken his seat again. While the observer was sitting and watching the fish a second person ran a motor boat over a circular course about half a mile in circumference, the course passing close to the pocket at one point. As the motor boat passed the pocket the fish were closely scrutinized by the observer. In no instance, either with the escape pipe of the motor boat above water or under water, did the mackerel sink into the deeper part of the pocket nor did they show in any other observable way that they were disturbed by the noise from the boat. Seven of them were then isolated in the cage previously mentioned and tested under close inspection by running the motor boat past the cage, but again the mackerel gave no evidence of being disturbed by the noise.

Although these tests seem to be quite conclusive in showing that the faint noises produced in the water by a motor boat have no marked effect on the ordinary activities of certain fishes, it is not impossible that the same noises may interfere with other activities of these fishes, such as feeding, pairing, egg laying, etc. The only tests in this direction that were carried out had to do with feeding. Hungry killifish, scup, and kingfish were placed in the cage previously used and the cage was fastened to a float so that a motor boat could pass close to it. When the fish were feeding vigorously the motor boat was run by the cage several times, but in no case did the fish give up feeding in consequence of the noise.

Another test was made with baited lines. Two baited fish lines were lowered from the edge of a wharf until the bait was about 6 feet under water. In a short time the two baits were surrounded by

cunners (*Tautoglabrus adspersus*), which began to nibble actively. A motor boat was now backed up under its own power from a distance of about 50 feet till its stern was directly over the baited lines. During the approach of the motor boat the fishes continued to nibble, notwithstanding the increasing noise, till the boat was within 6 feet of the lines, whereupon the fishes ceased nibbling. On running the motor boat away for a short distance, 6 to 8 feet, vigorous nibbling recommenced. It is difficult to say whether the cessation of nibbling, which regularly occurred when the stern of the boat was brought close to the lines, was due to the noise that reached the fishes or to the churning of the water in their neighborhood by the propeller of the boat. However this may be, it is certain that cunners can be driven from bait by a motor boat only when it is very close to them and that they are apparently uninfluenced by the same boat at a distance of 10 feet or so.

If a cunner can be driven from bait by the disturbance from a motor boat close at hand, other fish may be affected in a like manner, and should these be more sensitive to noises than the cunners, it is possible that they may be influenced when boats are at greater distances than 6 to 8 feet. There is, however, very little conclusive evidence on this point. In August, about the dock at Woods Hole, young bluefish (*Pomatomus saltatrix*) are not uncommon. They are often angled for with rod and line and afford much sport for the local fishermen. They bite well, even with motor boats making much noise in the harbor and passing the dock at a distance of about a hundred feet. If, however, a motor boat comes close to the dock, they are almost certain to cease biting for a quarter of an hour or so. Observations of this kind are by no means conclusive, but they favor the opinion that some fishes are disturbed by the noises from motor boats, though these disturbances are always very temporary and local.

The noises produced by motor boats have only a slight and local influence on fishes, not only because the noises that really get into the water are very faint, but probably because they reach the fish in the most favorable way for nonstimulation. Most persons who have experimented with the effects of sound on fishes have been struck with the fact that after a fish has responded once or twice to a given sound, it often ceases to respond to further stimulation for some considerable time, and in experiments of this kind it is usual to allow relatively long intervals of time to elapse between tests in order that the fishes may return to a receptive state. In the approach of a motor boat the sound that first reaches the fish must be far too faint to call forth any response, and this sound grows so gradually in intensity and with such rapid reiteration that the fish probably acquires the state of nonreaction to sound by the time the stimulus

has grown to such an intensity as would have been effective had a single shock been delivered at once to the fish. The gradual approach of the boat, then, does away with the element of contrast between silence and loud noise, and the result is just the reverse of that of summation, so often seen in the application of minimal stimuli to sense organs; the fish fails to respond.

RESPONSE TO THE SOUND OF GUNSHOTS.

If this explanation of the general ineffectiveness of motor boats in disturbing fishes is correct, then these animals ought to be responsive at least to single, loud noises generated close to the water. As long ago as 1782 Hunter demonstrated that fishes were responsive to the discharge of a fowling piece. In his account of the internal ears of fishes he states that—

In the year 1762, when I was in Portugal, I observed in a nobleman's garden near Lisbon a small fishpond, full of different kinds of fish. Its bottom was level with the ground and was made by forming a bank all round. There was a shrubbery close to it. Whilst I was lying on the bank, observing the fish swim about, I desired a gentleman who was with me to take a loaded gun and go behind the shrubs and fire it. The reason for going behind the shrubs was that there might not be the least reflection of light. The instant the report was made the fish appeared to be all of one mind, for they vanished instantaneously into the mud at the bottom, raising as it were a cloud of mud. In about five minutes after they began to appear, till the whole came forth again.

It is quite evident from this observation by Hunter that fishes can be disturbed by the discharge of a gun in the air, even when it is some distance from them.

To test the effect of single, loud noises on fishes several *Fundulus* were liberated in a cage, and after they had become quieted a fowling piece was discharged a few feet from them, but in such a position that they could not see it. At the report of the gun most of the fishes gave a single leap forward and to one side. This was several times repeated at considerable intervals and invariably with the same results. Bait was then thrown into the cage, and while the *Fundulus* were busy tussling with this food the gun was again discharged. They immediately forsook the bait, but in half a minute they had returned to it with full vigor. From these tests it is evident that *Fundulus* is easily disturbed by such a noise in the air as the discharge of a gun, but it is also evident that this disturbance is of a very temporary kind.

To ascertain something of the strength of the sound stimulus that caused the *Fundulus* to react an observer dove under the water, and while he was there the gun was discharged in much the same relation to him as it had been to the fishes. Although the report of the gun in the air was almost deafening, when it was heard under

a foot or so of water it resembled the pop of a soda-water bottle both in quality and in intensity. This great reduction in intensity of the sound, as in the case of the motor-boat sounds, results from the reflection of most of the sound from the surface of the water, and hence its failure to enter the water. Yet the little that did enter the water sufficed to stimulate the fishes.

Fundulus is known to be quite sensitive to sound, but the fact that it lives under water renders it relatively inaccessible to sounds, since most sounds originate in the air. This explains why *Fundulus* and most other fishes fail to respond to the human voice. It is not that the human voice in itself is not strong enough to stimulate a fish, but rather that so little sound from it enters the water that stimulation is impossible. The surface between water and air is for fishes an effective screen through which very little sound can pass.

With the view of ascertaining something of the effectiveness of a gun report as a stimulus for *Fundulus*, trials were made by firing the gun at various distances from the cage of fish. *Fundulus* invariably responded to the discharge of the gun at 100 feet from the cage; they usually responded at 200 feet; but they never responded at 500 feet. From these observations it is evident that the effect of the report of a gun is distinctly local and in this respect it resembles the motor-boat noises.

It would be a matter of great interest to ascertain what influence the firing of heavy guns has on fishes, but thus far no good opportunity for prosecuting such investigations has been found. Through the courtesy of the commanding officer of the United States revenue cutter *Gresham* it was possible to study the effect of the explosion of a saluting charge of 2 pounds of powder from a 6-pound howitzer. In these tests a considerable number of *Fundulus* were retained in a cage and the tests made at varying distances from the gun. At 2,000 feet no response was given to the report, and the same was true at 1,000 feet. Within 30 feet of the gun the conditions for accurate observation, because of the heavy detonation, were very unfavorable, but the response at this position was at most only momentary and certainly not more striking than the reaction to the report from a fowling piece.

From these observations it seems quite clear that single, loud noises generated in the air enter water to a small extent, but in sufficient volume to disturb momentarily fishes that are in the immediate vicinity. But even this limited disturbance does not seem to be produced by the ordinary motor boat which, partly because of the faintness of its sound under water and partly because of the gradual increase and decrease of the sound in intensity as the boat approaches and recedes, is relatively inert so far as many fish are concerned.

CERTAIN SOUNDS ATTRACTIVE TO FISHES.

The problem of the relation of fishes to sounds is almost always taken up from the standpoint of negative reaction, in that it is assumed that noise drives fishes away. It must be remembered, however, that there are fishes, like the drumfish and especially the squeteague, that produce noises which are without much doubt concerned with bringing the sexes together in the breeding season and that these noises, therefore, are not repellent but serve to attract. Cases of this kind show that it is possible that even artificial noises, if appropriate in character, might attract fishes, for sound, even when disagreeable to the human ear, is not of necessity always disturbing to fishes and might even serve as a lure.

CONCLUSIONS.

The sounds produced by motor boats are extremely faint under water and have little influence on the movements and feeding of fishes. Such influence as they do have is temporary and very much restricted in local extent.

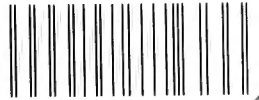
Single explosive sounds, like the report of a gun, may startle fish and cause them to cease feeding, but these responses are also temporary and local.

Although most sounds are repellent to fish, some may serve as lures to particular species.





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