RATE OF ESCAPE OF FISHES FROM HOOPNETS*

DONALD F. HANSEN
Illinois Natural History Survey

DESIGN OF THE HOOPNET

The traps used in the present experiment are called barrel nets, wing nets and fyke nets, as well as hoopnets. The nets of this type used by commercial fishermen vary in design with respect to number of chambers, size of mesh, size and shape of the funnels, and length of wings. The so-called buffalo net, which is similar except that wings are absent, is especially designed for use in strong current. The general design of the net described below is fairly typical of the wing type nets used on the Illinois River and at least on some parts of the Mississippi. These nets are nearly always made with two compartments and with wings under 10 feet long.

Figure 1 shows five freshly tarred nets loosely stretched for drying. The wings are doubled back over the hoops and are not clearly shown. Four other nets with poles attached are shown stacked in the upper right hand corner of this figure. The cylindrical part of the net is made of a series of metal or wooden hoops covered with netting, the mesh of which differs in size in accordance with various legal specifications and preferences of the fishermen. The wings are rectangular pieces of netting, one on either side of the front of the net and attached in such a way as to guide the fish toward the entrance funnel. Midway from front to back a second funnel divides the net into two compartments. The funnel openings are midway between top, bottom and sides. The opening of the front funnel is ordinarily considerably larger than that of the second. A fish entering the front compartment usually moves about until it either escapes from the net or passes through the second funnel into the rear compartment, from which chances of escape are lessened because of the smaller diameter of the back funnel opening and because the inner funnel is camouflaged by the finger-throat. See drawing. Finger-throats were used on the rear funnel of all the experimental nets. The commercial nets, however, are sometimes built with finger-throats on both funnels, but at other times the fingers are omitted from one or both funnels.

Three stout wooden poles, one at the end of each wing and the third at the end of the drawstring, which closes the back compartment, are pushed into the river or lake bottom to hold the nets in the "set" position. A separate piece of netting, mounted on poles, called a lead, has the function of guiding the fish to

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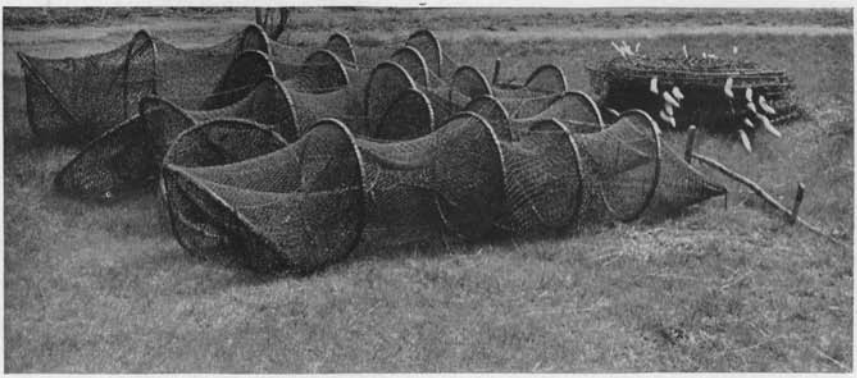

FIG. 1.—Freshly tarred hoopnets on a drying lot. The wings on the nets in the foreground are doubled back over the cylindrical part of the nets and are, therefore, not clearly shown.

the space between the wings. Leads are not often used in connection with nets set where there is strong current.

The nets used in the experiments had approximately the following dimensions. The cylindrical portion of the nets used was 10 to 12 feet long, with wings about 8 feet long, making the total length about 20 feet. The net diameters were of 2 sizes, 3½ feet and 4½ feet and were fished in water of these respective depths. The wings, front funnel and outside wall of the front compartment were of 1½ inch mesh bar measure. The second funnel and rear compartment were of 1 inch mesh bar measure. All nets had square or round entrance funnels except net No. 7 in the 1944 tests at Lake Glendale, which had vertical slots for entrances; these slots were the same height as the net itself. The average diameter for the front funnel opening was approximately 10 inches and for the back funnel 6 inches. Leads 60 feet long were used with all nets.

DESCRIPTION OF THE EXPERIMENTS

The experiments were conducted at Maple Lake, Cook County, in the fall of 1941 and at Lake Glendale, Pope County, in the spring of 1942 and 1944. Mr. Daniel Avery, field assistant with the Survey, was an enthusiastic participant. Shortly before the beginning of the experiments, it was learned that fish placed in the rear chamber of a net could make their exit by way of the funnel openings through which entrance to the net had originally been made. On one occasion largemouth bass and on another occasion warmouth bass had escaped when numbers of each had been stored in nets overnight.

The tests consisted of taking the fish caught in a given net, marking them with a metal tag or by cutting off part of a fin, and immediately replacing them in the same net in the rear or innermost of the two compartments. The nets were then reset and were not disturbed until a recount of the marked fish was made 1 or 2 days later. The fish were not credited with an escape unless absent from both compartments when the recounts were made. Escape necessitated an exit first through the rear funnel and finally through the front funnel.

The tests showed very conclusively that both the bluegill and the largemouth bass are adept at making escapes. Only a few individuals of other species were tested. The ability which some fish have of getting out of the net after capture has been recognized by Jacocks (1943). This ability is also recognized by some commercial fishermen, but generally the failure of the nets to capture certain species is attributed by the commercial fishermen to the alertness of the fish in avoiding the nets rather than in their ability to escape after original capture. The manner in which hoopnets are selective for certain species is strikingly shown by Schumacher and Eschmeyer (1943). A decided lack of correspondence in proportions of different species in hoopnet and anglers' catches has been shown by the writer (1942).

Species referred to in table 1 include the following:

Bluegill—Lepomis machrochirus machrochirus
Green Sunfish—Lepomis cyanellus
Pumpkinseed—Eupomotis gibbosus
Warmouth Bass—Chaenobryttus gulosus
Largemouth Bass—Huro salmoides
White Crappie—Pomoxis annularis
Black Crappie—Pomoxis nigro-maculatus
Black Bullhead—Ameiurus melas melas

EXPERIMENTAL RESULTS

The kinds and numbers of fish employed in the trials and the numbers of fish making escapes are shown in table 1. The number of escapes from individual nets ranged from none out of 6 bluegills kept in a net for 24 hours to 16 out of 16 bluegills (100 per cent) kept in a net for 50 hours. The results of the several trials may be summarized as follows:

One day trials at Maple Lake. Average time 23½ hours.
81 bluegills used: 26 or 32 per cent escaped.
3 white crappies used: 0 escaped.
2 warmouth bass used: 0 escaped.
1 pumpkinseed used: 0 escaped.

One day trials at Lake Glendale. Average time 23 hours.
44 bluegills used: 16, or 36 per cent, escaped.
16 largemouth bass used: 6 escaped.

Two day trials at Lake Glendale. Average time 51 hours.
36 bluegills used: 32, or 86 per cent, escaped.
5 largemouth bass used: 1 escaped.

It should be understood that the experiments were conducted with the hoopnets set in the usual way for catching fish. The actual numbers caught during these tests are shown in the right hand column of table 1. By clipped fins or metal tags the experimental fishes could be separated from those which were newly caught.

VALIDITY OF RESULTS

The validity of the experiments would, of course, depend on the conditions (1) that there were no broken meshes in the nets through which the fish could escape, and (2) that the experimental fish were not stolen from the nets. The nets were examined for holes both at the beginning and the end of each of the trials and no breaks were found. It is unlikely that any of the fish were stolen. While the nets remained unguarded at night, we are satisfied that we would have recognized a net that had been disturbed, especially since in both localities most of the residents are unaccustomed to hoopnet manipulation. Even if thieves had disturbed the nets and had tried to reset them, it is unlikely that the nets would have been left in good order.

The individual lengths of the fish used in the experiment at Maple Lake were not recorded. They were all of moderate size. At Glendale, the bluegills and bass were measured at the start of the experiments. The

TABLE 1.—DETAILS OF EXPERIMENTS TO FIND OUT HOW MANY FISH WOULD ESCAPE FROM AN ORDINARY TWO-COMPARTMENT HOOPNET WHEN FISH WERE MARKED AND PLACED IN THE REAR COMPARTMENT

Date	Net and fin marked	Period of experiment	Kinds of fish used	Number used in experiment	Number of escapes	Fish caught in the same net during the period of the experiment
			Maple Lake—1941			
Oct. 4	Net No. 6 Pelvic	22 hrs.	Bluegill	54	19*	26 Bluegills
			White crappie	3	0	4 White crappies
			Warmouth	2	0	1 Black crappie
			Pumpkinseed	1	0	1 Warmouth
						1 Black bullhead
Oct. 5	Net No. 6 Pelvic	25 hrs.	Bluegill	27	7**	24 Bluegills
						6 Black crappies
						1 White crappie
						1 Black bullhead
			Lake Glendale—1942			
March 12	Net No. 1 Right Pelvic	24 hrs.	Bluegill	6	0	99 Bluegills***
			Largemouth	2	0	1 Largemouth***
						1 Black bullhead***
	Same experiment continued	54 hrs.	Bluegill	6	no count	217 Bluegills
			Largemouth	2	1	11 Largemouth
						3 Black bullheads
						1 Green sunfish
March 12	Net No. 3 Left Pelvic	49 hrs.	Bluegill	8	5	29 Bluegills
			Largemouth	1	0	4 Largemouth
						5 Green sunfish
						1 Black bullhead
March 12	Net No. 5 Dorsal	50 hrs.	Bluegill	12	11	26 Bluegills
						2 Black bullheads
						1 Green sunfish
March 12	Net No. 7 Anal	50 hrs.	Bluegill	16	16	48 Bluegills
			Largemouth	2	0	8 Largemouth
March 14	Net No. 7 Anal	24 hrs.	Bluegill	38	16	20 Bluegills
						6 Largemouth
						1 Black bullhead
			Lake Glendale—1944			
March 27	Net No. 7 Metal Tag	24 hrs.	Largemouth	12	6	not observed
March 27	Net No. 8 Metal Tag	24 hrs.	Largemouth	2	0	not observed

* One more bluegill (not included among the 19) had succeeded in reaching the front compartment.
** Two more bluegills had reached the front compartment. Two of the experimental fish were dead in the rear compartment.
*** Counted and returned to net, but not marked. Included in the 54-hour set below.

bass ranged from 9.6 inches to 13.9 inches total length in the 1942 trials and from 8.2 inches to 19.0 inches in the 1944 trials. The bluegills ranged from 6.3 inches to 8.6 inches. The bluegills at Maple Lake were smaller, ranging from 4.5 inches to 7.0 inches. Since 1 inch mesh, bar measure, is fine enough to retain bluegills as small as 3.6 inches and largemouth bass as small as 6.5 inches, is is clear that the smallest sizes used in the experiments were too large to escape through the meshes.

Where several trials were started on the same day as at Lake Glendale (on March 12, 1942), the fish belonging to different experiments were marked by clipping a different fin except in 1944 when the bass were marked with metal tags. The practice of clipping different fins was followed in order that the fish could not escape from one experimental net into another without being recognized. There were no instances, however, of such mixing.

There was, of course, no way of recognizing a fish which might escape from a net and later return to the same net. Such occurrences probably were rare, but would result in the tests showing fewer escapes than actually occurred.

Controls to show the effect of fin clipping on the number of escapes were not used in connection with these experiments. The effect of fin clipping might be of two kinds. Fin clipping might interfere with swimming and hence tend to lessen the number of escapes. On the other hand, the operation might intensify the desire and the effort to escape. The latter effect, however, does not seem to be an especially likely one. Neither caudal nor pectoral fins, which are much used in swimming, were clipped.

THE EFFECT OF WATER TURBIDITY ON NUMBER OF ESCAPES

The escape trials at Maple Lake were run under quite different conditions of turbidity than those at Lake Glendale. At Maple Lake the (4 inch, white) Sechii disc disappeared at a depth of 29 inches while at Lake Glendale the disc could be seen to a depth of 13.5 inches on March 14, 1942; to a depth of 10 inches on March 15, 1942; and to a depth of 10.5 inches on March 27, 1944. The more turbid conditions found at Lake Glendale did not seem to have a noticeable effect on the number of escapes. This would be contrary to the expected result if the escapes are made with the aid of vision; that is, by the trapped fish seeing and purposely swimming through the funnel openings. It is quite possible, however, that a turbidity threshold might be found at which the number of escapes would be very much reduced.

It should be kept in mind that while the turbidity conditions were not the same in the two lakes, certain other conditions were also different, including sizes and ages of the fish used and temperature of the water. These factors, however, would not seem to have so much importance as turbidity differences.

THEORY OF HOW FISH ARE CAUGHT

Fish entering the trap do so by their own movements. Supposedly some are caught because the entrance hole happens to stand in the exact path of movement, while others are taken when they attempt to get past one of the wings which has interfered with forward movement. There is also the possibility that certain species, for example, members of the catfish family, are actually attracted by the enclosure, just as they are attracted by hollow logs and bank

holes. For certain other species the net might have the same attraction as brush or submerged tree tops. To some extent the fish within the net may decoy others. Also, a "sheep" reaction, in which one fish entering the net is followed in closely by others, may be important. Entrances and departures of fish in pairs has been observed by Mr. Robert Clark of Bath, Illinois. Some fishermen bait the nets, but this is not often done with the wing type hoopnet. Baits are almost never used in the hoopnet operations of the Illinois Natural History Survey.

THEORY OF FISH ESCAPE

A horizontal plane passed through the center of the hoopnet will show that the sides of the funnels and the sides of the net form a succession of hearts. The writer used to imagine that the heart-shape of the net chambers contributed to the success of the net in retaining captured fish. It was supposed that a trapped fish in trying to find its way out was kept swimming in circles. The writer also pictured the trapped fish as carrying on a more or less continuous and excited search for a route of escape and that its excitement contributed to failure to find that route. But this sort of behavior is not the kind described to me by Robert Clark and Jack Varnox, both of whom watched fish in hoopnets in the winter through clear ice at Bath, Illinois. According to these men, the fish which they watched showed not the least sign of excitement within the net; whether entering or escaping from the net, their movements were always leisurely. Clark has watched the entrance and escape of crappies, sunfish and bass, while Varnox has watched entrance and escape of bullheads. Clarence Pace of Liverpool, Illinois, has watched the behavior of carp (*Cyprinus carpio*) in the nets and found that they were much more sluggish in winter than in summer. In the summer he has seen carp enter a net and immediately turn around and go out without the slightest difficulty. In this connection we have noticed that fish brought from the wild to indoor aquaria seldom show any excitement as a result of the close confinement.

My colleague, Bruno von Limbach, suggests that fish captured in hoopnets ordinarily would have less cause for excitement than those placed in aquaria. For example, the aquarium fish has been removed from its natural surroundings, may have undergone changes in temperature, may have been placed in different water, and been handled more or less roughly in transit.

If the trapped fish in the wild accept captivity with little or no excitement, as was observed by Messrs. Clark and Varnox, it may be conjectured that they spend considerable time in idly swimming or in lingering in the middle of the net near the funnel opening. The captive might then escape by swimming through the funnel either by accident or by passing through purposely after seeing the opening.

If trapped fish are usually calm, conceivably they may be excited on occasions when the net is crowded or when large voracious species of fish or turtles are included among the captives. However, from experience in working with hoopnets, it may be said that ordinarily the fish within a net appear to be fairly "settled" until the fisherman grasps the net preparatory to lifting it into his boat. Only at that point is the charging of large fish against the sides of the net apparent.

EFFECTIVENESS OF THE FINGER-THROAT AS A HINDRANCE TO ESCAPES

The finger-throat is a device used on the inner funnel for the purpose of camouflaging the opening and further acts as a mechanical hindrance to exit. It may roughly be described as consisting of 2 half cones of twine, one on either side of the funnel mouth. The individual strings spaced an inch apart which make up the fingers are tied to a median string, which, in turn, is secured to the back hoop.

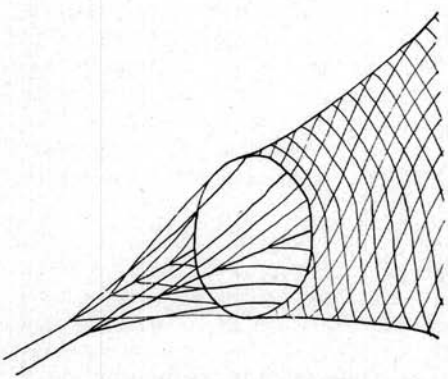

FIG. 2.—Sketch showing part of the rear hoopnet funnel with projecting finger-throat.

The design of the finger-throat is such that it is relatively inconspicuous to fish entering the funnel and thus has a minimum frightening effect. The lateral distance between the two halves of the throat is about 3 inches. When necessary the two halves may be forced apart to allow passage of fish of greater width. An examination of figure 2 will show why this device is not more effective in preventing the escape of fish caught in the rear compartment. Although it is apparent that the finger-throat would act as a barrier to fish approaching the mouth of the funnel from the side, it would seem to be relatively a much less effective barrier when the funnel is approached from directly in front or from slightly above or below the center of the opening.

EFFECT OF THE RATE OF ESCAPE ON HOOPNET EFFICIENCY

Usually hoopnets are raised at approximately one-day intervals. But for various reasons, the periods between raises may be stretched to two days or longer. On the basis of the above tests and from direct observations of Messrs. Clark, Varnox and Pace, it is clear that fish of certain species entering the hoopnets are not permanently confined but instead numbers of them will escape within a period of minutes or hours. Where the purpose of the fisherman is to catch the largest number of fish in the shortest time, there is thus an obvious advantage in raising the nets at frequent intervals in order to secure individuals which would otherwise escape.

Where hoopnets are used for quantitative evaluation of a fishery it would seem to be important to standardize the period of the set. In the past we have assumed that doubling the period of the set doubled the catch. As a general assumption this was doubtless not a valid one, although it might hold for certain species or under certain conditions.

A preliminary check on this matter as applied to a bluegill population was undertaken at Lake Glendale, March 25-31, 1944. We used six nets, of 1 inch mesh, set for alternate periods of one-day and two days so that the long and short sets were spread throughout the week in which the tests were made. During the week 17 one-day sets and 16 two-day sets were obtained. The one-day sets yielded 28.8 bluegills per net while the two-day sets yielded 38.8

bluegills per net. The two-day sets, therefore, yielded only 1.36 times as many bluegills as the one-day sets rather than twice the number. Presumably this ratio would vary with the species.

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