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FISH POPULATIONS IN AND AROUND BRUSH SHELTERS OF DIFFERENT SIZES PLACED  
AT DIFFERENT DEPTHS AND SEPARATED BY VARYING DISTANCES  
IN DOUGLAS LAKE, MICHIGAN\*

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At former meetings of the Michigan Academy the writer has presented various data on the use of brush shelters by fish and on the movements of marked fish in Douglas Lake, Cheboygan County, Michigan (Rodeheffer, 1939, 1940, 1941). As these studies progressed and public interest in lake improvement increased it became apparent that answers were needed to numerous problems which had already been suggested in "The Improvement of Lakes for Fishing" (Hubbs and Eschmeyer, 1938). Scientists, fisheries managers and fishermen wanted answers to many practical questions.

At what depth shall artificial fish shelters be placed in a lake to be most suitable for certain species favored by anglers? Do the young, half-grown or adults of such species have individual depth preferences? Among the many factors which may govern the optimum depth for shelters, consideration may be given to the species of fish for which protection or utilization is desired, the seasonal movements of the fishes, temperature (particularly during the summer months), extent of light penetration, relative amounts of deep and shallow water in a lake, ice and wave action, fluctuations in water level and types of bottom at various depths.

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Another question that puzzles the individual who attempts to improve a lake by installing shelter devices is, how many shelters shall be placed in a given area, or how far apart shall such constructions be placed for maximum efficiency? It is self-evident that numerous factors must be considered when answering this question, such as the available food supply, the habits of the species for which protection is desired, the amount of bottom area suitable for shelters, the funds available for the work, and the abundance of natural cover.

Shall a few large shelters or numerous small ones be installed in a lake? This is a question often asked after a few shelters have been built and placed. Much brush and much labor are required to build large shelters. They are difficult to handle and place where wanted. The ratio of economy in the building and placement of large and small shelters is dependent upon the materials and the equipment immediately available. The suggestion has been made (Hubbs and Eschmeyer, 1938: 66), and has been backed by limited testing, that small shelters be built for young fish and large shelters for "keeper" fish.

During the summer months of 1941 and 1942 studies designed to answer these questions were undertaken on Douglas Lake at the University of Michigan Biological Station.

#### Acknowledgments

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Fish populations in and around brush shelters placed at  
different depths

To obtain evidence on the optimum depth for the placement of brush shelters, six shelters of the hollow-center brush type (Hubbs and Eschmeyer, 1938: 80-81, fig. 20) were installed on the shoals of North Fishtail Bay, in Douglas Lake, two each at depths of 5, 10, and 15 feet. This region was selected for two main reasons: (1) the terrigenous bottom slopes evenly to a depth of twenty feet or more, with only moderate differences in angles of slope; (2) the bottom is of sand, covered by a thin layer of flaky marl. The area thus provided a uniform habitat without vegetation or bottom irregularities, which might have concentrated the fish locally. The shelters, spaced at equal intervals and similarly constructed, could therefore be assumed to present approximately equal availability and attraction, except for the one factor being tested, that of depth of water. Furthermore the bottom was favorable for seining, so that the total fish population in and about each brush structure could be caught periodically for counting.

The experiment was run in duplicate. The six shelters were placed in pairs 200 feet apart, with one pair on the 5-foot contour, one pair on the 10-foot contour, and the other two at 15 feet. The outermost structures were about 400 and 500 feet from shore. The pairs were staggered in such a fashion so that no shelter was nearer than 200 feet to any other.

#### Structures and Equipment

The shelters were made as nearly identical as possible. Scrub oak and maple poles were used to make the frames which consisted of an inner unit 9 feet square, with the ends of the poles protruding beyond the square, and a surrounding frame 11 1/2 feet square. The larger unit was fastened to the protruding ends of the smaller one in such a way as to make a sturdy base for the brush. The brush, consisting of maple, scrub oak, tag alder and cherry was placed in bundles about 18 inches in diameter at the butt end and laid on this frame with the tops pointing away from the center. Each bundle was securely wired to the pole of the inner frame with number 9 galvanized wire. All bundles were placed as close together as possible so as to form a complete circle of brush. The outer edges were trimmed to make each shelter 18 feet in diameter. The double framework provided a flat surface on the bottom to permit the net to slide under the shelter when it was raised to the surface. To facilitate raising, a special bridle was attached to the four corners of the inner frame, using a sufficient length of wire to allow the apex of the bridle to be fastened to a float.

To capture the fish populations around these shelters a specially constructed fine-meshed bag seine was used. This seine, 158 feet in length, was made with a center section of 1/4-inch square mesh which formed a bag 8 feet long, 8 feet wide and 12 feet deep, tapering to 4 by 4 feet at the closed end. On each side of the bag for 47 feet the seine was 12 feet

deep and made of  $3/8$ -inch mesh. The end sections, 28 feet in length and tapering to 6 feet in depth, were of  $3/4$ -inch mesh. This seine was equipped with sufficient floats to make it float upright in the water and with enough weights to keep the lead line on the bottom. The net was laid from a boat outside a shelter in such a fashion that the device was completely encircled. Ropes fastened to the brails led to shallow water, thus allowing the net to be pulled shoreward under the shelter immediately after the structure was hoisted to the surface. While being hauled toward shore the seine was pursed by keeping the brails together, so as to prevent the escape of the fish already in the net and not to capture any fish occurring in the water between the shelters and the beach. For seining the fish from the shelters in fifteen feet of water a straight seine 5 by 100 feet made of  $7/8$ -inch mesh was fastened to the top of the center section of the bag seine.

In earlier experiments with brush shelters (Rodeheffer, 1939, 1940, 1941) the structures were pulled to shallow water after being enclosed by the net. When the fish had been gathered the shelter was replaced in its original position. To save time, labor and wear on the shelters, Dr. A.S. Hazzard suggested that a floating hoist be used to lift the shelters to the surface, so as to allow the seine to be pulled under them. The hoist that was constructed (Fig. 1) had a base 25 by 25 feet in size. Nine oil drums, later increased to thirteen, were fastened at the corners of this hoist to give it buoyancy. Poles extending upward from the corners of this square were brought together to form an apex twenty feet above the surface of the water. This framework was equipped with a steel cable extending from a geared drum and hand-operated crank secured at one of the corners, passing upward through a fixed pulley at the peak and downward to the surface of the water. At this point the cable was threaded through a

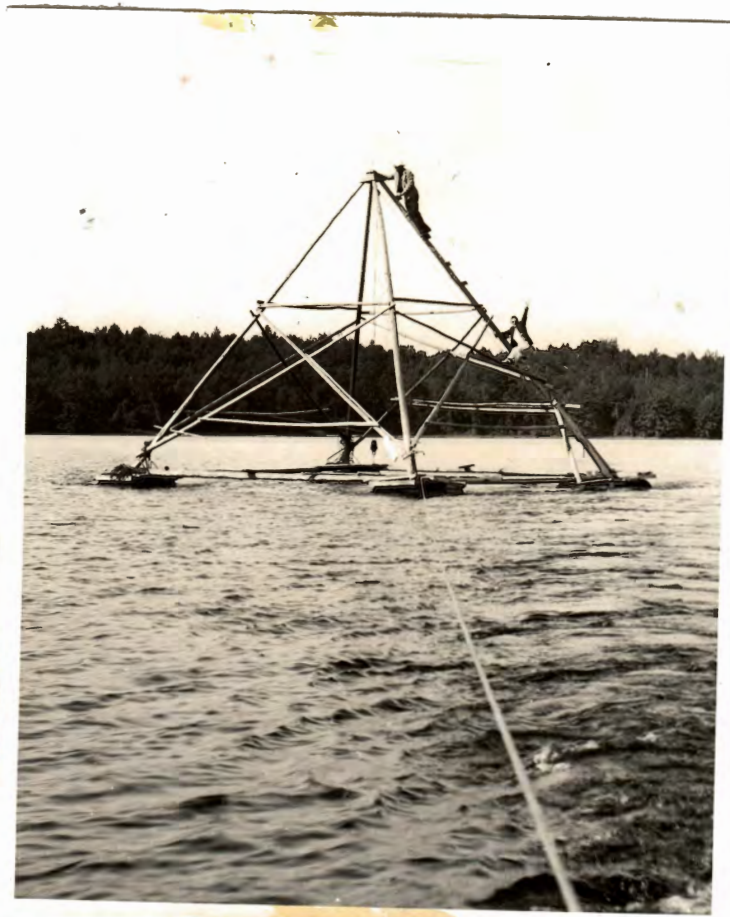


Fig. 1. Hoist used in lifting brush shelters. The device is being towed to the site of a shelter.

movable pulley, brought upward and fastened to the fixed pulley at the top. The movable pulley was hooked onto the bridle attached to the brush shelter, after the floating hoist had been anchored over the shelter. The turning of the crank ~~would~~<sup>wound</sup> the cable on the drum, and thus lifted the installation to the surface (the power ratio of the block and tackle and gears was 1:3 $\frac{1}{4}$ ). After the seine was hauled through the area, the shelter was lowered to its original position.

Number and size of fish caught around shelters and in control areas, at different depths

To secure data on the fish living in and around the six shelters, these structures were lifted in daylight a total of 35 times at intervals of 2 to 9 days during July and August of 1941. All captured fish were identified, measured and counted, with results shown in Table I. After the shelter was replaced the fish were returned to the water over the shelter. The open waters, treated as control areas, between and on the sides of the shelters, were seined three times at each depth. When seining the control areas the net was laid in a circle to cover an area similar to that encircled when taking fish in and around a shelter. While bringing the net shoreward the brails were kept together to prevent the capture of fish from waters other than the designated control areas. These seinings formed a basis for a comparison of the fish population in and around shelters and in similar places without protection.

The number of fish per seine haul of some species, particularly the yellow perch, increased at the greater depths. The number of perch per haul was less than 3 in the shelters placed at the 5-foot depth, increased to 1 $\frac{1}{2}$  per haul from the shelters in 10 feet of water and mounted to almost 1,000 per haul from the shelters in 15 feet of water. It is possible that even greater numbers of young perch would be protected by shelters placed deeper than 15 feet. Control areas yielded only 4 perch per haul at the

TABLE I

NUMBER PER HAUL AND SIZE (TOTAL LENGTH IN CENTIMETERS) OF FISH OF EACH  
SPECIES TAKEN FROM HOLLOW-CENTER BRUSH SHELTERS PLACED AT DIFFERENT DEPTHS  
IN DOUGLAS LAKE, MICHIGAN

Species <sup>∇</sup>	Number per haul at given depths			Size range at given depths			Average size at given depths		
	5 feet (10 hauls)	10 feet (13 hauls)	15 feet (12 hauls)	5 feet	10 feet	15 feet	5 feet	10 feet	15 feet
<b>Game fishes</b>									
Northern pike	...	...	0.1	...- ...	...- ...	63.0-63.0	...	...	...
Yellow perch	2.7	112.2	996.5	5.0-13.4	3.1-14.7	3.5-21.7	7.7	5.5	5.4 <sup>∇*</sup>
Smallmouth bass	7.0	6.2	1.3	4.3-22.2	4.2-18.7	5.7-25.3	7.7	7.9	10.7
Largemouth bass	29.1	15.7	3.3	3.5- 7.2	3.1- 8.2	3.5-10.5	5.3	4.9	5.9
Bluegill	0.3	0.2	...	10.0-15.3	9.8-14.6	...- ...	12.2	12.2	...
Pumpkinseed	55.2	60.0	56.3	1.9-17.1	1.5-19.0	1.9-19.7	8.3	8.3	9.0
Rock bass	67.0	64.8	44.7	2.1-21.6	2.5-19.7	2.3-28.5	8.9	8.2	11.5
<b>Coarse fishes</b>									
Sucker	0.2	0.2	0.5	37.9-40.6	37.8-41.8	5.9-39.8	39.0	38.8	22.5
Bullhead	0.3	0.5	0.8	6.2- 7.4	4.7- 7.1	4.4- 7.0	6.8	5.8	5.9
<b>Forage fishes</b>									
Common shiner	0.3	...	0.7	5.3- 6.0	...- ...	5.2-11.0	5.8	...	8.3
Spottail shiner	3.5	7.2	90.8	2.7- 6.7	1.9- 9.3	1.5- 9.3	5.1	4.8	5.0 <sup>**</sup>
Sand shiner	1.2	0.2	3.2	2.1- 7.2	1.6- 6.0	4.4- 7.6	4.3	4.5	6.3
Mimic shiner	...	...	0.6	...- ...	...- ...	2.2- 6.0	...	...	3.6
Log perch	0.7	21.5	37.3	4.7-10.6	5.3-10.6	4.3-12.5	9.1	8.9	8.9
Johnny darter	2.5	5.7	5.0	3.1- 5.8	2.1- 6.1	3.3- 7.1	4.6	4.4	4.7
Iowa darter	0.2	0.8	0.4	3.4- 4.4	2.9- 5.7	3.6- 5.5	4.0	4.8	4.8
Muddler	...	0.1	0.1	...- ...	2.8- 2.8	7.0- 7.0	...	2.8	7.0
Total fish per haul	170.2	325.3	1,241.6						
Total fish taken	1,702	4,226	11,899						

<sup>∇</sup>The scientific names are listed at the end of the article.

<sup>\*\*</sup> Only a percentage of the perch between 3 and 7 centimeters, and the spottail shiner between 4 and 6 centimeters were measured; the others were merely counted. The average sizes for these species are based on actual measurements taken.



10 foot depth, and none at 5 or 15 feet. The perch from the shelters at the three depths varied little in size. The modal size class was 5-6 cm. at all depths. There is another common size (age group?) at about 11 cm. Only 6 perch were recorded with a length of 6 inches or more, all from shelters in 15 feet of water. The fact that perch are markedly dwarfed in Douglas Lake (Weller, 1938) may account for the limited size range. Large schools of small fish (estimated to be 2-3 cm. long), so densely crowded as to give the water a bluish-green tinge, sometimes rose to the surface when a shelter was being lifted from 15 feet of water and occasionally from a shelter at the 10-foot depth. Capture of a few of these with a hand net revealed them to be young yellow perch. Undoubtedly the shelters harbored thousands of such small fish which were without question young perch, but they were too small to be retained by the net and hence are not included in the table.

Certain other species, such as the largemouth and smallmouth bass showed a definite preference for the shelters in shallower water. Shelters in 5 feet of water harbored almost twice as many largemouths as did those in 10 feet of water and about 9 times as many as did those placed at 15 foot depths. The shallowest shelters produced more than 5 times as many smallmouths as did the deepest ones and slightly more than the shelters in 10 feet of water. Young smallmouth bass, although present in small numbers, appeared consistently in every haul from the shelters in 5 feet of water. This substantiates former findings (Hubbs and Eschmeyer, 1938: 64). Largemouth bass were taken in greater numbers than the smallmouth bass but this is possibly due to the type of bottom which is a flaky marl. The young of these species, having a size range of 3 to 10 cm., were the most common, with a scattering of smallmouths 14 to 25 cm. long from the shelters at all three depths. No fish of legal size (10 inches or more) were caught.

Nine seining of the control areas netted a total of only 6 young smallmouth bass at the 5 foot depth and 2 in 10 feet of water. Only one largemouth bass was taken in the 10-foot controls and none was captured at the 5-foot depth. No largemouth or smallmouth bass were taken from the controls in 15 feet of water.

The pumpkinseed, ranking second in abundance in shelters on the 5 and 15-foot contours and third in abundance from shelters in 10 feet of water, was found in about equal numbers at all depths. Nor was there any marked difference in the minimum, maximum, average or modal size of the fish taken from the shelters at the stated depths. Two sizes are commonly represented, one of about 3 to 4 centimeters and another of about 7 to 8 centimeters. Only a few (18) were of legal size (six inches or more). That this fish seeks protection is apparent when one considers that no pumpkinseeds were taken from the shallow controls, only two from the control areas in ten feet of water and just one from the controls at the 15-foot depth.

In number of fish taken from the shelters, rock bass showed a slight but gradual decline with increasing depth of water. Hauls from the shelters on the 5-foot contour averaged about 1.5 times as many rock bass as from those on the 15-foot contour. Rock bass 7 to 8 cm. long were particularly common around shelters at all three depths, and constituted almost one-third of all the rock bass taken. However, enough larger rock bass were taken from the deep shelters to increase the average size from 8 to 9 cm. for the shelters in 5 and 10 feet of water, to 11.5 cm. from the shelters at the 15-foot depth. This increase was primarily due to the number of fish taken in the size range between 8 and 15 cm. Only 32 of the 316 fish 8 cm. or more in length were of legal size (six inches or more). The percentages of legal-sized fish among the rock bass caught from the shelters on the 5, 10 and 15-foot contours were 3.7, 1.2 and 6.0, respectively.

Although fewer rock bass inhabited the shelters in the deepest water, those found there included the highest percentage of legal size. In conformance with their preference for cover, no rock bass were taken in the seinings in the control areas.

The almost total absence of the northern pike in the shelters was surprising, for Douglas Lake is known as a good pike lake. These fish are commonly caught from the larger weed beds which in places extend from shallow water to a depth of about 18 feet in this lake. The capture of only one northern pike from a shelter in 15 feet of water indicates that this fish does not seek such a habitat.

Very few bluegills were taken about the shelters, but this fact does not indicate a lack of preference for brush cover on the part of this species. Bluegills are not common in Douglas Lake. Artificial plantings of this species have been made but these fishes do not seem to reproduce naturally to any extent. Seining of waters where one might expect to take bluegills seldom yielded any results.

Several of the forage fishes were well represented in the catches from the shelters. The spottail shiner sought protection in the deeper shelters. Ninety-one fish per haul were taken from the deepest water, while only 7 fish per haul were seined from the 10-foot contour shelters and less than  $\frac{1}{4}$  fish per haul were caught in shelters on the 5-foot contour. Only one spottail was taken from the control areas, at the 10-foot depth. Very little variation in size was noted from all three depths. Most of the fish were young and half-grown.

The largest numbers of log perch were found in the deeper water associated with shelters. The average catch was less than one fish per haul from the shelters in 5 feet of water. This increased to over 21 fish per haul from shelters on the 10 foot contour and to more than 37 fish

per haul from the shelters in 15 feet of water. Seining of the control areas at the 10 foot depth netted almost 6 fish per haul. No fish were taken at the other two depths. The average size was about 9 cm. at all depths.

The johnny darter, well known as a fish of the open bottom, was captured in comparatively small numbers in the shelters, about 5 fish per haul from shelters on the 10 and 15-foot contours and 2.5 fish per haul from the shelters at the 5-foot depth. In the control areas this species averaged more fish per haul than any other. Seining of the controls at the 10 and 15-foot depths captured 5 fish per haul and from the 5-foot control areas the hauls netted an average of 15 fish.

Almost all suckers caught were adults. In the control areas the three suckers captured at 15 feet and the 6 taken at 10 feet were full-grown. The one fish taken at 5 feet was young, 7 cm. long.

Other species seined in the shelters listed in Table I were recorded in such small numbers in both the control areas and the shelters that conclusions are not warranted.

The total catch of fish per seine haul from the shelters increased with an increase in depth. Brush shelters placed on the 5, 10 and 15 foot contours averaged 170, 325 and 1,241 fish per haul, respectively. It should be noted, however, that these figures are largely influenced by the perch catch.

Control areas at the same depths averaged 13, 16 and 8 fish per haul. These relative numbers emphasize the fact that fishes in general seek shelter.

Fish taken from shelters placed fifty and two hundred  
feet apart

Determining the most desirable concentration of shelters in a lake was one of the major projects for the summer of 1942. To provide information on this subject, fish collections were made from brush shelters placed 50 and 200 feet apart. For this experiment 8 hollow-centered shelters were used. Four of these were placed on the 8 foot contour, 50 feet apart. The other 4 were located at the same depth but at a distance of 200 feet from one another. To reduce the cost and to save labor the six constructions made in 1941 to test the effectiveness of such devices at different depths were used. Two additional shelters were built in 1942 in replica of the 6 already made. All of these were placed in North Fishtail Bay in the same locality where they had been used the summer before. Fish populations were determined as in the previous experiment, using the hoist and the large seine. The determinations were made for the two center shelters only in each group. To reduce the variables the two newly built shelters were placed at the ends. Fish of all species taken from the brush installations and from the control areas between the shelters were identified, counted and measured (Table II). A study of the data reveals little variation in the average size of the fish netted from either group of protection devices.

The capture of northern pike in shelters 50 feet apart arouses interest. The data presented are too scanty to warrant definite conclusions but suggest that this species may utilize close-set shelters.

TABLE II

NUMBER PER HAUL AND SIZE (TOTAL LENGTH IN CENTIMETERS) OF FISH TAKEN

FROM HOLLOW-CENTER BRUSH SHELTERS PLACED DIFFERENT DISTANCES APART IN

DOUGLAS LAKE, MICHIGAN

Species	Number per haul at given distances		Size range at given distances		Average size at given distances	
	200 feet (9 hauls)	50 feet (11 hauls)	200 feet	50 feet	200 feet	50 feet
Game fishes						
Northern pike	0.2	1.4	26.8-47.5	17.3-192.0	37.0	35.6
Yellow perch	113.6	50.8	4.8-14.5	5.5- 20.3	9.8	9.9
Smallmouth bass	2.1	0.4	2.8-40.5	13.5- 16.0	16.2	14.8
Largemouth bass	5.8	5.9	3.3-35.0	3.2- 35.3	5.9	5.8
Bluegill	0.3	0.6	7.0- 7.7	7.2- 8.6	7.5	8.4
Pumpkinseed	69.7	75.6	2.3-18.6	2.2- 17.3	6.4	5.3
Rock bass	40.8	21.3	2.1-19.8	2.7- 18.5	9.4	9.2
Coarse fishes						
Sucker	0.8	0.2	33.0-42.7	37.3- 39.0	38.8	38.5
Bullhead	2.4	0.9	10.2-15.5	6.5- 15.7	13.3	12.1
Forage fishes						
Spottail shiner	0.4	1.4	4.2- 4.5	2.1- 4.8	4.5	4.0
Sand shiner	...	0.4	...- ...	2.8- 3.7	...	3.5
Log perch	3.6	1.6	6.7-10.7	8.5- 10.4	9.6	9.5
Johnny darter	0.9	2.4	3.7- 5.5	3.3- 5.8	4.6	4.4
Iowa darter	0.3	0.5	4.0- 5.5	4.2- 5.6	4.8	5.2
Muddler	...	0.1	...- ...	3.0- 3.0	...	3.0
Total fish per haul	240.9	163.5				
Total fish taken	2,168	1,797				

Yellow perch averaged about 11 $\frac{1}{4}$  fish per haul from the brush constructions separated by 200 feet, and 51 per haul from those set 50 feet apart. None of the 1,022 fish taken in the shelters that were 200 feet apart were of legal size (six inches or more), and only 5 of the 559 fish caught in the more closely placed covers were six inches or more in length (it should be noted again that the perch of Douglas Lake are greatly stunted). Control areas yielded an average of 2.2 and 3.8 fish per haul between shelters separated 200 and 50 feet, respectively.

Rock bass also concentrated more heavily in brush constructions separated by the greater distance. Shelters 200 feet apart produced 367 or an average of 41 rock bass per haul. Eight of these were six inches or more in length (legal-sized fish). Only 23 $\frac{1}{4}$  or 21 fish per seine haul were netted from shelters located 50 feet apart. Nine of these were legal-sized fish. No rock bass were taken when seining the control areas.

Smallmouth bass, brown bullheads and log perch although taken in small numbers showed a similar tendency to collect in larger numbers in shelters separated by the greater distance. Smallmouth bass averaged 2.1 and 0.4 fish per haul from shelters separated by 200 and by 50 feet. Only 3 fish from the more widely separated shelters were of legal size (10 inches or over). Control hauls caught 0.3 fish per haul between the devices placed close together and 0.2 fish per haul between the shelters farther apart. The brown bullhead averaged 2.4 fish per haul from shelters placed 200 feet apart and 0.9 fish per haul from shelters separated by a distance of 50 feet. None were taken in the control areas. The log perch produced 3.6 and 1.6 fish per haul from the shelters separated by distances of 200 and 50 feet, respectively. In the respective controls 4 and 3 fish per seine haul were netted.

The largemouth bass were taken in approximately equal numbers (about 6 per haul) from each group of shelters. Almost all the fish were young, only one legal-sized fish (10 inches or over) being taken from shelters in each group. Control areas between the devices separated by a distance of 50 feet averaged 2 young largemouth bass per haul. None were taken in the other controls. Adams and Hankinson (1928: 481) observed that the largemouth bass showed a decided preference for areas with an abundance of vegetation and also that the young over an inch in length were solitary. Placing shelters close together may make not only the shelters but the areas between them a good habitat for the young of this species.

The pumpkinseed congregated in slightly larger numbers in shelters placed close together. The average seine haul netted about 76 pumpkinseed from installations placed 50 feet apart and 70 fish from those located 200 feet apart. Open waters between the artificial covers installed 50 feet apart yielded 7.5 fish per seine haul, or more than twice the number (3.6 per haul) taken between shelters sunk 200 feet apart. Almost all fish taken in the shelters and the controls were young, with a modal size of 3 to 4 cm. Probably other age groups at 6 to 7 cm. and 9 to 10 cm. are represented in the pumpkinseed populations. Only one legal-sized fish (6 inches or over) was netted from the shelters placed close together. Nine legal-sized fish were taken from the other shelters.

The spottail shiner and the Johnny darter, although poorly represented in the seine hauls, averaged more numerous in shelters placed close together. The few suckers taken in the shelters and the one taken in the wider open water were all adults. Other species, namely the bluegill, the sand shiner, the Iowa darter and the northern muddler were caught in such limited numbers in both the shelters and controls that interpretations are not attempted.



Shelters placed 200 feet apart yielded 240 fish of all species per seine haul. Those 50 feet apart averaged 163 fish per haul. The shelters spaced four times as far apart yielded 1.5 times as many fish per shelter. Control areas which were seined nine times produced 18 fish per haul between the shelters 50 feet apart and 13 fish per haul between those placed at the greater distance. More fish per unit length of shoreline were therefore sheltered when the constructions were placed closer together, though fewer fish were then concentrated about each installation.

#### Fish taken in and around brush shelters of different sizes

In order to determine the relative effectiveness of shelters of different size, six structures of the ladder-shaped type (Rubbs and Eschmeyer, 1938: 74-79) were built and installed in 1942. Three of these were constructed and trimmed to 16 x 12 x 3 feet, and three were made 8 x 6 x 3 feet. The smaller ones therefore had one-half the area and one-fourth the volume of the larger. Except for size all were as nearly identical as they could be made. The devices were made of available brush (cherry, ironwood, beech, oak and maple), closely packed. They were installed on the 8-foot contour along the south shore of Bryants Bay, in Douglas Lake. Here the clean and fairly hard-packed bottom is largely composed of sand, clay and some rocks, ranging in size from a baseball to that of a man's head. The area is devoid of aquatic vegetation. Conditions along the line of installation were rather uniform. The shelters, alternately large and small, were spaced 200 feet apart.

Again the hoist and net employed in former seining operations were used to catch fish populations in and around the shelters. Fourteen hauls were made from the larger shelters and 17 hauls from the smaller ones. The fish from all six shelters were identified, counted and measured (Table III). Areas between shelters were seined 5 times to furnish a

TABLE III  
NUMBER PER HAUL AND SIZE (TOTAL LENGTH IN CENTIMETERS)  
OF FISH TAKEN FROM LARGE AND SMALL LADDER-SHAPED BRUSH  
SHELTERS IN DOUGLAS LAKE, MICHIGAN

Species	Number per haul for different shelters		Size range for different shelters		Average size for different shelters	
	16 feet (14 hauls)	8 feet (17 hauls)	16 feet	8 feet	16 feet	8 feet
Game fishes						
Northern pike	0.1	...	16.2-16.7	...- ...	16.5	...
Yellow perch	24.4	27.2	7.5-16.0	6.0-15.5	10.6	9.8
Smallmouth bass	1.9	1.2	5.1-38.2	5.2-39.0	23.0	16.9
Largemouth bass	1.2	1.3	3.4- 6.1	3.5- 5.7	4.4	4.5
Bluegill	0.4	...	7.2- 8.3	...- ...	7.8	...
Pumpkinseed	28.9	18.6	2.6-20.6	2.0-20.1	8.5	8.5
Rock bass	48.1	20.3	2.4-26.6	2.7-27.8	11.1	11.1
Coarse fishes						
Sucker	1.5	0.6	35.9-41.0	34.6-40.7	38.8	38.8
Bullhead	0.2	0.1	3.3- 5.9	3.2- 3.2	4.5	3.2
Forage fishes						
Common shiner	...	0.1	...-...	4.7- 4.7	...	4.7
Spottail shiner	5.2	14.8	2.0- 5.0	2.0- 4.0	3.0	3.0 <sup>✓</sup>
Sand shiner	1.0	3.8	5.0- 7.0	5.2- 8.3	6.0	6.4
Log perch	2.3	1.6	5.5-10.5	9.2-10.0	9.5	9.9
Johnny darter	0.3	0.2	3.3- 4.5	2.5- 4.5	3.8	3.5
Muddler	0.1	...	2.7- 7.0	...- ...	5.0	...
Total fish per haul	115.6	89.8				
Total fish taken	1,618	1,527				

✓ Only a percentage of the spottail shiners were measured. The others were merely counted. The average size given for this species is based on actual measurements taken.

comparison of fish populations in and around shelters as contrasted with the open areas in this part of Douglas Lake.

Rock bass were taken in the ratio of 5 to 12 from the small and large shelters. More legal-sized fish were netted from the bigger constructions where  $4\frac{1}{4}$  fish, six inches or more in length, were caught. Twenty-nine legal fish were taken from the other shelters. However, in percentages of total rock bass taken at the different sized shelters, the greater percentage of legal fish came from the smaller shelters. These harbored 8.4 per cent legal fish, the larger only 6.5 per cent.

Pumpkinseed were also found in greater numbers in the larger shelters. Here they averaged 29 per seine haul. In the smaller shelters the average haul netted about 19 fish. Two dominant size classes are represented, respectively 5-6 and 9-10 cm. in total length; the smaller size was somewhat the more abundant in the smaller shelters, the larger size more common in the larger shelters. Only  $\frac{1}{4}$  of the  $40\frac{1}{4}$  or about 1.0 per cent of the pumpkinseeds taken from the 16-foot constructions were of legal size (6 inches or more), whereas seven or 2.2 per cent of the 317 fish taken from the 8 foot installations were of legal size.

The yellow perch was the most common fish from the 8-foot shelters where an average of 27 fish per haul was netted. The larger shelters produced  $2\frac{1}{4}$  per haul. The larger number of perch recorded for the small shelters is primarily due to one haul of 171. Most of this particular school of fish were 8 to 9 cm. in length. Another size group of 11 to 12 cm. was also found in the smaller shelters. Only one legal fish (6 inches or more) was taken from the shelters of both sizes.

Largemouth bass and smallmouth bass averaged between 2 fish per seine haul from either size of shelter. All largemouth bass netted were young fish between 3 and 7 centimeters in length. Of the 26 smallmouth bass caught around the 16 foot shelters, 10 or 38.5 per cent were legal-sized.

From the 8-foot shelters, 6 or 30 per cent of the 20 fish netted were over 10 inches in length.

Of the forage fishes, the spottail shiner was the most abundant. Almost 3 fish per seine haul were taken from the small shelters for every one taken in the larger ones. This difference in populations around these brush constructions is mostly due to one haul from the middle 8-foot shelter, from which 125, or about one-half of the total number of spottail shiners from the small shelters, were netted. The white suckers, although taken in small numbers, were all adults. The sand shiner, caught in limited numbers, was more common in the smaller shelters. The few log perch taken seemed to show a preference for the larger shelters.

Except for the smallmouth bass a comparison of the average sizes of all species taken in the small and large shelters shows little difference.

Five <sup>seine</sup> ~~seine~~ hauls made through the areas between the shelters netted two 16-cm. pumpkinseeds or 0.4 fish per haul, and 74 log perch or 18.5 fish per haul. The latter averaged 9.3 cm. in length. Two smallmouth bass, 13 and 45 cm. in total length, and one johnny darter of 3.5 cm. were also taken in the control seining.

#### Conclusions and suggestions for fish management

The conclusions stated here are based on five summers experiments in providing shelter for fishes in Douglas Lake, Michigan, supplemented by limited earlier work in other lakes by Dr. R. W. Eschmeyer (Rodeheffer, 1939: 188). No attempt has yet been made to determine whether such devices will increase the total productivity of fishes in a lake. Rather the aim has been to determine as far as possible the practicability of such constructions and the extent of their use by the various species of fish found in a lake. These conclusions are weakened by not knowing the relative

abundance of the various species in Douglas Lake. It may be stated that rock bass, yellow perch, pumpkinseed, smallmouth bass, largemouth bass and northern pike are present in sufficient numbers (although unquestionably in varying degree of abundance) to tempt fishermen to try for these species. Bluegills are not common in Douglas Lake. In general it may be stated that fish shelters located in barren parts of a lake attract primarily the young and half-grown fish of certain species (Rodeheffer, 1939). However, there is a change in such fish populations by night and by day (Rodeheffer, 1940). If fish are transported from the part of a lake where brush constructions are located, other fish will repopulate such areas (Rodeheffer, 1940).

More work needs to be done on the effectiveness of fertilizers in the increase of vegetation in and about shelters before definite conclusions regarding this suggested practice can be justified.

Shelters placed in deep water harbor more fish, particularly yellow perch, spottail shiners and log perch than those located in shallow water during the warm summer months, although the reverse is true for largemouth and smallmouth bass and rock bass. When shelters are located varying distances apart, those separated by the greater distances support larger populations of yellow perch and rock bass while pumpkinseeds are somewhat more abundant in and around shelters placed close together. Likewise a comparison of the fish populations in and around large and small brush installations reveals greater concentrations of fish in the larger shelters. This is notably true of rock bass and pumpkinseeds. Yellow perch occur in somewhat fewer numbers in the large shelters.

These studies on the effectiveness and utilization of brush shelters suggest certain conclusions regarding fish management. It is clear that given types of lake improvement will effect the several kinds of game fishes in different ways. With full realization that this work on brush shelters covers only one phase of the complex problems involved in the management

of lake fishes, I now discuss this work and suggest some of the possible applications under the headings of the species that are most commonly taken about brush shelters.

#### Rock bass

Young and half-grown rock bass were the most common fish consistently taken in and around the brush constructions placed on the 5 to 6 foot contour in Douglas Lake. However, when the fish taken from a shelter were transported to another part of a lake the number of rock bass taken in subsequent seining was always less than in the first seining. In like manner, the numbers taken at night were always fewer and their average size smaller than during the day (Rodeheffer, 1940). These fish also show the greatest tendency to live at or to return to the same refuge (Rodeheffer, 1941). Shelters placed at a greater depth or located closer together attract fewer rock bass. Small shelters harbor fewer rock bass than large ones.

It should not be difficult to increase the numbers of rock bass in a lake if this should be desired. Adams and Hankinson (1928, page 499) found them generally distributed in Oneida Lake and in shallow water, showing a preference for areas with abundant aquatic vegetation and stony bottom. Its preference for cover is well known to anglers and ichthyologists. It has been shown that this species seeks artificial cover in Douglas Lake. It is likely that the numbers of this fish may be increased in a given body of water by placing adequate brush shelters in the lake, granted of course that other conditions, such as spawning facilities, are adequate. If, on the other hand, rock bass are found to be overabundant and stunted, as they are in some northern Michigan lakes (Eschmeyer, 1936: 336) it may be desirable and possible to control their numbers by destroying their spawning beds, or by giving preferential treatment to other species, by placing

artificial shelters in deeper water and by building small shelters. On the other hand it may be practicable, particularly if other species which are to be encouraged use the same habitat, to build and place these shelters where they will attract the rock bass in great numbers, so that the excess may be taken out for other use by the method of seining employed in the experiments herein reported.

#### Yellow perch

Yellow perch were commonly found around all shelters but the increased concentration around shelters in deeper water shows that they have a decided preference at least during the summer months for constructions so placed. These fish were found to be more numerous at night both in shelters and on the open shoals in shallow water than during the day. If yellow perch were removed from a shelter and transported to another part of a lake others would move in until the original population was approximately duplicated. Marking of these fish shows that they seem to live in or come back to the locality where first taken during that season. Few were found there the following summer. Shelters located far apart harbored more yellow perch than those placed close together. It is questionable if the size of a brush construction is a factor controlling the number of yellow perch that use it as a habitat. If an increase of the yellow perch is desired brush constructions should very likely be placed in deep water. Brush shelters may be used by perch for spawning or if it is considered advisable a brush carpet may be installed for this purpose (Hubbs and Eschmeyer, 1938: 83). When these fish are abundant and stunted as they are in Douglas Lake, control may be aided by limiting the number or by locating shelters in shallow water. If northern pike are found in the lake, placing shelters close together at the depths of weed beds inhabited by pike may attract these predacious fish into the area where they may help to keep the perch under control. Seining of the fish around shelters in

fairly deep water and destroying the sizes of which there is an overabundance may be helpful. Localized poisoning of such fish in shelters might also be practicable, provided these devices did not harbor desirable species that should not be destroyed.

#### Northern pike

Northern pike although abundant in Douglas Lake were seldom found around brush constructions in either shallow or deep water when the shelters were separated by several hundred feet. Shelters placed close together (50 feet apart) harbored enough pike to permit one to conjecture that if the encouragement of pike is desired such devices should be placed fairly close together and so arranged as to cover a considerable area. It has been observed that the best catches of northern pike by fishermen are generally made close to large weed beds, which in a barren lake might be simulated by a concentrated arrangement of shelters.

#### Pumpkinseed

The pumpkinseed is another game fish found abundantly in Douglas Lake. This fish shows a decided preference for brush installations, although an unequal concentration is represented around shelters placed in different parts of the lake. In Douglas Lake, North Fishtail Bay with its somewhat quiet water and marl bottom harbored more young and half-grown pumpkinseeds around the shelters than did other parts of the lake where brush constructions were located. The depth at which a shelter is placed seems to make little difference to this species, but the fish did prefer those shelters placed closer together. Large constructions make a hiding place for more fish of this species than small installations. As with other species large numbers of the pumpkinseed desert the covers at night. If pumpkinseeds are taken from a shelter and transplanted to another part of a lake the original concentration will be approached by others coming in.



Provided spawning and other conditions are satisfactory, the pumpkinseed may be encouraged by supplying an abundance of cover, natural (weed beds) or artificial (brush constructions). If possible, a part of a lake, such as a bay simulating a pond with comparatively quiet water, should be chosen.

Control of numbers should be possible by limiting the cover available, placing artificial covers in parts of a lake not conducive to pumpkinseeds or by destroying the spawning beds.

#### Largemouth and smallmouth bass

Largemouth and smallmouth bass were taken in small numbers around shelters in the several different parts, each with distinctive environmental conditions, of Douglas Lake. At Grapevine Point on the lee side of prevailing winds, where the shoals are clean and sandy, the smallmouth predominated. In North Fishtail Bay, which is somewhat sheltered, with a bottom composed of sand covered with flaky marl, the largemouths were more common. In Bryants Bay, which is more exposed than either of the other two places mentioned, and where the bottom is composed of packed sand, clay and rocks, smallmouth and largemouth bass were taken in very limited numbers but a larger percentage of the smallmouths were legal fish (10 inches or more in length). When both species were captured from the shelters and transported to other parts of the lake other young fish were found to seek the shelters in numbers about equal to those transplanted. Both smallmouth and largemouth bass were seined from shelters and control areas by night and by day, but fewer were taken in either place at night than during the day. Largemouths, although taken in smaller numbers, revealed a greater preference for the shelters. A larger percentage of marked smallmouths were recaptured around the shelters, indicating a somewhat limited population in such areas.

Neither species displays any particular preference for large or small shelters. Their solitary nature may be the controlling element rather than the size of shelter. Smallmouth bass indicate some preference for shelters far apart. Largemouth bass inhabit shelters either far apart or close together in about equal numbers, but more of these fish seem to occupy the areas between shelters when they are placed close together. The young of both species were collected in larger numbers in brush installations placed in 5 feet of water than in those placed at a depth of 10 or 15 feet. Environments should be chosen that are well adapted for the species desired. Shelters should be placed in shallow water and numerous small ones will probably prove more effective than a few large ones, at least for the largemouth bass.

If it should be desirable to control the numbers of these fish, it is suggested that the amount of shelter be limited or that such constructions be placed in deeper water. The amount of spawning can of course also be controlled.

#### Forage fishes

Several species of forage fishes were taken about shelters in sufficient numbers ~~as~~ to warrant conclusions as to their use of such structures and to permit suggestions that may be of value in fisheries management work. The aim of the experimental work was to test the practicability of improving conditions for game fishes, rather than for forage species. It may be possible to construct special devices or to place them so that they will be particularly enticing to individual species of forage fishes.

With few exceptions the spottailed shiner was taken in limited numbers. This probably was due to the fact that most of the constructions were placed in fairly shallow water, on the 5 to 6 foot and 8 foot contours. This fish was found in much larger numbers around shelters placed in 15 feet of water than in shallow shelters. Small shelters located at a depth

of 8 feet harbored almost three times as many of these fish as did larger shelters similarly placed. From the limited evidence presented it is suggested that small shelters be placed in deep water (about 15 feet) and fairly close together (50 feet or less apart), if the aim should be to increase the production of this forage fish.

In Douglas Lake the log perch was found inhabiting shelters placed in 15 feet of water many times more abundantly than those in shallow water. It is questionable what role the log perch plays in the welfare of most of our game fishes.

Other species were represented in the shelters. Very few were taken, either because there were few of these fish in the lake or because these species preferred some habitat other than those existing where the shelters were installed.

#### Further investigations required

As experimental work with brush shelters progresses many additional problems present themselves. What kind of shelter is the most efficient, the circular, ladder, hollow-square, single-log, tree, clump, brush carpet, deadhead, stump, stone, tile or others that may be devised? Are some more desirable for certain species, or for the young or half grown or adults of such species? What kinds of brush shall be used in constructing brush shelters? Does the water which becomes tea-colored around shelters made of scrub oak and evergreens become objectionable or even toxic to fish? Should shelters be placed in certain areas fairly close together to simulate large weed beds or should they be placed at regular intervals along the shores of a lake? Are shelters anchored on a sharp drop-off more effective

than those placed on the shoal? Are artificial shelters superior or inferior to similar natural protection areas (weed beds)? Will artificial shelters aid in starting aquatic vegetation and if so what kinds of shelters are most satisfactory and where, in what part of a lake and on what kind of a bottom should they be placed to accomplish this? Will shelters increase the food supply of fishes and if so what kinds of brush shelters are most satisfactory for this purpose? What effect will local fertilizing of brush shelters have on such food production? How long will shelters last when properly submerged? Thus we may go on with questions that a practical fisheries manager will ask when he attempts to improve a lake with brush shelters.

At present large hollow-center brush shelters are under observation in exposed parts of Douglas Lake, some of which are supplied with black soil to see if aquatic vegetation will start and grow in such areas. Two unsuccessful attempts have been made to plant aquatic vegetation in these. It is hoped that continued observations and possibly additional plantings may be made. Spring planting of aquatic vegetation is suggested. The unsuccessful attempts were made in July and August.

A study of the food growing on or being harbored by shelters seems of vital importance. This should be investigated from the standpoint of determining the food available for all sizes of desired species from fry to adults. In this connection it may be feasible to develop shelters that will be particularly conducive to the increase of the forage fish populations. In experimental shelter work so far conducted little has been done to emphasize improvements for the forage fishes.

Studies of individual lakes with limited cover are in progress at present. It is hoped when present populations have been established that such lakes may be improved with artificial shelters to what may be considered ideal conditions. Population studies should then be continued to

determine the effect of the shelters on the production of fish.

Many brush shelters and spawning beds have been installed in Michigan lakes since the beginning of 1933. Plans are being made to carefully check some of these installations to determine their durability, the extent to which they have aided in establishment of aquatic vegetation, and to learn to what degree they are being utilized by fish. Far too little of such checking of results of fish management practices has been undertaken.

#### Summary

Experiments in Douglas Lake with brush shelters placed at 5, 10 and 15-foot depths indicate that:

1. Shelters placed at a depth of 15 feet harbor about 7 times as many fish as those placed on the 5-foot contour. The shelters at 10 feet offer cover for about twice as many fish as do those at the 5-foot depth.
2. Yellow perch are by far the most common fish in the shelters placed in the deeper water.
3. Pumpkinseeds inhabit shelters placed at the stated depths in about equal numbers.
4. Rock bass show a slight but gradual increase in the numbers inhabiting a shelter as the depth of water decreases.
5. Young largemouth and smallmouth bass show a preference for shelters placed in 5 feet of water.

The trials with shelters placed 50 and 200 feet apart reveal that:

1. Shelters placed 200 feet apart protect about 1.5 times as many fish per unit as do those placed 50 feet apart.
2. Yellow perch and rock bass are about twice as abundant in the shelters placed farther apart.
3. Smallmouth bass are more common in the shelters separated by 200 feet.

4. Largemouth bass are found in about equal numbers in either group of shelters but given areas between the closely set shelters produce more largemouths than similar areas between the shelters spaced farther apart.

5. Pumpkinseeds gather in somewhat greater numbers in shelters placed 50 feet apart.

6. Northern pike congregate in larger numbers in shelters placed close together.

Data gathered in the work with small and large brush shelters support the views that;

1. Large shelters harbor more fish than small shelters.
2. Rock bass and pumpkinseeds are found in greater numbers around the larger shelters.
3. Yellow perch are more common around the smaller shelters.
4. Largemouth and smallmouth bass are found in approximately equal numbers around the shelters of each size.

These findings support the views that if artificial covers are to be effectively used by certain desired species of fish the placement of such shelters must vary accordingly. Rock bass prefer large shelters spaced far apart and placed in comparatively shallow water of about 5 or 6 feet. Pumpkinseeds seek large shelters on the quiet, protected shoals, placed at any convenient depth and preferably set close together. Largemouth and smallmouth bass collect in the large or small shelters which are located close together and placed in shallow water of about the 5-foot depth. Yellow perch find small shelters placed in water about 15 feet deep most desirable, while the northern pike seem to seek the shelters which are placed close together. Possibly they should cover a considerable area simulating large weed beds.

*But not the same as  
the other shelters  
because they are  
not the same size  
and are not the same  
shape.*

Appendix

List of scientific and common names of fishes  
mentioned in this report

<u>Catostomus e. commersonii</u> (Le Sueur)	Common white sucker
<u>Notropis cornutus frontalis</u> (Agassiz)	Northern common shiner
<u>Notropis hudsonius hudsonius</u> (Clinton)	Great Lakes spottail shiner
<u>Notropis deliciosus stramineus</u> (Cope)	Northeastern sand shiner
<u>Ameiurus nebulosus nebulosus</u> (Le Sueur)	Northern brown bullhead
<u>Esox lucius</u> (Linnaeus)	Northern pike
<u>Perca flavescens</u> (Mitchill)	Yellow perch
<u>Percina caprodes semifasciata</u> (De Kay)	Northern log perch
<u>Boleosoma nigrum nigrum</u> (Rafinesque)	Central johnny darter
<u>Poeciliichthys exilis</u> (Girard)	Iowa darter
<u>Micropterus dolomieu dolomieu</u> Lacepede	Northern smallmouth bass
<u>Huro salmoides</u> (Lacepede)	Largemouth bass
<u>Lepomis macrochirus macrochirus</u> Rafinesque	Common bluegill
<u>Lepomis gibbosus</u> (Linnaeus)	Pumpkinseed
<u>Ambloplites rupestris rupestris</u> (Rafinesque)	Northern rock bass
<u>Cottus bairdii bairdii</u> Girard	Northern maddler

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