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Examples of the use of two-way fish weirs in Michigan[1]

[1] Contribution from the Michigan Institute for Fisheries Research

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Abstract

Description and reasons for the installation and operation of the most important types of two-way fish weirs used in Michigan are presented, with a summary of the results obtained and the conclusions reached as a result of the operations.

Five weirs are in operation at the present time at the Hunt Creek Fisheries Experiment Station. Four of the weirs (one of a self-cleaning rotary type) installed near the mouths of tributaries are used to determine the movements of native and planted fish between the tributaries and the main stream, and the fifth weir was installed at the outlet of East Fish Lake to block the re-entry of undesirable species into the lake. During 1943, a total of 1,161 brook trout (fingerlings and fish approaching legal size) moving downstream and 292 moving upstream were captured in these weirs. The contribution by tributaries to the main stream is evident.

The Muskegon River weir was installed just below Houghton Lake for the purpose of determining the extent of the migration of fishes to and from Houghton Lake and the role of Houghton Lake in contributing to the

fish stock of the impoundment formed by the Reedsburg Dam (about 11 miles below Houghton Lake). There is some migration of fish between Houghton Lake and the Muskegon River in the spring and early summer; this movement appears to be associated with spawning. Common suckers and redhorse made up 92.5 per cent of the total upstream and downstream migrants in 1939 and 1940, while only 3.0 per cent was composed of the important game species, northern pike and yellow pikeperch.

A weir was installed in the Ontonagon River below Lake Gogebic to determine the nature and extent of the movement of yellow pikeperch and other fish to and from the lake. Except for suckers, there was no significant loss of fish from Lake Gogebic by migration down the outlet. During the period of operation of the weir, more game fish migrated into the lake than were counted leaving the lake.

Occasionally during low water and following strong on-shore winds, temporary sand bars may develop across the mouth of the Platte River where it enters Lake Michigan. A weir was installed on the Platte River to determine the extent of fish migration and to what extent this migration was blocked by sand bars. During the 20 months that the weir was in operation, fish were able to enter the river at all times. Unless future observations indicate a change of conditions, no improvements need be made in the channel of the river mouth.

Introduction

One of the tools at the disposal of the biologist is the two-way fish weir. Foerster (1929), Taft (1934), Shetter (1938), Rayner (1942), Raney and Webster (1942), Carbine (1942 and 1943), and others, have recognized the usefulness of the structure in fishery research. Since 1936, more than a dozen different weirs have been used in Michigan to provide information on many controversial questions of fishery management. The value of

these structures in studying diverse fishery problems can be illustrated best by some examples of the information that may be obtained on such problems as: (1) the role of tributary streams in contributing to the fish supply of lakes and streams; (2) the sex ratio, size range and number of fish in the spawning runs of several species; (3) the efficiency of natural reproduction as estimated by trapping all spawning adults and resulting young; (4) migratory tendencies of hatchery-reared fish as compared with native fish; (5) growth and survival of marked fish; (6) effects of temperature, water level and other physical factors upon the spawning run; (7) the abundance of certain undesired species of fish (the destruction of undesired species taken by means of weirs also provides a method of partial control).

The purpose of this paper is to give the reasons for the operation of weirs at the Hunt Creek Fisheries Experiment Station, at the outlet of Gogebic Lake, on the Muskegon River below Houghton Lake, and on the Platte River, to summarize the results obtained, and to present the conclusions reached as a result of the operations. A brief description of the type of weir used at each site is also given.

Hunt Creek weirs

Five weirs are in operation at the present time at the Hunt Creek Fisheries Experiment Station of the Institute for Fisheries Research. One weir, located at the outlet of East Fish Lake, was installed primarily to block the re-entry of undesirable species into the lake after its population was eliminated by poison and brook trout were planted. Data on migration are also available from its operation. The other four weirs (one of a self-cleaning rotary type) installed near the mouths of tributaries are being used to determine the movements of native and planted fish between the tributaries and the main stream.

Description of weirs. The weirs on the tributaries of Hunt Creek are of two types; a modified V-shaped structure, constructed from lumber and wire screen built on single sheet-piling to prevent undercutting (Fig. 1); and a self-cleaning rotary type built of concrete over Wakefield piling (Fig. 2). Where the volume of water is relatively small and uniform, the first-mentioned type operates efficiently with a minimum of care. Where the flow is large and is likely to fluctuate, a self-cleaning rotary screen is very desirable, since it will eliminate much of the labor necessary to keep the screens cleaned in periods of high water. One of the stationary weirs can be installed for between 40 and 70 dollars, while cost of a rotary, self-cleaning weir such as installed in Fuller Creek (Fig. 2), is approximately 1,000 dollars. The initial high cost of the rotary weir will be offset by the saving in labor after installation since this type of weir will not require the constant cleaning demanded by a stationary structure in a similar location.

Results. During 1943, a total of 1,161 brook trout moving downstream and 292 moving upstream were captured in these weirs. The majority of these fish were fingerlings or fish approaching legal size. All were native trout. The contribution by the tributaries to the main stream is evident. Details of this investigation which is still in progress will appear in a subsequent paper.

The Muskegon River weir

Houghton Lake, located in Roscommon County, has always had a reputation as one of the best northern pike lakes in Michigan. The decline in the abundance of northern pike in 1931 and again in 1935, as demonstrated by creel censuses taken by Conservation Officer Thomas White since 1928, resulted in numerous complaints by fishermen and resort owners who believed that adult northern pike left Houghton Lake to spawn in the Muskegon River

Figure 1.--The East Fish Lake weir (looking downstream). The weir is located in the outlet about 50 feet below the lake. Fish moving downstream are taken in either of the two traps at the side, and fish moving upstream are caught in the trap at the apex of the V. The purpose of the weir is to prevent re-entry into the lake of all fish other than trout (which are passed over the weir), and to determine the number of trout that leave the lake.

Figure 2.--The Fuller Creek weir. The revolving drum (made of quarter-inch-mesh wire screen) can be seen between the trash rack and the water wheel which operates it. A reverse gear causes the drum to turn with the current. It is self-cleaning, except for the larger pieces of debris which are caught on the trash rack and must be removed by hand. The cover of the downstream trap is open.

and that neither the adults nor the resulting young returned to the lake. For several years the Houghton Lake Chamber of Commerce prevented fish from leaving Houghton Lake by placing blocking bars across the Houghton Lake dam. Considerable pressure was brought to bear upon the Department of Conservation to make a survey of conditions and to take steps to prevent the alleged movement of fish from the lake.

At about this same time another problem arose. The Game Division of the Michigan Department of Conservation proposed to construct a dam on the Muskegon River approximately 11 miles below Houghton Lake which would flood several thousand acres of river bottom and marsh and back the water up to within a short distance of the Houghton Lake dam. This impoundment, which was subsequently created late in 1940 and is known as the Reedsburg Dam, is used for the improvement of the habitat of water-fowl, fur-bearing animals and fish. In the winter of 1938-1939, it was suggested by Mr. F. A. Westerman, Chief of the Fish Division, that the Institute for Fisheries Research should install a two-way fish weir on the Muskegon River below Houghton Lake for the purpose of determining: (1) the extent of the migration of fishes to and from Houghton Lake; (2) the role of Houghton Lake in contributing to the fish supply of the new impoundment formed by the proposed Reedsburg Dam; and (3) the probable effect of a dam on the fish movements, and the fish population of Houghton Lake, the new impoundment and the Muskegon River.

A two-way fish weir was installed and was operated in the Muskegon River, approximately one eighth of a mile below the Houghton Lake dam, from April 7 until June 19, 1939, and from March 31 until July 11, 1940. At the site selected for the weir, the river was 120 feet wide, with a maximum depth of 3 feet. The bottom was composed of clay covered by from 6 inches to 2 feet of sand.

Description of weir. In 1939, the weir consisted of a single wing extending across the river at an angle of about 25 degrees with the current. The traps were connected to the ends of this main arm. Numerous changes were made throughout 1939 in order to increase the efficiency of the structure. These changes resulted finally in a double-V weir with the traps located near the center of the main wing, at the apex of each V. We were not too well satisfied with the design of the 1939 weir. Consequently, in 1940 a much improved double-V weir was designed and installed. The weir consisted of a 12- by 5-foot trap, located approximately in the center of the river, with the long axis parallel to the river banks (Fig. 3). A partition of blocking bars divided the trap into equal parts, each 6- by 5-feet. The trap on the upstream side of the weir captured all fish moving downstream, and the other trap captured all fish moving upstream. Four wings or blocking arms, each approximately 85 feet long, and set at an angle of about 25 degrees with the current, connected the corners of the trap with the shore. This arrangement resulted in a double-V weir, with the trap forming the apex of each V (Fig. 3). The blocking bars which were installed in a lumber frame consisted of 1- by 2-inch wooden slats, pointed at one end and driven into the bottom. The weir was constructed in such a manner that slats could be removed or driven farther into the bottom at any time. The distance between the blocking bars was 1 1/2 inches. This spacing allowed all but the mature individuals of the larger species free movement, either upstream or downstream. A 4- by 4-foot removable gate which rested on sheet piling projecting about one foot above the bottom, formed the entrance to each trap. Each gate was built so that it could be lifted out of the trap (by sliding upward) to facilitate cleaning of the weir. The cone-shaped funnel, made of 1/2-inch-mesh wire screen, was attached to the bottom half

Figure 3.--View of the Muskegon River weir, looking downstream. The traps are located in the center of the weir, at the apex of each V.

of the gate. The apex of the funnel projected into the trap. The funnel was 24 inches long, with a diameter of 6 inches at the small end. The large end was 36- by 24-inches. The upper half of the gate was made of 1- by 2-inch slats, spaced 1 1/2 inches apart. The total cost of materials for the completed 1939 weir was $89.84, and for the 1940 weir, $126.06. No estimate is available of labor and transportation costs (furnished in part by the C.C.C. Camp Houghton Lake, of the Houghton Lake State Forest).

Results. During 1939 and 1940, 15 species of fish were taken in the Muskegon River weir (Table 1). Common suckers made up the bulk of the run followed by redhorse, bowfin, northern pike, and yellow pikeperch in that order of abundance. These five species made up 99.4 per cent of the total downstream run of fish and 99.6 per cent of the total upstream run for the 2-year period. Very few other fish were taken in the weir although over 60 species are listed from Houghton Lake and the Muskegon River. The small number of species taken was partially due to the wide spacing of the blocking bars of the weir which allowed the smaller varieties such as perch, bluegills, minnows, etc., to pass through the weir.

In 1939 and 1940, all northern pike, yellow pikeperch, and channel catfish were "jaw-tagged." Other fish taken in the traps in 1940 were marked by clipping fins. Different fins were clipped on upstream and downstream migrants to permit future identification of all fish which passed through the weir. After marking, each fish was released in the direction in which it had been moving when captured.

Because of faulty construction, no fish were taken in 1939 in the weir during the first 13 days after completion, although the downstream migration (which begins earlier than the upstream movement) started shortly after the weir was completed. For example, observations disclosed that if one sucker found an opening in the trap and escaped, the remaining

Table 1.--Total catch and the size range of each species taken in the Muskegon River weir between April 7 and June 19, 1939, and between March 31 and July 11, 1940, all dates inclusive

Common name	Scientific name	Number of fish captured					Total length (inches)		
		1939		1940		Total			
		Downstream trap	Upstream trap	Downstream trap	Upstream trap	1939-1940	Minimum	Average	Maximum
Common sucker	Catostomus c. commersonnii	902	435	4,393	856	6,586	11.0	18.5	25.0
Northern redhorse	Moxostoma aureolum	117	28	906	373	1,424	9.8	18.6	22.3
Dogfish or bowfin	Amia calva	150	10	113	66	339	21.5	25.2	30.5
Northern pike	Esox lucius	13	16	140	48	217	17.2	21.8	40.2
Yellow pikeperch	Stizostedion v. vitreum	16	...	23	6	45	10.9	17.7	23.2
Bullheads	Ameiurus sp.	8	...	8	2	18	...	...	...
Channel catfish	Ictalurus l. lacustris	...	1	10	...	11	...	...	...
Rock bass	Ambloplites r. rupestris	3	...	5	3	11	37.6	38.5	39.7
Bluegill	Lepomis m. macrochirus	1	...	1	...	2	...	...	...
Largemouth black bass	Huro salmoides	...	...	1	...	1	...	...	...
Black crappie	Pomoxis nigro-maculatus	...	...	1	...	1	...	...	...
Longnose gar	Lepisosteus osseus oxyurus	...	...	1	...	1	...	...	...
Yellow perch	Perca flavescens	...	...	...	1	1	...	...	...
Spotted sucker	Minytrema melanops	1	...	...	...	1	...	...	...
Total		1,211	490	5,602	1,355	8,658	...	...	...

suckers followed it. Eight different types of trap entrances were installed before we were able to hold substantially all of the fish that entered the traps. The funnel entrance finally devised was most satisfactory (the construction of this entrance was described earlier). No doubt many fish that would normally have moved downstream in 1939 were not recorded because of the faulty entrances to the traps.

Another fault of the Muskegon River weir was that it was not always "fish-tight." During periods of high water, holes developed due to undercutting. The weir was checked daily and all blocking bars in the weir were driven farther into the bottom when undercutting was noted. Maintenance of a "fish-tight" weir in a flowing stream having a sand bottom is extremely difficult unless sheet piling is used. Several northern pike that were tagged going downstream were captured in Houghton Lake by anglers in 1940 before the weir had been removed. These fish, and undoubtedly other marked and unmarked fish, passed through holes in the weir and were therefore not recorded.

Data on the upstream and downstream migration of fish in the Muskegon River are not complete because the weirs were not in operation throughout the entire year. Fish were still moving upstream when the weirs were removed in 1939 and 1940, and it is possible that more of the fish would have been recorded as returning to Houghton Lake if the weirs had been in operation for a longer period. In 1939 and in 1940, several northern pike that were tagged going downstream and not retaken going upstream, were recovered in Houghton Lake by anglers after the weirs had been removed. If the weirs had been left in longer each year, there might have been a better balance between the number of upstream and the downstream migrants.

The main reason for removing the weirs when we did was the shortage of help and the pressure of other duties. The early removal was also prompted because so few game fish were captured in the weir.

The effect on the total catch of fish in the Muskegon River weir of the three factors discussed above, namely, (1) the faulty construction of the weir in 1939, (2) the fact that the weir was not always "fish-tight" in 1939 and in 1940, and (3) that the weirs were not in operation through the entire year, should be kept in mind when considering the data that follow.

The first fish were captured in the downstream trap of the weir in 1939, on April 19, 13 days after the weir had been in operation. The first fish were captured in the upstream trap on April 28. In 1940, the first fish were taken in the downstream trap on April 2, the third day that the weir had been in operation, and the first fish were taken in the upstream trap on April 17. The heaviest run of downstream migrants (all species combined) occurred between April 19 and May 30, 1939, and between April 6 and June 7, 1940 (Table 2). The greatest run of upstream migrants took place between April 29 and May 27 in 1939, and between April 23 and June 7 in 1940.

In 1939, a total of 1,701 fish were taken in the traps of the weir--1,211 (80.5 per cent) in the downstream trap and 490 (19.5 per cent) in the upstream trap. Of the 6,957 fish captured in 1940, 5,602 (71.2 per cent) were moving downstream and 1,355 (28.8 per cent) were moving upstream. A total of 5,575 of the 5,602 fish that were taken in the downstream trap in 1940 were marked either by tagging or by fin-clipping, and 465 (8.3 per cent) of these individuals returned through the upstream trap (Table 3). Of the 1,348 fish that were marked in the upstream trap, 355 (26.3 per cent) returned downstream again. In other words, 355 of the 5,602 fish

Table 2.--The weekly catch of the most important species of fish taken in the Muskegon River Weir in 1939 and 1940

Time period[1]	Common sucker				Northern redhorse				Dogfish				Northern pike				Yellow pikeperch				Other species				Total (all species)			
	Downstream trap		Upstream trap		Downstream trap		Upstream trap		Downstream trap		Upstream trap		Downstream trap		Upstream trap		Downstream trap		Upstream trap		Downstream trap		Upstream trap		Downstream trap		Upstream trap	
	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940
April 1-6	...	40	...	...	...	1	...	...	...	...	...	...	...	16	...	...	...	...	...	...	...	...	...	...	...	51	...	...
April 7-13	...	416	...	...	...	...	...	...	...	...	...	...	...	52	...	...	...	6	...	...	...	...	...	...	...	474	...	...
April 14-20	134	530	...	1	...	1	...	...	...	...	...	...	4	33	...	2	5	8	...	...	...	...	...	...	143	572	...	3
April 21-27	345	821	...	39	4	9	...	...	28	14	...	...	5	17	...	6	6	3	...	1	1	1	...	...	389	865	...	46
April 28-May 4	220	1,619	115	137	11	24	...	1	60	34	...	2	3	9	14	13	1	1	...	...	...	4	...	1	295	1,691	129	154
May 5-11	164	680	213	268	37	40	1	5	38	22	...	15	1	11	1	4	1	1	...	...	3	2	...	...	244	756	215	292
May 12-18	27	75	6	235	26	211	...	95	13	24	...	3	...	4	...	13	3	1	...	1	2	1	...	...	71	316	6	347
May 19-25	6	14	79	43	13	257	10	84	3	9	1	...	...	4	1	5	...	...	...	...	1	1	...	1	23	285	91	133
May 26-June 1	4	12	13	44	25	152	12	41	5	2	3	4	...	...	...	1	...	1	...	...	...	2	...	1	34	169	28	91
June 2-8	2	168	5	30	1	200	5	79	3	5	5	7	...	...	...	1	...	...	...	1	3	1	1	...	9	374	16	118
June 9-15	...	2	3	9	...	8	...	27	...	...	1	20	...	...	...	...	...	...	...	...	3	9	...	...	3	19	4	56
June 16-22	...	4	1	35	...	3	...	22	...	1	...	6	...	...	...	3	...	...	...	1	...	5	...	2	...	13	1	69
June 23-29	...	10	...	15	...	...	...	14	...	1	...	1	...	...	...	...	...	2	...	...	...	1	...	1	...	14	...	31
June 30-July 6	...	2	...	...	...	...	...	5	...	1	...	8	...	...	...	...	...	...	...	2	...	...	...	...	...	3	...	15
Total	902	4,393	435	856	117	906	28	373	150	113	10	66	13	140	16	48	16	23	0	6	13	27	1	6	1,211	5,602	490	1,355

[1] In 1939 the weir was in operation from April 7 to June 19; the first fish were taken in the weir on April 19.
In 1940 the weir was operated from March 31 to July 11.

Table 3.--The number and percentage of marked fish that were recovered in the Muskegon River weir in 1940

Species	Total number of fish marked (downstream trap)	Return of marked fish upstream	Percentage of returns	Total number of fish marked (upstream trap)	Return of marked fish downstream	Percentage of returns
Common sucker	4,393	278	6.3	856	300	35.0
Northern redhorse	906	107	11.8	373	51	13.7
Northern pike	140	33	23.6	48	2	4.2
Dogfish	113	43	38.1	66	2	3.0
Yellow pikeperch	23	4	17.4	6	0	0.0
Totals	5,575	465	8.3	1,349	355	26.3

that were captured in the downstream trap were marked fish, and 465 of the 1,355 fish taken in the upstream trap were marked fish. Actually then, only 465 of the 5,247 fish that left Houghton Lake returned during the period of operation of the weir. These figures show a net loss to the lake of 91.1 per cent of all of the fish that left Houghton Lake. A part of this loss was made up by the 890 upstream migrants (fish that were not returning from a downstream movement) that did not return down the river again. Therefore, the total loss of fish to the lake amounted to 74.6 per cent, or 3,892 fish.

Because the bulk of the run was composed of suckers and redhorse, the loss to the lake of game fish was not large. Only 37 of the 163 northern pike and yellow pikeperch (numbers of the two species combined) that left Houghton Lake returned through the weir again. This net loss to Houghton Lake of 126 fish was reduced by the 52 of the 54 upstream migrants that did not return downstream again. The net loss to Houghton Lake of these two species was therefore 74 fish, or 44.7 per cent of the original 163 fish.

Doubtless some of all of the species taken in the weir were normal residents of the river. The first upstream migrants of all species in 1940 were presumed to be inhabitants of the river since they were unmarked fish. Whereas the downstream migration was mainly a spawning run, the upstream run was composed mainly of spent fish. It is possible that many of the downstream migrants found suitable habitats and remained in the river. Conditions for fish were favorable in the river. Food for all species was plentiful. Shelter was adequate for young and adults of all species. All species were observed to spawn in the river, with the possible exception of the yellow pikeperch.

It is known that many fish, especially suckers and redhorse, die after spawning. In 1939, and 1940, a number of dead fish were found above the weir, and others floated down to and lodged against the weir (Table 4).

Table 4.--Number of fish found dead above or lodged against the Muskegon River weir in 1939 and 1940

Species	Number of fish		Total
	1939	1940	
Northern redhorse	289	77	366
Common sucker	7	65	72
Bullhead	19	11	30
Pumpkinseed sunfish	2	9	11
Yellow pikeperch	5	2	7
Bluegill	...	6	6
Smallmouth black bass	2	4	6
Rock bass	2	2	4
Northern pike	...	3	3
Dogfish	...	2	2
Black crappie	...	1	1
Rainbow trout	...	1	1
Total	326	183	509

Redhorse and suckers were observed to spawn above the weir, and many of these species were found dead against the weir immediately after spawning activity was noted. The number of fish that died below the weir is not known, but there was undoubtedly some mortality due to spawning and other factors. This mortality may account in part for the relatively few recaptures of all species and especially of the suckers and redhorse.

Anglers were exceedingly active in the Muskegon River in the late spring and early summer of both 1939 and 1940. Many northern pike, suckers, redhorse and yellow pikeperch which normally would have returned to Houghton Lake were taken by fishermen.

Some of the migrants traveled downstream a considerable distance. For example, fin-clipped suckers were found spawning in Townline Creek, a tributary of the Muskegon River, 45 miles below the weir, and three tagged yellow pikeperch were recovered by anglers in the impoundment formed by the Big Rapids Dam, a distance of 132 miles below the weir.

Conclusions. There is some migration of fish to and from Houghton Lake and the Muskegon River in the spring and early summer. The movement appears to be associated with spawning. Common suckers and the redhorse together made up 92.5 per cent of the total number of upstream and downstream migrants in 1939 and 1940, while bowfin made up 3.9 per cent, northern pike 2.5 per cent, yellow pikeperch 0.5 per cent and all other species 0.6 per cent. Suckers and redhorse are seldom captured in Houghton Lake by anglers and in the river only when spearing is permitted in the spring. Dogfish are seldom used as food and considerable agitation for the removal of this species is usually manifest by sportsmens groups. Despite the fact that more northern pike and yellow pikeperch were taken in the weir in 1940 than in 1939, the numbers are insignificant. More northern pike ran up Peterson's ditch in 1939 and 1940 (Carbine, 1942)

than ran down the Muskegon River. Peterson's is only one of perhaps a dozen spawning areas for northern pike at Houghton Lake. The northern pike run in the Muskegon River is therefore only a small percentage of the total run from the lake. The Muskegon River produces good northern pike fishing. From the small number taken in the weir we might assume that few yellow pikeperch leave Houghton Lake to spawn in the river. The yellow pikeperch population in this part of the Muskegon River was probably small as indicated by the small catch of this species made by anglers.

There are sufficient numbers of northern pike, rock bass, perch, and other species in the Muskegon River to form an adequate breeding stock for the impoundment formed by the Reedsburg Dam. From present indications, northern pike should do well in this impoundment because the habitat is ideal for this species. The weir records indicate that Houghton Lake will not contribute much to the new impoundment in the way of fish except suckers and redhorse. Before the construction of the Reedsburg Dam, at least 24.2 per cent of the 153 northern pike that left Houghton Lake to spawn in the river in 1939 and 1940 returned again to Houghton Lake. Of course, each year some fish undoubtedly find conditions to their liking in the river and never return to the lake. Also, there might now be an upstream spawning run of northern pike from the new impoundment that might enter Houghton Lake and remain there. The only way to determine whether such a movement of northern pike into the lake is occurring would be to reinstall the weir in the river between Houghton Lake and the impoundment.

Whether or not the Reedsburg Dam would block the migration of fishes in the Muskegon River presents a problem that is of great concern to the Houghton Lake Chamber of Commerce. The dam was provided with a fish ladder, but its effectiveness is questionable. From the operation of the weir, and the results of tagging experiments, we know that a considerable number

of suckers and a few northern pike and yellow pikeperch travel downstream, some farther than the dam. The return of part of the downstream migrants to Houghton Lake may be prevented by the Reedsburg Dam. We are of the opinion that even though the fish ladder is not too successful, little difference in the fish populations of Houghton Lake and the new impoundment will result whether or not the fish are able to get over the dam.

The Lake Gogebic weir

Prompted by a succession of poor fishing seasons, especially from 1936 to 1939, interested groups began to search for a solution to the problem of improving fishing in Gogebic Lake (Gogebic and Ontonagon Counties), the largest inland lake (14,780 acres) in Michigan's Upper Peninsula. Sportsmen and resort operators contended that large numbers of yellow pikeperch and other fish escaped each year down the Ontonagon River outlet and did not return to the lake. The basis for this belief was that fishing in the spring was good in the channel between Gogebic Lake and the outlet dam and in the river below the dam. Sentiment for the prevention of the supposed migration increased until several petitions had been circulated and the County Board of Supervisors formally requested the Department of Conservation to install an electric fence across the lake outlet. Instead of complying with this request the Department directed its Institute to determine the nature and extent of fish movement at this point.

A weir was installed in the Ontonagon River about one-half mile below the lake proper but just above the Bergland Dam of the Copper District Power Company. At this point the depth of the river ranges from 6 to 9 feet and the width from 130 to 145 feet, according to the water level. The weir was in operation from April 10, 1940 until September 14, 1941.

Description of weir. The weir crossed the Ontonagon River at right angles to the banks. This method of construction was not the most desirable or the most efficient, but was the only one that could be used in the location available. The details of construction were similar to those described by Shetter (1938) for the Canada Creek weir. Bars of 5/8-inch reinforcing iron placed in a frame at 2-inch intervals left openings of 1 3/8 inches. The total cost of the weir including materials, labor (furnished in part by the C.C.C. Camp Gogebic of the Ottawa National Forest) and transportation expenses was $676.05. The reinforcing iron which alone cost $352.50 was recovered and used in construction work when the weir was dismantled.

Results. The traps were checked at least twice a day during the principal run of fish and at least three times a week during the remainder of the period of operation. There were two periods when the structure was not effective due to breaks caused by high water and debris.

Only eight species of fish were taken in the Gogebic weir (Table 5). All yellow pikeperch and northern pike were "jaw-tagged," and the other species were marked by clipping fins. Different fins were clipped on upstream and downstream migrants to permit future identification of all fish which passed through the weir.

There is some upstream and downstream movement of fish in the outlet of Gogebic Lake during the period when the lake is not covered by ice (Table 6). The major movement occurs from mid-April to the end of June, which period covers the spawning season of most of the species taken. Suckers, yellow pikeperch, northern pike, and rock bass, in that order, were the species observed most frequently in the river at that time.

Except for the suckers, there was no significant loss of fish from Lake Gogebic by migration down the outlet. More game fish were counted

Table 5.--Total catch and the size range of each species taken in the Lake Gogebic weir between April 10, 1940 and September 14, 1941, both dates inclusive. For scientific names, refer to Tables 1 and 6

Common name	Number of fish captured			Total length (inches)		
	Downstream trap	Upstream trap	Total	Minimum	Average	Maximum
Common sucker	420	169	589	...	...	...
Yellow pikeperch	56	53	109	12.4	17.0	27.7
Rock bass	13	59	72	6.4	8.9	11.4
Northern pike	14	14	28	15.6	18.0	29.7
Black crappie	7	2	9	11.9	13.5	14.1
Yellow perch	2	6	8	8.2	10.5	12.0
Smallmouth black bass	4	2	6	14.0	16.6	20.2
Largemouth black bass	1	0	1	...	...	...
Total	517	305	822	...	...	...

Table 6.--Weekly catch of the most important species of fish taken in the Lake Gogebic weir, 1940 and 1941

Time period	Common sucker		Yellow pikeperch		Rock bass		Northern pike	
	Upstream trap	Downstream trap	Upstream trap	Downstream trap	Upstream trap	Downstream trap	Upstream trap	Downstream trap
1940								
April 14-20	...	...	...	...	...	...	...	1
April 21-27	34	100	11	8	...	...	3	6
April 28-May 4	43	304	2	9	1	...	1	...
May 5-11	10	1	...	28	...	1	...	...
May 12-18	32	6	2	2	...	1	...	...
May 19-25	2	1	...	5	...	1	...	...
May 26-June 1	...	1	...	...	...	...	...	...
June 2-8	9	1	1	...	...	3	...	1
June 9-15	13	1	2	2	9	2	...	...
June 16-22	2	...	...	1	11	3	...	...
June 23-29	...	...	...	...	7	2	...	...
June 30-July 6	2	...	...	...	10	...	...	...
July 7-13	1	...	5	...	6	...	1	...
July 14-20	5	...	2	...	3	...	3	...
July 21-27	1	...	3	...	3	...	1	...
July 28-Aug. 3	4	...	1	...	...	...	...	...
Aug. 4-10	...	...	1	...	2	...	...	...
Aug. 18-24	5	1	1	...	1	...	...	...
Aug. 25-31	...	1	3	...	1	...	...	...
Sept. 1-7	...	...	8	...	1	...	...	...
Sept. 8-14	...	...	2	...	...	...	...	1
Oct. 6-12	...	...	1	...	...	...	...	...
Oct. 20-26	...	...	...	1	...	...	...	...
Oct. 27-Nov. 2	...	...	...	...	...	...	...	1
Nov. 10-16	...	...	...	...	...	...	1	1
1941								
April 6-12	...	...	...	...	...	...	...	1
April 13-19	1	...	1	...	...	...	...	1
April 29-26	...	...	...	...	...	...	...	1
April 27-May 3	1	1	...	...	...	...	...	...
May 4-10	...	2	...	...	...	...	...	...
May 11-17	2	...	...	...	1	...	...	...
May 18-24	1	...	1	...	1	...	...	...
May 25-31	...	...	1	...	1	...	...	...
June 15-21	...	...	...	...	...	...	1	...
June 22-28	...	...	...	...	...	...	2	...
June 29-July 5	...	...	...	...	...	...	1	...
July 6-12	1	...	...	...	1	...	...	...
July 20-26	...	...	5	...	...	...	...	...
Total	169	420	53	56	59	13	14	14

going upstream than were counted going downstream during the period of operation of the weir.

Conclusions. From the data obtained from the operation of the weir, it was determined that the erection of a fish screen for the prevention of fish movement out of Lake Gogebic would not benefit the fishery in that water.

The Platte River weir

Occasionally during low water and following strong on-shore winds, temporary sand bars may develop across the mouth of the Platte River (Benzie County), where it enters Lake Michigan. It was believed by sportsmen that because of these bars, fish were not able to ascend the river. The Platte River is famous for its trout fishing, particularly for the big rainbow trout (steelheads) that enter the stream from Lake Michigan. Previous to the summer of 1941, many interested people agitated for stream-improvement devices, or for dredging or breakwater construction to remedy the situation created by these temporary sand bars. Since it was known that these types of improvement suggested were quite expensive, the Department of Conservation decided that it was first necessary to determine the nature and extent of the fish migration at this point and to what degree this migration was blocked by sand bars.

The site chosen for the weir was approximately 1 1/2 miles upstream from Lake Michigan. It had the advantage of being state-owned and close to a county road. The width of the stream was 45 feet and the depth at the time that the weir was installed was 29 inches.

Description of weir. Construction of the weir was complicated by the fact that at certain times of the year there was considerable boat traffic between the upper river and Lake Michigan. The final design of the weir incorporated all of the best features of previous weirs used by the Institute, plus a pair of boat gates operated by pulleys and cranks.

The entire structure was placed on single-board sheet-piling driven from 3 to 5 feet into the bottom. This construction eliminated most of the undercutting usually experienced in weir operation. The original plans which called for triple Wakefield piling could not be used because of the difficulties encountered in driving the piling into the subsurface material of rubble and boulders. A double row of round pilings, at intervals of 5 feet, supported the framework that carried the blocking bars of the weir (Figs. 4 and 5). All piling was driven into the bottom with a power-driven pile-driver and a jet pump.

The diagram (Fig. 4) shows the most prominent features of the weir. A and B are the boat gates, each approximately 5 by 15 feet. C and D are the traps, downstream and upstream respectively, each 6 by 5 by 5 feet. Each trap has a board floor to eliminate any hiding places for fish. A funnel made of 1/2-inch, galvanized wire screen acts as an entrance for fish into each trap. E and F are the stationary blocking arms, both about 45 by 5 feet. The individual blocking bars were 1- by 2-inch slats, spaced 1 1/2 inches apart. This spacing allowed all but the larger fish to pass through the structure without being trapped. The blocking bars on the Platte River weir were nailed directly to the framework, but it is possible to make these in frames so that a section of the blocking arm can be removed or replaced at any time. G is a 6-foot working platform. A catwalk on the downstream side of the blocking arms facilitates the cleaning and repair of the weir. H is a solid row of single-sheet piling, built as a safety

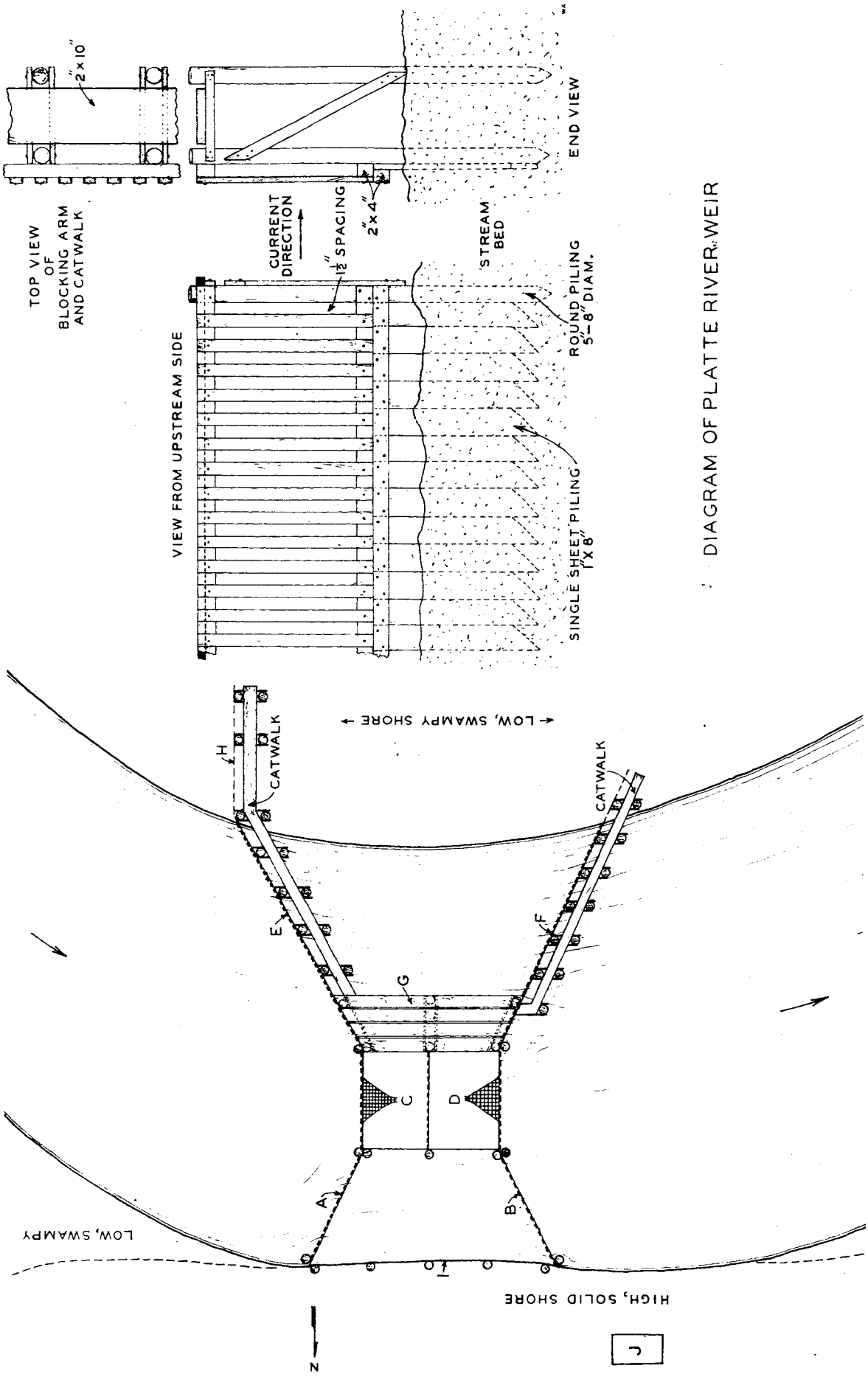

Figure 4.--Diagram of the Platte River weir, showing details of construction. See text for explanation.

Figure 5.--View of the Platte River weir looking downstream. The movable boat gates are to the right. The upper boat gate is in place, and the lower gate has been raised. The chute to the left is used to return the fish moving upstream to the water after the required data are obtained. The traps are at the left of the boat gates.

measure in time of high water, across a 150-foot stretch of marsh to higher ground on the south side of the river. I is a sea wall to prevent erosion of the north bank. The blocking arms, traps, boat gates, and sea wall all rested on sheet-piling. J is the attendant's cabin.

Results. The weir was in constant operation from November 1, 1941 until June 20, 1943 except for several brief periods when pressure from slush ice and snow broke the boat gates or made it necessary to leave the gates open.

In 1942 all upstream migrants were either "jaw-tagged" or marked by clipping fins. Tags were used on most rainbow trout and all northern pike. All other fish, including some rainbow trout, were "fin-clipped." In 1943, all suckers taken in the weir were distributed free to anyone possessing a current fishing license. Because of a shortage of help, only a few of the rainbow trout were marked in 1943.

A total of 14 species of fish were taken in the Platte River weir (Table 7). The numbers of the two species of suckers taken in the weir were recorded together. The rainbow trout and suckers made up 94.27 per cent of the catch; the remaining 5.73 per cent was divided among eleven species.

The heaviest run of all species combined occurred between April 1 and May 31 (Table 8). The spring upstream migration of rainbow trout extended from March 25 to May 10 in 1942, and from April 19 to June 14 in 1943. Weather conditions are probably responsible for the difference in the time of the run each year. In 1942, 756 mature rainbow trout were passed upstream through the weir and in 1943 only 196. Possible reasons for this difference may have been: (a) passage of fish through holes in the sheet-piling (h) or when the boatslip was open in the early winter of 1943 because of slush ice; (b) a smaller run of fish in 1943; and (c) discouragement of fish from running in 1943 by opening-day anglers. In 1942

Table 7.--Total catch of each species taken in the Platte River weir between November 1, 1941 and June 20, 1943, both dates inclusive

Common name	Scientific name	Number of fish captured		
		Upstream trap	Downstream trap	Total
Common sucker Sturgeon sucker	Catostomus c. commersonnii) Catostomus c. catostomus)	4,365	169	4,534
Rainbow trout	Salmo gairdneri irideus	965	97	1,062
Smelt	Osmerus mordax	216	1	217
Yellow perch	Perca flavescens	76	...	76
Rock bass	Ambloplites r. rupestris	13	...	13
Lake herring	Leucichthys a. artedi	12	...	12
Dogfish or bowfin	Amia calva	2	7	9
Northern pike	Esox lucius	2	2	4
Yellow pikeperch	Stizostedion v. vitreum	4	...	4
Bullhead	Ameiurus sp.	2	...	2
Smallmouth black bass	Micropterus d. dolomieu	1	...	1
Eastern burbot	Lota lota maculosa	1	...	1
Carp	Cyprinus carpio	1	...	1
Total		5,660	276	5,936

Table 8.--The number of suckers and rainbow trout taken in the Platte River weir between November 1, 1941 and June 20, 1943, both dates inclusive. Time periods when no fish or very few fish were taken have been combined

Time period	Suckers		Rainbow trout	
	Upstream trap	Downstream trap	Upstream trap	Downstream trap
1941				
Nov., Dec.	4	...	1	4
1942				
Jan., Feb.	...	...	...	...
March-April 2	1	1	17	1
April 3-9	4	...	220	...
April 10-16	26	...	344	7
April 17-23	1,043	...	121	2
April 24-30	447	...	51	7
May 1-7	313	...	2	1
May 8-31	51	...	1	6
June, Sept.	...	...	...	1
Oct. 1-7	...	...	12	...
Oct. 8-31	5	...	...	...
Nov., Dec.	4	1	...	1
1943				
Jan., March	...	...	...	1
April 1-15	...	...	...	...
April 16-30	206	1	113	4
May 1-15	1,075	...	57	2
May 16-31	762	166	18	59
June 1-20	424	...	8	1
Total	4,365	169	965	97

and 1943, before starting their upstream migration, between 500 and 800 large adult rainbow trout entered and stayed in the river between the weir and Lake Michigan from mid-November until the following spring. In 1942 the heavy run started on April 5 and the majority had been dipped over the weir by the time the fishing season opened on April 25. In 1943 the run was delayed by cold weather and the fish did not begin to move upstream until April 19. Anglers fished over heavy concentrations of rainbow trout below the weir when the fishing season opened on April 24. Observations indicated that this angling activity frightened the fish to such an extent that the majority of them returned to Lake Michigan.

From the data obtained from measurements of random samples, the length of the rainbow trout ranged from 17 to 34 5/8 inches, and the weight varied from 2 to 18 pounds. Males averaged 26 1/4 inches in length and 7 pounds in weight, while females had an average length of 28 1/8 inches and an average weight of 8.7 pounds.

The downstream movements of fish through the weir were confined chiefly to the spring spawning periods or following the spawning periods.

Conclusions. During the 20 months that the weir was in operation, observations indicated that fish were able to enter the river at any time. Therefore, no improvements need be made in the channel of the river mouth, unless future observations indicate a change of conditions.[2] During the

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[2] The Platte River weir will be operated during the spring of 1944 and perhaps in other years.

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period of operation of the weir the depth of water in the main channel at the river mouth varied from 17 to 48 inches. The position of the river mouth changed noticeably. In 1943 the confluence of the river with Lake Michigan was approximately 700 feet west and somewhat south of its position in 1941.

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Literature cited

Carbine, W. F.

1942. Observations on the life history of the northern pike, Esox lucius L., in Houghton Lake, Michigan. Trans. Am. Fish. Soc., Vol. 71 (1941), pp. 149-164.

1944. Egg production of the northern pike, Esox lucius L., and the percentage survival of eggs and young on the spawning grounds. Papers of the Mich. Acad. of Sci., Arts, and Letters, Vol. 29 (1943), pp. 123-137.