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AN EVALUATION OF THE AIR BUBBLE CURTAIN AS A BARRIER TO ALEWIVES

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ABSTRACT

The effectiveness of an air bubble curtain to impede, redirect, or stop the annual migration of alewives in the Milwaukee River was studied in the spring of 1964. Its operation during a $1\frac{1}{2}$-month period indicated that the curtain reduced the migration of alewives.

BACKGROUND

The opening of Welland Canal provided a path for alewives to migrate into the upper Great akes (Miller, 1957). Reaching Lake Michigan by the late 1940's, the alewives grew to phe-omenal numbers, each year apparently increasing several fold in numbers over the previ-us year. During the last 6 years, the City of Milwaukee has been plagued by large migra-ons of alewives into the Milwaukee, Kinnickinnic, and Menomonee Rivers during May, June, uly, and part of August. Soon after entering these rivers they die in large numbers, and ause an extensive sanitation problem. This discourages owners from improving their prop-rties abutting the river in such a manner as to make the river an asset to the community.

Mortalities of alewives in fresh water are not new. Although records of mortalities in ake Ontario date back to 1890 (Smith, 1892), no reasons are given for the possible cause of eath. Graham (1956) and Threinen (1958) suggest that mortalities are due to detrimental hanges in body metabolism probably following abrupt changes in water temperature. Obser-ations and data from this study in 1964 indicate that a lack of sufficient dissolved oxygen is lso a contributing factor.

An initial survey of the local situation in March 1964 revealed limitations to devices that ould be used to control migrations up the rivers. Because of low water and navigation in e Menomonee, Kinnickinnic, and lower Milwaukee Rivers, barriers could not be used in ose portions generally navigated by large lake vessels. These rivers, from the junction of e Milwaukee and Menomonee Rivers south and east to the lake, have become silted, and aximum depth is about 25 feet. The Milwaukee River after it separates from the Menomo-ee is navigable by smaller pleasure craft to the North Avenue Dam.

The development of an air bubble curtain apparatus by the U. S. Bureau of Commercial isheries demonstrated the practicality of guiding the Atlantic herring (Smith, 1961). Air umped through perforated polyethylene pipe made an air curtain that tended to direct the novements of young herring in clear water. Upon review of this work, the city officials of Milwaukee, Wis., implemented a study to determine the effectiveness of the air bubble cur-ain and assess its possible application as a permanent control.

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STUDY AREA

Since large ships travel north on the Menomonee River beyond the junction with the Milwaukee River, the air bubble curtain was installed in the Milwaukee River just north of its confluence with the Menomonee before reaching the heavily populated downtown business area (fig. 1). The east bank of the river was chosen as the site to install the air compressor unit because a municipally owned lot was available at that point immediately adjacent to a fire station that was manned continually (fig. 2). The availability of fire department personnel to

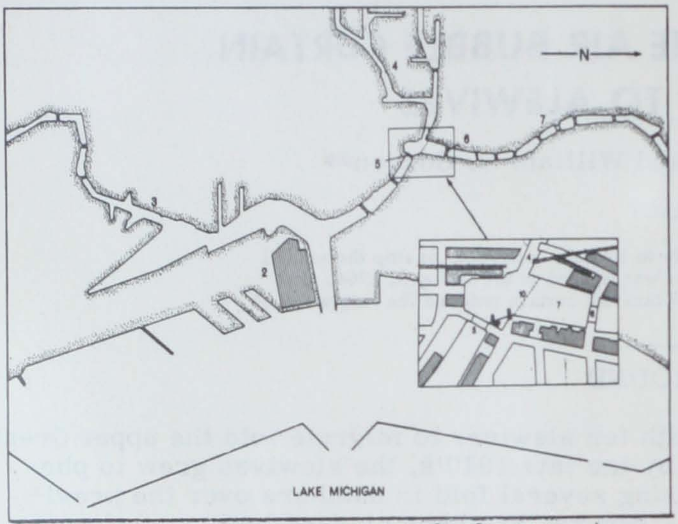


Fig. 1 - City of Milwaukee Harbor Area: (1) Government breakwater, (2) Sewage Treatment Plant - Jones Island, (3) Kinnickinnic River, (4) Menomonee River, (5) North Water Street bridge, (6) Buffalo Street bridge (7) Milwaukee River, (8) Fire station, (9) Compressor and other equipment, (10) Air hose.

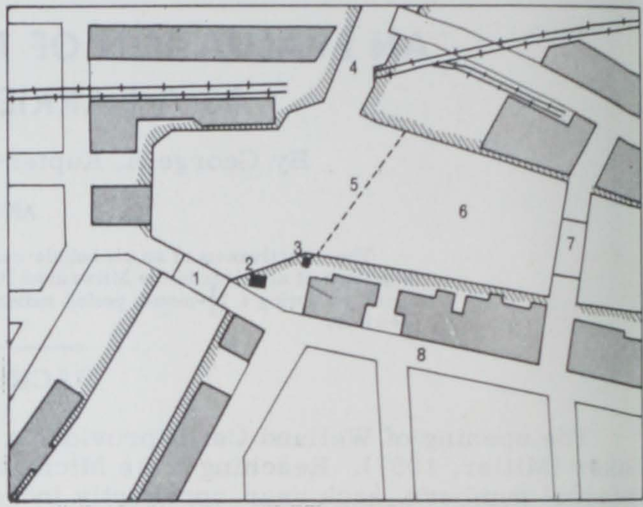


Fig. 2 - Diagram of study area: (1) North Water Street bridge, (2) Fire station, (3) Equipment location, (4) Menomonee River, (5) Air hose, (6) Milwaukee River, (7) Buffalo Street bridge, (8) North Water Street.

check on the operation of unit assured uninterrupted operation. At this point, the hose was 500 feet long and transversed the river on a 45° angle to the shoreline. This would tend to lead the fish along the trailing edge to the west bank of the river where commercial netting was planned. The depth of the water in this area was about 22 feet.

EQUIPMENT AND INSTALLATION

THE PLASTIC HOSE: Two lengths of plastic hose, rated to withstand 100 pounds per square inch, were connected by a regular air hose reducer fitting. The first 250 feet of this hose was 1 inch in diameter and the remaining 250 feet was $\frac{3}{4}$-inch diameter. Holes (0.0135-inch diameter) were drilled every 6 inches with a No. 80 jewelers drill. One end of the hose was plugged. A length of $\frac{3}{8}$-inch chain was attached along the entire length of the hose by nylon seaming twine to keep the hose on the bottom in the desired position. As the hose was drilled and the chain attached, the two sections were placed on two large reels aboard a barge (fig. 3). This technique made it easy to place hose on the bottom of the river by attaching a line in the desired diagonal across the river and moving the barge along this line (fig. 4). The end of the plastic pipe was secured to a rigid pipe secured to a piling on the west bank of the river (see cover page).

Fig. 3 - Barge used to place air hose.

COMPRESSOR UNIT: A diesel-powered air compressor which delivered 315 cubic feet p minute (free air rating) was set up on the east shore of the study area. This unit supplied a at about 80 pounds per square inch presse on 18-second cycles, i.e., 9 seconds "" time followed by 9 seconds "off" time. A ressure tank of 200-gallon capacity, with pssure valve and gauge, was installed at the clet of the compressor. The tank helped cl the air through expansion and a large iation surface.

Fig. 4 - Reeling out hose and chain.

Operation during warm weather produced a of extremely high temperature; therefore, aitional cooling was needed to prevent softeng or melting the plastic pipe. From the ulated pressure tank, 120 feet of copper er tubing 1-inch diameter was spiraled sely into about 5-foot coils. The air was ected from the pressure tank to this tubing, ich was hung on a rod so that the coils were merged below the surface of the water. le "radiator" sufficiently cooled the air to emperature compatible with the semirigid stic pipe. The temperature of the air ening the rigid pipe after flowing through the oling coil never exceeded 76° F. even in ° F. weather. Constant maintenance, such as oil changes and greasing, is needed on a diesel it which is to be kept in operation for extended periods of time. A 160-cubic foot per mine standby compressor was kept on the site for emergency use and was connected so that the it could be operated to ensure constant air flow when the main compressor was not funcning.

Because of the excessive noise of the compressor unit, a plywood structure, consisting three walls and a roof, was built over the unit (fig. 5). Since the installation obstructed the east shore of the river, a lighted sign was posted on the river bank to inform boat traffic of the obstruction. As the main compressor unit consumed about 80 gallons of diesel fuel every 24-hour period, a 275-gallon fuel supply was hooked directly to the compressor engine to reduce the number of refueling operations.

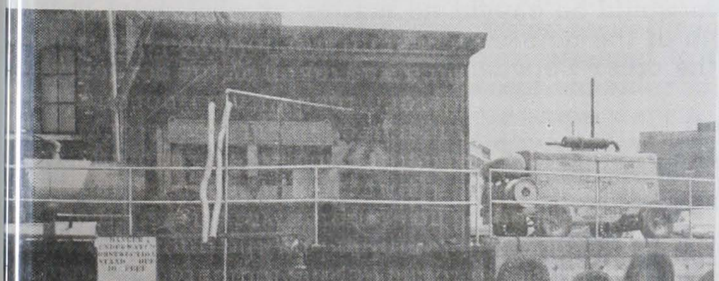


Fig. 5 - Equipment installation.

After the pipe was installed, the compressor unit was started to prevent silt from entering or clogging the holes in the plastic pipe and the pressure was slowly brought up to the desired pounds per square inch. During early operation, the air curtain was a solid and continus stream of readily visible bubbles (fig. 6). As the study progressed the initial holes tended close, because of the burrs left on the inside of the pipe during drilling. To correct this, UBA divers punched holes with a fine pin at 2-inch rather than 6-inch intervals. This dieter (0.02 inch) was about double that of the No. 80 drill. The close-spaced holes produced much more vigorous, uniform, and probably more effective curtain (fig. 7). Unfortunately, the study went on, even the larger holes became partially plugged and the action was reced.

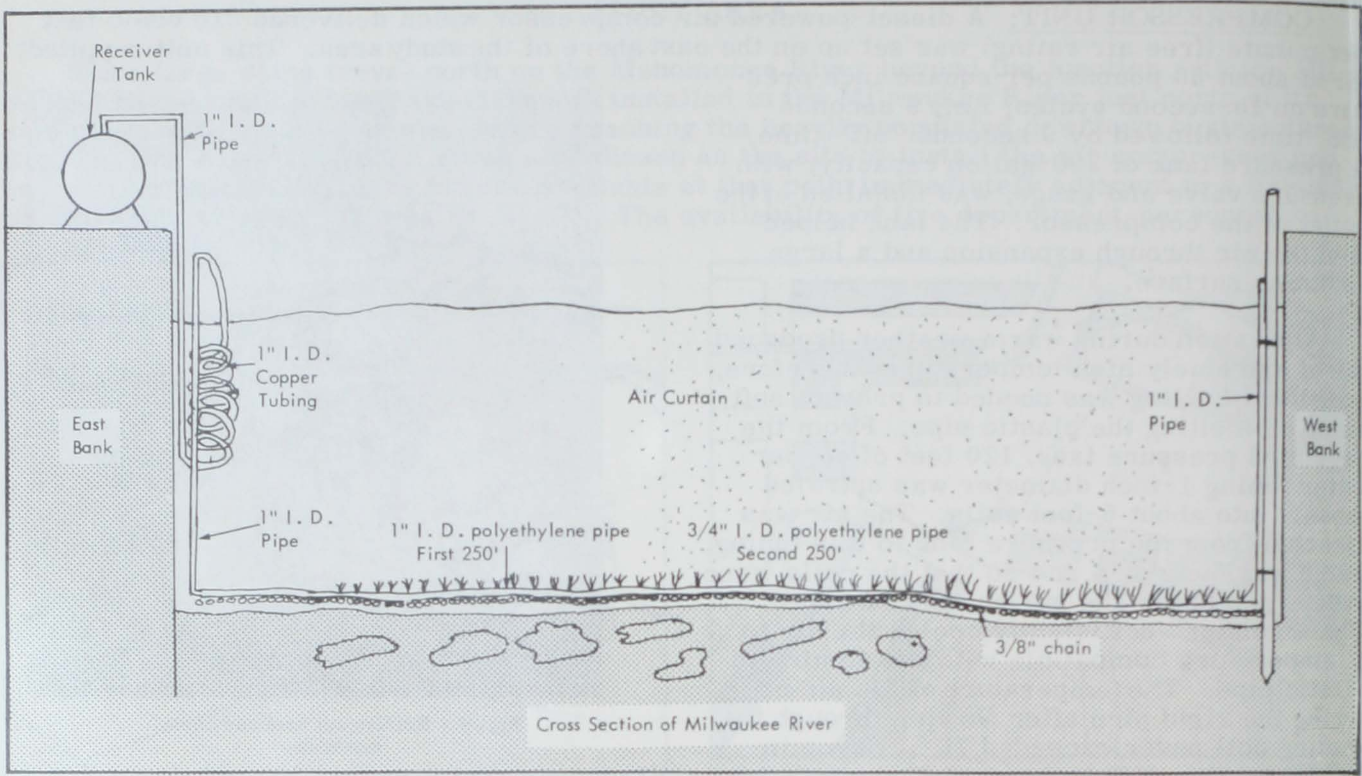


Fig. 6 - Diagram of air hose installation.

MEASURE OF EFFECTIVENESS

Gill nets, one on each side of the air curtain, were used to evaluate the number of fish traveling through the air curtain. Because the rivers are navigated by pleasure boats and other smaller craft, the nets had to be set below the normal draft of such boats. Gill nets were 6 feet deep by 100 feet long and made of $1\frac{1}{2}$-inch (stretch) nylon webbing. These nets extended across the river so that fish near the bottom would be caught no matter at what point in the river they migrated. To minimize the length of the nets needed, one was placed between the abutments of the Buffalo Street bridge and the other between the abutments of the North Water Street bridge (see fig. 2). The width of the river at those points (between the abutments) is about 100 feet. The nets were fished each Monday, Wednesday, and Friday. The nets

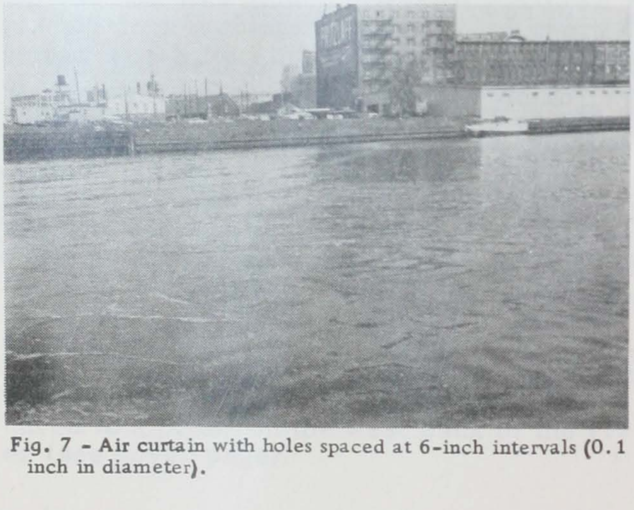


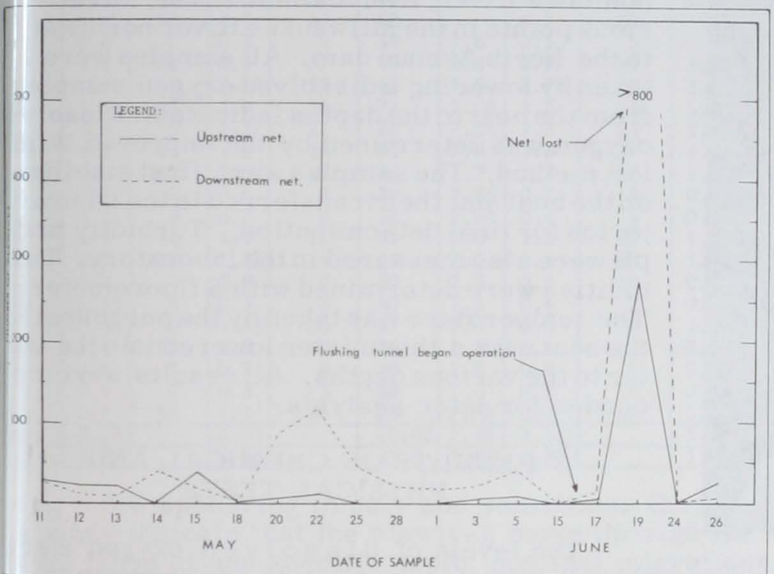
Fig. 7 - Air curtain with holes spaced at 6-inch intervals (0.1 inch in diameter).

Fig. 8 - Setting test net.

re fished a shorter time on days when many fish were present in the netting area. Both ts, however, were fished for the same length of time and during the same period to obtain mparable results. Because of strong currents, a line was attached between the pilings of t bridges, along which a small barge was operated for setting and picking up the nets (fig. 8 As the nets were picked out of the water, the enmeshed alewives were counted and re-ded.

FISHING RESULTS

Gill-netting during the first week gave inconsistent results (fig. 9). At first, the net a-ve the air curtain would have greater numbers of fish than the net below. From May 18 through June 15, 1964, the downstream net consistently caught more fish than the upstream net. The first erratic results may have resulted from fish in the river before the study began.



. 9 - Number of alewives caught by gill nets above and below the air-ble curtain during summer 1964.

The results of gill-netting on June 19 indicated that a large run of alewives apparently moved up the river on about June 18 or 19. The upstream net had about 285 fish, while the downstream had over 800 (estimated) fish. The downstream net at the North Water Street bridge was lost because personnel could not lift it out of the water owing to the many alewives in the net. A flushing station, the outlet of which was located just below the North Avenue dam on the Milwaukee River, was turned off at the beginning of the study. The flushing station is used ring dry weather in the summer to alleviate the stagnant condition of the river by discharg-g about 18 million gallons of water per hour through the outlet. The intake for this flushing ation was located in the main harbor adjacent to the Milwaukee Yacht Club. A small self-eaning screen over the intake was not considered feasible for such a short experiment; erefore, the pumps at the flushing station were turned off and remained off until 9:00 a.m. June 16, 1964. Then, because of dry weather flow and adverse river conditions, the flush-g tunnel was used. As a result, alewives were pumped into the river behind the air curtain the rate of about 2,000 fish a day. Undoubtedly these fish contributed to the catch of the t upstream.

A commercial minnow dealer who regularly fished in the entire river and had daily con-ct with these areas reported that the alewives were present in the rivers before this study gan. He reported netting small numbers of alewives as far upstream as the dam. He stated, wever, that about 1½ to 2 weeks after the air curtain installation, no alewives were found in at stretch of the river which extended from the curtain to the dam. He stated that after June , he again began to catch alewives in his minnow nets. This fisherman believed that the rtain was successful. His observations would again tend to lend credence to the experi-nces of City personnel and to explain some of the early results.

CHEMICAL AND PHYSICAL TESTS OF WATER QUALITY

To provide data from this study which might be comparable with like studies at a future me, basic chemical and physical determinations of the water quality in the study area were ade. Surveys were made on Mondays, Wednesdays, and Fridays to measure temperature and obtain samples to determine turbidity, dissolved oxygen, and pH (fig. 10). The dissolved oxygen measurements were taken at three points: (1) 25 feet upstream from the air curtain, (2) 25 feet downstream, and (3) 75 feet downstream. Two samples for oxygen and pH were taken at each of those points, one at the 6-foot depth and the other at the 15-foot depth. In addition, a turbidity sample was taken 25 feet upstream from the air curtain. Other samples also were taken at various other locations in the river system throughout the study period but these are not shown in this report. These included the Menomonee River, Kinnickinnic River, and at various points in the Milwaukee River northward to the North Avenue dam. All samples were taken by lowering a dissolved oxygen sampler from the boat to the depths indicated. Dissolved oxygen was determined by the improved Winkler method. The samples were first stabilized on the boat and then transferred to the laboratories for final determination. Turbidity and pH were also measured in the laboratory. Turbidities were determined with a fluorometer. The temperature was taken by the personnel in the boat with a thermister lowered into the water to the various depths. All results were recorded for later analysis.

Fig. 10 - Dissolved oxygen determination.

RESULTS OF CHEMICAL AND PHYSICAL TESTS

The levels of dissolved oxygen were lower downstream from the air curtain than they were upstream. The Menomonee River was extremely low in dissolved oxygen concentrations. The mixing of waters of the Menomonee River and Milwaukee River resulted in lower dissolved oxygen readings, both 25 feet and 75 feet below the air curtain.

The dissolved oxygen determinations (table 1) revealed that the median dissolved oxygen 75 feet upstream of the air curtain was 1.25 mg. per liter at the 6-foot level and 1.50 mg. per liter at the 15-foot level. The median at the sampling point 25 feet downstream was 1.35 mg. per liter at 6 feet and 1.45 mg. per liter at 15 feet. At the point 75 feet downstream, the 6-foot depth showed a median dissolved oxygen content of 1.40 mg. per liter, while at 15 feet the reading was 1.20 mg. per liter. These changes apparently result from the influence of the Menomonee River and stratification as the two rivers combine. As stated previously, the dissolved oxygen during the study steadily decreased during dry weather until the influence of the fresh water from the flushing tunnel was noted at the sampling points.

Samples taken upstream in the Milwaukee River showed increasingly more dissolved oxygen to the North Avenue dam, while the Menomonee River was low in dissolved oxygen, which may account for the heavier fish kill observed there. The dissolved oxygen in the Milwaukee River was less than 0.5 p.p.m. when the flushing was resumed. The low oxygen content indicated that the river was in a critical state and that flushing was necessary. The average daily water temperatures varied from 61.5° F. through 73° F. during this period. The mean turbidity in the Milwaukee River was 37 p.p.m. during the study period (see table 1), the median pH was 7.63.

OBSERVATIONS

The migration of alewives into the Milwaukee River during the test period appeared erratic. During previous years, fish entered the river to spawn from mid-May through mid-

Table 1 - Water Samples of the Milwaukee Rivers for Chemical Analyses by the Milwaukee Health Department, Summer 1964. Dissolved Oxygen (DO) is Expressed in Milligrams/Liter and Turbidity in Parts/Million.

te	75 Feet Upstream of Air Curtain						25 Feet Downstream of Air Curtain				75 Feet Downstream of Air Curtain				Av. Water Temp. of Air Curtain °F.	Av. Air Temp. °F.
	6 Ft. Depth		15 Ft. Depth				6 Ft. Depth		15 Ft. Depth		6 Ft. Depth		15 Ft. Depth			
	DO	% Sat.	DO	% Sat.	Turb.	pH	DO	% Sat.	DO	% Sat.	DO	% Sat.	DO	% Sat.		
14:																
5	4.4	48	4.0	44	-	-	3.5	38	3.2	35	3.6	40	2.8	30	68	71
11	4.85	52	4.1	44	60	-	3.2	34	3.25	34	3.9	42	3.75	40	66.25	58
13	3.76	40	3.0	32	60	-	2.4	26	2.25	24	2.45	26	2.23	24	67	46
15	5.05	51	4.7	47	52	-	4.5	45	4.05	41	3.95	40	3.95	40	61.5	61
18	0.6	7	0.3	3	38	1.6	0.3	3	0.6	6	0.5	5	0.3	3	67.5	71
20	4.8	54	3.3	37	45	8.2	3.5	39	3.0	33	2.9	32	2.9	32	70	45
22	2.6	28	3.15	33	42	7.8	2.75	30	3.2	34	2.75	29	3.25	33	65.25	76
25	1.0	11	1.0	11	74	7.66	1.2	13	1.1	12	1.1	12	1.1	12	69	64
27	1.3	15	1.1	13	62	7.68	1.3	14	1.2	14	1.2	14	0.0	0	70.5	57
28	1.2	13	1.3	14	51	7.6	1.6	17	1.9	21	1.5	16	1.6	17	69	50
1	1.6	18	1.6	17	36	7.7	1.7	18	1.6	17	1.5	16	1.3	14	67	51
3	0.6	7	0.6	7	29	7.68	0.7	8	0.7	8	0.7	8	0.7	8	69	55
5	0.2	3	0.2	2	32	7.63	0.4	4	0.3	3	0.4	4	0.2	2	68	58
8	1.3	14	1.1	12	31	7.6	1.1	12	1.2	13	1.3	15	1.3	14	69	64
10	1.2	14	1.25	14	33	7.5	1.4	16	1.4	16	1.6	18	1.6	18	72	59
12	0.8	9	0.8	9	30	7.5	0.9	10	0.8	9	0.6	7	0.7	8	70	68
15	0.45	5	0.3	3	30	7.5	0.4	5	0.4	5	0.4	5	0.4	5	73	60
17	0.85	10	1.75	20	27	7.6	0.8	9	1.5	16	0.7	8	0.8	9	70.75	62
19	7.8	85	6.2	67	25	7.6	4.4	50	5.1	55	4.3	47	5.6	60	67	81
22	0.6	7	0.5	6	20	7.5	0.5	6	0.5	6	0.6	7	0.5	6	73	68
24	0.8	9	0.3	3	48	7.6	0.5	6	0.4	4	0.6	7	0.4	4	69.5	67
26	4.7	53	4.1	46	28	7.78	3.4	37	3.4	37	3.1	35	3.0	33	70	82
ean	2.29		2.03		40.62	7.32	1.82		1.87		1.80		1.74		68.74	62.45
edian	1.25		1.50		37.0	7.63	1.35		1.45		1.40		1.20			

une, a few appearing in July and sometimes the early part of August. Observations during e study indicate that the alewives move through the entire cross-sectional area of the river, not move at any specific depth, and that migrations may be related to temperature or other eather factors.

In early May, the local fishing fleet reported that the fish had moved close to the harbor rea by the time the study began. Later reports by commercial fishermen indicated that large chools of the fish were present in the lake and also in the main harbor and lower river. They eported, however, that fish seemed to move constantly between the air curtain and the outer arbor. Few fish were seen at or near the air curtain at most times.

A visual survey was ade three times a week to etermine numbers of dead sh in the areas above and elow the air curtain. All uch results were recorded nd returned to the Health Department for analysis. In ddition to these observations, local commercial fish perators made echo-soundings throughout the test period and were able to determine concentrations of fish n the various areas of the ivers, harbor, and lake. All observations made by commercial operators, as well as their catch, were recorded and retained by the Health Department (see table 2).

Table 2 - Alewives Harvested by Commercial Fishermen from the Milwaukee Harbor During Air Curtain Study, Summer 1964

Date	Location	Fishing Gear	Catch in Pounds
1964			
May 16	Outer Harbor ¼ mile North of River Mouth	Lampara	350
	Outer Harbor - North Cut	"	600
	South of Air Curtain	"	1
May 20	Outer Harbor	Lampara	400
	Kinnickinnic River Mooring Basin	"	125
May 29	Outer Harbor	Trawl	600
June 2	Outer Harbor	Trawl	2,000
June 3	Outer Harbor	Trawl	3,450
June 4	Outer Harbor	Trawl	1,500
June 11	Outer Harbor	Trawl	925
Total			9,951

Commercial fishermen reported that the heaviest run of fish up the river was encountered around June 19 and that the main run may have been over by June 29, even though some schools of alewives remained in the harbor. They also reported extremely large schools of alewives in Lake Michigan. As funds were unavailable to continue operation of the air curtain, the study was ended June 30, but the main run of the alewives was apparently encountered during the study. Further migrations of alewives into the Milwaukee River was not apparent during July, and caused no further nuisances.

Generally, the visual observations revealed large numbers of dead fish below the air curtain and smaller numbers above. The largest numbers of dead fish were noted at the junction of the Menomonee River and in the area of the junction of the Kinnickinnic River. Although dead fish were constantly sighted upstream, it is not known how long they had been dead. Many of the fish above the air curtain were quite deteriorated. Most fish were probably noted several times in the week-to-week searches.

Fish were often observed dying downstream from the air curtain. In only a few cases, however, were dying fish noted in the Milwaukee River above the air curtain. Because of inability to determine when those fish had died, the visual method of observation was unreliable for showing quantitatively the effectiveness of the air curtain. It did indicate, however, that the air curtain was somewhat successful in stopping the alewives from migrating up the Milwaukee River.

Commercial establishments in the downtown area were checked to determine whether the water intakes for their air conditioning systems were affected by large numbers of alewives. Personnel of these establishments reported an exceptional decrease of alewives found in their intakes during May and June. All establishments reported that around the third week of June, many fish were again found in their intakes, which coincides with the time that the large run of alewives was encountered and the time that the flushing tunnel was being operated.

Fig. 11 - Dead fish and debris in river.

The effectiveness of the air curtain may have been biased by several factors. The location of the curtain during the study may have hindered evaluation since the fish had few alternative routes when the curtain was reached. Commercial operators, while attempting to fish in the test area, ran into difficulties due to currents and large amounts of debris that tore their nets during fishing (fig. 11). Consequently, commercial netting was discontinued after two attempts to remove alewives in this area. The gill-netting data showed that about 36 percent of the fish near the bottom may have gone through the air curtain during this study. Thus, migration through the curtain may have been due to the large number of fish involved, the lack of alternative routes, and a "forcing" of the fish through the barrier. Commercial harvesting of the alewives in the main harbor may have alleviated this problem by reducing the number of fish reaching the area below the air curtain.

The migration of fish up the Milwaukee River may also have been affected to some extent by the removal of about 10,000 pounds of alewives by fishing in the harbor area by commercial fishermen (table 2). Most of those fish were caught in the outer harbor and only one small catch was made in the Kinnickinnic River.

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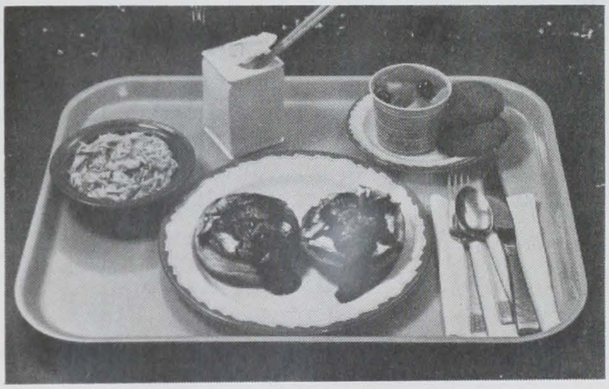
HOT SARDINE SANDWICH

3 cans ($3\frac{3}{4}$ or 4 ounces each) Maine sardines
6 hamburger buns
2 tablespoons butter or margarine
$\frac{3}{4}$ cup catsup
1 tablespoon chopped onion
$\frac{3}{4}$ teaspoon oregano
Dash garlic powder
$\frac{1}{2}$ cup grated cheese



Drain sardines and break into large pieces. Cut rolls in half and spread with butter. Place rolls, butter side up, on a cookie sheet, 15 x 12 inches. Place sardines on each half roll. Combine catsup, onion, oregano, and garlic powder. Place approximately 1 tablespoon catsup mixture over sardines. Sprinkle cheese on top. Bake in a very hot oven, 450° F., for 8 to 10 minutes or until cheese melts and rolls toast. Serve hot. Serves 6. (Recipe by the home economists, National Economics Research Center, U. S. Department of the Interior, Bureau of Commercial Fisheries, College Park, Maryland.)