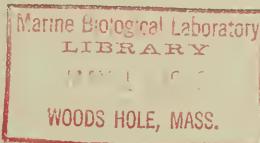


SURFACE CURRENTS OF LAKE MICHIGAN 1931 AND 1932

SPECIAL SCIENTIFIC REPORT-FISHERIES No. 413



UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR, Stewart L. Udall, *Secretary*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

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by

John Van Oosten



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ABSTRACT

Seven hundred forty-five bottles containing post cards for recording of information were released at stations in Lake Michigan; 283 were released June 17 to August 17, 1931, south of a line from Frankfort, Michigan, to Algoma, Wisconsin, and 462 during May 9 to August 25, 1932, both south and north of that line.

One hundred eighty-six bottles or 65.7 percent of those released in 1931, 331 bottles or 71.6 percent of 1932 releases, and 517 bottles or 69.4 percent of releases in the 2 years were recovered.

Recoveries of bottles from both years indicated that the surface currents were somewhat variable, but their general direction was from west to east and predominately northeast in 1931 and northeast and southeast in 1932.

INTRODUCTION

Currents have been observed in the Great Lakes by many people. These water movements affect navigation, kind of water at intakes, temperatures, plankton, fishes, beaches, and recreation. Currents of Lake Michigan have been discussed in numerous papers. The present study is based on the recovery of drift bottles that were dropped from the research vessel *Fulmar*, operated by the U. S. Bureau of Fisheries in 1931 and 1932. I am greatly indebted to the members of the scientific staff of this vessel who prepared and deposited the bottles. Asa T. Wright drafted all of the figures.

HISTORY OF LAKE MICHIGAN CURRENT STUDIES

Harrington (1895) reported, on the basis of recoveries of bottles released in 1892, 1893, and 1894 by the U.S. Weather Bureau, that the main current of Lake Michigan passed southward off the west shore, curved eastward along Illinois and Indiana, and moved northward along the east shore, although certain cross currents and eddies occurred in the center of the lake. Russell (1895) discussed the friction of winds on water movements of the Great Lakes and showed the Weather Bureau's map of Great Lakes currents. Ward (1896) described the Bureau's chart of Lake Michigan.

Judson (1909) listed nine factors that may influence the currents of Lake Michigan but concluded that the all-important one was the wind. The winds and barometric pressure produce currents that travel in any direction; even in the Straits of Mackinaw the current may flow either into Lake Huron or Lake Michigan and vary greatly in velocity. (This reverse flow in the Straits of Mackinaw was observed by explorers as early as 1673.) According to Judson, surface currents travel a maximum of about 5 percent of the wind speed up to 3 miles per hour and extend to a depth of 30 to 40 feet.

Barnard and Brewster (1909a and 1909b) reported that local shore currents reach a maximum distance of 5 miles from Michigan City and at times beyond 10 miles from certain areas of the Indiana coast. These currents flow in many directions according to the prevailing winds. McLaughlin (1912) mentioned winds and inshore currents but stated that the prevailing current of Lake Michigan sweeps southward into Grand Traverse Bay and moves from west and east and then northward toward the open lake. At times the currents reverse from east to west.

Townsend (1916) derived his paper from a voluminous document of the House of Representatives (No. 762, 63d. Congress, 2d. Session) that included Great Lakes data on winds, water levels, temperatures, and currents. He pointed out that curvilinear surface currents illustrated by Harrington's map of Lake Michigan were absurd because the 2 points of a drift bottle's course could only represent a straight line. No permanently defined currents are developed, he contended, because as a rule they follow the direction of surface winds and perhaps are affected by barometric pressures. The currents may flow opposite the wind when its intensity is low. Floats deposited close to Wisconsin were recovered on that shore, north or south of the release point, whereas the floats released farther out in the lake were driven by prevailing westerly summer winds across to Michigan. Eddies may develop but only in deep bays or between extended points along the shore--not along an unbroken shore.

Shelford (1918) described the conditions in Lake Michigan and among them referred to the wave action that varied from depths up to 5 feet, the limit of sand-moving waves, to 26 feet; the limit of wave action is 82 feet.

Horton and Grunsky (1927) also reported that strong wind action and barometric pressure increase the normal current in the Straits of Mackinaw and at times reverse it from Lake Huron into Lake Michigan.

Crohurst and Veldee (1927) stated that no constant or clearly defined water currents exist in the Calumet region of Illinois and Indiana. The movements vary continuously with wind direction and velocity and should be termed "wind drifts" rather than true currents. Their observations with floats were not useful.

It is unfortunate that our 1931 and 1932 data on the surface currents of Lake Michigan were not recorded years ago. However, Deason (1932) published a preliminary report of our 1931 program including records of five of our interesting recoveries of drift bottles. A short notice of the drift-bottle study of 1931 appeared in the U.S. Fisheries Service Bulletin, No. 202, March 1, 1932.

The limnological surveys of Lake Michigan by the Bureau of Commercial Fisheries in 1954-56 and 1960 were briefly reported in the Commercial Fisheries Review. Several reports showed the pattern and direction of currents as indicated by drift cards.

Smith (1956) described the release of 4,000 drift bottles in the northern half of Lake Michigan in 1955. Nearly 60 percent of them were returned by the end of the year. An experiment indicated that the shortening of wire between the drag and the bottle from 3 feet to 1 foot and the addition of a movable brass ring at the neck of the bottle reduced the loss of drags. In his 1957 paper Smith reported a total of 6,300 drift bottles released in the southern half of Lake Michigan in 1954 and in the northern half in 1955.

Lauff (1957) released no drift bottles during his 2-day survey of Grand Traverse Bay on

July 30-31, 1954, but recorded the Lake Michigan bottles that were recovered in the bay, 6 reported in 1892 by Harrington (1894) and 11 in 1955 by the Great Lakes Research Institute. These bottles indicated that the main current flowed into the West Arm and a small portion deflected into the East Arm.

Ayers et al. (1958) reported the release of 1,297 drift bottles in Lake Michigan during four synoptic cruises (15 round trips) on June 28 and 29 and August 9 and 10, 1955; 239 bottles or 18.4 percent were recovered. Eighteen percent of the recovered bottles were found in the southern half and 82 percent in the northern half of the lake. Nearly all bottles recovered from releases in June had traveled northeastward but most of those of August floated southeastward. Fifty-seven percent of the retrieved bottles were from the eastern area of the lake, while 17, 16, and 10 percent, respectively, were recovered from the western, central, and northern areas. Twenty-one bottles were discovered in Lake Huron.

Johnson (1960) described surface currents in Lake Michigan during 1954 and 1955. From July 9 through September 15, 1954, 1,080 drift bottles, 1,080 drift envelopes, and 100 plastic tubes were released along two transects (six trips) in the southern area and one transect (one trip) in the central region. Returns of these drift units amounted to 587 bottles (54.4 percent), 77 envelopes (7.1 percent), and 18 tubes (18.0 percent). In general, the 1954 drift was from west to east. Recoveries toward the north and south were about equal.

During April 26 to November 8, 1955, 2,000 drift bottles with drags and 2,000 bottles with sand ballast were released along two transects (six trips) in the central region, two transects (nine trips) in the northern area, and one cruise between Manitowoc and Sturgeon Bay, Wisconsin. Returns included 1,128 or 56.4 percent of the bottles with drags and 1,060 or 53.0 percent of those with ballast. The general drift of the 1955 bottles was from west to east. Bottles released in the eastern areas moved mainly to the north, but those dropped to the west showed no prevailing pattern.

MATERIALS AND METHODS

Our drift bottles released in 1931 and 1932 had a capacity of 13.9 ounces and were made of heavy glass with the initials U.S.B.F. blown in the side (fig. 1). A metal drag suspended by 3 feet of wire from the bottom of the wired bottle could rotate within a restricted arc. The drag, composed of 22-gauge galvanized iron, was bent in such a manner that the bottles resisted direct effects of wind and thus gave a true indication of surface currents. Each bottle contained a numbered post card (fig. 2) that requested the following information: locality, date, and hour of recovery; whether or not a metal drag was attached; name and address of the finder. The cards were addressed to the U.S. Bureau of Fisheries, Washington, D. C., and included a notice that the finder would be informed where and when the bottle was set adrift. The bottles also contained a strip of red muslin about 1-inch wide, part of which extended outside and floated along the surface, to attract attention. The corks and muslin that stoppered the bottles were heavily waxed.

Series of bottles (table 1; fig. 3) were released across Lake Michigan between the following ports: Chicago, Illinois, and St. Joseph, Michigan; Waukegan, Illinois, and St. Joseph, Michigan; Racine, Wisconsin, and Grand Haven, Michigan; Grand Haven, Michigan, and Sheboygan, Wisconsin; Manistee, Michigan, and Two Rivers, Wisconsin; Frankfort, Michigan, and Two Rivers, Wisconsin; Frankfort, Michigan, and Kewaunee, Wisconsin; and Manistique, Michigan, and Manistee, Michigan. In addition, bottles were released along the courses between ports of the same coast, between ports and net stations, and at various locations where gill nets were set.

In 1931, 293 bottles were released from June 17 to August 17 in the open lake south of a line from Frankfort, Michigan, to Algoma, Wisconsin (table 1). One hundred eighty-six bottles or 65.7 percent were recovered. The percentages varied from 25.0 to 100.0. From May 9 to August 25, 1932, 462 bottles were deposited south and north of the above-defined line and in Green Bay. The recoveries totaled 331 bottles or 71.6 percent. The percentages



Figure 1.--Drift bottle with a metal drag, was deposited from the research vessel *Fulmar*.

BREAK BOTTLE, REMOVE CARD, FILL IN INFORMATION AS INDICATED AND SEND BY POST	
No. _____	
Where found (as near as possible) _____	
When found, date _____	Hour _____
Was metal drag attached? _____	
Your name _____	(Please print plainly)
Your address _____	
This card does not require a stamp. On receipt of this card you will be informed where and when the bottle was set adrift.	
U. S. GOVERNMENT PRINTING OFFICE 1930	

Figure 2.--Post card, $3\frac{1}{4}$ by $5\frac{1}{2}$ inches, included in bottle.

ranged from 46.2 to 95.1. A grand total of 745 bottles were deposited, and 517 bottles or 69.4 percent were recovered. Most of the release stations were approximately 2 miles apart although a distance of about 1 mile was employed on three dates.

Unknown numbers of bottles landed many weeks or months before their recovery; many of them no doubt remained at about the same location, but some could have been moved by winds, waves, or ice. However, the largest monthly numbers and percentages (table 2) followed the month when the bottles were released except August, when the major recoveries occurred in the month of release. The majority of the bottles had been recovered by the end of August 1931 and of July 1932. For the combined years, the greatest number of recoveries was in July. As the season progressed in both 1931 and 1932 the monthly figures decreased and reached zero as early as September (May release of 1932).

The numbers and percentages of the bottles recovered were recorded also according to the number of days (table 3). During the first 9 days 6 bottles (2.1 percent) were recovered in 1931 and 46 bottles (10.0 percent) in 1932--a total of 52 bottles (7.0 percent) for both years. From the 10th until the 50th day the percentages for the 10-day period varied from 9.9 to 13.4 in 1931, 8.2 to 10.8 in 1932, and 9.7 to 11.8 in the 2 years combined. They then decreased until the 80th day, and thereafter averaged below 2 percent (including those beyond 129 days). The highest

percentages were between 30 and 39 days.

Many recovered bottles had lost their drags. In 1931, 120 (64.5 percent) and in 1932, 133 (40.2 percent) of the bottles had no drags, a grand total of 253 (48.9 percent)--see table 3. The percentages of the lost drags of 1931-32 bottles increased generally to a maximum of 80.0 during the period of 90-99 days but subsequently averaged about 59 percent. Bottles that held their drags amounted to 58 (31.2 percent) in 1931, 169 (51.0 percent) in 1932, and 227 (43.9 percent) in both years. Thirty-seven (7.2 percent) of the cards gave no report on the drag.

Only 16 drift bottles, at least 10 of which had lost their drags, were found more than 1 year after release (table 3)--13 in 1932-36, 2 in 1938, and 1 in 1942. Only two bottles were recovered beyond Lake Michigan. One released June 22, 1931, 43.5 miles from Frankfort, Michigan, was found April 8, 1935, at St. Martins Point, St. Martins Bay, Lake Huron. Another, released June 24, 1932, 6.7 miles from Kewaunee, Wisconsin, was recovered June 6, 1942, near Jefferson Beach, Lake St. Clair.

RELEASES AND RECOVERIES BY TRANSECT AND COURSE

The following sections include 19 graphs of recoveries showing the directions followed by recovered bottles. Tables 4-24 list the stations of release and recovery of drift bottles, number of days, minimum miles traveled, and records of drags.

Chicago to St. Joseph

On June 17, 1931, 27 bottles (table 4) were released along the transect (fig. 4) and 23 (85 percent) were recovered in 17-76 days, an average of 43.7. Eight (40 percent) of the 20 bottles held their drags. The bottles had covered minimum distances from 9-144 miles an average of 61.5. Sixteen bottles, including six on the western part of the transect, scattered widely on the east coast from 8 miles south of St. Joseph to 7 miles south of Manistee.

TABLE 1.--Number of drift bottles released along various transects or courses (and station numbers) by the research vessel *Fulmar* in Lake Michigan, 1931 and 1932, and the numbers and percentages recovered

Date	Transect or course	Stations ¹	Number of bottles		Percentages recovered
			Released	Recovered	
<i>1931</i>					
June 17	Chicago, Ill.-St. Joseph, Mich.	1- 27	27	23	85.2
June 18	St. Joseph, Mich., -Grand Haven, Mich.	28- 40	13	12	92.3
June 22	Grand Haven, Mich., -Ludington, Mich.	41- 44	4	4	100.0
June 23	Ludington, Mich., -Manistee, Mich.	45- 48	4	1	25.0
June 24	Manistee, Mich., -Two Rivers, Wis.	49- 75	27	24	88.9
June 26	Sheboygan, Wis., -Sheboygan Reef	76- 82	7	4	57.1
June 27	Sheboygan, Wis., -Sheboygan Reef	83- 91	9	5	55.6
June 27	Sheboygan Reef-Racine, Wis.	92-117	26	20	76.9
June 30	Waukegan, Ill., -St. Joseph, Mich.	118-147	30	24	80.0
July 17	Racine, Wis., -Grand Haven, Mich.	148-183	36	27	75.0
July 22	Frankfort, Mich., -Two Rivers, Wis.	184-217	34	18	52.9
July 23	Two Rivers, Wis., -Nets	218-221	4	2	50.0
July 30	Frankfort, Mich., -Nets-Kewaunee, Wis.	222-249	28	7	25.0
Aug. 12	Kewaunee, Wis., -Nets-Port Washington, Wis.	250-282	33	14	42.4
Aug. 17	Grand Haven, Mich., -Nets	283	1	1	100.0
Total or average	. . . . .	283	283	186	65.7
<i>1932</i>					
May 9	Escanaba, Mich., -Menominee, Mich.	284-308	25	16	64.0
May 17	Menominee, Mich., -Nets and return	309-337	29	19	65.5
June 2	Two Rivers, Wis., -Frankfort, Mich.	338-413	76	57	75.0
June 3	Frankfort, Mich., -Charlevoix, Mich.	414-483	70	51	72.8
June 6	Charlevoix, Mich., -Manistique, Mich.	484-537	54	35	64.8
June 7	Manistique, Mich., -Escanaba, Mich.	538-559	22	16	72.7
June 20	Manistique, Mich., -Manistee, Mich.	561-587	27	20	74.1
June 21	Manistee, Mich., -Grand Haven, Mich.	588-628	41	39	95.1
June 23	Grand Haven, Mich., -Sheboygan, Wis.	629-666	38	27	71.0'
June 24	Sheboygan, Wis., -Sturgeon Bay, Wis.	667-699	33	25	75.8
Aug. 9	Charlevoix, Mich., -Guiken's Reef	700-714	15	8	53.3
Aug. 20	Gull Island-Manistique, Mich.	715-726	12	7	58.3
Aug. 23	Charlevoix, Mich., -Dahlia Shoal	727-739	13	6	46.2
Aug. 25	Charlevoix, Mich. (12 3/8 miles NW 1/8 W)	740-746	7	5	71.4
Total or average	. . . . .	462	462	331	71.6
Grand total or average	. . . . .	745	745	517	69.4

¹ No. 560 was not used.

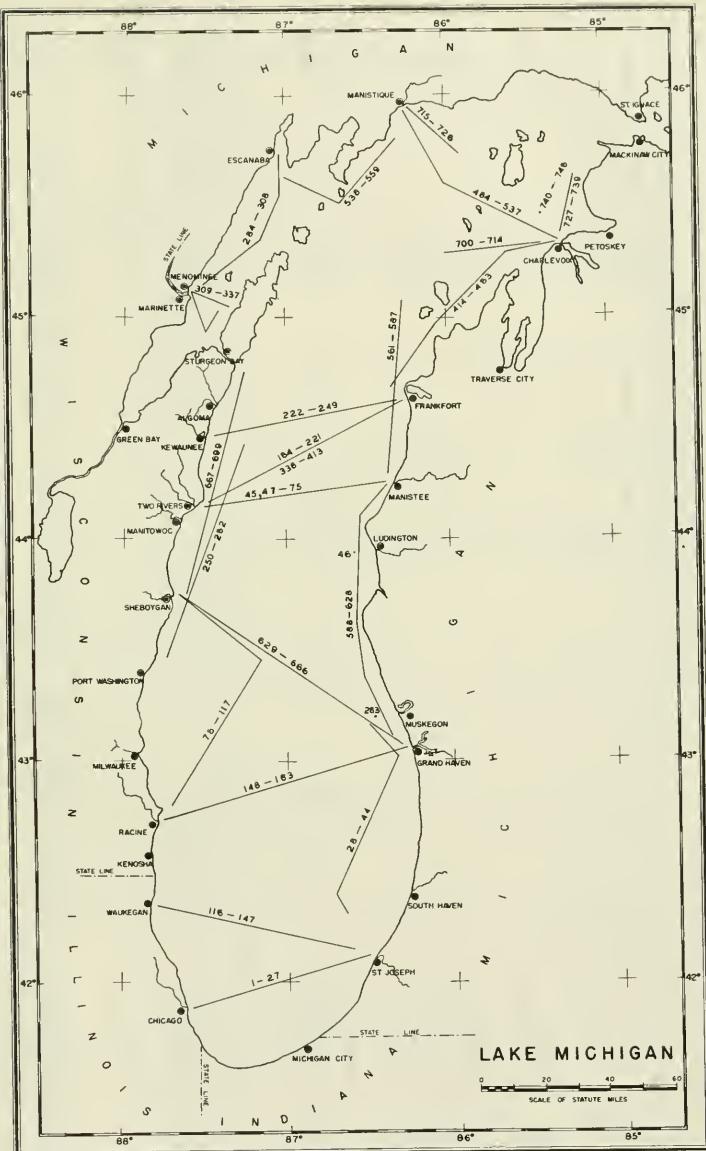


Figure 3.--Bottles were released along the transects and along the coasts of Lake Michigan.

TABLE 2.-Numbers of bottles recovered and their percentages of the bottles released in Lake Michigan 1931-32
 [Numbers of released bottles in parentheses below dates of releases]

Released	Item	Numbers of recoveries and percentages of bottles released									Totals
		May	June	July	August	September	October	November	December	Beyond December	
<i>1931</i>											
June 17-30 (147)	Number	...	1	67	45.6	29.2	4	1	0	0	117
	Percentage	...	0.7	45.6	29.2	2.7	0.7	0.0	0.0	0.7	79.6
July 17-30 (102)	Number	...	3	32	7	7	1	0	4	54	54
	Percentage	...	2.9	31.4	6.9	6.9	1.0	0.0	3.9	52.9	
Aug. 12-17 (34)	Number	...	...	13	1	0	0	0	0	1	15
	Percentage	...	...	38.2	2.9	0.0	0.0	0.0	0.0	2.9	44.1
All dates (283)	Number	1	70	88	12	8	1	0	6	186	186
	Percentage	0.4	24.7	31.1	4.2	2.8	0.4	0.0	2.1	65.7	
	Cumulative	0.4	25.1	56.2	60.4	63.2	63.6	63.6	65.7	65.7	
May 9-17 (54)	Number	2	19	8	1	0	0	0	1	4	35
	Percentage	3.7	35.2	14.8	1.8	0.0	0.0	0.0	1.8	7.4	64.8
June 2-24 (361)	Number	59	129	50	13	4	3	0	12	270	270
	Percentage	...	35.7	13.8	3.6	1.1	0.8	0.0	3.3	74.8	
Aug. 9-25 (47)	Number	...	...	8	7	1	1	0	9	26	26
	Percentage	...	...	17.0	14.9	2.1	2.1	0.0	19.1	55.3	
All dates (462)	Number	2	78	137	59	20	5	4	1	25	331
	Percentage	0.4	16.9	29.6	4.3	1.1	0.9	0.2	5.4	71.6	
	Cumulative	0.4	17.3	46.9	59.7	64.0	65.1	66.0	66.2	71.6	71.6
Both years (745)	Number	2	79	207	147	32	13	5	1	31	517
	Percentage	0.3	10.6	27.8	19.7	4.3	1.7	0.7	0.1	4.2	69.4
	Cumulative	0.3	10.9	38.7	58.4	62.7	64.4	65.1	65.2	69.4	69.4

TABLE 3.--Numbers and percentages of bottles from the 1931 and 1932 releases recovered, and the lost and nonreported drags according to days between release and recovery

Numbers of days from release to recovery	Bottles recovered from 1931 releases		Bottles recovered from 1932 releases		Bottles recovered from 1931-32 releases		Bottles from 1931-32 releases that had lost drags		Number without data on drags
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	
10	6	2.1	46	10.0	52	7.0	8	15.4	1
10- 19	29	10.2	43	9.3	72	9.7	23	31.9	4
20- 29	36	12.7	38	8.2	74	9.9	41	55.4	3
30- 39	38	13.4	50	10.8	88	11.8	36	40.9	9
40- 49	28	9.9	48	10.4	76	10.2	43	56.6	6
50- 59	17	6.0	33	7.1	50	6.7	33	66.0	6
60- 69	14	4.9	13	2.8	27	3.6	18	66.7	3
70- 79	4	1.4	12	2.6	16	2.1	12	75.0	2
80- 89	3	1.1	5	1.1	8	1.1	5	62.5	0
90- 99	5	1.8	5	1.1	10	1.3	8	80.0	0
100-109	...	...	3	0.6	3	0.4	2	66.7	0
110-119	...	...	3	0.6	3	0.4	2	66.7	0
120-129	...	...	3	0.6	3	0.4	2	66.7	0
130-139	2	0.7	17	3.7	19	2.6	10	52.6	0
> 366	4	1.4	12	2.6	18	2.1	10	62.5	3
All periods	186	65.7	331	71.6	517	69.4	253	48.9	37

TABLE 4.—Release and recovery points of drift bottles released June 1⁷, 1931, at 27 stations on the transect,
Chicago, Illinois to St. Joseph, Michigan

Station number	Station of release			Recoveries			Minimum miles covered	Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release		
1	41° 54.1'	87° 30.8'	August 6	43° 1.0'	86° 13.9'	50	100	Yes
2	41° 54.7'	87° 28.6'	August 23	43° 17.8'	87° 53.7'	67	97	No
3	41° 54.9'	87° 26.1'	...	...	...	...	...	...
4	41° 55.6'	87° 24.2'	August 21	42° 11.0'	87° 46.7'	65	26	No
5	41° 55.9'	87° 22.0'	September 1	43° 20.2'	86° 25.0'	76	107	?
6	41° 56.5'	87° 19.5'	July 29	42° 15.5'	86° 21.7'	42	54	No
7	41° 57.0'	87° 17.3'	July 29	42° 36.8'	86° 14.4'	42	71	No
8	41° 57.3'	87° 14.9'	July 30	42° 21.4'	86° 13.5'	43	56	No
9	41° 58.0'	87° 12.3'	...	...	...	...	...	...
10	41° 58.4'	87° 9.8'	August 2	42° 9.4'	86° 27.3'	46	42	No
11	41° 59.1'	87° 7.4'	August 22	41° 37.6'	87° 13.5'	66	26	Yes
12	42° 0.0'	87° 5.0'	...	...	...	...	...	...
13	42° 0.4'	87° 2.5'	August 10	41° 38.0'	87° 10.7'	54	27	Yes
14	42° 0.9'	87° 0.0'	July 11	42° 7.7'	86° 28.5'	24	30	No
15	42° 1.4'	86° 57.9'	August 1	42° 16.8'	87° 49.7'	45	48	No
16	42° 1.8'	86° 55.2'	July 30	41° 40.5'	87° 27.8'	43	38	Yes
17	42° 2.5'	86° 53.0'	...	...	...	...	...	...
18	42° 2.9'	86° 50.7'	August 25	41° 37.7'	87° 11.6'	69	35	?
19	42° 3.4'	86° 48.4'	July 29	42° 1.3'	86° 33.2'	42	14	Yes
20	42° 3.6'	86° 46.2'	July 23	42° 18.8'	86° 19.6'	36	28	Yes
21	42° 3.9'	86° 43.7'	July 21	42° 58.4'	86° 13.5'	34	67	Yes
22	42° 4.7'	86° 41.0'	July 30	42° 0.3'	86° 33.6'	43	9	No
23	42° 5.2'	86° 38.9'	July 13	43° 21.7'	86° 25.3'	26	86	No
24	42° 5.8'	86° 36.5'	July 13	43° 39.1'	86° 33.0'	26	108	?
25	42° 6.0'	86° 34.6'	July 11	44° 9.4'	86° 24.5'	24	144	Yes
26	42° 6.4'	86° 32.5'	July 4	44° 7.5'	86° 26.2'	17	140	No
27	42° 6.7'	86° 30.6'	July 13	42° 59.4'	86° 13.5'	26	61	No
Average	...	...	...	...	...	43.7	61.5	...
Number recovered	...	...	...	...	...	23	23	...

¹ With drags; 8; without drags, 12; no data, 3.

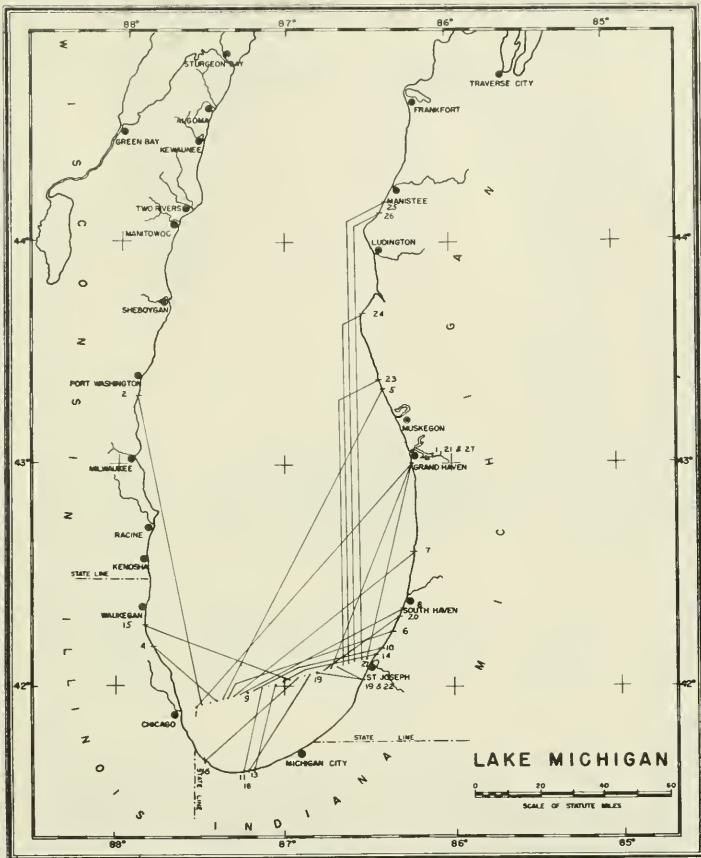


Figure 4.--Movements of bottles released along the transect, Chicago to St. Joseph, June 17, 1931.

Four bottles from the central part landed on the southern coast and three moved to the western coast; one was taken as far as 6 miles south of Port Washington, Wisconsin. Some of the eastern bottles had floated more than 60 miles along the Michigan shore within 26 days.

St. Joseph to Grand Haven to Nets

Sixteen bottles (94 percent) were recovered from the 17 released June 18 and 22, 1931 (table 5), along the Michigan shore (fig. 5).

Seven (44 percent) of the 16 bottles had retained the drag. The recoveries were recorded over a period of 5-93 days, an average of 32.6. The minimum distances of travel were 15-160 miles, an average of 80.6.

Thirteen bottles were scattered northward from $3\frac{1}{2}$ miles north of South Haven to the North Manitou Island--two landed to the southeast down to three-quarters of a mile north of Bridgman; and one floated to the western shore at the Great Lakes Naval Station (Illinois). The fact that eight bottles floated beyond 75

TABLE 5.-Release and recovery points of drift bottles released in 1931 between St. Joseph and Grand Haven, Michigan
(June 18--13 stations), and between Grand Haven and nets (June 22--4 stations)

Station number	Station of release			Recoveries			Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	
June 18							
28	42° 17.5'	86° 37.5'	August 19	41° 56.7'	86° 35.1'	62	24
29	42° 17.5'	86° 37.5'	August 1	42° 19.2'	87° 49.0'	44	60
30	42° 23.3'	86° 41.7'	July 20	42° 17.0'	86° 21.2'	32	20
31	42° 23.3'	86° 41.7'	July 22	42° 26.9'	86° 15.2'	34	23
32	42° 28.0'	86° 39.3'	July 20	42° 59.6'	86° 13.7'	32	40
33	42° 32.0'	86° 36.7'	...	...	...	...	...
34	42° 36.3'	86° 34.5'	July 14	43° 2.7'	86° 15.5'	26	33
35	42° 40.1'	86° 32.2'	July 14	43° 51.8'	86° 26.5'	26	33
36	42° 44.4'	86° 29.8'	July 8	44° 13.3'	86° 26.9'	20	104
37	42° 48.5'	86° 27.3'	July 13	44° 47.3'	86° 4.8'	25	142
38	42° 52.4'	86° 25.1'	September 19	45° 7.3'	86° 3.8'	93	160
39	42° 57.0'	86° 22.8'	July 8	44 55.0'	86° 2.7'	20	140
40	43° 0.7'	86° 20.1'	June 23	43 14.7'	86° 21.6'	5	15
June 22							
41	43° 7.0'	86° 23.7'	July 8	44° 51.8'	86° 4.0'	20	127
42	43° 7.0'	86° 23.7'	July 15	45° 6.7'	86° 3.8'	27	144
43	43° 10.8'	86° 31.7'	July 18	44° 35.7'	86° 12.4'	30	100
44	43° 10.8'	86° 31.7'	July 14	44° 12.6'	86° 26.9'	26	No
Average Number of bottles	...	...	...	...	...	32.6	80.6
	...	...	...	...	...	16	16

¹ With drags, 7; without drags, 9.

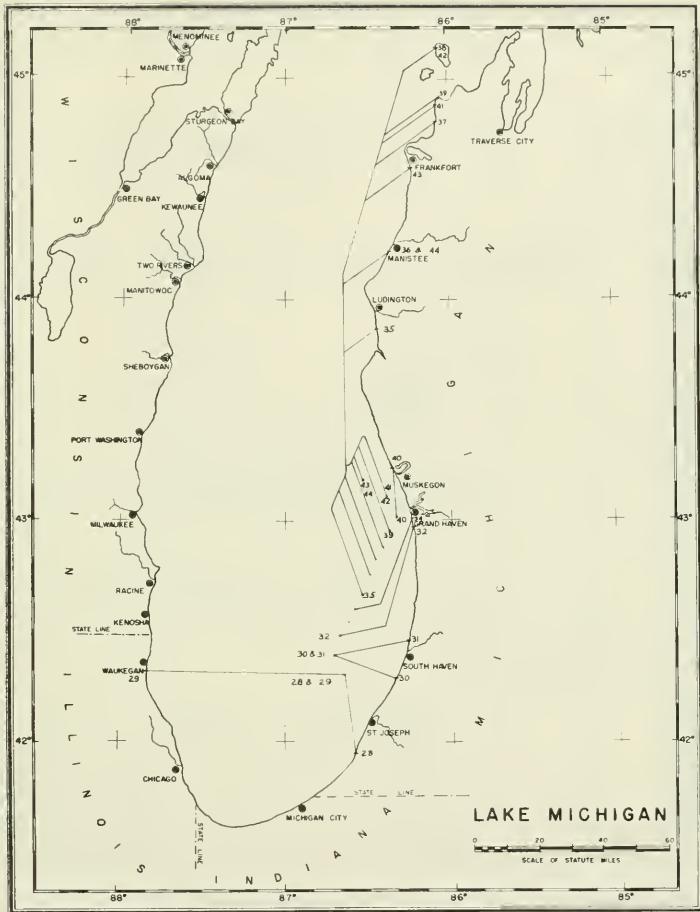


Figure 5.--Movements of bottles released between St. Joseph and Grand Haven, June 18, and between Grand Haven and nets, June 22, 1931.

miles along the Michigan shore within 30 days gives evidence of a strong northerly current.

Ludington to Nets and Manistee to Two Rivers

Four bottles were released off Ludington on June 23, 1931, and 27 were dropped on June 24 (table 6) along the Manistee to Two Rivers transect (fig. 6). Twenty-five bottles (81 percent) were recovered--24 during a period of

10-57 days and 1 in 298 days. The average was 27.3 days for 24 bottles and 38.1 days for 25; 16 of them were landed within 30 days. All of the bottles had drifted northeast from about 1 mile north of Walther League Camp near Arcadia to Cross Village (Weikamp Creek), except the last one (no. 75) that was found in Wisconsin off Centerville, 14 miles north of Sheboygan. The minimum distances of movement ranged from 18-136 miles and averaged 79.8 miles. Although the bottles moved

TABLE 6.—Release and recovery points of drift bottles released in 1931 off Ludington (June 23--4 stations), and on the transect, Manistee, Michigan, to Two Rivers, Wisconsin (June 24--27 stations).

[Asterisk indicates recovery in years beyond 1931; no. 56 was recovered April 17, 1932.]

Station number	Station of release		Date	Latitude	Longitude	Recoveries			Minimum miles covered	Drag attached ¹
	Latitude	Longitude				Days after release	Days after release			
<i>June 23</i>										
45	43° 55.6'	86° 36.5'	...							...
46	43° 55.6'	86° 36.5'	July 5	44° 56.4'	85° 50.8'	...	12	87	No	...
47	43° 55.0'	86.41.1'	...	...	...	...	...	...	...	...
48	43° 55.0'	86° 41.1'	...	...	...	...	...	...	...	...
<i>June 24</i>										
49	44° 14.8'	86° 23.2'	July 8	44° 53.6'	86° 4.4'	14	52	Yes		
	44° 14.7'	86° 25.7'	July 14	45° 23.4'	84° 54.7'	20	120	No		
50	44° 14.6'	86° 28.0'	July 4	44° 55.5'	85° 57.9'	10	55	Yes		
51	44° 14.4'	86° 30.3'	July 21	44° 54.3'	85° 58.4'	27	58	Yes		
52	44° 14.0'	86° 32.8'	July 12	45° 12.4'	85° 32.3'	18	86	No		
53	44° 13.8'	86° 35.3'	July 15	45° 1.5'	85° 45.9'	21	70	No		
54	44° 13.6'	86° 37.8'	July 22	44° 59.5'	85° 46.7'	28	72	No		
55	44° 13.4'	86° 40.4'	April 17*	45° 16.0'	85° 23.0'	298	98	No		
56	44° 13.3'	86° 43.0'	August 6	45° 22.9'	84° 55.8'	43	128	No		
57	44° 13.1'	86° 45.5'	July 22	45° 4.9'	86° 2.0'	28	78	Yes		
58	44° 12.9'	86° 47.9'	July 26	44° 54.3'	85° 59.6'	32	65	No		
59	44° 12.6'	86° 50.3'	July 15	44° 56.4'	85° 49.8'	21	76	Yes		
60	44° 12.4'	86° 52.9'	...	...	...	...	...	...
61	44° 12.3'	86° 55.2'	July 25	45° 36.0'	85° 1.6'	31	136	No		
62	44° 12.0'	86° 56.8'	July 13	44° 39.5'	86° 15.2'	19	57	Yes		
63	44° 11.8'	86° 58.2'	July 13	44° 38.3'	86° 14.4'	19	57	No		
64	44° 11.5'	87° 1.9'	July 29	45° 22.9'	84° 55.8'	36	136	Yes		
65	44° 11.5'	87° 4.7'	August 1	45° 22.5'	85° 8.3'	38	126	No		
66	44° 10.9'	87° 7.8'	July 15	44° 37.3'	86° 13.8'	21	54	Yes		
67	44° 10.7'	87° 10.7'	...	...	...	...	...	...
68	44° 10.5'	87° 13.6'	July 23	44° 54.3'	85° 58.4'	29	79	No		
69	44° 10.3'	87° 16.3'	August 2	44° 55.0'	85° 57.7'	39	81	No		
70	44° 10.0'	87° 18.5'	July 28	44° 34.4'	86° 13.7'	34	60	No		
71	44° 9.6'	87° 22.6'	July 24	44° 30.8'	86° 14.0'	30	59	No		
72	44° 9.4'	87° 24.5'	July 23	44° 56.8'	85° 56.3'	29	88	No		
73	44° 9.3'	87° 27.8'	...	...	...	...	...	...
74	44° 8.9'	87° 30.7'	August 20	43° 55.3'	87° 44.0'	18	79.8	...		
75	44° 8.6'	...	...	...	...	...	25	38.1	...	
<i>Average</i>		...	...	...	...	...	25	79.8	...	
<i>Number of bottles</i>		...	...	...	...	...

¹ With drags, 9; without drags, 16.

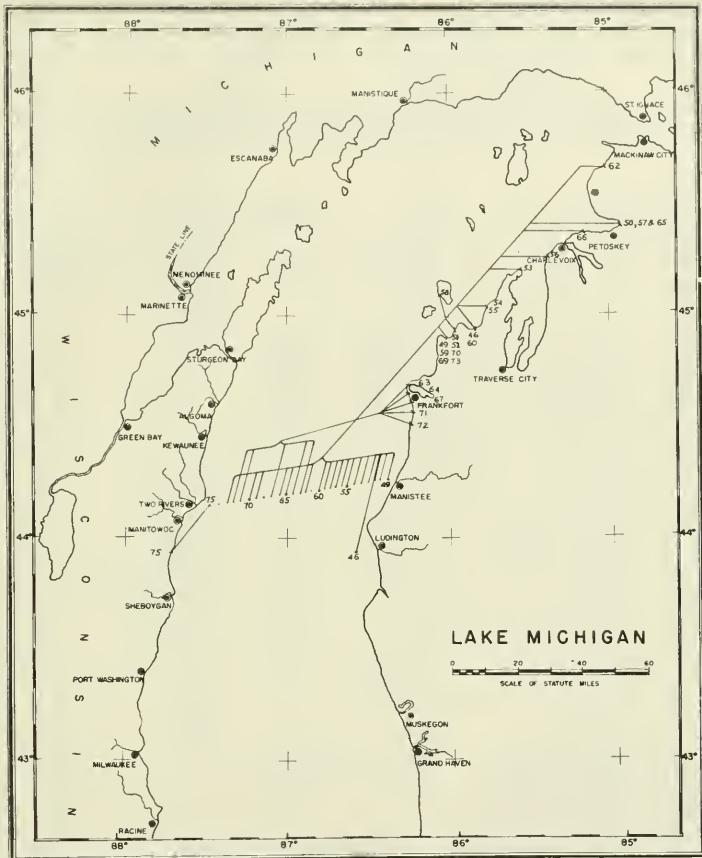


Figure 6.--Movements of bottles released off Ludington, June 23, and along the transect, Manistee to Two Rivers, June 24, 1931.

northward none had entered Traverse Bay or reached the Straits of Mackinaw. Nine (36 percent) of the bottles retained their drags.

Sheboygan to Sheboygan Reef to Racine

Forty-two bottles (table 7) were released June 26 and 27, 1931, in Wisconsin from Sheboygan to Sheboygan Reef to Racine (fig. 7). Of the 29 (69 percent) bottles recovered 11 moved northeast, 7 southeast, 3 east, 7 southwest, and 1 northwest. Twenty-one bottles that crossed the lake floated 37-124 minimum

miles, an average of 60.7, and were scattered along the Michigan shore from 7 miles north of Holland to 3 miles southwest of Good Harbor. It is unusual that 18 of these bottles had moved to the same extended area across the lake. The other eight bottles ranged from Lake Forest, Illinois, to 9 miles north of Sheboygan, Wisconsin, and had floated from 2-55 miles, an average of 24.4. All but three of the bottles in Michigan were found in 32 days and all but one on the west coast in 61 days. Only six (23 percent) of 26 bottles kept the drag.

TABLE 7.--Release and recovery points of drift bottles released in 1931 from Sheboygan to Sheboygan Reef (June 26 and 27--17 stations) and from Sheboygan Reef to Racine (June 27--25 stations)

Station number	Station of release		Recoveries					Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
June 26								
76	43° 43.9'	87° 40.0'	August 26	43° 44.1'	87° 42.7'	61	2	No
77	43° 42.7'	87° 38.0'	...	...	...	...	...	...
78	43° 41.7'	87° 36.1'	August 23	43° 52.9'	87° 43.2'	58	13	...
79	43° 40.5'	87° 34.3'	August 28	43° 18.8'	87° 54.4'	63	30	No
80	43° 39.6'	87° 32.4'	...	...	...	...	...	...
81	43° 38.4'	87° 30.1'	August 11	44° 56.4'	85° 50.8'	46	124	No
82	43° 37.2'	87° 27.7'	...	...	...	...	...	...
June 27								
83	43° 35.8'	87° 26.0'	...	...	...	...	...	...
84	43° 34.8'	87° 24.3'	July 30	43° 9.4'	86° 18.2'	34	62	Yes
85	43° 33.7'	87° 22.2'	...	...	...	...	...	...
86	43° 32.6'	87° 20.3'	July 24	43° 20.8'	86° 25.1'	28	49	No
87	43° 31.6'	87° 18.7'	July 29	42° 59.6'	86° 13.7'	33	66	Yes
88	43° 30.4'	87° 16.7'	...	...	...	...	...	...
89	43° 29.4'	87° 14.8'	July 29	42° 52.4'	86° 13.6'	33	67	Yes
90	43° 28.4'	87° 12.8'	July 28	43° 6.5'	86° 17.0'	32	54	Yes
91	43° 27.0'	87° 11.1'	...	...	...	...	...	...
92	43° 26.0'	87° 9.5'	July 27	43° 10.8'	86° 19.3'	31	46	?
93	43° 24.8'	87° 11.0'	...	...	...	...	...	...
94	43° 23.5'	87° 11.8'	July 29	43° 32.3'	86° 29.5'	33	37	No
95	43° 21.6'	87° 13.4'	...	...	...	...	...	...
96	43° 20.4'	87° 14.8'	...	...	...	...	...	...
97	43° 18.7'	87° 15.7'	July 27	43° 23.0'	86° 26.4'	31	43	No
98	43° 17.3'	87° 17.2'	July 27	43° 13.3'	86° 20.3'	31	48	?
99	43° 16.6'	87° 18.4'	July 21	43° 38.7'	86° 32.9'	25	46	No
100	43° 14.0'	87° 19.5'	September 30	44° 3.2'	86° 30.9'	96	68	No
101	43° 12.6'	87° 20.8'	...	...	...	...	...	...
102	43° 11.1'	87° 22.0'	July 22	43° 36.2'	86° 32.3'	26	50	No
103	43° 9.4'	87° 24.5'	July 20	43° 21.7'	86° 25.3'	24	51	Yes
104	43° 7.8'	87° 25.5'	July 27	43° 9.9'	86° 18.8'	31	57	No
105	43° 6.3'	87° 26.7'	August 28	42° 57.5'	87° 50.4'	63	23	No
106	43° 4.5'	87° 28.1'	July 31	43° 30.5'	86° 32.4'	35	68	No
107	43° 3.9'	87° 29.5'	July 27	43° 9.7'	86° 18.4'	31	59	No
108	43° 1.3'	87° 30.7'	July 28	43° 33.4'	86° 30.7'	32	61	No
109	42° 59.7'	87° 31.9'	August 25	42° 15.5'	87° 49.3'	60	55	No
110	42° 58.4'	87° 33.2'	July 30	43° 25.7'	86° 26.8'	34	63	No
111	42° 57.2'	87° 34.6'	July 30	43° 25.7'	86° 26.8'	34	65	No
112	42° 55.5'	87° 35.6'	...	...	...	...	...	...
113	42° 53.9'	87° 37.1'	August 22	42° 27.4'	87° 47.6'	57	33	No
114	42° 52.2'	87° 38.1'	August 27	42° 36.8'	87° 49.3'	62	21	Yes
115	42° 50.5'	87° 39.2'	September 26	43° 49.7'	86° 25.9'	92	90	No
116	42° 49.1'	87° 40.3'	...	...	...	...	...	...
117	42° 47.4'	87° 41.8'	July 11	42° 32.0'	87° 48.8'	15	18	No
Average Number of bottles	...	...	...	...	...	42.4	50.6	...
	...	...	...	...	...	29	29	...

¹With drags, e; without drags, 20.

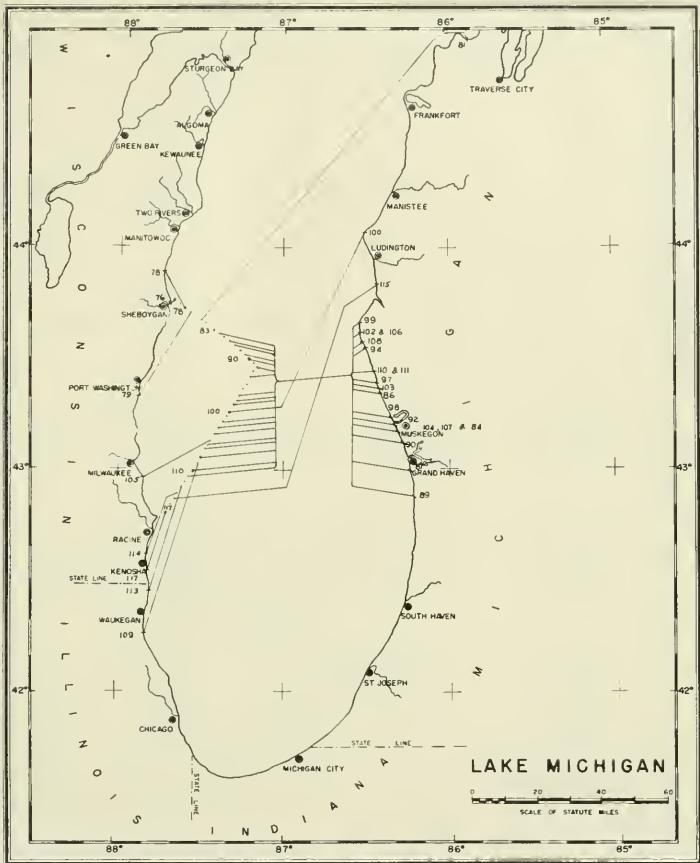


TABLE 8.--Release and recovery points of drift bottles released June 30,¹ 1931, at 30 stations on the transect, Waukegan, Illinois, to St. Joseph, Michigan

Station number	Station of release			Recoveries			Days after release	Minimum miles covered	Drag attached
	Latitude	Longitude	Date	Latitude	Longitude				
118	42° 21.4'	87° 46.6'	July 5	42° 14.7'	87° 48.9'	5	7	Yes	
119	42° 20.8'	87° 43.6'	August 11	43° 40.7'	87° 42.8'	42	92	No	
120	42° 20.4'	87° 41.3'	August 13	43° 44.1'	87° 42.7'	44	95	No	
121	42° 20.0'	87° 39.0'	August 26	42° 35.2'	87° 48.8'	57	18	No	
122	42° 19.6'	87° 36.7'	...	...	...	...	...	...	...
123	42° 19.4'	87° 34.1'	August 12	42° 26.4'	87° 48.1'	43	15	No	
124	42° 19.0'	87° 32.3'	...	...	...	...	...	...	...
125	42° 18.7'	87° 29.3'	...	...	...	...	...	...	...
126	42° 18.3'	87° 27.0'	October 2	42° 3.8'	86° 31.2'	94	130	No	
127	42° 17.7'	87° 24.9'	August 24	42° 10.3'	87° 46.4'	55	20	No	
128	42° 17.2'	87° 22.6'	August 25	43° 11.5'	87° 53.7'	56	68	No	
129	42° 16.6'	87° 21.4'	August 29	42° 35.0'	86° 13.5'	60	62	No	
130	42° 16.2'	87° 18.0'	August 29	42° 13.8'	86° 22.7'	60	49	No	
131	42° 15.8'	87° 15.7'	August 26	42° 1.8'	86° 31.1'	57	42	No	
132	42° 15.1'	87° 12.5'	August 26	41° 37.3'	87° 17.8'	57	44	No	
133	42° 14.7'	87° 10.4'	August 29	42° 57.6'	86° 14.1'	60	68	...	
134	42° 14.4'	87° 7.9'	July 29	42° 13.4'	86° 23.5'	29	40	No	
135	42° 13.9'	87° 5.7'	August 14	42° 0.7'	86° 33.4'	45	32	No	
136	42° 13.4'	87° 3.2'	...	...	...	...	...	...	...
137	42° 13.0'	87° 0.9'	August 10	41° 37.3'	87° 17.8'	41	44	No	
138	42° 12.6'	86° 58.8'	August 13	41° 44.6'	86° 52.2'	44	33	No	
139	42° 12.0'	86° 56.4'	August 13	41° 40.7'	87° 29.1'	44	44	Yes	
140	42° 11.6'	86° 54.0'	August 11	41° 40.3'	87° 2.8'	42	37	Yes	
141	42° 11.3'	86° 51.7'	August 13	41° 39.3'	87° 6.3'	44	39	No	
142	42° 10.7'	86° 49.5'	...	...	...	...	...	...	...
143	42° 10.4'	86° 47.0'	August 21	41° 42.7'	87° 31.6'	52	50	Yes	
144	42° 10.0'	86° 44.6'	August 1	42° 13.8'	87° 48.4'	32	56	No	
145	42° 9.5'	86° 42.4'	August 14	42° 28.1'	87° 47.8'	45	60	No	
146	42° 8.9'	86° 39.0'	August 25	41° 41.5'	86° 39.9'	56	36	No	
147	42° 8.4'	86° 36.8'	...	...	...	...	...	...	...
Average	...	...	...	...	...	48.5	49.2	...	...
Number of bottles	...	...	...	...	...	24	24	...	...

¹ With drags; 4^o without drags, 19.

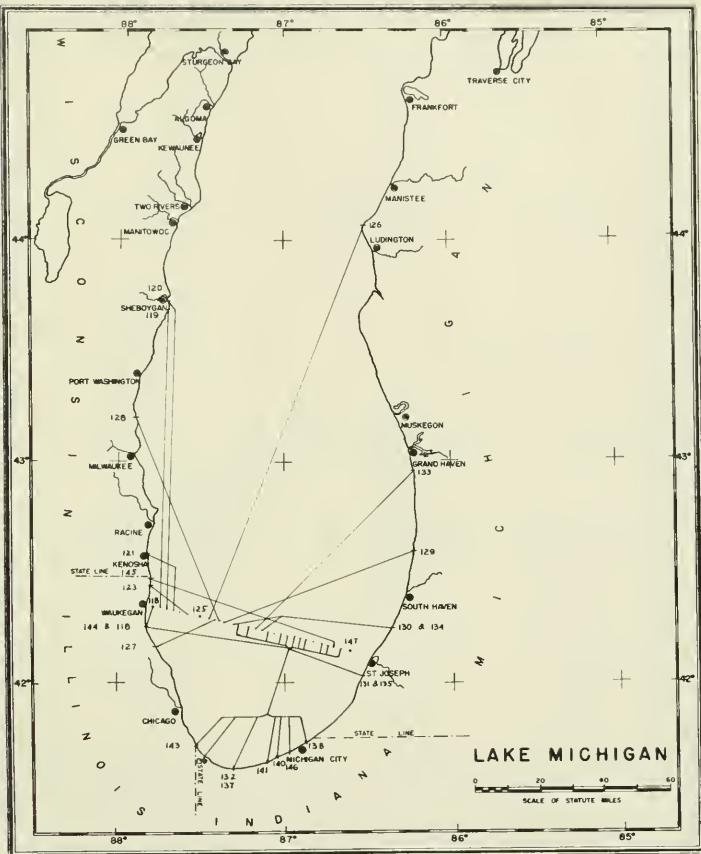


Figure 8.--Movements of bottles released along the transect, Waukegan to St. Joseph, June 30, 1931.

Only three bottles moved more than 90 miles; all others were taken within 70 miles. Ten of the bottles were recovered in 41-45 days and nine between 55 and 60 days. Most of the former were found on the south and west shores; the latter were distributed on all coasts but mostly on the east shore. Only four (17 percent) of the 23 bottles retained the drag.

Racine to Grand Haven

Of the 36 bottles (table 9) released on July 17, 1931, along the transect (fig. 9) 27 (75

percent) were recovered. Only six (22 percent) of these bottles held the drags. The bottles had covered minimum distances from 3-121 miles, an average of 44.2, during a period of 12-96 days, an average of 46.3. Half of the bottles from the western part of the transect and all from the eastern landed on the Michigan shore, a total of 20. Along the western shore, three bottles scattered northwest as far as Sheboygan, Wisconsin, and four drifted southwest as far as $1\frac{1}{2}$ miles south of Highland Park, Illinois. On the eastern shore, eight were distributed southeast down to St. Joseph,

TABLE 9.--Release and recovery points of drift bottles released July 17, 1931, at 36 stations on the transect,
Racine, Wisconsin, to Grand Haven, Michigan¹

Station number	Station of release			Recoveries				Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
148	42° 44' 8"	87° 43.5'	August 2	43° 31.3'	87° 48.0'	16	54	Yes
149	42° 45.0'	87° 41.3'	September 14	43° 3.4'	87° 52.8'	59	23	No
150	42° 45.6'	87° 38.2'	October 21	44° 3.4'	86° 30.6'	96	106	No
151	42° 46.1'	87° 35.9'	October 2	43° 21.7'	86° 25.3'	77	72	No
152	42° 46.8'	87° 33.5'	...	...	...	...	...	...
153	42° 47.4'	87° 30.9'	August 31	43° 12.2'	86° 20.0'	45	67	No
154	42° 48.1'	87° 28.6'	September 17	43° 45.7'	87° 42.5'	62	67	Yes
155	42° 48.7'	87° 26.6'	...	...	...	...	...	...
156	42° 49.0'	87° 24.2'	...	...	...	...	...	...
157	42° 49.6'	87° 21.8'	August 20	42° 10.0'	87° 45.9'	34	49	No
158	42° 50.2'	87° 19.4'	August 18	42° 39.5'	87° 48.8'	32	27	No
159	42° 50.7'	87° 16.8'	August 20	42° 22.6'	87° 59.0'	34	41	No
160	42° 51.3'	87° 14.4'	August 27	42° 24.7'	87° 48.2'	41	40	Yes
161	42° 51.9'	87° 11.6'	October 2	42° 28.4'	86° 14.5'	77	121	No
162	42° 52.3'	87° 9.8'	October 11	43° 33.0'	86° 30.0'	86	59	No
163	42° 52.8'	87° 7.7'	...	...	...	...	...	...
164	42° 53.4'	87° 5.2'	October 8	42° 44.5'	86° 12.1'	83	45	No
165	42° 54.1'	87° 0.7'	September 26	43° 44.9'	86° 27.7'	71	65	No
166	42° 54.7'	86° 58.3'	...	...	...	...	...	...
167	42° 55.3'	86° 56.0'	...	...	...	...	...	...
168	42° 55.7'	86° 53.8'	August 30	42° 6.4'	86° 30.0'	44	60	No
169	42° 56.3'	86° 51.3'	...	...	...	...	...	...
170	42° 57.0'	86° 48.8'	August 29	42° 6.7'	86° 29.8'	43	60	No
171	42° 57.5'	86° 46.3'	August 5	43° 3.6'	86° 15.4'	19	27	No
172	42° 58.3'	86° 43.0'	September 14	43° 3.6'	86° 15.4'	59	26	No
173	42° 58.8'	86° 40.5'	...	...	...	...	...	...
174	42° 59.3'	86° 38.0'	August 29	42° 23.4'	86° 17.7'	43	46	No
175	42° 59.7'	86° 35.8'	August 17	43° 2.7'	86° 16.6'	31	18	Yes
176	43° 0.0'	86° 33.7'	August 30	42° 53.5'	86° 13.3'	44	19	Yes
177	43° 0.5'	86° 31.3'	July 29	42° 45.6'	86° 13.3'	12	21	No
178	43° 1.2'	86° 28.8'	August 30	43° 1.6'	86° 16.1'	44	12	No
179	43° 1.8'	86° 26.4'	...	...	...	...	...	...
180	43° 2.1'	86° 24.2'	July 29	42° 43.2'	86° 13.1'	12	24	No
181	43° 2.6'	86° 21.8'	August 10	42° 38.7'	86° 14.0'	24	29	No
182	43° 3.0'	86° 19.9'	August 8	43° 2.7'	86° 15.5'	22	3	Yes
183	43° 3.3'	86° 16.2'	August 26	43° 16.0'	86° 23.0'	3	13	No
Average	...	...	...	...	...	46.3	44.2	...
Number of bottles	...	...	...	...	...	27	27	...

¹ With drags; 6; without drags; 21.

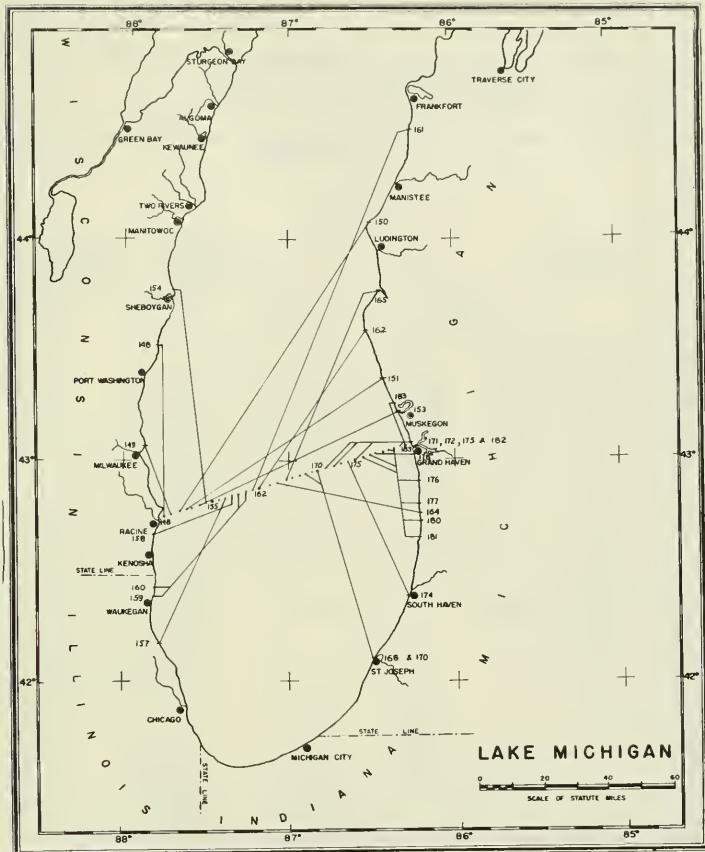


Figure 9.--Movements of bottles released along the transect, Racine to Grand Haven, July 17, 1931.

five moved eastward near Grand Haven, and seven were scattered northeast up to Arcadia. All five bottles recovered north of Muskegon had traveled between 59 and 121 miles and were not found until 71-96 days. These bottles perhaps had altered their direction after a change of the wind.

Frankfort to Two Rivers to Nets

Twenty bottles (53 percent) were returned of the 38 (table 10) released along the transect on July 22 and near the nets off Two Rivers,

July 23, 1931 (fig. 10). Eight (42 percent) of 19 bottles still possessed their drags. Seventeen bottles were recovered in 5-122 days, an average of 33.8, and the other three were found in 1933, 1935, and 1936. Minimum distances were 9-86 miles, an average of 37.0, for 17 bottles; the miles for the other 3 ranged from 104-185, an average of 134.7.

Thirteen bottles including four from the western part of the transect moved northeast and one southeast. They scattered from about $1\frac{1}{2}$ miles north of Arcadia to the islands of

TABLE 10.--Release and recovery points of drift bottles released in 1931 on the transect,
Frankfort, Michigan, to Two Rivers, Wisconsin (July 22--34 stations), and near
the nets off Two Rivers (July 23--4 stations)

[Asterisk indicates recovery in years beyond 1931; no. 200 was recovered on July 22, 1936, no. 204 on April 8,
1935, and no. 217 on June 17, 1933]

Station of release			Recoveries					Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
July 22								
184	44° 37.2'	86° 15.8'	August 4	44° 51.1'	86° 3.8'	13	20	No
185	44° 36.4'	86° 20.2'	...	...	...	...	...	...
186	44° 35.6'	86° 22.4'	August 11	44° 31.3'	86° 13.7'	20	9	Yes
187	44° 34.7'	86° 25.0'	August 5	44° 42.1'	86° 13.9'	14	12	Yes
188	44° 33.8'	86° 27.0'	August 20	44° 56.4'	86° 50.8'	29	46	Yes
189	44° 33.0'	86° 29.6'	July 27	44° 37.3'	86° 13.8'	5	14	No
190	44° 32.3'	86° 30.9'	August 1	44° 50.0'	86° 2.7'	10	39	Yes
191	44° 31.3'	86° 33.5'	August 30	44° 56.8'	85° 56.3'	39	45	No
192	44° 30.5'	86° 35.8'	...	...	...	...	...	...
193	44° 29.5'	86° 38.2'	...	...	...	...	...	...
194	44° 28.6'	86° 40.5'	September 19	45° 6.0'	86° 3.2'	59	54	No
195	44° 27.8'	86° 42.7'	...	...	...	...	...	...
196	44° 26.9'	86° 45.3'	...	...	...	...	...	...
197	44° 26.3'	86° 47.9'	August 9	45° 22.7'	85° 49.4'	18	80	No
198	44° 25.3'	86° 50.4'	...	...	...	...	...	...
199	44° 24.5'	86° 51.6'	...	...	...	...	...	...
200	44° 23.7'	86° 54.0'	July 22*	45° 37.0'	85° 38.0'	1,825	104	No
201	44° 22.6'	86° 55.2'	...	...	...	...	...	...
202	44° 21.8'	86° 58.8'	...	...	...	...	...	...
203	44° 21.0'	87° 1.1'	August 9	44° 58.1'	85° 55.5'	18	69	Yes
204	44° 20.1'	87° 3.5'	April 8*	45° 58.0'	84° 32.0'	1,355	185	?
205	44° 19.4'	87° 5.6'	November 21	45° 53.0'	86° 19.8'	122	115	No
206	44° 17.6'	87° 8.0'	August 27	44° 21.6'	87° 32.1'	36	20	No
207	44° 17.4'	87° 10.6'	...	...	...	...	...	...
208	44° 16.7'	87° 12.8'	...	...	...	...	...	...
209	44° 16.0'	87° 15.1'	...	...	...	...	...	...
210	44° 15.0'	87° 17.3'	...	...	...	...	...	...
211	44° 14.3'	87° 19.5'	August 13	44° 12.7'	87° 30.3'	21	11	Yes
212	44° 13.3'	87° 20.5'	August 20	43° 45.7'	87° 42.5'	29	38	Yes
213	44° 12.6'	87° 22.6'	...	...	...	...	...	...
214	44° 11.8'	87° 25.0'	...	...	...	...	...	...
215	44° 10.9'	87° 27.2'	August 24	44° 7.9'	87° 36.2'	33	10	No
216	44° 10.2'	87° 29.3'	...	...	...	...	...	...
217	44° 9.4'	87° 31.6'	June 17*	45° 0.0'	86° 8.0'	695	86	Yes
July 23								
218	44° 0.3'	87° 23.4'	...	...	...	...	...	...
219	44° 0.3'	87° 23.4'	October 4	43° 28.5'	87° 48.0'	74	42	No
220	43° 55.7'	87° 18.5'	August 25	43° 30.8'	87° 47.5'	34	34	No
221	43° 55.7'	87° 18.5'	...	...	...	...	...	...
Average Number of bottles	...	...	...	...	...	33.8	37.0	...
	...	...	...	...	...	17	17	...

¹ With drags, 8; without drags, 11; no data, 1.

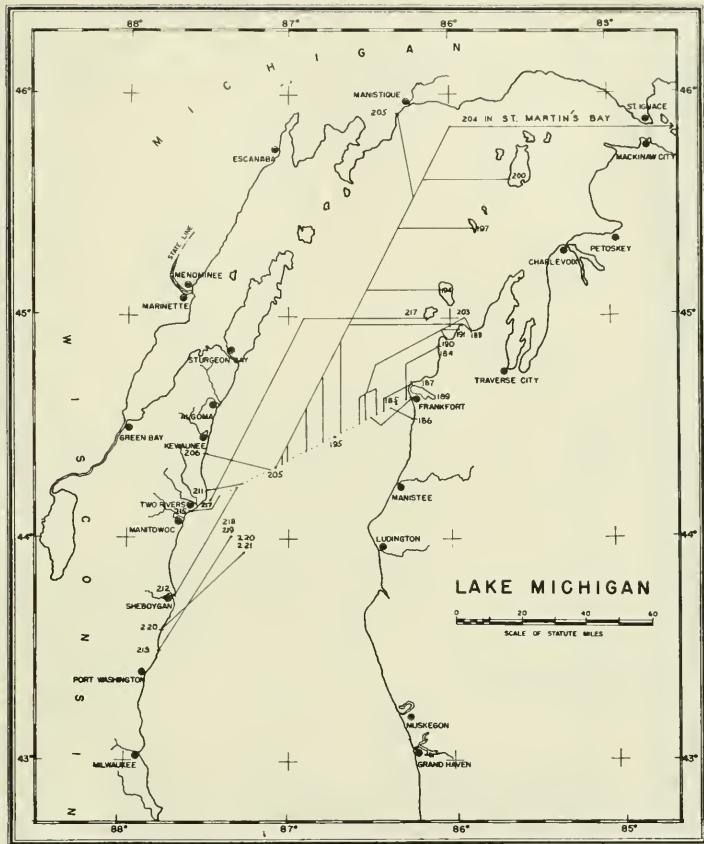


Figure 10.--Movements of bottles released along the transect, Frankfort to Two Rivers, July 22, and near the nets off Two Rivers, July 23, 1931.

northeastern Lake Michigan to south of Thompson; one was found in St. Martins Bay, Lake Huron. Only six bottles were recovered beyond Pyramid Point and three were discovered more than a year after release. One was found in Lake Huron 3.7 years later and two others in Lake Michigan after 1.9 and 5 years. Only five bottles were collected southwest and one northwest; they extended from 7 miles north of Port Washington to 7 miles south of Kewaunee.

Frankfort to Kewaunee

Only seven (75 percent) of the 28 bottles dropped on July 30, 1931, were recovered along the transect (fig. 11 and table 11), and six of them (86 percent) had lost their drags. These few bottles were discovered in 10-80 days, an average of 36.4, and at a distance of 13-98 miles, an average of 55.1. Two bottles floated northeast, two northwest, and three southwest. The most northerly recovery was

TABLE 11.—Release and recovery points of drift bottles released July 30, 1931, at 28 stations on the transect,
Frankfort, Michigan, to Keweenaw, Wisconsin

Station number	Station of release			Recoveries				Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
222	44° 36.3'	86° 19.1'	August 27	43° 39.1'	87° 42.9'	28	96	No
223	44° 36.0'	86° 21.5'	...	...	...	...	...	***
224	44° 35.8'	86° 24.0'	...	...	...	...	...	***
225	44° 35.3'	86° 26.8'	...	...	...	...	...	***
226	44° 35.0'	86° 29.3'	...	...	...	...	...	***
227	44° 34.8'	86° 32.1'	...	...	...	...	...	***
228	44° 34.5'	86° 34.6'	...	...	...	...	...	***
229	44° 34.3'	86° 37.2'	...	...	...	...	...	***
230	44° 33.8'	86° 39.8'	...	...	...	...	...	***
231	44° 33.6'	86° 52.5'	October 18	45° 52.3'	86° 19.4'	80	92	No
232	44° 33.3'	86° 45.3'	...	...	...	...	...	***
233	44° 32.9'	86° 47.7'	...	...	...	...	...	***
234	44° 32.6'	86° 49.5'	September 19	45° 7.3'	86° 3.8'	51	54	No
235	44° 32.4'	86° 52.4'	...	...	...	...	...	***
236	44° 32.0'	86° 54.9'	August 20	43° 18.8'	87° 54.4'	21	98	No
237	44° 31.7'	86° 57.4'	...	...	...	...	...	***
238	44° 31.3'	87° 0.1'	...	...	...	...	...	***
239	44° 30.9'	87° 3.1'	...	...	...	...	...	***
240	44° 30.5'	87° 5.3'	...	...	...	...	...	***
241	44° 30.2'	87° 8.3'	...	...	...	...	...	***
242	44° 29.9'	87° 11.1'	...	...	...	...	...	***
243	44° 29.5'	87° 13.8'	...	...	...	...	...	***
244	44° 29.0'	87° 16.3'	...	...	...	...	...	***
245	44° 28.7'	87° 18.8'	...	...	...	...	...	***
246	44° 28.5'	87° 2.6'	August 9	44° 14.3'	87° 32.2'	10	19	Yes
247	44° 28.3'	87° 22.9'	August 29	44° 40.9'	87° 21.3'	30	14	No
248	44° 27.9'	87° 25.4'	...	...	...	...	...	***
249	44° 27.6'	87° 27.3'	September 3	44° 39.3'	87° 22.5'	35	13	No
Average Number of bottles	***	***	***	***	36.4	55.1	***	
	***	***	***	***	7	7	***	

¹ With drags, 1; without drags, 6.

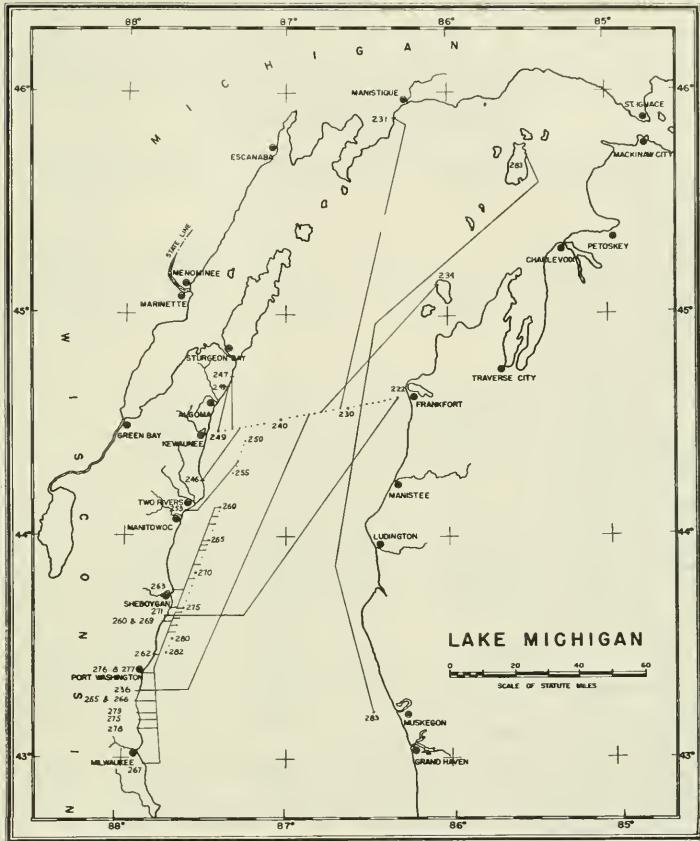


Figure 11.--Movements of bottles released along the transect, Frankfort to Kewaunee, July 30, from Kewaunee to Port Washington, August 12, and off Muskegon, August 17, 1931.

near Thompson, Michigan, and the most southerly one about 7 miles south of Port Washington, Wisconsin.

Kewaunee to Port Washington

Thirty-three bottles (table 12) were thrown overboard along the Wisconsin shore (fig. 11) on August 12, 1931, and one on August 17 off Muskegon. The last bottle was recovered 320 days later and 190 miles distant at Beaver Island. Fifteen bottles (44 percent) and eight (24 percent) with drags were recovered. Dur-

ing a period of 8-48 days, averaging 15.6, the 14 bottles dropped August 12 had floated minimum distances along Wisconsin from 12-67 miles, averaging 34.4. All of them had floated southwest from about 3 miles south of Two Rivers to Cudahy, Wisconsin.

Escanaba to Menominee

Twenty-five bottles (table 13) were released in Green Bay from Escanaba to Menominee on May 9, 1932 (fig. 12). Sixteen (64 percent) were discovered along the shore or in the

TABLE 12.--Release and recovery points of drift bottles released in 1931 from Kewaunee, Wisconsin, to Port Washington, Wisconsin (August 12--33 stations), and off Muskegon, Michigan (August 17--1 station).

[Asterisk indicates recovery in year beyond 1931; no. 283 was recovered August 3, 1932.]

Station of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
August 12								
250	44° 25.3'	87° 17.2'	...	...	...	...	...	...
251	44° 23.7'	87° 18.1'	...	...	...	...	...	...
252	44° 21.9'	87° 18.8'	...	...	...	...	...	...
253	44° 19.9'	87° 19.7'	September 27	44° 7.2'	87° 38.1'	48	23	No
254	44° 18.5'	87° 20.8'	...	...	...	...	...	...
255	44° 16.7'	87° 21.9'	...	...	...	...	...	...
256	44° 14.8'	87° 22.6'	...	...	...	...	...	...
257	44° 13.0'	87° 23.8'	...	...	...	...	...	...
258	44° 10.5'	87° 24.6'	...	...	...	...	...	...
259	44° 9.2'	87° 25.8'	...	...	...	...	...	...
260	44° 7.1'	87° 26.9'	August 24	43° 35.8'	87° 45.4'	12	40	Yes
261	44° 5.5'	87° 27.2'	...	...	...	...	...	...
262	44° 3.6'	87° 27.7'	August 28	43° 27.2'	87° 48.0'	16	47	No
263	44° 1.9'	87° 28.2'	August 28	43° 45.7'	87° 42.5'	16	26	No
264	44° 0.0'	87° 29.7'	...	...	...	...	...	...
265	43° 58.2'	87° 30.6'	August 27	43° 14.8'	87° 55.0'	15	54	No
266	43° 56.7'	87° 31.8'	August 22	43° 14.8'	87° 55.0'	10	52	Yes
267	43° 54.8'	87° 32.2'	August 28	42° 57.5'	87° 50.4'	16	67	Yes
268	43° 53.2'	87° 33.3'	...	...	...	...	...	...
269	43° 51.3'	87° 34.4'	September 2	43° 35.2'	87° 45.9'	10	21	No
270	43° 49.5'	87° 35.2'	...	...	...	...	...	...
271	43° 47.7'	87° 35.8'	August 22	43° 39.9'	87° 42.6'	12	12	Yes
272	43° 45.8'	87° 37.1'	...	...	...	...	...	...
273	43° 44.0'	87° 38.3'	...	...	...	...	...	...
274	43° 42.3'	87° 39.0'	...	...	...	...	...	...
275	43° 40.0'	87° 40.3'	August 20	43° 10.2'	87° 52.9'	8	37	Yes
276	43° 38.3'	87° 41.1'	August 27	43° 21.6'	87° 53.0'	15	22	No
277	43° 36.7'	87° 42.0'	August 25	43° 21.6'	87° 53.0'	13	20	Yes
278	43° 34.6'	87° 43.0'	August 21	43° 7.8'	87° 54.1'	9	34	No
279	43° 33.0'	87° 43.9'	August 21	43° 11.5'	87° 53.7'	9	27	Yes
280	43° 31.2'	87° 45.2'	...	...	...	...	...	...
281	43° 29.0'	87° 46.0'	...	...	...	...	...	...
282	43° 27.5'	87° 47.1'	...	...	...	...	...	...
August 17								
283	43° 12.1'	86° 30.0'	August 3*	45° 42.5'	85° 29.5'	320	190	Yes
Average	...	...	...	...	...	² 15.6	² 34.4	...
Number of bottles	...	...	...	...	...	14	14	...

¹ With drags, 8; without drags, 7.

² Based on recoveries in year of release.

TABLE 13.--Release and recovery points of drift bottles released May 9, 1932, at 25 stations on an indirect transect,

Escanaba, Michigan, to Menominee, Michigan

[Asterisk indicates recovery in year beyond 1932; no. 285 was recovered on April 22, 1933, and no. 308 on May 10, 1933.]

Station number	Station of release			Recoveries				Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
286	45° 42.5'	87° 2.3'	...	45° 39.0'	87° 11.0'	...	...	...
285	45° 41.4*	87° 2.2*	April 22*	45° 42.0*	86° 54.0*	348	7	No
284	45° 39.6*	87° 1.9*	July 17	45° 45.0*	86° 59.0*	69	8	Yes
287	45° 37.9*	87° 1.8*	June 3	45° 45.0*	86° 59.0*	25	9	Yes
288	45° 36.2*	87° 1.7*	...	...	...	...	...	...
289	45° 32.7*	87° 1.5*	...	...	...	...	...	...
290	45° 31.7*	87° 2.5*	June 26	44° 59.0*	87° 38.0*	48	49	Yes
291	45° 29.8*	87° 3.8*	July 6	45° 9.0*	87° 16.0*	58	25	No
292	45° 28.2*	87° 4.8*	June 17	45° 29.0*	87° 16.0*	39	9	?
293	45° 26.6*	87° 5.7*	June 16	45° 13.5*	87° 31.0*	38	25	Yes
294	45° 24.9*	87° 7.2*	...	...	...	...	...	...
295	45° 23.3*	87° 8.1*	...	...	...	...	...	...
296	45° 21.7*	87° 9.4*	June 12	45° 7.0*	87° 36.0*	34	28	Yes
297	45° 20.3*	87° 11.4*	...	...	...	...	...	...
298	45° 19.2*	87° 13.1*	July 4	45° 21.0*	86° 57.0*	56	14	No
299	45° 18.0*	87° 15.0*	June 21	45° 29.0*	87° 16.0*	43	12	Yes
302	45° 16.7*	87° 16.7*	June 19	45° 21.0*	87° 24.0*	41	7	?
300	45° 16.5*	87° 18.5*	July 9	44° 53.5*	87° 26.5*	61	28	No
301	45° 14.7*	87° 20.5*	...	...	...	...	...	...
303	45° 13.4*	87° 22.7*	...	...	...	...	...	...
304	45° 12.4*	87° 24.5*	July 19	45° 31.0*	87° 17.0*	71	22	No
305	45° 11.4*	87° 26.3*	June 8	45° 17.5*	87° 26.0*	30	7	No
306	45° 10.4*	87° 28.0*	June 24	45° 4.5*	87° 16.5*	46	12	?
307	45° 88.0*	87° 30.2*	...	...	...	...	...	...
308	45° 7.7*	87° 32.5*	May 10*	45° 0.0*	87° 38.0*	397	11	No
Average	...	...	...	...	...	2 47.1	17.1	...
Number of bottles	...	...	...	...	...	14	16	...

¹ With drags, 6; without drags, 7; no data, 3.² Based on recoveries in year of release.

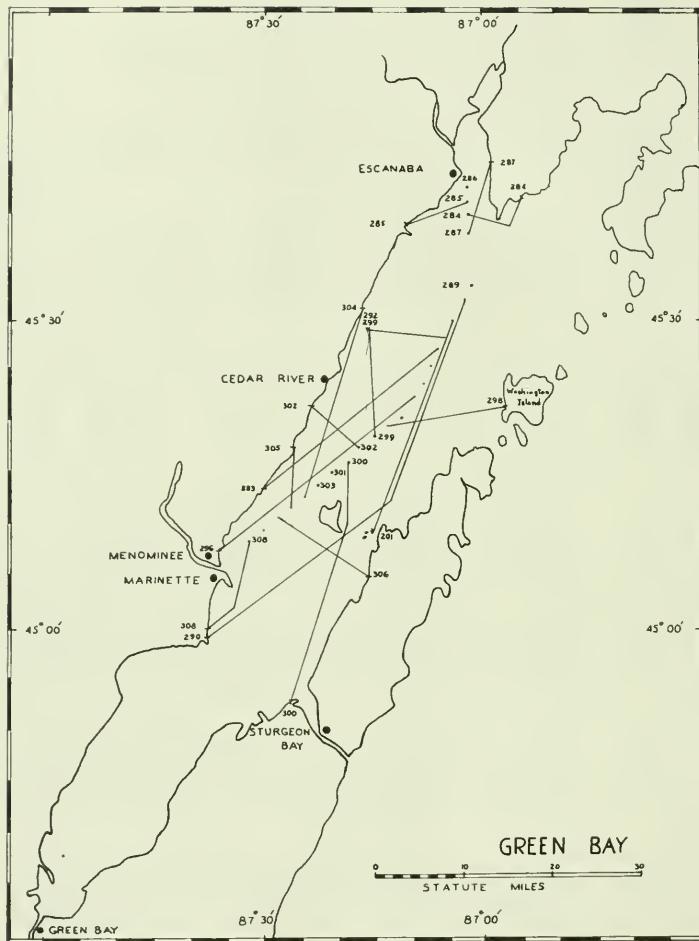


Figure 12.--Movement of bottles released along the transect, Escanaba to Menominee, May 9, 1932.

water at distances between 7 and 49 miles, an average of 17.1. Ten bottles had floated less than 15 miles. Two of the bottles were found at 348 and 397 days only 7 and 11 miles from release points; the other 14 were recovered between 25 and 71 days, an average of 47.1. Ten bottles landed along the western shore from 7 miles south of Marinette, Wisconsin, to 3 miles south of Ford River, Michigan,

and six on the eastern shore of Green Bay from Sherwood Pt. to opposite Escanaba. Six (46 percent) of 13 bottles kept their drags.

Menominee to Nets and Return

Nineteen bottles (66 percent) were recorded of the 29 (table 14) that were floated on May 17, 1932, off Menominee (fig. 13). Their minimum

TABLE 14.--Release and recovery points of drift bottles released May 17, 1932, at 29 stations from Menominee, Michigan to nets and return

[Asterisk indicates recovery in years beyond 1932; no. 317 was recovered on October 30, 1933, and no. 329 on October 29, 1933.]

Station number	Station of release			Recoveries				Minimum miles covered	Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release			
311	45° 5.0*	87° 34.6*	June 16	44° 50.5*	87° 52.5*	30	24	Yes	
309	45° 4.2*	87° 34.2*	June 24	45° 8.5*	87° 36.0*	38	6	Yes	
310	45° 3.3*	87° 33.7*	June 6	45° 6.0*	87° 36.0*	20	4	Yes	
312	45° 2.5*	87° 33.3*	***	45° 0.0*	87° 37.5*	***	4	Yes	
313	45° 1.6*	87° 33.0*	June 5	45° 0.0*	87° 37.5*	19	***	Yes	
314	45° 0.5*	87° 32.7*	***	45° 0.0*	88° 0.5*	37	34	***	No
315	44° 59.6*	87° 32.2*	June 23	44° 38.0*	87° 30.5*	5	5	Yes	
316	44° 58.8*	87° 31.9*	May 22	45° 3.5*	87° 30.5*	532	16	Yes	
317	44° 58.1*	87° 31.5*	October 30*	45° 9.5*	87° 19.5*	55	23	No	
318	44° 57.3*	87° 31.2*	July 11	45° 17.5*	87° 26.2*	28	6	Yes	
319	44° 56.3*	87° 30.8*	June 14	45° 0.0*	87° 35.5*	***	***	Yes	
320	44° 55.4*	87° 30.2*	***	45° 0.0*	87° 35.5*	70	22	?	
321	44° 55.0*	87° 29.7*	July 26	44° 47.5*	87° 35.0*	26	8	No	
322	44° 56.7*	87° 28.9*	June 12	44° 58.0*	87° 37.5*	***	***	Yes	
323	44° 57.6*	87° 28.4*	***	45° 13.0*	87° 29.0*	80	16	Yes	
324	44° 58.4*	87° 27.8*	August 5	45° 13.0*	87° 29.0*	***	***	Yes	
325	44° 59.5*	87° 27.3*	***	45° 58.0*	87° 37.5*	75	9	Yes	
326	45° 0.3*	87° 26.8*	July 31	44° 58.0*	87° 37.5*	24	16	Yes	
327	45° 3.1*	87° 22.0*	June 10	45° 13.5*	87° 9.5*	8	8	Yes	
328	45° 3.4*	87° 23.5*	May 25	45° 9.0*	87° 1.9*	531	12	Yes	
329	45° 3.8*	87° 25.0*	October 29*	45° 12.5*	87° 30.0*	37	9	Yes	
330	45° 4.0*	87° 26.1*	June 23	45° 6.0*	87° 36.0*	***	***	Yes	
331	45° 4.4*	87° 27.3*	***	45° 13.5*	87° 36.0*	***	***	Yes	
332	45° 4.7*	87° 28.5*	***	45° 13.5*	87° 36.0*	***	***	Yes	
333	45° 4.9*	87° 29.8*	***	45° 13.5*	87° 36.0*	***	***	Yes	
334	45° 5.2*	87° 31.0*	***	45° 13.5*	87° 37.5*	34	8	Yes	
335	45° 5.5*	87° 32.5*	June 20	45° 0.0*	87° 19.5*	217	12	No	
336	45° 5.8*	87° 33.4*	December 20	45° 2.0*	87° 19.5*	***	***	Yes	
337	45° 6.0*	87° 34.8*	***	45° 2.0*	87° 19.5*	***	***	Yes	
Average	***	***	***	***	***	2 36.6	12.7	***	
Number of bottles	***	***	***	***	***	16	19	***	

¹ With drags, 14; without drags, 4; no data, 1.² Excludes 1 bottle recovered in December 1932 and 2 recovered in 1933.

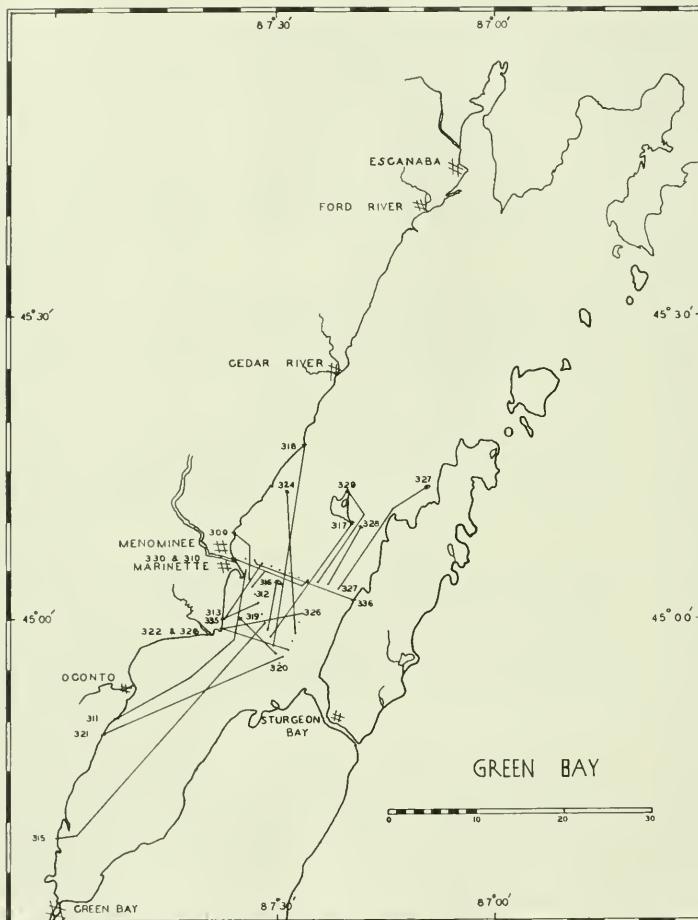


Figure 13.--Movements of bottles released from Menominee to nets and return, May 17, 1932.

miles ranged from 4-34, and averaged 12.7. Three of the bottles were found after 217, 531, and 532 days; the others were collected in 3-80 days, average of 36.6. Two were picked off pound nets and one from a spar buoy. Fourteen bottles (78 percent) retained their drags. It is unusual that the same number of six bottles

landed southwest, northwest, and northeast. These different movements demonstrate that the current does not always flow northward in Green Bay. Along the western coast the bottles were found from Suamico, Wisconsin, to Pt. Rochereau and along the eastern shore from Egg Harbor, Wisconsin, to Little Sister Island.

Two Rivers to Frankfort

Seventy-six bottles (table 15) were released June 2, 1932, along the transect from Two Rivers to Frankfort (fig. 14) and 57 (75 percent) were recovered. Twenty-one (41 percent) of 51 bottles had retained their drags. The bottles were found in 4-113 days (except one, no. 412, that was recovered 437 days after release on August 14, 1933), an average of 43.6, and from 7-120 miles distant, an average of 60.0.

Thirty-nine (68 percent) of the bottles had floated northeastward (5 of them into Traverse Bay), 13 (23 percent) had moved southwestward, and 5 (9 percent) were found to the northwest, southeast, or east. The bottles along the eastern shore had scattered from 2 miles north of Big Point Sable (except one that had floated to 3 miles south of Saugatuck, Michigan), to eastern Cecil Bay. The bottles recovered to the west were distributed from near the Ozaukee-Sheboygan County line to 9 miles north of Two Rivers, Wisconsin.

Frankfort to Charlevoix

On June 3, 1932, 70 bottles (table 16) were deposited between Frankfort and Charlevoix (fig. 15). Fifty-one (73 percent) were found—all in the State of Michigan. Thirty-two (65 percent) of 49 bottles had their drags attached. Fifty bottles were recovered in 3-130 days averaging 45.4; one bottle was found in 5.75 years, 6 miles south of Cross Village. Minimum distances ranged from 2-93 miles, an average of 33.0, but 47 percent of the bottles were found inside 26 miles and averaged only 13 miles. Nine bottles had floated southward and 42 or 82 percent northward. Eight bottles had entered Grand Traverse Bay. The bottles had been scattered from 1 mile south of Pt. Betsie Light to Sturgeon Bay near Cross Village.

Charlevoix to Manistique

On June 6, 1932, 54 bottles (table 17) were dropped between Charlevoix and Manistique, Michigan (fig. 16)—35 (65 percent) were recovered and 19 (59 percent) of 32 bottles held their drags. Six bottles were discovered from

0.93-5.8 years after release in 1933, 1934, 1935, and 1938 but had floated an average of only 18.8 miles. The other 29 bottles were recovered in 1-177 days, an average of 54.8, and 22 of these bottles averaged only 35.3 days. All recovered bottles had moved 1-51 miles, average 25.9. Twenty-three bottles were found southeast, 10 northeast, and 2 southwest near Fisherman's Island and Point Detour. The 33 bottles had scattered from northern Antrim County, Grand Traverse Bay, to 1 mile west of Cross Village and to the Gull and Beaver Islands.

Manistique to Escanaba

Of the 22 bottles (table 18) dropped on June 7, 1932, between Manistique and Escanaba (fig. 17), 16 (73 percent) were collected in 4-516 days and at minimum distances of 6-66 miles, average 26.6. Excluding the 2 bottles discovered beyond 1 year (390 and 516 days), the other 14 bottles were found during an average of 66.3 days (4-173). Drags were noted on six (38 percent) bottles. Only 2 bottles floated eastward; 4 were recovered in northern Green Bay; and 10 drifted southwest as far south as Jacksonport, Wisconsin.

Manistique to Manistee

Twenty-seven bottles (table 19) were released on June 20, 1932, along the eastern shore of the lake (fig. 17). All of the 20 recoveries (74 percent) were found between Good Harbor Bay and 6 miles south of Manistee. Fourteen floated southeast and six northeast. These bottles were recovered in 4-92 days, an average of 15.6, but 18 bottles had an average of only 10.2 days. The minimum distances covered by the bottles ranged from 5-22 miles, an average of 10.6. Nineteen (95 percent) of the 20 bottles possessed their drags.

Manistee to Grand Haven

Thirty-nine (95 percent) of the 41 bottles (table 20) released June 21, 1932, between Manistee and Grand Haven (fig. 17) were recovered from the day of release up to 60 days, an average of 10.5, and at 3-26 minimum miles, an average of 10.9. More than half of these bottles had times and distances well

TABLE 15.--Release and recovery points of drift bottles released June 2, 1932, at 76 stations
on the transect, Two Rivers, Wisconsin, to Frankfort, Michigan

[Asterisk indicates recovery in year beyond 1932; no. 412 was recovered August 14, 1933.]

Station of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
338	44° 8.3'	87° 33.0'	July 11	44° 2.0'	87° 41.0'	39	9	No
339	44° 8.5'	87° 31.7'	June 9	43° 58.0'	87° 42.0'	7	14	Yes
340	44° 8.9'	87° 30.4'	June 18	43° 56.0'	87° 42.0'	16	15	Yes
341	44° 9.5'	87° 29.1'	June 18	44° 7.0'	87° 38.0'	16	7	Yes
342	44° 9.9'	87° 27.7'	...	...	...	...	...	...
343	44° 10.3'	87° 26.7'	...	...	...	...	...	...
344	44° 10.7'	87° 25.8'	June 15	43° 46.0'	87° 43.0'	13	31	Yes
345	44° 11.2'	87° 24.7'	...	...	...	...	...	...
346	44° 11.5'	87° 23.3'	June 21	44° 17.0'	87° 32.0'	19	9	No
347	44° 11.9'	87° 22.0'	June 6	44° 13.0'	86° 29.0'	4	?	?
348	44° 12.3'	87° 21.1'	June 12	43° 42.0'	87° 42.0'	10	39	Yes
349	44° 12.7'	87° 20.0'	June 12	43° 42.0'	87° 42.0'	10	40	Yes
350	44° 13.1'	87° 18.8'	July 6	43° 41.0'	87° 42.0'	34	42	No
351	44° 13.7'	87° 17.8'	...	...	...	...	...	...
352	44° 14.2'	87° 16.6'	June 26	43° 32.0'	87° 47.0'	24	54	No
353	44° 14.6'	87° 15.0'	...	...	...	...	...	...
354	44° 15.0'	87° 13.9'	July 10	44° 11.0'	87° 31.0'	38	14	Yes
355	44° 15.5'	87° 12.4'	July 5	43° 43.0'	87° 42.0'	33	44	Yes
356	44° 16.0'	87° 11.5'	June 16	43° 45.0'	87° 42.0'	14	42	Yes
357	44° 16.5'	87° 10.5'	August 6	42° 28.0'	87° 13.0'	65	120	No
358	44° 16.8'	87° 9.4'	June 16	43° 45.0'	87° 42.0'	14	44	Yes
359	44° 17.3'	87° 8.2'	...	...	...	...	...	...
360	44° 17.6'	87° 7.0'	August 3	44° 56.0'	85° 22.0'	62	116	No
361	44° 18.0'	87° 5.8'	July 28	44° 44.0'	80° 6.0'	56	58	Yes
362	44° 18.4'	87° 4.6'	August 11	44° 44.0'	80° 6.0'	70	58	No
363	44° 18.8'	87° 3.3'	July 5	44° 37.0'	80° 14.0'	33	45	No
364	44° 18.8'	87° 3.3'	July 2	45° 6.0'	85° 20.0'	30	108	No
365	44° 18.8'	87° 3.3'	July 6	44° 5.0'	86° 30.0'	34	31	?
366	44° 18.8'	87° 3.3'	July 8	44° 18.0'	86° 19.0'	36	33	No
367	44° 18.8'	87° 3.3'	...	...	...	...	...	...
368	44° 19.7'	87° 3.5'	...	...	...	...	...	...
369	44° 20.0'	87° 2.4'	July 29	45° 8.0'	85° 21.0'	57	104	No
370	44° 20.3'	87° 1.2'	July 22	44° 42.0'	80° 15.0'	50	45	Yes
371	44° 20.7'	87° 0.0'	July 14	44° 55.0'	80° 3.0'	42	61	No
372	44° 21.0'	86° 58.8'	September 18	45° 7.0'	86° 4.0'	108	69	No
373	44° 21.4'	86° 57.8'	...	...	...	...	...	...
374	44° 21.8'	86° 56.7'	July 13	44° 29.0'	80° 15.0'	41	35	Yes
375	44° 22.2'	86° 55.6'	...	...	...	...	...	...
376	44° 22.5'	86° 54.4'	July 27	45° 0.0'	85° 47.0'	55	71	No
377	44° 22.9'	86° 53.2'	August 3	45° 0.0'	85° 29.0'	62	102	No
378	44° 23.3'	86° 52.3'	July 21	45° 2.0'	85° 45.0'	49	70	No
379	44° 24.2'	86° 50.1'	July 13	44° 43.0'	86° 12.0'	41	36	Yes
380	44° 24.6'	86° 48.8'	...	...	...	...	...	...
381	44° 24.8'	86° 48.1'	July 16	44° 54.0'	80° 1.0'	44	61	No
382	44° 25.3'	86° 46.6'	...	...	...	...	...	...
383	44° 25.8'	86° 45.7'	September 7	45° 17.0'	85° 20.0'	97	90	No
384	44° 26.3'	86° 44.4'	July 16	45° 4.0'	85° 59.0'	44	55	No
385	44° 26.7'	86° 43.2'	July 23	44° 57.0'	85° 22.0'	51	96	No
386	44° 27.0'	86° 41.8'	...	...	...	...	...	...
387	44° 27.6'	86° 40.0'	July 21	45° 0.0'	86° 8.0'	49	45	No
388	44° 27.6'	86° 40.0'	July 24	45° 23.0'	85° 0.0'	52	107	Yes
389	44° 27.6'	86° 40.0'	...	...	...	...	...	...
390	44° 27.6'	86° 40.0'	July 23	45° 22.0'	85° 0.0'	51	107	No
391	44° 27.6'	86° 40.0'	July 27	45° 22.0'	85° 6.0'	55	102	No

TABLE 15.--Release and recovery--Michigan--Continued

Station of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
392	44° 28.0'	86° 39.1'	July 22	45° 23.0'	84° 55.0'	50	109	?
393	44° 28.3'	86° 38.1'	July 11	44° 53.0'	86° 4.0'	39	38	Yes
394	44° 28.7'	86° 36.9'	July 13	45° 0.0'	85° 47.0'	41	45	Yes
395	44° 29.1'	86° 35.8'	July 13	44° 57.0'	86° 5.0'	41	32	No
396	44° 29.5'	86° 34.7'	...	...	...	...	...	...
397	44° 30.0'	86° 33.6'	July 23	45° 39.0'	85° 1.0'	51	105	Yes
398	44° 30.4'	86° 32.5'	July 30	45° 13.0'	85° 24.0'	58	77	No
399	44° 30.9'	86° 31.5'	August 19	45° 22.0'	85° 9.0'	78	91	No
400	44° 31.3'	86° 30.9'	July 9	44° 40.0'	86° 10.0'	37	16	?
401	44° 31.7'	86° 30.2'	September 23	45° 22.0'	85° 4.0'	113	95	No
402	44° 32.0'	86° 29.2'	July 20	45° 2.0'	85° 46.0'	48	50	No
403	44° 32.3'	86° 28.0'	July 27	45° 42.0'	85° 0.0'	55	107	?
404	44° 31.8'	86° 27.1'	July 13	45° 0.0'	86° 9.0'	41	34	Yes
405	44° 33.2'	86° 26.0'	...	...	...	...	...	...
406	44° 33.7'	86° 25.0'	July 8	45° 4.0'	85° 42.0'	36	51	Yes
407	44° 34.0'	86° 24.0'	July 3	45° 6.0'	85° 41.0'	31	52	?
408	44° 34.4'	86° 22.9'	...	...	...	...	...	...
409	44° 34.6'	86° 21.8'	...	...	...	...	...	...
410	44° 35.1'	86° 20.6'	July 28	45° 21.0'	85° 14.0'	56	77	No
411	44° 35.5'	86° 19.7'	July 11	45° 19.0'	85° 16.0'	39	73	Yes
412	44° 35.9'	86° 18.5'	August 14*	45° 45.0'	84° 50.0'	437	112	No
413	44° 36.3'	86° 17.4'	...	...	...	...	...	...
Average Number of bottles	...	...	...	...	...	² 43.6	60.0	...
	...	...	...	...	...	56	57	...

¹With drags, 21; without drags, 30; no data, 6.²Based on recoveries within the year of release.

below the averages. It is also unusual that nearly all bottles were located somewhere near or between the above-mentioned ports. The northernmost bottle was found 2 miles north of the Big Sable Point and the southernmost caught in a pound net 4 miles south of Grand Haven. Five bottles moved northeastward, five eastward, and the rest in a southerly direction. Thirty-three (87 percent) of 38 bottles held their drags.

Grand Haven to Sheboygan

Thirty-eight bottles (table 21) were released June 23, 1932, along this transect (fig. 18), and 27 (71 percent) were recovered. Only seven (26 percent) retained the drag. Not a single bottle was found on the west shore. Sixteen floated southeast and 11 northeast, distributing from 1 mile north of Macatawa, Michigan, to 12 miles south of Frankfort, Michigan. Although all of the bottles, excluding

the one found after 335 days, were picked up between 8 and 48 days, averaging 29.7, those released toward Sheboygan were recovered during the later days because of greater distances. For example, the averages of the first 5 bottles dropped near Grand Haven were 12.6 days and 32.8 miles, the central bottles averaged 28.2 days and 35.2 miles, and the last 8 bottles showed 42.9 days and 60.6 miles. The minimum miles ranged from 5-84 and averaged 37.6.

Sheboygan to Sturgeon Bay

Thirty-three bottles (table 22) were released on June 24, 1932, along the Wisconsin shore (fig. 19). All recovered bottles were found along the eastern coast of the lake except one that was discovered 445 miles distant in Lake St. Clair on June 6, 1942. Eighteen floated northeast (one entering Grand Traverse Bay) and seven moved southeast. The 24 bottles

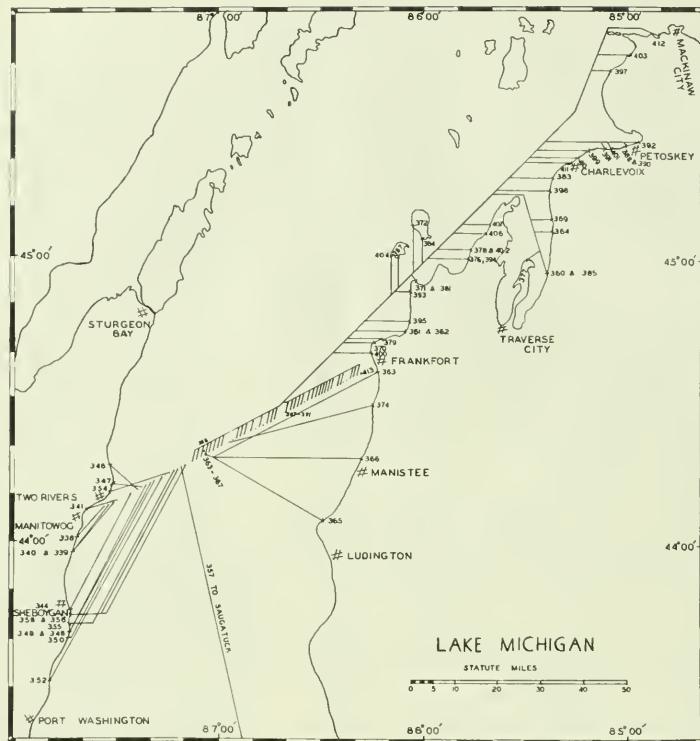


Figure 14.--Movements of bottles released along the transect, Two Rivers to Frankfort, June 2, 1932.

recovered in Lake Michigan were picked up from 1 mile south of the White Lake outlet to Fisherman's Island. These bottles were collected in 29-86 days, an average of 46.4, and at minimum distances of 48-114 miles, averaged 71.7. Only four (16 percent) of the bottles retained their drags.

Charlevoix to Guiken's Reef

Of the 15 bottles (table 23) released August 9, 1932, along the course from Charlevoix to Guiken's Reef (fig. 20), 8 (53 percent) were found. Six moved toward the south and two toward the north. Two bottles were recovered nearly a year later in July and August 1933; one of them landed on the Lake Michigan shore

of the east peninsula of Delta County. The other bottles extended from Glen Arbor, Michigan, to South Fox Island. The bottles were recorded from 8-49 miles, an average of 22.9, and six of them were found in 10-41 days, average of 19.3. Five bottles (62 percent) held their drags.

Gull Island to Manistique

Seven (58 percent) of the 12 bottles released between Gull Island and Manistique on August 20, 1932 (table 23 and fig. 20) were recovered. All seven floated toward the east, four going northeast and three southeast. Points of recovery extended from Five Mile Creek, north-

TABLE 16.--Release and recovery points of drift bottles released June 3, 1932, at 70 stations
between Frankfort, Michigan, and Charlevoix, Michigan

[Asterisk indicates recovery in year beyond 1932; no. 417 was recovered March 1, 1938]

Station of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
414	44° 41.3'	86° 21.4'	August 10	45° 40.0'	85° 0.0'	68	93	No
415	44° 42.2'	86° 20.5'	July 3	45° 4.0'	85° 42.0'	30	39	Yes
416	44° 43.0'	86° 19.6'	July 25	45° 23.0'	85° 0.0'	52	80	No
417	44° 43.6'	86° 19.0'	March 1*	45° 35.0'	85° 6.0'	2,098	81	No
418	44° 44.3'	86° 18.3'	August 2	45° 39.0'	85° 1.0'	60	86	No
419	44° 45.3'	86° 17.5'	July 31	45° 16.0'	85° 23.0'	58	57	No
420	44° 45.8'	86° 16.5'	July 8	45° 11.0'	85° 37.0'	35	47	Yes
421	44° 46.4'	86° 16.0'	July 3	45° 5.0'	85° 42.0'	30	36	Yes
422	44° 47.0'	86° 15.3'	July 27	45° 40.0'	85° 0.0'	54	85	?
423	44° 47.7'	86° 14.6'	...	...	...	...	...	...
424	44° 48.4'	86° 14.0'	July 30	45° 19.0'	85° 16.0'	57	57	No
425	44° 49.1'	86° 13.0'	...	...	...	...	...	...
426	44° 49.8'	86° 12.5'	...	...	...	...	...	...
427	44° 50.4'	86° 11.4'	...	...	...	...	...	...
428	44° 51.3'	86° 10.7'	September 3	45° 40.0'	85° 10.0'	92	74	No
429	44° 52.0'	86° 10.0'	...	...	...	...	...	...
430	44° 52.5'	86° 9.3'	...	...	...	...	...	...
431	44° 53.0'	86° 8.5'	...	...	...	...	...	...
432	44° 54.1'	86° 7.7'	June 6	44° 58.0'	85° 55.0'	3	12	Yes
433	44° 54.7'	86° 7.0'	September 25	45° 9.0'	86° 4.0'	114	16	No
434	44° 55.5'	86° 6.4'	August 4	45° 6.0'	85° 23.0'	62	47	Yes
435	44° 56.0'	86° 5.6'	July 22	45° 19.0'	85° 17.0'	49	48	No
436	44° 56.6'	86° 4.4'	...	...	...	...	...	...
437	44° 57.5'	86° 3.0'	September 9	45° 7.0'	85° 40.0'	98	22	Yes
438	44° 58.2'	86° 1.9'	July 27	45° 13.0'	85° 24.0'	54	36	No
439	44° 59.0'	86° 0.5'	July 26	45° 10.0'	85° 24.0'	53	37	Yes
440	45° 0.0'	85° 68.9'	July 2	44° 57.0'	85° 52.0'	29	6	Yes
441	45° 0.7'	85° 57.8'	July 8	45° 10.0'	85° 38.0'	35	18	Yes
442	45° 1.6'	85° 56.7'	...	...	...	...	...	...
443	45° 2.3'	85° 55.5'	June 30	45° 8.0'	85° 23.0'	27	33	Yes
444	45° 2.8'	85° 54.5'	July 10	45° 10.0'	85° 33.0'	37	36	Yes
445	45° 3.5'	85° 53.5'	...	...	...	...	...	...
446	45° 4.3'	85° 52.6'	July 24	45° 37.0'	85° 5.0'	51	53	?
447	45° 4.8'	85° 51.7'	June 24	45° 6.0'	85° 59.0'	21	7	No
448	45° 5.6'	85° 50.8'	July 10	45° 37.0'	85° 5.0'	37	51	Yes
449	45° 6.0'	85° 49.9'	September 10	45° 3.0'	86° 8.0'	99	16	No
450	45° 6.6'	85° 49.0'	August 17	44° 55.0'	85° 25.0'	75	36	No
451	45° 7.3'	85° 47.3'	July 21	45° 38.0'	85° 2.0'	48	48	Yes
452	45° 8.5'	85° 46.2'	July 6	45° 28.0'	85° 5.0'	33	40	Yes
453	45° 8.5'	85° 46.2'	July 2	45° 1.0'	85° 46.0'	29	5	Yes
454	45° 8.5'	85° 46.2'	July 3	44° 57.0'	85° 49.0'	30	14	Yes
455	45° 8.5'	85° 46.2'	...	...	...	...	...	...
456	45° 9.4'	85° 47.2'	June 27	44° 41.0'	86° 16.0'	24	41	Yes
457	45° 10.3'	85° 46.2'	July 8	45° 22.0'	85° 1.0'	35	39	Yes
458	45° 11.1'	85° 45.0'	August 12	45° 13.0'	85° 32.0'	70	11	No
459	45° 11.7'	85° 44.0'	June 28	45° 11.0'	85° 38.0'	25	5	Yes
460	45° 12.3'	85° 43.0'	...	...	...	...	...	...
461	45° 13.0'	85° 42.0'	July 10	45° 24.0'	85° 51.0'	37	15	Yes
462	45° 13.6'	85° 41.0'	...	...	...	...	...	...
463	45° 14.3'	85° 40.0'	...	...	...	...	...	...
464	45° 15.0'	85° 39.0'	July 10	45° 24.0'	84° 56.0'	37	36	Yes
465	45° 15.4'	85° 37.8'	July 10	45° 33.0'	85° 7.0'	37	32	No
466	45° 15.8'	85° 36.8'	...	...	...	...	...	...
467	45° 16.1'	85° 35.8'	June 26	45° 16.0'	85° 23.0'	23	11	Yes
468	45° 16.3'	85° 34.8'	June 7	45° 23.0'	84° 55.0'	4	33	No

TABLE 16.--Release and recovery...Michigan--Continued

Station of release			Recoveries					Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
469	45° 16.4'	85° 33.5'	June 23	45° 17.0'	85° 22.0'	20	9	Yes
470	45° 16.6'	85° 32.4'	June 24	45° 9.0'	85° 34.0'	21	13	Yes
471	45° 16.8'	85° 31.2'	...	...	...	...	...	...
472	45° 17.0'	85° 30.5'	July 28	45° 22.0'	85° 1.0'	56	25	Yes
473	45° 17.3'	85° 29.5'	July 19	45° 19.0'	85° 18.0'	46	11	Yes
474	45° 17.6'	85° 28.0'	July 3	45° 7.0'	85° 34.0'	30	14	Yes
475	45° 17.8'	85° 26.8'	June 19	45° 18.0'	85° 17.0'	16	9	Yes
476	45° 18.1'	85° 25.5'	October 11	45° 21.0'	85° 13.0'	130	10	Yes
477	45° 18.3'	85° 24.5'	...	...	...	...	...	...
478	45° 18.5'	85° 23.4'	July 23	45° 18.0'	85° 20.0'	50	3	No
479	45° 18.8'	85° 22.3'	June 13	45° 17.0'	85° 23.0'	10	2	Yes
480	45° 19.2'	85° 21.0'	July 10	45° 36.0'	85° 5.0'	37	22	Yes
481	45° 19.4'	85° 19.5'	July 13	45° 39.0'	85° 1.0'	40	26	Yes
482	45° 19.6'	85° 17.0'	...	...	...	...	...	...
483	45° 19.8'	85° 16.5'	...	...	...	...	...	...
Average Number of bottles	...	...	...	...	...	² 45.4	33.0	...
	...	...	...	...	...	50	51	...

¹With drags, 32; without drags, 17; no data, 2.²Based on recoveries in year of release.

west of Harbor Springs, Michigan, to the west side of Epoufette Point. Three bottles were recovered at 256 and 313 days at 1933 and 3.2 years in 1935; the other four were found at 15-44 days, averaging 26.2. The seven bottles had floated from 7-64 miles, an average of 41.4. Only two bottles held drags.

Charlevoix to Dahlia Shoal and Northwest of Charlevoix

All recovered bottles (table 24 and fig. 21) from releases of August 23, 1932, floated northeast and all but one of those reported from the August 25, 1932, releases moved southeast. The former extended from about 3 miles south of Good Hart, Michigan, to Waugoshance Island and the latter from 2 miles north of Charlevoix to halfway between Good Hart and Cross Village, Michigan. Six (46 percent) of the first 13 (table 24) and 5 (71 percent) of the other 7 bottles were recovered, but 4 were found from April 16 to May 4, 1933-236-252 days. The rest of them were located in 5-16 days, averaging 9.0, and 24-73 days, averaging 42.0. Their minimum miles varied from 4-24, averaging 14.8 and from

12-22, averaging 16.0. Three (50 and 60 percent) of bottles recovered from each release held drags.

GENERAL CHARACTERISTICS

Most of the bottles released in 1931 along transects were recovered along the eastern shore. On only two dates were the small majorities found on the western coast. Eighty-three transect bottles or 65.9 percent were found in the State of Michigan, 31 bottles or 24.6 percent in Wisconsin and Illinois, and 12 bottles or 9.5 percent in Indiana. Other bottles were deposited along both shores. Sixteen of the 17 bottles recovered from releases between St. Joseph and Grand Haven and 21 of the 29 bottles returned from releases between Sheboygan and Racine were found on the eastern coast; the remaining 9 were found along the western shore. All 14 recovered bottles from the Kewaunee-Port Washington releases were discovered in Wisconsin. Of the entire total of recovered bottles, 120 (64.5 percent) were located in the State of Michigan, 54 (29.0 percent) in Wisconsin and Illinois, and 12 (6.5 percent) in Indiana.

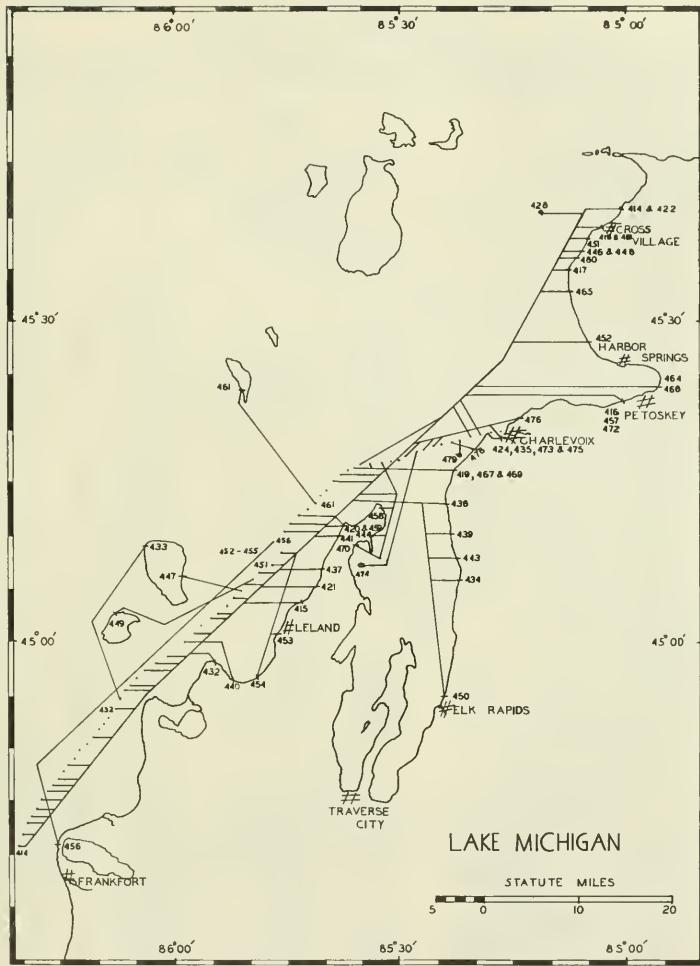


Figure 15.--Movements of bottles released from Frankfort to Charlevoix, June 3, 1932.

Table 17. --Release and recovery points of drift bottles released June 6, 1932, at 54 stations on the transect, Charlevoix, Michigan, to Manistique, Michigan

[Asterisk indicates recovery in years beyond 1932; no. 487 was recovered on July 9, 1933, no. 515 on March 27, 1932, no. 520 on May 10, 1933, no. 522 on June 5, 1933, no. 526 on August 30, 1933, and no. 527 on Oct. 5, 1934.]

Stations of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
484	45° 19. 8'	85° 16. 5'	June 10	45° 19. 0'	85° 16. 0'	4	1	Yes
485	45° 20. 3'	85° 17. 8'	June 7	45° 18. 0'	85° 22. 0'	1	3	Yes
486	45° 20. 7'	85° 19. 1'	...	...	...	...	...	...
487	45° 21. 2'	85° 20. 5'	July 9*	45° 19. 0'	85° 16. 0'	398	4	No
488	45° 21. 8'	85° 21. 7'	...	...	...	...	...	...
489	45° 22. 4'	85° 23. 0'	August 25	45° 35. 0'	85° 7. 0'	80	21	Yes
490	45° 22. 8'	85° 24. 2'	...	...	...	...	...	...
491	45° 23. 2'	85° 25. 4'	July 14	45° 37. 0'	85° 5. 0'	38	23	Yes
492	45° 23. 7'	85° 26. 5'	July 3	45° 22. 0'	85° 0. 0'	27	22	Yes
493	45° 24. 2'	85° 27. 6'	July 10	45° 19. 0'	85° 19. 0'	34	10	Yes
494	45° 24. 5'	85° 28. 8'	July 15	45° 37. 0'	85° 7. 0'	39	24	Yes
495	45° 25. 0'	85° 30. 1'	July 12	45° 19. 0'	85° 19. 0'	36	12	Yes
496	45° 25. 4'	85° 31. 1'	...	...	...	...	...	...
497	45° 25. 8'	85° 32. 2'	...	...	...	...	...	...
498	45° 26. 3'	85° 33. 3'	November 8	45° 35. 0'	85° 7. 0'	155	24	Yes
499	45° 26. 7'	85° 34. 5'	July 7	45° 22. 0'	85° 0. 0'	31	28	Yes
500	45° 27. 2'	85° 35. 7'	August 3	45° 22. 0'	85° 3. 0'	58	26	No
502	45° 27. 7'	85° 36. 9'	July 14	45° 22. 0'	85° 0. 0'	38	30	?
503	45° 28. 0'	85° 38. 0'	July 20	45° 22. 0'	85° 0. 0'	44	31	Yes
504	45° 28. 4'	85° 39. 2'	July 3	45° 13. 0'	85° 33. 0'	27	18	Yes
501	45° 28. 9'	85° 40. 3'	August 28	45° 22. 0'	85° 0. 0'	83	33	Yes
505	45° 29. 3'	85° 41. 5'	July 14	45° 22. 0'	85° 0. 0'	38	34	?
506	45° 29. 7'	85° 42. 7'	October 9	45° 11. 0'	85° 23. 0'	125	27	No
507	45° 30. 0'	85° 43. 7'	...	...	...	...	...	...
508	45° 30. 5'	85° 44. 9'	...	...	...	...	...	...
509	45° 31. 0'	85° 46. 0'	July 9	45° 22. 0'	85° 3. 0'	33	35	Yes
510	45° 31. 4'	85° 47. 0'	October 1	45° 21. 0'	85° 14. 0'	117	29	Yes
511	45° 31. 8'	85° 48. 0'	...	...	...	...	...	...
512	45° 32. 1'	85° 49. 0'	August 4	45° 22. 0'	85° 0. 0'	59	41	No
513	45° 32. 7'	85° 50. 1'	July 18	45° 22. 0'	85° 0. 0'	42	42	Yes
514	45° 33. 0'	85° 51. 2'	...	...	...	...	...	...
515	45° 33. 5'	85° 52. 4'	March 27*	45° 37. 0'	85° 37. 0'	2, 120	13	No
516	45° 33. 9'	85° 53. 5'	...	...	...	...	...	...
517	45° 34. 4'	85° 54. 6'	...	...	...	...	...	...
518	45° 34. 8'	85° 55. 8'	July 19	45° 38. 0'	85° 4. 0'	43	42	Yes
519	45° 35. 2'	85° 57. 0'	November 30	45° 37. 0'	85° 37. 0'	177	16	No
520	45° 35. 8'	85° 58. 1'	May 10*	45° 42. 0'	85° 50. 0'	338	9	Yes
521	45° 33. 3'	86° 3. 0'	August 21	45° 27. 0'	85° 3. 0'	76	47	No
522	45° 33. 3'	86° 3. 0'	June 5*	45° 29. 0'	85° 47. 0'	1, 094	13	?
523	45° 33. 3'	86° 3. 0'	...	...	...	...	...	...
524	45° 35. 2'	85° 59. 8'	...	...	...	...	...	...
525	45° 36. 8'	86° 0. 7'	July 22	45° 35. 0'	85° 35. 0'	46	21	No
526	45° 38. 2'	86° 2. 0'	August 30*	45° 45. 0'	85° 33. 0'	450	25	No
527	45° 39. 8'	86° 3. 0'	October 5*	45° 27. 0'	85° 3. 0'	851	49	No
528	45° 41. 2'	86° 3. 8'	July 13	45° 28. 0'	85° 5. 0'	37	49	No
529	45° 42. 7'	86° 4. 8'	July 17	45° 38. 0'	85° 4. 0'	41	51	No
530	45° 44. 1'	86° 5. 9'	...	...	...	...	...	...
531	45° 45. 6'	86° 6. 9'	July 25	45° 24. 0'	85° 51. 0'	49	28	No
532	45° 47. 1'	86° 7. 8'	...	...	...	...	...	...
533	45° 48. 6'	86° 9. 0'	June 18	45° 37. 0'	86° 37. 0'	12	26	Yes
534	45° 50. 2'	86° 10. 0'	...	...	...	...	...	...
535	45° 51. 6'	86° 11. 0'	...	...	...	...	...	...
536	45° 53. 0'	86° 12. 1'	...	...	...	...	...	...
537	45° 54. 4'	86° 13. 1'	...	...	...	...	...	...
Average	...	...	...	...	...	...	54. 8	25. 9
Number of bottles	...	...	...	...	...	...	29	35

¹ With drags, 19; without drags, 13; no data, 3.

² Based on recoveries in year of release.

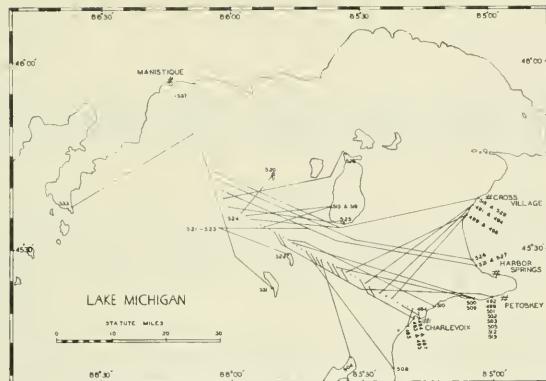


Figure 16.--Movements of bottles released along the transect, Charlevoix to Manistique, June 6, 1932.

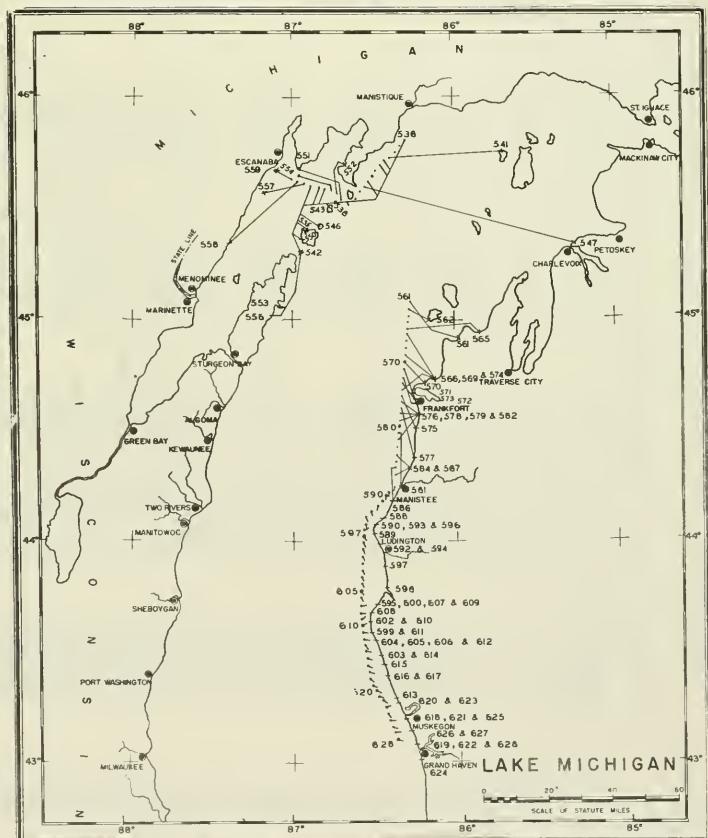


Figure 17.--Movements of bottles released from Manistique to Escanaba, June 7, from Manistique to Manistee, June 20, and from Manistee to Grand Haven, June 21, 1932.

TABLE 18. --Release and recovery points of drift bottles released June 7, 1932, at 22 stations from Manitistique, Michigan to Escanaba, Michigan, via Poverty Island

[Asterisk indicates recovery in years beyond 1932; no. 538 was recovered on July 2, 1933, and no. 546 on November 5, 1933]

Station number	Station of release		Recoveries					Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
538	45° 46.6'	86° 18.1'	July 2*	45° 31.0'	86° 43.0'	390	30	No
539	45° 45.1'	86° 19.6'	...	...	...	...	...	...
540	45° 43.8'	86° 21.7'	...	...	...	...	...	...
541	45° 42.4'	86° 23.2'	November 27	45° 45.0'	85° 42.0'	173	34	Yes
542	45° 41.7'	86° 25.2'	July 19	45° 18.0'	86° 57.0'	42	40	Yes
543	45° 40.5'	86° 27.0'	August 1	45° 30.0'	86° 46.0'	55	34	Yes
544	45° 38.0'	86° 29.0'	...	...	...	...	...	...
545	45° 37.6'	86° 30.1'	...	...	...	...	...	...
546	45° 36.0'	86° 32.0'	November 5*	45° 25.0'	86° 50.0'	516	22	No
547	45° 34.7'	86° 33.5'	August 3	45° 20.0'	85° 15.0'	57	66	No
548	45° 33.2'	86° 35.3'	...	...	...	...	...	...
549	45° 31.3'	86° 37.6'	...	...	...	...	...	...
550	45° 30.0'	86° 39.5'	October 6	45° 22.0'	86° 57.0'	121	18	No
561	45° 31.3'	86° 42.0'	September 17	45° 40.0'	86° 58.0'	102	16	Yes
562	45° 32.5'	86° 43.5'	September 19	45° 42.0'	86° 40.0'	104	11	No
564	45° 33.2'	86° 46.2'	June 15	45° 38.0'	86° 58.0'	8	11	Yes
565	45° 33.8'	86° 48.5'	August 17	45° 3.0'	87° 5.0'	71	41	No
566	45° 34.2'	86° 51.0'	July 1	45° 25.0'	86° 54.0'	24	13	No
567	45° 34.8'	86° 53.6'	July 5	45° 0.0'	87° 10.0'	28	42	No
568	45° 35.4'	86° 55.9'	June 11	45° 33.0'	87° 13.0'	4	13	Yes
569	45° 35.9'	86° 58.0'	August 3	45° 20.0'	87° 25.0'	57	28	No
560	45° 36.5'	87° 0.1'	August 28	45° 39.0'	87° 9.0'	82	6	No
Average Number of bottles	...	...	...	...	...	...	...	...
	...	...	...	...	...	3/ 66.3	26.6	***
	...	...	...	...	...	14	16	***

¹ With drag; 6/ without drag, 10.

* Bottle kept for sample.

Based on recoveries in year of release.

TABLE 19.-Release and recovery points of drift bottles released June 20, 1932, at 27 stations between Manistique, Michigan, and Manistee, Michigan

Station number	Station of release			Recoveries				Minimum miles covered	Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release			
561	45° 2.8'	86° 16.1'	July 2	44° 54.0'	85° 58.0'	12	19	Yes	
562	45° 1.1'	86° 16.2'	September 20	45° 0.0'	86° 9.0'	92	7	Yes	
563	44° 59.3'	86° 16.4'	...	...	...	...	...	...	...
564	44° 57.5'	86° 16.6'	...	...	...	...	...	...	...
565	44° 55.8'	86° 16.9'	July 4	44° 56.0'	85° 50.0'	14	22	Yes	
566	44° 54.1'	86° 17.2'	July 2	44° 44.0'	86° 7.0'	12	16	Yes	
567	44° 52.3'	86° 17.5'	...	...	...	...	...	...	...
568	44° 50.5'	86° 17.7'	...	...	...	...	...	...	...
569	44° 48.8'	86° 17.8'	July 2	44° 44.0'	86° 7.0'	12	12	Yes	
570	44° 47.1'	86° 18.0'	July 3	44° 43.0'	86° 12.0'	13	9	Yes	
571	44° 45.3'	86° 18.2'	June 28	44° 40.0'	86° 16.0'	8	8	Yes	
572	44° 43.2'	86° 18.6'	July 25	44° 37.0'	86° 13.0'	35	9	Yes	
573	44° 41.7'	86° 18.8'	July 1	44° 38.0'	86° 16.0'	11	6	Yes	
574	44° 40.0'	86° 19.0'	July 2	44° 44.0'	86° 7.0'	12	11	Yes	
575	44° 37.4'	86° 19.2'	June 29	44° 29.0'	86° 15.0'	9	11	Yes	
576	44° 36.6'	86° 19.5'	June 26	44° 33.0'	86° 14.0'	6	6	Yes	
577	44° 34.7'	86° 19.7'	June 27	44° 22.0'	86° 16.0'	7	16	Yes	
578	44° 33.0'	86° 19.9'	July 10	44° 31.0'	86° 15.0'	20	6	Yes	
579	44° 31.2'	86° 20.0'	July 2	44° 32.0'	86° 14.0'	12	6	Yes	
580	44° 29.4'	86° 20.2'	...	...	...	...	...	...	...
581	44° 27.7'	86° 20.5'	June 27	44° 15.0'	86° 21.0'	7	17	Yes	
582	44° 26.9'	86° 20.8'	July 5	44° 34.0'	86° 14.0'	15	10	No	
583	44° 24.4'	86° 21.0'	...	...	...	...	...	...	...
584	44° 22.3'	86° 21.2'	June 24	44° 19.0'	86° 17.0'	4	6	Yes	
585	44° 21.0'	86° 21.5'	...	...	...	...	...	...	...
586	44° 19.3'	86° 21.7'	June 25	44° 10.0'	86° 24.0'	5	10	Yes	
587	44° 17.6'	86° 22.0'	June 25	44° 19.0'	86° 17.0'	5	5	Yes	
Average	...	...	...	...	...	15.6	10.6	...	...
Number of bottles	...	...	...	...	...	20	20	...	...

¹ With drags, 19; without drags, 1.

Table 20. --Release and recovery points of drift bottles released June 21, 1932, at 41 stations from Manistee, Michigan, to Grand Haven, Michigan

Station of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
588	44° 13. 6'	86° 22. 8'	August 7	44° 5. 0'	86° 30. 0'	47	10	Yes
589	44° 12. 4'	86° 24. 5'	June 29	44° 1. 0'	86° 31. 0'	8	14	Yes
590	44° 10. 9'	86° 26. 3'	June 27	44° 4. 0'	86° 32. 0'	6	9	Yes
591	44° 9. 5'	86° 27. 8'	...	...	...	...	...	...
592	44° 8. 1'	86° 29. 7'	June 28	43° 58. 0'	86° 28. 0'	7	12	Yes
593	44° 6. 8'	86° 31. 2'	August 10	44° 4. 0'	86° 32. 0'	50	4	Yes
594	44° 5. 3'	86° 33. 1'	June 29	43° 58. 0'	86° 28. 0'	8	9	Yes
595	44° 3. 6'	86° 33. 8'	July 5	43° 42. 0'	86° 31. 0'	14	22	No
596	44° 1. 8'	86° 34. 0'	July 4	44° 3. 0'	86° 31. 0'	13	4	?
597	44° 0. 0'	86° 34. 0'	June 25	43° 52. 0'	86° 26. 0'	4	11	Yes
598	43° 58. 4'	86° 34. 0'	July 1	43° 46. 0'	86° 27. 0'	10	16	Yes
599	43° 56. 6'	86° 34. 2'	July 1	43° 34. 0'	86° 31. 0'	10	26	Yes
600	43° 54. 8'	86° 34. 3'	June 30	43° 42. 0'	86° 31. 0'	9	15	Yes
601	43° 53. 0'	86° 34. 4'	...	...	...	...	...	...
602	43° 51. 0'	86° 34. 5'	July 1	43° 37. 0'	86° 32. 0'	10	16	Yes
603	43° 49. 2'	86° 34. 6'	July 4	43° 28. 0'	86° 28. 0'	13	25	Yes
604	43° 47. 5'	86° 34. 7'	July 11	43° 32. 0'	86° 29. 0'	20	18	Yes
605	43° 46. 5'	86° 34. 8'	June 29	43° 33. 0'	86° 30. 0'	8	16	No
606	43° 43. 6'	86° 34. 9'	June 26	43° 33. 0'	86° 30. 0'	5	14	Yes
607	43° 41. 9'	86° 35. 0'	June 22	43° 42. 0'	86° 31. 0'	1	5	Yes
608	43° 40. 0'	86° 35. 1'	July 1	43° 40. 0'	86° 33. 0'	10	3	Yes
609	43° 38. 0'	86° 35. 0'	June 23	43° 42. 0'	86° 31. 0'	2	7	Yes
610	43° 36. 5'	86° 34. 8'	June 24	43° 37. 0'	86° 32. 0'	3	3	Yes
611	43° 34. 5'	86° 34. 5'	July 1	43° 35. 0'	86° 31. 0'	10	3	Yes
612	43° 32. 8'	86° 34. 1'	June 22	43° 33. 0'	86° 30. 0'	1	3	Yes
613	43° 31. 0'	86° 33. 8'	June 26	43° 17. 0'	86° 23. 0'	5	19	Yes
614	43° 29. 2'	86° 33. 5'	June 25	43° 28. 0'	86° 28. 0'	4	5	No
615	43° 27. 5'	86° 33. 2'	June 22	43° 26. 0'	86° 27. 0'	1	6	Yes
616	43° 25. 9'	86° 33. 0'	June 25	43° 23. 0'	86° 26. 0'	4	7	Yes
617	43° 24. 2'	86° 32. 8'	June 22	43° 23. 0'	86° 26. 0'	1	6	Yes
618	43° 22. 3'	86° 32. 6'	June 26	43° 12. 0'	86° 18. 0'	5	16	Yes
619	43° 20. 7'	86° 31. 2'	June 25	43° 4. 0'	86° 16. 0'	4	22	Yes
620	43° 19. 1'	86° 30. 0'	June 21	43° 16. 0'	86° 22. 0'	0	7	Yes
621	43° 17. 4'	86° 29. 0'	June 29	43° 11. 0'	86° 18. 0'	8	11	No
622	43° 16. 7'	86° 28. 0'	July 2	43° 4. 0'	86° 16. 0'	11	17	Yes
623	43° 14. 2'	86° 26. 5'	June 28	43° 16. 0'	86° 22. 0'	7	4	No
624	43° 12. 6'	86° 25. 7'	July 2	43° 0. 0'	86° 17. 0'	11	17	Yes
625	43° 10. 7'	86° 24. 2'	July 9	43° 11. 0'	86° 18. 0'	18	5	Yes
626	43° 9. 0'	86° 23. 3'	June 22	43° 8. 0'	86° 17. 0'	1	6	Yes
627	43° 7. 4'	86° 22. 0'	June 23	43° 8. 0'	86° 17. 0'	2	5	Yes
628	43° 5. 7'	86° 20. 9'	August 20	43° 4. 0'	86° 16. 0'	60	6	Yes
Average Number of bottles	...	...	...	...	...	10.5	10.9	...
	...	...	...	...	...	39	39	...

¹ With drags, 33; without drags, 5; no data, 1.

Table 21.--Release and recovery points of drift bottles released June 23, 1932, at 38 stations on the transect,
Grand Haven, Michigan, to Sheboygan, Michigan

[Asterisk indicates recovery in years beyond 1932; no. 632 was recovered on May 24, 1933.]

Station of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
629	43° 5 1'	86° 20.5'	July 8	42° 58.0'	86° 13.0'	15	11	No
630	43° 6 2'	86° 23.0'	July 1	43° 9.0'	86° 17.0'	8	5	Yes
631	43° 7 3'	86° 25.0'	July 3	43° 5.0'	86° 15.0'	10	7	Yes
632	43° 8 4'	86° 27.0'	May 24*	43° 12.0'	86° 18.0'	335	7	No
633	43° 9 5'	86° 29.0'	...	...	...	...	...	...
634	43° 10.6'	86° 31.1'	July 8	42° 47.0'	86° 12.0'	15	30	Yes
635	43° 11.7'	86° 33.2'	July 8	43° 12.0'	86° 18.0'	15	11	No
636	43° 12.5'	86° 35.4'	...	...	...	...	...	...
637	43° 13.5'	86° 37.7'	...	...	...	...	...	...
638	43° 14.6'	86° 39.8'	...	...	...	...	...	...
639	43° 15.7'	86° 42.1'	...	...	...	...	...	...
640	43° 16.7'	86° 44.3'	July 24	42° 58.0'	86° 13.0'	31	35	No
641	43° 17.7'	86° 46.4'	July 20	43° 21.0'	86° 25.0'	27	18	No
642	43° 18.8'	86° 48.5'	July 20	43° 15.0'	86° 21.0'	27	23	No
643	43° 19.8'	86° 50.8'	July 22	43° 19.0'	86° 24.0'	29	22	No
644	43° 20.9'	86° 52.9'	July 20	43° 2.0'	86° 14.0'	27	39	No
645	43° 22.0'	86° 55.1'	...	...	...	...	...	...
646	43° 23.1'	86° 56.0'	July 24	43° 55.0'	86° 26.0'	31	46	No
647	43° 24.2'	86° 57.2'	July 18	43° 40.0'	86° 32.0'	25	29	No
648	43° 25.0'	86° 59.5'	July 21	43° 26.0'	86° 27.0'	28	27	No
649	43° 26.1'	87° 1.6'	July 26	43° 15.0'	86° 21.0'	33	36	No
650	43° 27.2'	87° 4.0'	July 20	44° 3.0'	86° 31.0'	27	51	No
651	43° 28.2'	87° 6.1'	July 20	43° 22.0'	86° 25.0'	27	36	No
652	43° 29.2'	87° 8.1'	July 20	44° 3.0'	86° 31.0'	27	51	No
653	43° 30.0'	87° 10.2'	July 21	43° 14.0'	86° 21.0'	28	45	No
654	43° 31.3'	87° 12.5'	...	...	...	...	...	...
655	43° 32.2'	87° 14.8'	August 10	44° 5.0'	86° 30.0'	48	67	Yes
656	43° 33.2'	87° 17.0'	July 20	43° 14.0'	86° 21.0'	27	53	No
657	43° 34.3'	87° 19.0'	August 15	43° 12.0'	86° 18.0'	43	58	No
658	43° 35.4'	87° 21.3'	...	...	...	...	...	...
659	43° 36.4'	87° 23.5'	...	...	...	...	...	...
660	43° 37.3'	87° 25.0'	August 5	43° 33.0'	86° 30.0'	43	47	No
661	43° 38.4'	87° 26.5'	August 5	43° 14.0'	86° 21.0'	43	62	No
662	43° 39.5'	87° 28.7'	August 8	44° 5.0'	86° 30.0'	46	61	Yes
663	43° 40.5'	87° 30.5'	...	...	...	...	...	...
664	43° 41.6'	87° 32.5'	August 7	43° 40.0'	86° 32.0'	45	53	Yes
665	43° 42.6'	87° 34.7'	...	...	...	...	...	...
666	43° 43.7'	87° 36.9'	August 10	44° 27.0'	86° 14.0'	48	84	Yes
Average	...	...	...	...	...	² 29.7	37.6	...
Number of bottles	...	...	...	...	...	26	27	...

¹ With drags, 7; without drags, 20.

² Based on recoveries in year of release.

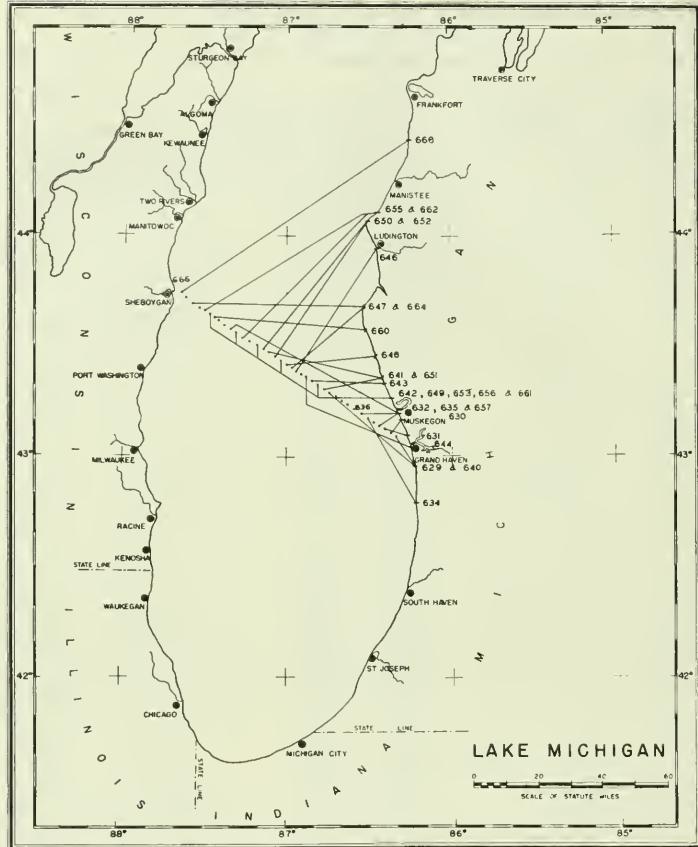


Figure 18.--Movements of bottles released along the transect, Grand Haven to Sheboygan, June 23, 1932.

TABLE 22. --Release and recovery points of drift bottles released June 24, 1932, at 33 stations between Sheboygan, Wisconsin, and Sturgeon Bay, Wisconsin

[Asterisk indicates recovery in years beyond 1932; no. 691 was recovered on June 6, 1942]

Station of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
667	43° 45.5'	87° 39.5'	August 5	44° 22.0'	86° 16.0'	42	80	No
668	43° 47.2'	87° 38.5'	August 6	43° 22.0'	86° 25.0'	43	65	No
669	43° 48.7'	87° 37.5'	...	...	...	...	...	...
670	43° 50.6'	87° 37.0'	August 5	43° 24.0'	86° 26.0'	42	64	No
671	43° 52.7'	87° 36.2'	August 5	43° 57.0'	86° 27.0'	42	55	No
672	43° 54.4'	87° 35.5'	...	...	...	...	...	...
673	43° 56.1'	87° 34.7'	August 4	43° 49.0'	86° 26.0'	41	56	No
674	43° 57.7'	87° 34.0'	...	...	...	...	...	...
675	43° 59.4'	87° 33.3'	...	...	...	...	...	...
676	44° 1.0'	87° 32.6'	August 8	44° 7.0'	86° 26.0'	45	55	Yes
677	44° 2.8'	87° 31.9'	August 6	44° 0.0'	86° 29.0'	43	50	No
678	44° 4.8'	87° 31.4'	July 26	45° 0.0'	86° 7.0'	32	92	No
679	44° 6.6'	87° 30.7'	August 4	44° 50.0'	86° 4.0'	41	86	No
680	44° 8.1'	87° 30.0'	September 10	45° 3.0'	86° 6.0'	78	92	Yes
681	44° 10.2'	87° 29.0'	August 19	44° 4.0'	86° 31.0'	56	48	No
682	44° 12.3'	87° 28.4'	August 18	44° 7.0'	86° 26.0'	45	51	Yes
683	44° 14.2'	87° 27.6'	July 30	44° 38.0'	86° 15.0'	36	64	No
684	44° 15.9'	87° 26.8'	August 5	44° 37.0'	86° 14.0'	42	63	No
685	44° 17.6'	87° 26.0'	September 18	45° 7.0'	86° 4.0'	86	87	No
686	44° 19.6'	87° 25.4'	August 3	44° 40.0'	86° 16.0'	40	61	No
687	44° 21.3'	87° 24.7'	July 29	44° 54.0'	86° 2.0'	35	78	No
688	44° 23.2'	87° 24.0'	...	...	...	...	...	...
689	44° 24.8'	87° 23.2'	August 18	44° 56.0'	85° 49.0'	55	86	No
690	44° 26.6'	87° 22.3'	July 28	45° 18.0'	85° 22.0'	34	114	Yes
691	44° 28.3'	87° 21.6'	June 6*	42° 28.0'	82° 56.0'	3,634	445	No
692	44° 30.2'	87° 21.0'	...	...	...	...	...	...
693	44° 32.0'	87° 20.3'	...	...	...	...	...	...
694	44° 33.8'	87° 19.5'	July 23	45° 2.0'	85° 46.0'	29	84	No
695	44° 35.6'	87° 18.8'	...	...	...	...	...	...
696	44° 37.5'	87° 18.1'	July 26	45° 3.0'	86° 0.0'	32	69	No
697	44° 39.9'	87° 17.4'	August 7	44° 37.0'	86° 14.0'	44	52	No
698	44° 42.0'	87° 17.8'	September 10	45° 3.0'	86° 8.0'	78	58	No
699	44° 44.4'	87° 17.4'	August 17	44° 57.0'	85° 23.0'	54	110	No
Average Number of bottles	...	...	...	...	...	² 46.4	² 71.7	...
	...	...	...	...	...	24	24	...

¹ With drags, 4; without drags, 21.

² Based on recoveries in year of release.

Figure 19.--Movements of bottles released from Sheboygan to Sturgeon Bay, June 24, 1932.

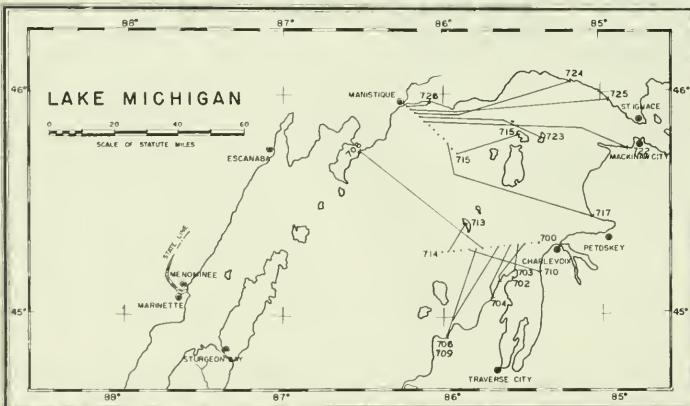
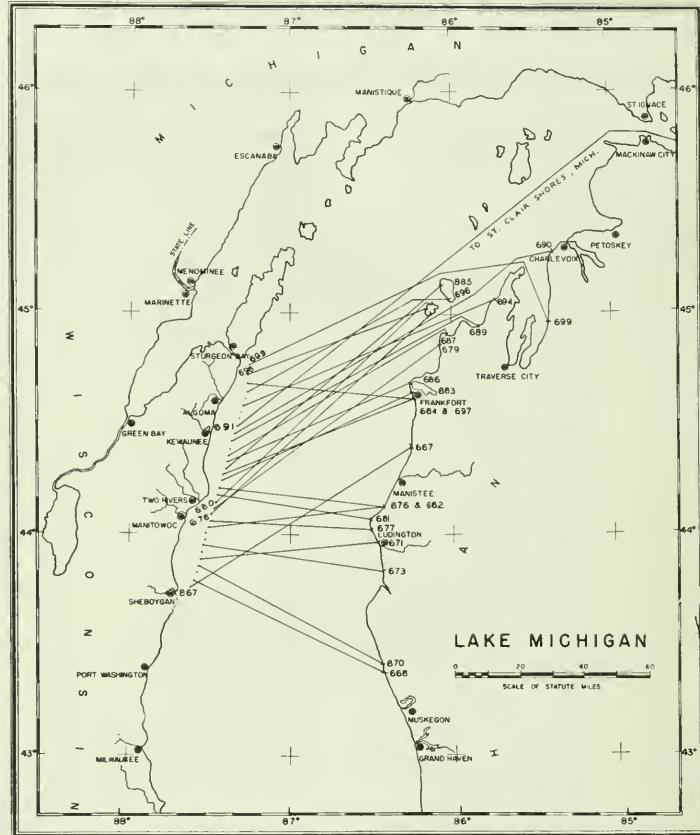


Figure 20.--Movements of bottles released from Charlevoix to Guiken's Reef, August 9, and from Gull Island to Manistique, August 20, 1932.

TABLE 23. --Release and recovery points of drift bottles released in 1932 from Charlevoix to Guiken's Reef
 (August 9--15 stations) and from Gull Island to Manistique, Michigan (August 20--12 stations)

[Asterisk indicates recovery in years beyond 1932; no. 703 was recovered on August 6, 1933, no. 708 on July 19, 1933,
 no. 722 on May 3, 1933, no. 713 on November 1, 1935, and no. 724 on June 29, 1933.]

Station of release			Recoveries					Drag attached ¹
Station number	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
August 9								
700	45° 19. 0'	85° 22. 8'	...	...	...	...	...	...
701	45° 18. 8'	85° 25. 2'	...	...	...	...	...	...
702	45° 18. 7'	85° 28. 0'	August 19	45° 8. 0'	85° 39. 0'	10	15	Yes
703	45° 18. 5'	85° 30. 7'	August 6*	45° 13. 0'	85° 33. 0'	362	8	Yes
704	45° 18. 3'	85° 33. 2'	September 19	45° 3. 0'	85° 45. 0'	41	17	Yes
705	45° 18. 1'	85° 35. 8'	...	...	...	...	...	...
706	45° 18. 0'	85° 38. 5'	August 19	44° 54. 0'	85° 58. 0'	10	32	No
707	45° 17. 8'	85° 41. 1'	...	...	...	...	...	...
708	45° 17. 7'	85° 44. 0'	July 19*	45° 45. 0'	86° 30. 0'	334	49	No
709	45° 17. 6'	85° 46. 8'	August 27	44° 54. 0'	85° 58. 0'	18	29	Yes
710	45° 17. 5'	85° 49. 5'	August 27	45° 11. 0'	85° 23. 0'	18	23	No
711	45° 17. 3'	85° 53. 4'	...	...	...	...	...	...
712	45° 17. 1'	85° 55. 0'	...	...	...	...	...	...
713	45° 16. 8'	85° 57. 3'	August 28	45° 25. 0'	85° 52. 0'	19	10	Yes
714	45° 16. 6'	85° 59. 8'	...	...	...	...	...	...
Average Number of bottles	...	...	...	...	...	² 19.3	22.9	...
	...	...	...	...	...	6	8	...
August 20								
715	45° 42. 6'	85° 54. 0'	September 4	45° 49. 0'	85° 31. 0'	15	19	No
716	45° 43. 8'	85° 55. 7'	...	...	...	...	...	...
717	45° 45. 0'	85° 57. 3'	September 9	45° 28. 0'	85° 5. 0'	20	52	No
718	45° 46. 3'	85° 59. 2'	...	...	...	...	...	...
719	45° 47. 5'	86° 1. 4'	...	...	...	...	...	...
720	45° 48. 8'	86° 2. 8'	...	...	...	...	...	...
721	45° 50. 0'	86° 4. 6'	...	...	...	...	...	...
722	45° 51. 1'	86° 6. 6'	May 3*	45° 45. 0'	84° 49. 0'	256	64	Yes
723	45° 52. 3'	86° 8. 4'	November 2*	45° 47. 0'	85° 22. 0'	1,169	38	No
724	45° 53. 6'	86° 10. 0'	June 29*	46° 3. 0'	85° 11. 0'	313	49	No
725	45° 54. 8'	86° 11. 7'	October 3	45° 57. 0'	84° 56. 0'	44	61	No
726	45° 56. 1'	86° 13. 5'	September 15	45° 58. 0'	86° 4. 0'	26	7	Yes
Average Number of bottles	...	...	...	...	...	² 26.2	41.4	...
	...	...	...	...	...	4	7	...

¹ August 9--with drags, 5; without drags, 3. August 20--with drags, 2; without drags, 5.

² Based on recoveries in year of release.

TABLE 24. --Release and recovery points of drift bottles released in 1932 from Charlevoix, Michigan to Dahlia Shoal
 (August 23--13 stations) and northwest of Charlevoix (August 25--9 stations)

[Asterisk indicates recovery in years beyond 1932; nos. 735 and 738 were recovered on April 16, 1933
 no. 740 on April 22, 1933, and no. 743 on May 4, 1933]

Station number	Station of release			Recoveries				Drag attached ¹
	Latitude	Longitude	Date	Latitude	Longitude	Days after release	Minimum miles covered	
August 23								
727	45° 22. 6'	85° 14. 7'	August 31	45° 24. 0'	84° 55. 0'	8	16	Yes
728	45° 23. 4'	85° 14. 0'	...	45° 42. 0'	84° 57. 0'	...	...	Yes
729	45° 24. 5'	85° 13. 7'	September 8	...	...	16	24	Yes
730	45° 25. 4'	85° 13. 4'	...	...	...	...	...	Yes
731	45° 26. 3'	85° 13. 2'	...	...	...	...	...	Yes
732	45° 27. 2'	85° 12. 9'	August 28	45° 35. 0'	85° 7. 0'	5	10	Yes
733	45° 28. 1'	85° 12. 5'	...	...	...	...	...	Yes
734	45° 29. 0'	85° 11. 9'	...	...	...	...	...	Yes
735	45° 29. 9'	85° 11. 5'	April 16*	45° 46. 0'	85° 2. 0'	236	19	No
736	45° 30. 8'	85° 11. 0'	August 30	45° 33. 0'	85° 7. 0'	7	4	No
737	45° 31. 7'	85° 10. 7'	...	...	...	...	...	No
738	45° 32. 6'	85° 10. 3'	April 16*	45° 46. 0'	85° 2. 0'	236	16	No
739	45° 33. 5'	85° 9. 9'	...	...	...	...	...	No
Average	...	...	...	...	...	2	9. 8	Yes
Number of bottles	...	...	...	...	...	4	6	Yes
August 25								
740	45° 26. 6'	85° 21. 2'	April 22*	45° 37. 0'	85° 5. 0'	240	22	Yes
741	45° 26. 6'	85° 27. 2'	September 23	45° 21. 0'	85° 15. 0'	29	12	Yes
742	45° 26. 6'	85° 27. 2'	November 6	45° 22. 0'	85° 0. 0'	73	22	No
743	45° 26. 6'	85° 27. 2'	May 4*	45° 21. 0'	85° 15. 0'	252	12	Yes
744	45° 26. 6'	85° 27. 2'	September 18	45° 21. 0'	85° 15. 0'	24	12	No
745	45° 26. 6'	85° 27. 2'	...	...	...	...	...	Yes
746	45° 26. 6'	85° 27. 2'	...	...	...	...	...	Yes
Average	...	...	...	...	...	2	42. 0	Yes
Number of bottles	...	...	...	...	...	3	5	Yes

¹ August 23--with drags, 3; without drags, 3. August 25--with drags, 3; without drags, 2.

² Based on recoveries in year of release.

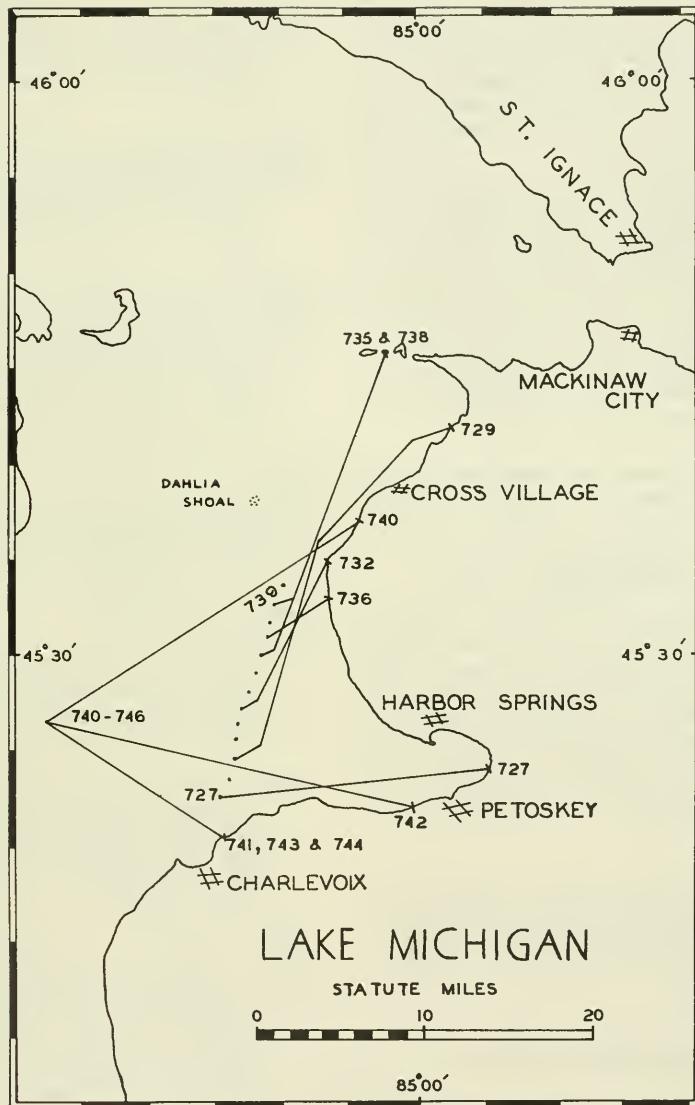


Figure 21.--Movements of bottles released from Charlevoix to Dahlia Shoal, August 23, and northwest of Charlevoix, August 25, 1932.

In 1932, the transect bottles were deposited only from Grand Haven to Sheboygan, from Two Rivers to Frankfort, and from Charlevoix to Manistique; all others were dropped along the shores. Of the 119 recoveries of transect bottles, 103 or 86.6 percent were found on the eastern shore and only 16 or 13.4 percent along the western coast. Of the other 212 bottles recovered, 173 or 81.6 percent were discovered along the eastern shore and 39 or 18.4 percent along the western coast (38 of which were found in Green Bay). It is unusual to find that all 25 recovered bottles deposited from Sheboygan to Sturgeon Bay floated to the eastern shore. Of the entire total of recovered bottles, 276 (83.4 percent) were taken along the eastern shore and 55 (16.6 percent) along the western coast.

Most of the bottles had drifted northeast in 1931 and northeast and southeast in 1932.

SUMMARY

The U.S. Bureau of Fisheries conducted studies of movements of drift bottles in Lake Michigan in 1931 and 1932. Releases totaled 283 in 1931, 462 in 1932, and 745 in both years. Dates of releases were June 17 to August 17, 1931, and May 9 to August 25, 1932. Returns amounted to 186 cards or 65.7 percent of the 1931 releases, 331 or 71.6 percent of the 1932 releases, and 517 or 69.4 percent for the 2 years.

Most of the recovered bottles dropped along transects moved to the eastern shore. About 68 percent of the bottles deposited along the western shore had also floated to the eastern coast.

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