SEA LAMPREY SPAWNING RUNS IN THE GREAT LAKES, 1950

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Explanatory Note

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SEA LAMPREY SPAWNING RUNS IN THE GREAT LAKES IN 1950

by

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Fishery Biologists

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Introduction

As the result of a special Congressional appropriation (Public law 249-81st Congress) the Service's sea lamprey investigations were greatly expanded at the beginning of the 1950 calendar year. A permanent staff of seventeen individuals with an equal number of seasonal employees was assigned specifically to these investigations. Permission to occupy the former Hammond Bay Coast Guard Station on northern Lake Huron was obtained from that agency and the nine buildings and other properties involved are now known as the Hammond Bay Fishery Laboratory. Alterations and additions to provide office and laboratory space, running-water aquaria and tank rooms, work shop, net-shop, boathouse, and raceway facilities have been completed or are in progress. Considerable time and energy have been expended to equip this field station and in training the permanent staff.

A number of investigations of both the biology of the sea lamprey and of methods of controlling that parasite are currently underway. This report is the first of a series describing the results of one group of studies and activities brought to a conclusion during the 1950 season. Subsequent reports will treat other phases of the work.

<u>Installation and operation of sea lamprey control structures in 1950</u>

<u>Lake Huron</u>.--In northern Lake Huron 11 weirs and traps were operated in an area which was termed Control Zone H-1. This zone extends a distance of about 90 miles from Waugochance Point at the west end of the Straits of Mackinaw to the southern boundary of Presque Isle County, Michigan (Figs. 1 and 2). Weirs were placed in every stream in this zone in which sea lampreys were known to run. Among these structures were the Ocqueoc River and Carp Creek weirs which were operated in former years. During the 1950 season these two traps were run cooperatively with the Michigan Department of Conservation by crews made up of employees of both agencies. With the exception of the permanent-type Ocqueoc weir all others installed were standard, portable-type sea lamprey weirs (Figures 3, 4, and 5). Complete runs were captured in all but two streams and in these, only a minor escapement occurred.

The objectives in establishing this "control zone" were manifold and may be briefly outlined as follows:

(1) To institute immediately a measure of sea lamprey control on an organized basis. Experience gained from such an operation would be, and was, invaluable in revealing administrative and operational problems which would present themselves in a large-scale control program;

(2) To determine whether destroying the potential to produce sea lampreys in the streams tributary to a limited area of shoreline would

Figure 1.--Map of upper Great Lakes showing established and proposed sea lamprey control devices.

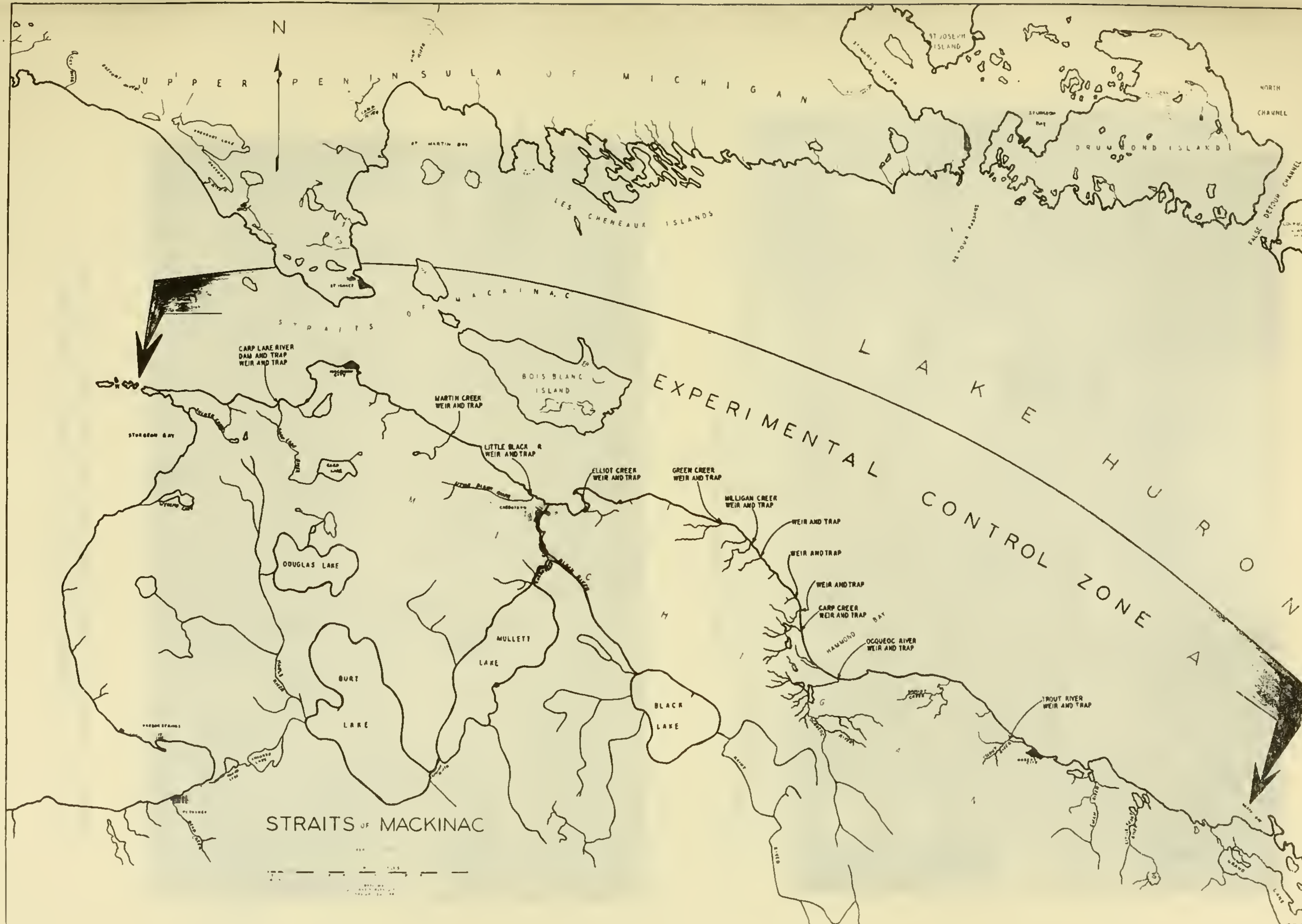

Figure 2.—Map of northern Lake Huron and Straits of Mackinaw showing location of weirs and traps in Control Zone H-1.

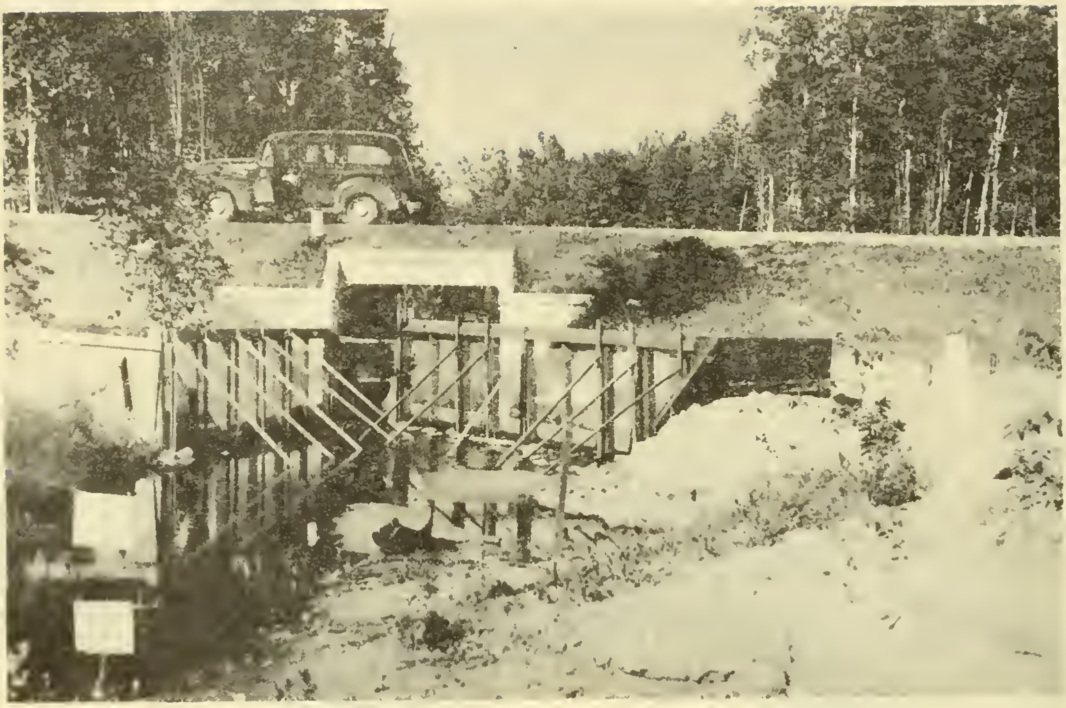

Figure 3.—Portable-type weir in Milligan Creek, Presque Isle County, Michigan

Figure 4.—Small portable-type weir and trap in Cedar Creek, Presque Isle County, Michigan

Figure 5.—Large portable-type weir and trap in Pendill's Creek, Chippewa County, Michigan.

have any local beneficial effects on fish stocks in the lake:

(3) To develop and test improvements in the design and construction of mechanical control structures; and,

(4) To provide needed additional sites where adequate checking structures (weirs and traps) were present for testing other devices or techniques of control

Continued operation of the devices in this zone in future years is essential to the successful attainment of all objectives sought.

Lake Michigan—In Lake Michigan the Service contributed materials and technical assistance for construction of 7 portable-type weirs and traps operated by the Wisconsin Conservation Department. Entire runs were captured by most of these weirs. In some streams only part of the runs were taken since inadequate knowledge of the spawning grounds resulted in the location of the trapping devices too far upstream. Re-location of improperly placed weirs was effected by the Wisconsin Conservation Department during the summer of 1950. One portable-type trap was subsidized by the Service for operation in Trail Creek near Michigan City, Indiana, by the Indiana Conservation Department. Only a portion of the run was captured due to frequent flood damage and operation by inexperienced personnel.

One portable-type weir and trap was installed in the Black River, Mackinaw County (Upper Peninsula shore of Lake Michigan) for operation by Michigan Department of Conservation personnel as a checking device in an experiment on the effectiveness of a barrier dam for blocking the upstream movement of sea lampreys. The operation of this weir was intermittent; it is estimated that 50 percent of the run was captured.

The Michigan, Wisconsin, and Indiana Conservation Departments have kindly permitted us to utilize much or all of the data collected by them in preparing subsequent sections of this report.

Lake Superior.--In Lake Superior a weir and trap in Pendill's Creek, a tributary of Witefish Bay, captured the entire run. Subsequent to the spawning-run season, another weir and trap were installed in the Chocolay River near Marquette. This structure will serve as a check on the effectiveness of an electric fish screen which is in place and is to be tested in the spring of 1951.

Numbers of lampreys taken by control devices.--A total of 48,894 spawning-run sea lampreys were captured in 1950 in 21 trapping devices (exclusive of 2,843 individuals captured and released in a tagging experiment). Biological data were recorded for many of these lampreys; all individuals were subsequently destroyed. These catches are summarized in Table 1. Individual totals are given for streams in which trapping devices were operated directly by the Fish and Wildlife Service or coöperatively with the Michigan Conservation Department. Gross totals only are given for trapping operations effected with other agencies.

Relative abundance of sea lampreys

Lake Huron.--In northern Lake Huron weir and trap catches suggest a leveling-off or even a slight diminution in the sea lamprey population in that area. The total run in the Ocqueoc River in 1949 was 24,643 lampreys; that in 1950 was 18,882. Tagging studies indicated that an appreciable portion of the Ocqueoc River run in 1950 was "siphoned off" through the operation of weirs in all other nearby streams. If this fact is taken into consideration, the numbers in the 1949 and 1950 runs in this stream may be said to be nearly equal. Weir operations, fishing operations in the lake, and contacts with commercial fishermen

Table 1.--Numbers of spawning-run sea lampreys taken by control devices during 1950 season. (Structure designated by number may be located on map in Figure 1)

Stream	Total taken
Lake Huron tributaries:	
Control Zone H-1:	
1. Carp Lake River, Emmet County	3,821
2. Martins Creek, Cheboygan County	3
3. Little Black River, Cheboygan County	953
4. Elliott Creek, Cheboygan County	266
5. Green Creek, Cheboygan County	1,945
6. Milligan Creek, Presque Isle County	700
7. Cedar Creek, Presque Isle County	0
8. Grace Harbor Creek, Presque Isle County	52
9. Carp Creek, Presque Isle County	1,161
10. Ocqueoc River, Presque Isle County	18,822
11. Trout River, Presque Isle County	1,702
Total-Control Zone H-1	29,425
Lake Michigan tributaries:	
12. Black River, Mackinaw County	2,144
Seven weirs operated cooperatively with the Wisconsin Conservation Department	16,391
One weir operated cooperatively with the Indiana Conservation Department	896
Total - Lake Michigan	19,431
Lake Superior tributaries:	
Pendill's Creek, Chippewa County	38
Grand Total	48,894

indicate that fish stocks in the area are sorely reduced, somewhat almost to the point of disappearance. A decline in the sea lamprey population would be a natural sequel to the recently observed abrupt decline of available prey species.

As a matter of historical interest and as an aid in predicting the future status of this parasite in Lakes Michigan and Superior, all available records of the spawning runs entering the Ocqueoc River are assembled herewith. (This run was first observed and reported in 1937 by Conservation Officer Marvin Norton according to Shetter (1949).

Year	Numbers trapped or enumerated
1944	1/ 3,366
1945	1/ 4,608
1946	(NO DATA)
1947	2/ 10,000
1948	2/ 13,000
1949	2/ 24,643
1950	18,882

Lake Michigan.--Whereas the population in Lake Huron appears to have at least leveled off, Wisconsin Conservation Department reports for Hibbard Creek in Door County reflect a near trebling of the population in northwestern Lake Michigan over 1949 levels. This point is illustrated in the following records of weir and trap catches of spawning migrants 3/ in the afore-mentioned stream over a 4-year period.

1/ Shetter (1949); partial capture of run; examination of Shetter's data suggests that these catches represent about three-quarters of the run entering in each year.

2/ Applegate (1950); data for 1947 and 1948 are estimates from counts of total number of nests in watershed with consideration given for observed spawning habits and sex ratio in those years; catch in 1949 is entire run taken in new permanent-type Ocqueoc River weir and trap.

3/ Data for 1945-1946 provided by Mr. Matt Patterson of the Wisconsin Conservation Department. The number of lampreys trapped in 1945 is not the complete run into the stream; trapping operations were intermittent in that year.

3/ Data for 1947-1949 extracted from Wisconsin's report in the "Report of the Great Lakes Sea Lamprey Committee-1947," "Report of the Great Lakes Sea Lamprey Committee-1948," and "Report of the Great Lakes Sea Lamprey Committee-1949," (Mimeographed).

Year	Number trapped
1945	25
1946	125
1947	596
1948	989
1949	1,579
1950	5,422

Whether or not the sea lamprey had reached the peak of its abundance in Lake Michigan will not be revealed until the conclusion of the 1951 season. Judging, however, by the rate of decline of the lake trout (an apparently preferred prey species) in this lake, the time when the demand for food far exceeds the supply is fast approaching.

Lake Superior.--In Lake Superior, stream survey reports and records of occurrence in the Lake proper indicate that the lamprey is more firmly entrenched than heretofore suspected and, although still not numerous, is on the increase. The presence of spawning runs in streams tributary to the southeastern area of the lake is definitely established. Adults have been captured throughout the lake to its extreme western end. In August 1950, representatives of the Minnesota Conservation Department captured mature spawning migrants in several streams in the vicinity of Duluth, Minnisota.

Further expansion of the sea lamprey population in Lake Superior may be anticipated. Although adult sea lampreys or their nests were found in slightly less than 10 percent of the 325 streams on the southeastern shore of the lake examined in 1950, roughly one-third of the streams in the area are of a character suitable for sea lamprey reproduction. 4/ Utilization of these watersheds by the lamprey may be expected in the near future if the characteristic rate of increase of the species after establishment in a new water (as evidenced in Lakes Huron and Michigan) is displayed.

Other species of fish taken in weirs and traps and degree of scarring among them

Counts by species were made of fish in 10 of the weirs and traps in Control Zone H-1 in northern Lake Huron and in Pendill's Creek which flows into Lake Superior. A total of 103,544 fish were taken along with the sea lampreys in the 10 streams of Zone H-1; in Pendill's Creek, 1,243 were captured (Table2). Data were collected also on the numbers of lamprey-scarred suckers of several species taken in eight of the streams in Zone H-1 and in Pendill's Creek (Table 3). Scarring records for other species were incomplete. The data presented in this section not only reflect the continuing decline of certain species but also contain a hint that the balance among the remaining fish stocks in this area of Lake Huron may have been profoundly affected by the sea lamprey.

4/ A detailed report of a survey of streams tributary to Lake Superior which was conducted in 1950 is now in preparation.

Table 2.--Numbers and kinds of fish (upstream migrants) taken along with sea lampreys in weirs and traps in 10 streams in Control Zone H-1 and Pendill's Creek (Lake Superior basin) during the 1950 season

Species of fish	Trout River, Presque Isle Co.	Ocqueoc River, Presque Isle Co.	Carp Creek, Presque Isle Co.	Grace Harbor Cr., Presque Isle Co.	Cedar Creek, Presque Isle Co.	MilliganCreek, Presque Isle Co.	Green Creek, Cheboygan Co.	Elliott's Creek, Cheboygan Co.	Little Black River, Cheboygan Co	Carp Lake River, Emmet Co.	Pendill's Creek, Chippewa Co.	Totals
White suckers:												
Mature	52	296	152	18	10	358	134	204	2,141	141	13	3,519
Immature	211	37	25	15	-	146	-	77	-	-	13	524
Sturgeon suckers	1,223	35	9	-	-	42	-	-	6	438	839	2,592
Smelt	3	-	276	-	-	-	2,436	-	5,544	68	-	8,327
Yellow perch	-	16	-	-	-	-	-	-	-	-	-	16
Rainbow trout	22	54	5	-	-	-	6	1	1	12	16	117
Brook trout	2	5	3	-	-	2	9	308	-	1	83	413
Walleye	-	1	-	-	-	-	-	-	1	3	-	5
Northern pike	1	3	-	-	-	-	1	-	10	8	-	23
Smallmouth bass	-	68	4	-	-	-	-	-	-	-	-	72
Rock bass	1	21	16	-	-	-	-	-	31	14	11	94
Pumpkinseed sunfish	-	8	1	-	-	-	-	-	3	-	-	12
Black bullheads	5	57	11	-	-	-	1	-	17	413	-	504
Lake chubs	7	97	3,204	4,705	7,913	12,083	17,255	7	111	72	1	45,455
Great Lakes Longnose dace	763	3,429	30,028	30	13	739	1,431	4	61	849	252	37,599
Common shiners	409	548	180	-	-	16	10	32	933	974	5	3,107
Creek Chubs	101	1	1	-	1	36	14	209	74	-	-	437
Muddlers	351	55	43	5	1	8	27	-	47	5	10	552
Log perch	-	23	-	-	-	-	-	-	3	-	-	26
Darters, misc.	-	-	-	-	-	-	1	-	12	-	-	13
Mudminnows	-	-	-	-	-	-	1	5	6	-	-	12
Misc. other Cyprinids	21	1,160	15	4	-	39	3	117	1	-	-	1,360
Silver lampreys	-	-	-	-	-	-	2	-	1	5	-	8
Total	3,172	5,914	33,973	4,777	7,938	13,469	21,331	964	9,003	3,003	1,243	104,707

Table 3.--Total catch, number scarred, and percentage scarred of migrant white and sturgeon suckers taken in eight streams in Control Zone H-1 and in one Lake Superior tributary during the 1950 season

Stream	White suckers (mature only)			Sturgeon suckers		
	Total trapped	Number scarred	Percentage scarred	Total trapped	Number scarred	Percentage scarred
Lake Huron:						
Control Zone H-1:						
Trout River, Presque Isle Co.	52	22	42.3	1,221	468	38.3
Ocqueoc River, Presque Isle Co.	296	94	31.8	35	5	14.3
Carp Creek, Presque Isle Co.	152	46	30.3	9	4	44.4
Milligan Creek, Presque Isle Co.	358	15	4.2	42	15	35.7
Green Creek, Cheboygan Co.	101	21	20.8	0	-	-
Elliott's Creek, Cheboygan Co.	202	38	18.8	0	-	-
Little Black River, Cheboygan Co.	2,074	675	32.5	6	0	0.0
Carp Lake River, Emmet Co.	141	12	8.5	438	13	3.0
Lake Superior:						
Pendill's Creek Chippewa Co.	13	0	0.0	839	6	0.7

Comparison of weir catches of the larger fishes (food, game and coarse species) with those of former years reflects a drastic decline in the size of their spawning runs (Applegate 1950). Concurrently with this decline, the percentage of lamprey-scarred individuals has increased. For example, in Carp Creek and the Ocqueoc River (Control Zone H-1) the spawning runs of suckers and the number and percentage of lamprey-scarred individuals among them over a 4-year period were as follows:

Stream	Year	Total suckers taken (all species)	Percentage of suckers scarred
Carp Creek	1947	3,700	7.0
Carp Creek	1948	2,848	6.8
Carp Creek	1949	1,811	17.2
Carp Creek	1950	161	31.1
Ocqueoc River	1949	3,137	25.5
Ocqueoc River	1950	331	30.0

The decline of these runs most certainly reflects a severe depletion of the stocks of suckers in the lake proper. Fishing operations conducted in this area of the lake substantiate this view. It may be reiterated here that the decline of these and other species of fishes has been coincident with, and (directly) proportional to, the increase in the numbers of sea lampreys (see text table, p.8).

On the other hand, the numbers of smaller species of fish, primarily cyprinids and presumably forage species, seem to have increased each year. For example, the numbers of Great Lakes longnose dace taken in the Carp Creek weir and trap over a 4-year period were as follows: 1947-804; 1948-5,798; 1949-15,694; and 1950-30,028. These minnows, too small to be preyed upon by the sea lamprey and in the absence of any effective numbers of their normal predators, appear to be increasing apace.

Some biological characteristics of the sea lamprey runs

Sex ratio.--Records of sex were made for all or nearly all of the sea lampreys taken in eight streams in Control Zone H-1 and in one stream tributary to Lake Superior (Table 4). Examination of these data collected in 1950 indicates that the sex ratio of entire runs in northern Lake Huron continues to shift in favor of the males. Specific figures for four consecutive years are as follows (where data for runs in more than one stream are available, an average has been obtained for the combined runs).

Year	Sex Ratio
1947	165 males : 100 females
1948	169 males : 100 females
1949	211 males : 100 females
1950	252 males : 100 females

Table 4.—— Sex ratio of sea lamprey runs in eight tributaries of northern Lake Huron and one of Lake Superior during 1950 season.

STREAM	TOTAL CATCH	TOTAL FOR WHICH SEX DETERMINED	NO. OF MALES	NO. OF FEMALES	RATIO OF MALES TO FEMALES
Lake Huron:					
Control Zone H-1					
Trout River, Pres. Isle, Co.	1,703	1,703	1,206	497	243:100
Ocqueoc River, Pres. Isle, Co.	18,822	18,065	12,946	5,119	253:100
Carp Creek, Pres. Isle, Co.	1,161	1,161	863	298	290:100
Grace Harbor Cr., Pres. Isle, Co.	52	51	41	10	410:100
Green Creek, Cheboygan Co.	1,945	1,325	995	330	302:100
Carp Lake River, Emmet Co.	3,821	3,821	2,666	1,155	231:100
Little Black River, Cheboygan, Co.	953	754	522	232	225:100
Elliott's Creek, Cheboygan, Co.	266	208	157	51	308:00
TOTAL	28,723	27,088	19,396	7,692	252:100
Lake Superior:					
Pendill's Creek, Chippewa, Co.	38	38	20	18	111:100

It is possibly significant that in Pendill's Creek, in the Lake Superior basin, where the species is relatively recently established, the sex ratio of the run was 111 males : 100 females.

Range in length and average size of migrant adult sea lampreys.--The range in length of 5,287 migrant sea lampreys, sexes combined, that were measured in 1950 was 9.9 to 22.9 inches. The average length, sexes separately or combined, varied a little among the two runs studied but was generally close to a mean of 16.5 inches (Tables 5,6,and 7). These data were collected in Carp Creek and the Ocqueoc River according to a predetermined sampling schedule: 57.5 percent of the Carp Creek run and 24.5 percent of the Ocqueoc River run were measured.

Although a slight decline in average length was observed this year for these two runs, the difference was not significant. This year's runs did, however, include a number of individuals of a smaller size than had ever been encountered in three earlier years. Prior to 1950, 10,411 migrant adults from these two streams had been measured. The extreme range in length of this sample was 11.0 to 23.5 inches of which only eight individuals measured less than 12.0 inches (Applegate, 1950). In 1950, among 5,287 sea lampreys the total length of 17 individuals were less than 12.0 inches.

The range in size of migrant adults is being followed closely for any significant decline in size would seriously affect the structural requirements of mechanical control devices. A decrease in average length of the sea lamprey must be considered possible in the presence of a declining food supply.

Characteristics of spawning runs and their response to the several factors affecting them.--Other than in the matter of the sex ratio, as previously noted, the spawning runs in the Ocqueoc River and Carp Creek did not differ in character or in their response to certain environmental factors from those runs of former years (Tables 6, 7, and 8).

Differences in migrations related to sex and size were again apparent. The percentage of males was relatively greater at the beginning of the run. The relative abundance of females was greater toward the end of the run, although they never approached the males in total number. The largest individuals of both sexes appeared early in the runs and the average size of migrants declined during the period of movement.

Upstream migration into the weirs commenced when the mean daily water temperature rose above 40°F.; it was sporadic or light close to that temperature. Movement increased as daily mean of 50°F. was approached and the greatest numbers migrated at temperatures above the 50°F. level.

Table 5.--Length-frequency of sea lampreys collected in Carp Creek and the Ocqueoc River, Presque Isle County, Mich., in 1950. (Data presented by 0.2-inch size groups)

Midpoint of length group (inches)	Carp Creek			Ocqueoc River		
	Males	Females	Total	Males	Females	Total
9.9	...	...	...	...	1	1
10.1	...	...	...	...	...	...
.3	...	...	...	...	...	...
.5	...	...	...	...	...	...
.7	...	...	...	..1	...	1
.9	...	...	...	...	...	...
11.1	...	...	...	3	1	4
.3	...	...	...	...	...	...
.5	...	...	...	3	...	3
.7	...	...	...	2	4	6
.9	...	...	...	2	...	2
12.1	...	...	...	7	...	7
.3	...	1	1	7	3	10
.5	1	...	1	14	1	15
.7	...	...	...	24	1	25
.9	3	...	3	30	10	40
13.1	3	...	3	36	11	47
.3	6	...	6	33	9	42
.5	12	1	13	59	20	79
.7	2	1	3	66	16	82
.9	14	3	17	78	16	94
14.1	11	3	14	87	22	109
.3	20	2	22	96	35	131
.5	16	4	20	104	31	135
.7	16	1	17	106	31	137
.9	17	5	22	138	42	180
15.1	16	5	21	94	28	122
.3	16	6	22	102	49	151
.5	37	9	46	142	55	197
.7	21	4	25	148	55	203
.9	32	14	46	131	63	194
16.1	18	3	21	111	46	157
.3	11	6	17	124	67	191
.5	37	9	46	138	53	191
.7	13	4	17	130	45	175
.9	16	16	32	128	55	183
17.1	19	4	23	90	43	133

Continued on next page

Table 5, continued

Midpoint of length group (inches)	Carp Creek			Ocqueoc River		
	Males	Females	Total	Males	Females	Total
17.3	8	5	13	87	45	132
.5	18	5	23	96	46	142
.7	11	4	15	95	37	132
.9	15	6	21	101	56	157
18.1	14	7	21	75	39	114
.3	15	1	16	67	28	95
.5	14	4	18	87	51	138
.7	5	2	7	67	37	104
.9	9	5	14	94	39	133
19.1	4	4	8	44	31	75
.3	4	4	8	49	23	72
.5	8	3	11	44	18	62
.7	6	1	7	33	10	43
.9	6	2	8	22	17	39
20.1	2	2	4	19	22	41
.3	3	1	4	14	16	30
.5	2	1	3	16	4	20
.7	1	2	3	9	3	12
.9	2	1	3	4	5	9
21.1	1	...	1	6	3	9
.3	1	...	1	4	2	6
.5	...	...	...	1	2	3
.7	...	...	...	1	...	1
.9	...	1	1	2	...	2
23.1	...	...	...	...	1	1
Total	506	162	668	3,271	1,348	4,619
Mean Length	16.4	16.9	16.5	16.4	16.7	16.5
Stand. Deviation	1.78	1.75	1.76	1.89	1.86	1.88

Table 6.--Mean water temperatures, number and average length by sexes of samples of sea lampreys and total number of sea lampreys taken in Carp Creek Presque Isle County, Mich., by dates and by periods in 1950

Date 1950	Mean water temperature (F^{o})	Males: Number measured	Males: Average length (inches)	Females: Number measured	Females: Average length (inches)	Number not measured	Total number taken
April 26-May 2 (Weir operation continuous - no lampreys taken)							
May 3	43.0	1	17.6	...	...	1	2
4	41.0	...	...	...	...	...	...
5	43.0	1	17.4	2	19.0	...	3
May 1-5	...	2	17.5	2	19.0	1	5
6	47.5	1	14.7	...	...	...	1
7	43.0	...	...	...	...	...	...
8	43.5	...	...	...	...	...	...
9	46.5	...	...	...	...	...	...
10	46.5	1	17.6	...	...	...	1
May 6-10	...	2	16.2	...	...	...	2
11	47.5	2	19.3	2	17.7	...	4
12	50.0	5	15.9	2	18.6	...	7
13	56.0	10	16.7	3	16.6	...	13
14	56.0	26	16.6	14	16.6	...	40
15	56.0	...	...	...	...	31	31
May 11-15	...	43	16.7	21	16.9	31	95
16	58.5	6	17.9	7	17.9	24	37
17	52.0	...	...	...	...	38	38
18	53.5	20	16.5	1	17.6	...	21
19	54.0	...	...	...	...	46	46
20	58.0	106	16.4	32	16.8	13	151
May 16-20	...	132	16.4	40	17.0	121	293
21	63.0	...	...	...	...	25	25
22	62.5	73	16.9	23	17.7	...	96
23	59.5	...	...	...	...	83	83
24	62.0	62	15.9	15	16.4	...	77
25	64.0	...	...	...	...	79	79
May 21-25	...	135	16.4	38	17.2	187	360
26	64.5	64	16.5	20	16.6	...	84
27	56.0	...	...	...	...	45	45
28	56.0	13	16.2	6	17.7	...	19
29	61.0	...	...	...	...	32	32
30	65.0	25	16.0	6	16.6	...	31
31	63.0	...	...	...	...	12	12
May 26-31	...	102	16.3	32	16.8	89	223

Continued next page

Table 6, continued

Date 1950	Mean water temperature (F°)	Number measured	Average length (inches)	Number measured	Average length (inches)	Number not meas.	Total number taken
June 1	63.0	4	17.9	2	19.0	...	6
2	63.0	...	...	...	...	11	11
3	58.0	2	17.6	1	18.9	...	3
4	59.0	...	...	...	...	5	5
5	58.0	3	15.8	2	16.8	...	5
June 1-5	...	9	17.1	5	18.1	16	30
6	65.0	...	...	...	...	8	8
7	63.0	9	16.4	2	17.8	...	11
8	70.0	...	...	...	...	3	3
9	71.5	6	14.7	1	17.3	...	7
10	71.0	...	...	...	...	7	7
June 6-10	...	15	15.7	3	17.6	18	36
11	64.0	5	16.3	...	...	...	5
12	62.0	...	...	...	...	...	...
13	64.5	18	16.0	8	16.3	...	26
14	66.0	...	...	...	...	3	3
15	65.5	14	15.8	4	16.3	...	18
June 11-15	...	37	16.0	12	16.3	3	52
16	...	...	...	...	...	18	18
17	63.5	20	16.6	8	15.0	...	28
18	57.0	...	...	...	...	9	9
19	56.5	7	16.6	1	19.0	...	8
20	60.0	...	...	...	...	...	...
June 16-20	...	27	16.6	9	15.5	27	63
21	61.0	1	18.2	...	...	...	1
22	59.0	...	...	...	...	...	...
23	60.5	...	...	...	...	...	...
24	65.0	...	...	...	...	...	...
24	68.0	...	...	...	...	...	...
June 21-25	...	1	18.2	...	...	...	1
26	68.0	...	...	...	...	...	...
27	68.0	1	16.6	...	...	...	1
28	64.0	...	...	...	...	...	...
29	64.0	...	...	...	...	...	...
30	64.0	...	...	...	...	...	...
June 26-30	...	1	16.6	...	...	...	1
July 1-20 (Weir operations continuous - no lampreys taken)							
Totals and averages		506	16.4	162	16.9	493	1,161

Table 7.--Number and average length by sexes of samples of sea lampreys and total number of sea lampreys taken in the Ocqueoc River, Presque Isle County Mich., by dates and by periods in 1950

Date 1950		Males		Females			
		Number measured	Average length (inches)	Number measured	Average length (inches)	Number not measured	Total no. taken
April 25-May 10 (Weir operation continuous - no lampreys taken)							
May	11	...	...	...	...	...	...
	12	5	17.6	...	...	...	5
	13	17	18.3	4	18.7	...	21
	14	9	18.9	6	18.4	...	15
	15	...	...	...	...	390	390
	16	35	18.3	12	18.6	59	106
	17	...	...	...	...	66	66
	18	57	17.5	32	18.3	0	89
	19	...	...	...	...	288	288
	20	155	16.9	48	17.3	1,472	1,675
May	11-20	278	17.4	102	17.9	2,275	2,655
	21	...	...	...	...	989	989
	22	146	16.4	67	16.9	1,135	1,348
	23	...	...	...	...	377	377
	24	154	16.4	53	16.5	781	988
	25	...	...	...	...	702	702
	26	144	16.3	71	17.1	373	588
	27	...	...	...	...	380	380
	28	106	17.0	41	17.4	...	147
	29	...	...	...	...	541	541
	30	145	16.0	68	16.7	399	612
	31	...	...	...	...	755	755
May	21-31	695	16.4	300	16.9	6,432	7,427
June	1	142	16.4	58	16.5	266	466
	2	...	...	...	...	366	366
	3	155	16.9	48	17.3	175	378
	4	...	...	...	...	419	419
	5	118	16.1	55	16.7	94	267
	6	...	...	...	...	319	319
	7	154	16.5	61	16.9	187	402
	8	...	...	...	...	476	476
	9	195	16.6	84	16.9	141	420
	10	...	...	...	...	499	499
June	1-10	764	16.5	306	16.8	2,942	4,012

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Date 1950	Males: Number measured	Males: Average length (inches)	Females: Number measured	Females: Average length (inches)	Number not measured	Total no. taken
June 11	172	16.1	76	16.8	193	441
12	...	...	...	...	348	348
13	138	16.0	65	16.9	...	203
14	...	...	...	...	231	231
15	117	16.3	64	16.7	30	211
16	3	17.6	2	16.4	249	254
17	165	16.4	57	16.6	76	298
18	...	...	...	...	419	419
19	146	16.5	55	16.9	59	260
20	...	...	...	...	297	297
June 11-20	741	16.3	319	16.8	1,902	2,962
21	165	16.5	60	17.0	85	310
22	...	...	...	...	244	244
23	101	16.3	35	16.1	1	137
24	...	...	...	...	163	163
25	31	16.2	12	17.0	51	94
26	26	15.8	9	16.7	11	46
27	105	15.7	46	16.0	...	151
28	30	16.2	13	16.9	46	89
29	58	16.3	26	16.1	1	85
30	32	16.1	12	15.8	34	78
June 21-30	548	16.2	213	16.5	636	1,397
July 1	43	15.4	27	15.9	...	70
2	51	15.5	17	16.6	...	68
3	13	14.9	5	18.6	...	18
4	...	...	...	...	8	8
5	1	14.0	...	...	...	1
6	1	14.9	2	15.6	...	3
7	15	14.5	10	16.0	...	25
8	16	14.9	5	15.9	...	21
9	17	15.4	5	16.0	...	22
10	5	16.5	2	15.4	...	7
July 1-10	162	15.3	73	16.3	8	243
11	4	13.7	3	16.5	1	8
12	1	16.8	1	15.7	...	2
13	1	14.6	1	15.8	...	2
14	5	15.6	...	...	...	5
15	8	13.9	2	15.5	1	11
16	10	15.7	3	15.4	...	13
17	5	15.2	1	17.1	...	6
18	7	15.5	3	16.4	...	10

Continued on next page

Table 7, continued

Date 1950	Males Number measured	Males Average length (inches)	Females Number measured	Females Average length (inches)	Number not measured	Total no.taken
July 19	5	15.1	4	13.3	...	9
20	2	14.4	...	...	...	2
July 11-20	48	15.0	18	15.4	2	68
21	2	14.9	3	13.5	...	5
22	7	14.9	6	13.8	...	13
23	6	15.3	...	...	...	6
24	4	14.9	1	15.0	...	5
25	2	13.7	...	...	...	2
26	2	15.0	...	...	...	2
27	...	...	1	14.2	...	1
28	...	...	...	...	...	...
29	...	...	...	...	...	...
30	...	...	...	...	...	...
31	...	...	...	...	...	...
July 21-31	23	14.9	11	13.8	...	34
August 1	...	...	...	...	...	...
2	1	16.1	...	...	...	1
3	1	11.2	...	...	...	1
4	5	14.4	1	12.5	...	6
5	1	18.3	1	13.2	...	2
6	...	...	...	...	...	...
7	...	...	1	9.9	6	7
8	1	15.5	...	...	...	1
9	...	...	1	15.5	...	1
10	1	16.0	...	...	...	1
August 1-10	10	14.9	4	12.8	6	20
11	...	...	...	...	...	...
12	1	13.0	1	13.5	...	2
13	...	...	...	...	...	...
14	...	...	...	...	...	...
15	...	...	...	...	...	...
16	...	...	...	...	...	...
17	...	...	...	...	...	...
18	...	...	...	...	...	...
19	...	...	...	...	...	...
20	...	...	...	...	...	...
August 11-20	1	13.0	1	13.5	...	2
21	...	...	...	...	...	...
22	...	...	...	...	...	...
23	...	...	...	...	...	...
24	...	...	...	...	...	...
25	...	...	...	...	...	...
26	...	...	...	...	...	...
27	1	14.5	...	...	...	1
28	...	...	...	...	...	...
29	...	...	...	...	...	...
30	...	...	1	14.5	...	1
August 21-30	1	14.5	1	14.5	...	2
Totals and Averages	3,271	16.4	1,348	16.8	14,203	18,822

Table 8.--Daily minimum, maximum, and mean water temperatures and water gauge readings for the Ocqueoc River (Presque Isle Co., Mich.) with mean air temperature and wind and weather records for the locality: April 25 -August 30, 1950

Date 1950		Water temperature 1/ Min.	Mean	Max.	Water Gauge 2/	Mean air temperature	Wind direction and shift	Weather	
April	25	36	38.5	41	15.4	-	E	Overcast;	rain
	26	38	38.5	39	15.0	-	S	" ;	cool
	27	39	40.5	42	16.5	-	SW	"	"
	28	38	39.0	40	16.1	-	S	"	"
	29	37	38.5	40	15.5	36.0	N	"	"
	30	37	39.5	42	15.0	36.0	N	"	"
May	1	39	40.0	41	13.5	40.0	E	"	"
	2	39	40.0	41	13.0	36.5	W	Clear ;	fair
	3	40	42.0	44	13.0	43.0	NE	Overcast;	rain
	4	40	40.5	41	13.0	43.0	N	" ;	cool
	5	42	42.5	43	13.0	45.5	S	" ;	warm
	6	43	45.0	47	13.0	63.5	S	" ;	windy
	7	44	44.5	45	14.0	58.5	N	Clear ;	cool
	8	43	46.5	50	13.0	42.5	NE	" ;	"
	9	45	47.5	50	12.4	43.0	S	Overcast;	rain
	10	45	47.5	50	12.4	51.0	SW	" ;	cool
	11	44	47.5	51	12.4	43.5	S	" ;	warm
	12	46	50.0	54	Guage	54.0	WNW	Clear ;	"
	13	48	52.0	56	Broken:	53.0	WNW	Overcast;	cool
	14	49	52.5	56	Low	55.5	S	" ;	warm
	15	52	55.0	58	Water	59.0	NW	Clear ;	"
	16	52	55.0	58	"	53.5	N	" ;	"
	17	43	50.5	58	"	46.5	NE	" ;	mild
	18	52	54.0	56	"	40.5	NE	Overcast;	"
	19	53	56.0	59	"	46.5	NE	Clear ;	warm
	20	54	59.0	64	"	50.0	NE	" ;	"
	21	54	59.0	64	"	52.5	E	" ;	"
	22	59	62.0	65	"	61.5	NE	Overcast;	cool
	23	55	59.5	64	"	51.0	NE	Clear ;	warm
	24	58	62.0	66	8.0	63.5	N	Overcast;	cool
	25	60	63.5	67	8.0	64.0	SE	" ;	warm
	26	58	62.5	67	7.6	62.5	NW	" ;	rain
	27	61	62.5	64	8.0	57.0	NW	" ;	cool
	28	58	61.0	64	Low	53.5	NW	" ;	warm
	29	58	62.0	66	8.0	57.0	NE	Clear ;	"
	30	58	63.0	68	7.5	54.5	SE	Overcast;	"
	31	61	64.5	68	7.5	61.5	W	" ;	"
June	1	62	65.0	68	8.0	59.5	S	Clear ;	warm
	2	62	65.0	68	Low	58.0	S	" ;	"
	3	58	61.0	64	8.0	52.0	N	" ;	cool
	4	57	62.5	68	7.5	51.5	W	" ;	"
	5	58	63.0	68	7.2	57.5	None	Overcast;	"
	6	62	64.0	66	7.2	67.0	SW-N	" ;	warm

Continued on next page

Table 8, continued

Date 1950		Water temperature 1/ Min.	Mean	Max.	Water guage 2/	Mean air tempera- ture	Wind direction and shift	Weather
June	7	62	64.0	66	7.0	66.0	SW	Clear ; warm
	8	62	67.0	72	6.7	74.0	SW	" ; hot
	9	66	69.5	73	7.5	76.0	SW	Overcast ; "
	10	68	71.0	74	7.3	59.0	W	" ; cool
	11	60	66.0	72	7.5	56.0	N	Clear ; warm
	12	60	61.0	62	6.5	56.0	E	" ; "
	13	63	68.5	74	6.0	55.0	NW	" ; "
	14	66	70.5	75	6.0	62.0	NW	Overcast ; "
	15	66	70.0	74	6.1	67.0	E	Clear ; "
	16	68	71.0	74	6.5	64.0	NW	Overcast ; cool
	17	51	56.5	62	6.0	62.0	NE	Clear ; fair
	18	60	64.5	69	6.0	49.0	SW	Overcast ; cool
	19	60	64.0	68	6.0	53.0	W	" ; "
	20	62	65.0	68	6.4	64.5	SW	" ; warm
	21	60	65.0	70	6.0	58.0	W	Partly " ; cool
	22	60	64.0	68	5.8	54.0	E	Overcast ; rain
	23	62	66.0	70	5.5	67.5	SW	" ; warm
	24	66	69.0	72	6.7	74.5	W	Partly " ; "
	25	68	73.0	78	6.0	71.0	NW	Clear ; "
	26	68	73.0	78	7.0	71.5	SW	Clear ; "
	27	64	71.0	78	6.5	67.5	W	Overcast ; cool
	28	64	68.0	72	6.5	62.5	SW	" ; warm
	29	64	68.0	72	6.5	71.0	W	Clear ; cool
	30	64	69.0	74	6.5	64.0	SW	Partly overcast ; cool
July	1	68	70.0	72	6.5	56.0	SW	Clear ; fair
	2	62	66.0	70	5.5	67.0	SW	Overcast ; warm
	3	63	65.5	68	6.0	58.0	N	Clear ; fair
	4	62	66.0	70	5.6	61.0	E	Overcast ; cool
	5	61	65.5	70	6.0	59.0	W	Partly " ; warm
	6	62	66.0	70	6.5	60.0	W	Overcast ; "
	7	62	68.0	74	6.0	65.0	W	Clear ; "
	8	63	64.5	66	6.0	67.0	None	" ; hot
	9	66	71.0	76	6.0	67.5	"	" ; warm
	10	68	73.0	78	6.0	75.0	"	" ; "
	11	68	69.0	70	6.0	71.0	"	" ; "
	12	70	75.0	80	6.0	72.0	"	" ; "
	13	52	65.0	78	6.4	72.0	W	Overcast ; cool
	14	63	68.0	73	8.0	52.5	W	" ; "
	15	61	64.5	68	6.5	62.0	SW	Clear ; warm
	16	66	72.0	78	6.5	73.0	S	Partly overcast ; warm
	17	66	71.0	76	7.0	73.5	None	" " ; warm
	18	68	71.0	74	7.4	67.0	NW	Clear ; cool
	19	66	71.0	76	7.0	66.0	E	Overcast ; "
	20	62	65.0	68	6.0	59.0	NW	Partly " ; warm

Continued next page

Table 8, continued

Date 1950		Water temperatures 1/ Min	Mean	Max	Water gauge 2/	Mean air temperatures	Wind direction and shift	Weather
July	21	66	71.0	76	7.5	59.0	W	Part. overc ; warm
	22	66	71.0	76	7.5	70.0	NW	" ; "
	23	66	72.0	78	6.0	68.0	S	Clear ; "
	24	68	71.0	74	5.5	70.0	W	Overc ; "
	25	68	70.0	72	9.0	66.0	W	Clear ; fair
	26	66	71.0	76	7.5	66.0	SW	" overc ; warm
	27	66	72.0	78	7.5	67.0	S	" " ; "
	28		72.0		8.0	76.0	None	Clear ; "
	29	70	74.0	78	8.0	71.0	"	Overc ; "
	30	70	74.0	78	7.3	72.0	SW	" ; rain
	31	68	70.0	72	7.0	65.0	None	" ; warm
August	1	66	68.0	70	9.0	61.0	NE	" ; rain
	2	62	65.0	68	8.0	58.0	NE	" ; fog
	3	62	65.0	68	9.0	56.0	-	" ; "
	4	60	63.0	66	9.0	58.0	NW	" " ; cool
	5	60	64.0	68	8.5	61.0	W	Clear ; warm
	6	62	67.0	72	8.0	64.0	SE	" ; "
	7	62	67.0	72	8.5	63.0	SE	" ; "
	8	64	69.0	74	8.5	68.0	SW	" Overc ; "
	9	66	70.0	74	10.0	72.0	SW	" " ; "
	10	66	70.0	74	8.5	68.0	NW	" " ; cool
	11	62	68.0	74	9.5	63.0	N	Clear ; "
	12	62	68.0	74	8.5	58.0	NW	" ; warm
	13	62	68.0	74	7.5	56.0	None	" ; "
	14	64	69.0	74	7.0	63.0	SW	" ; "
	15	64	69.0	74	7.5	69.0	S	Overc ; "
	16	64	69.0	74	7.3	70.0	W	" " ; cool
	17	68	71.0	74	7.5	69.0	S	" overc ; warm
	18	64	69.0	74	9.0	63.0	NE	" Clear ; cool
	19	54	63.0	72	8.5	52.0	SW	" overc ; "
	20	62	66.0	70	12.0	56.0	NW	" " ; "
	21	60	65.0	70	10.3	66.0	SE	" " ; "
	22	68	69.0	70	8.0	52.0	None	Clear ; "
	23	58	63.0	68	8.0	53.0	S	Overc ; "
	24	62	63.0	64	8.0	59.0	SE	" " ; "
	25	60	65.0	70	8.0	69.0	N	" ; "
	26	58	63.0	68	7.0	60.0	N	" ; "
	27	60	64.0	68	7.0	59.0	None	" ; rain
	28	62	64.0	66	8.5	58.0	"	" ; "
	29	60	62.0	64	9.5	56.0	NE	" ; "
	30	58	60.0	62	9.5	49.0	NE	" ; cool

1/ Water-temperature station at weir
2/ Water-gauge readings are absolute depths in inches across the deck of the weir

The migration was almost exclusively a nocturnal one, with the exceptions appearing very late in the season and only in the larger of the two streams.

Variations in time and character of migration in different streams of differing characteristics in the same zone.--The runs in the following five streams of diverse character in Control Zone H-1 were selected for comparison: Ocqueoc and Trout Rivers and Green, Milligan, and Grace Harbor Creeks (Fig.6). Essentially, all runs in a limited area such as this, regardless of the size of the stream entered, begin on about the same date. The first migrants entered traps in these streams on the following dates: Ocqueoc River--May 12; Trout River--May 3; Green Creek--April 25; Milligan Creek--May 6; Grace Harbor Creek--May 9. The lateness of the first capture in the Ocqueoc River is not normal for that river and is attributable to the blocking action of the right-angle-type weir installed in the stream (see Applegate, 1950). The early captures in Green Creek were due to the location of the weir which was practically on the Lake Huron beach. Earlier researches demonstrated that lampreys explore the mouths of streams for many nights prior to upstream movement until stream temperatures attain a satisfactory level for migration. Such exploring individuals evidently were captured in this trap. The weirs in the other four streams are located some distance upstream.

Although water temperature is the greatest governing factor in determining when and in what numbers upstream movement will occur, the general character (Continuity) and duration of the runs can be strongly influenced by the size of the stream and the stability of its volume of flow. The Ocqueoc River, a moderately large stream with the most stable volume of flow from season to season, has the most prolonged and consistent run in the area. In 1950, this run continued until August 30 (Fig.6). Green Creek, small, but with a stable volume of flow throughout the year, attracted scattered migrants until August 15 but in far less numbers than the Ocqueoc River. During the period of major movement, the run in Green Creek increases and decreases abruptly as in the other smaller streams of the area in quick response to climatic changes.

The Trout River and Milligan Creek, small streams with severe daily and seasonal changes in flow, tend to decline to a trickle by the end of June. This change is reflected in the sea lamprey runs which cease at that time. Carp Creek, mentioned in previous sections, falls in this category (Table 6).

Very small tributaries, 2 to 4 feet wide, attract occasional migrants where the flow of the stream crosses the lake beach in a narrow concentrated channel. Grace Harbor Creek was typical of this type. In another small tributary in the area, Cedar Creek, the discharge was dispersed across the beach zone in a broad, shallow sheet. No lampreys

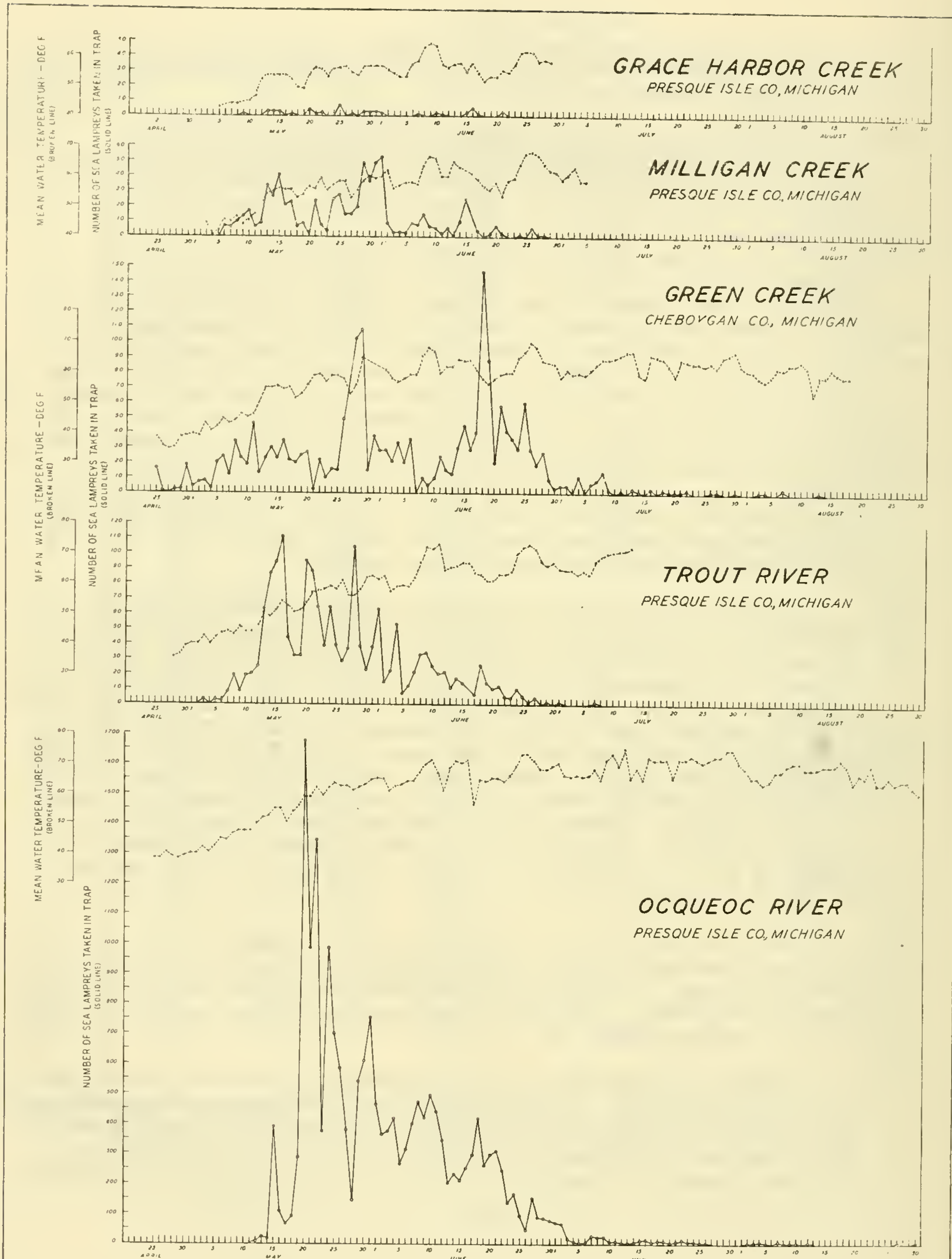

Figure 6.--Number of sea lampreys taken each day during 1950 season in five northern Lake Huron tributaries of different size and character, and mean stream water temperatures for period.

entered this creek. Runs in these small tributaries are erratic and tend to cease early; that in Grace Harbor Creek ended on June 21.

Variations in the time of migration in different areas (latitudes) of the same lake and in different lakes.--It may be remarked here, in passing, that the opening of the 1950 season on northern Lake Huron was the latest in four years. The first sea lamprey did not enter Carp Creek in Presque Isle County, Michigan, until May 3. During four years of widely differing climatic conditions, sea lamprey runs in this creek have commenced as early as April 9 (1949), April 14 (1948), and April 22 (1947). Observations indicated that conditions were similarly late in 1950 throughout the entire upper Great Lakes area.

Five streams in widely separated areas of Lakes Michigan and Superior in which weirs were operated in 1950 were specifically selected for this study (Fig.7). These streams from south to north were: Trail Creek, near Michigan City, Indiana; Hibbard's Creek, Door County, Wisconsin; Carp Lake River, Emmet County, Michigan; Black River, Mackinaw County, Michigan (all tributary to Lake Michigan); and Pendill's Creek, Chippewa County, Michigan (tributary to Lake Superior). Complete runs were not captured in two of these five streams but where complete data were lacking, extrapolations were made, based on past studies of spawning runs.

Examinations of these data reveals that the peak of upstream movement is progressively later in each stream from south to north (Fig.7). In 1950, the run in the stream tributary to the southern tip of Lake Michigan (Trail Creek) reached its peak about 3 weeks earlier than that entering a tributary of the more central area of the lake (Hibbard Creek), and was about 4 weeks earlier than those entering flowages tributary to the lake's northern tip (Carp Lake River and the Black River). Runs in streams in comparable latitudes in Lake Huron attain their peak of migration at the same time as those in Lake Michigan (Fig . 6; Tables 6 and 7). The small run captured in Pendill's Creek, tributary to the eastern extension of Lake Superior, suggests that the major upstream movement in streams of this area occurs as late as or later than that which takes place in streams tributary to the northernmost reaches of Lake Michigan. Data collected in 1950 demonstrated that the Pendill's Creek run did not even commence until 3 1/2 weeks after migrants first appeared in streams of the Mackinaw Straits area (northernmost extensions of Lakes Huron and Michigan). No point is made of actual calendar dates in conjunction with the beginning and peak of sea lamprey migrations. Past studies have indicated that such dates are highly unreliable, since they vary from year to year with climatic conditions. It is sufficient to know the differences in time of migration between different latitudes of one lake and among the different lakes so that operations for control of the species may be properly scheduled.

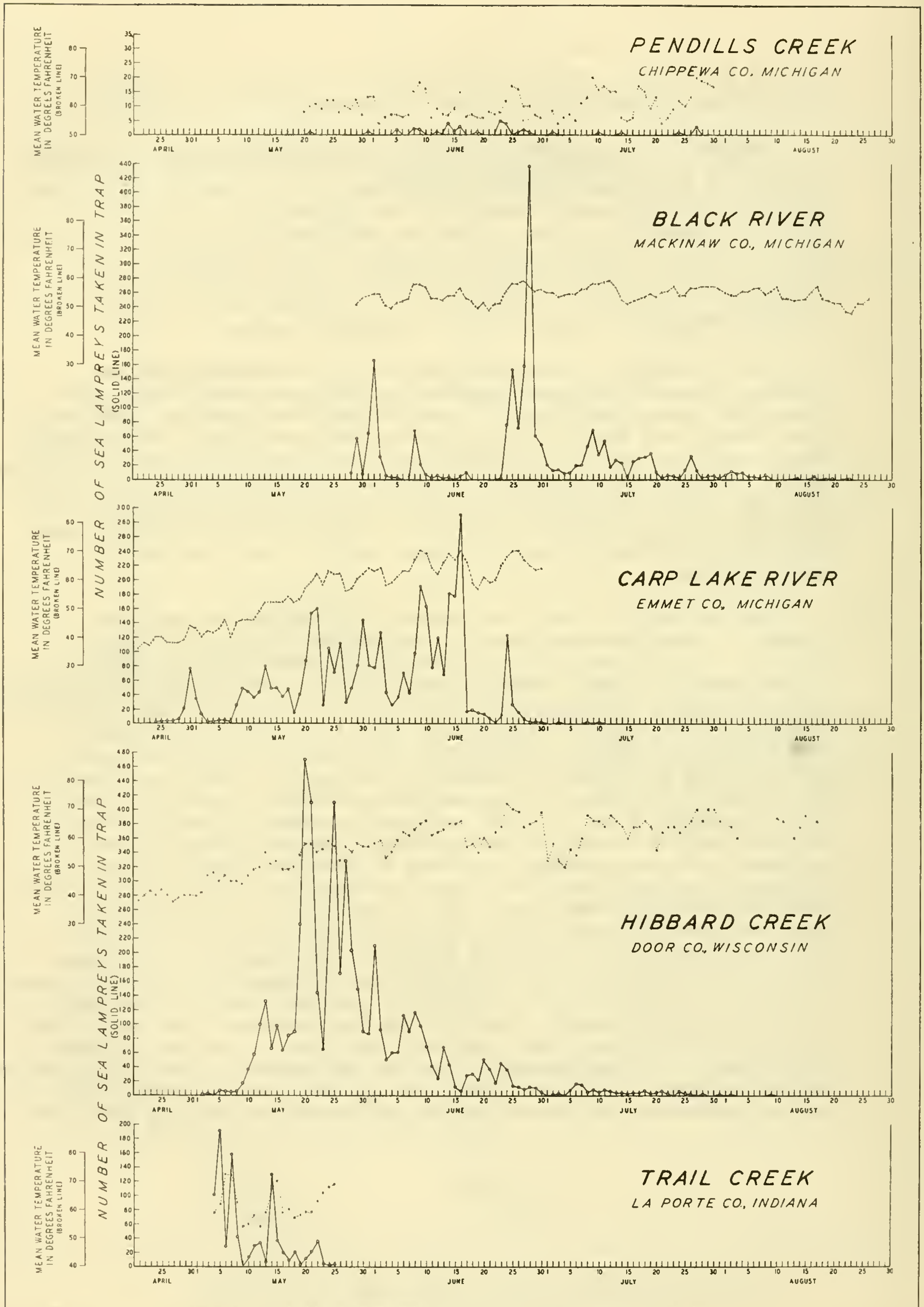

Figure 7.--Number of sea lampreys taken each day during 1950 season in five streams in different geographic latitudes, with mean stream water temperatures for period.

Movement and dispersion of a blocked spawning run of sea lampreys.

In several large Great Lakes watersheds sea lamprey spawning runs are blocked near the mouth of the main stream by power dams. An example of such a watershed is that of the Cheboygan River flowing into the northwest tip of Lake Huron in Control Zone H-1 (Figs. 2 and 8). To determine whether or not it is worthwhile to trap and destroy these large runs which are prevented by barriers from reaching suitable spawning grounds, a tagging experiment was conducted in that river during the spring spawning migration of 1950. Conditions were favorable for such an experiment as the weirs and traps operated within the control zone provided extensive facilities for the recapture of marked lampreys.

Field experiments, anatomical studies, and other observations seemed to indicate that many of these blocked individuals do not locate suitable streams in which to spawn and ultimately die in the lake proper without spawning. The tagging experiment was conducted to find the answers to the following questions.

(1) What proportion of a blocked run is diverted to other streams along the shoreline and what proportion disappears back into the lakes presumably to die without spawning?

(2) In what directions do blocked migrants travel, how far and how fast do they travel, and in what numbers do they enter other watersheds in relation to distance from the blocked stream?

(3) Do these diverted migrants make a significant contribution to the spawning runs in other streams?

A total of 2,843 adult lampreys were trapped below the paper mill power dam in the Cheboygan River and tagged during the period May 7 to June 10, 1950. Of this number, 289 or 10.2 percent were recovered. Of the lampreys recaptured, 254 were trapped in the sea lampreys weirs in the streams of Control Zone H-1, 34 specimens were returned through the cooperation of commercial fishermen who captured them in trap nets and gill nets set for other fishes, and the remainder were captured in a stream on the eastern tip of the Upper Peninsula (Figs. 10 and 11; Table 9).

Forty-two lampreys taken had obviously been tagged but the tag had been torn out. A ragged, "V-shaped" scar was observed in the area where the tag had been placed. These lampreys were counted as tag recoveries in analysing the data, except in those calculations involving the number of days between tagging and recapture. A few dead, marked lampreys were recovered from the Cheboygan River, most of them hanging by the tag from steel wire tangles (city refuse) on the river bottom. These were not counted in the total number tagged or as recoveries. From observations at time of tagging it is known that a few tagged

Table 9.--Location of point of recovery of marked sea lampreys and distance from point of tagging (With number recovered, percentage of total tags recovered, percentage of total tagged, and days out)

Location	Distance from point of tagging (miles)	Tags recovered Number	Tags recovered Percentage	Percentage of total tagged	Days Out Minimum	Days Out Mean	Days Out Maximum
Control Zone H-1:							
In streams:							
Little Black River	2	55	19.0	1.93	2	10.7	30
Elliott Creek	3	18	6.2	0.63	2	10.3	26
Martin Creek	8	3	1.0	0.11	28	29.7	31
Green Creek	12	89	30.7	3.13	3	14.2	65
Milligan Creek	15	3	1.0	0.11	6	7.7	11
Grace Harbor Creek	23	1	0.4	0.04	11	11.0	11
Carp Creek	25	7	2.4	0.25	6	9.2	12
Carp Lake River	25	5	1.7	0.18	8	14.0	18
Ocqueoc River	30	71	24.5	2.50	4	14.8	37
Trout River	43	2	0.7	0.07	13	15.5	18
Total in streams	...	254	87.6	8.95	...	...	...
In the lake:							
West of Cheboygan	2-5	17	5.9	0.60	2	15.5	42
Lighthouse Point	3	1	0.4	0.04	15	15.0	15
Poes Reef	5	2	0.7	0.07	27	38.5	50
Bois Blanc Island	5-10	5	1.7	0.18	11	25.4	35
Fly Point	15	1	0.4	0.04	14	14.0	14
Mackinaw City	17	2	0.7	0.07	6	10.7	14
Round Island	17	1	0.4	0.04	31	31.0	31
Cecil Bay	23	1	0.4	0.04	12	12.0	12
Total in lake	...	30	10.6	1.08	...	...	...
Total in Control Zone H-1	...	284	98.2	10.03	...	...	...
Other Areas:							
In streams:							
Mackinaw Creek (Hessel, Mich.)	25	1	0.4	0.04	(6 to 19 days)		
In the lake:							
St. Martins Bay (Lake Huron)	25	3	1.0	0.11	7	12.0	21
Glen Arbor Bay (Lake Michigan)	150	1	0.4	0.04	...	52	...
Total in other areas	...	5	1.8	0.19	...	...	...
Grand Total	...	289	100.0	10.22	2	...	65

Figure 8.--Power dam in Cheboygan River at Cheboygan, Michigan.

Figure 9. Peterson-type tag applied to migrant sea lamprey.

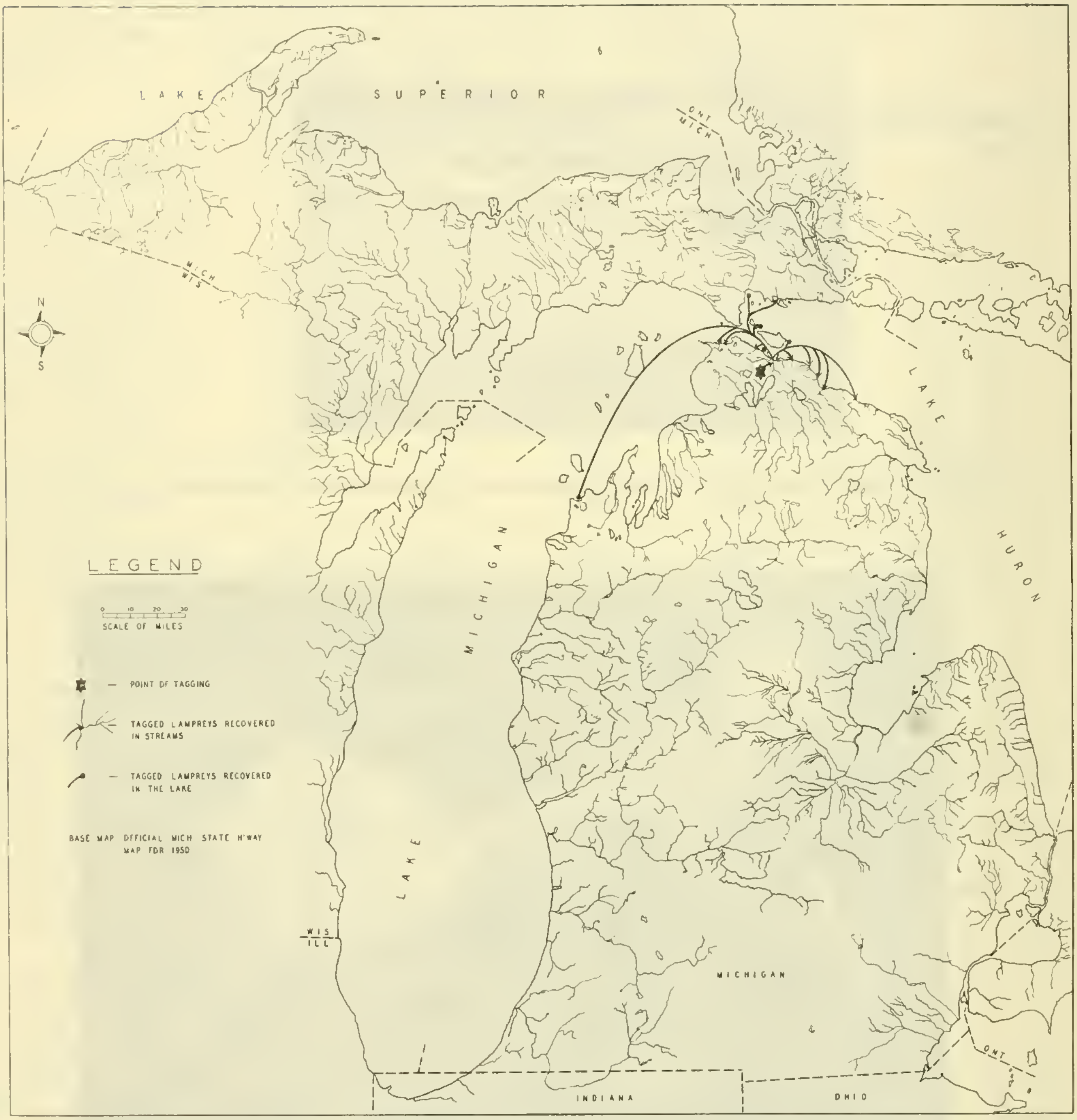

Figure.--10.--Small-scale chart of upper Grest Lakes showing generel dispersion of marked lampreys from blocksded spawning run.

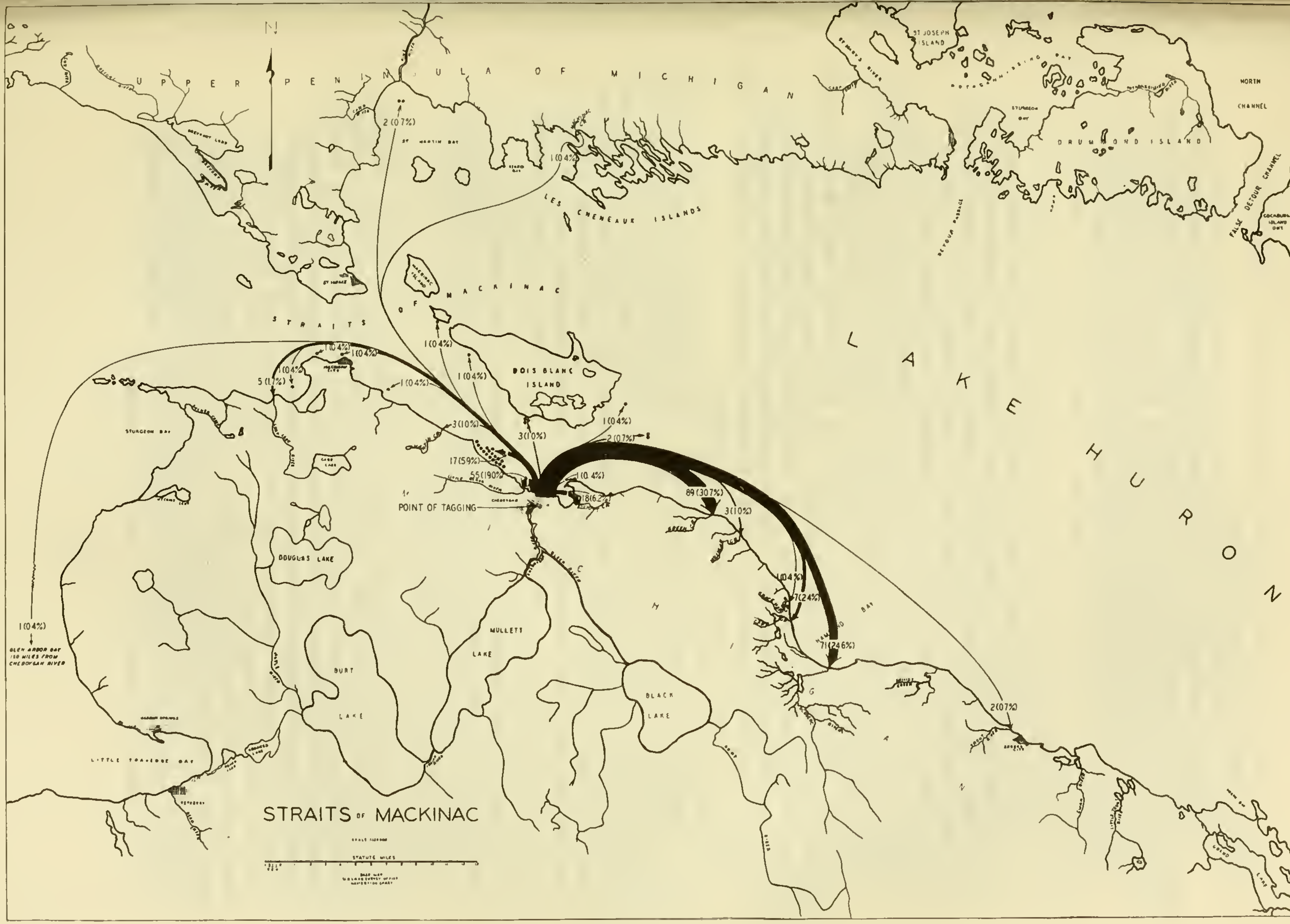

Figure 11.--Large-scale chart of Control Zone H-1 (northern Lake Huron, showing movements of marked lampreys from blockaded Cheboygan River spawning run.

lampreys escaped upstream through the power dam boat locks into the Mullett Lake-- Burt Lake drainage.

Specimens for tagging were obtained by dipnetting at night below the paper mill power dam on the Cheboygan River. Sea lampreys collected early in one night were held in live boxes overnight and tagged the following morning. Originally a special experimental trapnet was operated but it proved to be inefficient because of improper mesh-size, strong currents, and the accumulation of large amounts of detritus on the webbing.

Two types of tags were used in the experiment. The first groups of the lampreys (1,585 individuals) were tagged with numbered Peterson-type tags, three-eights of an inch in diameter. One disc was red and the other was white. These were applied with 1 3/4 nickel wire pins through the dorsal musculature just anterior to the first dorsal fin (Fig. 9). The remainder of the lampreys (1,258 individuals) were marked with numbered jaw tags of fingerling size. The jaw tags were clamped through the anterior portion of the first dorsal fin just above its juncture with the back. Prior to tagging, the lampreys were anesthetized with a 5-percent solution of urethane. Anesthetized lampreys were measured, tagged, and held in a live box until they had recovered fully. They were then released. No lampreys so handled were held in excess of 2 hours. Any individuals not appearing fully recovered in this time were destroyed to exclude them from the experiment.

There was evidently a difference in the efficiency of the two types of tags used. Of the 247 tags recovered, only 74 were jaw-type tags. It was noted that lampreys taken in commercial gear were almost always captured when the Peterson-type tag became entangled in the mesh. The jaw tag could not similarly ensnare the lamprey. If the 34 Peterson-type tags recovered in the commercial fishery are disregarded, the jaw tags still made up only 35 percent of the tags recovered although 44 percent of the lampreys were marked with this type of tag. The difference in efficiency still evident in the figures after this adjustment is probably attributable to difficulty in detecting the small tags under night working conditions at the weirs. The large red and white disc tags were highly visible even in subdued light.

The recovery of 254 marked lampreys in the weirs and traps of Control Zone H-1 indicates that at least 9 percent of the blocked Cheboygan River run was diverted to other streams within the zone in both directions along the shoreline. The Cheboygan River sea lamprey run was conservatively estimated by experienced observers at 40,000 migrant individuals. On the basis of this estimate, the total number tagged, and the percentage recovery of tags, it appears that about 3,600 of the spawning run sea lampreys captured in the streams of the control zone were diverted Cheboygan River migrants. By the same token, 91 percent or an estimated 36,400 sea lampreys from the blocked run were diverted into streams outside the control area or wandered aimlessly in the lakes, presumably to die without spawning.

Several tagged lampreys were taken by commercial fisherman in the Straits of Mackinaw, St. Martins Bay, and Mackinaw Creek near Hessel, Michigan. These recoveries indicate that many of the Cheboygan River migrants find their way across the deeper waters of the Straits and into the streams and rivers of the Upper Peninsula of the Michigan and perhaps contribute significantly to the spawning runs of those streams.

The portion of the blocked run that is diverted into other streams apparently moves in all directions from the mouth of the Cheboygan River with the majority following the Lake Huron and Lake Michigan shorelines of the lower peninsula (Figs. 10 and 11). It is difficult to define the farthest limits of dispersion of the blockaded Cheboygan River run as there were few devices for recapturing the tagged specimens in any area other than Control Zone H-1. Since little publicity concerning the experiment was given beyond the local area, it is entirely possible that some tags recovered by commercial fishermen in more distant locales were not returned. It is significant, however, that no tagged lampreys were taken in the Pendill's Creek weir and trap (Chippewa Co.), the Black River weir and trap (Mackinaw Co.), the Trail Creek trap (La Porte Co., Indiana), any of the 7 installations operated in Wisconsin, or those operated by the Province of Ontario.

The most distant reported recovery was from Glen Arbor Bay, Lake Michigan, approximately 150 miles west and south of Cheboygan (Fig.10). This lamprey was taken by a commerical fisherman in a gill net 52 days after it was tagged and released at the power dam. In the other direction the farthest recoveries were two lampreys taken in the trap in Trout River, Presque Isle Co., 43 miles east of the point of tagging (Fig.11). The first capture was recorded 13 days after release and the second 5 days later.

Evidently little correlation exists between distance traveled and the number of days elapsing between tagging and recapture within the limited area where devices were present for recovering the migrants. The number of days from the time the lampreys were tagged until they were recovered varied greatly (Table 9). Within a radius of 2 to 10 miles of the point of tagging, total time out varied from 2 to 50 days; 11 to 20 miles distant it varied from 3 to 65 days; and 21 to 43 miles away it varied from 4 to 37 days. Obviously some of the tagged lampreys wandered in the Lakes for a considerable time before entering another stream in search of a spawning area. Others apparently did not deviate from the most direct route to the stream they entered.

The influence of the diverted Cheboygan River run on the runs of other streams varied with the size of the stream and the distance from the Cheboygan River. For example, the Ocqueoc River which is the largest unobstructed stream in Control Zone H-1, is 30 miles east and south of the point of tagging; 71 tagged lampreys were trapped there.

Green Creek, 12 miles east of Cheboygan is only about one tenth the size of the Ocqueoc River and yet 89 tagged lampreys were captured in this stream. In two even smaller streams, Elliott Creek (3 miles distant) and Little Black River (2 miles distant) 18 and 55 tagged specimans respectively were recovered (Table 9).

Significant contributions by the blocked Cheboygan River run were made to other runs in streams 40 miles distant alongshore in one direction and 25 miles in the other. The proportion of lampreys among the runs of several streams studied that had their origin in the Cheboygan River varied inversely with distance from that blockaded stream (Table 10). For instance, the Little Black River, 2 miles west of Cheboygan, had a run of 953 lampreys. On the basis of the aforementioned estimate of 40,000 lampreys as the size of the blocked Cheboygan River run, the 55 tagged lampreys recovered in this stream would indicate that 772 specimens or 81 percent of the total catch were diverted lampreys. From similar computation it is found that in the Carp Lake River, 25 miles west of Cheboygan, 2 percent or 76 of the 3,821 individuals taken there were from the Cheboygan River run. In an easterly direction, 95 percent or an estimated 253 of the lampreys taken in Elliott Creek (3 miles distant) were diverted migrants. It is further indicated that of the run in Green Creek, 12 miles east, 64 percent were originally from the same river. The Ocqueoc River, 30 miles east, attracted an estimated 1,000 individuals from the diverted run. This figure was only 5.3 percent of the total Ocqueoc River run. The two tagged lampreys caught in the Trout River weir and trap, 43 miles distant, indicated that 1.6 percent or a probable 28 individuals had originally entered the Cheboygan River.

It is apparent from the results of this tagging experiment that a significant portion of such a blocked run is diverted to other streams in the immediate area which have accessible spawning grounds. Significant contributions by this blocked run were made to spawning runs in streams 40 miles distant alongshore in one direction and 25 miles distant in the other. It was also of interest to note that some sea lampreys swam offshore, rather than following the shoreline in their search for a spawning stream, crossed the Straits of Mackinaw, and appeared off the shoreline and in streams of the Upper Peninsula of Michigan.

It may be concluded from this experiment that trapping operations to "siphon off" these large blocked runs may be of considerable beneficial effect. Against such actions is the observation in Control Zone H-1 that these blocked and diverted migrants appearing in other streams contributed only a portion to an already existing surplus of lampreys entering these streams for which no spawning facilities were available.

Table 10.--Probable contribution of the blocked and diverted Cheboygan River sea lamprey run to runs in other near-by streams with accessible spawning grounds.

Stream	Distance from Cheyboygan River (miles)	Total number of lampreys entering stream1/	Probable proportion of run that were diverted migrants from Cheyboygan River	
			Number	Percentage
Little Black River	2	953	772	81.0
Elliot's Creek	3	266	253	95.0
Green Creek	12	1,945	1,252	64.0
Milligan Creek	15	700	42	6.0
Carp Creek	25	1,161	98	8.4
Carp Lake River	25	3,821	76	2.0
Ocqueoc River	30	18,882	1,000	5.3
Trout River	43	1, 702	28	1,6

1/ Number taken in weir and trap

Evaluation of various types of mechanical control devices 5/

In the following paragraphs the various types of devices for the control of sea lampreys mentioned frequently in this and earlier reports are evaluated as an aid in the planning of sea lamprey control programs. Five types of devices have been refined to a point where they may be considered effective, if somewhat expensive, control mechanisms.

(1) Permanent-type weirs and traps similar to that installed in the Ocqueoc River for capturing spawning runs (Figure 12).

Although the Ocqueoc River weir and traps, as installed, were functionally satisfactory, their structural characteristics were not. Designs have been tentatively worked out for a permanent-type sea lamprey weir which will be a vast improvement over the Ocqueoc weir in stability and ease of operation. Construction materials are reinforced concrete and steel throughout. This type of structure can be placed in streams of moderately large size and of almost any width provided it can be so installed that not more than 5 feet of water will pass across the deck of the weir during flood stages. This limitation on depth is necessary because of the very narrow spacing required in the grates (racks) or screens of a sea lamprey weir; any aperature or spacing wider than 1/2-inch will permit the upstream escapement of smaller individuals. It is almost impossible during floods to keep the grates of such a weir cleared of water-borne trash by manual means where the water depth is greater than 5 feet. Presently designed structures will handle up to 2,500 cubic feet per second; larger volumes can undoubtedly be handled with proper designing.

Permanent-type structures of suitable design can be installed at an average unit cost of $222.00 per linear foot of structure, exclusive of engineering and construction-supervision costs. This figure is based on engineering estimates prepared for a typical group of larger northern Michigan streams. It is not recommended that these structures be built at right angles to the direction of stream flow (shortest distance across stream). No economy can be attained in a long-term program of operation by such construction. The impounding action of the structure creates serious erosion

5/ These devices are distinguished from electrical (electronic), chemical, and biological control devices or techniques which are currently under investigation.

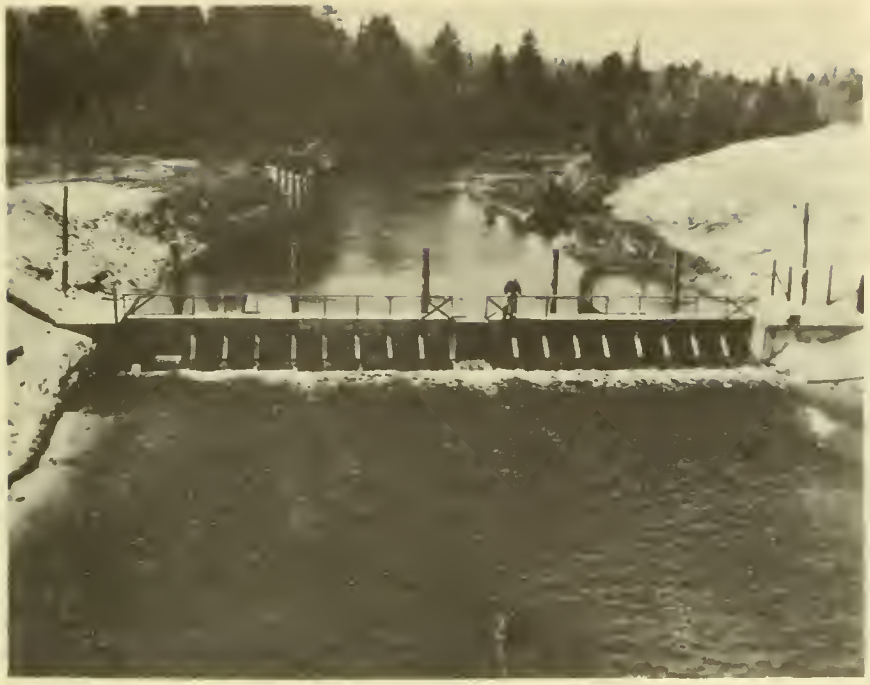

Figure 12.--Permanent-type sea lamprey weir and trap in Ocqueoc River, Presque Isle Co., Mich.

Figure 13.--Dam and inclined-screen sea lamprey trap in Carp Lake River, Emmet Co., Mich.

problems in the loose soils characteristic of the Lake States area which require continual and expensive attention. These problems can be alleviated to a great extent by constructing such weirs diagonally across the stream or in a "V" plan. The increased area for passing water thus produced decreases the impounding action of the weir to a minimum; scouring and erosion are likewise brought to a minimum.

(2) and (3) Portable-type weirs and traps of the Carp Creek and Milligan Creek styles for medium-and small-size streams respectively, for capturing spawning runs (Figs. 3-5, 14 and 15).

Carp Creek style portable weirs and traps can be installed and operated effectively in streams up to 50 feet wide if maximum flood levels passing through the screens do not exceed 30 inches in depth, and if careful maintenance is accorded the weirs during flood periods. The maximum volume of flow which these weirs can probably handle is about 300 cubic feet per second. Where greater volumes of water must be passed, permanent-type structures are recommended.

These weirs, constructed of lumber, 1/2-inch-mesh hardware cloth and steel fence posts, are perhaps the most economical control device which has been developed to date (Figs. 14 and 15). They may be prefabricated and installed for a unit cost of $26.00 per linear foot of stream width exclusive of engineering and construction-supervision costs. This unit cost is based on a "V"-plan structure with the wings of the weir set at a 32° angle to the bank. The term "portable" weir is derived from the fact that after each spawning run season, all of the structure except the sills, up-right posts, and abutments is removed from the stream and stored until the next season.

Where experience gained from one or more years of operation has shown that a portable-type weir can be operated effectively in a given stream, an inexpensive weir substructure and abutments of concrete can be installed. Portable-type weirs can be reinstalled repeatedly and operated with increased ease and with maximum effectiveness for many years upon such a stable base.

The Carp Creek stye is impractical in most streams less than 10 feet wide. The Milligan Creek style weir was developed for these smaller tributaries, 10 feet or less in width, in which maximum flood levels passing through the screens do not exceed 24 inches (Figs. 3 and 15).

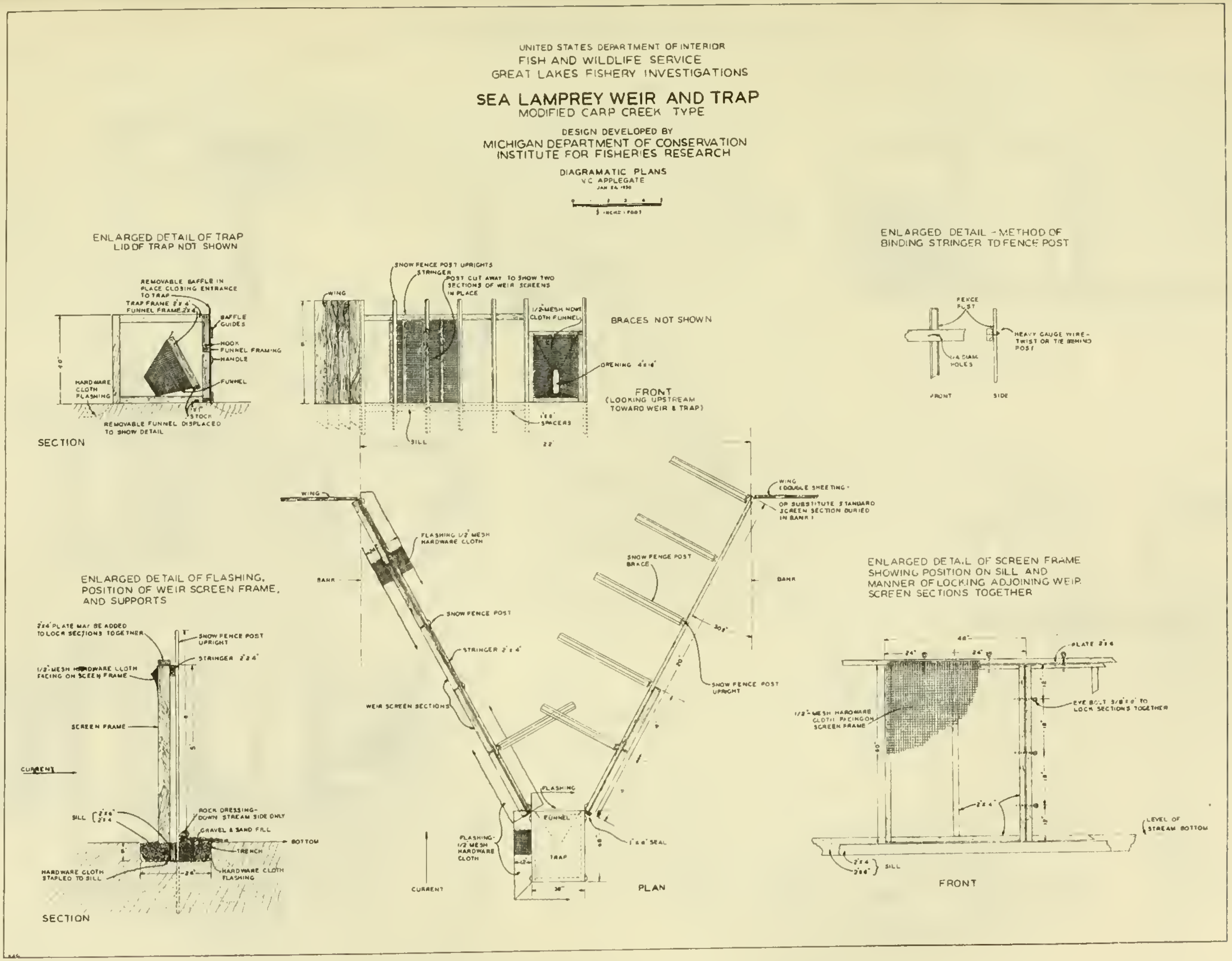

Figure 14.--Diagrammatic plans of the Carp Creek style portable-type sea lamprey weir and trap.

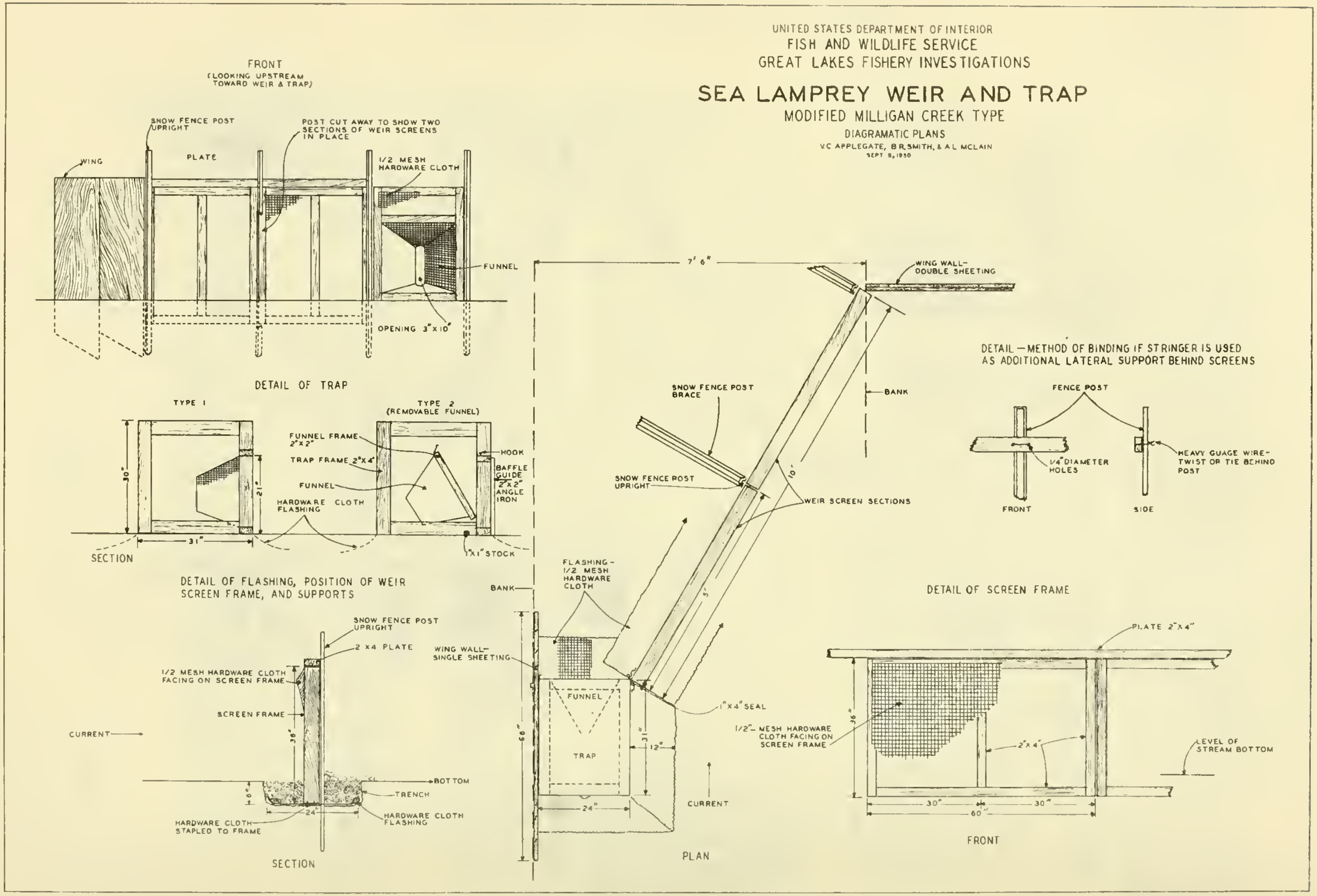

Figure 15.--Diagrammatic plans of Milligan Creek protable-type sea lamprey weir and trap.

what diminutive weir and trap can be built and installed in a 10-foot-wide stream for less than $50.00. If a greater volume of water must be handled than is indicated above or if the volume of flow is estimated at greater than 40 cubic feet per second, it is recommended that the stream bed and banks be so altered as to permit the installation of a Carp Creek style structure.

These portable weirs, if properly installed, are amazingly sturdy and will give many years of service. The prototype of this weir in Carp Creek, Presque Isle Co., Michigan, has been used for four consecutive years and will serve for many more before the replacement of any of its parts is necessary. However, the limitations of the device should not be overlooked and where any doubt exists as to its ability to handle spring floods, only a permanent-type weir should be considered.

(4) Dam and inclined-screen trap units of the Carp Lake River type for capturing young downstream migrants (Figs. 13 and 16).

This device is extremely effective in capturing all of the young, recently transformed sea lampreys which are moving downstream to begin their parasitic existence in the lakes. It can be installed, however, only in streams in which it is practical to construct a dam. The flat topography of the land and the generally low gradients of the streams of the Lake States thus place a limitation on the use of this device. At least a 5-foot head must be created by the dam in order that the tailwater will not interfere with the installation or operation of the trapping screens. It is frequently difficult, at least in Michigan drainages, to find a satisfactory site in the lower water-course where a dam creating such a head can be built.

Generally speaking, the use of the dam and inclined-screen trap is probably limited to those streams that are less than 75 feet wide and in which only mild, or at worst moderate, spring floods occur.

The pilot model of this type of structure was installed and developed in the Carp Lake River, Emmet Co., Michigan, by the Michigan Department of Conservation at an aggregate cost of approximately $6,000.00. Although the Carp Lake River was originally only 33 feet wide (at mean level) at the point of construction, a 90-foot, double-wall dam was required because of the porosity of the surrounding soils. Installation cost will, therefore, vary widely with stream and soil conditions and resulting construction requirements.

(4) Barrier dams for diverting spawning runs of sea lampreys such as that installed in the Black River, Mackinaw Co., Michigan (Fig. 17).

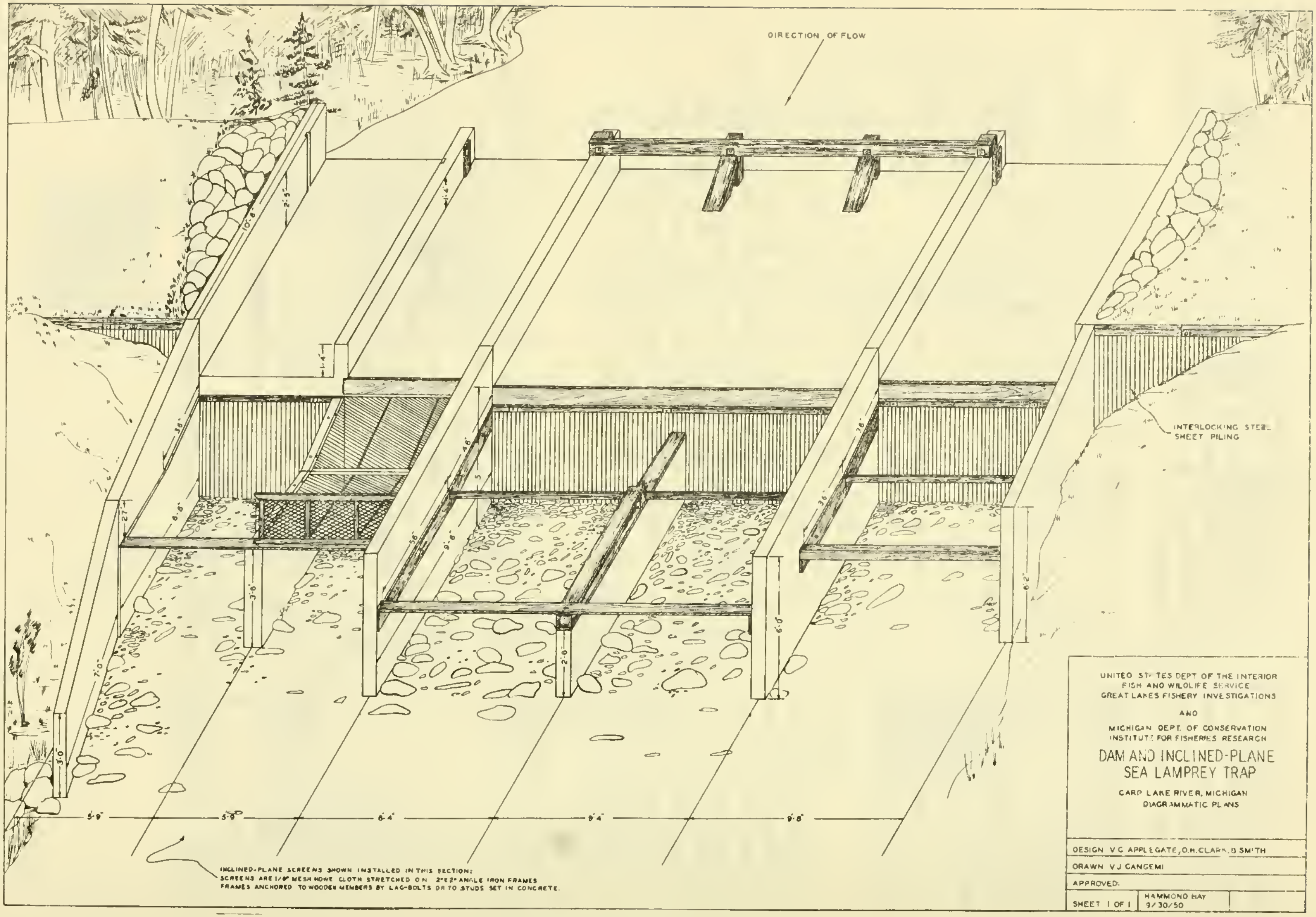

Figure 16.--Perspective drawing of Carp Lake River dam and inclined-screen sea lamprey trap.

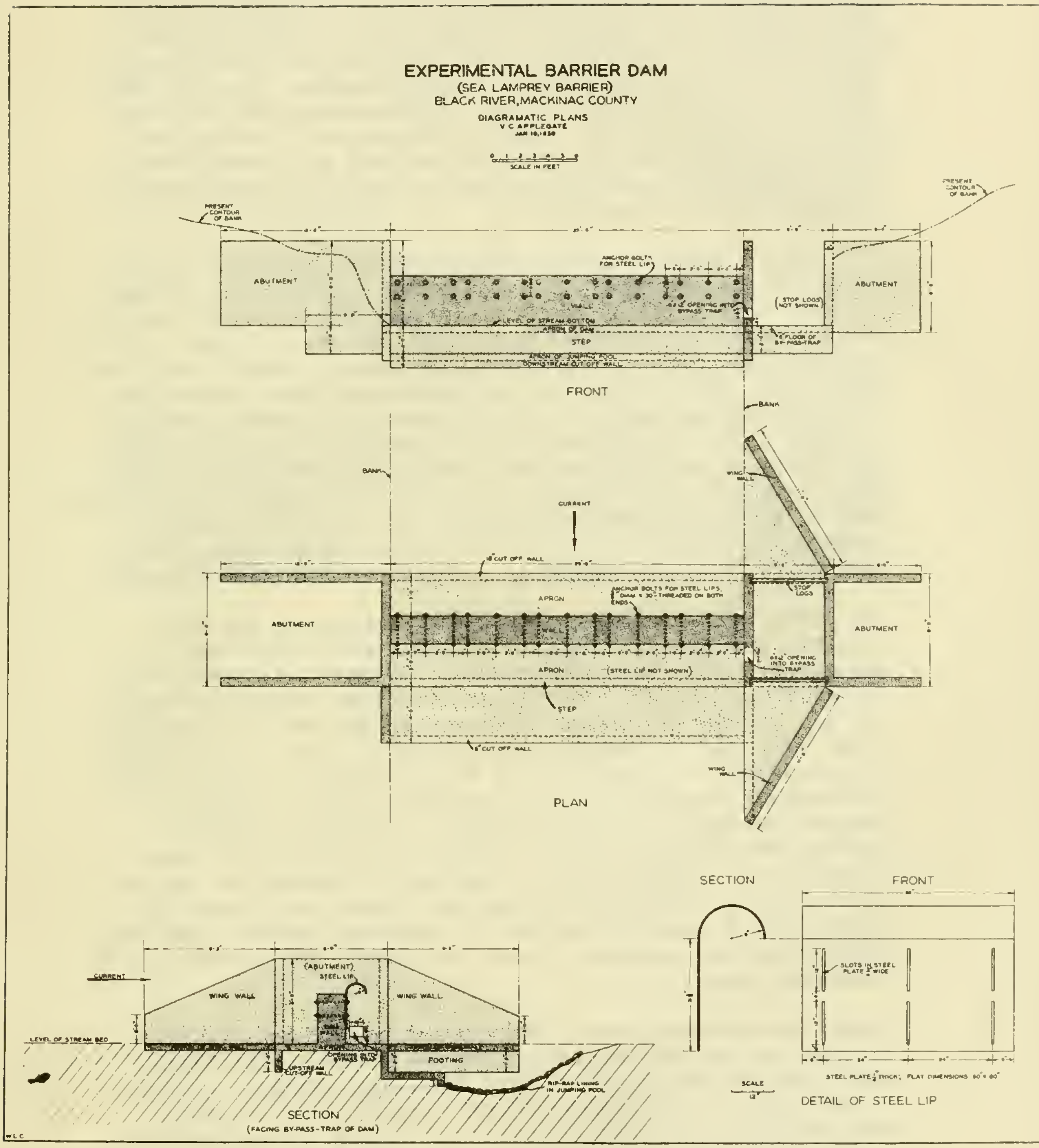

Figure 17.--Diagrammatic plans of a sea-lamprey barrier dam(reinforcing details not shown).

This device, when properly adjusted, is self-operating and prevents the upstream migration of sea lampreys to their spawning grounds while permitting the escapement upstream of most migrating food and game fishes. It is desirable that barrier dams be used singly or in groups in conjunction with weirs and traps in adjacent or nearby streams. Thus, diverted migrants may be trapped in other streams along with the runs initially entering them. Used in this manner, the barrier dam, an essentially self-operating device, may serve as an aid in reducing the operating costs of a control program based primarily on weirs and traps.

All of the limitations with which the dam and inclined-screen device was burdened apply to the barreir dam. At least a 4 foot head must be created for proper functioning of the special curved lip applied to the dam wall or spillway. In all respects the problems confronting the installation of both the barrier dam and the dam and inclined-screen trap are similar and construction costs of both devices will be approximately, the same. The experimental barrier dam built by the Michigan Department of Conservation cost about $3,500.00 for a wooden-type structure in a stream 25 feet wide. Construction of these dams of wood is deemed inadvisable. If a sounder and more permanent structure were built of reinforced concrete, the cost would be about doubled in a stream of this size (Fig.17).

The preceding structureds, if properly maintained and given regular attention will capture or block entire upstream or downstream runs. This 100-percent efficiency of operation is absolutely essential. In view of the known natural history of the sea lamprey it appears biologically unsound to effect anything less than the entire destruction of a run into a stream if control of the species is to be accomplished. This total destruction requires continual attendance upon the weirs by trained personnel to keep the racks or screens cleaned, to prevent over-topping, and to check the structure for breaks or failures. Such continual attendance is expensive. Weirs of the Fish and Wildlife Service are cleaned and checked at least every 8 hours during spring high-water levels. Day and night crews are required. Costs for proper weir operation are therefore high.

Since construction costs of the preceding mechanical control devices are not excessive (and for the portable-type weirs and traps may be considered very low), one dangerous pitfall in effecting a sea lamprey control program based on these devices must be avoided; that is, of judging the cost of the program in terms of the initial cost of installing the structures and dismissing their annual operation as a minor maintenance problem. As a measure of the relationship between initial cost and annual operating costs, an example may be cited. A plan has been prepared for the installation and operation of 15 additional weirs and traps in streams tributary to Lakes Huron and Michigan (Fig.1). Ten of these structures are permanent-type; the balance are of the portable-type. The purpose of these installations is two-fold: first, to provide much needed additional sites for experimentation with other techniques of control; second, to extend the active control program throughout the United States waters of Lake Huron and into Lake Michigan. This plan, requiring the organization of two additional control zones in Lake Huron and one in northern Lake Michigan, effects complete control of the lamprey in the United States waters of Lake Huron and places two pilot structures in the first organized control unit in Lake Michigan (see Fig.1, Zones H-2, H-3, and M-1).

These 15 structures, predominatly of the permanent-type, will cost an estimated $165,882.00 to install. By careful planning for the best utilization of personnel and equipment, it has been computed that operating costs can be held to about $76,969.00 annually. This ratio of initial cost to annual operating expenses can be considered typical of that which will be met in almost any area of the Great Lakes in initiating a program centered exclusively around mechanical control measures.

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1949. A brief history of the sea lamprey problem in Michigan waters. Trans. Am. Fish. Soc., 76 (1946), pp. 160-176.

Appendix

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

Black bullhead	*Ameriurus m. melas*
Brook trout	*Salvelinus f. fontinalis*
Common shiners	*Notropis cornutus frontalis*
Creek chubs	*Semotilus a. atromaculatus*
Great Lakes Longnosed dace	*Rhynichthys c. cataractae*
Lake Chub	*Couesius plumbeus*
Lake trout	*Salvelinus (Cristivomer) n. namaycush*
Log perch	*Percina caprodes*
Muddler	*Cottus b. bairdii*
Mudminnow	*Umbra limi*
Northern pike	*Esox lucius*
Pumpkinseed sunfish	*Lepomis gibbosus*
Rainbow trout	*Salmo gairdnerii*
Rock bass	*Ambloplites rupestris*
Sea lamprey	*Petromyzon marinus*
Silver lamprey	*Ichthyomyzon unicuspis*
Smallmouth bass	*Micropterus d. dolomieu*
Smelt	*Osmerus mordax*
Sturgeon sucker	*Catostomus c. catostomus*
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion v. vitreum*
White sucker	*Catostomus c. commersonnii*

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