SEASONAL ABUNDANCE OF CLAM LARVAE IN RHODE ISLAND WATERS, 1950-52

SPECIAL SCIENTIFIC REPORT–FISHERIES No. 117

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

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SEASONAL ABUNDANCE OF CLAM LARVAE IN RHODE ISLAND WATERS, 1950-52

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Special Scientific Report: Fisheries No. 117

Washington, D.C.
March, 1954

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Since 1948, the Fish and Wildlife Service has carried on a biological study of the soft clam, Mya arenaria, and the hard clam, Venus mercenaria, of the Atlantic coast of the United States. Much of the research was done in Narragansett Bay in Rhode Island, where there is a considerable commercial fishery for the hard clam or quahaug. From collections of larvae of soft and hard clams at two locations in Narragansett Bay, quantitative data on seasonal abundance were compiled. This report presents these data.

Quantitative data on seasonal abundance of clam larvae may help explain the success or failure of particular year classes and thus help in finding reasons for fluctuations in abundance and in developing ways to control the fluctuations. Review of the literature on the early life histories of soft and hard clams reveals a lack of quantitative data, though there is considerable general information on the early life history of each of these clams, summarized as follows:

Mya.--Meade and Barnes (1904), discussing the spawning season of Mya in Rhode Island waters, state that on the basis of direct evidence (presence of swimming young) and indirect evidence (mature sex products) the season extends from the latter part of May through the whole of June and sometimes into July. They conclude also, from the presence of very small clams in early spring, that spawning must take place to some extent all summer and probably until late fall.

Stafford (1912) gives the spawning season in Malpeque, Prince Edward Island, as June, July, and August, with the peak in July and August. Sizes of larvae range from 90 microns at the earliest straight-hinge stage to approximately 400 microns at a stage not defined.

Belding (1931) states that the spawning season on the south side of Cape Cod, Mass., is June and July, and north of Boston, Mass., is July and August. Spawning takes place when the water temperature is suitable for development of the larvae, which in Massachusetts is 70° to 74° F. Clams near high-water mark spawn first. On the south side of Cape Cod there are frequently two sets a year.

Thorson (1946) states that this larva begins to appear in the Sound (Øresund, Denmark) in June and may be met with as late as October but "usually it is not particularly numerous." He gives the size at metamorphosis as extremely variable. A definite trend toward larger larvae in deeper water is apparent; the range is from 210 microns (average of 10 measurements) in up to 30 cm. of water to 225 microns to 300 microns in 15 to 16 mm.

Sullivan (1948) gives the spawning season in Malpeque as late May to late August, with the bulk of the spawning in June. Water temperature at beginning of spawning is given as 10° to 12° C. Size of larvae is given as 105 microns, earliest straight-hinge stage to 250 microns, metamorphosing larvae. Good photomicrographs are presented.

Wells (1927) and Loosanoff (unpublished) also give good photomicrographs of Mya larvae of various sizes from early straights to metamorphosed individuals.

Turner (1948) states that the length of larval life varies with the temperature of the water, warmer water favoring more rapid development. The period may be as short as 12 days in Massachusetts and as long as 3 weeks in Maine.

Deevey (1949) says the Mya veligers are the dominant bivalve larvae in Tisbury Great Pond, Mass., from late April into June and are present throughout the summer.

Venus.--Belding (1931) gives the spawning season of Venus in Massachusetts waters as the middle of June to the middle of August. The water temperature at Wellfleet, where most of the work was done, at the beginning of spawning was 76° F., and the duration of the free-swimming stage was 6 to 12 days.

Kerswill[1] says that in Bideford River, Prince Edward Island, in 1938, 1939, and 1940, spawning did not begin until the water temperature reached 23° C. Spawning continued until about September 1 as a gradual process.

Deevey (1949) states that Venus larvae were present in Tisbury Great Pond in June, July, and August and are the dominant bivalve larvae in late July and early August.

Loosanoff (1937) and Loosanoff and Davis (1950; 1951), and Loosanoff, Miller and Smith (1951) give much information on the physiology of Venus larvae. They note that unprovoked spawning will take place at temperatures as low as 20.6°C. This is lower than hitherto recorded in the literature. The range of larval sizes is given as 105 microns, earliest straight-hinge stage, to 227 microns, ready-to-set larvae.

Wells (1927) and Loosanoff and Davis (1950) have published photomicrographs of Venus larvae of various sizes and ages. Those of Loosanoff and Davis are particularly helpful for identification purposes because they represent a greater variety of sizes and ages and are accompanied by a supplementary description of changes in appearance with age.

1/ Kerswill, C. J. 1941. Some environmental factors limiting growth and distribution of the quahaug, Venus mercenaria, Doctoral Thesis, Univ. of Toronto.

METHODS AND MATERIALS

The samples on which this report is based were collected in two locations in Narragansett Bay (fig. 1): Wickford Harbor, approximately 1 mile long, with an irregular shoreline and an average depth at mean low water of 2 to 3 feet; and Greenwich Bay, rectangular in shape about 2-1/2 miles long and 1 mile wide, with an average depth of about 10 feet.

Salinities in both places are usually within the 25 to 30 parts per thousand range. Current velocities are uniformly low, the greatest being about 1 knot. Many of the plankton samples and other supplementary observations were taken by Thomas F. Kane, Fishery Aid.

All samples from Greenwich Bay were taken with a rotary pump powered by a small gasoline engine. Wickford Harbor samples were taken with the pump when possible and with a 12-quart bucket otherwise. When time and facilities permitted, at least two samples, surface and bottom, were obtained, and occasionally other levels were also sampled. A sample consisted of 35 to 50 gallons of water strained through a No. 18XXX net with mesh openings approximately 75 microns on a side. The net was equipped with a detachable plankton bucket. The samples were transferred to plastic-topped jars, brought back to the laboratory, and preserved with 1 percent formalin neutralized with borax.

Each sample was concentrated to a definite volume, either 10 or 20 ml., depending upon the abundance of material, and 1 ml. was removed with a pipette. This subsample was placed in a Sedgewick-Rafter cell and the larvae were counted and assigned to one or more of the following size categories: (1) Up to 135 microns, greatest diameter, or straight-hinge stage; (2) 136 to 160 microns, or early umbone stage; (3) 161 to 185 microns, or medium umbone stage; and (4) 186 microns and up, late umbone or larvae approaching setting stage. This size grouping was designed for *Venus* larvae, but is serves adequately for *Mya* larvae also. There is evidence from the literature that bivalve larvae tend to patchiness in their vertical and horizontal distribution. Because of this it would seem that the level with the highest count of larvae in its sample would best represent the degree of spawning success in the area. Consequently the samples with the highest counts for each of the two kinds of larvae from all levels sampled at any one station were taken as representing that station on that particular date.

In this report, only categories 1 and 4 are presented. The graphs were prepared as follows: The average highest sample count for the size category under consideration was obtained for each week and was plotted as a bar covering the middle 3 days of the week. For example, during the week of June 11-17, 1950, six samples were taken at the Wickford Habor station. Four samples, of 35 gallons each, contained *Mya* larvae of size category 1 as follows: 5,960, 5,160, 5,400, and 2,960. The average number per sample is 4,870. On figure 3 this is plotted as a bar covering June 13, 14, and 15. Five samples, of 35 gallons each, contained *Venus* larvae of

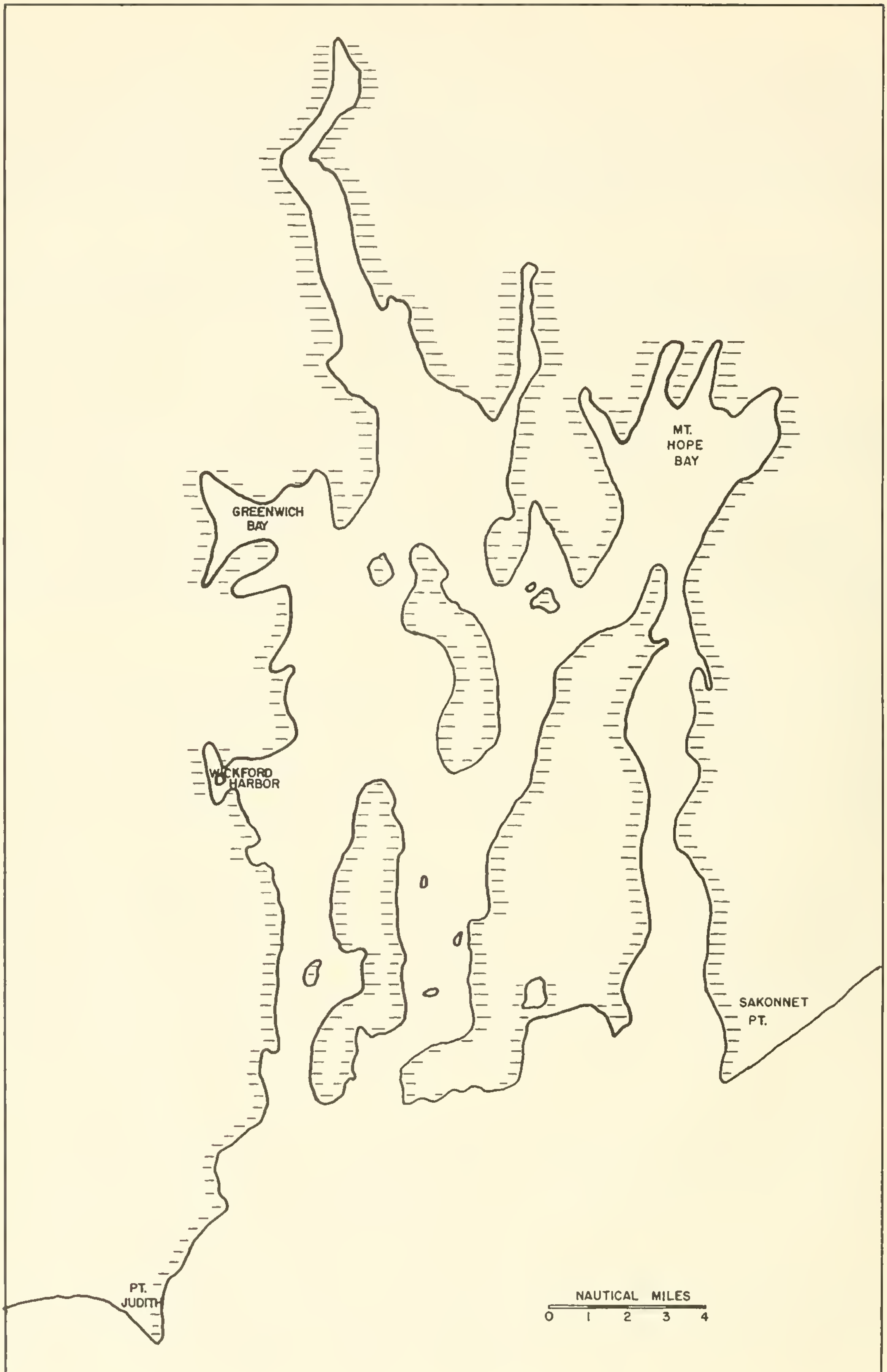

FIG. I NARRAGANSETT BAY

size 1 as follows: 200, 2,520, 6,800, 3,780, and 2,960. The average number per sample is 3,252. This is plotted on figure 4 as a bar covering the same 3 days.

Because of the scale necessary to accommodate high abundances, no count below 11 per 35 gallons is recorded on the graphs, but reference is made in the text to the occurrence of these larvae.

Surface temperatures were taken regularly in Wickford Harbor. Since the mean depth at low water is only 2 to 3 feet, no other levels were measured. Both surface and bottom temperatures were taken in Greenwich Bay. Since it is logical to assume that whatever influence water temperature has on spawning will be of the water immediately over the bottom, only the bottom temperatures in Greenwich Bay are presented in this report.

IDENTIFICATION OF THE LARVAE

Mya larvae

The literature contains photomicrographs and descriptions of *Mya* larvae of sufficient accuracy to make identification relatively simple. Sullivan's (1948) description was particularly instructive and I readily found and accepted as diagnostic the brown pigment which begins under the shoulders at 120 microns and, as the larva grows, proceeds in a broken ring around the animal and into the visceral mass. Thorson (1946) also mentions this pigment in specimens nearly 200 microns long and states that it will "no doubt prove to be a reliable specific character." This pigment ring, together with the larva's lack of color otherwise, and with its transparency and shape, make the *Mya* larva one of the easiest of all bivalve larvae to identify. The identify of *Mya* larvae was further substantiated by holding late umbone stage specimens in beakers where with suitable care they readily grew to a size and shape characteristic of *Mya* juveniles approximately 1 mm. long.

Venus larvae

Identification of *Venus* larvae is somewhat more difficult. No adequate description such as that for *Mya* exists in the literature. Loosanoff and Davis (1950) include photomicrographs of *Venus* larvae, and they provided mounted stained specimens and preserved series of artificially reared larvae to aid in identification.

Venus larvae are identified by a combination of features: (1) Shape, which tends to roundness after the straight-hinge stage is past; (2) size, which ranges from approximately 110 microns as early straight-hinge larvae to approximately 225 microns when they disappear from the plankton; (3) color, which is bright yellow, usually more pronounced toward the perimeter of the shell in a young larva, and which, as the larva grows, permeates the whole animal until it is entirely yellow; (4) appearance of the shell outline, which is relatively delicate when compared to the heavy outlines of some other bivalve larvae with which *Venus* might otherwise be confused.

OBSERVATIONS

Wickford Harbor, 1950

Weekly sampling in Wickford Harbor began April 4, 1950. On May 8, sampling was intensified to a daily basis, as far as time permitted, at three vertical levels, surface, mid-depth, and bottom. This schedule was maintained until October 11, when weekly sampling was adopted again. Sampling ceased October 23. The samples were taken in 6 to 10 feet of water from a dock jutting out about 150 feet into the harbor. Surface temperatures in Wickford Harbor during 1950 are shown in table 1 and figure 2.

Mya larvae.--Quantitative estimates of *Mya* larval abundance derived from these samplings are presented in figure 3 and table 2. Although an occasional young *Mya* larva was seen during the previous week they did not appear in quantity until the week of May 21, when the surface temperature was about 14.0° to 14.5° C. Peak abundance was reached during the week of June 11 when the average of the highest daily counts of straight-hinge larvae was close to 5,000 per 35 gallons of filtered sea water. Late umbone stage larvae first appeared during the week of May 28 and reached a peak of abundance the week of June 18 when about 300 per 35 gallons as a daily average were counted. From mid-July to the first week in September no *Mya* larvae were present in the samples. During the first 2 weeks of September and again during the first 2 weeks of October there were larval concentrations of up to 120 late umbone stage larvae per 35 gallons.

Venus larvae.--Figure 4 and table 3 show the abundance of straight-hinge and mature larvae during the 1950 spawning season by weekly averages. Larvae appeared abruptly during the week of June 11 when the surface temperature was about 18.5° to 19° C. This week showed the greatest abundance of straight-hinge larvae of the summer, an average of a little over 3,000 per 35 gallons. Straight-hinge larvae were present each week, with two exceptions from June 11 until spawning ceased, about the second week of September. Late umbone stage larvae appeared during the week of June 18 and for the next 3 weeks. The greatest abundance during this period was 300 per 35 gallons. Another group of late umbone stage larvae made its appearance during the week of August 20.

Wickford Harbor, 1951

Sampling from the dock in Wickford Harbor began April 16, 1951, and was continued without interruption through the spawning season. Both sur-

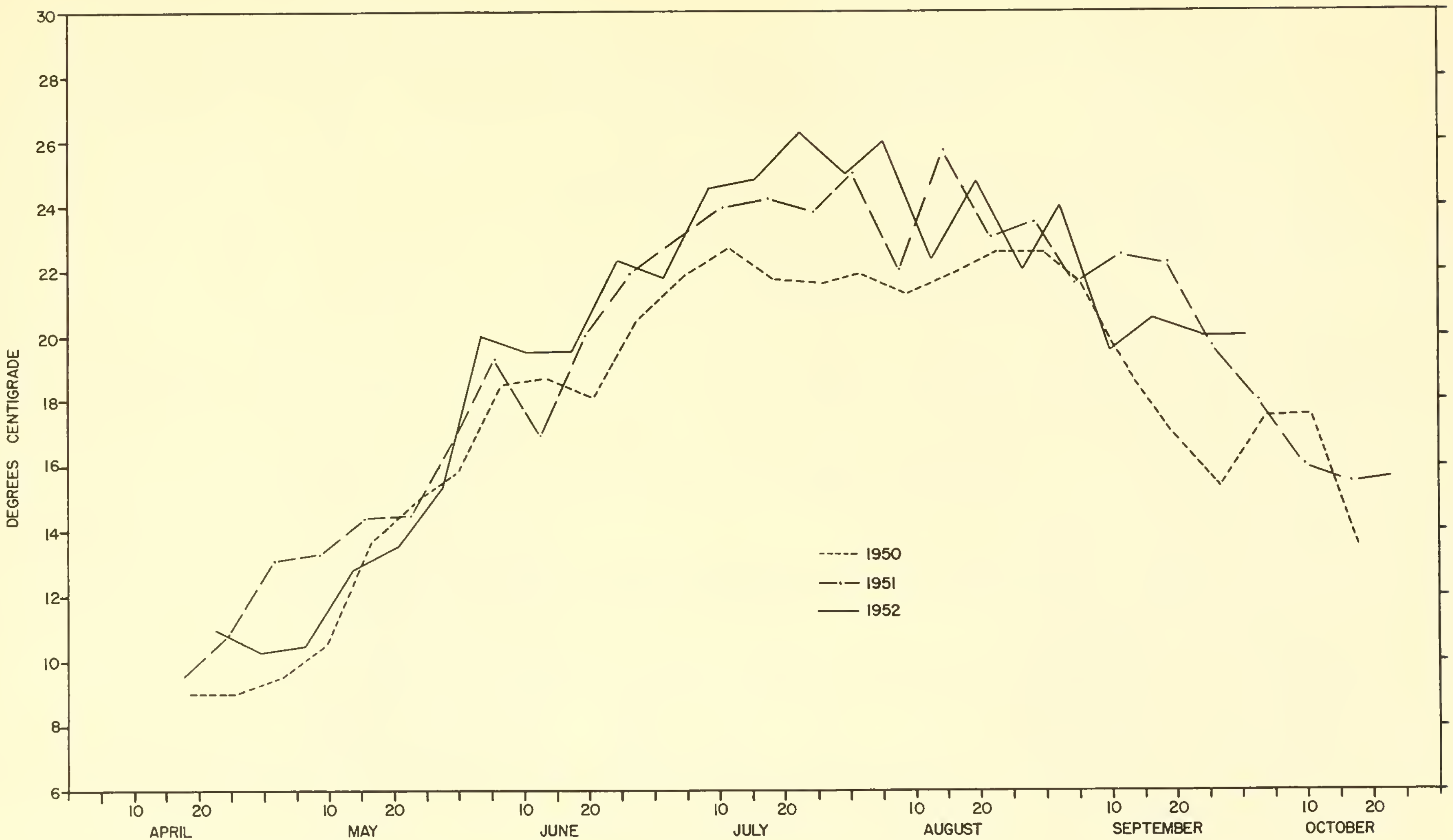

FIG. 2 WEEKLY AVERAGES OF SURFACE TEMPERATURES IN WICKFORD HARBOR.

Table 1.--Weekly average[1] water temperatures in Wickford Harbor and Greenwich Bay, 1950-52.

Week Beginning	Wickford Harbor (surface)	Week Beginning	Wickford Harbor (surface)	Greenwich Bay (bottom)	Week Beginning	Wickford Harbor (surface)	Greenwich Bay (bottom)
1950		1951			1952		
Apr. 16	9.0	Apr. 15	9.5	-	Apr. 20	11.0	-
23	9.0	22	10.8	-	27	10.3	-
30	9.5	29	13.1	-	May 4	10.5	-
May 7	10.5	May 6	13.3	-	11	12.9	-
14	13.7	13	14.4	-	18	13.5	-
21	14.9	20	14.5	16.1	25	15.3	16.4
28	15.8	27	16.9	16.5	June 1	20.0	19.2
June 4	18.5	June 3	19.3	18.8	8	19.5	19.2
11	18.7	10	16.9	17.7	15	19.5	21.2
18	18.1	17	20.0	18.8	22	22.3	20.8
25	20.5	24	21.9	21.4	29	21.8	21.8
July 2	21.8	July 1	-	22.5	July 6	24.5	24.3
9	22.7	8	23.9	23.4	13	24.8	24.6
16	21.7	15	24.2	24.6	20	26.3	24.6
23	21.6	22	23.8	-	27	25.0	25.0
30	21.9	29	25.0	24.7	Aug. 3	26.0	25.2
Aug. 6	21.3	Aug. 5	22.0	22.1	10	22.3	22.7
13	21.9	12	25.7	24.5	17	24.8	24.5
20	22.6	19	23.0	22.2	24	22.0	22.0
27	22.6	26	23.5	22.4	31	24.0	23.0
Sept. 3	21.6	Sept. 2	21.6	21.3	Sept. 7	19.5	21.2
10	19.0	9	22.5	22.0	14	20.5	-
17	17.0	16	22.2	22.2	21	20.0	20.0
24	15.4	23	19.7	20.2	28	20.0	-
Oct. 1	17.5	30	18.0	17.2			
8	17.6	Oct. 7	16.0	-			
15	13.5	14	15.5	-			
		21	15.7	-			
		28	-	-			
		Nov. 11	12.2	-			
		18	11.8	-			

1/ In 1950, temperatures were recorded approximately daily; in 1951 and 1952, 2 to 3 times per week.

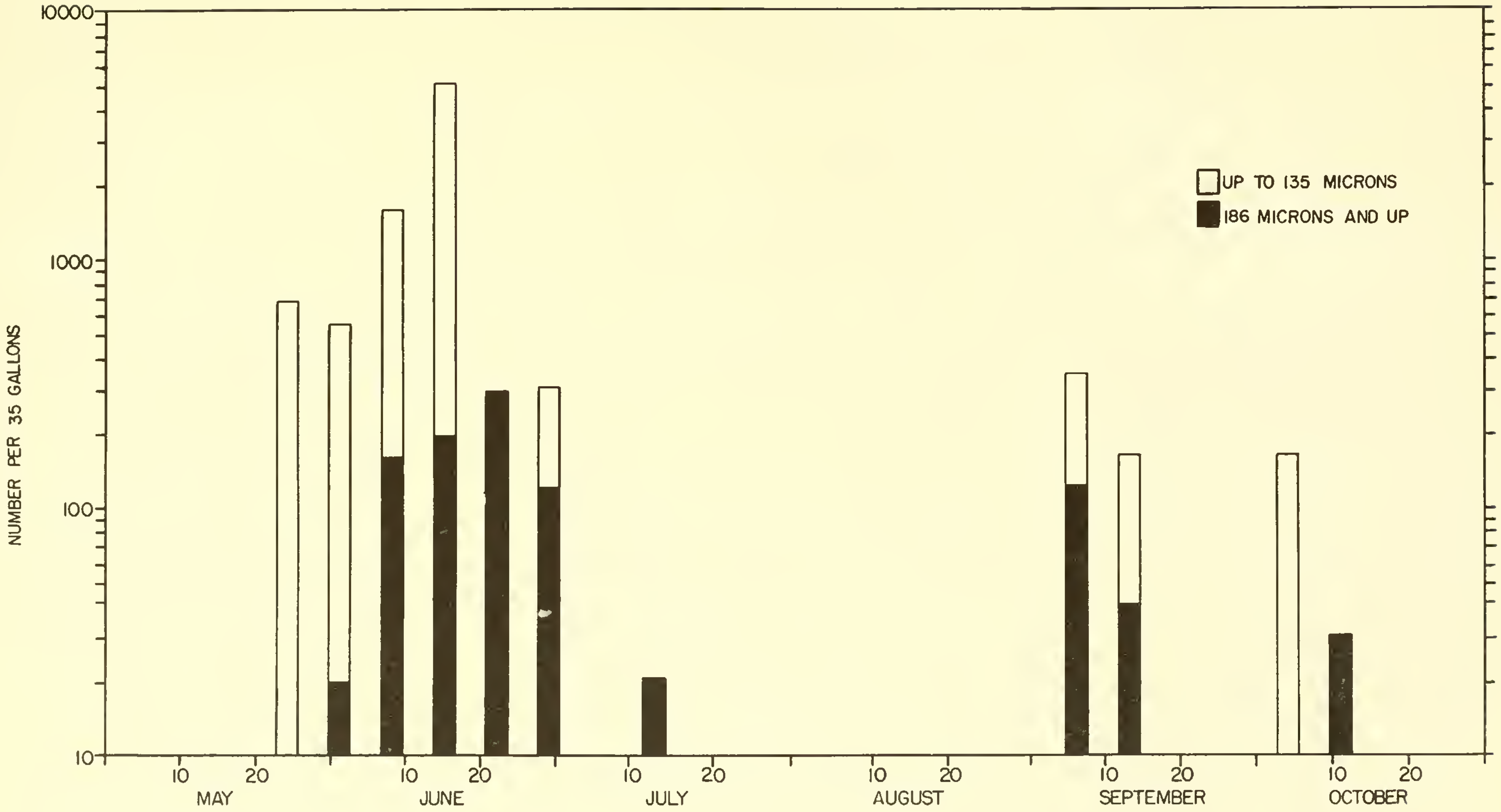

FIG.3 WEEKLY AVERAGES OF MYA LARVAL ABUNDANCE IN WICKFORD HARBOR IN 1950.

Table 2.--Wickford Harbor: Weekly average[1/] abundance of *Mya* larvae, by size groups, 1950-52
(Average number larvae in 35 gallons of sea water)

Week Beginning	Larvae in size group - Up to 135 µ	Larvae in size group - 186 µ and up	Week Beginning	Larvae in size group - Up to 135 µ	Larvae in size group - 186 µ and up	Week Beginning	Larvae in size group - Up to 135 µ	Larvae in size group - 186 µ and up
1950			1951			1952		
Apr. 16	-	-	Apr. 15	4	-	Apr. 20	-	-
23	-	-	22	94	-	27	28	-
30	-	-	29	1279	-	May 4	-	42
May 7	-	-	May 6	-	45	11	85	27
14	-	-	13	8393	415	18	144	91
21	670	-	20	3010	135	25	1624	115
28	517	20	27	3332	486	June 1	63	50
June 4	1400	160	June 3	-	114	8	70	228
11	4870	195	10	1169	35	15	294	46
18	-	287	17	-	196	22	32	102
25	180	120	24	-	28	29	-	14
July 2	-	-	July 1	28	-	July 6	-	-
9	-	20	8	-	14	13	-	-
16	-	-	15	-	7	20	-	-
23	-	-	22	-	-	27	-	-
30	-	-	29	-	-	Aug. 3	-	-
Aug. 6	-	-	Aug. 5	-	-	10	-	-
13	-	-	12	-	7	17	-	-
20	-	-	19	14	-	24	-	-
27	-	-	26	47	-	31	7	-
Sept. 3	220	120	Sept. 2	49	-	Sept. 7	7	-
10	120	40	9	-	-	14	-	-
17	-	-	16	7	-	21	1	-
24	-	-	23	7	-	28	21	-
Oct. 1	160	-	30	4	-			
8	-	30	Oct. 7	70	-			
15	-	-	14	14	-			
22	-	-	21	1001				
			28	21	-			
			Nov. 4	-	15			
			11	-	-			
			18	-	-			
			25	-	-			

1/ Method of calculating averages explained in text, page 3.

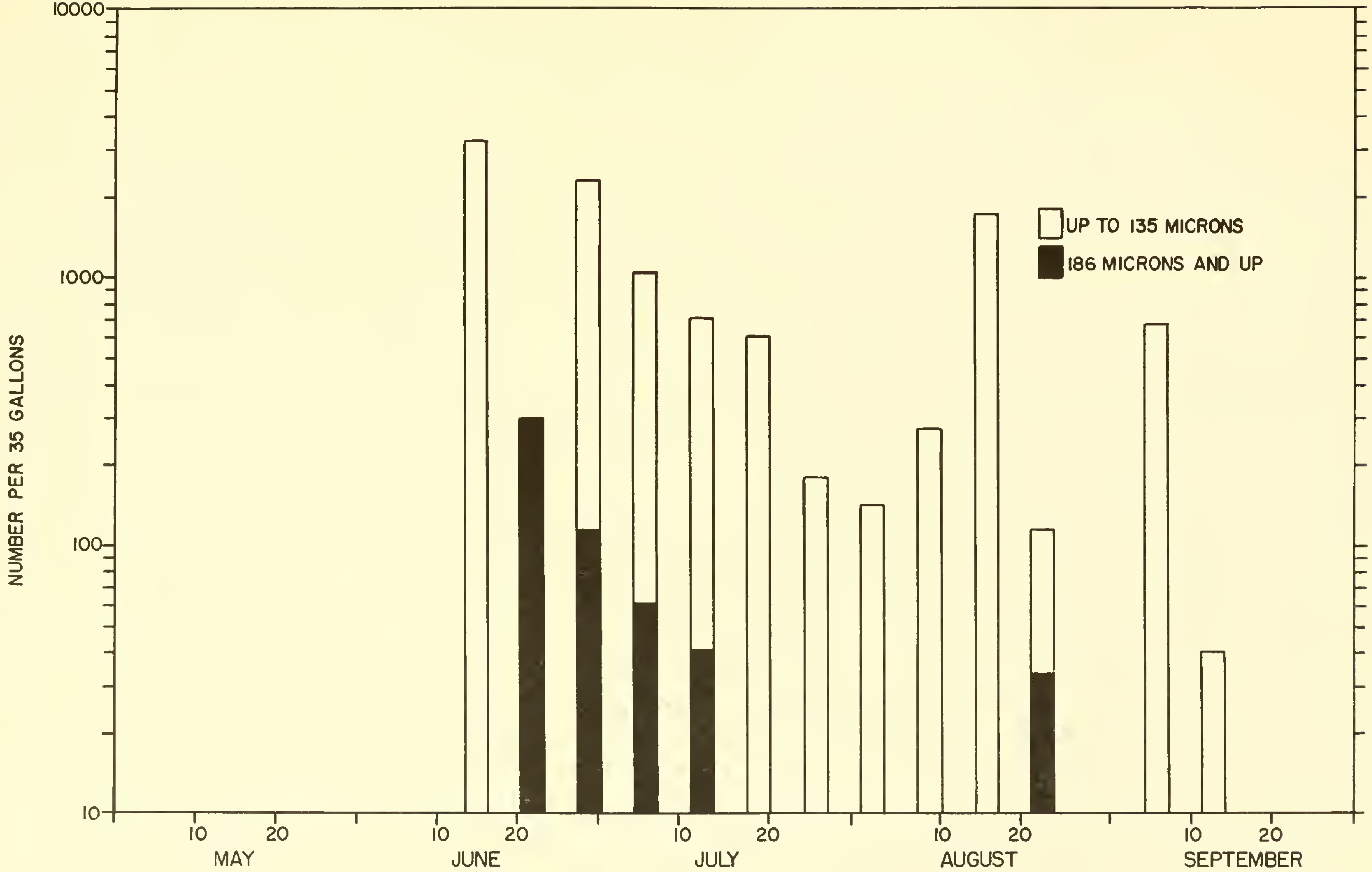

FIG. 4 WEEKLY AVERAGES OF VENUS LARVAL ABUNDANCE IN WICKFORD HARBOR IN 1950.

Table 3.--Wickford Harbor: Weekly average[1] abundance of *Venus* larvae by size groups, 1950-52.
(Average number larvae in 35 gallons of sea water)

Week Beginning	Larvae in size group-		Week Beginning	Larvae in size group-		Week Beginning	Larvae in size group-	
	Up to 135 µ	186 µ and up		Up to 135 µ	186 µ and up		Up to 135 µ	186 µ and up
1950			1951			1952		
May 28	-	-	May 20	38	-	May 18	14	-
June 4	-	-	27	24	-	25	49	-
11	3252	-	June 3	238	-	June 1	560	-
18	-	293	10	770	14	8	742	-
25	2140	112	17	-	7	15	5376	-
July 2	960	60	24	2415	14	22	4004	63
9	650	40	July 1	378	-	29	329	35
16	593	-	8	182	72	July 6	340	84
23	175	-	15	60	-	13	714	217
30	140	-	22	-	-	20	-	-
Aug. 6	270	2	29	98	-	27	-	20
13	1700	1	Aug. 5	-	-	Aug. 3	14	-
20	80	33	12	130	-	10	-	-
27	-	-	19	7	-	17	40	-
Sept. 3	660	5	26	56	-	24	-	-
10	40	3	Sept. 2	-	-	31	7	-
17	-	-	9	7	-	Sept. 7	7	-
24	-	-	16	41	-	14	21	-
			23	21	-	21	2	-
			30	7	-	28	1	-
			Oct. 7	7	-			

1/ Method of calculating average explained in text, page 3 face and bottom samples were taken by pump until June, and surface samples from that time on were taken by bucket. Surface temperatures in Wickford Harbor in 1951 are shown in table 1 and figure 2.

Mya larvae.--Figure 5 and table 2 are a record of the occurrence of Mya larvae for 1951. A few straight-hinge larvae were present on the first day of sampling. Not until the week of April 22, when the surface water temperature was about 11° C., did an appreciable number of larvae appear. From this date until the week of July 15, Mya larvae were in the water each week, reaching a peak of abundance of 8,400 straight-hinge larvae per 35 gallons during the week of May 13 and nearly 500 late umbone stage larvae per 35 gallons during the week of May 27.

A small concentration of young larvae appeared in the latter part of August and early September and a larger one appeared in October, resulting in a few setting-stage larvae in early November. No other distinguishable spawning waves were noted but occasional late umbone stage larvae were seen in the samples well into early 1952.

Venus larvae.--Abundance data for Venus larvae for 1951 are presented in figure 6 and table 3. Larvae first appeared during the week of May 20, when the surface water temperature was 14° to 15° C., increasing to a peak of 2,400 straight-hinge larvae per 35 gallons during the week of June 24. The abundance of young larvae then decreased to a level of approximately 100 per 35 gallons by mid-July, and no more young larvae were seen after September 29. Late umbone stage larvae exceeding an abundance of 10 per 35 gallons were noted in only three weekly periods during the season. These occurred between June 10 and July 10. The peak of abundance was approximately 70 per 35 gallons. As with Mya, occasional late umbone stage Venus larvae were seen in the samples as late as February 8, 1952.

Wickford Harbor, 1952.

Sampling began in Wickford Harbor April 17 on a semiweekly schedule and was discontinued after October 2, at which time there were still a few young Mya in the water but no Venus larvae. All samples were taken from the same station as in previous years and only surface samples were obtained. Surface temperatures in Wickford Harbor in 1952 are shown in table 1 and figure 2.

Mya larvae.--Figure 7 and table 2 show the abundance of Mya larvae in Wickford Harbor in 1952. Straight-hinge larvae first appeared during the week of April 27, when the surface water temperature was 10.5° to 11.0° C., and late umbone stage larvae were in the samples a week later. The abundance of young larvae was consistently low all during the spawning season with one exception: during the latter part of May one weekly average of 1,600 per 35 gallons was attained. Otherwise, the weekly average for the season was usually below 200 per 35 gallons. Late umbone stage larvae were

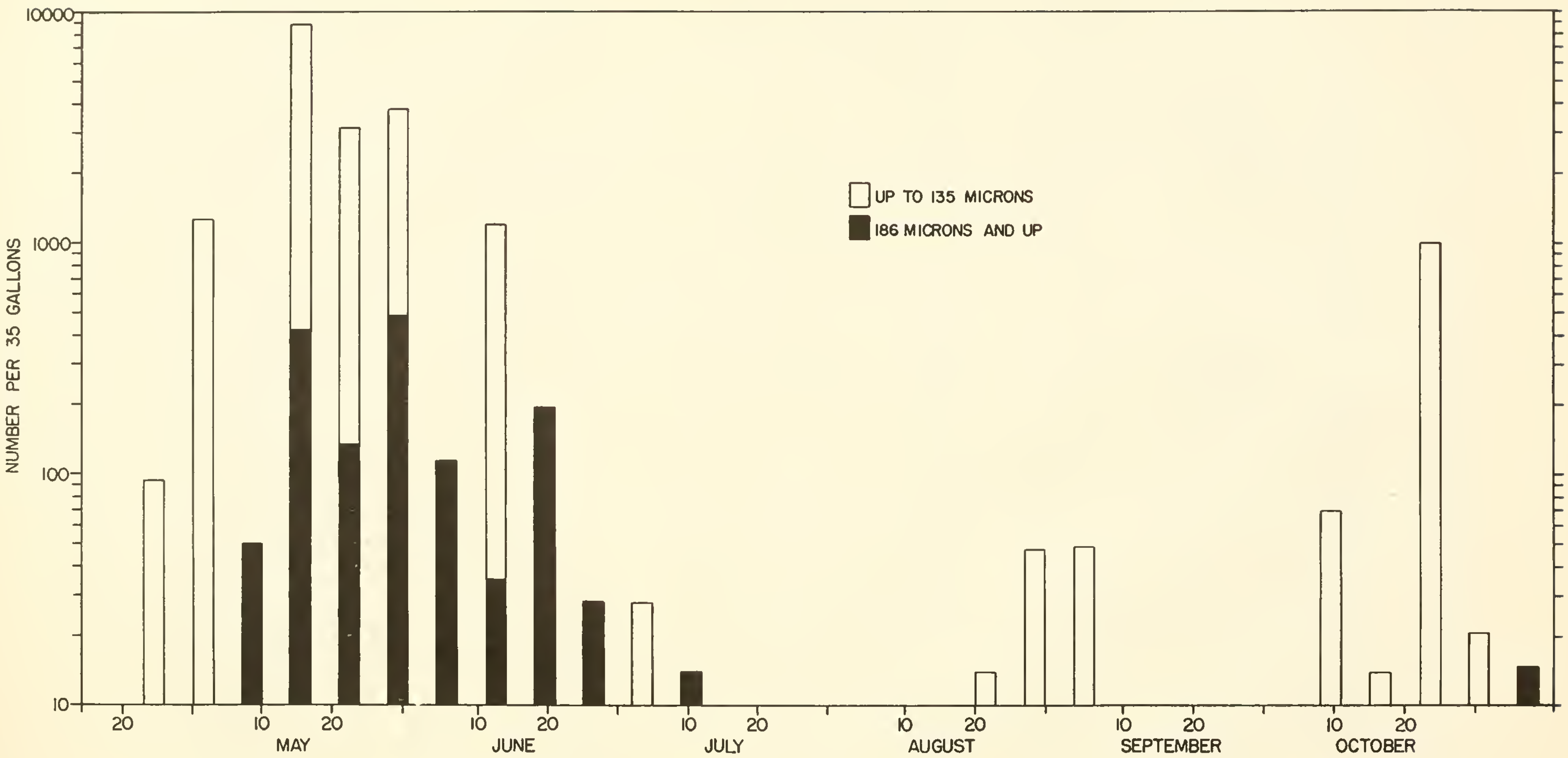

FIG. 5 WEEKLY AVERAGES OF MYA LARVAL ABUNDANCE IN WICKFORD HARBOR IN 1951.

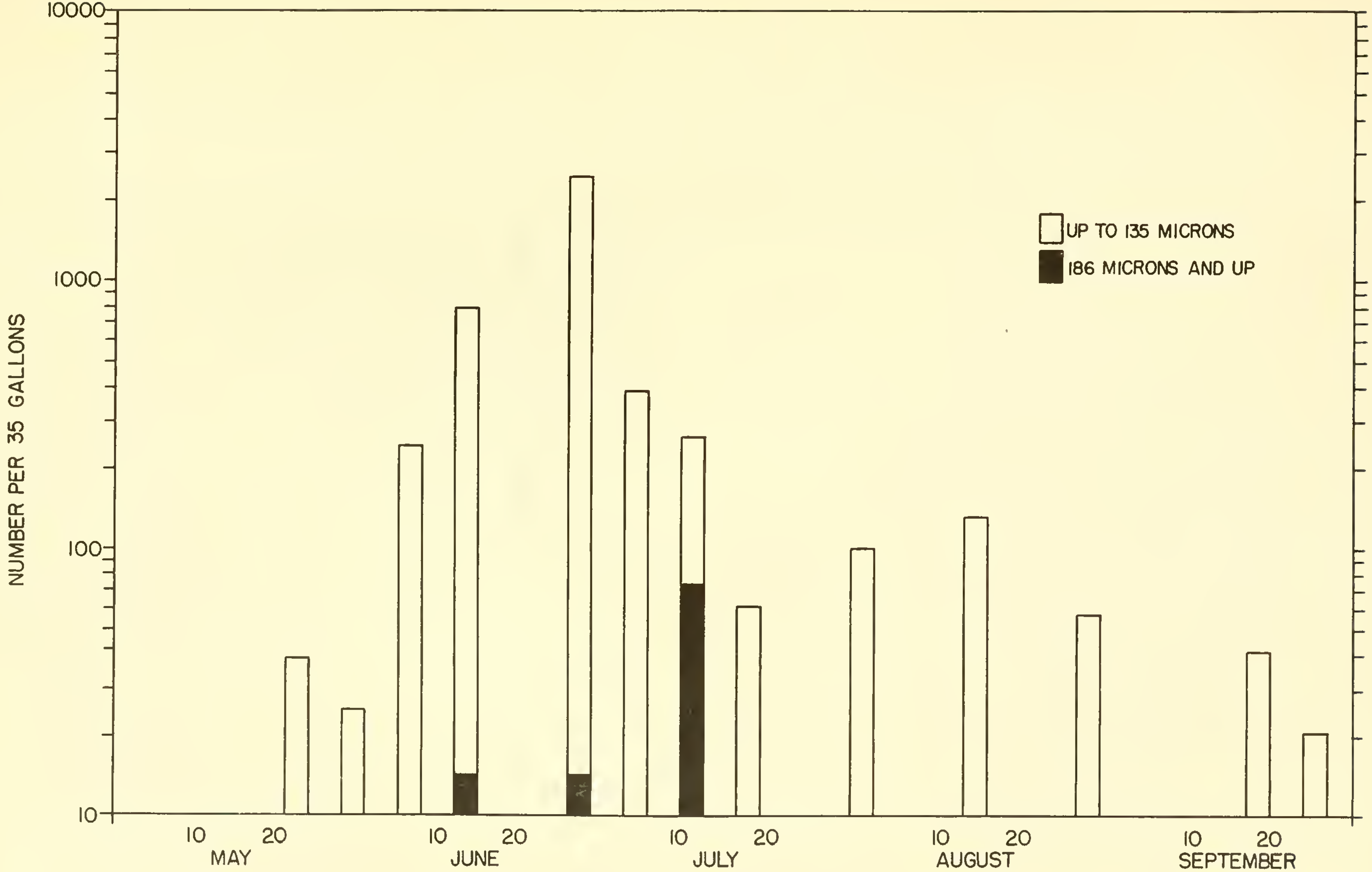

FIG. 6 WEEKLY AVERAGES OF VENUS LARVAL ABUNDANCE IN WICKFORD HARBOR IN 1951.

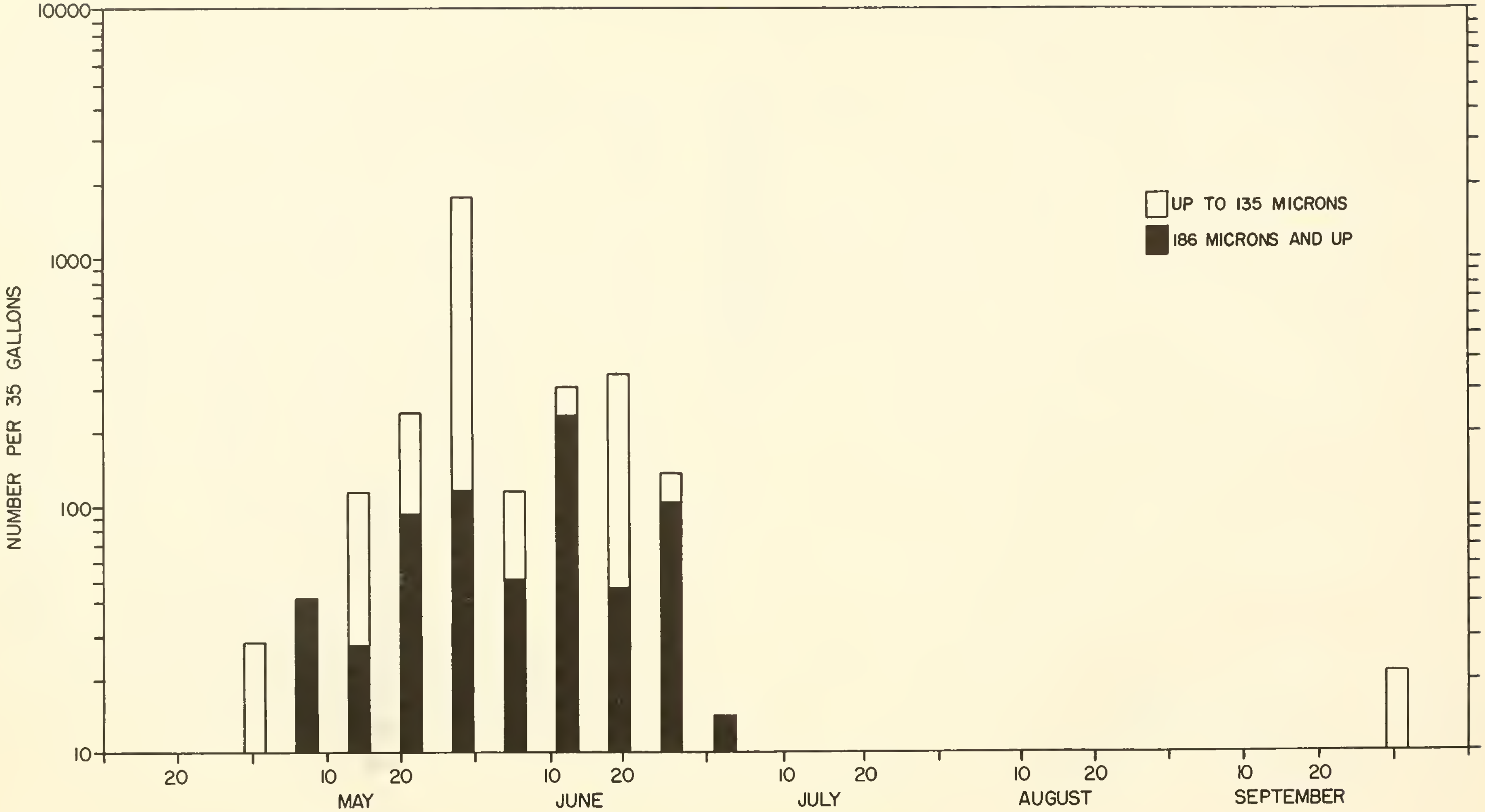

FIG. 7 WEEKLY AVERAGES OF MYA LARVAL ABUNDANCE IN WICKFORD HARBOR IN 1952.

present in varying intensities from early May through June with a high point of 230 per 35 gallons during the week of June 8. With the exception of one small concentration of larvae around the first part of October, the spawning season was over by the end of June.

Venus larvae.--Figure 8 and table 3 depict abundance data for Venus larvae in Wickford Harbor for 1952. Larvae first appeared during the week of May 18, when the surface temperature was about 13° C., and reached a maximum of 5,400 straight-hinge larvae per 35 gallons the week of June 15. Late umbone stage larvae appeared for the first time around June 23 and were present consistently in the samples through the middle of July. The peak of abundance occurred during the week of July 13, when the weekly average was 219 mature larvae per 35 gallons. Although there was a small count of late umbone stage larvae the latter part of July, spawning for all practical purposes appeared to be over by mid-July.

Greenwich Bay, 1951

Figures 9 and 10 and table 4 show the abundance of Venus larvae at two stations in Greenwich Bay. Figure 9 is a composite of two stations in the western half of the bay, and figure 10 is a similar composite of two stations in the eastern half. Samples were taken twice a week during the spawning season. Bottom water temperatures in Greenwich Bay during 1951 are shown in table 1 and figure 11.

Sampling began May 4, and the first young larvae appeared the week of May 20 in the western half of the bay, when the bottom water temperature was between 15° and 16° C. The first late umbone stage larvae appeared during the week of June 10 in the eastern half, and they occurred sporadically in the samples throughout the summer. The greatest weekly average of young larvae was 1,500 per 35 gallons from the eastern half of the bay, and the largest weekly average of late umbone stage larvae was 70 per 35 gallons in both sections of the bay. The last sample containing Venus larvae of any kind was taken October 12.

Greenwich Bay, 1952

Figures 12 and 13 record the abundance of Venus in the eastern half and in the western half of Greenwich Bay during 1952. A semi-weekly schedule was maintained throughout the spawning season. Bottom temperatures in Greenwich Bay for 1952 are shown in table 1 and figure 11.

Sampling began on May 20, and the first larvae appeared during the week of May 25 in both parts of the bay, when the bottom water temperature was probably between 16° and 17° C. Spawning continued at varying intensities for the remainder of the summer, finally ceasing by the end of September. Much of the time, the spawning intensity was low. Seldom did the

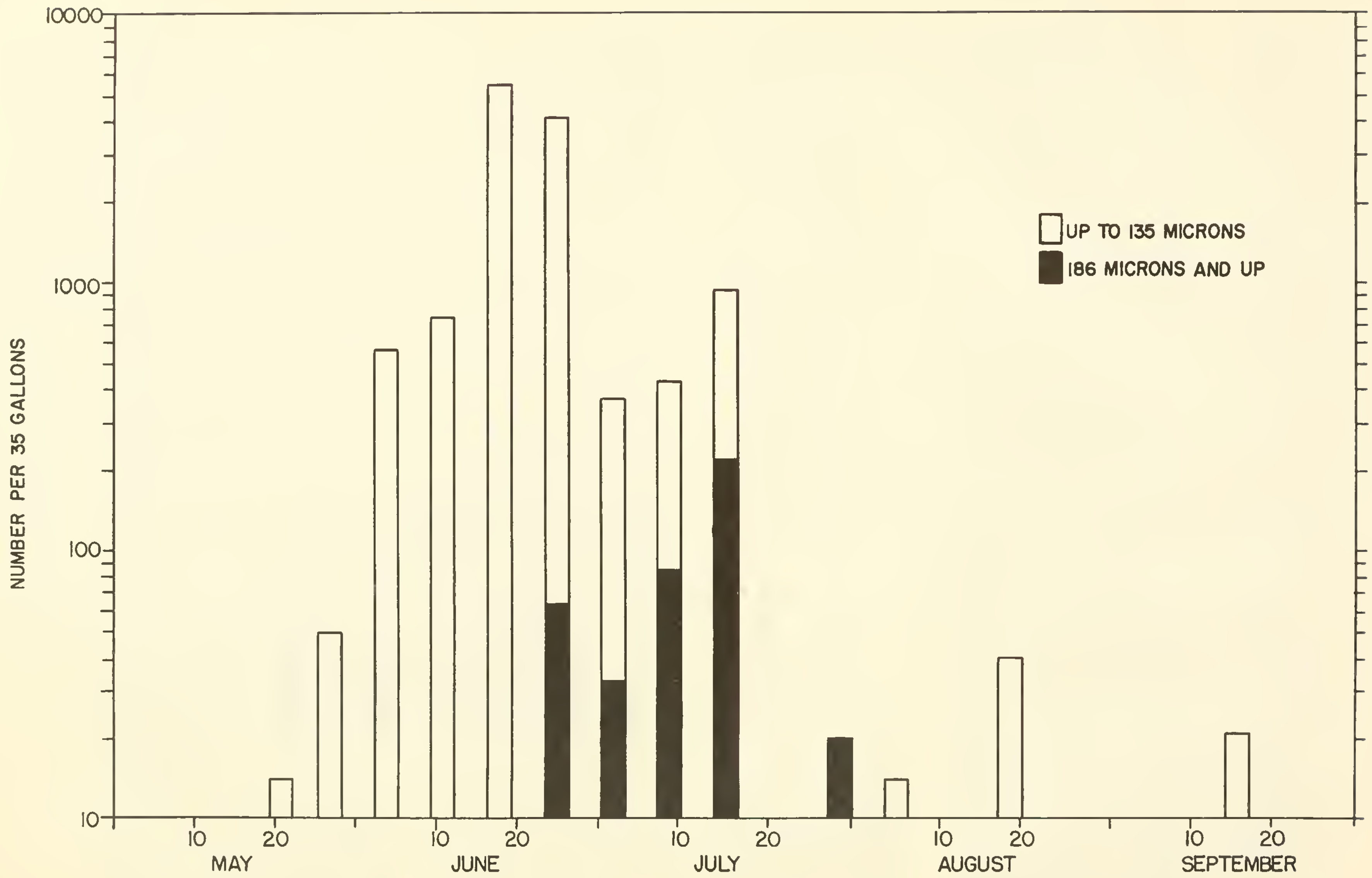

FIG. 8 WEEKLY AVERAGES OF VENUS LARVAL ABUNDANCE IN WICKFORD HARBOR IN 1952.

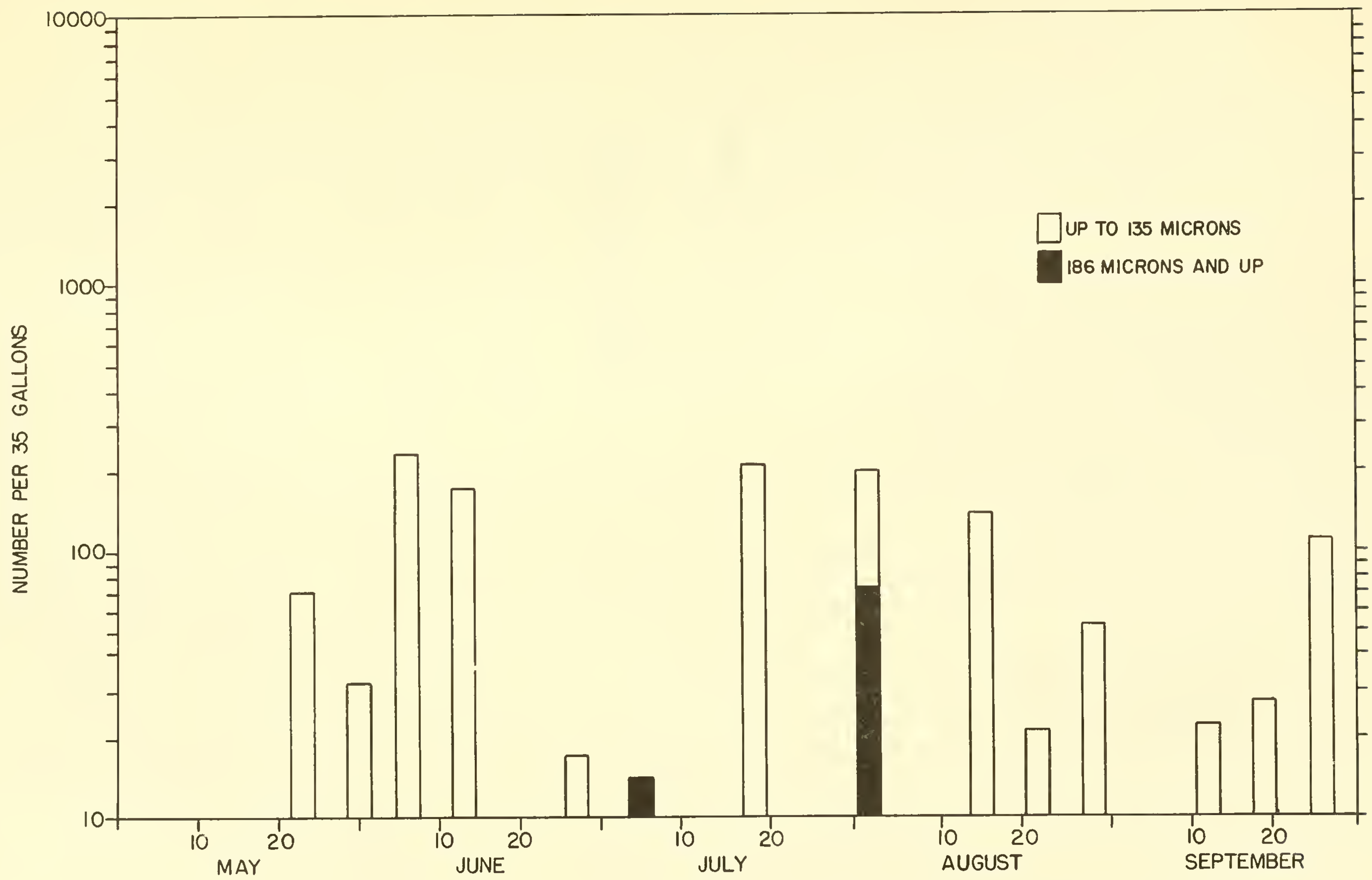

FIG. 9 WEEKLY AVERAGES OF VENUS LARVAL ABUNDANCE IN THE WESTERN HALF OF GREENWICH BAY IN 1951.

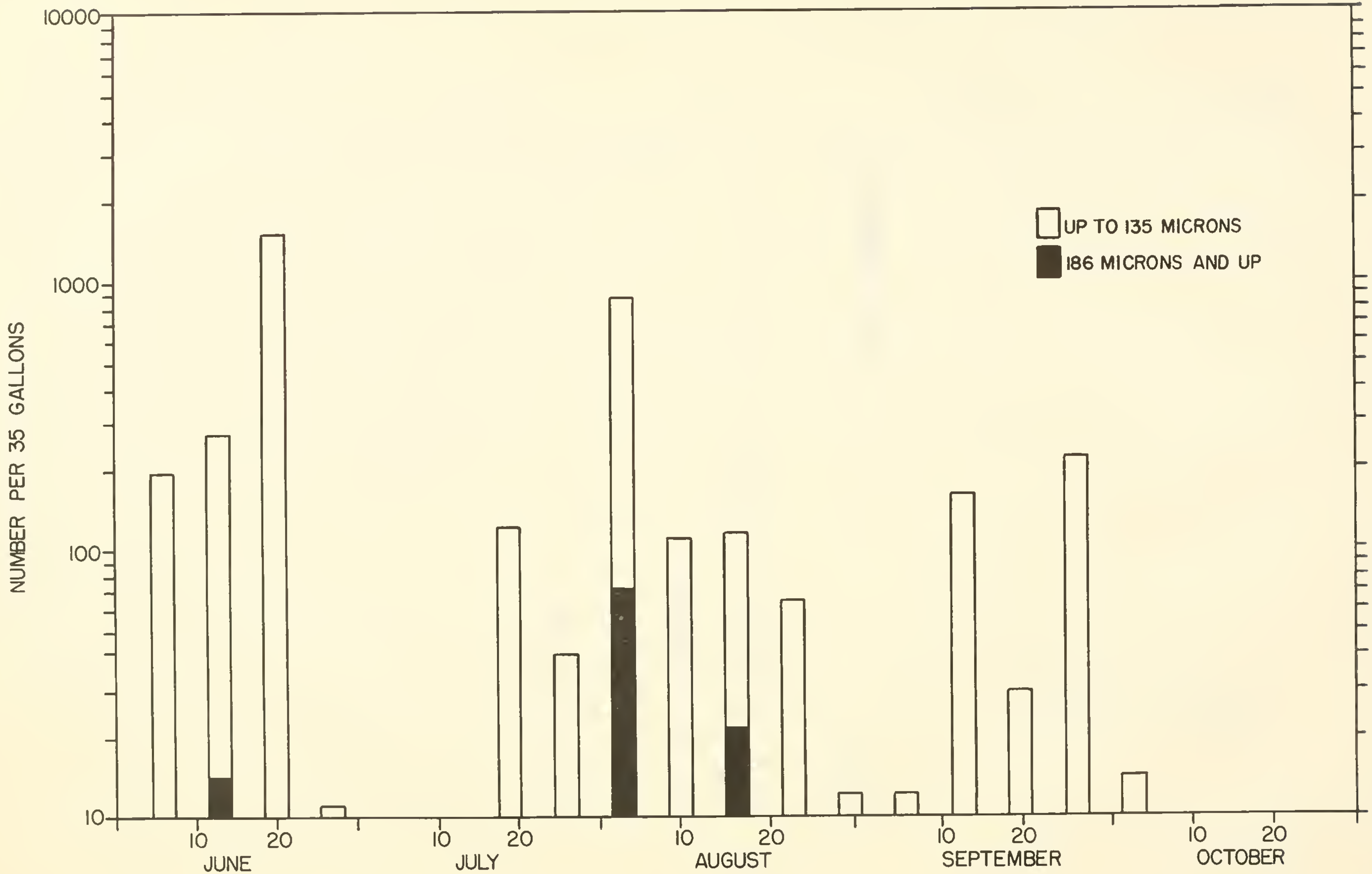

FIG. 10 WEEKLY AVERAGES OF VENUS LARVAL ABUNDANCE IN THE EASTERN HALF OF GREENWICH BAY IN 1951.

Table 4.--Greenwich Bay: Weekly average[1] abundance of *Venus* larvae, by size groups, 1951-52.
(Average number larvae in 35 gallons of sea water)

Week Beginning		Western half, larvae in size group: Up to 135 μ	Western half, larvae in size group: 186 μ and up	Eastern half, larvae in size group: Up to 135 μ	Eastern half, larvae in size group: 186 μ and up	Week Beginning		Western half, larvae in size group: Up to 135 μ	Western half, larvae in size group: 186 μ and up	Eastern half, larvae in size group: Up to 135 μ	Eastern half, larvae in size group: 186 μ and up
1951						1952					
May	20	70	-	-	-	May	25	105	-	21	-
	27	32	-	10	-	June	1	50	-	612	-
June	3	230	-	192	-		8	136	-	798	-
	10	170	-	256	14		15	136	-	88	14
	17	-	3	1500	1		22	66	1	9	7
	24	17	4	11	2		29	4	1	46	1
July	1	4	14	7	4	July	6	-	3	57	6
	8	1	3	8	1		13	193	6	27	15
	15	207	10	120	1		20	6	4	7	12
	22	1	2	40	4		27	29	18	575	34
	29	125	72	788	70	Aug.	3	7	7	7	11
Aug.	5	4	6	106	-		10	-	7	-	-
	12	137	-	93	21		17	686	12	124	6
	19	21	1	63	5		24	66	6	7	-
	26	52	5	12	2		31	209	2	49	-
Sept.	2	-	-	12	-	Sept.	7	4	-	10	-
	9	22	-	155	7		14	98	-	7	-
	16	27	-	29	-		21	144	-	35	-
	23	109	-	217	-		28	-	-	-	-
	30	6	-	14	-						
Oct.	7	1	-	8	-						
	14	1	-	-	-						
	21	-	-	1	1						
	28	-	-	-	-						
Nov.	4	-	-	-	-						
	11	-	-	-	-						

1/ Method of calculating average explained in text, page 3.

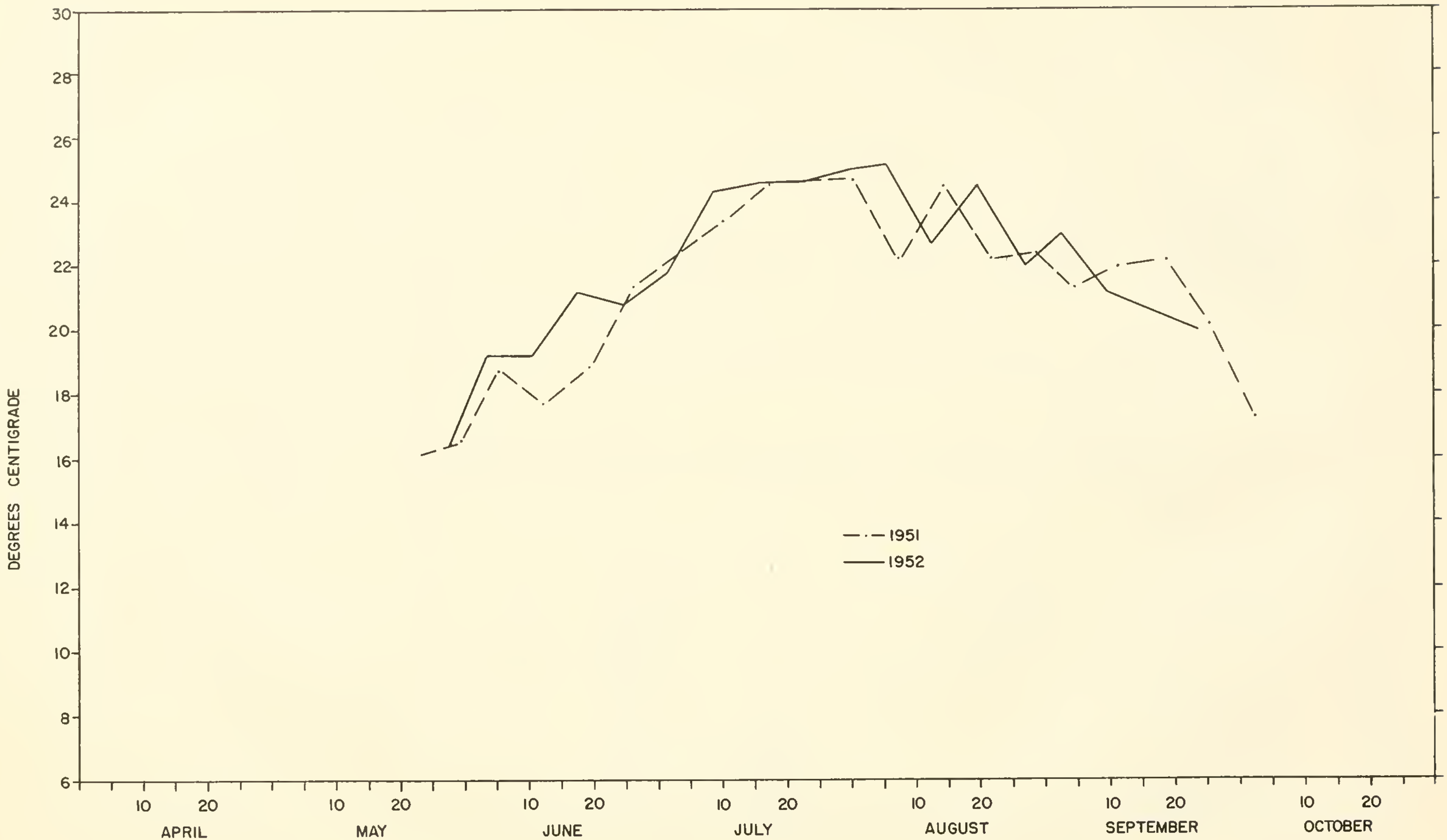

FIG. 11 WEEKLY AVERAGES OF SURFACE TEMPERATURES IN GREENWICH BAY.

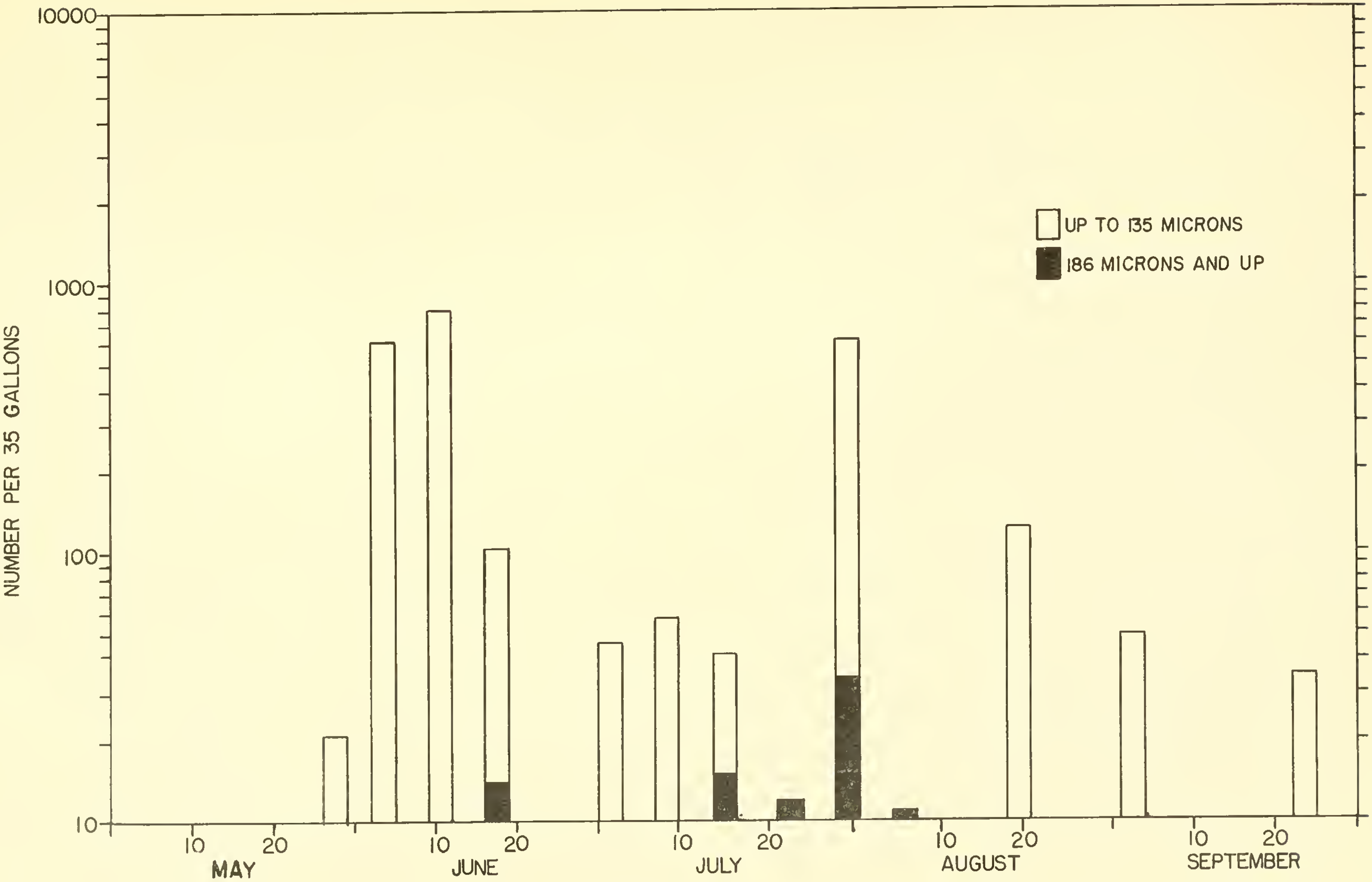

FIG. 12 WEEKLY AVERAGES OF VENUS LARVAL ABUNDANCE IN THE EASTERN HALF OF GREENWICH BAY IN 1952.

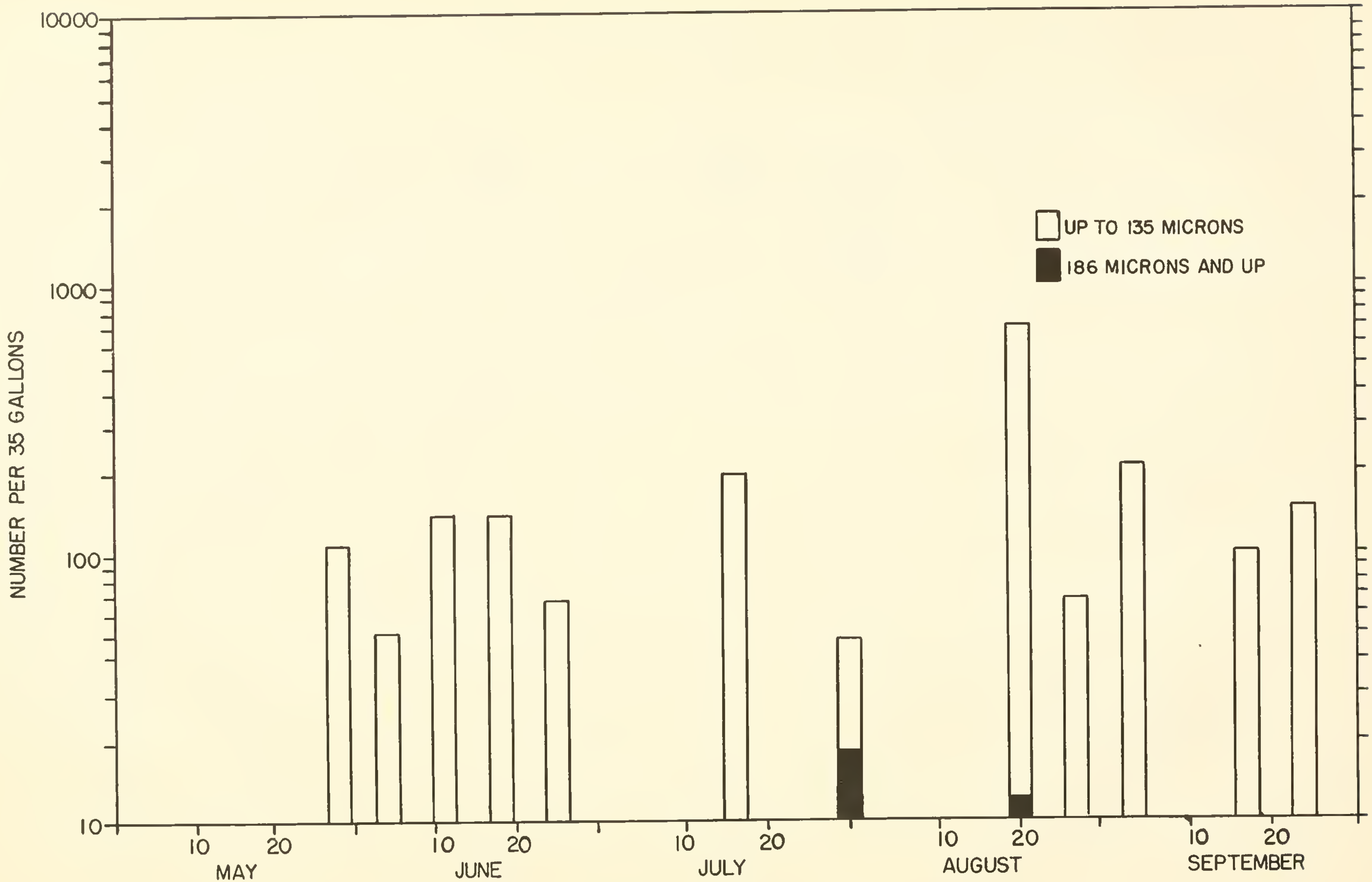

FIG. 13 WEEKLY AVERAGES OF VENUS LARVAL ABUNDANCE IN THE WESTERN HALF OF GREENWICH BAY IN 1952.

abundance of early larvae exceed 200 per 35 gallons, and the abundance of late umbone stage larvae never exceeded 40 per 35 gallons. In general, late umbone stage larvae were present in the samples during the latter half of July and the first half of August. Sampling was discontinued by the first part of October.

DISCUSSION AND CONCLUSIONS

The problem of the reliability of plankton-sampling techniques has been recognized and investigated in the past. Winsor and Walford (1936) concluded that the variability of their vertical net hauls could be explained on the basis of random distribution of the population, but they also realized that nonrandom distribution in other cases had not necessarily been ruled out. Ricker (1937), in studying variability of catches of freshwater plankton, found evidence of aggregation of organisms in some cases. Barnes and Marshall (1951) concluded that when population density is low the distribution of catch from replicate plankton samples closely approaches that of a random population. At higher densities, nonrandom distribution or clumping is indicated. These findings suggest that the abundance values in this paper are subject to some error. However, since only the general trends of abundance are inferred from the results, an attempt to estimate variability would be superfluous.

Mya arenaria and Venus mercenaria have different geographical ranges along the Atlantic Coast of the United States. Mya is abundant in more northerly latitudes than Venus, and Venus occurs abundantly in southerly latitudes where Mya is rare or nonexistent. Because of this it is to be expected that their spawning patterns in Rhode Island waters will differ. Mya begins to spawn in late April or early May in Narragansett Bay, when according to the literature the water temperature has risen to about 10° to 12° C. Spawning increases in intensity to a peak and then decreases steadily until late June or early July, when spawning ceases temporarily. In late summer or early fall there are one or more waves of spawning smaller than the spring spawning. Venus, on the other hand, doesn't begin to spawn until late May or early June, when according to the literature the water has warmed to about 20° C. Spawning continues for the remainder of the summer, usually decreasing in intensity until it ceases sometime in September. Isolated late umbone stage larvae of both Mya and Venus can occasionally be found well into the winter.

It is logical to assume that the beginning and duration of spawning of any bivalve will vary from year to year with variations in environmental conditions. A reexamination of the Wickford Harbor data for 1950, 1951, and 1952 indicates that this is true. When either the Mya or the Venus seasonal larval abundance data for the 3 years are studied, it becomes apparent that the pattern for 1950 differs from those for 1951 and 1952, which are similar. In the case of Mya, larvae did not appear until the week of May 21 in 1950, whereas in both 1951 and 1952 larvae first appeared in the latter part of April. Venus larvae first appeared in the week of June 11 in 1950, but late in May in 1951 and 1952. In addition, Venus spawning continued at a relatively high level until nearly mid-September in 1950, whereas in 1951 and 1952 practically all of the spawning was completed by mid-July. The answer appears to lie in the water temperature in 1950 as compared with 1951 and 1952. Figure 2 shows that in 1950 water temperature was consistently lower than in either 1951 or 1952. This condition may contain an explanation of the late beginning of spawning of both Mya and Venus in 1950. It could also be the cause of the continued relatively intense spawning of Venus throughout the summer of 1950, assuming that high water temperatures lead to the rapid spawning out of a population, while relatively low temperatures, perhaps not much above the minimum necessary to stimulate spawning will result in prolonged spawning at a high level.

No attempt has been made to determine the temperature necessary to stimulate spawning in either Mya or Venus. In cases where the animals studied are intertidal as well as subtidal, it may well be, as Belding (1931) suggested, that individuals living intertidally or in shallow water reach their spawning temperature considerably earlier than those living in deeper water. This point is emphasized so that the water temperatures given in this paper at the time larvae were first taken each year will not be construed as spawning temperatures for Mya and Venus in Narragansett Bay. However, since the temperatures presented are a product of the same heat exchanges as determine the temperature of an intertidal flat or a shallow cove, they may serve to show the thermal trends anywhere in the area during the spawning season, and explain differences in spawning patterns of the same bivalve from year to year.

Influence of early warming of exposed flats and shallow water on the spawning pattern of a bivalve population may be indicated by a comparison of Venus spawning in Wickford Harbor and in Greenwich Bay in 1951 or 1952. In Wickford Harbor in 1951 and 1952, Venus spawning (figs. 6 and 8) was finished for all practical purposes by mid-July. Only a relatively few Venus larvae of any age were seen after this date. On the other hand, in Greenwich Bay during the same period, Venus spawning (figures 9, 10, 12, and 13) was much more generally distributed over the summer months. A comparison of the water-temperature records (figures 2 and 11) from Wickford Harbor and Greenwich Bay shows no obvious differences that might account for the difference in spawning pattern. When the average depths of water and the percentages of exposed flats in the two areas are compared, a decided difference is apparent. Wickford Harbor has an average depth at mean low water of 2 to 3 feet, while Greenwich Bay averages about 10 feet. Exposed flats are from one-tenth to one-fifth of the total area of Wickford Harbor at low tide while exposed lfats are a negligible part of the total area of Greenwich Bay. If clams in shallow water and exposed flats spawn earlier at the same temperature than those in deeper water, the spawning early in the season will be more intense in Wickford Harbor than in Greenwich Bay, and the data suggest that this actually occurred.

The range of larval sizes noted in the samples agrees fairly well with the literature. With regard to *Mya*, Thorson (1946) gives the size at metamorphosis in shallow water as 210 microns. Sullivan gives the range of size as 105 microns, earliest straight-hinge stage, to 250 microns metamorphosing larva. Loosanoff's photomicrographs show the earliest shelled larvae to be 93 microns long. Larvae taken in Wickford Harbor and Greenwich Bay range from 90 to 100 microns, earliest shelled larvae, to 225 microns, when they disappear from the plankton, evidently as metamorphosing larvae.

Loosanoff and Davis (1950) give the range of *Venus* larvae as 105 microns, earliest straight-hinge stage, to 227 microns, ready-to-set larvae. Loosanoff, Miller and Smith (1951) give the length at which metamorphosis takes place as ranging from 175 to 236, with metamorphosis occurring most commonly between 200 and 210 microns. Sizes taken in our samples ranged from 110, earliest straight-hinge larvae, to 200 to 225, when they disappear from the plankton.

SUMMARY

1. The literature concerning *Mya arenaria* and *Venus mercenaria* early life-history was reviewed, and quantitative data on seasonal abundance were found to be lacking.

2. Identification of the larvae was made by a combination of two or more of the following methods: Use of photomicrographs of field-obtained or artificially reared larvae; use of diagnostic features such as color and transparency not apparent in photographs; and rearing of field-collected late umbone stage larvae to a post-setting size for positive identification.

3. Samples of larvae were collected with a rotary pump and strained through a plankton net. Counts were made with a Sedgewick-Rafter cell.

4. In Wickford Harbor, larvae of *Mya arenaria* are most abundant in May and June, those of *Venus mercenaria* in June and July. In the western half of Greenwich Bay, *Venus* is present in some abundance from June to September.

5. Variations in spawning patterns at the two locations are similar and are probably caused by variations in water temperature.

6. The range of size of *Mya arenaria* larvae is 90 to 100 microns in length as earliest straight-hinge stage to approximately 225 when late umbone stage is reached. *Venus mercenaria* larval size range is 110 microns to 225 microns.

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