ADMINISTRATIVE REPORT

Mysis relicta sampling in Lake Huron, 1969

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MYSIS RELICTA SAMPLING IN LAKE HURON, 1969

The material on which this preliminary report is based was collected by staff of the Limnology Program during June through September 1969. Four cruises of the R/V *Kaho* were completed in northern Lake Huron as the initial stage of a continuing investigation of zooplankton, benthos, and fish distribution. A trawling report (Reynolds, et. al., 1969) has already been prepared, summarizing the data on fish distribution and abundance. The present report is a summary of the results of the sampling for *Mysis relicta*, and tentative recommendations for the direction of future work.

Methods

The samples were taken at ten depth intervals from 5 to 60 fathoms along transects running lakeward out of two different bays (Thunder Bay and Hammond Bay) in northern Lake Huron (figs. 1-3). Dates of the cruises were as follows: June 5-9, July 12-16, August 22-29, September 26-29, 1969. The 50- and 60-fathom depths were sampled only in August at Thunder Bay and in July, August, and September in Hammond Bay. The primary sampling tool was a plankton sled consisting of a meter net (656 Nitex) mounted in a rigid frame on skids (fig. 4), so that the area from approximately 28 cm to 128 cm above the bottom was theoretically sampled. The sled was towed along the bottom following the prescribed sampling depth contour for 10 minutes (a distance of about 724 meters) at all stations deeper than 10 fathoms. At 5 and 10 fathoms the towing time was 5 minutes. A discussion of the performance and limitations of this apparatus is included in the recommendations below. In addition to the sled, vertical plankton tows were taken with a 0.5-meter net (351 Nitex) from approximately 2 meters above bottom to the surface. In a concurrent study of the benthos, three replicate bottom samples with a Ponar dredge (22 cm square) were taken, and the occasional capture of *Mysis* by this gear provides some qualitative distribution information. In most cases it was possible to preserve the whole of a sled collection, but at 50 and 60 fathoms the catch was often so great (5 kg) that a subsample by weight was sometimes taken. In the laboratory *Mysis* were picked out of the sled haul samples and all the individuals examined. In some cases it was necessary to subsample in order to reduce the total number to a manageable size. The subsampling technique (selecting a small volume of sample mixture) was tested by couting replicates of five from several different samples.

The individuals were measured (under a binocular dissection scope) from the tip of the rostrum to the last solid structure of the telson to the nearest millimeter below. If an individual was 10 or more millimeters long, an attempt was made to sex it, and to place it within one of the following arbitrary maturity classifications:

Male I: fourth pleopod showing minimal development, shorter than or just reaching base of fifth pleopod;

Male II: fourth pleopod extending beyond fifth pleopod base but not extending past base of telson;

Male IIIA: fourth pleopod extending beyond base of telson but lacking complete development of exopod;

Male IIIB: as above, but exopod fully developed with delicate extension on last segment of exopod; this is the fully mature male, and spermatic material is sometimes visible in the ducts at the base of the sixth swimming leg.

Female I: oostegites minimally developed, not meeting at midline and usually non-pigmented;

Female II: oostegites well developed, meeting at midline to form (in plan view) a triangular shape, and usually pigmented;

Female III: oostegites fully developed and pigmented, brood pouch firm and ballooned out (or loosely collapsed but of large size); brood pouch may contain eggs or embryos, which are enumerated and described; this is the fully mature female and it is presently assumed all in this category are producing or have recently released brood.

Intact individuals which were not sexually differentiated were classified immature. The smallest individuals found free in the sample (2-3 mm), which were recognizable as unhatched brood were not counted or classified. The embryonic stages noted by Berrill (1969) made this distinction fairly simple.

Sampling and Environmental Variables

The sampling variables of time of day, wave height, and cloud cover are presented in fig. 5 and tables 1 and 2. The bottom temperatures corresponding to the sled haul dates are given in fig. 5b. The effect of any or a combination of these variables on *Mysis* is not fully known. The diurnal migrations of *Mysis* are well documented, and although all the present samples were taken in fully daylight hours, there is the possibility that cloudy conditions may lead to a more dispersed population and sampling errors. Absence of *Mysis* in concurrent vertical tows indicates this was not a serious problem. There was a systematic trend toward sampling the shallow end of the transects after noon and the deep ends in the morning (fig. 5b).

Results

Depth distribution and abundance

The total numbers of *Mysis* in the various sled tows are presented in table 3, in vertical tows in table 4, and in a few of the concurrent Ponar

Table 1.--Surface wave heights[1/] by date, area, and depth for sled hauls

Depth	Thunder Bay				Hammond Bay			
(fathoms)	June	July	August	September	June	July	August	September
5	2	2	2	2	-	1	1	2
10	2	2	2	2	-	1	1	2
15	2	2	2	3	1	0	1	2
20	2	2	2	3	1	1	1	2
25	2	2	2	3	1	1	1	3
30	2	1	2	3	1	1	1	3
35	2	1	2	3	1	2	1	3
40	2	1	2	3	1	2	1	3
50	-	-	3	-	-	2	1	2
60	-	-	3	-	-	2	1	2

1/ 0 = 0 feet; 1 = <1; 2 = 1-2; 3 = 2-4

Table 2.--Cloud cover[1/] by date, area, and depth for sled hauls

Depth (fathoms)	Thunder Bay June	Thunder Bay July	Thunder Bay August	Thunder Bay September	Hammond Bay June	Hammond Bay July	Hammond Bay August	Hammond Bay September
5	4	2	1	4	-	1	0	4
10	4	2	1	4	-	1	0	4
15	4	2	1	4	2	1	0	4
20	4	2	1	2	2	1	0	4
25	4	3	1	2	2	1	0	4
30	4	3	1	2	2	1	0	3
35	4	3	1	2	3	1	0	3
40	4	3	1	2	3	1	0	3
50	-	-	1	-	-	0	0	2
60	-	-	1	-	-	0	0	3

1/ 0 = 0% cloud cover; 1 = 25%; 2 = 50%; 3 = 75%; 4 = 100%

Figure 5a. Bottom temperatures by date and depth, at Thunder Bay and Hammond Bay, Lake Huron, 1969.

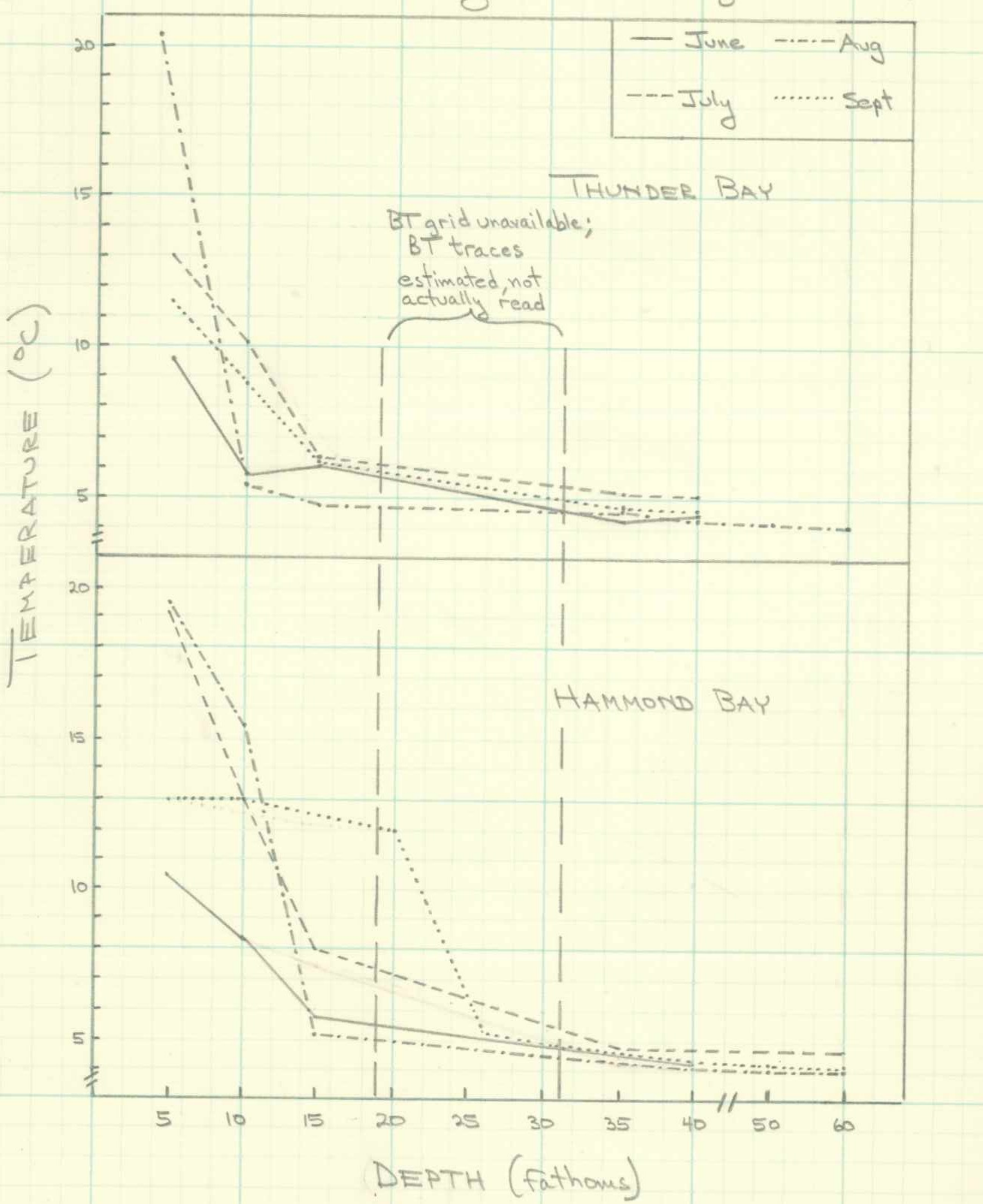
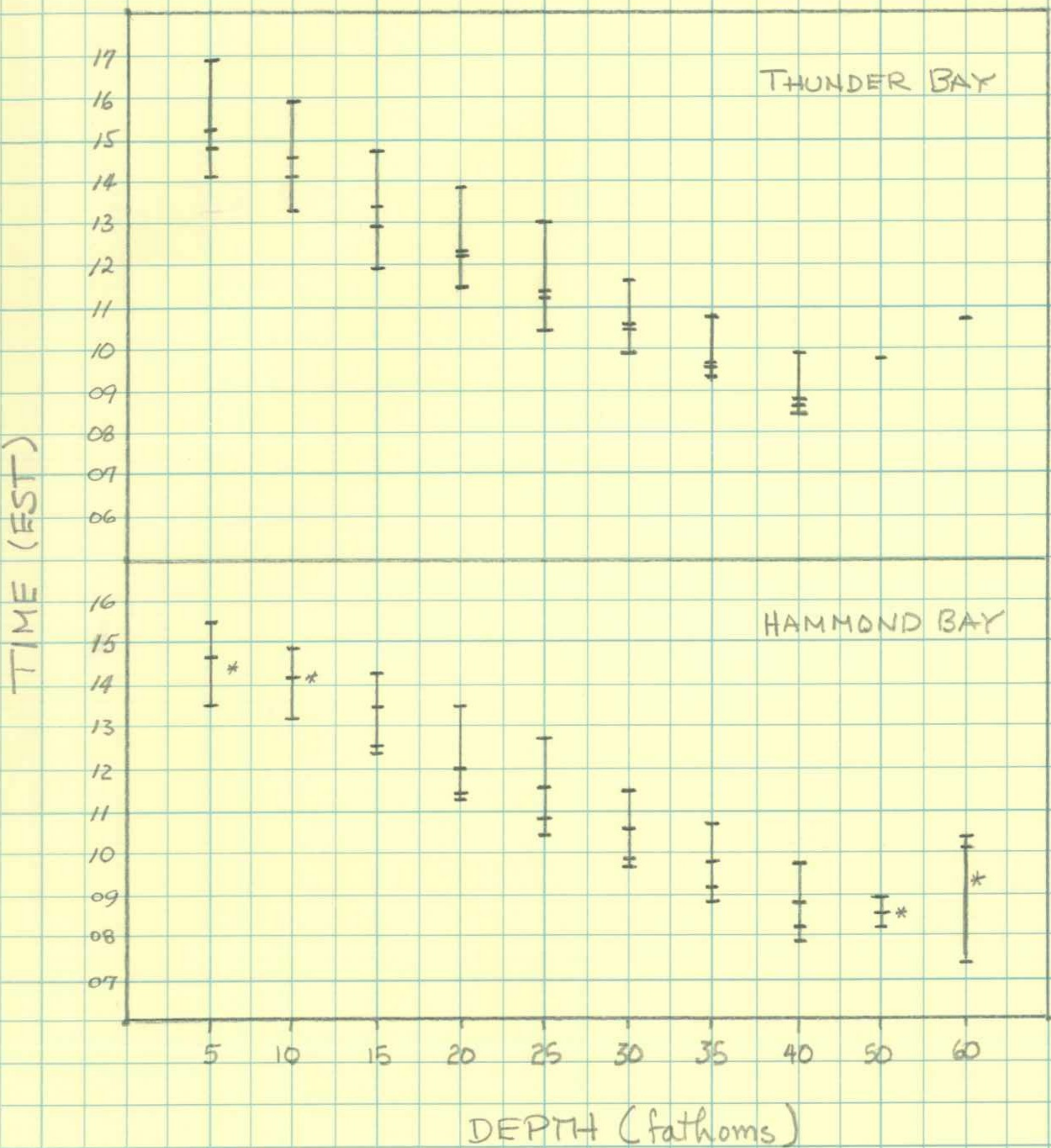


figure 5b. Times of sled hauls by depth and location



* Do not include June samples

Table 3.--Total estimated number of *Mysis* per 10-minute tow of plankton sled

Depth (fathoms)	Thunder Bay June	Thunder Bay July	Thunder Bay August	Thunder Bay September	Hammond Bay June	Hammond Bay July	Hammond Bay August	Hammond Bay September
5	0	0	0	0	-	0	0	0
10	0	0	0	0	-	0	0	0
15	0	1	0	0	0	0	0	2
20	0	1	0	0	1	1	0	0
25	0	0	1	0	0	4	1	1
30	1	0	1	0	2	5	51	4
35	62	2	0	0	103	170	1054 1/	33
40	92	49	89	12	92	60		4702
50	-	-	3999	-	-	542	687	67800
60	-	-	49200	-	-	189000	39200	22640

1/ The 35- and 40-fathom samples were accidentally combined.

Table 4.--Occurrence of *Mysis relicta* in vertical plankton tows concurrent with sled hauls. Figures are total numbers counted regardless of depth of tow. All were immature except Thunder Bay, July, 40 fathoms

Depth (fathoms)	Thunder Bay June	Thunder Bay July	Thunder Bay August	Thunder Bay September	Hammond Bay June	Hammond Bay July	Hammond Bay August	Hammond Bay September
35 1/	0	0	0	0	0	0	0	0
40	0	1	0	1 2/	0	0	0	1 2/
50	-	-	0	-	-	0	0	0
60	-	-	0	-	-	0	4	7

1/ No *Mysis* were caught in vertical tows at 35 fathoms or shallower.

2/ Sediment in sample indicated net collapsed on bottom.

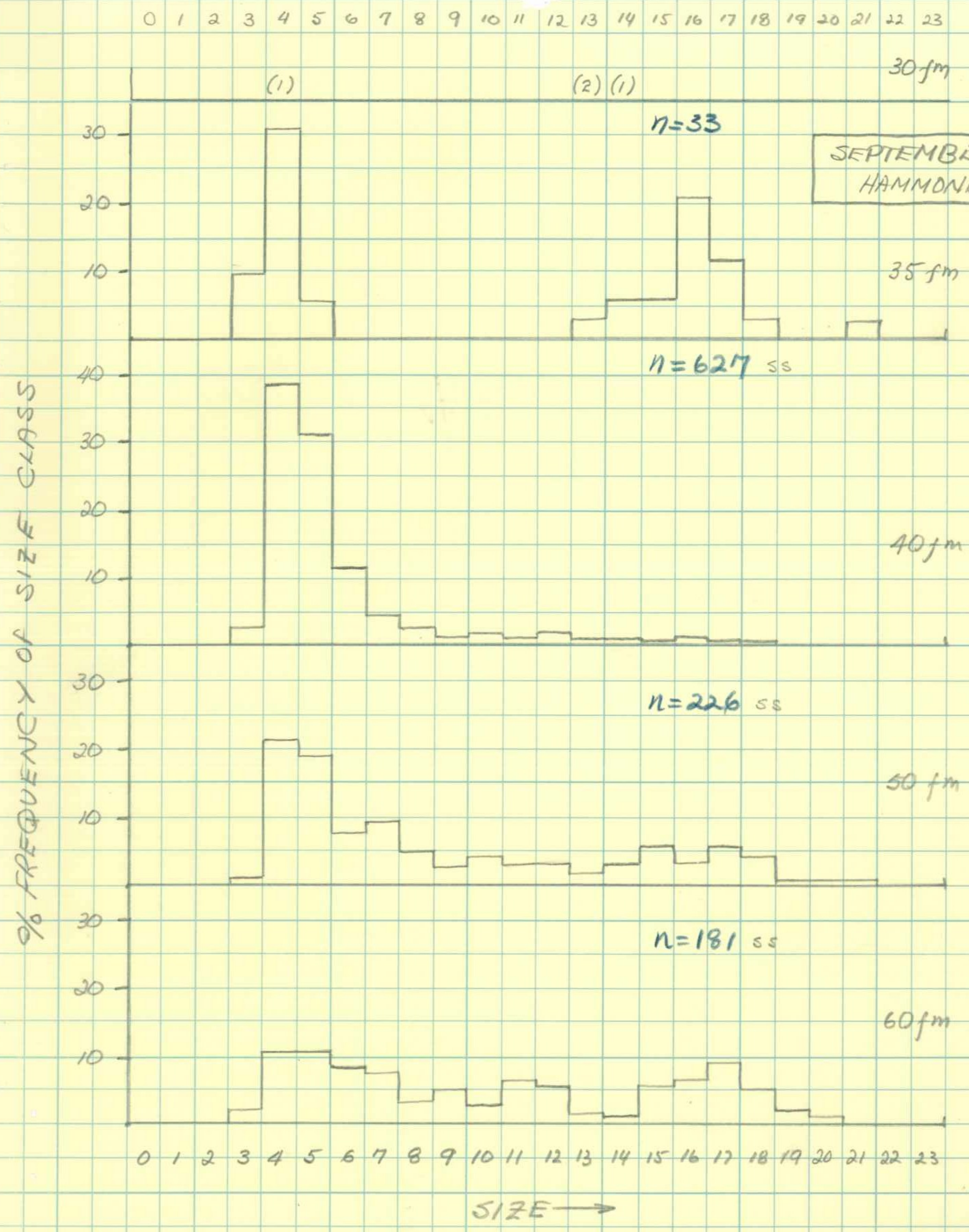


Fig 6. Length frequency of Mysis at Hammond Bay cont.

dredge samples in table 5.[1/] In the case of the two net tows, numbers are simply Mysis estimated in the whole tow (i.e., not an actual density figure) whereas for the Ponar dredge the figures represent computed density of numbers per square meter. There is no basis for quantitative comparison between these three methods, but it does appear from the dredge data that Mysis occurred in significant numbers considerably shallower than suggested by the sled tow results. In gross terms, however, it appears that large concentrations of Mysis were restricted to water deeper than 30 fathoms; in nearly all cases where there was a full depth transect, there was an approximately exponential increase in numbers with depth. The absence of Mysis in most of the vertical tows is not unexpected since Mysis is well known to remain near the bottom during daylight hours (Beeton, 1960). The few specimens (immature) caught in the 60-fathom hauls at Hammond Bay in August and September may be an indication that juveniles tend to be slightly higher off the bottom in daylight in deeper areas (Beeton, op. cit., pg. 522).

There are only three series data points (July, August, September) in deeper depths at Hammond Bay and it is unwise to suggest the direction of any trends in absolute numbers. There does appear to have been a considerable shift of the maximum density from 60 to 50 fathoms and somewhat to 40 fathoms in September. No time series is available at these depths in Thunder Bay.

Length frequency

The percentage length frequency by depth and location is given in appendix figs. 1-6. The Hammond Bay data (figs. 3-6) indicates that there was usually a predominance of the younger stages (<10 mm) or a distinctly bimodal distribution of young and old individuals (ca. 17 mm) at the shallower end of the depth range (30-40 fathoms). At 50 and 60 fathoms the population was more or less evenly distributed throughout the whole range of sizes. Essentially, this appears to have been the inclusion of intermediate size categories (11-14 mm). The proportion of the populations at 30-40 fathoms which were immature appears to have increased from June to September. This is discussed further below.

Sexual differentiation and reproduction

The abundance (sum of all depths) in the various maturity classifications for Hammond Bay is plotted in fig. 6. Table 6 gives a summary of sex ratios and other parameters of interest for individual and grouped samples. Inspection of the figure and of column two of the table indicates that there was a considerable increase in the proportion of immature forms during August and September, arithmetically a result of lowered abundance of sexually differentiated forms rather than an increase in total number of immature forms. The continued presence of the smallest individuals (3-4 mm),

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1/ Data supplied by Jarl K. Hiltunen.

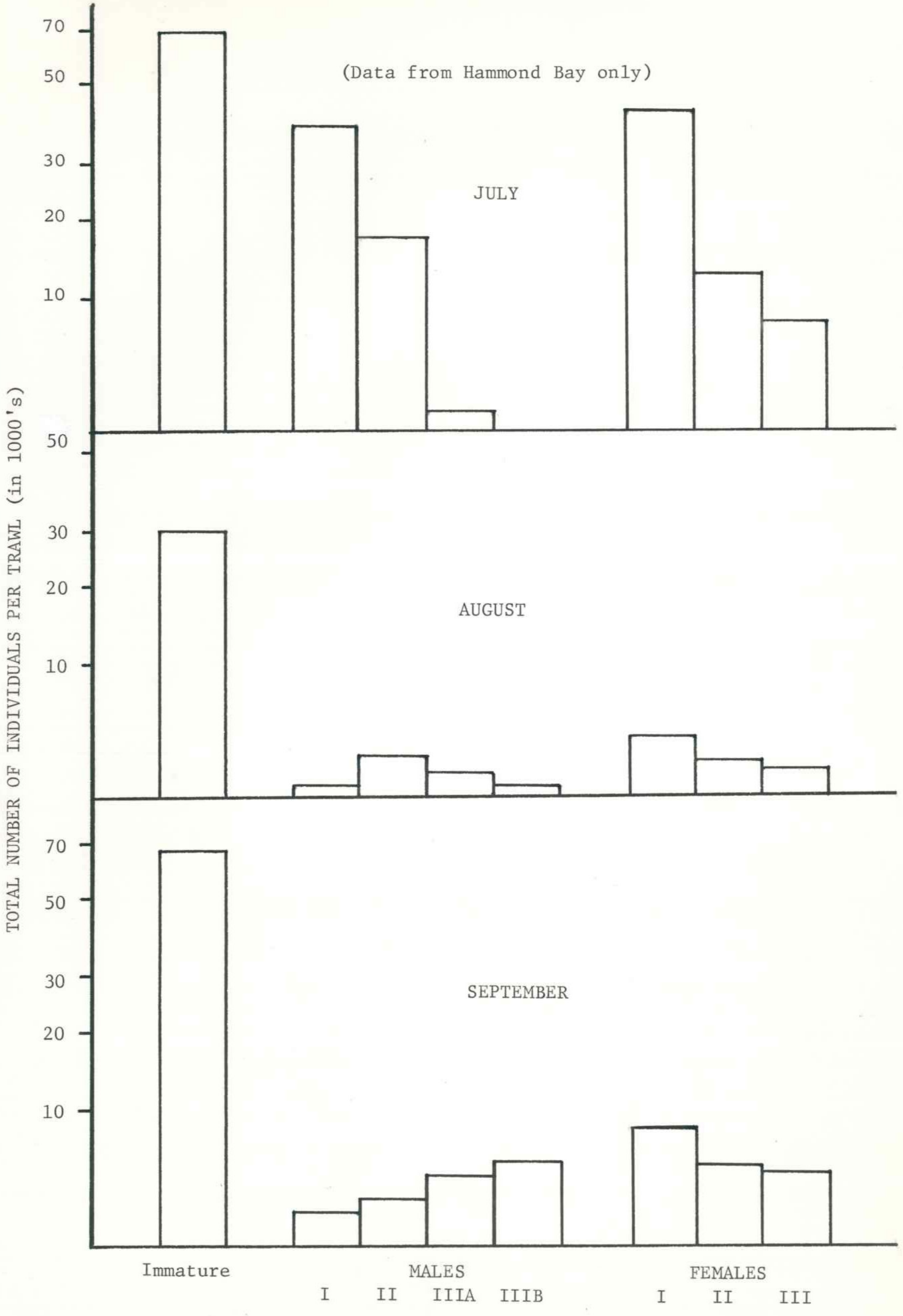

Figure 6. Total numbers (sum of all depths) of Mysis in various life stages.

Table 5.--Number of *Mysis relicta* per square meter estimated from three Ponar dredge hauls at each depth. Hammond Bay above; Thunder Bay below

	Hammond Bay									
Depth (fathoms)	5	10	15	20	25	30	35	40	50	60
June 8	0	7	7	28	20	7	14	0	X	X
July 12	X	0	7	28	55	55	21	0	X	X
Depth (fathoms)	2.5	4.2	5.0	8.3	11.7	12.8	13.3			
September 25	0	0	0	26	13	13	6			

	Thunder Bay									
Depth (fathoms)	5	10	15	20	25	30	35	40	50	60
July 15	0	0	7	7	21	7	96	82	X	X

Table 6.--Tabulation of population parameters at

Date	Depth (fathoms)	Hammond Bay Female/ male	Hammond Bay Immature/ mature	Hammond Bay % female IIIs gravid	Hammond Bay IIIB/ IIIA	Thunder Bay Female/ male	Thunder Bay Immature/ mature	Thunder Bay % female IIIs gravid	Thunder Bay IIIB/ IIIA
June	35	1.02	0.13	0	2/5	2.15	0.51	9.1	1/1
	40	0.91	0.51	0	2/4	1.33	0.64	0	4/1
	sum	0.97	0.28	0	-	-	-	-	-
July	35	1.46	0.17	10.0	7/18	-	-	-	-
	40	0.90	0.09	0	0/3	0.95	0.26	-	2/4
	50	0.61	1.00	0	0/2	X	X	X	X
	60	1.09	0.59	42.9	0/1	X	X	X	X
	sum	1.09	0.58	-	-	-	-	-	-
August	30	-	50.0	0	0/0	-	-	-	-
	35+40	1.33	1.87	0	3/19	1.26	0.46	-	1/9
	50	2.33	0.34	16.7	1/13	1.27	0.23	22.2	7/15
	60	1.57	2.47	52.9	7/11	1.42	0.42	58.1	14/26
	sum	1.58	2.35	-	-	-	-	-	-
September	35	1.00	0.83	0	0/7	-	-	-	-
	40	1.13	17.44	0	1/8	all female	3.00	-	0/0
	50	1.36	2.42	40.0	11/9	X	X	X	X
	60	1.12	0.99	8.3	14/12	X	X	X	X
	sum	1.26	2.02	-	-	-	-	-	-
Column No.		1	2	3	4	5	6	7	8

and the presence of sizable proportions of gravid females (column 3--high as 52.9%) with eggs as well as advanced brood indicates that these populations of Mysis were breeding during the summer months in the deeper water and that recruitment was continuing. The sex ratio (column 1) varied considerably with depth but was always greater than one (female; male) in the latter half of the summer, usually about one or less in June and July. Fully mature males (IIIB) were found in all months, and showed some increase in proportion relative to the next younger class (IIIA--see column 4). The data at Thunder Bay (columns 5-8) is based on fewer samples and is less reliable. Some gravid females as well as a few fully mature male IIIB were noted in June; in August breeding appeared to be at a high level, but the lack of July or September samples does not allow any trend to emerge.

Discussion

It should be emphasized that with only three good samples during a restricted time of the year, few generalizations can be made. However, as the basic objective of this 1969 sampling program was to arrive at information needed to define and organize a more comprehensive seasonal program, some further analysis is warranted for this preliminary report.

The life history of Mysis relicta is fairly well known in temperate and subarctic lakes in Europe and North America, but no detailed information on reproductive history in any of the Great Lakes has been published. Typically, breeding in temperate lakes takes place in October-December, with females holding the developing brood (about 20) for 5-6 months (until May-June) when the young (at 3-4 mm in size) are released. This situation has been implied in Wisconsin lakes (Juday and Birge, 1927) and in southern Ontario lakes (Berrill, 1969). There are, however, references to summer breeding in some European lakes (Ekman, 1920) at 40-76 m in cold water. A variety of lakes in Northern Germany have been studied (Samter, 1905; Samter and Weltner, 1904) and the conclusion drawn there that reproduction began at low temperatures (7° C) and was most active at winter temperatures of 3-4° C. In addition, these workers concluded the upper temperature limit for Mysis was 14° C. This figure might represent a maximum temperature for long term survival, but it has been shown that on occasion (Beeton, 1960; Juday and Birge, 1927) Mysis will diurnally migrate into water as high as 19-21° C.

The growth rate and age of first reproduction for Mysis is apparently not consistent throughout its range. For populations breeding for a limited time, only in winter, age at maturity has been reported from less than 1 year to more than two. Figure 7 summarizes three suggested rates of growth. Berrill's (1969) study on embryonic Mysis clearly states a 5-6 month period in the brood pouch (beginning October-December) on Stony Lake (Ontario) although Juday and Birge (1927) quote Samter (1905) as finding a 2-3 month embryonic period in some German lakes. Ekman (1920) agrees with

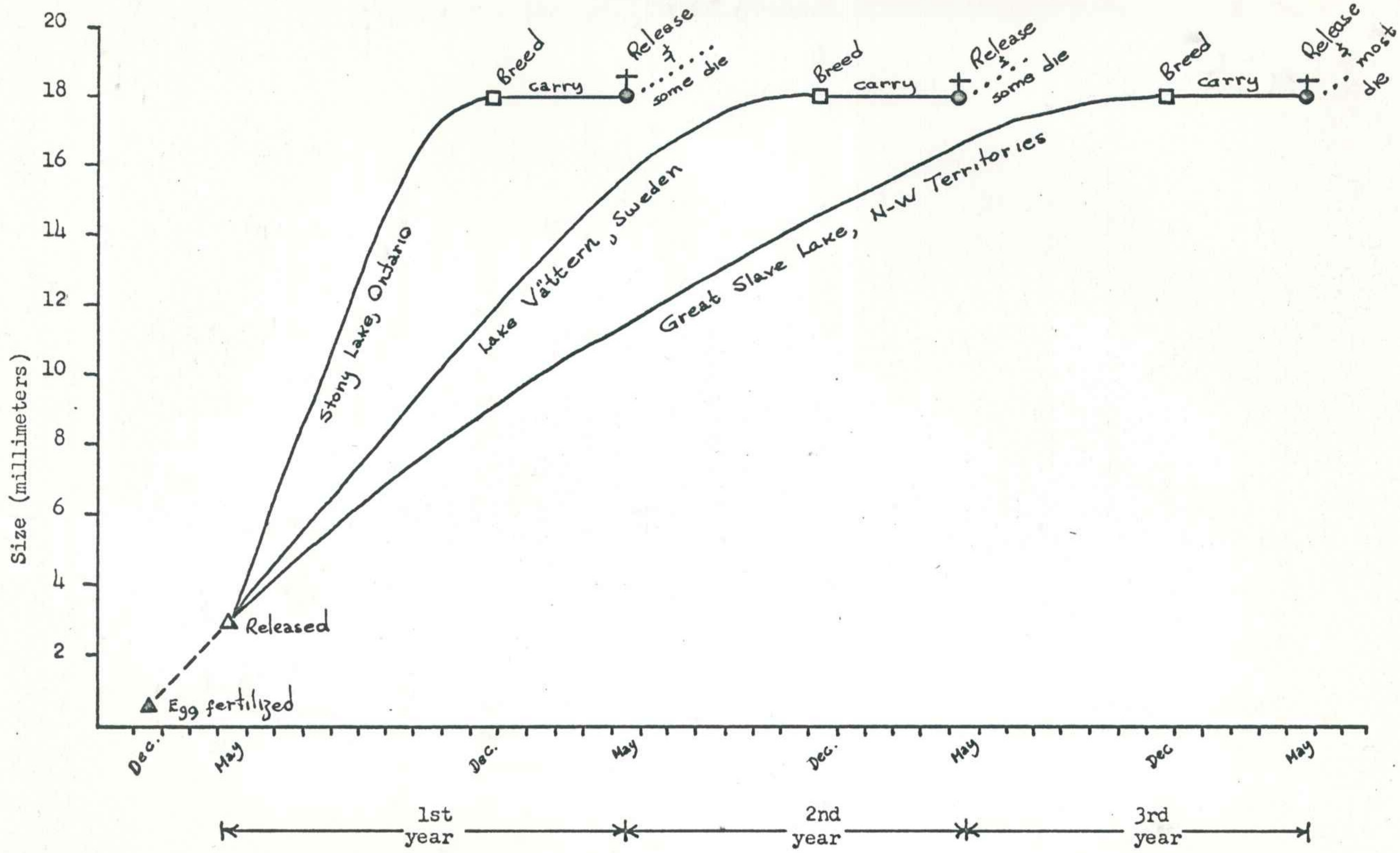

Figure 7. Growth rate of Mysis relicta in three temperate lakes based on data from Stony Lake, Ontario (Berrill, 1969), Lake Vättern (Ekman, 1920), and Great Slave Lake (Larkin, 1948). Work done by Beeton (in preparation, see appendix) suggests the growth rate in the Great Lakes may be like that in Stony Lake.

the 5-6 month period in winter breeding populations. Berrill assumes individuals hatched out in May are sexually mature and breed in the immediately following December (6-7 months of growth) whereas Ekman reports individuals won't breed until after a year old (i.e., one breeding season is spent as a juvenile and the next breeding season is active, implying some 18 months of growth). Larkin (1948) reports in Great Slave Lake individuals do not mature and breed until they are over 2 years old (actually 30 months after hatching). Berrill does not present data to substantiate his claim of only 6-7 months, and if true, it would be a surprizingly rapid rate compared to the embryonic development (i.e., egg to hatching at 3 mm in 6 months versus 3 mm to 17-18 mm in the following 6 months). Ekman reports some females may survive to breed a second time, although most die sometime (?) after release of the first brood. Larkin felt this was true in Great Slave Lake also, although only a very few females produced second broods there.

Since Stony Lake and Great Slave Lake seem to be extremes, it is possible to assume, to promote discussion, that in Lake Huron the growth rate is more like in Ekman's Lake Vattern. Figure 8 summarizes this interpretation. One definite point on the curve is in August at 3 mm size since this length, which represents the hatching size, was in fact in the August samples, the curve is extrapolated back to February (6 months) as the time eggs were deposited. If growth to maturity takes 18 months, then these individuals would breed in February, just 24 months after the parent generation bred. The actual shape of the curve is purely conjecture, and ignores environmental changes which might alter the pattern. Average lengths in the arbitrary maturity classes have been entered on the graph, and the corresponding age can be read on the time scale. Presumably most of the cohort would die at 24 months after releasing its brood. The average length of adult females (III) in these samples is over 1 mm greater than males. If males become mature at precisely the time that the females do, then a slightly lower growth rate for males is suggested, but of course it is possible that males simply mature at an earlier age and have a growth rate identical to females.

The observation of a full range of size categories in these samples is further evidence of extended breeding periods. In addition a considerable range of sizes within the arbitrary maturity classes was evident (table 7). Such ranges may be due in part to classification error (probably highest in the II category), or to simple variability in individual growth rate. This variability may well be amplified since, if breeding is more or less continuous, successive cohorts will be exposed to a seasonally varying environment. The extent of such seasonal variability, however, especially at 50-60 fathoms is minimal. The smallest female III was 13 mm, although the smallest female III carrying brood was 14 mm.

Table 7.--Ranges (in mm) of individual size in the various maturity classifications. Hammond Bay data only

Date	Indeterminate sex	Males I	Males II	Males IIIA	Males IIIB	Females I	Females II	Females III
June	3-11	9-14	13-19	14-17	14-16	10-19	14-20	15-20
July	3-12	9-17	11-18	15-18	14-17	10-20	15-21	13-22
August	3-12	10-14	11-17	14-18	15-19	10-18	12-21	14-21
September	3-12	10-12	11-17	13-18	14-19	10-18	14-20	15-22
Combined	3-12	9-17	11-19	13-18	14-19	10-20	12-21	13-22

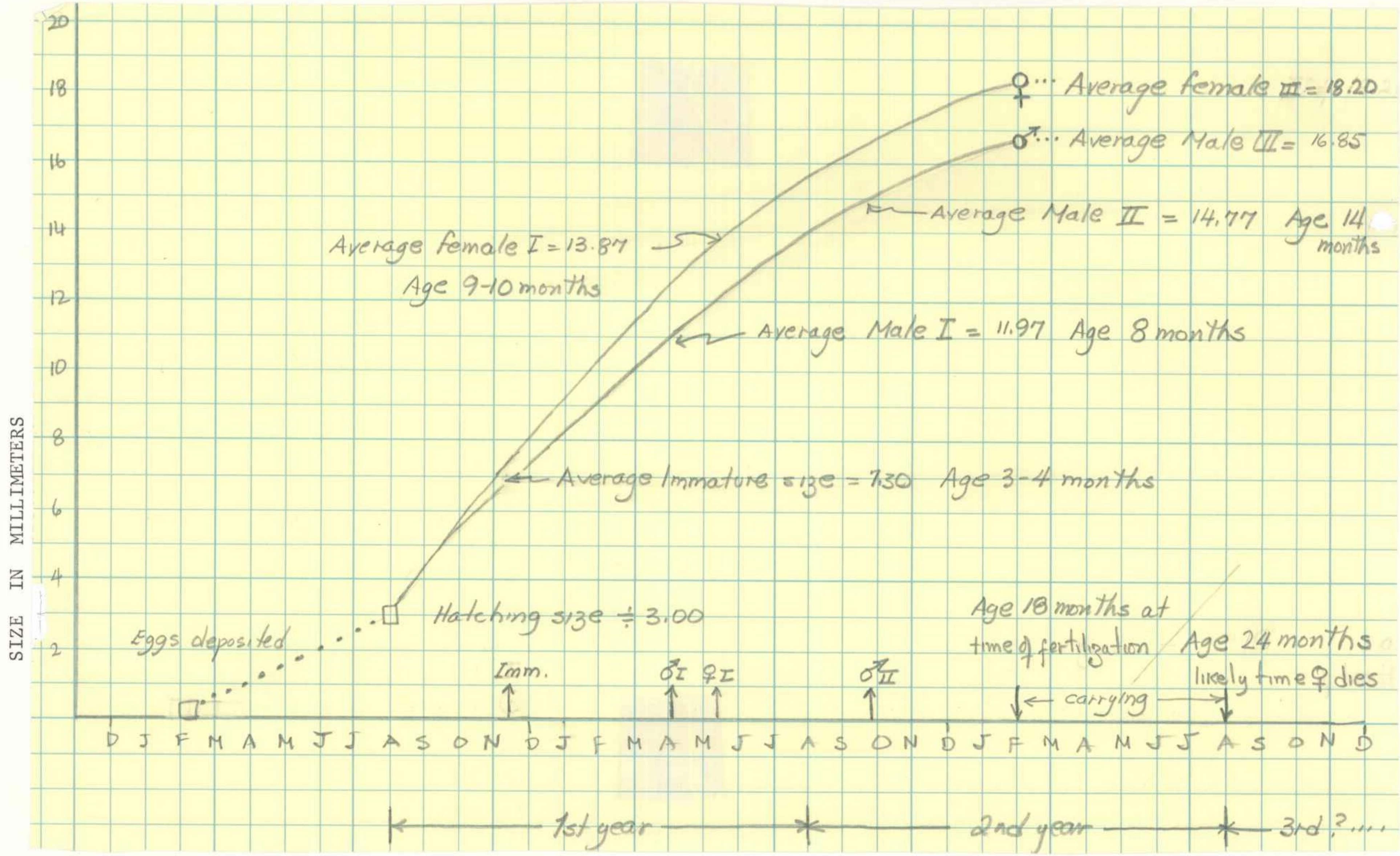

Figure 8. Growth rate of Mysis relicta in northern Lake Huron: one possible interpretation of the present data, assuming that individuals do not breed until over one year old.

Recommendations

A definitive proposal for the 1970-71 season is in preparation. Tentatively, effort will be expended along the following lines:

1. Continued search of the published and unpublished literature on life history and dynamics of *Mysis relicta*.

2. Solicitation of information and material for examination from other Great Lakes institutions.

3. Cooperation with Bureau of Commercial Fisheries Ashland in standardizing methods and gear in order to facilitate comparison between Lakes Superior and Huron.

4. Refinement of maturity classification system.

5. Development of a workable seasonal sampling program (R/V *Kaho*) to extend from April to November, covering out to the deepest water off Hammond Bay (80 fathoms). The 5-fathom intervals in the shallower water might well be expanded to 10 or 15 fathoms. Interim sampling, with lighter gear developed for the purpose, could be undertaken from R/V *Daphnia*. Isolated samples from December-March might be attempted from Coast Guard Cheboygan.

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December 29, 1969

Literature Cited

Beeton, A. M. 1960. The vertical migration of Mysis relicta in Lakes Huron and Michigan. J. Fish. Res. Bd. Canada, 17(4): 517-539.

Berrill, Michael. 1969. The embryonic behavior of the mysid shrimp, Mysis relicta. Can. J. Zool., 47: 1217-1221.

*Ekman, Sven. 1920. Studien über die marinen Relikte der nordeuropäishen Binnengewässer. Internat. Rev. ges. Hydrobiol. und Hydrog., 8: 543-589.

Juday, Chancy, and Birge, Edward A. 1927. Pontoporeia and Mysis in Wisconsin lakes. Ecology, 3(4): 445-452.

Larkin, P. A. 1948. Pontoporeia and Mysis in Athabaska, Great Bear and Great Slave Lakes. Bull. Fish. Res. Bd. Canada, 88: 1-33.

Reynolds, J. B., Robinson, A. H., and Heberger, R. F. 1969. Trawling in northern Lake Huron. Bureau of Commercial Fisheries Great Lakes Fishery Laboratory (Limnology Program) report, 17 pp.

*Samter, M. 1905. Die geographishe Verbreitung von Mysis relicta, Pallasiella quadrispinosa und Pontoporeia affinis in Deutschland als Erklärungsversuch ihrer Herkunft. Abh. preuss. Akad. Wiss., p. 549.

*Samter, M., and Weltner, W. 1904. Biologishe Eigentümlichkeiten der Mysis relicta, Pallasiella quadrispinosa und Pontoporeia affinis erklärt aus irher eiszeitlichen Entstehung. Zool. Anz. 27: 676-694.

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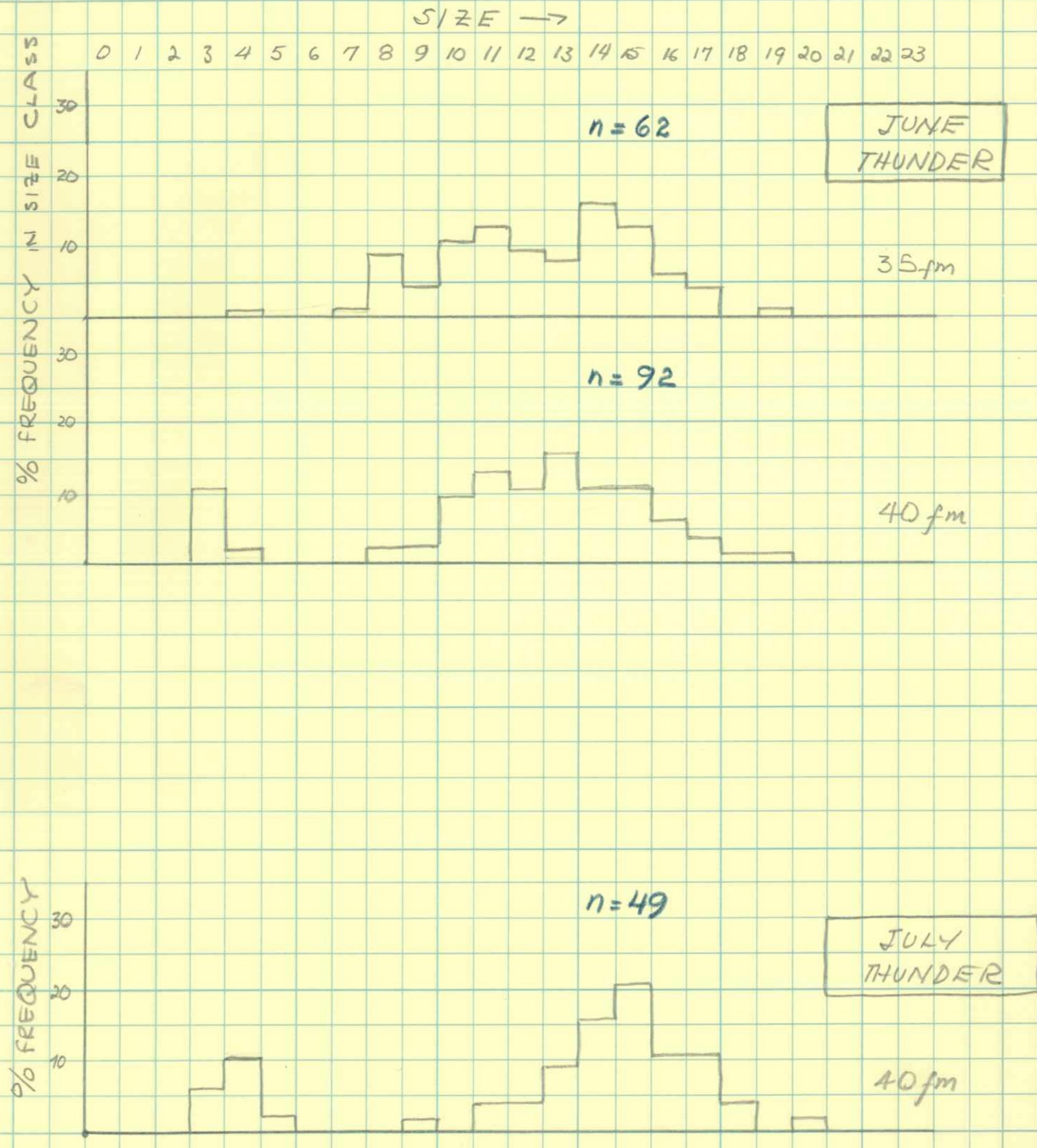
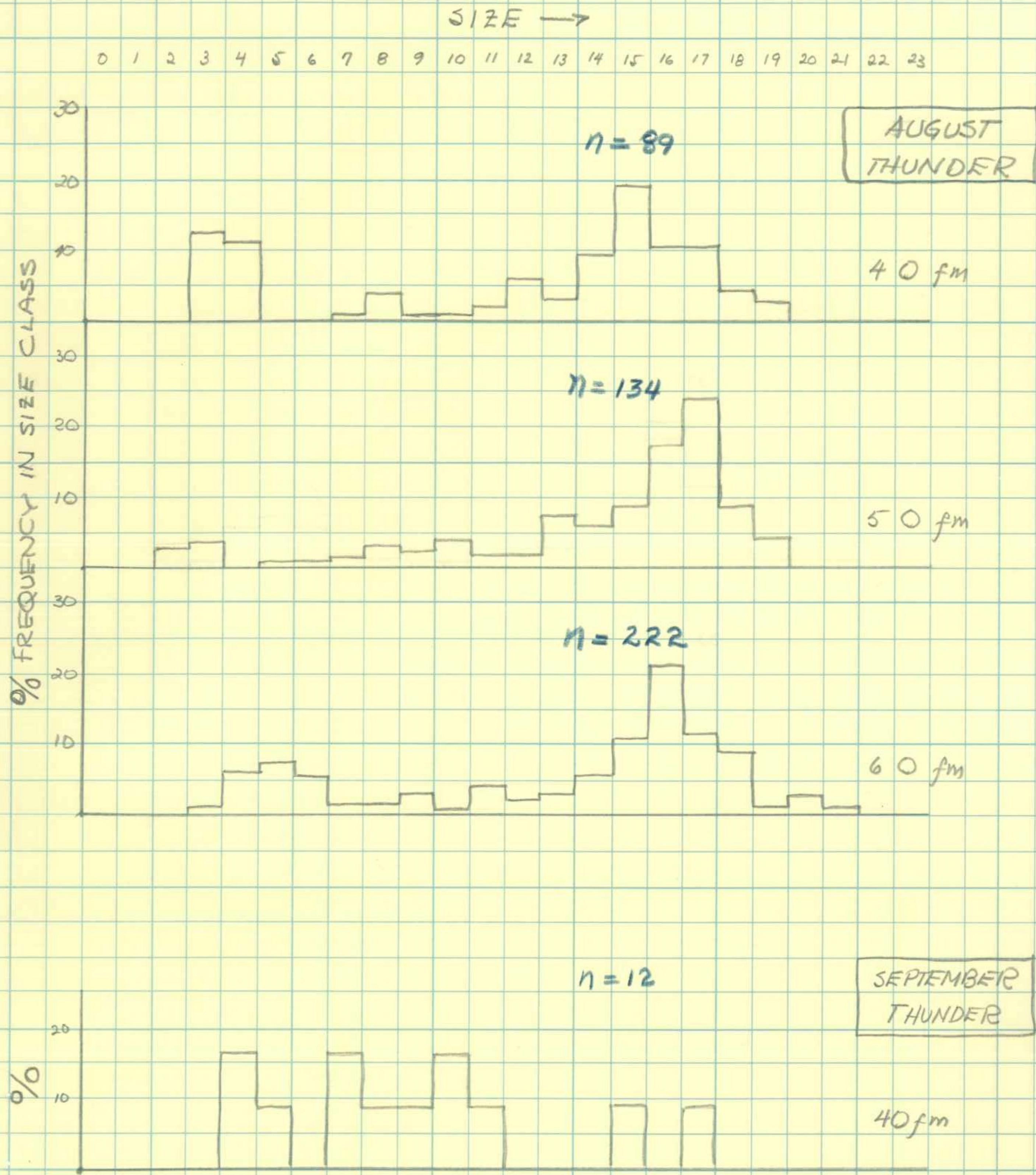
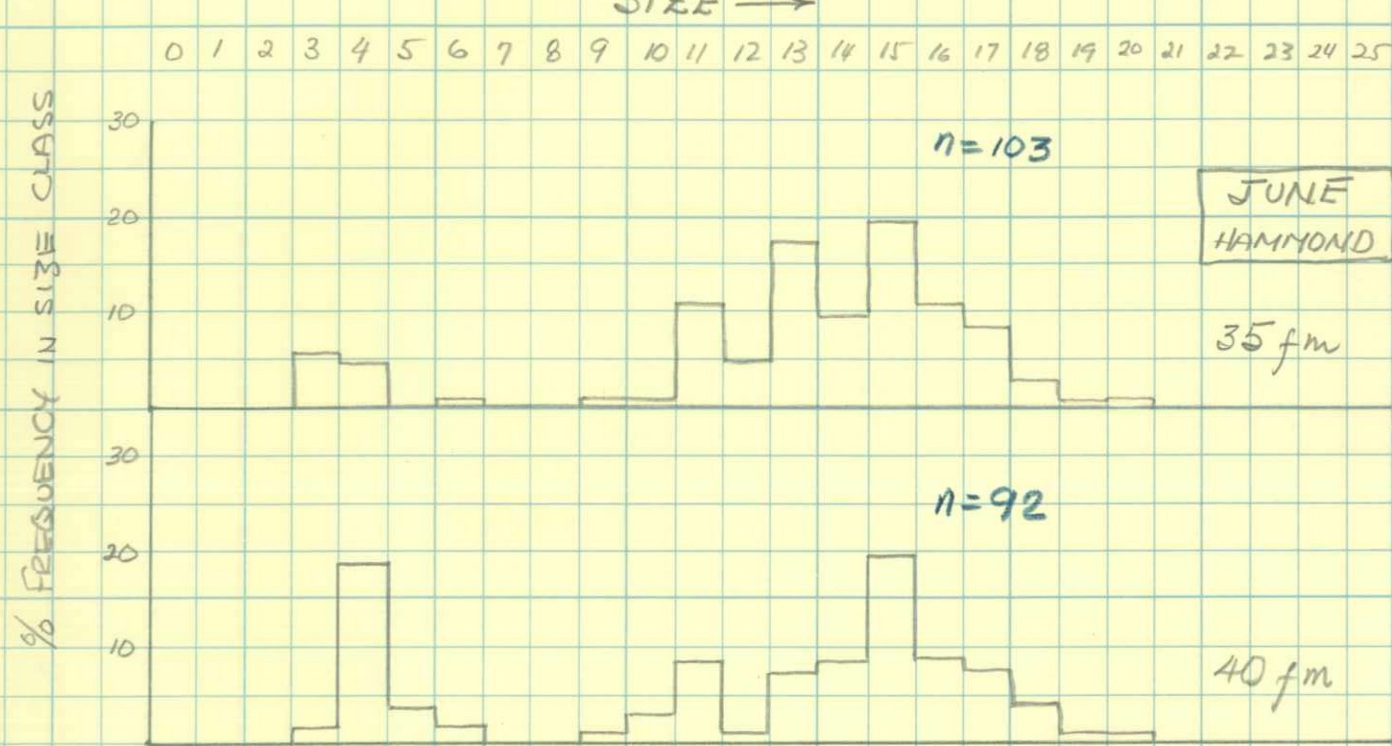
* Not personally consulted; quoted in Juday and Birge (1927).



Appendix figure 1. Length frequency distribution of *Mysis* at Thunder Bay



Appendix figure 2. Length frequency at Thunder Bay continued



no data for 50 & 60 fm

Appendix figure 3: Length frequency distribution of *Mysis* at Hammond Bay

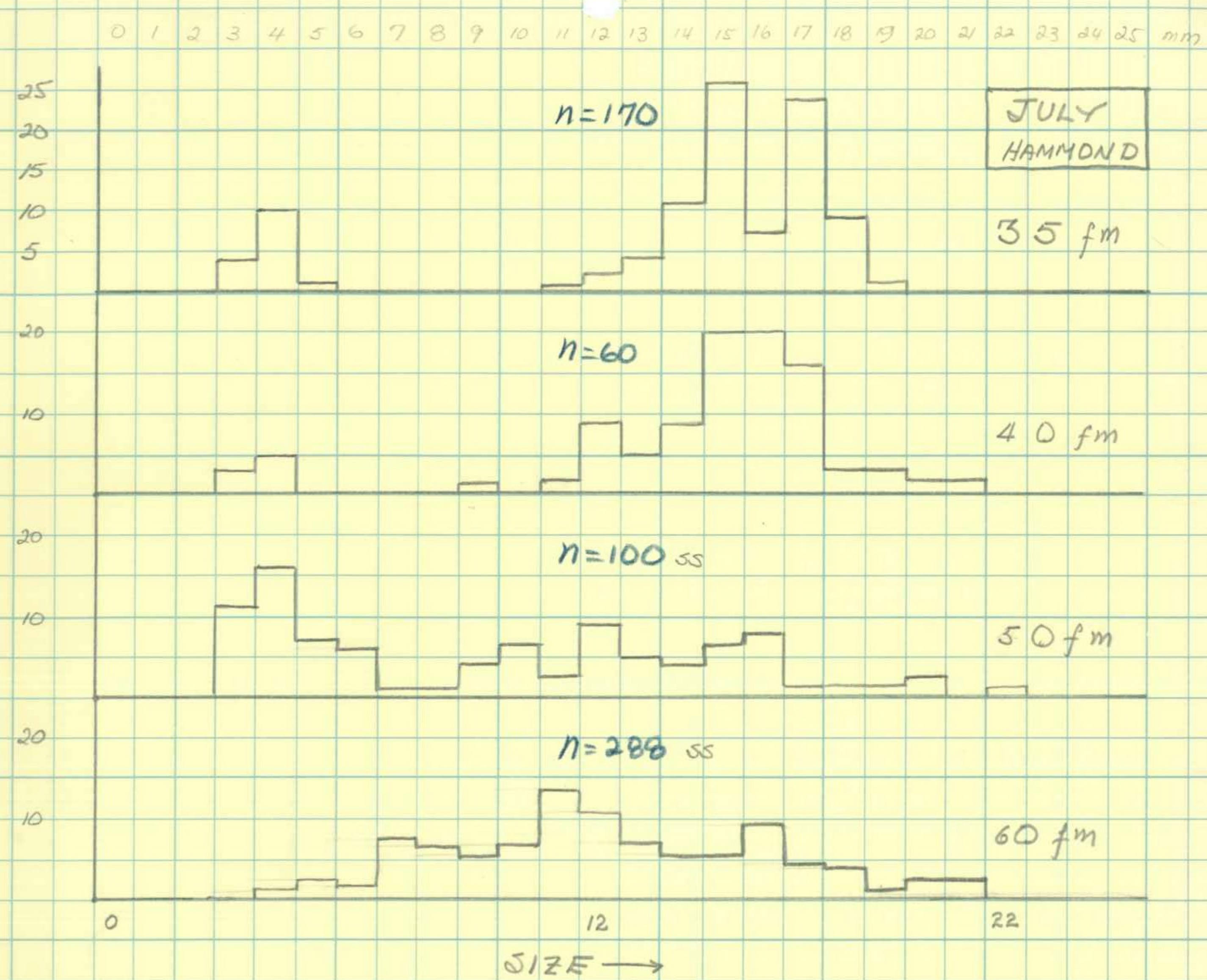


fig. 4. Length frequency at Hammond Bay cont.

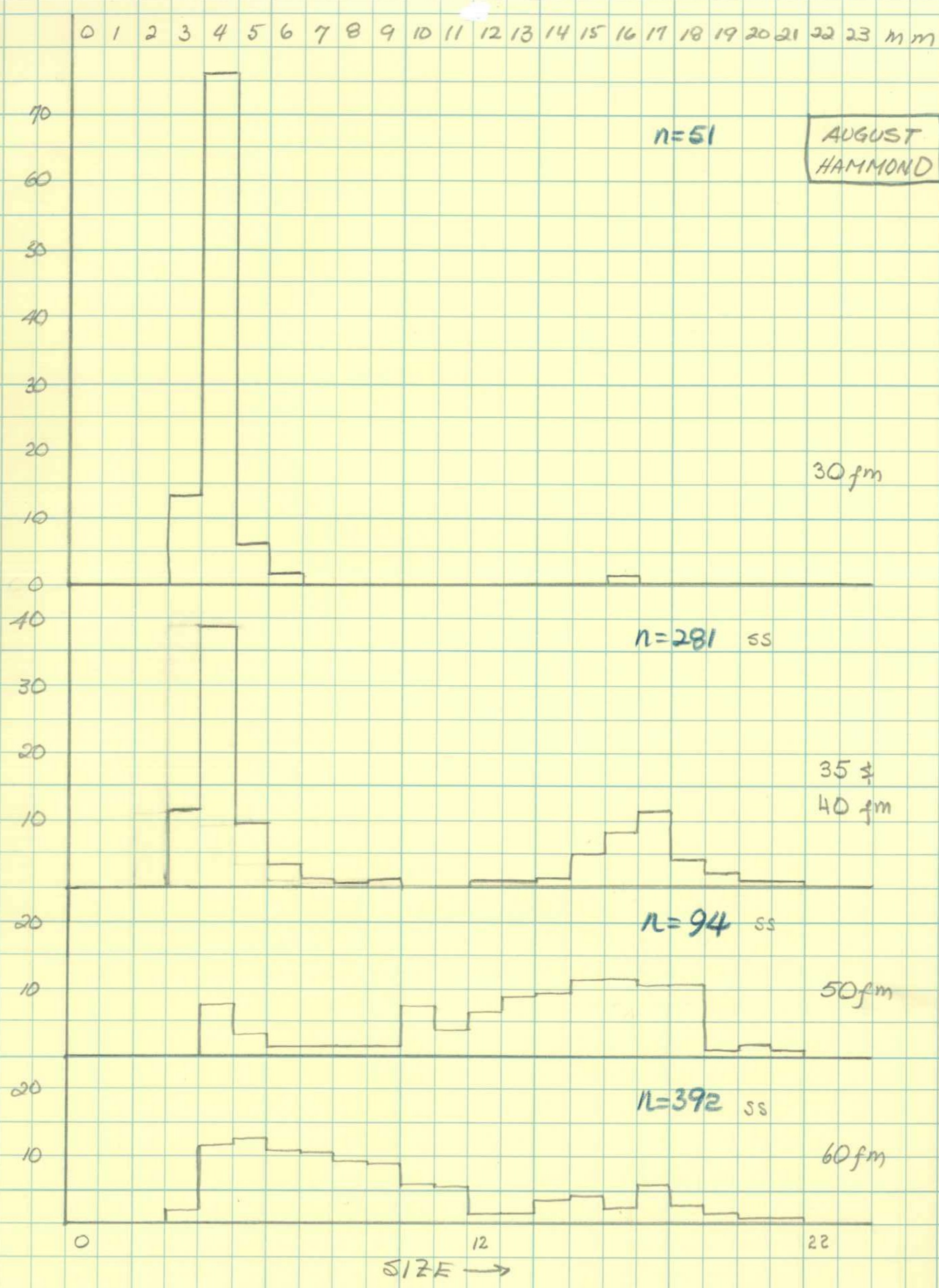


fig. 5. Length frequency of Mysis at Hammond Bay cont.