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RESULTS OBTAINED FROM THE MINNOW PROPAGATION EXPERIMENTS AT SCHUIL ACRES DURING THE SUMMER OF 1934, SUPPLEMENTED BY OBSERVATIONS MADE AT OTHER LOCALITIES

For the past several years, experimental rearing of forage fishes was the chief interest of the late Henry A. Schuil of the State Department of Conservation, and a resident of Grand Rapids. The station, Schuil Acres, at which he conducted many enlightening and valuable minnow propagation experiments, lies on the east edge of the city of Grand Rapids. Mr. Schuil corresponded at length with several of the leading fish culturists of the country, obtaining advice from them and relating to them his experiences in fish culture. Consequently the methods which he used were in step with the current fish-cultural practices and much of his work was of a pioneer nature. His very successful propagation of the Golden Shiner and other forage minnows has attracted the attention of conservation leaders for several years.

The Institute for Fisheries Research has followed Mr. Schuil's experiments with keen interest and has cooperated in obtaining breeding stocks for the experiments and in offering suggestions. Considerable aid was obtained from Mr. Claude Lydell and his men at the State Hatchery, Comstock Park. In the fall of 1933, Dr. Hubbs and the writer were present with Mr. Schuil to observe the draining of one of the ponds which gave a phenomenal production of Golden Shiners. At this time Mr. Schuil suggested that during the summer of 1934, the Institute work in closer cooperation with him. His suggestion was heartily received. Due to present pressing needs for information on our various forage fishes, it was decided that several promising species should be used instead of concentrating our efforts on one or two species. Seven of our common Michigan minnows seemed to offer the best possibilities under the then existing cir-

cumstances. During Mr. Schuil's stay in Florida the following winter, the station was under the care of Mr. Fred Kunnen, engaged permanently as an assistant on the grounds. Much repair and preparatory work was done by Mr. Lydell during the winter. Ponds 5, 6, and 7 were left dry during most of the winter in order to freeze out the abundant plant and animal life. Ponds 3 and 4 were drained in the early spring and all of the ponds were then fertilized with cow manure before they were allowed to fill with water. The breeding stocks of minnows were introduced into the ponds in the spring. Ponds 3, 5, 6 and 7, being most suitable for minnow propagation, were used for the most promising species. Observations were made by the writer during the early part of the summer, after which he was engaged by the New York Conservation Department, being financially unable to remain on the grounds during the summer. Mr. Schuil made continuous observations on the experiments during the early part of the summer, but was hindered considerably by prolonged illness. His observations have been presented to the Department in his brief resume, and will be referred to later in this report. Due to his illness and unfortunate death, much information which we expected to havewas not obtained.

Daily air and water temperatures were obtained during the period from May 23 to October 13. These data, somewhat condensed, are presented in Table I and Fig. 1. There is a distinct correlation between the temperatures of air and pond waters. The significance of the modes in these temperature curves will be mentioned later.

Data on the amounts and costs of fertilizer and feed used for all the ponds at Schuil Acres during the summer was furnished by Mr. Lydell as follows:

	Amount used	Cost
Fertilizer:		
Cow manure	7200 lbs.	$21.00
Sheep manure	300 lbs.	5.70
Feeds:		
Bone meal	200 lbs.	4.00
Clam meal	400 lbs.	24.00
Oatmeal and cornmeal	275 lbs.	6.75
Total		$61.45

Table I. Summer temperatures taken at Schuil Acres in 1934. Each entry is a 4-day average, figured to the nearest degree. All water temperatures were taken at 2 P.M.

Date:		Air temperatures			Water temperatures				
		7 A.M.	12 noon	6 P.M.	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7
	23-26	52	62	63	64	58	67	68	70
May	27-30	68	77	79	64	58	71	74	75
	31-3	75	87	93	64	59	77	81	81
	4-7	66	79	77	68	59	76	79	80
	8-11	65	76	78	67	60	73	77	78
	12-15	60	75	73	67	59	69	74	75
June	16-19	65	76	79	65	58	72	77	76
	20-23	62	75	78	66	58	71	74	74
	24-27	67	80	81	68	59	76	80	79
	28-1	76	86	84	69	60	79	84	85
	2-5	71	80	82	64	58	74	79	78
	6-9	66	76	76	67	59	76	80	80
	10-13	68	78	82	64	57	70	72	72
	14-17	65	81	81	67	60	71	75	77
	18-21	75	88	87	72	62	79	84	83
	22-25	78	92	95	75	63	83	88	86
	26-29	70	75	75	69	59	74	76	77
	30-2	62	76	73	69	59	73	76	75
	3-6	63	72	75	71	60	74	79	79
	7-10	73	85	84	70	60	76	77	79
	11-14	63	78	77	68	60	74	75	79
Aug.	15-18	65	79	79	66	59	72	73	75
	19-22	61	72	73	67	59	71	72	72
	23-26	54	71	70	66	61	68	70	72
	27-30	55	66	65	64	58	65	66	69
	31-3	66	72	74	63	56	67	69	69
	4-7	58	65	67	62	57	65	65	67
	8-11	59	70	66	64	58	69	69	71
Sept.	12-15	66	75	71	64	57	70	71	73
	16-19	50	68	59	60	55	64	64	67
	20-23	57	64	65	62	55	65	66	67
	24-27	60	69	67	66	56	69	69	72
	28-1	48	58	61	59	57	61	62	63
	2-5	47	67	62	63	65	66	65	66
	6-9	41	65	62	64	64	66	64	64
Oct.	10-13	39	62	62	65	64	66	64	64

In area, ponds 3 to 7 are about equal and the combined area of ponds 1 and 2 is much less than that of each of the other ponds. Thus the cost of fertilizer and feed was about $10.00 per pond. Each pond was fed daily throughout the summer. During the month of June, 5 1/2 lbs. of Daphnia were placed in pond 7 and 2 1/2 lbs. in pond 6.

Ponds 3 and 4 were not allowed to dry and freeze during the winter, thus the Chara growth in these two ponds was very heavy throughout the summer. Ponds 5, 6 and 7, having been drained and allowed to freeze during the winter, were slow in obtaining the plant growth; however, the growth was dense by the middle of summer. Estimates on the abundance of food organisms in ponds 5, 6 and 7 were obtained by: (1) taking bottom samples of a typical area after the pond was drained, and (2) estimating the abundance of the types of organisms which flowed from the pond during draining. The results of these food counts and estimates are given later.

Mr. Lydell and the writer drained ponds 5 and 7 on October 19, pond 6 on October 20, and ponds 3 and 4 on November 5. An effort was made to obtain, as completely as possible, the entire fish population of each pond. Random samples of the fish populations were preserved for further study. The remaining fish were taken to the Comstock Park hatchery where weights and counts were made.

Great Lakes Shiner - Notropis atherinoides

A stock of adult minnows of this species was placed in pond 1 early in June and held there during most of the summer, with no signs of reproduction. Failure of this fish to reproduce in hatchery ponds has been noticed at the Lydell Hatchery for several years and there is redent evidence that this species will not reproduce in our inland lakes. The failure of this species to reproduce in waters of limited area may be due to the nature of its spawning. Professor T. L. Hankinson of the Michigan State Normal College has offered the following information on the life history of this species. In the summer of 1930 he found ripe females, with eggs running, several miles from shore in eastern Lake Erie, and observed activities which he believes could only be interpreted as spawning. In the same locality he found eggs, probably of this minnow,

at various depths down to the bottom, a depth of 30 feet. Spawning occurred in the later part of June, and young (1" to 3" long) were found in this general region, several miles from shore, from the water surface to a depth of 12 feet. Ripe adults were found from May to August, the bulk of the spawning however occuring during June and July and always far out in the lake.

At present this species is not considered suitable for pond propagation.

Common shiner (Notropis cornutus chrysocephalus) and Hornyhead Chub (Nocomis biguttatus).

These two species, typically are stream-spawners. The Hornyhead Chub is a nest builder, constructing a pile of cleaned gravel. The Common Shiner does not build its own nest, but either deposits it's eggs on current-washed gravel or, perhaps normally, uses the nests of other species (Hankinson, 1932). These two species were used together to take advantage of this natural, symbiotic, spawning relationship. On May 5, 85 specimens of the Chub (4 to 7 inches in length) and 145 Common Shiners (3 1/2 to 7 inches in length) were placed in pond 4. Examination of females of both species indicated that they had not spawned prior to this introduction. A large percent of each species were adults. Throughout the summer they were watched closely by Mr. Schuil who states in his report that there were no signs of spawning or of young in this pond throughout the summer. No young were found when the pond was drained on November 5. The Common Shiner spawns in streams during May and early June at water temperatures near 20°C. (68°F.) (Hankinson, 1932). Pond 4 was spring fed and its water temperature seldom went above 60°F. during the season. Temperature may have been the factor inhibiting reproduction. However it appears probable that this species will not reproduce in small ponds. The general evidence is that the species, probably on account of its spawning habits, does not reproduce in ponds.

On May 11, 250 common shiners and a few chubs were put in pond 2. This pond was long and narrow, had a good supply of running water and somewhat approximated stream conditions. Mr. Schuil records observing apparent spawning on June 4 and appearance of

young on July 2. However, since his identifications were made on the fish in the pond, he may have mistaken the young of another species for the shiners. No young shiners were found in this pond when examined in October.

As far as the writer could determine, there was no successful production of either the Hornyhead Chub or the Common Shiner in either of the two ponds.

Western Golden Shiner (Notemigonus chrysoleucas auratus)

A breeding stock of 84 specimens, 4 1/2 to 7 inches long, were obtained from the Lydell Hatchery and put in pond 3 on May 5. Due to the continuous seepage of a large amount of spring water into this pond, the water temperature was low throughout the summer (see Table I and Figure 1). Although Chara flourished, the invertebrate fauna was not abundant: the pond was distinctly less productive than ponds 5, 6 and 7. Mr. Schuil first noted spawning activities on June 6, when the water temperature was 69°F. The first progeny were noted on June 16, 19 and 21, indicating an incubation period of about ten days.

The pond produced 6500 shiners weighing 9.2 pounds. They attained an average size of 46.4 millimeters in standard length (range 24 to 62 mm.) or 2 3/8 inches total length. Size frequencies of the young are indicated by the random sample represented by Table II and figure 2. Both sexes grew at the same rate. The young apparently did not spawn during their first summer. However the larger fish, at least half of the total number, would have spawned in their second summer. In the light of growth rate studies made by the writer on the Golden Shiner in natural waters in Michigan, the growth attained in pond 3 was poor, and, as mentioned later, the production was also poor. Both of these conditions are attributable to the low water temperature. Several of the Hornyhead Chubs, used in pond 4, found their way into pond 3. What effect the possibly carnivorous habits of these chubs had upon the production of shiners is not known.

Menona Killifish (Fundulus diaphanus menona)

The breeding stock of this species was obtained from Crooked Lake, 4 miles north of Grand Rapids. Of the 346 specimens liberated in pond 5 on June 11, 29% were

Table II. Size frequency distribution of young Golden Shiners Produced in pond 3, Schuil Acres, during 1934.

Standard length in mm.	Sex not determined	Males	Females	All young
24	1	...	...	1
25	1	...	...	1
26	1	...	...	1
27	2	...	...	2
28	3	...	...	3
29	2	...	...	2
30	...	...	...	...
31	1	...	...	1
32	1	...	...	1
33	1	...	...	1
34	1	...	...	1
35	3	...	...	3
36	4	...	...	4
37	5	...	...	5
38	4	...	...	4
39	7	...	...	7
40	10	...	...	10
41	9	...	...	9
42	...	5	3	8
43	...	3	2	5
44	...	1	6	7
45	...	2	3	5
46	...	4	4	8
47	...	8	6	14
48	...	6	5	11
49	...	4	5	9
50	...	5	4	9
51	...	4	3	7
52	...	4	4	8
53	...	2	5	7
54	...	3	5	8
55	...	5	5	10
56	...	4	5	9
57	...	3	2	5
58	...	2	1	3
59	...	3	1	4
60	...	2	1	3
61	...	...	1	1
62	...	1	...	1
No. specimens	56	71	71	198
Av. size (mm.)	...	50.6	50.2	46.4

males and 71% were females. This aberrant sex ratio among these breeders, obtained from Crooked Lake, was probably due to an inshore schooling of the females at the time they were collected. The young reared in pond 5 during the summer revealed an equal proportion of the sexes. On June 11, pond 5 possessed a luxuriant Chara growth over the entire bottom, and about 1/20 of the surface area of the pond was covered by floating filamentous algae. Tadpoles were very abundant.

When drained in October, the pond yielded the following:

Fundulus breeders:	196 specimens	(wt. 2 lbs. 1 oz.)
" young:	13,348 "	(wt. 13 lbs. 1 oz.)
Estimated loss of young in draining pond:	1,000 "	(wt. est. 1 lb.)
Total production of young:	14,348 "	(wt. 14 lbs. 1 oz.)

630 sticklebacks were recovered when the pond was drained, and it was estimated, after an examination of the pond, that several thousand had been left stranded. About half (318) of the crayfish, which were drained from the pond, weighed 6 lbs. and 15 ozs. The total population of crayfish (Cambarus immunis and C. virilis) in the pond was estimated at 2500+ or about 50 lbs.

Observations by Mr. Schuil on the appearance of young indicate a spawning season from the middle of June to the middle of July. Growth rates of the young and breeders are indicated in Table III and Figure 3. The sexual dimorphism in growth rate (greater in the females) is not manifest in the first year of life; whether or not it appears in the second year cannot be determined from these data. The increased growth rate of the females is pronounced by the end of the third summer of life. During the seining of the breeders from Crooked Lake on June 11, no small killifish were obtained, although several hundred yards of the shallows were seined. Since all the specimens taken were adult fish, and all the females were gravid with large eggs, the shoals were apparently being occupied only by the spawning fish. That all of the breeders were two-year old fish (beginning their third summer of life), was determined by scale examinations. Further, the scales indicated that these breeders had made no growth in the summer of 1934 up to June 11; therefore the size frequencies of the breeders, when put in pond 5,

Table III. Data on the size and growth of the Menona Killifish (Fundulus diaphanus menona) in pond 5, Schuil Acres, during the summer of 1934.

Standard length in mm.	Young of year[1] Fish produced in pond (One summers growth) Males	Females	Standard length in mm.	II-year old fish Breeders when put in pond. (Two summers growth) Males	Females	Breeders when taken from pond.[2] (Three summers growth) Males	Females
13	1	...	41	...	1	...	...
14	...	...	42	...	...	...	...
15	2	...	43	...	1	...	...
16	2	3	44	...	1	...	...
17	3	3	45	...	1	...	...
18	4	4	46	...	1	...	...
19	8	8	47	...	...	...	...
20	9	9	48	...	1	...	...
21	9	16	49	...	...	...	...
22	19	17	50	2	1	...	...
23	22	26	51	1	1	...	...
24	25	24	52	...	2	...	...
25	20	20	53	1	1	...	...
26	23	15	54	...	...	1	...
27	22	13	55	...	5	...	1
28	15	18	56	...	...	3	...
29	18	23	57	...	2	6	...
30	21	20	58	...	...	4	...
31	22	18	59	...	...	3	1
32	20	12	60	...	...	5	1
33	13	13	61	...	...	3	3
34	9	14	62	...	...	2	6
35	9	13	63	...	1	1	4
36	6	8	64	...	...	2	7
37	5	6	65	...	....	...	12
38	3	5	66	...	...	...	13
39	4	2	67	...	...	...	9
40	...	1	68	...	...	...	5
41	...	2	69	...	...	...	3
42	...	1	70	...	...	...	2
43	1	...	71	...	...	...	1
44	1	...	..	...	...	...	...
Total	316	314		4	19	30	68
Average	27.3	27.5		51.0	51.4	59.0	65.1

[1] The 316 males weighed 131 grams, the 314 females 135 grams. Weights were taken 2 months after preservation, the specimens having been in alcohol.

[2] The sex ratio of this sample is not typical of the breeders reclaimed from the pond; the size range, however, is typical.

represent the size attained at the end of the second summer of life. From data thus far obtained, there are indications of several possibilities, relative to the life-history of this species. They require further verification but are nevertheless given here, as suggestions:

1. The fact that no one-year-old mature fish were taken at Crooked Lake suggests that the fish first matures in its third summer of life. This hypothesis, although strongly questioned by the writer, is strengthened by an examination of the young produced in pond 5. Among these fish ~~were~~ was no indication of egg development in preparation for spawning in their second summer.

2. As Table III indicates, few if any fish live longer than three summers, and the mortality does not necessarily come immediately after spawning.

3. In Fundulus as well as in Chrosomus and Hyborhynchus, there is a rather definite and uniform maximum size, attained within a comparatively short time (quite in contrast with the growth rate of most game species). Due to a long spawning season the size range of the young is great, but this size range decreases in subsequent year groups. Scale examinations indicate a growth compensation, that is, those fish having a small growth the first summer usually grow more in the second summer than do those fish whose first year's growth is large. The factor limiting growth seems to be the onset of maturity.

Bluntnosed Minnow (Hyborhynchus notatus)

A stock of 750 breeders was obtained from the Lydell Hatchery and put in pond 6 on May 5. Approximately 20% of this stock were 2 to 2 1/2 inches in total length and 80% were 2 1/2 to 3 1/2 inches in total length. The production obtained in this experiment is given in Tables IV and V.

Table IV. Total fish population taken from pond 6 on October 20.

	Specimens taken in draining pond[2]			Specimens lost in draining (estimate)[3]		Total pond production	
	Number	Weight	Weight by percent	Number	Weight	Number	Weight
Bluntnose Minnow	19,494	49 lbs. 14 oz.	87.4	1000	2 lbs. 9 oz.	20,494	52 lbs. 7 oz.
Brook Stickleback	3,420	3 " 9 "	6.3	3000	3 lbs. 2 oz.	6,420	6 lbs. 11 oz.
Other fish[1]	?	3 " 9 "	6.3	?	?	?	3 lbs. 9 oz.
Total	22,914	57 lbs.		4000	5 lbs. 11 oz.	26,914	62 lbs. 11 oz.

Table V. Analysis of the Bluntnosed Minnow population taken from pond 6.

	Specimens taken from pond		Total pond population, including estimated loss			
	Number	Weight	Number	Number by percent	Weight	Weight by percent
Young females	9,747	15.1 lbs.	10,247	50.0	15.9 lbs.	30.3
" males	9,475	30.8 "	9,960	48.6	32.4 "	61.8
Adult females	114	.75 "	121	.6	.8 "	1.5
" males	158	3.2 "	166	.8	3.3 "	6.4
All young	19,222	45.9 "	20,207	98.6	48.3 "	92.1
" breeders	272	3.95 "	287	1.4	4.1 "	7.9
Total	19,494	49.85 "	20,494	100.0	52.4 "	100.0

[1] "Other fish" include a few each of Mud Minnows, Golden Shiners, Killifish, and the Hornyhead Chub.

[2] The entire lot of specimens was weighed; the number of specimens was calculated from an actual count of a 2 lb. random sample.

[3] The pond was poorly constructed for complete draining, hence seining was finally resorted to in obtaining these fish which did not drain from the pond. Sticklebacks were found to be very retreating in habit, burrowing into the bottom vegetation as the pond was drained.

The data obtained on growth rate are summarized on Table VI and Figures 4 and 5. The growth rate curve of each sex is distinctly bimodal, a condition which will be discussed later. A distinct sexual dimorphism in growth rate is manifest in the first year of life. Figure 5 is a graphical representation of accumulative percentages showing, in each sex, the percent of the total population that lies below (less in length) each size frequency and including that size frequency to which it corresponds. The amount of sexual dimorphism in growth rate is represented by the degree of divergence of the curves; the size at which the dimorphism becomes prominent is from 30 to 40 millimeters. This increased growth rate was so pronounced that all of the young above 45 millimeters (about2 inches) were males. Among the total pond population of Bluntnose there were produced, in the one summer, over 5000 males 2 inches or more in length. The difference in growth rate of the sexes increases greatly with life. My interpretation of the scales indicates that some specimens of each sex live through four summers of life, despite the claim by Van Cleave and Markus (1929) that the maximum age is three summers of life for the females and four for the males. The maximum size of 7~~1~~9 mm. given for this species by Van Cleave and Markus is exceeded by the size of some specimens from pond 6, which were 80 to 84 mm. in standard length or 3 1/2 to 4 inches in total length. There are no specimens in the large collections of this species in Museum of Zoology, University of Michigan, larger than those obtained in pond 6. The maximum sizes of 79 to 84 mm. refer to males entirely. The largest female indicated in Table VI represents about the maximum size (60-65 mm.) for that sex.

The spawning season extends throughout most of the summer. Mr. Schuil observed that spawning occurred during the latter part of May and extended to the middle of August. Young, 10 to 13 mm. long, were taken from pond 6 on June 10. In 1934 the earliest date of appearance of Bluntnosed Minnow eggs at the Northville Hatchery was May 17. Carmen, in 1932, ~~from~~ at the Northville Hatchery found the spawning period to extend from the end of May into August. Hankinson (1920) gives May 1 to August 26 as the period during which he found eggs of this species in Illinois.

Due to the protracted spawning season there is a wide dispersion in size of the young at the end of the first growing season. Fry 13 millimeters, and young males 64

Table VI. Data on size and growth of Bluntnosed Minnows (Hyborhynchus notatus) in pond 6, Schuil Acres, during the summer of 1934. A random sample of the young and breeders taken from the pond on October 20.

Standard length in mm.	Young		Standard length in mm.	Breeders					
	Males	Females		Males Summers of life			Females Summers of life		
				2nd	3rd	4th	2nd	3rd	4th
21	2	5	52	...	...	...	1	...	...
22	6	12	53	...	...	...	1	1	...
23	16	14	54	...	...	...	1	...	...
24	22	24	55	...	...	...	1	...	...
25	30	37	56	...	...	...	1	1	...
26	39	42	57	...	...	...	...	...	...
27	43	41	58	...	...	...	...	...	...
28	41	38	59	...	...	...	...	1	...
29	35	51	60	...	...	...	...	1	...
30	35	46	61	...	...	...	...	...	...
31	36	45	62	...	...	...	...	...	1
32	35	35	63	...	...	...	...	...	...
33	31	34	64	...	...	...	...	...	...
34	26	48	65	...	...	...	...	...	...
35	28	56	66	...	...	...	...	...	...
36	27	52	67	...	...	...	...	...	...
37	26	66	68	...	...	...	...	...	...
38	23	60	69	...	...	...	...	...	...
39	20	53	70	...	...	...	...	...	...
40	19	40	71	...	...	...	...	...	...
41	17	26	72	...	1	...	...	...	...
42	13	20	73	...	...	...	...	...	...
43	14	12	74	...	1	...	...	...	...
44	12	3	75	...	...	...	...	...	...
45	8	2	76	2	...	1	...	...	...
46	10	...	77	...	1	...	...	...	...
47	9	...	78	1	...	...	...	...	...
48	11	...	79	1	1	...	...	...	...
49	10	...	80	...	...	...	...	...	...
50	10	...	81	3	2	...	...	...	...
51	13	...							
52	14	...							
53	13	...							
54	16	...							
55	21	...							
56	26	...							
57	22	...							
58	13	...							
59	14	...							
60	15	...							
61	7	...							
62	5	...							
63	4	...							
64	1	...							
No. of specimens	838	862		7	6	1	5	4	1
Mean length	38.4	33.0		78.9	77.3	76.0	54.0	57.0	62.0

millimeters in standard length were taken from the pond on October 20. The larger ones young of both sexes showed a sexual development sufficient to indicate that they would spawn early in their second summer (the females contained large eggs, and the nuptial tubercles of the males were developing). It is doubtful if the smaller young of either sex would have attained sufficient growth to reach maturity in their second summer. Growth is slow among the spawning fish as indicated by a narrow spacing of the circuli on the scale. On this basis it appears that some of each sex of the breeders did not spawn until their third summer, as their scales indicated two years of rapid growth, the first being small, and some had spawned in their second and third summers. Size, rather than age, appears to be the factor determining maturity (in total length, approximately 2 to 2 1/2 inches for females and 3 to 3 1/2 inches for males).

The number of eggs in one nest and guarded by one male varies considerably. Hubbs (1933) records a nest of approximately 20,000 eggs at the Northville ponds. The writer has actual counts on nests containing as few as 1375 eggs, these eggs being in two or more distinct stages of development indicating that the number of eggs laid at one time may be considerably less than 1000. Nests having 20,000 eggs are unusual. Counts were made of the eggs in nests at the Northville ponds during the summer of 1934. Eggs deposited on a smooth surface could be removed, with practically no loss, with a dull-bladed scalpel. Only the advanced eyed eggs were readily broken by the instrument, and the fry could be obtained easily. Results of these counts are given in Table VII. The relative crowding of the eggs in the first three nests listedwas due to the small amount of available space, as compared with the other five nests. The first three nests were located in hollow tile bricks, each with an available spawning surface of 3 3/4 × 5 inches, while the remaining nests were on pieces of sewer crock with an excess spawning area. In all of these nests the eggs were sufficiently compact to indicate that few, if any, of the original eggs had hatched or been removed. On the basis of 164 eggs to the square inch, calculations were made on the number of eggs in nests for which dimensions of the egg cluster were taken, see Table VIII. Some of these nests contained only a few scattered eyed eggs (in the process of hatching) but the

outline of all the egg clusters could be determined, and the calculated number of eggs for these nests represents the number which the cluster contained before hatching. Newly laid eggs have always been found in a compact layer. The calculated number of eggs per nest is somewhat greater than indicated by actual counts, because somewhat smaller nests were chosen for counts. The average nest contains 3 to 4 thousand eggs, and represents contributions of at least two, and probably more, females.

Table VII. Counts of eggs in nests of the Bluntnosed Minnow at the Northville Hatchery during the summer of 1934.

Pond	Date	Dimensions of egg mass	Number of eggs	Number of developmental stages	Number of sq. in. in nest	Eggs per sq. inch
A	6/7	3 1/2" × 4 1/2"	4079	At least 2	15.75	259
A	"	3 3/4" × 5"	4330	" " 3	18.75	231
A	"	2 " × 3 1/2"	2028	" " 2	7.0	290
N	6/8	5" × 7"	4818	" " 2	35.0	138
N	"	3" × 3 1/2"	1408	" " 2	10.5	134
N	"	6" × 7"	3326	" " 3	42.0	79
K	"	3 1/2" × 4"	1375	" " 2	14.0	98
K	"	5" × 9 1/2"	3789	" " 3	47.5	80
Average ...	....		3144	....	23.8	164

Table VIII. Number of eggs in Bluntnosed Minnow nests, calculated from known nest dimensions, on the basis of 164 eggs per square inch

Locality	Date, 1934	No. nests	Area of egg clusters, sq. in. Min.	Max.	Av.	No. of eggs per nest Min.	Max.	Av.
Northville Hatchery Pond A[1]	June 7	11	6	22.5	12.6	984	3690	2066
Northville Hatchery Pond N	June 8	1	...	...	63.0	...	...	10,332
Schuil Acres Pond 6	June 10	14	6	70	35.0	984	11,480	5,740
All localities		26	6	70	26.0	984	11,480	4,362

[1] Most of the nests in pond A at Northville were on builders tile having a very limited area for egg deposition, while all of the nests at Schuil Acres were on boards with an excess spawning space. Thus the calculations on number of eggs at the first locality are probably too low, while those for the latter locality are too high. However the calculations for all localities are considered typical.

Counts of large eggs in two females, 55 and 57 mm. in standard length, obtained from the Northville ponds on May 30, gave the number of such eggs, apparently ready to be spawned, as 439 and 324. These counts, although decidedly insufficient for conclusions, indicate that probably several females contributed to each nest tabulated above. The great variation in size of the eggs in the ovary further suggests that one female spawns more than once during a summer.

During the examination of several hundred nests, the writer observed only one instance of egg predators. In this instance a large snail (Lymnaea) had apparently destroyed a few eggs although the male fish was guarding the nest. Mr. Carmen reported that, when nests were transported to a new pond without the guarding males, the eggs were apparently eaten by snails. An observation made by the writer at Cusic Lake, Macomb County, on June 3, 1934, makes the crayfish a suspected predator. A Bluntnosed Minnow nest was moved about 3 feet from its original position and was not taken up again by the guarding male. Four hours later a crayfish had moved in, directly under the nest, and most of the eggs were gone. No other predator was present, and the early-eyed eggs had not hatched.

The first eggs deposited on any area, lie in a compact, usually single, layer. Eggs added to the nest are deposited about the periphery of this original layer. As the eggs hatch the original compact group becomes more and more scattered. Occasionally new eggs are laid within this group of hatching eggs, usually when there is a limited space for egg deposition. Observations on several hundred nests indicated that one male guarded each egg cluster, regardless of the number of eggs present or their stage of development. The males are so intent in guarding their nest that they often maintain their position under the eggs and strike viciously at a hand inserted within a few inches of the nest. Observations made at the Northville Hatchery in 1934 indicate that, at a water temperature of 75°F., the incubation period is about 13 to 15 days, the eggs reaching an early-eyed stage in about 7 days. Mr. Carmen at Northville found a 15 days incubation period.

A variety of spawning devices was used at the Schuil and Northville ponds, including

several types of builders blocks, square builders tile, pieces of sewer crock, flat boards of various dimensions, elevated boards, large flat stones, and specially constructed "apartment houses". Each apartment house was made with four 9"x 1"x 3' boards, nailed together in tiers about 3" apart. Boards nailed upon the bottom of the structure supported it 3" above the bottom, and stones were used to weigh it down. The builders tile had from two to five available compartments for spawning. All the devices were installed in 5" to 18" of water (average about 12") and 2' to 5' from shore. The 73 devices used in pond 6 included: 10 pieces of sewer crock, 28 builders tile, 20 flat boards lying on the bottom, 12 apartment houses, 2 flat stones, 1 drain tile. An examination on June 10 of these 73 devices revealed a very decided preference for flat objects lying on the bottom of the pond. Five of the 20 boards had been used for 12 nests; each flat stone contained a nest and 1 of the pieces of sewer crock had a nest. None of the "apartment houses" or builders tile were used. All of the devices used lay flat on the bottom and a cavity had been hollowed out in the mud below the slab for each nest. The only available spawning space on the many builders tile and "apartment houses" was several inches above the bottom. This difference in elevation appears to be the factor accountable for the selection. No discrimination was made on the basis of water depth. Examinations made by Mr. Schuil on July 7 & 14 also revealed a very decided preference for the boards and stones lying on the bottom. In contrast to the Condition at Schuil Acres, all the nests at the Northville pond were on builder's tile, the nests being several inches above the bottom, but this was the only type of spawning device installed. No data are available as to which type of spawning device would give the best reproduction. However, it can be stated that the fish prefer objects lying very near to, or flat on, the bottom, but will use surfaces several inches above the bottom if these only are available. Males guarding nests live peacefully in close proximity to each other. The builder's tile, used as a spawning devices, contained from 3-5 compartments open on two sides and separated only by a one-inch partition. Commonly one tile contained three nests, each with a guarding male, and one five-compartment tile contained four such nests. Instances were observed of two nests, less than one foot apart on the under side of a board, where the two cavities below the nests were continuous.

Northern Red-bellied Dace (Chrosomus eos)

The breeders for this experiment, 1500 specimens collected on April 13 and 1200 specimens on May 4, were from Messmore's gravel-pit ponds at Utica, Macomb County, Michigan, and were put in pond 7 on the dates collected. These Utica ponds, on which the writer has made observations for the past eight years, are the result of a natural flooding of a gravel-pit which has been abandoned for many years, and they are made up of two series of shallow depressions which are broadly connected and which have numerous small marginal bays. The total ponded area is about 2 acres, the average depth 1 to 2 feet and the maximum depth 3 feet. Chara, the dominant aquatic plant, covers about 3/4 of the pond bottom. The ponds have a bottom deposit composed mostly of marl, and they are not rich in aquatic life. During the writer's observations on the Utica ponds, the Northern Red-bellied Dace has maintained a large population in competetion with the Pumpkinseeds and large numbers of several other minnows (Hyborhynchus, Pimephales, Notropis cornutus, etc.).

The scarcity of food and over-crowding induced a slow growth rate among all the fish in these ponds. The breeding stock of Chrosomus, obtained from these ponds, was notably stunted, and represented two year-classes (determined by examinations of scales of breeders taken from pond 7 on June 10 and October 19; see Table IX). Since originally in obtaining these breeders the larger specimens were selected, the numerical ratio between the two year-groups of breeders is not typical of the natural population.

On May 4 the Chara growth in pond 7 was slight but by June 10 there was a general growth of small plants throughout the pond. During the entire summer there was an abundant growth of filamentous algae, and frog tadpoles and aquatic invertebrates were abundant.

The production obtained from this pond is given in Table X.

Table IX. Growth rate of the red-bellied dace (Chrosomus eos) in Pond 7, Schuil Acres, during the summer of 1934, given as size frequency distributions.

Standard Length mm.	Young produced in pond							Breeders used									
	June			October 19				As put in pond May 4		Taken from pond on June 10				Taken from pond on October 19			
										I-year		II-year		I-year		II-year	
	10	12	28[1]	♂	♀	♂+♀[2]	Run. Ave. of 5	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
6	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
7	..	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8	..	..	11	..	..	..	..	..	..	..	..	..	..	..	..	..	..
9	2	..	2	..	..	...	..	..	..	..	..	..	..	..	..	..	..
10	19	1	1	..	..	1	..	..	..	..	..	..	..	..	..	..	..
11	18	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
12	10	1	..	..	..	3	2.6	..	..	..	..	..	..	..	..	..	..
13	2	..	..	..	..	5	4.8	..	..	..	..	..	..	..	..	..	..
14	2	..	1	..	..	3	6.6	..	..	..	..	..	..	..	..	..	..
15	..	2	..	..	..	12	8.2	..	..	..	..	..	..	..	..	..	..
16	2	1	..	..	..	10	10.0	..	..	..	..	..	..	..	..	..	..
17	4	1	..	..	..	11	13.0	..	..	..	..	..	..	..	..	..	..
18	3	1	..	..	..	14	11.8	..	..	..	..	..	..	..	..	..	..
19	1	..	..	..	..	18	12.2	..	..	..	..	..	..	..	..	..	..
20	..	..	..	..	..	6	11.0	..	..	..	..	..	..	..	..	..	..
21	..	..	..	..	..	12	10.2	..	..	..	..	..	..	..	..	..	..
22	..	..	1	..	..	5	8.0	..	..	..	..	..	..	..	..	..	..
23	..	..	..	..	..	10	8.6	..	1	..	..	..	..	..	..	..	..
24	..	..	..	..	..	7	7.8	..	..	..	..	..	..	..	..	..	..
25	..	..	1	..	..	9	7.0	2	1	..	..	..	..	..	..	..	..
26	..	..	3	..	..	8	5.2	2	2	..	..	..	..	..	..	..	..
27	..	..	2	..	..	1	4.8	6	3	..	..	..	..	..	..	..	..
28	..	..	2	..	..	1	5.0	7	2	..	..	..	..	..	..	..	..
29	..	..	1	..	..	5	5.6	2	5	..	..	..	..	..	..	..	..
30	..	..	2	..	..	10	8.0	4	5	..	..	..	..	..	..	..	..
31	..	..	..	..	..	11	10.0	2	2	..	..	..	..	..	..	..	..
32	..	..	..	..	..	13	10.8	11	4	..	..	..	..	..	..	..	..
33	..	..	..	..	..	11	12.6	14	10	..	..	..	..	..	..	..	..
34	..	..	..	..	..	9	15.0	7	13	..	..	..	..	..	..	..	..
35	..	..	..	7	12	19	15.6	9	9	..	..	..	..	..	..	..	..
36	..	..	..	7	16	23	19.4	9	6	..	..	..	..	..	..	..	..
37	..	..	..	6	10	16	23.4	8	5	1	..	1	1	..	..	..	..
38	..	..	..	18	12	30	26.4	3	7	..	..	1	..	..	..	..	..
39	..	..	..	19	10	29	28.4	3	3	2	2	1	1	..	..	..	..
40	..	..	..	16	18	34	29.2	1	2	7	1	2	1	..	..	..	..
41	..	..	..	10	23	33	27.8	..	1	..	..	2	1	..	..	..	..
42	..	..	..	6	14	20	25.6	..	1	..	..	..	3	1	..	..	..
43	..	..	..	14	9	23	22.2	1	1	1	1	..	1	1	..	..	..
44	..	..	..	11	7	18	18.4	1	1	..	1	..	2	1	..	1	..
45	..	..	..	12	5	17	15.4	..	..	..	..	..	2	2	1	..	..
46	..	..	..	8	6	14	11.6	..	..	..	..	..	..	4	1	2	1
47	..	..	..	3	2	5	8.8	..	..	..	..	..	..	1	1	2	2
48	..	..	..	..	4	4	..	..	..	..	..	..	..	1	3	4	2
49	..	..	..	..	4	4	..	..	..	..	..	..	..	..	2	1	4
50	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	3
51	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	1
52	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1
53	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2
No.	63	8	31	137	152	485	..	92	84	11	5	7	12	11	10	11	16
Mean	12.0	14.3	15.5	40.7	40.4	33.5	..	33.1	33.8	39.8	41.0	39.4	42.0	45.3	48.2	47.5	49.4

[1] The reproductive organs of the larger young (22-30 mm.) of this group showed no signs of development or approaching maturity.

[2]. Sex determinations were made only on the young above 34 millimeters in length.

[3] Two age groups, here included, are not distinguished.

Table X. Production of Northern Red-bellied Dace obtained from pond 7, Schuil Acres, during the summer of 1934[1].

	No. of specimens	Weight
Dace (drained from pond)	19,850	42 lbs.
Bluntnosed Minnows	320	11 oz.
Dace (estimated loss)	2000	2 lbs.
Dace (total pond population)	21,850	44 lbs.
Dace (breeders)	750	6 lbs.
Dace (total production of young)	20,100	38 lbs.

The spawning season of the Red-bellied Dace extended throughout most of the summer. The first young were seen on May 24, and young taken on October 19 were only 9 millimeters in standard length. The spawning season thus extended approximately from the middle of May to the middle of September. A sample of the breeders, taken from the pond on June 10, indicated: that about 85% of the males were in brilliant breeding colors; that 70% of the females were greatly distended with large eggs about ready to be spawned; that about 10% of the females (the largest) had already spawned; and that about 20% of the females were maturing and would not have spawned for a considerable length of time. During the summer there were two definite spawning peaks, as indicated by the size frequency distribution of the young (see Table IX and Figure 6). This bimodal distribution was not due to a sexual dimorphism in the growth rate of the young. Sex determination, made on all of the young above 34 millimeters in length, covered nearly all of the specimens in the second peak of the frequency distribution. This peak, including 64% of all the young, contained a slight preponderance of females, but the mean length of the two sexes within the peak was almost identical (see Table IX). There are several possible explanations for these two

[1] Estimates of the total population were based on an actual count of a 2-pound random sample.

spawning peaks: (1) the entire breeding population may have spawned twice during the summer; (2) the early hatched young may have reached maturity and spawned during their first summer; or (3) the breeders may have become divided into an early and late spawning group, on account of some ecological factor. None of the breeders were examined during the period from June 10 to October 19. Thus the first possibility will be dismissed until further information is obtained. Young of the first spawning peak were, when taken from the pond on October 19, of practically the same size range as were the breeders on June 10, when they were reaching maturity. Considering size alone it appears improbable that this group could have reached maturity by the time the second spawning peak appeared. As further negative evidence against the possibility of these young spawning in their first summer, examination of the reproductive organs of the females of this first spawning peak, taken from the pond on October 19, revealed that the ovaries were well developed and the eggs were about half the spawning size, but, more significant in this respect, the entire group was markedly uniform in the stage of maturity and in the condition of the sex organs, indicating a similar developmental history for the group as a whole. Had the second spawning peak been produced by this group of larger young, which numbered well over 10,000 individuals, this peak would have been far greater than the first. The main body of evidence indicates a relation between this bimodal frequency of the young and the summer water temperatures, as will be discussed more fully later.

On June 11, the writer observed what may have been the spawning activities of the adults. Clusters of 4 to 10 fish were "milling" in and over masses of filamentous algae near the bottom. A few fish eggs were found entangled but not adhering to several such algae masses. Mr. Schuil's report describes similar "milling" activities, which he also interpreted as spawning. Each spawning activity that he mentioned was associated with masses of algae or with shore-line vegetation. This data on spawning activities will at least give a lead for further observation.

Although the samples of the young obtained during the early part of the summer were not large, it is believed that they were representative of the size range of the

young in the pond at that time. The growth rates of the young and the breeders used in the experiment are indicated in Table IX and figure 6. The growth rate of this species varies considerably in different ponds. It was much greater in the rich pond at Schuil Acres than in the more barren Utica ponds. The average size attained by the young in pond 7 was 33.5 millimeters, approximately the same size as were the breeders at the time they were put into the pond. At this time the breeders averaged only 33.4 mm., despite the fact that the larger specimens were selected. These breeders represented, in approximately equal numbers two year classes (one and two year-old fish). The growth of the breeders before spawning was much more rapid in pond 7 than had been their growth in the Utica ponds, (indicated by their rapid increase in size in pond 7 during early spring, and by the much greater distance between the circuli on scale areas representing growth in pond 7 than between circuli on scale areas representing growth in the Utica ponds). Since the average temperatures in the two ponds in question were approximately the same, the better growth in the Schuil pond may be attributed to fertilizer and feed. There is a sexual dimorphism in growth rate: the females grow somewhat faster than the males, after the first year of life.

The complete data fails to confirm the possibility, expressed in the preliminary report (No. 257) of October 1, that this species spawns during its first summer of life. A large majority of this species spawns in its second summer, and some also spawn in their third summer. Few, if any, live longer than three years. The size at maturity is approximately 40 mm.

The maximum size of this species in the collection of the Museum of Zoology, University of Michigan, is 62 mm. or 2 1/2 inches. It is improbable that this species can ever be raised to a satisfactory pike-bait size. It is, however, large enough to warrant its consideration as bait for Perch, Crappie, Rock Bass, and other small game fish. The species is perhaps of greater promise as a forage fish to be reared in or for trout ponds.

The Northern Red-bellied Dace is one of the common minnow species in the waters of the northern part of Michigan. It especially prefers ponds and streams of the bog type, and is to be found commonly in beaver dams. It is a sufficiently important member

of our fish fauna to be worthy of further study, and it may prove to be a good species for introduction in certain new bodies of water. A portion of the stock taken from pond 7, was introduced into one of the ponds on John Ball Park, Grand Rapids, in an attempt to establish a supply for experimental plantings.

General

The productionsobtained with the four species which were successfully propagated are summarized in Table XI. For the comparison of these productions, various ecological data have been tabulated in Tables I and XII and Figure 1. The abundance of food organisms, predators, etc., at the time the ponds were drained, is given in Table XIII. The entire bottom of pond 7 was covered by a layer of black organic material, designated in Table XII as mud. This type of bottom was far more productive in invertebrate life than were the bottom types of the other ponds, in which a layer of marl, about 1 to 2 inches thick, lay over the black material. Although bottom samples, taken in October do not necessarily show the picture for the entire summer, the assumption is here made that such samples are of some value as indices of pond fertility. The difference in production among the four species was apparently due more to differences in ecological conditions than to differences in potentialities of the various species. The production per acre, both in number of individuals and in weight, is distinctly correlated with the water temperatures and with the pond fertility, indicated by the food counts (Figure 7). The production of 42,904 Golden Shiners per acre, in 1934 in the cold, rather barren pond 3, was poor compared to that of 42,252 Golden Shiners (235,000 per acre) produced by Mr. Schuil in pond 5 in 1933. The writer has no ecological data available on pond 5 for 1933, however, the pond was constructed and operated essentially the same in 1933 and 1934 and undoubtedly had somewhat similar conditions. The poor 1934 production of the Golden Shiner, essentially a warm water fish, was apparently due to the water temperature which would even be considered low for productive trout water. The phenomenal production of Golden Shiners by Mr. Schuil in pond 5 in 1933 was due, in a large part, to the fact that this pond was warm and fertile.

Crowding of the fish in these ponds, probably because it was accompanied by

Table XI. The production obtained with the four species successfully propagated at Schuil Acres, summer of 1934.

Pond	Area: in percent of an acre	Actual production		Calculated production per acre	
		Number	Pounds	Number	Pounds
1	5.17	...	...	...	...
2	1.24	...	...	...	...
3	15.15	6,500	9.2	42,904	60.8
4	15.15	...	...	...	...
5	17.96	14,348	14.1	79,888	78.3
6	19.28	20,207	48.3	104,808	250.5
7	15.70	20,100	38.0	128,025	242.0

Table XII. Physical data on the Schuil ponds, for the summer of 1934.

Pond	Estimated average depth ft.	Surface bottom composition	Dimensions	Water volume in cu. ft.	Av. daily (2 P.M.) water temp. in degrees F.					
					May (23-31)	June	July	Aug.	Sept. (1-23)	May 23-Sept. 23
1	2	marl	30' × 75'	4500	64	69	70	68	64	67
2	2	mud	9' × 60'	1080	67	72	74	72	65	70
3	4	marl	60' × 110'	26400	63	67	68	67	62	65
4	4	marl	60' × 110'	26400	58	59	59	59	56	58
5	3	marl	52' × 150'	23400	70	74	75	71	67	71
6	2	marl and mud	60' × 140'	16800	72	78	79	73	67	74
7	3	mud	57' × 120'	20520	73	78	79	75	69	75

fertilizing and feeding did not greatly effect their growth rate. Notably the Northern Red-bellied Dace and Bluntnosed Minnows grew very rapidly. Several of the breeders of the Bluntnosed Minnows attained a size greater than any specimens recorded by Van Cleave and Markus for Illinois, and are equalled by only one specimen in the extensive collection of this species in the Museum of Zoology, University of Michigan. The growth of the

~~of the~~ Golden Shiners was slow due to the low water temperature, not to overcrowding.

No comparative data are available on growth or production of the Menona Killifish.

Table XIII. Food organisms, predators, and fish species other than the one intended to be propagated, found in the Schuil ponds when drained.

	Number per square foot by bottom samples			Estimate of abundance or number obtained, specimens drained from pond[1]			
	Pond 5	Pond 6	Pond 7	Pond 3	Pond 5	Pond 6	Pond 7
Aquatic annelids	...	36	48	...	...	...	...
Mollusca:							
Helisoma antrosum	...	4	24	...	...	...	12
Helisoma trivolvis	...	...	...	...	...	...	3
Valvata tricarinata	6	...	48	...	...	...	10
Gyraulus parvus	22	128	560	...	...	...	10
Physa sp.	29	16	480	...	c.	c.	v. ab., 72
Arthropoda:							
Shrimp (H. knickerbockerii)	...	...	2064	...	...	...	v. ab.
Crayfish (C. immunis)	1	...	...	c.	1600	c.	c.
" (C. virilis)	...	...	...	...	700	...	...
Insects:							
Dragon fly nymphs	8	4	...	...	c.	ab.	v. ab.
Damsel fly "	3	...	8	r.	21	c.	ab.
May fly "	242	32	120	...	...	...	r.
Water-boatmen	...	...	...	c.	ab.	ab.	ab.
Back-swimmers	...	...	...	r.	ab.	ab.	ab.
Belostomatidae	...	...	...	...	4	c.	...
Naucoridae	...	...	...	...	1	...	...
Chironomidae	19	112	2912	...	...	...	...
Miscellaneous fly larvae	...	...	32	...	...	...	...
Haliplidae	...	...	...	...	...	...	ab.
Dytiscidae	...	...	...	...	3	c.	c.
Hydrophilidae	2	4	...	...	...	...	c.
Dyrinidae	...	...	...	...	...	...	c.
Amphibia:							
Rana clamitans (tadpoles)	...	...	...	r.	ab.	ab.	c.
Rana pipiens (adult)	...	...	...	...	...	...	1
Reptiles:							
Painted turtles	...	...	...	...	...	1	...
Foreign fish species:							
Golden Shiner	...	...	...	...	4	Few	...
Bluntnosed Minnow	...	...	...	...	...	...	320
Hornyhead Chub	...	...	...	Few	...	Few	...
Goldfish	...	...	...	...	3	...	...
Killifish	...	...	...	...	...	Few	...
Pumpkinseed	...	...	...	...	...	...	1
Walleye Pike	...	...	...	...	1	...	...
Stickleback	...	...	...	...	2630	6420	...
Mud Minnow	...	...	...	...	...	Few	...

[1] For the estimates of abundance of specimens which drained from the ponds, r. = rare, c. = common, ab. = abundant, and v.ab. = very abundant.

Several references have previously been made to the peculiar bimodal nature of the frequency distribution curves for the young of the preceeding species. The data available indicate, almost beyond a doubt, that these bimodal curves were the result of two spawning peaks during June and July. Figure 1 shows two peaks in the temperature curves for these two months for the four ponds under consideration, especially so for ponds 5, 6, and 7. While some spawning of Bluntnosed Minnows and Red-bellied Dace did occur during the temperature peak in May, the bulk of the spawning of these two minnows, and the entire spawning of Killifish and Golden Shiners occurred from about the middle of June through July. Since about 70% of the Red-bellied Dace were nearly ripe on June 10, most of the individuals of this species presumably spawned during the first temperature peak. This accounts for the unbalanced curve for the Chrosomus young (Figure 6). The extension of the spawning season of the Bluntnosed Minnows from about the first of June to the middle of August indicates that most of the spawning occurred during and after the second temperature peak (in late July). The differently unbalanced curve for the Hyborhynchus young (Figure 4) is thus explained. The spawning of the Killifish, from the middle of June through July, was about equally divided between the two temperature peaks (Figure 3); in agreement with this, the number of specimens in the two peaks in size distribution was about the same. The poorly defined temperature peaks for pond 3 probably explains why the young Golden Shiners reared in this pond do not clearly show a bimodal size distribution.

The close coincidence of the known spawning periods of the first three species mentioned with the two summer temperature peaks leaves little doubt as to the validity of the explanation for the bimodal size distribution of the young here presented.

Several facts which have come to the writer's attention illustrate the possibilities of minnow forage for game fish. Occasionally a game fish was found in the Schuil minnow-rearing ponds when they were drained in the fall. In 1933 a Walleyed Pike was taken from the Golden Shiner pond (No. 5). In 1934, a Pumpkinseed was taken from the Chrosomus pond (No. 7) and 3 Goldfish and one Walleyed Pike were taken from the Fundulus pond (No. 5). How these fish gained entrance to these ponds is a mystery. The two Walleyed Pike (each

exactly 10 inches in total length—much larger than any young obtained by H. J. Deason of the U. S. Bureau of Fisheries, from Lake Erie) were young of the year. They no doubt had entered the pond at a small size and, due to the excellent forage, had grown very rapidly and to a very large size in their first summer. The Pumpkinseed spent its first year of life in the quite barren gravel pit ponds at Utica during which according to scale studies, it attained a size of only 1 1/8 inches, but during its second summer (in pond 7) grew to a size of 4 1/2 inches (a remarkably greater growth). One of the 3 Goldfish obtained from pond 5 according to the scale examinations made on this one specimens was also a young-of-the-year, 7 1/8 inches long. There can be little doubt that wonders could be accomplished in fish propagation, if an unlimited supply of natural forage were available.

Summary

1. The Institute for Fisheries Research cooperated with the late Henry A. Schuil in conducting experiments in minnow propagation at Schuil Acres during the summer of 1934. These experiments were inaugurated during the spring and early summer, and were observed closely by Mr. Schuil during the early part of the summer. In October and November Mr. Claude Lydell and the writer drained the ponds and removed the fish, which were taken to the Lydell Hatchery where weights and counts were made. Random samples were preserved for laboratory study.

2. Seven species of our common Michigan minnows were used in these experiments, namely:

(1) Great Lake Shiner (Notropis atherinoides)

(2) Common Shiner (Notropis cornutus chrysocephalus)

(3) Hornyhead Chub (Nocomis biguttatus)

(4) Golden Shiner (Notemigonus chrysoleucas auratus)

(5) Menona Killifish (Fundulus diaphanus menona)

(6) Bluntnosed Minnow (Hyborhynchus notatus)

(7) Northern Red-bellied Dace (Chrosomus eos)

3. The first three species listed above gave no production. They are therefore

probably unsuited to pond propagation. The last four species gave the following production per acre:

Golden Shiner .....42,904 fish, weight 60.8 lbs.

Menona Killifish .....79,888 " " 78.3 "

Bluntnosed Minnow .....104,808 " " 250.5 "

Northern Red-bellied Dace...128,025 " " 242.0 "

4. The cost of fertilizer and feed was approximately $10 per pond.

5. The results obtained indicate that production is related to water temperatures, either directly or through pond fertility, and with bottom composition.

6. The approximate average and maximum total lengths in inches attained by these four species in their first summer of life are as follows:

	Average	Maximum
Golden Shiner	2 3/8	3
Killifish	1 1/2	2
Bluntnosed Minnow	1 3/4	3
Red-bellied Dace	1 3/4	2 3/8

The growth and production of Golden Shiners can be increased considerably above the 1934 growth and production obtained in pond 3 by rearing in more suitable ponds. While all four species would make good live bait for the smaller game fish, the Golden Shiner and Bluntnosed Minnow are the only two, of these four species, which can be expected to reach a size suitable for bass and pike bait, and relatively few attain that size in their first year.

7. The protracted spawning season of each of the four species produces a wide range in the size of the young of the year. Red-bellied Dace, Menona Killifish and Bluntnosed Minnows reach a rather definite maximum size in relatively few years. These three species show a growth compensation which causes the adults of either sex to be rather uniform in size.

8. A sexual dimorphism in growth rate manifests itself during the first year of life in the Bluntnosed Minnow, the males of which grow faster than the females. In the two

species of which the females grow faster than the males, namely the Red-bellied Dace and the Menona Killifish the difference in the growth rate of the sexes does not appear until after the first year of life.

9. Two mid-summer peaks in water temperatures resulted in two spawning peaks for Chrosomus, Fundulus, and Hyborhynchus. This fact illustrates that, in some instances, size frequency distributions cannot reliably be used as the sole method of age determination.

10. Crowding to the extent of 100,000 to 125,000 fish per acre did not inhibit the growth rate of the two species Hyborhynchus notatus and Chrosomus eos.

11. Phenomenal growths were attained by 2 Walleyed Pike, 1 Goldfish, and 1 Pumpkinseed. These fish had gained entrance into minnow ponds and had obtained ideal minnow forage. They are mentioned in this report as illustrating the possibilities in the use of forage fishes.

INSTITUTE FOR FISHERIES RESEARCH

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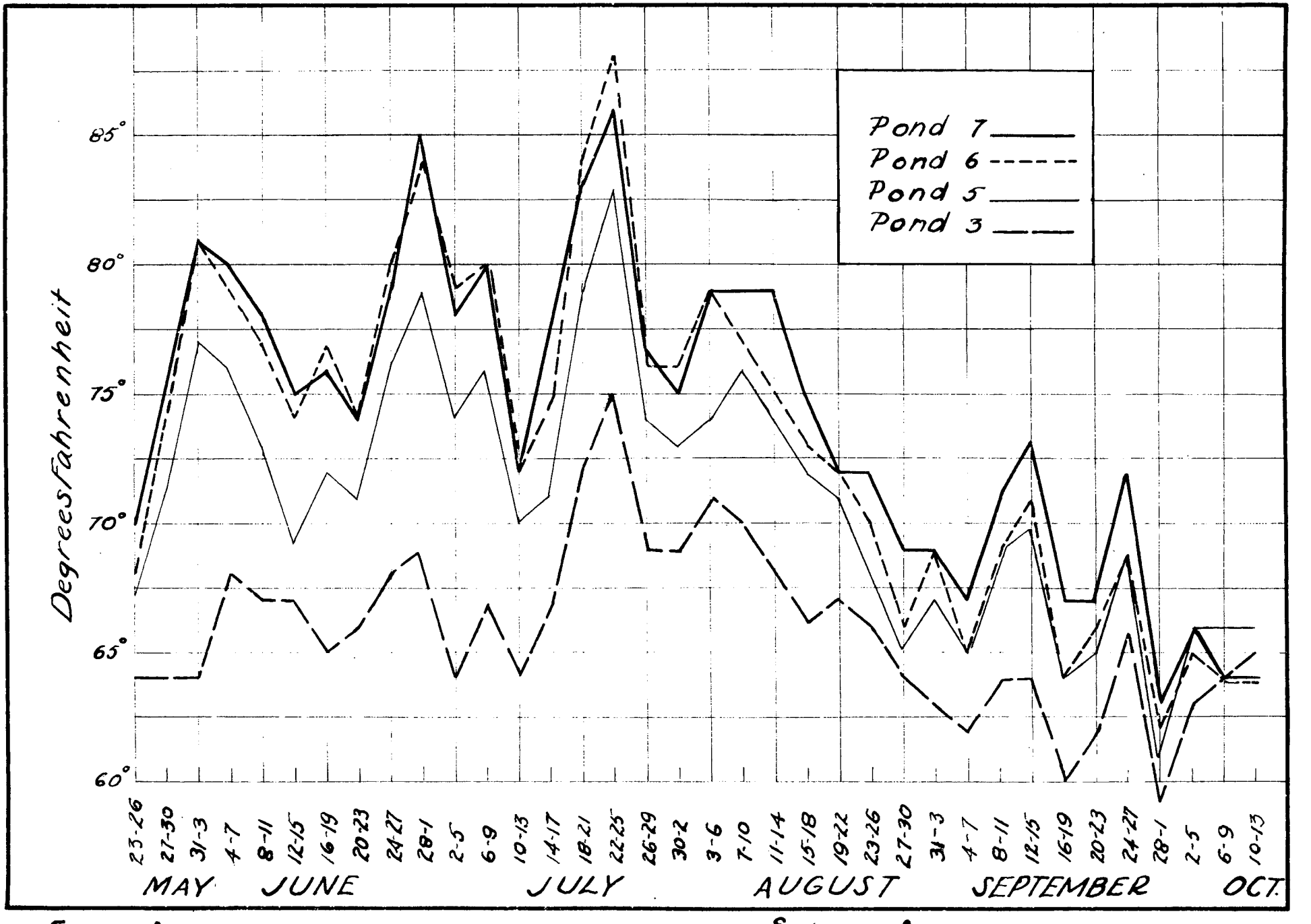
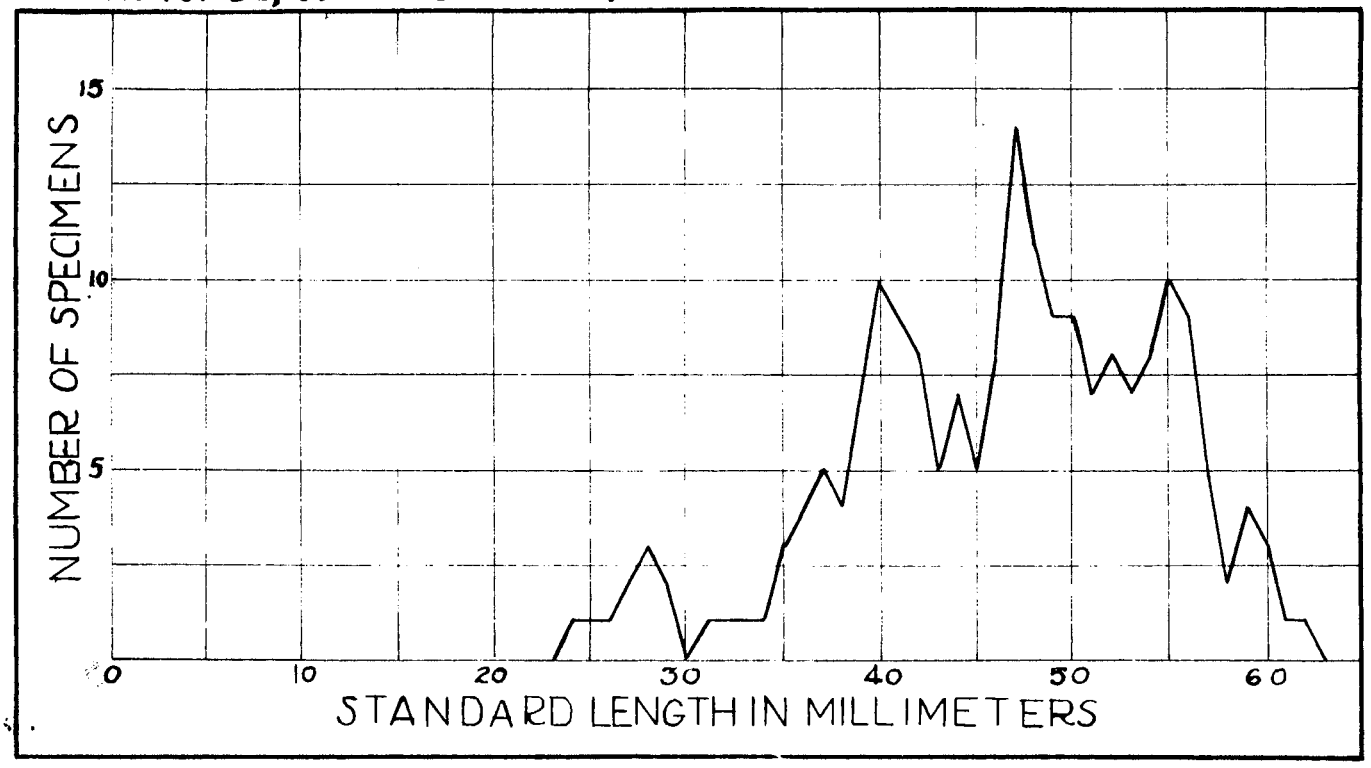


FIG. 1. AVERAGE WATER TEMPERATURE OF PONDS AT SCHUIL ACRES FOR SUMMER OF 1934. EACH TEMPERATURE PLOTTED ABOVE, REPRESENTS THE AVERAGE TEMPERATURE AT 2 P.M. FOR EACH FOUR DAY PERIOD.

FIG. 2. SIZE FREQUENCY GRAPH OF YOUNG GOLDEN SHINERS PRODUCED IN POND 3, SCHUIL ACRES DURING SUMMER OF 1934. DATA GIVEN IN TABLE I



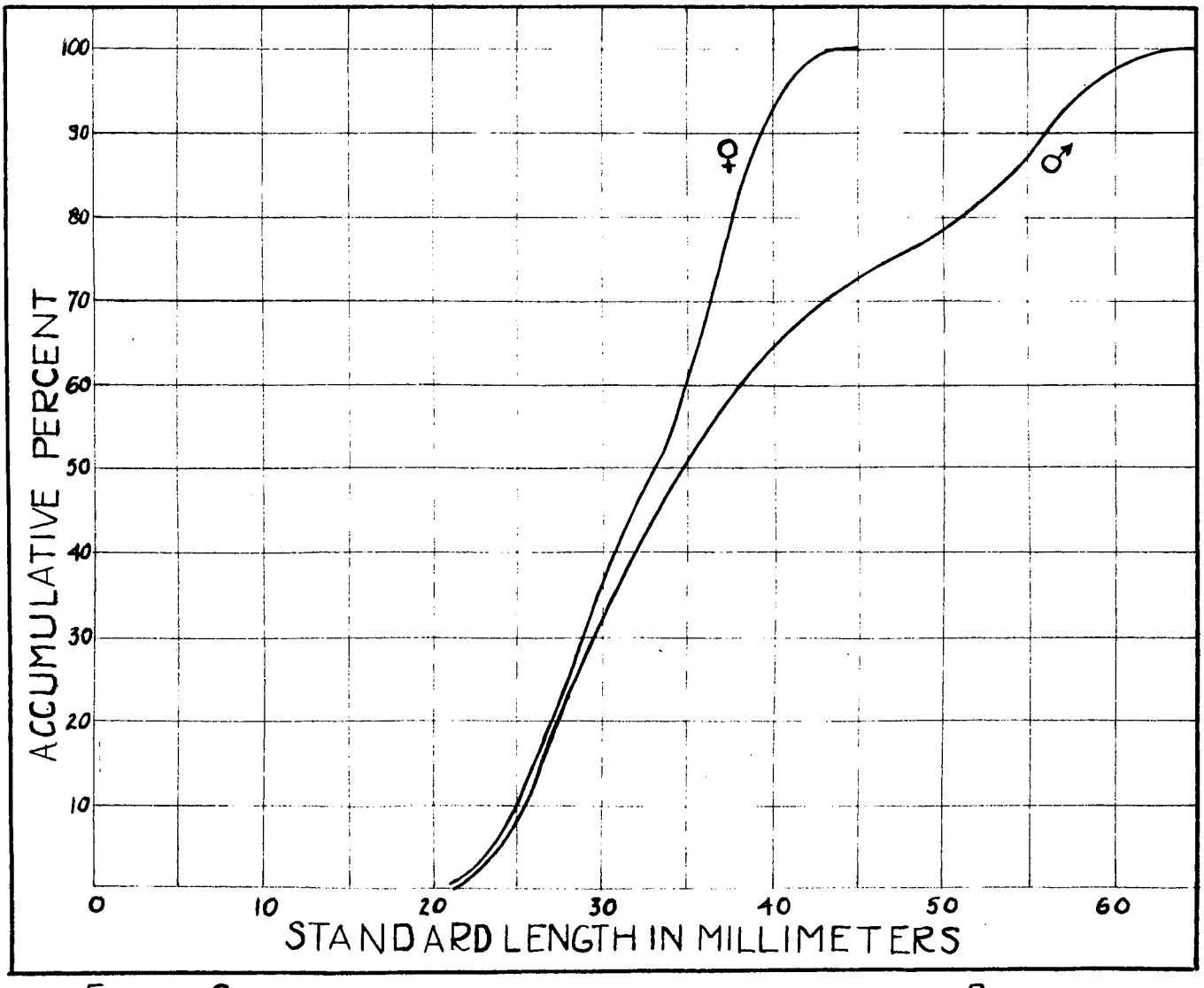


FIG. 5. SEXUAL DIMORPHISM IN GROWTH OF YOUNG BLUNTNOSE MINNOWS. SEE TEXT FOR EXPLANATION.

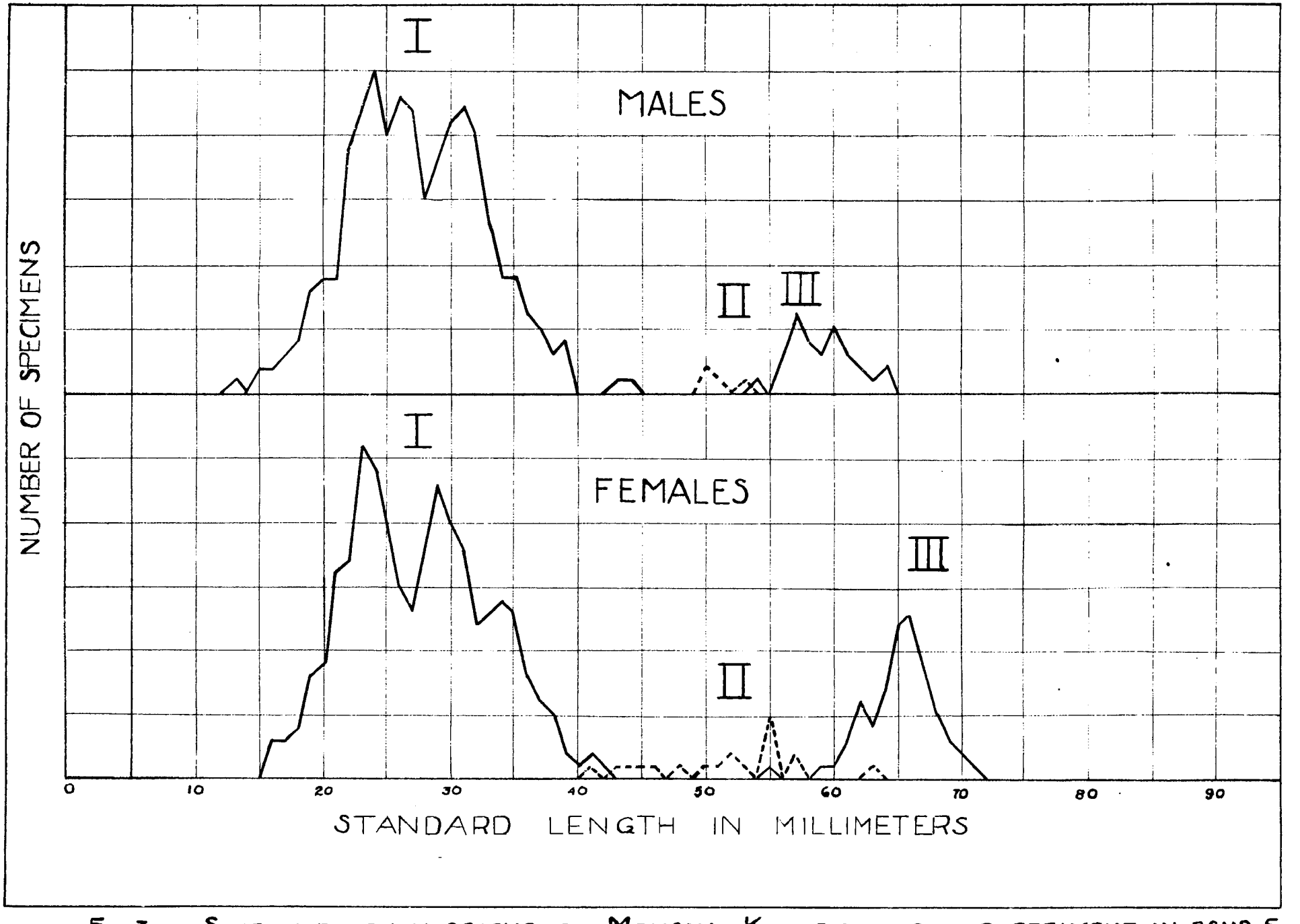


FIG. 3 SIZE FREQUENCY GRAPHS OF MENONA KILLIFISH FROM EXPERIMENT IN POND 5, SCHUIL ACRES, DURING THE SUMMER OF 1934. THE ROMAN NUMERALS INDICATE SUMMERS OF GROWTH COMPLETED. DATA GIVEN IN TABLE III.

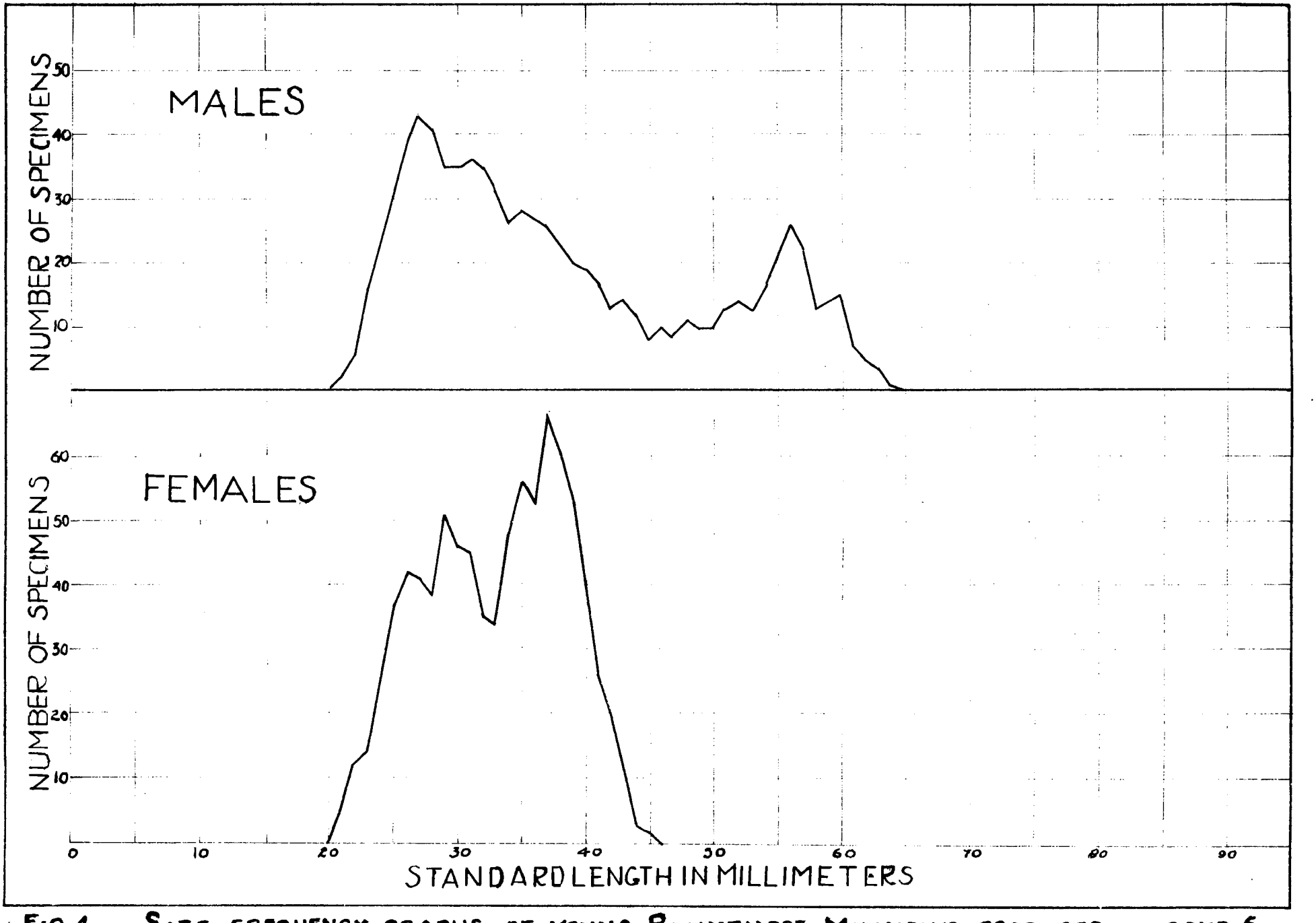


FIG. 4. SIZE FREQUENCY GRAPHS OF YOUNG BLUNTNOSE MINNOWS PRODUCED IN POND 6, SCHUIL ACRES DURING THE SUMMER OF 1934. DATA GIVEN IN TABLE VI.

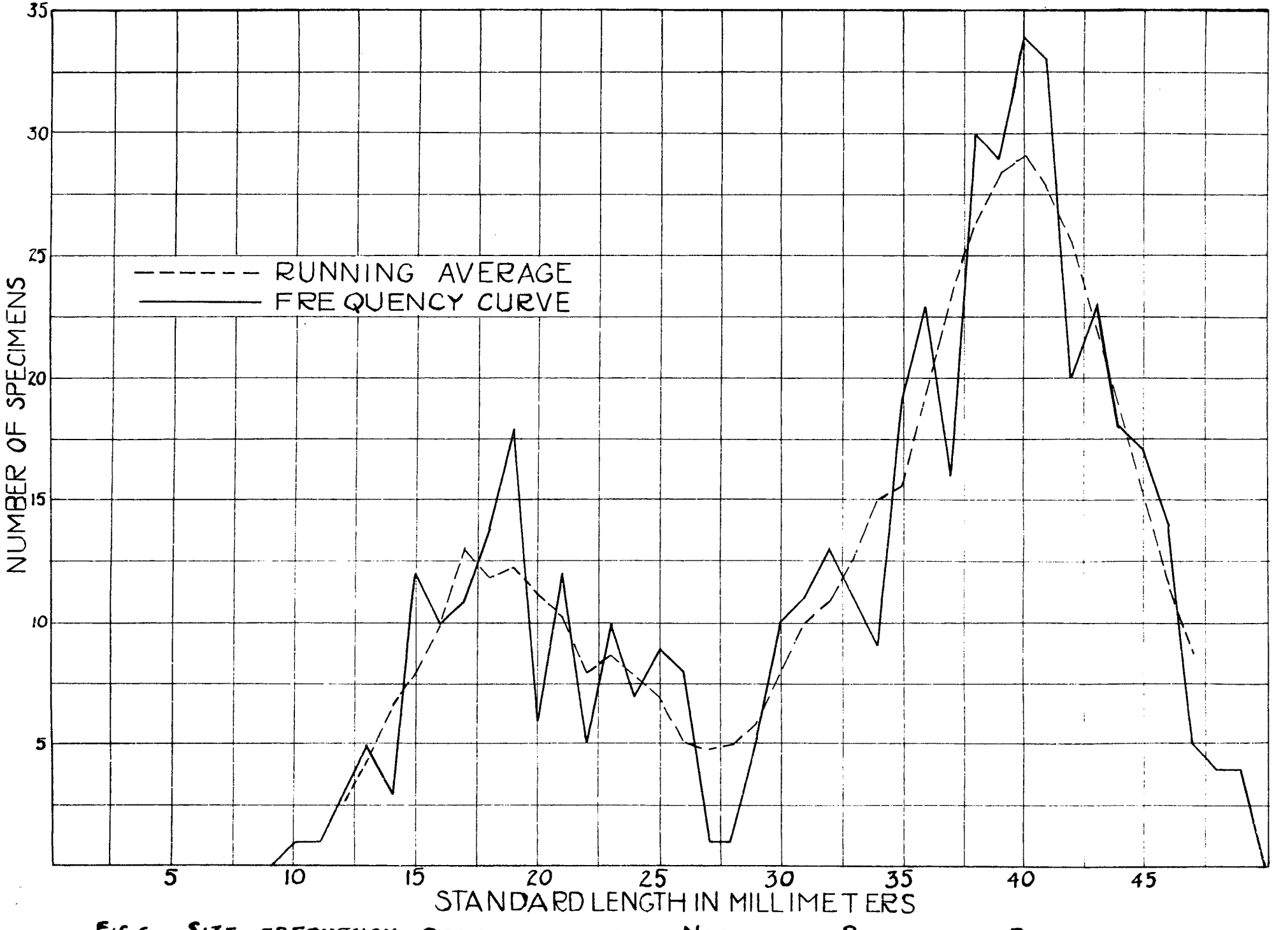


FIG. 6. SIZE FREQUENCY GRAPH OF YOUNG NORTHERN REDBELLIED DACE PRODUCED IN POND 7, SCHUIL ACRES, DURING THE SUMMER OF 1934. THE ACTUAL FREQUENCY AND A RUNNING AVERAGE OF FIVE ARE GIVEN. DATA GIVEN IN TABLE IX.

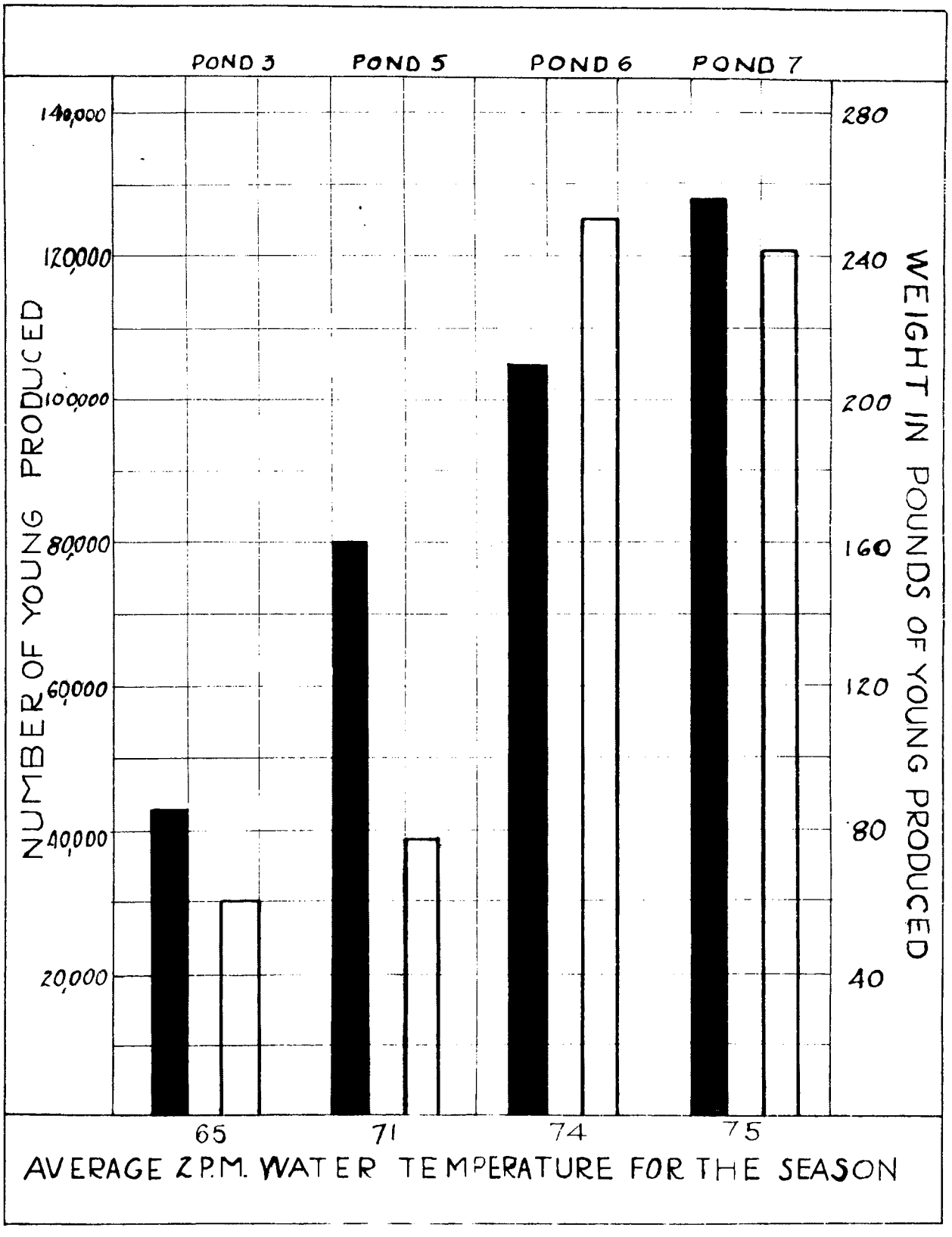


FIG. 7. PRODUCTIONS PER ACRE OF MINNOWS IN NUMBERS OF SPECIMENS [CLOSED RECTANGLES] AND WEIGHTS [OPEN RECTANGLES] AT SCHIUL ACRES DURING SUMMER OF 1934.