FURTHER STUDIES ON THE FAIRY SHRIMP POPULATIONS OF NORTHEASTERN OHIO

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Over a period of ten years, 1941–1950 inclusive, fairy shrimps have been collected from certain temporary pools and ponds in Portage, Summit, Stark, and Crawford Counties of Northeastern Ohio. Reports on the annual survey for the first six years have already been published (Dexter and Sheary, 1943; Dexter, 1943, 1946; Dexter and Kuehnle, 1948). The present paper summarizes studies of the past four years with additional information on annual fluctuations of populations of the fairy shrimp *Eubranchipus vernalis* (Verrill), its life history in four selected ponds, some ecological field notes and observations, and new records of geographic distribution. Acknowledgment is made to the trustees of the Research Fund of the Ohio Academy of Science for financial assistance in carrying out the field work, and to those who assisted with the field collections and contributed specimens for study. Each one is mentioned in the paper in connection with his particular contribution, but special thanks are due Mr. Paul Kuehnle for his coöperation in the study of Crawford County ponds over a period of seven years; Mr. Clarence F. Clark who has sent numerous specimens from time to time collected in the Western section of Ohio; and Mr. Frank W. Mead for his collections from Central Ohio.

Review of Field Collections, 1947

In the season of 1947, 91 pools and ponds were studied (33 in Portage County, 14 in Summit County, and 22 each in Stark and Crawford Counties). Only 38 of these contained fairy shrimps. This was the poorest year for fairy shrimp populations in the ten year survey. While the month of January had much more than average precipitation, February and March were periods of severe drought which may have been partly responsible for the failure of fairy shrimps to appear in some pools. Precipitation in the late spring was far in excess of normal rainfall, but this came too late in the year to fill the pools and ponds when hatching normally occurs. While five new ponds inhabited with *E. vernalis* were discovered in 1947, there were no new appearances of this animal in stations already under observation. *E. vernalis* returned to nine stations after an absence of one year, but it disappeared from 24 ponds inhabited in 1946. Four stations had a pronounced increase in the abundance of fairy shrimps over the preceding year, and three had a marked decrease in abundance. In general, the fairy shrimp populations were not well developed in Portage and Stark Counties during this year, although Summit County seemed to have nearly its usual abundance. The span of the season in Crawford County was shorter than usual, which is probably accounted for by the dearth of precipitation during the early spring and the shallowness of most of the pools studied in that county. Abundant rainfall in the spring did not seem to compensate for the low precipitation in the late winter. Dr. William C. Stehr, of Ohio University, also found *E. vernalis* to be scarce in 1947 in ponds he has studied in Athens County. A single specimen only was collected from one of his ponds located east of Athens on Route 50 where they were previously common.

Review of Field Collections, 1948

In the season of 1948, 95 ponds were investigated (27 each in Portage and Stark Counties, 11 in Summit County, and 30 in Crawford County). Twice as many ponds were found inhabited with *E. vernalis* this year over last year. A total of 75 contained populations. *E. vernalis* appeared for the first time in three of the

ponds which have been under investigation. Twelve new inhabited stations were added to the annual survey. Three of these were found for us by Miss Ruth Geib, now of Bethany College. In only two ponds populated in the previous year were the fairy shrimps absent. They returned to 18 stations after an absence of one year; to six after two years; and to one after an absence of three years. In addition they were considerably more abundant in 14 ponds, while they were less abundant in only two in comparison with the population of 1947. *Chirocephalopsis bundyi* was collected again in stations C7 and C18 for the first time in three years. As before, this species was not very numerous, a few specimens only being found among the collections of *E. vernalis*. The fairy shrimp season in 1948 did not begin generally until the last week of February. From that time on precipitation was unusually heavy, which undoubtedly was one of the principal reasons for the success of fairy shrimp populations that year. In general the season of 1948 was one of the best for fairy shrimps over a period of ten years. Dr. Stehr likewise found this season to be a very favorable one. He again collected numerous specimens from ponds which had not yielded specimens for several years previous.

Review of Field Collections, 1949

In the spring of 1949, 104 ponds were visited (31 each in Portage and Stark Counties, 12 in Summit County, and 30 in Crawford County). In spite of nine ponds inhabited with *E. vernalis* added to the survey, the total number inhabited, 76, was virtually the same as in the preceding year. Fairy shrimps could not be found in 11 former stations, all of which contained specimens in 1948. However, they did return to the two which failed to yield specimens in 1948 after a number of years of being present. They also returned to one station after an absence of three years. Nine ponds contained considerably more, and seven contained many less than in the preceding year. *E. vernalis* was the only species collected in 1949. This year was a very early season for the fairy shrimps. Hatching took place in some ponds in the third week of December, 1948, although in some cases the first hatching was destroyed by subsequent freezing of the shallow pools to the bottom. New hatchings occurred after thawing and with increasing rainfall received by the pools in January. Precipitation was somewhat higher than average during the winter months. The deeper pools got off to an early start, and large mature specimens were found early in certain ponds. Mr. Paul Kuehnle, assisting the junior author in the study of the Crawford County stations, found four ponds out of eight to contain fully-developed and matured specimens on January 23. The largest specimen he had ever seen was collected on that date. Mr. Alfred Linscheid, of the Shaker Heights Schools, failed to find fairy shrimps in the Warrensville Swamp pond in the spring of 1949, although they were numerous there in previous years and returned again in 1950. Mr. Alton Yarian, instructor at Emerson Junior High School in Lakewood, also failed to collect fairy shrimps in 1949 from a pool at Rocky River where they had been common from 1945 to 1948. On the other hand, Dr. William A. Dreyer, of the University of Cincinnati, found the population of *E. vernalis* to be more abundant in a pond near Goshen which he has observed over a number of years. In 1947 he collected a single specimen from under a covering of ice. A number of specimens were obtained in 1948, and an abundance of material collected in 1949. The following year they were still common but not as abundant as in 1949. Populations of both *E. vernalis* and *E. serratus* studied by the senior writer in East Central Illinois were found to be most abundant in 1949 in a period of nine years of collecting. Only one pool known to contain fairy shrimps in the area sampled failed to develop them that year (Dexter, 1951).

Review of Field Collections, 1950

In the tenth year of this survey, 110 pools and ponds were examined (31 in Portage County, 13 in Summit County, 32 in Stark County, and 34 in Crawford County). Altogether 89 of these contained fairy shrimps, including nine new sta-

tions added to the survey this year. The year 1950 proved to be second only to 1945 in general abundance and in the percentage of ponds containing these sporadic animals. It was the year of largest total number of ponds found inhabited. While they disappeared from six ponds since the previous year, they returned to seven others from which they were absent for one year, and to three ponds after an absence of three years. In addition, ten ponds had a greater abundance than in 1949, while only five had a smaller population. A small number of specimens of *C. bundyi* were again collected from station C18. The occurrence of this species in Geauga County is discussed in a later section of this paper. Again, the season of 1950 was a very early one for the appearance of fairy shrimps. They hatched out in many ponds in the third week in December, 1949, and were present for the follow-

TABLE 1

Summary of Field Collections

Year	1947	1948	1949	1950
Number on ponds studied	91	95	104	110
Number containing *E. vernalis*	38	75	76	89
Ponds drained or dry at time of examination.	0	S22	P1 (plowed over), P92 (drained), C21, C25	C20, C21, C22, C25
New appearance of *E. vernalis* in former stations.	0	C23, Cr16, Cr20	0	0
New stations containing *E. vernalis*.	P99, S22, C25, Cr21, Cr22	C26 thru C29, Cr23 thru Cr30	P100, C30 thru C34, Cr31 thru Cr33	P102, P103, S24, C35 thru C39, Cr34
Ponds from which *E. vernalis* disappeared since preceding year.	P17, P54, P89, P91, P92, P93, S2, C9, C10, C12 thru C17, C21, C22, Cr2, Cr3, Cr6, Cr10, Cr11, Cr13, Cr14	P8, C11	P37, P54, P55, P89, P91, P92, P95, S2, S4, C3, C21	C29, C4r, Cr21, Cr22, Cr25, Cr33
Return of *E. vernalis* after absence of one year.	P18, P50, P58, P80, P96, S3, S4, S11, C6	P17, P54, P89, P91, P92, S2, C9, C12, C13, C16, C21, Cr2, Cr3, Cr6, Cr10, Cr11, Cr13, Cr14	P8, C11	P37, P54, P55, P89, S2, S4, C3
Return of *E. vernalis* after absence of two years.	0	P23, P37, P42, P55, P90, P95	0	0
Return of *E. vernalis* after absence of three years.	0	C3	P30	C10, C14, C15
Increase in abundance of *E. vernalis* over preceding year.	P8, P79, C7, Cr9	P18, P43, S1, S3, S14, C2, C6, C18, C19, C25, Cr4, Cr8, Cr 12, Cr22	P23, P50, P88, S5, C9, C12, C16, Cr11, Cr16	P42, P90, P96, C13, C30, C32, Cr8, Cr14, Cr24, Cr31
Decrease in abundance of *E. vernalis* over preceding year.	P43, S14, Cr4	S4, Cr1	P58, P96, Cr8, Cr14, Cr20, Cr24, Cr25	P17, P79, P80, Cr2, Cr3
C. bundyi found with *E. vernalis*.	0	C7, C18	0	C18

ing 20 weeks which is the longest season for *E. vernalis* recorded in this study. Winter precipitation this year was far in excess of the average. As in 1949, a mild winter permitted rapid development of these animals. On January 14 three mature males collected from station C8 measured 19, 24, and 25 mm. respectively. However, populations did not develop at a uniform rate in various ponds, as the tables show, nor did they retain their maximum abundance over a similar length of time. For example, *E. vernalis* had become scarce in stations P88 and P96 by April 2, 1950. On this date it was still abundant in certain pools visited in Summit and Stark Counties. Thirty ponds in the four counties studied contained fairy shrimps during all of the four years covered by this report. Seven ponds did not contain any fairy shrimps during this same period of time, although three of these (P40, P93, C17) did have a small population in past years. The majority of those

temporary ponds of water which have not yielded specimens after several years of investigation have been dropped from the survey. Two new stations in Portage County were discovered by Raymond C. Burger, a student at Kent State University, while engaged in field collecting near Edinburg. Mr. Alton Yarian has reported to the writers three ponds near Rootstown from which he has collected fairy shrimps at various times in past years. Because these were not accurately located, they were not visited by the writer, and specimens taken from these pools by Mr. Yarian are not now available. For these reasons they have not been included in the present survey. Table 1 summarizes the field collecting data for the years 1947–50.

During the spring of 1950 Mr. Richard L. Snyder, another student at Kent State University, was engaged in a field study of temporary pools in Stark County under the direction of the senior author. Three of the 56 ponds which he visited were found to be inhabited by two species of phyllopods. *E. vernalis* was common in two and rare in the third; one pond had in addition an abundance of *Lynceus brachyurus* Müller, a conchostracan phyllopod; the second pond had a small population, while the third yielded but two specimens of that species. This is the first record of the Conchostraca (claw shrimps) in Northeastern Ohio and the only time it has been encountered during the ten-year study of temporary pools in this region. Determination of the species was made by Dr. N. T. Mattox, College of Agriculture and Mechanic Arts, Mayaguez, Puerto Rico.

In the investigation of the Crawford County ponds in the spring of 1950, it was discovered by the junior author and his brother, Paul Kuehnle, that flood waters of the Olentangy River had washed out the fairy shrimp population from four ponds located on the banks of this river. While such flooding may eliminate a population from certain places, this may possibly be an agent in the dissemination of the species to other flood plain ponds farther downstream where mature individuals or the eggs may eventually be deposited. Ferguson (1939) suggested such an explanation for the disappearance of *E. vernalis* from pools on the flood plain of the Salt Folk River in Illinois studied by him and the senior writer. Dr. Marian Smith, University of Massachusetts, sent a record of finding a single fairy shrimp on May 26, 1945, near Northampton, Mass., in a shallow flood plain pool filled by overflowing waters of the Connecticut River. The pool was known to have dried out before flooding. Possibly the egg or the specimen itself had been washed in from another pool farther upstream.

Comparison of the Life History of *E. vernalis* in Pond P88, 1947–1950

Pond P7 which had been studied throughout the entire fairy shrimp season in the years of 1943–1946 (Dexter, 1946; Dexter and Kuehnle, 1948) was destroyed during the summer of 1946. Weekly observations were continued, however, in pond P88 for the years 1947–1950. Visits were made nearly every week from the time water collected in this station and the subsequent hatching of fairy shrimps until they disappeared from the pond. A plankton-net sample and a dip-net sample were made at each visit; water temperature, pH, depth of water, and thickness of ice, if any, were recorded each time. Tables 2 and 3 summarize these physical data and measurements made on the fairy shrimp samples. A small number of specimens was taken, so as not to disturb the natural population any more than necessary. At certain times, however, such as very early or late in the season when they were few in number, all specimens encountered were taken. At other times a small sample was preserved which seemed to be representative of the size groups present in the pond. Earlier studies published by the writer on the life history of fairy shrimps were based upon measurements made on a sample which included only the first or oldest brood in the pond. In the present paper observations are reported and measurements have been made on all of the size groups which could be differentiated. Under certain conditions there is only one

major brood in a pond. This is true when the pond fills up with water early in the season. At other times, however, if a pond fills gradually, there is a succession of broods as the water reaches higher levels on the shore margin resulting in a succession of hatchings which may be spaced by days or weeks apart. Under these conditions a population will contain a wide range of different-sized individuals. Upon first hatching each brood can be distinguished from the older ones. Gradually, however, one group merges with another so that they cannot be distinguished. On several occasions we arbitrarily divided the specimens into size groups on the basis of previously distinguishable size groups rather than average together a wide range of sizes which would give a misleading average.

In 1947 pond P88 accumulated a few inches of water in the first week of January. On January 5, a plankton sample contained an abundance of copepods and ostracods, but no phyllopods were obtained. On January 12 a single fairy shrimp nauplius was collected in two inches of water under three inches of ice. Eggs were also obtained from the bottom sediments. Some of these eggs were in the process of hatching. The water remained very shallow until the first week of April when the pond became filled with four feet of water. At this time a new brood hatched as more eggs were now covered with water. A week later the pond was flooded and remained at high level for the remainder of the fairy shrimp season. Two distinct broods were present until the very last collection. As Coopey (1950) reported for *E. oregonus*, the rate of growth decreased noticeably at the time of maturity and the production of eggs. It seems to be generally true that during the time of egg production growth in total length is nearly suspended even though the shrimps continue to increase in length at a later time. This was also evident in the study of *E. serratus* published by Dexter and Ferguson (1943). Also, as was the case with that species, *E. vernalis* in pond P88 diminished in average size toward the end of its life history. Once again it is believed that the death of the oldest and largest specimens results in a smaller average with the persistence of younger and smaller specimens. The fairy shrimp season extended for 19 weeks, whereas in 1946 it lasted for 14 weeks, much of which time the population that year was decimated because of a long period of ice cover. The 1947 population extended to the latest date, May 25, on which *E. vernalis* has been found as a free-swimming animal in P88. The water was consistently cooler that season, and rainfall in April was much greater than normal, which facts undoubtedly explain the persistence of fairy shrimps to such a late date. Only once before was *E. vernalis* collected on that date. In 1943, pond P7 refilled on April 13 after drying out three weeks earlier, and a second generation of *E. vernalis* hatched which was collected up to May 25 (Dexter, 1946).

In 1948 the pond did not contain water until the middle of February. On February 22, hatching eggs and nauplii were found in shallow water under two inches of ice. Again, many unhatched eggs were recovered from the clay bottom. The depth of the water did not increase significantly for a month. On March 21, after the depth was nearly doubled, three distinct size groups were present, one of which was the result of a new hatching at the time of sampling. The pond failed to get more than 30 inches of water during the spring of 1948. The fairy shrimp population lasted until the first few days of May, a span of only 10 weeks, even though the depth of water was at its maximum at the end of the season and the temperature was not beyond the toleration limit for *E. vernalis*.

The next generation of *E. vernalis* hatched in the third week of December, 1948. Once again this appeared in just a few inches of water below a covering of ice. Within a week after hatching the pond froze to the bottom, destroying the fairy shrimps which had hatched up to that time. A thaw in the first week of January, 1949, permitted a second hatching. This brood survived even though the water remained shallow until the last week of February. At that time there were three broods present: the original hatching, a second one which appeared when the water level reached nearly a foot in depth, and a third one which appeared when the water

level reached a depth of one and one-half feet. Again the rate of growth diminished with the production of eggs, but later continued until a maximum length of 22 mm. was reached on April 10. Following this date the average size dwindled as noted in previous years. The second generation, and the only one to mature, existed

TABLE 2

Comparison of Life History of E. vernalis in Pond P88

1947	°C	pH	No. collec'd	Range in MM.	Aver. in MM.	Notes	1948	°C	pH	No. collec'd	Range in MM.	Aver. in MM.	Notes
1–12			1		1.0	3 in. ice over 2 in. water. Eggs just hatching.							
1–19	1.0	5.4	9	1.0–1.25	1.03	1.5 in. ice over 1.5 in. water.							
1–26	0.8	5.7	18	1.0–1.5	1.2	1.25 in. ice over 10 in. water.							
2–2	1.1		23	1.0–2.5	1.5	0.5 in. ice over 1.0 ft. water.							
2–11	1.1		22	1.5–5.0	3.1	8.75 in. ice over 6.5 in. water.							
2–16	0.5		9	2.5–5.8	3.8	8 in. soft ice over 7.25 in. water.							
2–23	0.5		20	3.0–6.3	4.8	8 in. ice over 7 in. water.	2–22	0.5		5	1.0–1.5	1.2	2 in. ice over 5.25 in. water. Eggs just hatching.
3–2	0.0		6		4.0	10 in. ice over 4 in. water.	2–29	0.5	6.8	4	2.25–2.75	2.5	Skim of ice. Greatest depth water 5.5 in.
3–9	0.0		2	3.0–7.0	5.0	8 in. ice over 5 in. water.	3–7	2.0	6.8	5	3.75–4.5	4.1	0.12 in. ice over 5 in. water.
										2	1.75–2.00	1.9	New hatching.
3–16	0.5	5.9	12	6.0–9.0	7.3	5.5 in. ice over 5.75 in. water.	3–14	1.5	6.3		4.0–6.5	5.3	3 in. ice over 6.5 in. water.
			1		3.0						2.25–3.0	2.7	
							3–21	14.5	5.9		12.0–14.5	13.7	15 in. water. New hatching with rise of water level.
											6.0–7.8	6.9	
											1.0–1.5	1.3	
3–30	0.5	5.6	15	4.5–9.3	7.2	7 in. soft ice over 9.5 in. water.	3–28	3.5	6.3		18.0–25.0	22.1	20 in. water. Larger group mature with developing eggs and mature coloration. Immature group still pinkish in color.
											3.0–10.0	6.8	
4–6	12.2	5.8	14	10.25–14.0	11.5	4 ft. water.	4–4	10.0	6.2	2		22.0	20 in. water.
			1		4.5					many	11.0–14.0	13.2	
4–13	9.5	6.0	5	9.0–16.0	12.3	5 ft. water. Abundance of recently-hatched larvae.	4–11	11.3	5.9	2		22.5	20 in. water. All females with egg sacs.
			many	4.0–6.0	5.1					many	14.0–17.0	15.8	
4–20	8.0	6.0	3	17.0–22.0	19.5	5 ft. water. First brood mature.	4–18	12.0	5.6	2	21.0–26.0	23.5	30 in. water.
			many	6.0–12.0	9.3					many	13.0–17.5	15.6	
4–27	10.5	6.1	4	18.0–22.0	19.3	5 ft. water. Females of first brood with eggs. Second brood still immature.	4–25	19.5	5.9	1		24.5	30 in. water.
				8.0–16.25	13.9					many	12.0–17.0	15.6	
5–4	13.6	6.1	2	20.8–21.5	21.1	5 ft. water.	5–2	15.0	5.9	5	13.5–17.0	14.9	30 in water. Last collection of season.
			10	13.0–18.5	15.3								
5–11	11.7	6.3	1		19.0	4 ft. water.							
			12	9.5–16.5	15.6								
5–18	17.2	5.9	13	11.0–19.5	18.7	4 ft. water.							
5–25	19.2	6.0	3		19.0	5 ft. water. Last collection.							

TABLE 3

Comparison of Life History of E. vernalis in Pond P88

1948	°C	pH	No. collec'd	Range in MM	Aver. in MM	Notes	1949	°C	pH	No. collec'd	Range in MM	Aver. in MM	Notes
12–19	0.5		10	1.0–1.5	1.2	0.5 in. ice over 3.5 in. water. Metanauplii abundant.	12–19			1		1.0	Several puddles in cow tracks 1–2 in. deep from rain of 12–18–49.
12–26						1.75 in. ice; frozen to bottom.	12–26			1		1.5	Scattered puddles 1–3 in. deep. Skim of ice.
1949							1950						
1–2	0.0		6	1.0–1.5	1.2	2.75 in. ice over 2 in. water Second hatching.	1–2	9.0	5.4	64	1.0–2.25	1.7	3.5 in. water. Many in process of hatching.
1–9	6.5	5.3	3	1.0–1.2	1.1	5.5 in. water. Hatching still in process.	1–8	1.0	5.2	30	1.0–1.75	1.3	0.75 in. ice over 7 in. water. Hatching still in process.
1–16	9.0	5.9	20	1.5–2.5	2.1	5.0 in water.	1–15	1.5	5.8	40	1.2–4.5	2.0	0.5 in. ice over 14 in. water.
1–23	1.7	6.0	19	1.2–4.0	2.8	0.5 in. ice over 4 in. water.	1–22	0.5	5.4	41	1.2–5.5	2.9	2 in. ice over 19 in. water.
1–30	2.2	5.2	12	1.0–1.4	1.2	2.1 in. ice over 11 in. water. New hatching only collected.	1–29	6.0	5.8	58	1.0–11.25	5.6	2 ft. water. Continuous hatching has produced wide range of sizes.
2–6	2.5	5.4	5	3.9–6.4	5.2	4 in. ice over 9 in. water.	2–5	3.0	5.9	10	4.2–10.25	7.6	1.5 in. ice over 2 ft. water.
			5	1.7–2.2	1.9								
2–13	3.0	5.3	18	5.7–8.8	7.2	1 in. ice, melting at edges, over 13.5 in. water.	2–12	3.0	6.0	26	4.5–12.0	7.9	0.25 in. ice over 2 ft. water. Mature specimens 18 mm. in length collected from P43 and P96.
			11	1.1–3.0	2.4								
2–20	7.5	5.7	9	11.0–17.0	12.9	18 in. water.	2–19	2.0	5.9	15	11.0–19.0	12.4	3 ft. water. Largest specimens mature, but egg sacs not yet developed.
			20	3.0–7.8	4.4					5	5.5–7.0	6.2	
			8	1.0–2.5	1.6					4	1.0–1.2	1.2	
2–27	5.5	5.8	5	13.0–17.0	15.2	0.25 in. ice over 19 in. water.	2–26	3.0	5.9	21	12.0–18.0	14.8	4 in. ice over 3.5 ft. water.
			20	4.5–11.0	6.8					6	10.2–8.0	8.7	
			3	2.8–3.5	3.1								
			1		1.0								
3–6	6.0	5.9	7	14.0–19.0	15.9	20 in. water. Largest females with egg sacs.	3–5	2.5	5.9	26	7.0–18.0	13.8	5.5 in. ice over 3 ft. water. Continuous variation in size.
			62	7.0–12.5	8.9								
			1		5.0								
			3		1.0								
3–13	4.0	5.9	7	13.5–17.0	15.0	1 in. ice over 20 in. water.	3–12	2.5	6.1	29	9.5–18.6	15.3	2.5 in. ice over 3.5 ft. water. Egg sacs developed. Adult coloration.
			25	7.8–12.0	10.0								
			3	6.3–6.5	6.3								
			1		4.3								
3–18	4.0	6.0	2		17.0	0.25 in. ice over 20 in. water. Size groups not distinct.	3–17	3.5	6.2	22	11.25–19.2	16.3	2.25 in soft ice in center over 3.5 ft. water. Egg sacs fully developed.
			20	11.0–14.5	12.0								
			17	5.0–10.5	8.4								
			1		4.0								
3–27	14.5	5.9	1		22.0	21 in. water.	3–26	4.0	6.2	22	14.0–22.3	18.7	4.5 ft. water.
			29	12.0–19.0	15.5								
			2	9.0–9.5	9.3								
			1		6.5								
4–3	6.5	5.9	20	17.0–21.3	18.2	21 in. water.	4–2	7.0	7.4	10	14.0–23.5	19.9	5 ft. water.
			11	10.0–16.0	12.3								
			9	7.5–9.0	8.6								
4–10	8.5	5.7	1		22.0	21 in. water.	4–9	9.0	7.4	24	16.0–25.8	19.4	5 ft. water.
			11	17.0–20.5	18.0								
			11	11.0–15.5	13.0								
			18	7.0–11.0	9.3								
4–17	13.0	5.5	13	16.5–20.0	17.8	22 in. water.	4–16	6.5	7.4	19	18.5–25.0	21.5	4.5 ft. water.
			10	11.0–15.0	12.8								
4–24	8.5	5.2	16	15.0–17.5	16.0	22 in. water.	4–23	12.5	7.4	20	17.0–24.0	20.5	4.5 ft. water. Adults gray in color.
			12	12.0–14.5	13.6					1		9.5	
5–1	16.0	5.2	12	16.0–19.0	17.5	21 in. water. Last collection of season.	4–30	9.5	7.4	13	19.5–26.0	23.1	4.5 ft. water.
			5	12.0–13.5	12.7								
							5–7	15.5	7.4	9	22.0–28.0	25.9	4.5 ft. water. Last collection of season.

over a period of 17 weeks. As in the previous two years the water level was near its seasonal maximum and the temperature was not excessive at the time the fairy shrimps disappeared for the year.

The population of the winter of 1949–1950 closely paralleled that of the previous winter in nearly all respects. However, the first hatching was not destroyed by freezing in spite of very shallow water again this season. After the water level ranged over two feet in depth, three distinct broods could be distinguished, but these soon merged with overlapping ranges so as to lose their identity. The pond was flooded to its maximum depth of five feet in April, but the fairy shrimps disappeared at about the same time as in the preceding year, during the first week of May. Apparently they do not live long after reaching their maximum development in spite of the presence of ample water and temperatures well below the threshold of tolerance. Nevertheless, the life span of a single generation for 20 weeks recorded this year is the longest observed in this study over a period of seven years. Ferguson (1939) estimated that the life span of *E. vernalis* in Ontario may be as long as six months. Coopey (1950) found the life span of *E. oregonus* to extend for 23–25 weeks in the state of Washington. These observations of Ferguson and Coopey were made farther north in one case and at higher altitude in the other than the present studies carried out in Northeastern Ohio. Undoubtedly these topographic differences with their associated climatic differences serve to modify the pattern of the development of invertebrate animals such as fairy shrimps. Some years the fairy shrimp population is limited by either the drying out of the temporary pools, water temperatures which go beyond the threshold of tolerance, or both. During the four years covered by this report those factors were not involved, since the water level increased in local ponds during the spring months of 1947–1950 rather than decreased as was the case in 1943–46. Also, water temperatures remained cool during the presence of fairy shrimps over the past four years. Fairy shrimps were more abundant in 1949 and 1950 in ponds P88 and P8 than for some years previous. The fact that these ponds dried out completely in the summer of 1948 and 1949, which they seldom do, may have been partly responsible for the larger population the following winters. It is known from experimental evidence (Weaver, 1943) that drying of the eggs stimulates hatching. The senior writer is conducting experiments on this problem with several species of phyllopods.

Comparison of the Life History of *E. vernalis* in Ponds C7, C19, and C23 in 1950

While the preceding section compares the life history of *E. vernalis* in one pond over a period of four years, it was thought desirable to study several ponds during a single season in order to compare the development of this fairy shrimp in different places and in different habitats simultaneously. Four ponds in Stark County were selected for that purpose. Table 4 presents the results of the observations. Since one pond, C8, had a very small population of fairy shrimps in 1950, the results from that station are not included. While all of the other three show a somewhat common pattern, it is clear that local conditions modify the life history of *E. vernalis* to a significant degree. Specimens had already attained a size up to 16 mm. in station C23 and up to 20 mm. in C19 by the time metanauplii appeared in pond C7. Water did not accumulate in C7 as early as it did in the other two ponds. At the time C7 filled in the fourth week in January, with subsequent hatching of fairy shrimps, new hatchings also occurred in C19 and C23 although the water level in the latter two was not noticeably higher. Fairy shrimps lasted until April 1 in one pond and persisted for at least four weeks later in the other two. In the case of C19 the fairy shrimp season extended over a period of 11 weeks, while in C7 it extended for 13 weeks. Since it is not known when hatching occurred in C23, the seasonal span cannot be determined, but it was for more than 16 weeks. The development of *E. vernalis* in pond P88 in Portage County began earlier and extended later than any of the Stark County stations. It is also clear that on or

about the same date specimens of the same species of fairy shrimp in different habitats and localities have reached a total length of wide diversity. In addition to comparisons shown on table 2, the following have been noted. Miss Frances J. Hindley collected *E. vernalis* on March 23, 1947, near Creston, Ohio, which were fully developed and mature, while those found in pond P88 at that time were only about one-half developed. On April 6, 1947, the shrimps in P88 had reached a maximum of 14 mm. and were still immature and orange-pink in color. On that same day in pond P96 they were up to 18.25 mm. in total length, were

TABLE 4

Comparison of Life History of E. vernalis in Ponds C7, C19, and C23 in 1950

Date	C7				C19				C23			
	No. collected	Range in MM.	Aver. in MM.	Notes	No. collected	Range in MM.	Aver. in MM.	Notes	No. collected	Range in MM.	Aver. in MM.	Notes
1-14					9	2.5-7.0	4.8	1.5 ft. water.	11	4.0-11.0	7.5	2 ft. water.
1-22					1		10.0	2 in. ice over	20		16.0	2 in. ice over
					7		3.0	1.5 ft. water.	23	8.0-11.0	9.5	2 ft. water.
									7	2.5-3.0	2.8	
1-28	26		2.5	Skim of ice over 3 ft. water.	1		20.0	Skim of ice	14	11.0-14.0	12.5	Skim of ice
					many	1.5-6.0	3.8	over 1.5 ft. water.	15	7.0-8.0	7.5	over 2 ft. water.
									53	1.5-5.0	3.3	
2-4	28	2.0-7.0	4.5	1.5 in. ice over 3 ft. water (on 2-5).	2		15.0	1 in. ice over	11		15.0	1 in. ice over
					many	3.0-12.0	7.5	1.5 ft. water.	5		10.0	2 ft. water.
									46	3.0-5.0	4.0	Large females with eggs.
2-14	69	2.0-6.0	4.0	2.5 ft. water.	5	15.0-20.0	17.5	1.5 ft. water.	26	12.0-20.0	16.0	2 ft. water.
					many	10.0-15.0	12.5		71	5.0-8.0	6.5	
2-18	25	4.0-8.0	6.0	Skim of ice over 2.5 ft. water.	304	12.0-21.0	16.5	Skim of ice	56	12.5-21.0	16.5	Skim of ice
					38		10.0	over 1.5 ft. water.	94	8.0-12.0	10.0	over 2 ft. water.
2-26	5		10.0	4 in. ice over	37	16.0-18.0	17.0	4 in. ice over	14	18.0-20.0	19.0	4 in. ice over
	17	3.5-7.0	5.3	2.5 ft. water.				1.5 ft. water.	54	8.0-14.0	11.0	2 ft. water.
3-4	4	9.0-12.0	10.5	3 in. ice over	79	15.0-20.0	17.5	5 in. ice over	14	18.0-20.0	19.0	5 in. ice over
	27	4.0-7.0	5.5	2 ft. water.	115	12.0-16.0	14.0	1.25 ft. water.	7	12.5-15.0	13.5	2 ft. water.
					10		12.0		45	8.0-12.0	10.0	
3-12	29	6.0-12.0	9.0	2 ft. water.	207	14.0-20.0	17.0	1 in. ice over 1.25 ft. water.	47	15.0-21.0	18.0	1 in. ice over
									80	8.0-13.0	10.5	1.5 ft. water.
3-18	9	7.0-14.0	10.5	2 ft. water.	52	12.0-22.0	17.0	1.25 ft. water.	28	13.5-22.0	17.5	1.5 ft. water.
									many	8.0-13.0	10.5	
4-1	2	15.0-17.0	16.0	1.5 ft. water.	5		25.0	1 ft. water.	52	15.0-17.0	16.0	1 ft. water.
	17	6.0-10.0	8.0					Last collection.	35	8.0-10.0	9.0	
4-16	63	14.0-20.0	17.0	1 ft. water.					59	10.0-22.0	16.0	1 ft. water.
	71	7.0-10.0	8.5									
4-29	40	10.0-20.0	15.0	2 ft. water. Last collection.					3	19.0-21.0	20.0	1.3 ft. water.
									7	7.0-11.0	9.0	Last collection.

mature, and had the characteristic coloring of adults (females, bluish-gray; males, light green). It has been mentioned earlier that on January 14, 1950, three males collected from C8 measured 19, 24, and 25 mm. respectively, whereas fairy shrimps collected from P88 on the following day were not over 4.5 mm. in length.

GENERAL AND ECOLOGICAL NOTES AND OBSERVATIONS

In previous reports it has been pointed out that the sex ratio of *E. vernalis* collected from ponds in Northeastern Ohio averaged 1 male to 1.5 females. However, it was noted that specimens collected from Stark County had a ratio of 1:0.5 (Dexter, 1946). With the study of ponds in Crawford County, beginning in 1944, it was discovered that here again males predominated in the collections with a sex

ratio of 1:0.75. In the spring of 1947 another sample of specimens from Crawford County gave the same ratio. In 1948 populations from Stark County showed a sex ratio of 1:0.88; and in Crawford County, a ratio of 1:0.84. In 1950 the ratio of the three ponds in Stark County which were studied throughout the season (C7, C19, C23) was determined to be 1:0.75, 1:0.85, and 1:0.83 respectively, based upon a sample of over 1200 specimens. At least in those ponds which have been sampled from Stark and Crawford Counties, males predominate over females in abundance, whereas in Portage and Summit Counties female specimens have been somewhat more abundant.

The pool in Portage County (P42) which had *E. vernalis* introduced experimentally in the spring of 1943, and which was found to contain a small number of fairy shrimps two years later (Dexter and Kuehnle, 1948), was discovered to have another small number in 1948. None was found during the two intervening years. In 1949 a total of 15 specimens was collected there; the following spring there was an abundant population. In spite of this pond having been plowed in the fall of 1943, fairy shrimps succeeded in becoming established although it required seven years for a sizeable population to develop.

Occasionally fairy shrimps are collected which contain a large number of attached organisms. On January 22, 1950, for example, most of the specimens collected from station P88 were covered with a dense population of a stalked protozoan (*Epistylis* sp.) which was especially abundant attached to the appendages of the fairy shrimps. On March 17, 1950, and again nine days later, most of the specimens collected from the same pond were covered with a growth of green algae. Again these attached organisms were largely concentrated on the appendages.

Sometimes fairy shrimps are found in a surprisingly small amount of water. Specimens of *E. vernalis* have been collected from a number of pools containing no more than a few quarts of water. This is especially true, of course, toward the end of the fairy shrimp season during those years when the temporary pools and ponds dry out at an early date. At such times fairy shrimps can be found in water no more than an eighth of an inch in depth. On one occasion *E. vernalis* was found in station S18 on April 6, 1946, still alive and kicking about on the surface of the wet mud in the last stages of drying out. In contrast to such limitation of water, fairy shrimps are occasionally reported from bodies of water which are somewhat permanent. It has already been pointed out that the ponds P8 and P88 do not dry out completely each year, but these and similar ponds which contain fairy shrimps do have a dry margin during the summer season so that there is ample opportunity for many of the fairy shrimp eggs to be dried before hatching. Kenk (1949) reported a similar situation in which both *E. vernalis* and *C. bundyi* have been collected from a permanent pond. Dr. Ann H. Morgan of Mt. Holyoke College has reported to us her experience in collecting fairy shrimps over a period of years in a spring-fed, permanent forest pond near South Hadley, Massachusetts. Mr. L. Wayne Wilson has sent specimens of *E. vernalis* from a permanent pond at Moorefield, West Virginia. Two unusual situations of this nature have come under our own observation. At C7 there is a small pool at the edge of the temporary pond which is spring-fed and contains water the year around; much of the water in the pond is derived from this spring. Fairy shrimps are usually most abundant in this pool although they do not occur there any earlier as a rule than they are found in the temporary pond itself. Plankton samples from this pool in the fall season have failed to produce specimens or larvae of fairy shrimps. Very possibly the shrimps hatch from the flooded temporary basin and then swim in to the adjoining pool where they become concentrated in very large numbers. The writers have never seen a greater density of fairy shrimps than they have found in this pool during certain years. It might be added that plankton samples taken in pond P88 during the summer and fall seasons likewise were devoid of larval stages of fairy shrimps. In spite of the persistence of water in these

two stations, and some others like them, the fairy shrimp eggs do not hatch in this region until the middle of December. Eggs of fairy shrimps normally are subjected to conditions of drying and freezing before hatching. While it has been shown that the eggs can be hatched experimentally (Weaver, 1943) without drying and/or freezing, the eggs of *E. vernalis* in temporary pools of temperate America do undergo those conditions and probably few eggs of these fairy shrimps hatch in a natural situation without having undergone either drying or freezing. In the spring of 1950 *E. vernalis* was collected in large numbers from a permanent pond (S24) in Summit County. Because of the permanent nature of this pond it had not been examined for fairy shrimps in previous years. In the summer of 1949 it was drained and remained dry until the following winter. When this filled to capacity in the spring months, it developed a large population of *E. vernalis*. Unfortunately, it is not known exactly when these crustaceans made their appearance. If they had been present in earlier years, this could be explained by the dry margin around the pond which is present during dry summers.

An unusual situation has been observed at station P55, a shallow woodland pool in the trough of an abandoned canal. At high water level two adjoining depressions are connected by a short, narrow channel. As the water level drops the two become separate pools. The occurrence of fairy shrimps has been uniform for both portions over a period of years, as one might expect. Shrimps were not found in either in 1941–43, 1946–47, and 1949. They were numerous in both in 1944; common in both in 1945; common in the west half in 1948, but the more shallow east half had dried out before a sampling was made. In 1950 they were numerous in the west half, but absent in the east portion even though both contained a normal amount of water and were connected by shallow water at the time of sampling.

Mr. Frank W. Mead, a graduate student at Ohio State University, collected a sample of *E. vernalis* in water of unusual temperature for this species. He collected his specimens from a small temporary pool some eight feet in diameter with a depth of four to five inches located near McComb in Hancock County. At the time of collecting on May 5, 1950, the water was 25°C.

The pond near Middlefield in Geauga County which has been reported with a population of *Chirocephalopsis bundyi* (Dexter and Kuehnle, 1948) was re-examined in 1948–1950. In April of 1948 the Donaldson family found this species to be common. The following year Miss Grace Donaldson found an abundant population of this species in the same woodland pool, and in addition found some specimens of the same species in a nearby pond from which they were recorded for the first time. In the spring of 1950 the senior writer accompanied by Miss Donaldson again found an abundant population in the original pool and a single specimen in the second one. Fairy shrimps have not been numerous in the second pond since discovery. However, it should be pointed out that the single specimen collected was taken somewhat late in the fairy shrimp season. Again, *C. bundyi* was the only species found in these two pools, and they remain the only ones known in the state of Ohio in which this species of fairy shrimp occurs by itself. Dr. Charles A. Dambach, Chief of the Wildlife Division, Ohio Department of Natural Resources, informed us of having observed fairy shrimps in a number of pools in Hambden Township of Geauga County some 25 years ago. Further investigation of this county is needed.

New Records of Geographical Distribution

Over the past four years a number of biologists have kindly sent specimens collected in various sections of Ohio. Nine new county records have been established by these collections, largely through the field work of Frank W. Mead. In addition, records have been made from 13 new localities in counties where *E. vernalis* has already been reported. Table 5 gives a digest of all of these. Figure 1 presents a map of Ohio showing the localities from which fairy shrimps have been known to occur up to the present time.

TABLE 5

New Records of Fairy Shrimps Collected in Ohio

County	Collector	Location	Species	Notes
		I. NEW COUNTY RECORDS		
Columbiana	Irene Weeks, Salem High School.	Perry Township	*E. vernalis*	From temporary orchard pool, Spring, 1948. Known since 1945; none found in 1949.
Pickaway	Frank W. Mead, Ohio State University.	Wayne Township, near Circleville.	" "	Woodland pools and Calamus Swamp, 3-25-48, 3-24-49, and 4-22-50.
Madison	" "	Between Chenoweth and Mt. Sterling.	" "	Grassy ditch, 3-25-49.
Union	" "	Darby Township, 2 miles east of Chuckery.	Unknown	Roadside ditch, about 1 ft. deep. Specimens not saved.
Fairfield	" "	Walnut Township, section 8.	*E. vernalis*	Woodland pool, 4-10, 22-48; 3-14-49.
Licking	" "	Lima Township, section 5.	" "	Collected 3-21-50.
Knox	" "	2 miles northwest of Centerburg.	" "	Buttonbush swamp, 3-27-49.
Morrow	" "	3 miles south of Johnsville.	" "	Collected 4-15-50.
Hancock	" "	1 mile south of McComb.	" "	From small and very shallow pool in open woods, 5-5-50.
		II. NEW RECORDS FROM COUNTIES PREVIOUSLY REPORTED		
Wayne	Frances J. Hindley, Creston High School.	Near Creston	*E. vernalis*	Collected 3-23-47.
Ashland	Kenneth Chiavetta, Ohio State University.	Mohican State Forest, Loudenville.	" "	Collected 5-2-47.
Athens	William C. Stehr, Ohio University.	2 miles east of Athens.	" "	From open woodland pasture pool, 3-18-48. First record known from this pond after many years of examination.
	Henri C. Seibert, Ohio University.	4 miles north of Athens.	Unknown	Collected 3-24-50. Specimens lost.
Clinton	Frank O. Hazard, Wilmington College.	Vernon Township.	*E. vernalis*	Collected 3-10-45.
Franklin	Frank W. Mead, Harold Tvedt, Kenneth Chiavetta, Douglas Stancombe, (students at O.S.U.)		" "	Many specimens have been collected from numerous pools of various types throughout the county, 1947-1950.
Delaware	Frank W. Mead, Ohio State University.	Near Olive Green.	" "	From open woodland pool, 3-27-49.
Marion	" "	Near Waldo	" "	Collected 3-27-49, from pool 10-14 in. deep.
Crawford	" "	Holmes and Bucyrus Townships.	" "	Collected 5-3, 5-50, from one pool in each township.
Seneca	Frank J. Ligas, Heidelberg College.	5 miles east of Tiffin.	" "	From woodland pool; first week of April, 1950.
Wood	Eugene Dustman, Ohio State University.	Liberty Township	Unknown	Collected in March, 1947.
Hardin	Clarence F. Clark, Ohio Dept. of Natural Resources.	Taylor Township, 5 miles southwest of Kenton.	*E. vernalis*	Collected 4-10-48.
Auglaize	"	Salem Township, section 32.	" "	Collected 4-9-48.
Shelby	"	1 mile west of Sidney.	" "	From woodland pool, 4-25-50.

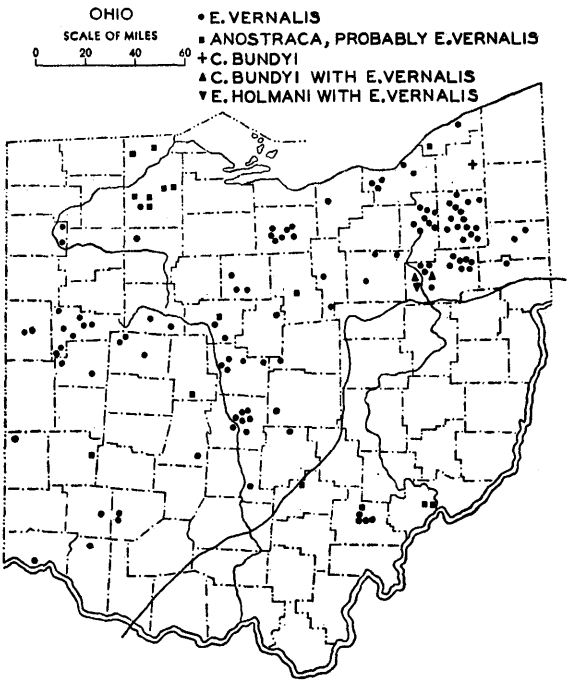

FIGURE 1. Location of all known records of Anostraca in Ohio. Each symbol includes all records within a radius of one-half mile. It will be observed that the great majority of records known to date are from the glaciated portion of the state.

SUMMARY AND CONCLUSIONS

The continuation of an annual survey of fairy shrimp populations in Portage, Summit, Stark, and Crawford Counties of Northeastern Ohio in 1947–50 has led to the following results:

1. The season of 1947 was the poorest one in the ten years of this survey, with only 38 pools from a total of 91 investigated inhabited with *Eubranchipus vernalis*. A winter drought is believed to be partly responsible for the dearth of records.

2. Twice as many ponds (75) were found inhabited in 1948 as in the preceding year. The species returned to 25 ponds after an absence of one to three years, and was generally more abundant than in 1947.

3. The season in 1949 was an early one, hatching beginning in the third week of December, 1948. Although it did not yield as large a percentage of ponds inhabited with *E. vernalis*, the total number was virtually the same and the general abundance was somewhat greater than in the previous year. Fairy shrimps were fully developed in some ponds by the third week of January.

4. In 1950 a total of 89 ponds contained *E. vernalis*, the largest number found in any one year. Altogether, 110 stations were examined. The percentage of ponds inhabited with this fairy shrimp and the general abundance were second only to 1945. Again, the season began with hatching in the third week of December, and it extended for 20 weeks, the longest one observed in ten years. A table summarizes the most significant fluctuations observed in 1947–50.

5. Thirty ponds contained *E. vernalis* each of the four years covered by this report.

6. *Chirocephalopsis bundyi* was again collected with *E. vernalis* from two stations in 1948, for the first time in three years, and was collected from one of those stations in 1950.

7. The first record of a conchostracan phyllopod is made for Northeastern Ohio. *Lynceus brachyurus* Müller was found in three temporary pools in Stark County among populations of the anostracan *E. vernalis*.

8. Tables compare the life history of *E. vernalis* in one pond (P88) for four consecutive years and in three ponds (C7, C19, C23) for the season of 1950.

9. *E. vernalis* has been collected as late as May 25 in Portage County.

10. Fairy shrimps which hatch early in very shallow pools are destroyed when the pools freeze to the bottom.

11. Several broods are produced by the gradual raising of the water level which reaches the eggs at various time intervals.

12. *E. vernalis* does not persist long as a free-swimming animal after completing its development even though water of a favorable temperature remains in the pond.

13. Local conditions produce variations in the development of *E. vernalis* populations in ponds having a somewhat different physical environment and geographic location.

14. On the same date, the size and abundance of *E. vernalis* may vary greatly from one pond to another.

15. Males are more abundant than females in collections of *E. vernalis* from Stark and Crawford Counties, although the opposite is true in collections from Portage and Summit Counties.

16. *E. vernalis* introduced into a new pond experimentally developed an abundant population in seven years.

17. Stalked protozoans and green algae are known to become attached to fairy shrimps in great abundance.

18. *E. vernalis* has been found living in extremely small amounts of water as well as in semi-permanent ponds.

19. *E. vernalis* has been collected from water with a temperature as high as 25°C.

20. *C. bundyi* was found to be common in 1948–50 in a pond in Geauga County where it was discovered in 1946, and was found in small numbers in an adjacent pond in 1949–50.

21. Nine new County records and 13 new locality records for the occurrence of *E. vernalis* in Ohio are reported. A map indicates the location of all known records of fairy shrimps from 42 of the 88 counties of Ohio.

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