Population Dynamics of Adult *Unionicola formosa* (Acari: Hydracarina), a Parasite of *Anodonta imbecillis* (Mollusca: Bivalvia), in West Virginia

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ABSTRACT.— Population dynamics of a parasitic aquatic mite, *Unionicola formosa*, were studied at the McClintic Wildlife Station (West Virginia) in two ponds that supported different densities of the host mussel, *Anodonta imbecillis*. Pond 27 with 26.0 host individuals/m^2 was categorized as a high-density pond, whereas Pond 14 with 8.6 host individuals/m^2 was considered a moderate-density pond. Collections were made monthly from May through November 1986. All hosts in both ponds were infested by female mites, but only 57 of 90 hosts from Pond 14 and 60 of 79 from Pond 27 were infested by males. Intensity of infestation, as mean adult mites/host, was lowest in May (5.4 for Pond 14; 19.7 for Pond 27) and highest in August (12.9 and 31.3) for those ponds. Although the number of mites per host was positively correlated with host shell length for mussels in Pond 27, there was little or no correlation in Pond 14. Mite sex ratios were heavily female-biased at 10.7:1 in Pond 14, and 18.5:1 in Pond 27.

May (1983) demonstrated, by an illustration based upon mathmatical modeling, that a relationship existed between the number of animal parasites per host and the host population density. In theory, at relatively high parasite burdens and correspondingly high levels of host mortality, a host population could be regulated by parasitic infestation (Anderson and May 1978). Lanciani (1975) showed that increased numbers of an ectoparasitic water mite, *Hydryphantes tenuabilis* Marshall, reduced the rate of population increase of its aquatic insect host, *Hydrometra myrae* Bueno, in a laboratory setting.

It is often difficult to assess the extent to which a parasite regulates host population growth in nature. Therefore, the primary goal of this study was to evaluate intensity of infestations of a parasitic aquatic mite in two freshwater mussel populations at different densities. This study was carried out during the 7-month seasonal period when mussels are most active, and a secondary objective was to examine changes in seasonal intensity levels of mites in the two host populations. We also attempted to correlate intensity of infestation with host size, a relationship investigated in several previous mite/mussel studies. This paper constitutes the first report of the parasitic mite *Unionicola formosa* (Dana and Whelpley, 1836) from West Virginia.

MATERIALS AND METHODS

The subject of this study was a parasitic aquatic mite, *Unionicola formosa,* and its freshwater mussel host, *Anodonta imbecillis* (Say, 1829). Work was carried out in two ponds at the McClintic Wildlife Station, Mason Co., W.Va. The station, outlined on USGS Topographic Map, Cheshire Quadrangle, Ohio–W.Va., is a 2,800-acre (1,135-ha) wildlife sanctuary dotted by 35 ponds and managed by the W.Va. Department of Natural Resources. Ponds 14 and 27 were chosen as study sites because they harbored thriving mussel populations at densities of 8.6 (moderate) and 26.0 (high) *A. imbecillis* individuals per m^2, respectively (Harmon 1987). Pond 14 had a surface area of approximately 1.4 ha. It was a shallow pond (maximum depth of 2.4 m) with a considerable amount of rooted aquatic vegetation (coon-tail, *Ceratophyllum demersum*) arising from a silt/clay substrate. Pond 27 had a surface area of approximately 0.75 ha. It also was shallow (maximum depth of 1.6 m) with a silt/clay substrate. With the exception of a few small shoreline patches of cattail, this smaller pond was virtually devoid of rooted aquatic vegetation.

A host sample was collected, by hand, from each pond monthly from May through November, 1986. Collections were not random because a randomized procedure resulted in a sample containing disproportionately large numbers of mussels in the shell-length range of 65-79 mm. Because one goal was to estimate intensity of infestation relative to host length, some additional effort was made to collect individuals with a shell length <65 mm or >79 mm.

Each mussel was processed at the site where it was collected: cleaned, measured for its shell length with vernier calipers to the nearest 0.1 mm, and opened by severing the adductor muscles with a # 60 autopsy scalpel blade. The entire open mussel was then placed in a separate, labeled (pond designation, date, shell length) jar containing a fixative of 10% buffered formalin acetate. This procedure precluded loss of mites and exchange of mites between hosts. Hosts thus collected and preserved were transported to the laboratory. In the laboratory mites were collected from the bottom of the jars and from host soft tissues with jeweler's forceps and the use of a Zeiss stereomicroscope as needed. Only adult mites were counted. Females were easily separated from males on the basis of two or more of the following criteria: larger body size, presence of eggs, shape of palps, and differences in anal plate morphology (Vidrine 1986). The data from two collections made in the same month were combined.

Counts of female and of male mites were transformed (log_{10} [Y] for female mites; log_{10} [Y+1] for male mites). These data were then backtransformed to show mean intensity levels (as mean number of mites per infested host) with 95% confidence limits (Fig. 1A-C). To detect seasonal differences in means, log-transformed data were used in calculating *F*-values (ANOVA) on an AT&T PC 6300 computer with Microstat® general-purpose statistics package developed by ECOSOFT, Inc. A Texas Instruments statistial calculator was used for *t*-tests (Table 1) and regression analyses (Fig. 2 and 3).

RESULTS

A total of 169 *Anodonta imbecillis* individuals—90 from Pond 14 and 79 from Pond 27—were examined for *Unionicola formosa* during the 7-month study period. All host mussels were infested by female mites (Fig. 1A), but male mites were recovered from only 57 of 90 (63.3%) and 60 of 79 (75.9%) hosts in Ponds 14 and 27, respectively (Fig. 1B-C). The sex ratio of *U. formosa* was 10.7:1 (794 females: 74 males) in *A. imbecillis* from Pond 14 and 18.5:1 (1,737 females: 94 males) for the host sample drawn from Pond 27.

Mean intensity levels of female *U. formosa* in *A. imbecillis* individuals from the high-host-density Pond 27 were significantly higher than mean intensities for hosts in the moderate-density Pond 14 for every month sampled from May through September (Table 1; Fig. 1A). There was no statistical difference between the means for October, and no comparison could be made for November when no mussels were taken from Pond 27 (Table 1). Conversely, mean intensity levels of male *U. formosa* in *A. imbecillis* were essentially the same for both ponds in every month in which comparisons could be made (Table 1; Fig. 1B-C).

Although mean intensities of female mites increased seasonally from May through September in Pond 27 (Fig. 1A), those increases were not significant as determined by ANOVA on log-transformed data ($F = 2.166$, 73 df; $P = 0.0671$). Seasonal variations in log-transformed means for female mites in Pond 14 mussels (Fig. 1A) were, however, significantly different ($F = 2.504$, 83 df; $P = 0.0282$). An ANOVA on log-transformed data revealed no significant differences in mean numbers of male mites by season in either pond ($F = 0.059$, 54 df; $P = 0.7681$ and $F = 1.861$, 50 df; $P = 0.1062$ for male mites in mussels from Ponds 27 and 14, respectively).

Adult mites were positively correlated with host shell length in the high-host-density Pond 27 for every month sampled (Fig. 2). Correlations between adult mites and host length in the moderate-host-density Pond 14 were, however, largely nonexistent (Fig. 3).

Fig. 1A. Back-transformed mean number of female mites, i.e. antilog [$\overline{\log Y}$]. Horizontal lines and closed circles indicate mean numbers of *U. formosa* females in host mussels from Ponds 14 and 27, respectively. Vertical lines are 95% confidence limits around the means. Numbers above vertical lines equal host sample size. Because prevalence was 100%, number of infested mussels is the same as sample size.

Fig. 1B. Back-transformed mean number of male mites, i.e. antilog [$\overline{\log Y+1}$]. Horizontal lines indicate mean numbers of *U. formosa* males in host mussels from Pond 14. Vertical lines are 95% confidence limits around the means. Fractions above vertical lines denote prevalence, with denominator the host sample size and numerator the number of hosts infested.

Fig. 1C. Back-transformed mean number of male mites, i.e. antilog [$\overline{\log Y+1}$]. Closed circles indicate mean numbers of *U. formosa* males in host mussels from Pond 27. Vertical lines are 95% confidence limits around the means. Fractions above vertical lines denote prevalence as in Fig. 1B.

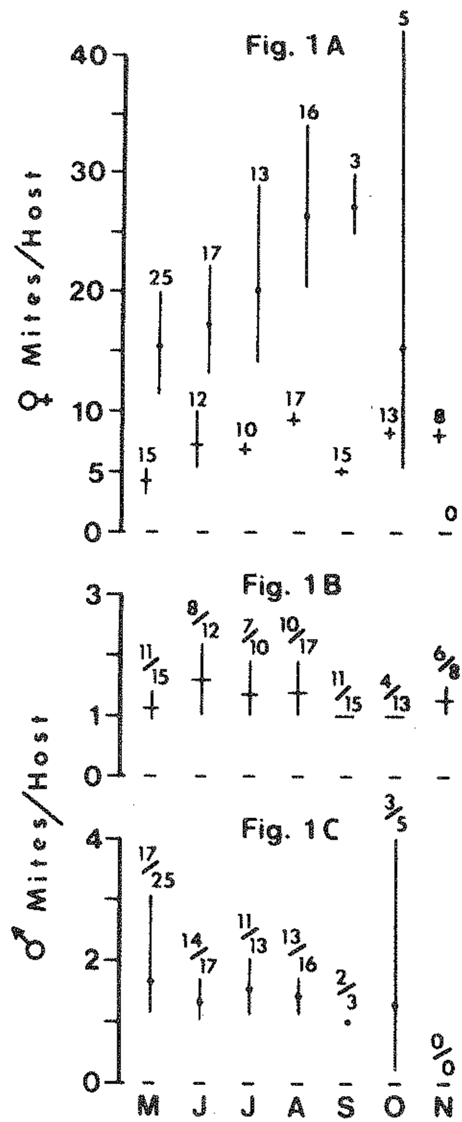

Table 1. Mean numbers of adult *Unionicola formosa* in *Anodonta imbecillis* in two po compared by month.[a]

Month	Female mites/host			Male mites/host		
	Pond 27	Pond 14	calculated t-value (two-tailed test)	Pond 27	Pond 14	calculated t-value (two-tailed test
May	18.48	4.67	$t_{0.05,38} = 5.05^b$	1.82	1.18	$t_{0.05,26} = 1.535$
	[1.19]	[0.63]	$[= 6.75]^b$	[0.42]	[0.33]	[= 1.585
Jun	19.47	8.25	$t_{0.05,27} = 3.86^b$	1.43	1.63	$t_{0.05,20} = -0.662$
	[1.24]	[0.83]	$[= 4.41]^b$	[0.37]	[0.41]	[=-0.667
Jul	23.50	8.10	$t_{0.05,21} = 3.88^b$	1.64	1.43	$t_{0.05,16} = 0.693$
	[1.31]	[0.85]	$[= 4.31]^b$	[0.41]	[0.38]	[= 0.634
Aug	29.56	12.10	$t_{0.05,31} = 4.41^b$	1.46	1.50	$t_{0.05,21} = -0.156$
	[1.42]	[0.98]	$[= 4.31]^b$	[0.38]	[0.38]	[=-0.023
Sep	27.30	6.80	$t_{0.05,16} = 7.09^b$	1.00	1.00	$t_{0.05,9}$ = nd[c]
	[1.44]	[0.73]	$[= 3.77]^b$	[0.30]	[0.30]	= [nd][c]
Oct	20.60	12.80	$t_{0.05,16} = 1.17^b$	1.33	1.00	$t_{0.05,5} = 1.187$
	[1.19]	[0.93]	[= 1.36]	[0.36]	[0.30]	[= 1.168
Nov	-	10.50	-	-	1.33	-
	-	[0.92]	-	-	[0.36]	-

[a]Initial t-tests based on raw data followed by log-transformed data in brackets.
[b]Significantly different at $\alpha = 0.05$.
[c]nd = not determined (mean = 1.0 and variance = 0 for male mites in mussels from both ponds).

DISCUSSION

The impetus for this study came primarily from two sources: (1) Vidrine's (1980) suggestion that concentrated populations of mussels harbored more *U. formosa* individuals than mussels in areas of lower density; and (2) Dimock's (1985) statement that "no association between the population biology of the host and that of symbiotic mites has yet been established." Vidrine's empirical observation should be evaluated with consideration of his extensive work on aquatic mite/freshwater mussel relationships. The present investigation strengthens, quantitatively, his generalization that mussels in a high-density population (as in Pond 27) harbor significantly greater numbers of female mites than host mussels in a moderate-density situation (as in Pond 14) (Table 1; Fig. 1A). Differences were so striking that mean numbers of female mites

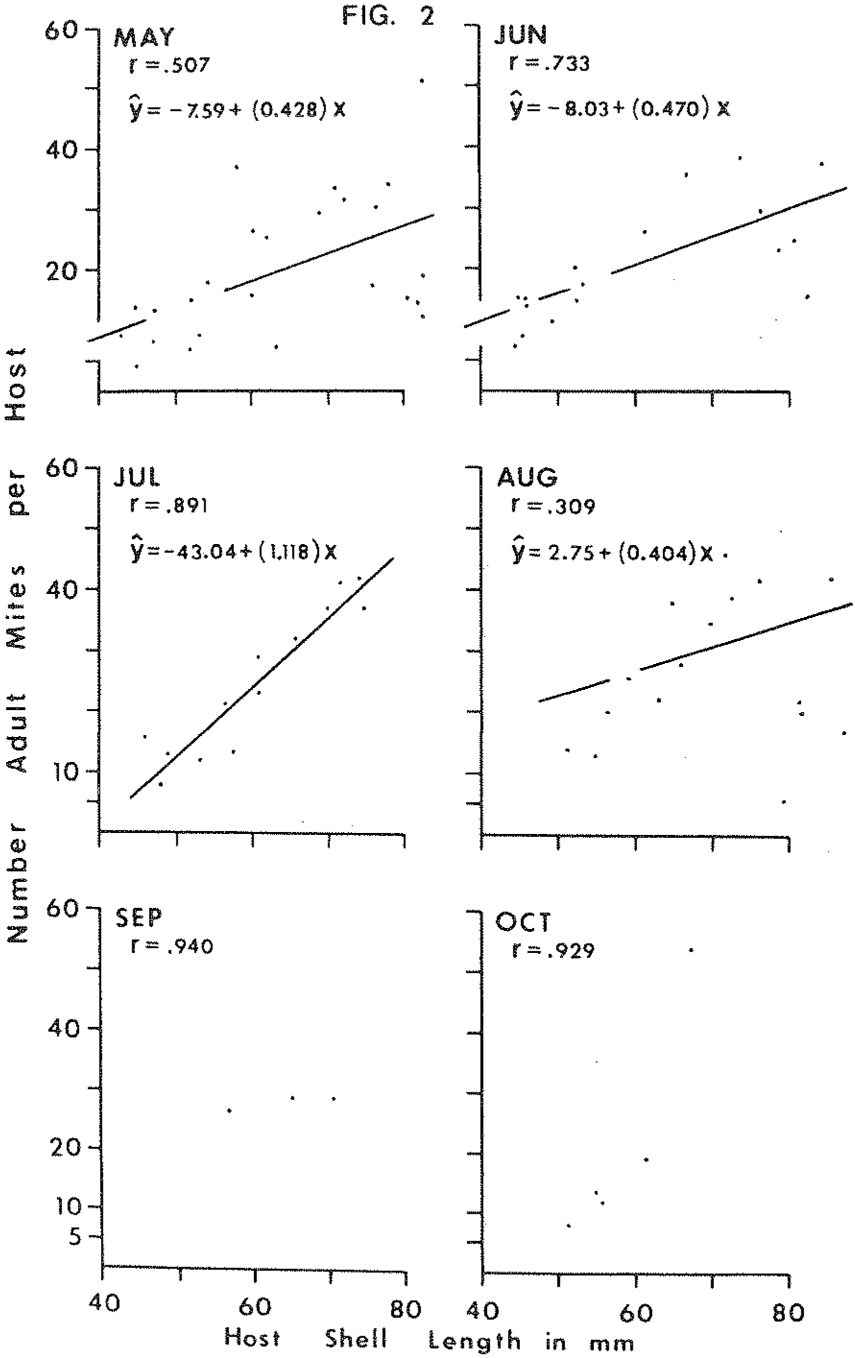

Fig. 2. Scatter diagrams showing monthly relationship between number of adult mites per host and host length. Each dot represents a single host from Pond 27.

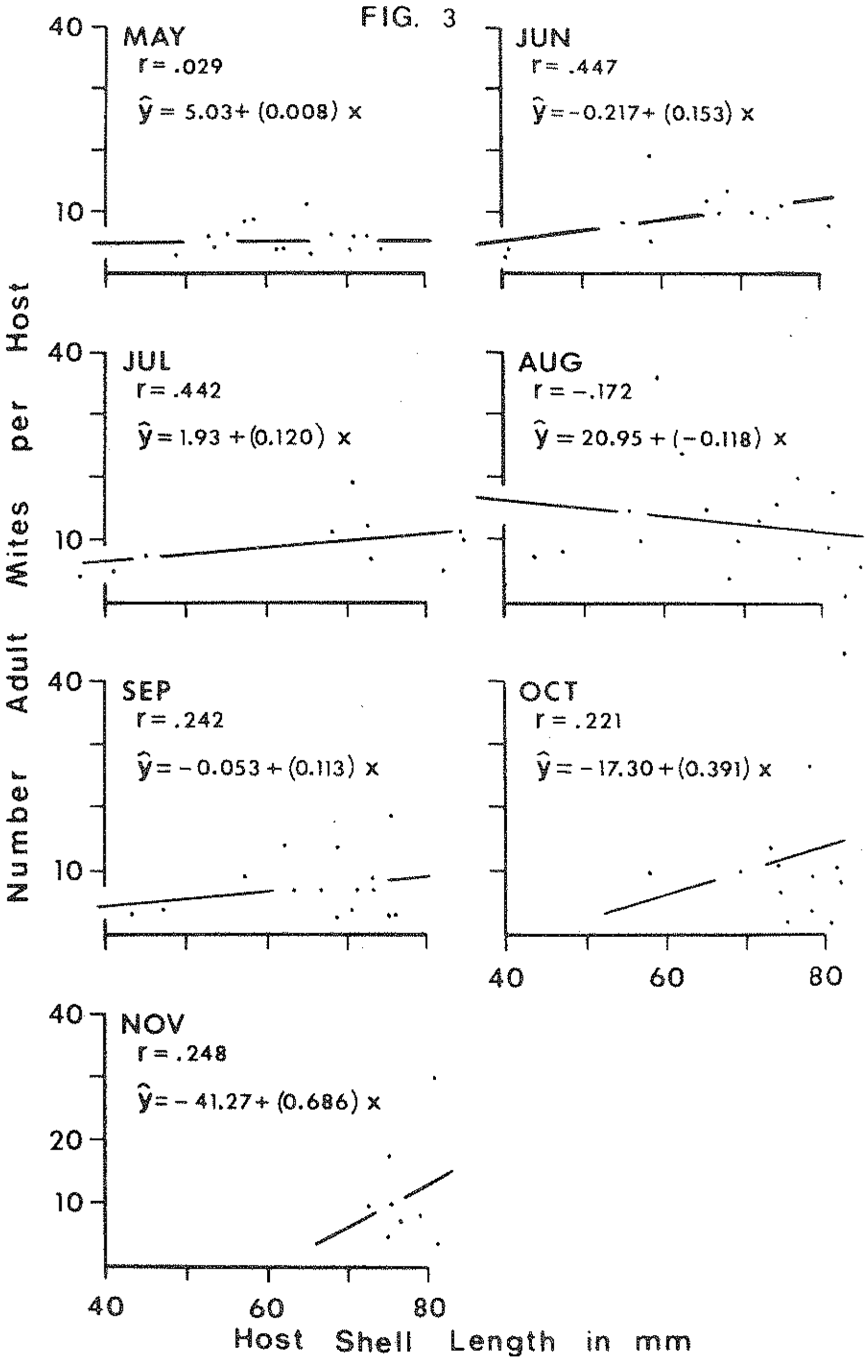

Fig. 3. Scatter diagrams showing monthly relationship between number of adult mites per host and host length. Each dot represents a single host from Pond 14.

recovered from Pond 27 hosts in May, July, and September exceeded the maximum numbers of female mites collected from mussels in Pond 14. Still, these findings must be tempered somewhat because they describe an association between host populations and the populations of their acarine parasites in only two ponds.

Although sex ratios of *Unionicola* species vary considerably (Humes and Jamnback 1950, Mitchell 1965, Gordon et al. 1979, Hevers 1980, Dimock 1983, 1985), a female-biased situation is almost universal. This condition, referred to as "harem-defense polygyny" by Dimock (1985), was also seen in the present study with female: male sex ratios of 10.7:1 and 18.5:1 in Ponds 14 and 27, respectively.

Humes and Jamnback (1950) reported an inverse relationship between prevalence of *Najadicola ingens* (Koenike, 1895) and size of *Elliptio complanata* (Lightfoot, 1786) and *Anodonta cataracta* Say, 1817, whereas Mitchell (1965) found no correlation between host size and any parameter of the population biology of *Unionicola fossulata* (Koenike, 1895). Conversely, Gordon et al. (1979) and Dimock (1985) cited positive correlations between host size and the presence of *U. formosa*, with which our findings in Pond 27 concur (Fig. 2). Previous workers tend to group all sample data on a single scatter plot to show correlations between host shell length and number of mites present. There is a possibility, however, that this approach obscures seasonal correlations. For example, if a disproportionate number of small mussels are examined in the spring, with predominantly larger mussels sampled in the fall, the question then becomes: Is the correlation size-related or season-related? To approach that question we attempted to collect *A. imbecillis* individuals across a broad spectrum of shell lengths for every sample month. Scatter diagrams were then constructed for each month (Fig. 2 and 3). Thus, in Pond 27 (Fig. 2) it is quite apparent that the positive correlations are indeed related to host shell length. The lack of correlation between host length and number of mites present in Pond 14 (Fig. 3) is not easily explained, but the seasonal factor has been removed because of a wide-ranging distribution of host lengths for each month (except for October and November).

An understanding of the growth rates and anticipated life expectancy of *A. imbecillis* individuals reveals why shell length may not be a good indicator of mites present. Harmon (1987) has rather convincingly argued that 70-79 mm will likely be the dominant size class of mussels in a population at McClintic Wildlife Station. Small *A. imbecillis* individuals grow rapidly, approaching their maximum shell length of ~80 mm after 3 to 4 years. Because a 75-mm-long individual could be in its fourth growing season, or in its eighth or ninth, it could be argued that shell length alone provides insufficient information for inferences about numbers of mites present. That argument is strengthened by our data, which suggest that host density should also be considered an important factor in determining the number of mites present per host mussel (Fig. 1A). Dimock (1985) noted that age of host may be correlated with number of mites present because increase in age would allow for increased exposure time to invasive stages of the mite. That is a reasonable conclusion even though no one has convincingly demonstrated how to age members of this mussel species—at least beyond the third growing season—with any degree of confidence. Availability of oviposition sites, as suggested by Mitchell (1965), might be a good estimator of number of mites present relative to host size. Certainly some inventive measure of weight, or of gill area, could be devised to test Mitchell's hypothesis. One feels tempted to assess the influence of mantle cavity volume, and perhaps host tissue response to mite infections as well, although the latter measure may prove exceedingly difficult to describe.

Over the past 3 years we have never been able to collect mussels from McClintic ponds in the winter months (December through February). Our lack of data for March and April is an unfortunate omission. That oversight, coupled with an unexplained population crash of *A. imbecillis* in Pond 27 that began in mid-August of 1986, further restricted our ability to draw definitive conclusions regarding seasonal influences on adult mite infections. Nevertheless, a couple of comparisons can be made. Gordon et al. (1979), whose study period covered the same months as ours, reported no seasonal differences in either prevalence or intensity of *U. formosa* infestations in *A. cataracta*. Our findings were basically similar, i.e. the prevalence was identical for every month sampled (100%) and differences in mean intensities were statistically insignificant for male mites in both ponds and for female mites in Pond 27 (Fig. 1A-C). On the other hand, Dimock (1985) noted seasonal variation for *U. formosa* in *A. imbecillis*: Adult females were most numerous in the winter and least so in late spring and summer. Although we detected significant differences between monthly means for female mites in Pond 14 ($F = 2.504$, 83 df; $P = 0.0282$), there was no seasonal trend. Means for August and September, for example, were widely separated (Fig. 1A). Thus, our knowledge of seasonal influence on populations of *U. formosa* cannot be presented as a simple generalization.

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