SOME OBSERVATIONS ON *HYDRA AMERICANA* HYMEN AS A PREDATOR OF *CULEX PEUS* SPEISER MOSQUITO LARVAE

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Predation by hydra upon mosquito larvae appears to have been a well appreciated fact by mosquito workers of the 1920's and early 1930's, but today this information comes as a surprise to many. In 1923 Hargreaves recorded, "a specimen of the coelenterate, *Hydra,* was encountered that had ingested a complete *Theobaldia* larva of the first or second instar." More meaningful is the observation of Hamlyn-Harris (1929) that hydra eat large numbers of mosquito larvae in rice fields. Matheson and Hinman (1931) considered hydra to be effective natural enemies of mosquito larvae and reported an undetermined species to ingest practically mature larvae. C. R. Twinn (1931), and more recently Stephanides (1961) however, have given to date the most informative accounts of mosquito predation by hydra.

As was the case with Twinn (1931), it was the sudden (2–3 days) destruction of a mosquito larva stock culture by a hydra population that inspired us to make the following studies. These studies include experiments to determine the feeding capacity of individual hydra for various instar mosquito larvae, hunger response and feeding intervals, influence of alternative prey, effect of hydra attachment on ability to capture prey, effect of filamentous algae on prey-predator encounter, effect of pollution, and the relative efficiency of hydra in suppressing mosquito emergence from one-time versus repeated introductions of mosquito larvae.

Methods and Materials. Several specimens of *Hydra americana* Hymen were collected from a small artificial pond at Riverside, California, where they were attached to the outside surfaces of windows of a submerged observatory. These hydra were placed in a 30 x 18 x 25 cm. plexiglass aquarium with aerated pond water 15 cm. deep recirculated through 2–3 cm. of fine gravel. Several strips of 32-mesh saran cloth were anchored into this gravel as a substrate for hydra attachment so that pieces could be cut and hydra could be transferred individually from one container to another with minimum disturbance.

Stock cultures of hydra were maintained on a diet of first instar *Culex peus* Speiser mosquito larvae hatched from egg rafts collected from a source cultivated to supply these and other experiments. This source was a square meter fiberglass tub containing a submerged dead fowl. Mosquito oviposition at this polluted source produced several hundred egg rafts per day for several weeks. Since *C. peus* is an ornithophilic species, humans in the area were not attacked. Had the attracted species been anthropophilic, alternate breeding units could have been used, each being discontinued as mosquito emergence began.

In laboratory experiments, mosquito larvae, and also entomostraca used as alternative prey, were fed Tetramin [3] flake tropical fish food. In a given experiment, care was taken to employ mosquito larvae of uniform age. This uniformity was attained by hatching *Culex* egg rafts

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[3] Tetramin Staple Fish Food. Mfg. TetraWerke DR. rer. nat. Baensch MELLE, West Germany.

in enamel trays of pond water for prescribed time periods after which unhatched eggs were removed. Desired numbers of given larval instars were then removed as needed.

DESTRUCTIVE CAPACITY OF HYDRA. In order to determine the destructive capacity of individual hydra for various instar mosquito larvae, they were isolated in small (50 mm.) petri dishes. Ten dishes were each filled 1 cm. deep with water and individual well-fed hydra were placed in five of these while five were left as checks. Twenty-five first instar mosquito larvae were then added together with larval food, to all dishes. After 24 hours, surviving larvae in all petri dishes were counted by means of a dissecting microscope. The difference in the number of surviving larvae in treatments and controls was attributed to hydra. The study was repeated using second, third, and fourth instar larvae and pupae of *Culex peus*.

RESULTS. Individual hydra receiving only mosquito larvae as prey destroyed an average of 21 (18–24) first instar larvae within 24 hours. The 24-hour mortality of second and third instar larvae averaged 12.6 (7–15) and 6 (4–8) larvae, respectively. Only one fourth instar larvae and no pupae were destroyed in any replicate.

Table 1 compares larval survival from this study with that from the following where hydra had available a mixture of entomostraca as alternative prey.

TABLE 1.—Survival of different instar larvae and pupae of *Culex peus* Speiser exposed to individual *Hydra americana* Hymen for 24 hours in petri dishes with and without alternative prey (entomostraca). Percent survival from 5 replicates per instar with 25 prey each.

Prey instar	Percent survival: With entomostraca (Alt. prey)	Without entomostraca (Alt. prey)	Check
I	12.0	13.3	100.0
II	60.7	54.0	100.0
III	72.7	75.2	100.0
IV	100.0	99.2	100.0
Pupa	100.0	100.0	100.0

EFFECT OF ALTERNATIVE PREY. The influence of alternative prey on mosquito larva destruction by hydra was studied in two sets of experiments, the first in 50-mm. petri dishes as used previously and the second in 1200-ml. filter aquaria (Bay, 1967). Alternative prey offered hydra included various mixed entomostraca (Cladocera, Copepoda and Ostracoda). In the petri-dish experiments the general procedures were the same as in the earlier series except for the addition of entomostraca. Each of five petri dishes received 1 hydra, 25 mosquito larvae of a given instar, and a mixture of cladocerans, copepods and ostracods. Five check dishes contained mosquito larvae and mixed entomostraca, but no hydra. Mortality was determined at 24 hours.

In the filter aquaria introductions of 200 first instar larvae were made singly with or without entomostraca present. In each unit with the exception of checks, they were exposed to five hydra. All treatments were replicated 5 times. The efficiency of hydra as predators on mosquito larvae with and without entomostraca as alternative prey was based on the number of mosquito adults that emerged in treatments with hydra compared with checks. Changes that occurred in hydra populations were noted at the conclusion of the experiment.

RESULTS. Mosquito larvae were not injured directly by entomostraca. Also, the availability of entomostraca did not reduce the number of mosquito larvae preyed upon by hydra either in petri dishes (Table 1) or in filter aquaria (Fig. 1). Noteworthy, however, is that in filter aquaria hydra survival was 42 percent greater with entomostraca present than without. Where entomostraca were present only one replicate had fewer than the original five hydra at the completion of the experiment and one replicate had increased to six hydra. Without entomostraca all except one replicate ended with fewer than five hydra. An interesting sidelight of the filter aquarium studies is that although

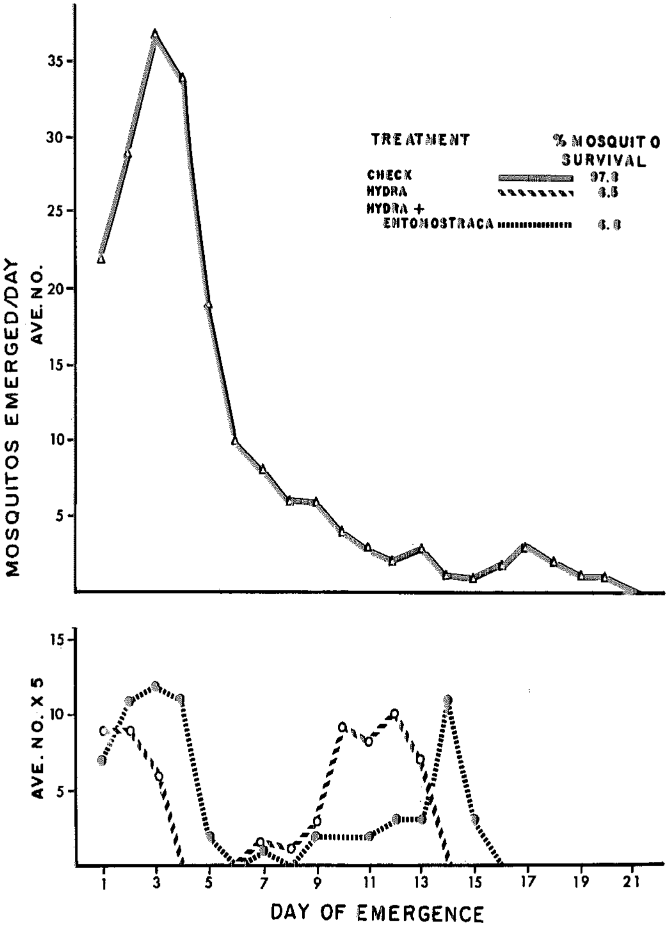

Fig. 1.—*Culex peus* mosquito emergence from fifteen 1,200-ml. aquaria, ten with and five without hydra predation, and of the ten with hydra five of these with entomostraca present as alternative hydra prey. Each aquarium was initially supplied with 200 first instar larvae. Hydra aquaria each contained 5 hydra.

the initial mosquito emergence was more than 90 percent reduced by hydra, enough larvae survived in 9 out of 10 units to enable a second emergence of equal magnitude 10 to 12 days later. One explanation for this second emergence might be that a percentage of the introduced larvae could have had their development temporarily retarded by some labile substance perhaps produced by the first maturing individuals, and that these late developing larvae were at such low density as to escape predation. This hypothetical substance would logically be produced in even greater quantities in the checks but, without predators to temporarily eliminate the critical stage producing the substance, its attenuation would be more gradual thus extending emergence while preventing a second peak. This phenomenon is not an isolated instance but has occurred in other predator studies to be published at a later date.

HYDRA ATTACHMENT AND PREY CAPTURE. It is not uncommon for hydra to float inverted against the surface film of quiet water buoyed by a gas bubble secreted by the basal disc. It is reasonable to assume that hydra, in this attitude, would be in a particularly good position to prey upon mosquito larvae. It was observed that free-floating hydra are capable of capturing first and second instar larvae of *Culex peus,* but that larger larvae escape quite easily, freeing themselves by jerking the floating hydra about. Also, the time taken to devour a larva is much longer for floating than for attached hydra. In five trials the average engulfment time beginning with capture for first instar larvae by floating hydra was 13 minutes (range 10–15 minutes) compared with 7 minutes (5–10 minutes) for attached hydra. In similar trials second instar mosquito larvae were captured and consumed in average times of 22 and 10 minutes, respectively, by floating and attached hydra. Third instar mosquito larvae were captured and engulfed in an average of 12 minutes by attached hydra, but not at all by free-floating hydra.

Unattached hydra generally had difficulty maneuvering their prey into position for engulfment. When they succeeded it was by working their prey to the bottom substrate and inverting themselves over it in the feeding attitude of a starfish.

FILAMENTOUS ALGAE INFLUENCE. From the preceding study, it might be assumed that filamentous algae could aid hydra in mosquito larva capture by providing a network for hydra distribution and attachment. On the other hand the algae, like other submerged vegetation, might afford the larvae protection from hydra as it can from other predators. To investigate these alternate possibilities ten 90-mm. petri dishes were half filled with pond water and a loose web of *Cladophora* was placed in each so that, as occurs in nature, some of its strands barely broke the water surface. The algae used were first washed with tap water and closely examined for unwanted organisms. Next, 50 first instar mosquito larvae were introduced into each dish, five dishes with 3 hydra apiece and five without hydra. Mosquito larvae were kept fed in all treatments. As with previous experiments this one was repeated with older larvae through fourth instar.

RESULTS. Algae interfered appreciably with frequency of predator-prey contact between hydra and mosquito larvae. Despite a higher (3:50 vs. 1:25) predator to prey ratio substantially fewer (2 vs. 21) first instar larvae were killed within 24 hours than in earlier individual feeding capacity studies without algae. Some larvae were destroyed in all first instar units, whereas second and third instar larval mortality was more localized. Nine second instar larvae were killed in one unit and none in four others while third instar mortality was 11, 3, 1, 0, 0 in the respective dishes. This would seem to suggest that the smaller first instar larvae were better able to negotiate the algal matrix coming more frequently into contact with the hydra. Larger larvae presumably were restricted in movement and only those that happened in immediate reach of the hydra were destroyed. No fourth instar larvae were killed.

HUNGER RESPONSE AND SATIATION. Five pairs of hydra were observed with a dissecting microscope to determine the frequency with which individuals accepted prey. Observations of each pair were each made with 25 larvae of a given instar placed in a 50-mm. petri dish containing fresh pond water. The elapsed time between which each hydra engulfed one prey and accepted a second was recorded. This time varied appreciably, ranging from 25 to 120 minutes for ten observations with first instar larvae. However, most hydra took their second prey within an hour. The number of prey consumed varied with the age and size of the hydra, with newly detached buds usually being satisfied with a single first instar larva. Within any one feeding period as many as 8 first instar larvae or 3 second instar larvae were successively consumed by a mature hydra before satiation occurred. If a third instar larva was first taken no additional prey were accepted until after digestion was complete. Digestion time following repletion varied from 1½ to 3 hours. The remains of larger meals such as a single third instar or eight first instar larvae were usually voided en masse in about 3 hours.

Hungry hydra normally captured the first prey they contacted while satiated hydra did not. It was also noted that once a hydra had captured a larva, neighboring unfed hydra responded by lengthening themselves or "walking" in the direction of the capture (Fig. 2). Often more than one hydra would attack the same larva although only one would succeed in engulfing it. Also our observations confirmed those of Twinn (1931) that hydra will kill more larvae than they can consume as food. This happens particularly with captured larvae that are too large to be consumed (Fig. 3). These larvae were frequently held paralyzed and immotile for several minutes until too late for them to recover, and ultimately released.

Hungry or unsatiated hydra were observed to maintain an extended "hunting" posture for from 24 to 30 hours after which, if food was not obtained, the tentacles gradually withdrew and the column-like body began to shrink. With continued lack of food, the hydra became increasingly cyst-like but remained sensitive to prodding for approximately 72 hours. Within a week unfed hydra were reduced to cysts 1 mm. in diameter.

Pollution Response. Hydra are generally found associated with clear unpolluted water not characteristic of most *Culex peus* habitats. Therefore, brief attention was given to testing the response of hydra to organic pollution by contaminating their water with slight amounts of poultry mash. The resulting response by hydra was similar to that caused by starvation except that it was much more rapid. In polluted water the hunting posture was

Fig. 2.—*Culex peus* second instar larva engulfed by *Hydra americana*. Observe second hydra at upper end of twig extending in direction of capture.

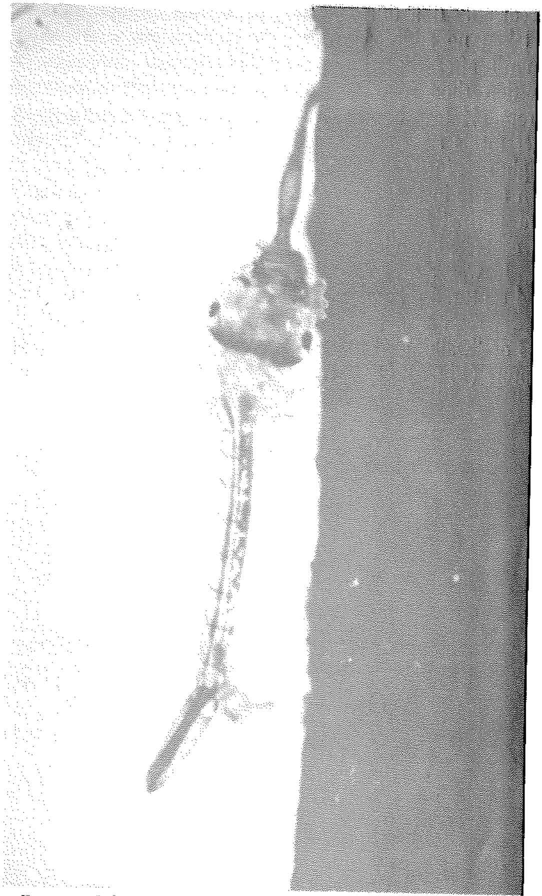

FIG. 3.—*Culex peus* larva too large for ingestion suspended paralyzed by *Hydra americana.* Mosquito larvae so paralyzed seldom recover.

maintained for a maximum of 24 hours after which the hydra shrank into a ball and died usually within 24 hours unless fresh water was substituted. In this case hydra often recovered.

EXPANDED ENVIRONMENT. Lastly, it was decided to use a larger environment than the experimental units described in order to quantify the ability of an established hydra population to reduce mosquito emergence from repeated larval introductions. It was noted that while several thousands of surplus mosquito larvae from preceding experiments had been supplied the 12-liter plexiglass hydra culture aquarium and regularly fed for more than a month, none of these survived to become adult. The exact number of hydra in the culture at any time was never determined, but was estimated to range between one and two hundred individuals. From a total of 12,500 first instar mosquito larvae introduced into this aquarium over a 30-day period only two adult mosquitoes ever emerged. These introductions comprised nine collections of larvae given at 3-day intervals. A check aquarium without hydra given 250 larvae on the first day of this experiment produced 100 percent emergence.

DISCUSSION. The ability of hydra to destroy populations of mosquito larvae in the laboratory is startling. Undoubtedly there must be many urecognized instances where the same occurs in the field. However, to quote from Hamlyn-Harris (1929) ". . . it would be very unwise to place false faith in what we know only to be effective under the most ideal conditions." Laird (1956) has suggested that hydra might profitably be introduced into certain of the South Paific Islands where they apparently do not occur, and Stephanides (1960) has suggested that *Hydra vulgaris* might be put to practical use in mosquito control if their breeding places could be studied on a large scale and their propagation artificially encouraged. This may be. However, at best it appears that hydra would be applicable to very limited mosquito control situations. One problem is their apparent inability to thrive in organically rich water favored by many mosquitoe species. Another is their seasonally sporadic ocurrence in nature.

Hydra populations commonly occur for only a few weeks in the spring in temperate lakes and ponds, and sometimes again in the fall. This is one drawback that with study could conceivably be circumvented since it is possible to sustain continuing populations of hydra for more than a year in the laboratory. Although hydra normally reproduce by vegetative budding, syngamic reproduction is induced as living conditions became unfavorable due to cold or drying. This reproduction results in the production of thecated embryos that are said to be highly resistant to both drying and freezing (Pennak 1953). If research could exploit this phase of hydra reproduction and thecae could be economically mass produced then hydra might indeed find practical if limited application in mosquito control, especially against species of *Anopheles* and *Culex* that frequent clear water.

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