

A LABORATORY STUDY OF PREDATION BY DAMSELFLY NYMPHS, *ENALLAGMA CIVILE*, UPON MOSQUITO LARVAE, *CULEX TARSALIS*

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ABSTRACT. The nymph of the damselfly, *Enallagma civile*, feeds on the larvae of the mosquito *Culex tarsalis* amongst a variety of other small aquatic invertebrates. Average daily consumption of 3rd instar *Cx. tarsalis* larvae by the last nymphal stage of *E. civile* was 6.06 larvae (range 4.64–8.67). Experiments in which density of prey (mosquito larvae) and predators (*E. civile* nymphs) were varied, showed that more prey was consumed as prey density increased. However, fewer prey were consumed at higher predator densities; mutual interferences among predators at higher predator densities was suspected.

INTRODUCTION

The damselfly nymph, *Enallagma civile* (Hagen) is the most abundant aquatic insect inhabiting many San Joaquin Valley rice fields in California (Miura et al. 1981). The nymphs feed chiefly on small crustacea, annelids and aquatic insects including mosquito larvae (Penak 1953, Lee 1967, Collin and Resh 1985). Laird (1956) based upon field observations and laboratory studies concluded that zygopterans were more effective predators of immature mosquitoes than anisopteran nymphs because the former generally tend to prey closer to the proximity of the mosquito, i.e., near the water surface. The objective of this study was to determine the predation performance of *E. civile* nymphs upon *Culex tarsalis* Coquillett larvae by varying both the predator and prey densities.

MATERIALS AND METHODS

Enallagma civile nymphs used in these experiments were collected from commercial rice fields in Western Fresno County, California. Nymphs collected from fields were sorted to species and held in the laboratory for 48 hr before use. The nymphs were then placed in 75 mm diam × 100 mm high plastic foam cups containing 200 ml tap water (pH 7) and a few strings of *Chara* sp. or *Najas graminea* (their natural substrate in the aforementioned rice fields). The substrate provided clinging sites and allowed the damselfly nymphs access to all parts of the testing cup. All experiments were performed in the insectary or holding room maintained at a temperature of 80°F (26.7°C) and a L:D light cycle of 14:10. A laboratory colony of *Cx. tarsalis* provided 3rd instar larvae for use as prey animals in all experiments. The allocated prey densities were added to each test cup containing predators and on the following day (24 hr exposure) the remaining live prey were removed and counted to determine the rate of

predation. Controls without predators were used for each test.

Predation performance test. The last nymphal stage (12th) of *E. civile* was used for this study. The nymphs had well developed wing pads and were ca. 10 mm from front of prothorax to rear tip of the abdomen minus the caudal gills. Fifteen mosquito larvae were introduced daily into each testing cup, containing a single damselfly nymph, until the nymph emerged into an adult. Our preliminary tests indicated prey density of 15 larvae per nymph was above the maximum this damselfly species could consume in 24 hours. The test cups were counted every 24 hr just before introducing new prey. There were 15 test cups and the test was replicated 10 times.

Prey density test. Medium size nymphs with small wing pads (9th–11th instars, Parman 1981¹) were used for this test. Two nymphs were placed into each testing cup but were denied food for 48 hr before testing. Mosquito larvae were then introduced daily into the testing cups at 6 rates: 10, 20, 30, 40, 50, and 60 larvae per cup per day. After a 24 hr exposure, the remaining larvae were counted, discarded and a new set was added for the next 24 hr exposure. The test was continued until all damselfly nymphs emerged and each test was replicated six times.

Predator density test. Predation response to predator density was determined for 2 response groups. One group was fed daily for 5 days and the other group was fed on 5 occasions every 3 days. In both groups prey densities of 10, 30, 50 and 80 mosquito larvae were introduced to predator densities of 1, 3, 6 and 9 medium sized nymphs in test containers. There were 10 test cups for predator density = 1; 8 cups for density = 3 and 6; and 7 cups for density = 9. Counts and replacements were made every 24 hr, as with other tests.

RESULTS AND DISCUSSION

Predation performance. The results of the predation performance test are shown in Fig. 1. The

mean daily predation rate of the last instar (12th) *E. civile* was 6.06 third instar larvae of *Cx. tarsalis* (range = 4.64–8.67 per nymph per day). It is well known that the feeding behavior of damselfly nymphs changes according to the developmental stages; younger instars prey on smaller whereas older instars prey on larger organisms (Lee 1967, Collin and Resh 1985). Our data (Fig. 1) show that the predation performance of *E. civile* changes even within the same instar; the older age group of the last instar nymphs appear to consume less larvae per day (Fig. 1). The daily consumptions were examined by student *t* test; the results of the test indicate that the older age groups were markedly consuming less larvae starting ca. 6 days prior to emerging into adults ($P < 0.05$).

Effects of prey density. The number of larvae consumed by two medium-sized *E. civile* nymphs during a 24 hr period at various prey densities are shown in Fig. 2. Although at lower prey densities a higher percentage of the offering was consumed by the predator, at higher prey densities more prey were consumed per predator (Fig. 2); thus exhibiting a typical invertebrate functional response for increasing prey density (Solomon 1949, Holling 1961). At the higher prey densities (e.g., 40, 50 and 60 per cup) the number of prey consumed seems to taper off to an apparent asymptote. This peak may be the maximum consumption rate for two *E. civile* under these conditions.

Effects of predator density. The results of this test are shown in Fig. 3. Nymphs fed every 3rd

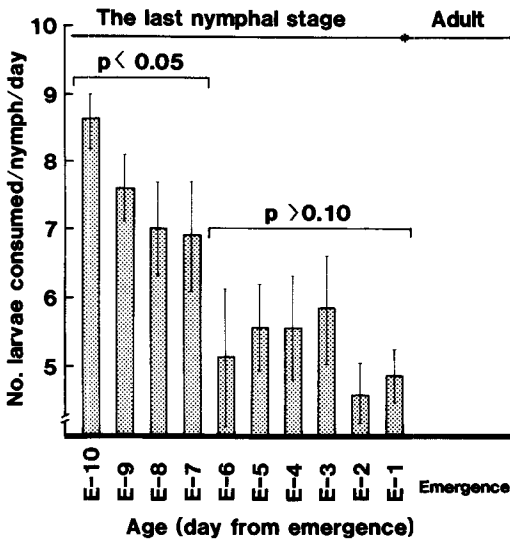


Fig. 1. Daily predation rate of *Enallagma civile* nymphs during the last instar stage on *Culex tarsalis* 3rd instar larvae. Each bar indicates mean ± SEM. Age in days for each instar is calculated from start of emergence (E to 1, E to 2, . . . , E to 10 days).

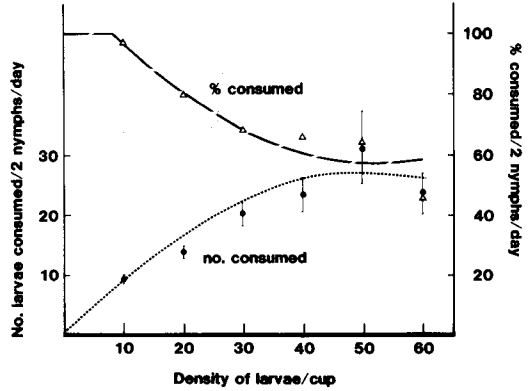


Fig. 2. Predation rate by *Enallagma civile* nymphs (9–11th instar) on *Culex tarsalis* larvae (3rd instar) due to varying the number of prey. Each bar indicates mean ± SEM.

day always consumed significantly more larvae than those fed daily. Among predator densities tested, solitary nymphs consumed more larvae than nymphs that were grouped (3, 6, 9 per cup). As predator density increases consumption rate decreases, indicating mutual interference among predators (Holling 1961). This phenomenon was more pronounced among the daily fed nymphs. Among nymphs fed every 3rd day, interference appeared to be a factor only in the higher (6 and 9 per cup) nymphal density group.

In summary, we have demonstrated that the last instar *E. civile* are capable of preying on 3rd instar *Cx. tarsalis* at a rate of 6.06 larvae per day. Since the last instar lives for about 30 days (Parman 1981¹), it could potentially eat about 182 larvae or, in other words, all the larvae from the offspring of certain California *Cx. tarsalis* egg rafts (183 eggs × hatch rate is 0.728, White 1980²) provided no other prey organisms are available. Although there are dozens of other predators which prey on mosquito larvae in the Central California rice field environment (Miura et al. 1981), we feel damselfly nymphs are a major contributor to mosquito predation in rice fields because, among the predators known to prey on *Cx. tarsalis* larvae in this particular environment, they dominate overwhelmingly in numbers and also because they share the same type of habitats as those of the mosquito larvae (Miura et al. 1981).

¹ Parman, R. 1981. The seasonal life histories of two species of *Enallagma* (Charpentier) in Madera County, California. M.S. Thesis. California State University, Fresno. 33 p.

² White, K. D. 1980. Effects of larval density on the growth rate and size of a *Culex tarsalis* mosquito population. Ph.D. dissertation. University of California, Davis. p. 67–76.

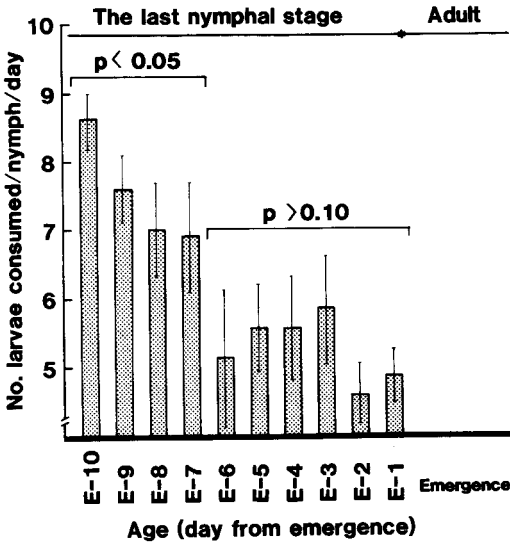


Fig. 3. Predation rate by *Enallagma civile* nymphs (9–11th instar) on *Culex tarsalis* larvae (3rd instar) due to varying the number of predators and feeding regimes. Each bar indicates mean ± SEM.

We have also demonstrated a positive correlation between prey density and prey consumed. However, there is an inverse correlation between predator density and prey consumed. This was apparently due to predator interference.

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