# AN ASSESSMENT OF *PLEA STRIOLA* [HEMIPTERA: PLEIDAE] AS A MOSQUITO CONTROL AGENT IN CALIFORNIA

R. M. TAKAHASHI, R. J. STEWART, C. H. SCHAEFER

University of California Mosquito Research Laboratory, 5544 Air Terminal Drive, Fresno, CA 93727 AND

R. D. SJOGREN

Metropolitan Mosquito Control District, 1802 Como Avenue, St. Paul, MN 55108

ABSTRACT. Adults of the pigmy backswimmer, *Plea striola* (Fieber) were brought to California from Minnesota. Pleid adults readily feed on mosquito larvae and do not attack other mosquito predators. Adult *P. striola* require an exposure to overwintering conditions prior to reproduction. Releases of pleid adults at 2 field locations did not result in the establishment of permanent populations. High temperatures at a 415 m elevation site and the predation by notonectid backswimmers at a 1800 m site apparently were responsible for their elimination.

## INTRODUCTION

Members of the species *Plea striola* (Fieber) are minute (2mm), predatory hemipteran insects commonly called pigmy backswimmers. They are best known for feeding on small aquatic crustaceans (Bare 1926, Gittelman 1974), but also have been observed feeding readily on mosquito larvae. Personnel from the Metropolitan Mosquito Control District ("MMCD," St. Paul, Minn.) have made field observations of *P. striola* feeding on mosquito larvae, and our own preliminary laboratory assessment supports this observation (Fig. 1).

The species is widely disseminated in the eastern United States and southern Canada but even the genus appears not to be represented in California. In terms of predation on other beneficials, there is no evidence of harm to other predators nor to plant life (Gittelman 1974).

Their method of attack appears to be one of clinging to emergent or floating vegetation just below the water surface and waiting until their prey come close enough so that the pigmy backswimmers have to move only short distances for the capture. As *P. striola* prefer shallow, standing or sluggish water with abundant vegetation (Drake and Chapman 1953, Gittelman 1974), they seem suited for introduction as control agents where vegetative cover may deter or reduce the effectiveness of other control measures. Although there have been laboratory and field studies concerning their range, description and habitat (Bare 1926, Drake and Chapman 1953, Ellis 1965, Gittelman 1974,-1975,-1977,-1978), virtually no work has been done aimed at their possible use as biological control agents.

Laboratory observations were made to observe the effectiveness of backswimmer adults as predators of the southern house mosquito, *Culex quinquefasciatus* Say, by introducing the mosquito's 1st and 4th instars to the predators.

In addition we made field releases of *P. striola* adults in ponds at 2 geographically different sites to determine if the insect would survive.

## MATERIALS AND METHODS

LABORATORY STUDIES. To determine predatory effectiveness, *P. striola* adults were introduced singly into storage dishes (80 × 100mm) containing 250ml of conditioned tap water; 5, 10, 20 or 40 first or 1, 5, 10 or 20 fourth instars of the southern house mosquito were added to each dish in duplicate. Another duplicated series was run with predator densities of 0, 1, 5 or 10 adults/dish and prey densities of 40 first or 20 fourth instars/dish.

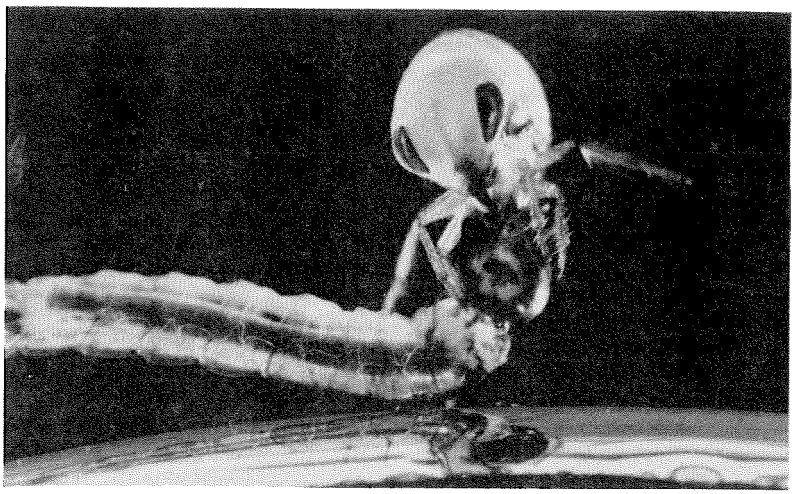

Fig. 1. *P. striola* feeding on mosquito larva.

Additional tests compared jars containing floating substrates (either duckweed, *Lemna* sp., or 15 × 70mm styrofoam chips for the backswimmers to cling onto) to jars without floating substrates. For these comparisons each jar contained 1 pleid adult and 1, 5, 10 or 20 fourth instars (in duplicate). Each day the mortalities of mosquito larvae were recorded; all larvae were then removed and fresh batches of larvae were added.

Laboratory observations were also made to determine if the pleids would prey on known mosquito predators. In 1 gal. glass jars containing 2 liters of tap water, individual *Gambusia affinis* (Baird and Girard) fry (ca. 8mm) were introduced to *P. striola* adults at densities of 1, 10, 20 and 40 adults/jar. In addition adult *Notonecta unifasciata* Guerin were individually compared under the same conditions to densities of 1, 10 and 20 pleids/jar. Each density was duplicated and each jar was checked daily for mortality. The pleids were fed the day before introduction, the mosquitofish were given 25mg powdered fish food every 3 days and the notonectids were given 20 fourth stage mosquito larvae every 6 days, which were readily consumed. The tests were run 18 days for mosquitofish and 15 for notonectids.

In August of 1977, several hundred *P. striola* adults were received at Fresno from the MMCD; these were held at ambient temperatures (19–31°C) until November but no matings were observed and no oviposition occurred. Surviving adults were then divided into 3 groups of about 50 each. One group was held outdoors under a covered patio, the 2nd was placed in an incubator at 20°C, under a 7 hr light-17 hr dark cycle, and the 3rd remained under ambient laboratory conditions. Since no oviposition was apparent in any of the groups by December, the temperature of the incubator was lowered to 4.5°C and left there for 32 days.

FIELD RELEASE. Two sites were selected for the release of the pigmy backswimmers. The first was located near Yosemite National Park in a yellow pine forest at an elevation of about 1800m in Mariposa County, Ca. The release was made to a pond of about 0.16 hectare. Dominant vegetation surrounding the pond was sugar pine, white fir, incense cedar, deer brush, greenleaf manzanita, sierra

gooseberry, sierra currant, mountain misery and western azalea. The emergent vegetation in the pond consisted of common horsetail *Equisetum arvense* L., sedges *Carex paucicostata* Mackenzie and *Carex feta* Bailey, rush *Juncus macrandrus* Coville, manna grass *Glyceria elata* (Nash) Mitchell, bulrush *Scirpus microcarpus* Presl, bedstraw *Galium trifidum* L., and *Trisetum spicatum* (L.) Richter. The pond was fed by snow runoff and was estimated to be 2m at maximum depth. There were one inlet and two outlets (one was seepage). Two sides (N. & W) had feathered slopes and the other sides were moderately steep. Invertebrate predators in the pond included the backswimmer *Notonecta kirbyi* (Hungerford), predacious diving beetles *Agabus lutosis* LeConte and *Rhantus* spp. Dejean, in addition to the water strider *Gerris remigis* Say. Other arthropods were corixids, mayfly naiads, midge larvae, ostracods, water fleas, copepods and water mites. Also found in samples were 2 mosquito species *Culiseta incidens* (Thomson) and *Cs. impatiens* (Walker). The pond water had a pH of 5.9 and conductivity of 15$\mu$mhos/cm at 12.5°C.

The 1st release was made on May 22, 1978. Adult *P. striola*, which were collected in Hennepin County, Minnesota with battery powered light traps a few days before, were acclimated to the Yosemite pond temperature (13°C) in plastic bags. The pond was inoculated with about 2000 adults on the north side, where the emergent vegetation was the densest and the pond slope was shallowest (ca. 0.2m). A 2nd release, June 5, 1978, was made at the same site with an estimated 10,000 adults.

The pond was sampled on 6 occasions between May 22 and August 22; at least 10 sweep samples were taken on each occasion near the pond edge and in vegetation with a 25cm diam. aquatic net (8 mesh/cm) using a 1.7m long sweep at about 30 cm/sec. Also 10 to 60 samples were taken, on collection days, near the periphery with a 450 ml enamelled dipper. Samples were condensed with a fine nylon screen, placed in alcohol jars and transported to the laboratory for examination.

In addition 2 to 6 battery powered aquatic light traps were set just below the water surface, first at only the release site but later around the pond's perimeter. Traps were 9 × 15 cm clear plastic or glass jars modified with inverted funnels with 15mm openings over which 2.5cm drain cups (with numerous 4mm holes) were attached to prevent entry of large predators. Each trap had 2 "D" cell batteries powering a G.E.™ PR9 bulb.

The second release locale was an "L-shaped" pond (0.2 hectare) located on flat, grass and farm land surrounded by rolling hills, at an elevation of 415m, in Lake County, Ca. Vegetation surrounding the pond consisted mostly of narrow leaf annual grasses with only a few trees. This pond, also relatively shallow (ca. 0.5-2m) appeared to be fed by seepage and farm runoff waters. The vegetation in the "L" pond was more abundant than the Yosemite pond and with algae as well as emergent vegetation. Dominant aquatic vegetation consisted of algae *Diatoma* sp., *Porphyrosiphon notarisii*, (Menegh.) Kütz. *Spirogyra* sp., *Mougeotia* sp.; hornwort *Ceratophyllum demersum* L., rush *Juncus* spp., and cattail *Typha* sp. Although most of the banks were relatively steep, the release site was shallow, somewhat feathered and dominated by a stand of rush. This pond had a pH of 9.5 and conductivity of 600$\mu$mhos/cm at 23°C.

The only release made on the "L" pond was on June 16, 1978. The pleids were acclimated to the 27°C water temperature at the release site and approximately 1600 were inoculated in the pond. Post-inoculation samples were taken by Lake County Mosquito Abatement District personnel principally with a 25×25×30 triangular aquatic dip net by sweeping three 1m samples, 20cm below the surface, at each of the 5 sampling stations located around the periphery. One of the stations was the release site.

## RESULTS

LABORATORY TESTS. Based on average

Table 1. Duncan's Multiple Range Analysis indicating the effect of prey on the number of *Culex quinquefasciatus* 1st and 4th instars killed/day by *Plea striola* adults. Underscoring shows non-significance between a range of means.

| *Cx. quinquefasciatus* | Signifi. level | Mean no. of prey killed/predator/day and underlined ranges of non-significance[a] Prey Density[d] 1 | 5 | 10 | 20 | 40 | LSD | df |
|---|---|---|---|---|---|---|---|---|
| First instar[b] | .05 | | 1.9 | 3.2 | 3.75 | 4.95 | 1.644 | 76 |
| | .01 | | 1.9 | 3.2 | 3.75 | 4.95 | 2.183 | |
| Fourth instar[c] | .05 | 0.208 | 0.458 | 0.542 | 0.958 | | 0.224 | 272 |
| | .01 | 0.208 | 0.458 | 0.542 | 0.958 | | 0.294 | |

[a] Duncan's Multiple Range Test.
[b] 10 day feeding trial with 2 replicates.
[c] 18 day feeding trial with 2 replicates.
[d] Predator (pleid) density was 1 per container.

number killed (Table 1) *P. striola* adults are apparently better predators of 1st instars of the southern house mosquito larvae than 4th. Also the number of prey killed increased as prey density increased for both 1st and 4th instars. Analysis of the sample means showed a significant difference between any 3 means but not between any two (Duncan's Multiple Range test, 5% level).

Analysis of predator density (Table 2) shows that the number of prey, in both stages, killed per individual predator decreased as predator density increased; i.e. 1 pigmy backswimmer per sample killed significantly more per predator than both 5 or 10 per sample.

There were no significant differences in predation between arenas with and without floating substrates.

The results of laboratory observations to determine if *P. striola* adults prey on *Gambusia affinis* fry and *Notonecta unifasciata* adults showed that no mortality occurred to these organisms when introduced to the pigmy backswimmers at the ratios described.

All the pleid adults maintained under

Table 2. Duncan's Multiple Range Analysis indicating the effect of predator density on the number of *Cx. quinquefasciatus* 1st and 4th instars killed/individual/day by *P. striola*. Underscoring shows non-significance between a range of means.

| *Cx. quinquefasciatus* | Mean no. of prey killed/predator/day and underlined ranges of non-significance[a] Predator density 1 | 5 | 10 | 0 | LSD | df |
|---|---|---|---|---|---|---|
| First instar[b] (40 larvae) | 4.95 | 2.67 | 2.31 | 1.15 | 1.978 | 76 |
| Fourth instar[c] (20 larvae) | 1.029 | 0.435 | 0.365 | 0.147 | 0.287 | 132 |

[a] Duncan's Multiple Range test of 5% level of significance.
[b] 10 day feeding trial with 2 replicates.
[c] 17 day feeding trial with 2 replicates.

ambient laboratory conditions during the winter of 1977 died before any mating was observed or any oviposition occurred. Those held outdoors, where temperatures were as low as 0°C for 8.5 hr on 1 day and at or below 4.5°C for 12 hr or less on 21 days, produced a total of 14 viable eggs. Adult pleids held in the incubator at 4.5°C for 32 days were inactive during the cold exposure and remained motionless on the bottom of the aquarium. However, when the temperature was increased to 20°C following the cold exposure, they were observed copulating and over 340 viable eggs were obtained. Oviposition occurred ca. 1 month following resumption of adult activity. The resulting nymphs were successfully reared to adults.

FIELD RELEASES. Only a few pleid adults could be recaptured at the Yosemite pond and these were collected within 10 days of the release (Table 3).

## DISCUSSION

LABORATORY TESTS. The larger number of 1st stage mosquito larvae killed, as compared to 4th was probably tied to the pigmy backswimmer's inability to chase down faster prey and also due to the larger mosquito larvae being able to satiate the backswimmer's appetite. Although *P. striola* is perfectly capable of handling prey much larger than itself (Gittelman 1977), it is noticeably slower than 4th stage southern house mosquito larvae. The wiggling movement of the larger larvae apparently also makes them more difficult to catch by smaller predators. Moreover, since the larger mosquito larvae have more food value, fewer prey need to be killed. This is evident with other prey of pleids as well, e.g. with daphnids (Gittelman 1978).

The decrease in prey mortality when predator density was increased was apparently due to increased predator interaction and reduced chances of any predator finding prey ("interference and exploitation," Holling 1961); this has been observed with other predator-prey relationships (Holling 1961, Hazelrigg

Table 3. Total number of *P. striola* captured on sample dates at the 2 release locations in California.[a]

| | YOSEMITE POND | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sample | No. of Adult Pleids per no. of Samples | | | | | | | |
| Method | 5/22[b] | 6/1 | 6/5[b & c] | 6/14 | 6/15 | 7/18 | 8/21 | 8/22 |
| Sweep | | 4–14 | 0–10 | 0–10 | 0–19 | 0–10 | 0–10 | 0–10 |
| Dip | | 1–10 | 0–35 | 0–60 | | 0–60 | 0–80 | |
| Trap | | 0–2 | 0–0 | 4–3 | | 0–2 | 0–6 | |

| | "L" POND | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Pleids[d] per 16 samples | | | | | | | | | |
| Stadia | 6/16[b] | 6/22 | 6/27 | 7/1 | 7/13 | 7/20 | 8/10 | 8/25 | 10/3 | 10/24 |
| First | | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| Second | | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| Adult | | 14 | 11 | 10 | 0 | 9 | 0 | 0 | 0 | 0 |

[a] See text for description of sampling apparatus.
[b] Date of release.
[c] Samples taken before 2nd release.
[d] All pleids caught at or within 5 m of release site.

The samples taken at the "L" pond yielded *P. striola* for about a month (Table 3). These samples contained 1st and 2nd instars as well as adults. None was captured between July 20 and October 24, when the last sample was taken.

1973). This action was undoubtedly enhanced in the relatively small test arenas utilized. Also contributing to decreasing prey mortality was the occasional behavior of *P. striola* to feed simultaneously on large larvae already attacked by another.

It is apparent that *P. striola* has an obligate adult diapause that must occur prior to reproduction. Exposure of adults to 4.5°C under a short photoperiod was sufficient to induce diapause in the laboratory, and it was broken by increasing the temperature and light cycle. Adults cannot be maintained indefinitely in the laboratory without exposure to simulated overwintering conditions.

FIELD RELEASE. A probable cause for the disappearance of *P. striola* from the Yosemite pond was the presence of a large number (mean = 23/sweep) of the large backswimmer *N. kirbyi*. Laboratory experiments confirmed the potential effect of *N. kirbyi*. When 10–20 *N. kirbyi* adults were added to aquaria containing 2 pigmy backswimmer adults, daily mortality to the pleids was observed. This mortality was reduced in aquaria in which mosquito larvae were also added. Thus, the large backswimmers have a preference for mosquito larvae. Since the mosquito larval density in the Yosemite pond was low, the *N. kirbyi* apparently attacked and eliminated the pleids.

The disappearance of *P. striola* in samples at the "L" pond was probably due to the relatively high water temperatures which occurred during midsummer (ca. 39°C at 15 cm depth). Also as the water receded (ca. 0.4 m in depth) in this pond, the pigmy backswimmers were forced out of their protective emergent, vegetative cover and were exposed to the predators of the open water.

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