

Role of the Predator *Hemerobius pacificus*¹ in a Non-Insecticide Treated Artichoke Field²

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ABSTRACT

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Hemerobius pacificus oviposition closely followed the population densities of *Myzus persicae* which peaked in late fall and declined to zero in spring in an untreated artichoke field. A second peak of oviposition by the predator followed the increasing populations of the artichoke plume moth (=APM), *Platyptilia carduidactyla* in spring. Where *Hemerobius* eggs were released, the aphid populations were reduced consistently, while the APM damage was reduced only at larval infestation levels of APM above 10%. Oviposition by wild *Hemerobius* was lower in plots where aphids had been reduced by released predators. APM infestations were estimated to be lowered by 30% by wild *Hemerobius* populations, while hymenopterous parasites accounted for 14% of the larval mortality of APM. Protein + sugar food sprays applied 5 times during the year slightly increased *Hemerobius* oviposition which in turn led to lower aphid populations and slightly reduced APM infestations.

Hemerobius, the only common active predator in artichokes during winter, is considered an important control agent of aphids under cool conditions, and is a mortality factor of APM larvae. *Hemerobius* should be preserved in integrated control programs.

Introduction

The most important pest on California artichokes is the artichoke plume moth (APM), *Platyptilia carduidactyla* (Riley) (Lepidoptera: Pterophoridae) (Essig 1922, Lang 1941, Lange et al. 1954). For the control of the APM most growers rely on aerial applications of parathion. In isolated fields in Carmel Valley, however, a good production of artichokes is achieved by the sole use of the cultural practices devised by Lange (1941). This suggests that natural enemies are partly responsible for the APM suppression where parathion is not used. The impact of parasites on APM has been dealt with considerably by Lange (1941) and Bragg (1971), but the role of general predators has received little attention. In a preliminary investigation by Hagen (unpubl. results), *Hemerobius* increased considerably in experimental plots where the usual spray schedule with parathion was omitted. This surge of the brown lacewings was followed by a reduction of the APM. In the present study the influence of the main hemerobiid, namely *Hemerobius pacificus* Banks, on its two potential prey sources in artichoke fields, aphids and APM larvae, was therefore measured. The predator populations were thereby artificially increased by release of *H. pacificus* eggs, or by arresting the wild females by means of food sprays (Hagen et al. 1970).

Materials and Methods

This study was conducted from October 1973 until May 1974 in a 40 ha artichoke field near Carmel Valley, California. The field is surrounded by natural vegetation and does not receive any insecticide treatments. The plots were laid out in a randomized block design towards the center of the field, with the 4 blocks 100 m apart.

Each block consisted of a row of 60 m containing th 3 small plots with 3 artichoke plants each. In one set of plots 20 *Hemerobius pacificus* eggs per plant were released weekly, from the end of October to the end of April, i.e., 240 eggs per week. The eggs from a laboratory culture were attached to a loose piece of cotton, which was added to the heart of the artichoke plants. Another set of plots served as control. Each week, all insects on two leaves in two hearts and in all artichokes more than 5 cm in diameter were counted in the field. In an attempt to aggregate wild *Hemerobius* adults, a third set of plots was sprayed with Wheat[®], a commercial yeast product to which sugar was added (Hagen et al. 1970). A total of 5 sprays was applied during sunny weather, 2 in late fall, and 3 in spring. Counts on these plots were made only on the date of spray and one week later. All blocks were harvested normally, whereby infested as well as uninfested artichokes of commercial size were removed from the experimental counts. In addition the artichoke yield of the entire field and shade temperatures were recorded.

For the evaluation of the counts of wild *Hemerobius* eggs and aphids in the *Hemerobius* release plots and the control, 3 consecutive sampling dates had to be pooled because of the paucity of the eggs. The sampling unit therefore consisted of 18 leaves sampled in a 3 week interval from 3 plants. The analysis of variance according to a split plot design (Snedecor and Cochran 1967) had 71 degrees of freedom (d.f.) distributed as follows: In the main plot, one for treatment with *Hemerobius* eggs, 3 for blocks, and 3 for the error; in the sub-plot, 8 for periods, 8 for interactions, and 48 in the error. *Hemerobius* egg numbers of each sampling unit were $\sqrt{x+1}$ transformed, whereas the aphid counts needed a $\log(x+1)$ transformation. Means were compared with a t-test according to Dunn applied for 10 chosen comparisons (Kirk 1968). Differences in the percentage of infested artichokes were evaluated in a Chi-square test (with correction for continuity) (Snedecor and Cochran 1967).

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The efficiency of the Wheat spray, on the other hand, was evaluated by utilizing only the counts of the dates when the Wheat plot was sampled. The sampling unit (for 15 chosen comparisons) therefore consisted of a total of 12 leaves sampled over a two week period from 3 plants.

In the laboratory, individual pairs of *Hemerobius pacificus* were kept at $18.3 \pm 0.8^\circ\text{C}$, $75 \pm 15\%$ RH under short day conditions (Neuenschwander 1976). They were provided with water and fed with pea aphids, *Acyrtosiphon pisum* (Harris) or with Wheat (Hagen and Tassan 1970).

All statistical tests were performed at the level of $p = 0.05$; significant t or χ^2 values were marked with an asterisk. Significantly different means were followed by different letters, and the critical interval t_{Dunn} , SE was given.

Results and Discussion

The most numerous phytophagous insects on artichokes during the main growing season in this study were the green peach aphid (GPA), *Myzus persicae* (Sulzer), and larvae of the artichoke plume moth. Both species reproduced without interruption throughout the mild winter in this coastal area (mean maximum temperature in December-January = 12.6°C , mean minimum = 5.4°C). Most predators like the coccinellids, syrphids, and chrysopids, on the other hand, were inactive during winter and early spring. In late October they entered diapause, and during spring they were scarce in the fields possibly because of low aphid populations. From the end of October until mid-March, *Hemerobius pacificus* therefore was the only common predator. During this time, *H. neadelphus* Gurney and the hemipterans *Nabis* and *Orius* were present, but only in low numbers.

In the laboratory, first and late second instar *Hemerobius* larvae were unable to pierce the tough chorion of the eggs of APM. First instar APM larvae were readily attacked and allowed normal growth of the predator. In the field, *Hemerobius* eggs were found to be depos-

ited singly, and mostly on the underside of the leaves, i.e., in the same microhabitat where most aphids and APM eggs were also observed. Upon emergence, APM larvae were attacked by predators until APM reached shelter in the freshly formed flower buds in the heart of the plant.

Hemerobius reproduced throughout winter and showed two peaks in oviposition, one in November, and the other in the second half of February (Table 1). Its reproductive activity declines abruptly in late April. The continued oviposition throughout winter was explained by the observation that the lowest weekly mean temperature (6.5°C at the beginning of January) never reached the lower thermal threshold for reproduction or for development of the immatures (Neuenschwander 1975, 1976).

APM infestation (Table 1) showed a minor peak in October, declined to zero in late November, and reached the highest number at the end of the harvesting season. This pattern was also reflected in the percentage of artichokes culled from the entire field. From January onward the percentage of artichokes infested with APM increased with the absolute number of artichokes available to the APM. The aphid population, on the other hand, declined from October onward, and disappeared almost completely on the aging plants in May.

The ratio of *Hemerobius* to APM eggs (Table 1)—both roughly the same size and equally difficult to detect—showed that from the beginning of November to mid-April *Hemerobius* was more abundant than the APM (in the control plots a total of 34 APM eggs and 108 *Hemerobius* eggs were discovered). From November to mid-February, oviposition of *Hemerobius* closely followed the aphid population as witnessed by the significant regression between GPA (X) and *Hemerobius* eggs (Y) : $Y = 0.554 + 1.071 X$ (block by block, calculated with transformed values, $N = 16$, $t = 3.64^*$, r^2 the explained variance = 0.49). From mid-February to mid-April, however, *Hemerobius* increased its reproductive activity despite further declining aphid populations (Table 1). During this period artichoke yields and APM infestations were also increasing.

Table 1.—Percentage artichoke plume moth (APM) infestation, mean numbers of green peach aphid (GPA) and *Hemerobius* eggs on 18 leaves, in the untreated control (C) and the *Hemerobius* eggs release plots (H), together with the respective ratios and the total harvest in the field. Carmel Valley, 1973–74.

Sampling dates	Infest. %		Mean densities				Ratios		Total harvest	
	APM		GPA N ¹		Hemerobius eggs N ²		APM eggs per Hemerobius egg ratio in C ³	Hemerobius eggs per GPA ratio in C ³	Boxes per ha	Culled %
	C	H	C	H	C	H				
16–30 Oct	7.3	13.6	72.3	51.2	0.65	1.43	1.00	0.01	2.7	10.1
8–20 Nov	4.7	0.0	58.6	24.3	7.09	7.04	0.03	0.12	11.8	7.2
27 Nov–11 Dec	0.0	3.8	39.0	4.4	3.24	0.56	0.14	0.08	7.0	4.6
18 Dec–17 Jan	6.6	2.5	11.2	1.1	1.36	0.00	0.00	0.12	3.9	9.3
22 Jan–12 Feb	16.7	15.4	4.6	0.7	0.83	1.46	0.00	0.18	11.6	10.1
19 Feb–5 Mar	9.5	15.4	4.3	1.3	3.14	0.93	0.20	0.73	16.8	12.3
12–26 March	17.7	12.0	4.3	1.1	2.97	0.83	0.50	0.69	26.9	11.8
3–17 April	22.2	16.9	2.1	0.6	4.01	0.83	0.61	1.91	28.1	15.5
23 April–8 May	23.0	24.3	0.6	0.0	0.00	0.22	14.00	0.00	22.5	17.5

¹ calculations in $\log(x+1)$.

² calculations in $\sqrt{x+1}$.

³ with untransformed counts.

The correlations which were observed between the population densities of the predator and its two main prey species in the control plots were further elucidated by a comparison between the control plots and the release plots (Table 1): The larvae from the released *Hemerobius* eggs reduced the aphid population consistently at all densities throughout the season. This suppression was significant for two comparisons (27 November and 17 January) as well as for the overall means: control 9.47 and release plot 2.89 GPA per 18 leaves (the transformed means were 1.02^a and 0.59^b respectively, and the critical interval was 0.23). The released *Hemerobius*, however, were not capable of significantly suppressing the APM number in any single week. The mean infestation, covering 22 sampling dates, was 15.3% in the check plots as compared to 13.9% in the release plots. In the control plots 68% of all artichokes were harvested when APM infestations were above 10%. During these weeks, the mean infestation level in the control reached 19.3%, while in the release plots it remained significantly lower at 15.5% ($\chi^2 = 4.3^*$ based on a total of 1856 observations). It is concluded that, at the low aphid levels found in spring, *Hemerobius* as a general predator could only survive and prey on APM larvae when the APM density was relatively high.

The *Hemerobius* larvae from the released eggs reduced the prey population sufficiently to induce a significant reduction in the number of eggs laid by the wild *Hemerobius* females (Table 1). While an average of 3.03 eggs per 18 leaves were laid in the check plots (between 8 Nov. and 17 April), 1.36 eggs were found in the release plots (the transformed means were 2.008^a and 1.535^b with the critical interval = 0.469). Given the low density of APM first instar larvae, the reduced oviposition by the predator was mainly attributed to the reduction in GPA. The female *Hemerobius* thereby clearly responded to the density of its prey, and distinguished between such low prey densities as about 4 versus one aphid per 18 leaves.

The plants that were full grown in December consisted of 57.8 ± 3.9 (SE) leaves (N=12). The 20 eggs released per plant each week therefore amounted to 0.35 eggs per leaf, or 6.23 eggs per sampling unit of 18 leaves. Because of the suppression of the aphids by the released *Hemerobius* the release plots received 1.67 wild *Hemerobius* eggs less than the control each week. The mean APM infestation of 15.5% in the release plots in spring therefore corresponded to an equivalent of 7.59 (= 3.03 + 6.23 - 1.67) eggs per sampling unit. Under the reasonable assumption of a 50% cannibalism among the freshly hatched larvae on the same piece of cotton, this egg density corresponded to 4.47 larvae in the release plots. It was then estimated by extrapolation that in the absence of the predator, APM infestations would have been 27.3% instead of the 19.3% found in the control plots with their average of 3.03 wild eggs. Thus, the wild *Hemerobius* population in this study reduced the original APM population by about 30% [= (27.3 - 19.3)/27.3] during periods of relatively high APM infestations, while no reduction occurred at low infestation levels.

In conclusion, the control and release plots demon-

strated that *Hemerobius* populations at the inconspicuous densities found in this study had a great impact on the overwintering aphid population, to whose fluctuations they easily responded. Though the relatively rare APM first instar larvae served only as secondary food source, the impact of *Hemerobius* was measurable at least at higher APM densities. It probably exceeded the toll taken by the only common ichneumonid parasite in this field, *Diadegma acuta* (Viereck) (13.5% at its maximum in April, N=52).

In the plots which had been treated with the food sprays, the densities of *Hemerobius* and its prey species indicated some arrestment of the wild *Hemerobius* females: The mean egg densities of this predator were 1.64^a eggs per 12 leaves in the control plots, 2.12^a in the Wheat plots, and 0.56^a in the *Hemerobius* release plots, during the 5 × 2 weeks when counts from the Wheat plots were made. At least in one two-week interval there were significantly more eggs in the Wheat plots than in the control (12-19 March: 7.70^a vs. 1.89^b eggs). The mean aphid density, on the other hand, was significantly lower in the Wheat and *Hemerobius* release plots, namely 3.6^a and 2.5^a aphids per 12 leaves respectively, than in the control plot with 8.0^b aphids (critical interval = 1.74 x). During the 3 periods when the APM attack was above 10% in the control, APM infestations in the Wheat plots were on the average lowered by 3.2 APM per 100 artichokes to 11.4%. But this difference was significant only in February, when the infestation in the Wheat plots was a mere 3.0% versus 12.4% in the control ($\chi^2=6.7^*$ based on a total of 253 artichokes).

In the laboratory, the survival of *Hemerobius* females was 41.6^a days on aphids, 59.7^a days on Wheat, 19.2^b days on honey, 13.4^b days on sugar, and 2.9^c days on water alone (based on 43 pairs). Males survived significantly less on all diets, namely 67% of the lifespan of the females. Oviposition was clearly reduced in the females which were fed only Wheat + sugar, namely 161.6^a eggs in the first 15 days of the oviposition period, as compared to 399.8^b eggs from females fed aphids only or 331.8^b eggs from females fed aphids and Wheat (based on 32 females, critical interval between Wheat and aphids as only food source = 100.1). In another experiment with 2 × 5 pairs over a period of 48 days, an average of 8.8 eggs per female was laid per oviposition day under ample supply of aphids, as compared to 3.0 eggs when aphids were provided only during the preoviposition period and Wheat was the only food in the oviposition period. Thus, the Wheat mixture used in the field sustained the predaceous *Hemerobius* adults, but did not yield more than 40% of the eggs laid when aphids were provided.

In the study area, which is isolated from the main artichoke growing region, artichokes were grown for many years without the use of insecticides. This must be attributed mainly to the use of good cultural practices, like removal of the infested artichokes, burying the plant material at the end of the season, and a crop free period in summer, all of which help disrupt the reproductive cycle of the APM (Lange 1941, Lange et al. 1954). The harvest of the study field of 132 boxes per ha with a

mean of 12.7% culled, which included also dry artichokes and black tip damage, has to be rated as very good (Parsons and Sciaroni 1957). This study suggests that general predators, and among them particularly *Hemerobius*, have some impact on APM. It is evident, however, that the APM is only a secondary prey for *Hemerobius*. Aphids, on the other hand, elicit an oviposition response by this predator already at extremely low densities. While hemerobiids are unable to exert any appreciable influence on aphids during summer (Neuenschwander et al. 1975), they must be considered an important control agent for aphid populations which cause problems during the cool season, like GPA and the artichoke aphid *Capitephorus braggi* (Gillette). On artichokes, aphids recently reached damaging levels every season thereby requiring still another pesticide treatment. Similarly, it was experimentally proven that the frequent applications at least of methyl-parathion against the APM induced damaging levels of the leaf miner *Phytomyza syngenesiae* (Hardy) (Bragg 1974). In order to avoid such secondary pest outbreaks in artichokes, pest management systems which rely more on the well known cultural control measures have gained new esteem since this study was completed (W. H. Lange, pers. comm.). The data presented here suggest that under these conditions *Hemerobius* plays a more important role during winter than hitherto assumed and clearly deserves more research.

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