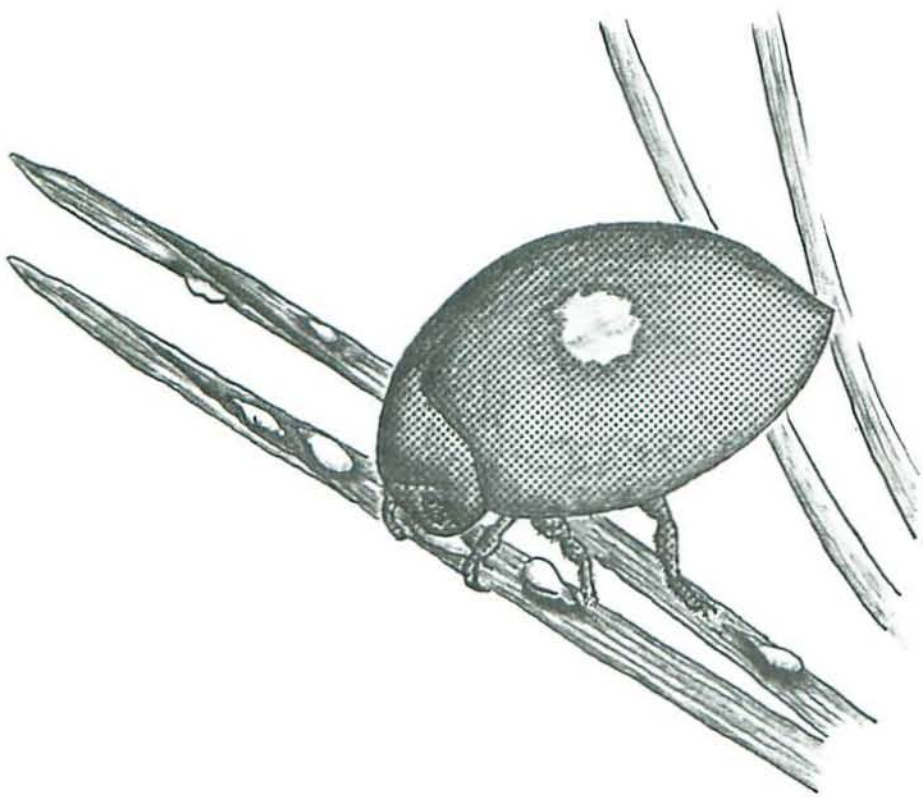
Plantation Research: XIV. Studies on the predation of pine needle scale, *Phenacaspis pinifoliae* (Fitch), by the coccinellid, *Chilocorus stigma* (Say).

by

R.F. DeBoo and J.A. Weidhaas, Jr.



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FOREWORD

During the course of the senior author's graduate study and the junior author's project work, incidental investigations were conducted as opportunities arose in the field. The studies reported herein are significant and useful to entomologists and foresters even though a decade has elapsed since the work was done. Changes in positions and work commitments, especially on the junior author's part, contributed to a long delay in publishing the results of the investigations.

The role of coccinellids, as well as other predators and parasites, is important to the development of applied insect pest management practices and integrated pest control. Hopefully these studies will encourage further investigation of the influence that natural enemies exert on the population fluctuations of tree pests and of their potential use in managed population manipulation in the future.

As chemicals including insecticides, pheromones, and hormones, along with bacterial spores, virus polyhedra, and parasites have been synthesizid or produced and utilized in the control of insects, so should predators in the family Coccinellidae be reared artificially and released as a supplementary method of regulating pest populations. These studies show that the potential exists, although more detailed and thorough investigations are necessary to develop the effective application of the technique.

ABSTRACT

Chilocorus stigma effectively reduced severe infestations of *Phenacaspis pinifoliae* to extremely low levels in a *Pinus sylvestris* Christmas tree plantation in New York State from 1963 to 1965. Adults and larvae of the twice-stabbed lady beetle consumed an average of nearly 100 scale insect nymphs over a 2-hour period in laboratory feeding tests. The coccinellid colonized moderately and severely infested trees under natural field conditions, but did not tend to establish itself on lightly infested trees. Two generations of both the lady beetle and the pine needle scale occurred each year and were well synchronized seasonally. These studies indicate promise for the rearing and controlled release of the twice-stabbed lady beetle as a supplementary method of pine needle scale control on extensive monocultures of Scots pine.

RÉSUMÉ

Entre 1963 et 1965, *Chilocorus stigma* a permis de réduire à un niveau extrêmement bas *Phenacaspis pinifoliae* dans une plantation d'arbres de Noel *Pinus sylvestris* gravement infestée, dans l'État de New York. En laboratoire, des sujets adultes et des larves de la coccinelle stigma consomment en moyenne près de 100 nymphes de cochenilles en deux heures. Dans les conditions naturelles, la coccinelle colonise les arbres moyennement et gravement atteints mais ne s'établit généralement

pas sur ceux qui ne le sont que légèrement. Deux générations, bien synchronisées, de la coccinelle et de la cochenille des aiguilles du pin sont produites chaque année. Les études indiquent que l'élevage et le lâchage dirigé de coccinelles à l'appui de la lutte contre la cochenille des aiguilles du pin dans des monocultures extensives de pins sylvestres sont prometteurs.

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R.F. DeBoo and J.A. Weidhaas, Jr.[1]

INTRODUCTION

The pine needle scale, *Phenacaspis pinifoliae* (Fitch) (Homoptera:Diaspididae), is a common, widely distributed pest of certain pines (*Pinus* spp.) and spruces (*Picea* spp.). Damaging infestations have been controlled effectively with insecticides on individual landscape trees and on young trees in small plantations. However, in large, dense, multihectare plantings, chemical control may be prohibitive or impractical due to 1) difficulty in achieving the thorough spray coverage required and in reaching the trees with spray equipment; 2) difficulty in applying treatments within the limited optimal time period of susceptibility; and 3) the high cost of high volume ground or aerial spray treatments (Peterson and DeBoo 1969, Nielsen 1970, Nielsen and Johnson 1972, and DeBoo and Weidhaas 1973).

Insecticidal treatments too often are recommended or applied with little consideration for the beneficial insect

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populations that occur naturally on scale-infested trees. It is true, unfortunately, that natural enemies usually exert a regulatory influence on the pest populations after significant damage has occurred. However, there is very little known and the scientific documentation is meager on natural factors that contribute to the natural regulation or decline in population densities of this scale insect. Rearing and designed releases of parasites or predators for biological control of the pine needle scale are unknown to the authors, but might be feasible in man-made monocultures for Christmas tree production or reforestation.

An opportunity arose in New York State in 1963 to study a natural "invasion" of the twice-stabbed lady beetle, *Chilocorus stigma* (Say) (Coleoptera: Coccinellidae), during the third year of a severe infestation of the pine needle scale on Scots pine, *Pinus sylvestris* L., in a large Christmas tree plantation. A series of small-scale insecticide tests had been designed for the several hectares of the most severely infested trees. However, the appearance of the lady beetle in early spring presented an excellent opportunity to observe and document the impact of a naturally occurring predator population on an established and extensive infestation of its prey in a monocultural plantation.

An immediate review of the literature indicated that a predation study might provide a significant contribution to entomological science. Lintner (1889) and Cumming (1953) recognized the importance of the twice-stabbed lady beetle

in reducing population levels of the pine needle scale. Muma (1955), Sweetman (1958), and Swan (1964) have reviewed and discussed the role of this predator in regulating populations of citrus scales in Florida. According to Muma (1955), *C. stigma* is the most common lady beetle attacking scale insects in Florida, but "alone, the beetle seems incapable of reducing scale populations and does not appear to be as important as formerly believed." Edmunds (1973) also indicated that a species of *Chilocorus* was ineffective in controlling infestations of the black pineleaf scale, *Nuculaspis californica* (Coleman).

In view of the large numbers of lady beetles observed in the New York plantation; the lack of conclusive evidence of their role as predators in the literature, and the paucity of data on seasonal development and prey consumption, insecticide evaluation tests were abandoned and studies were initiated to determine:

1) the role of *C. stigma* in reducing population densities of *P. pinifoliae* naturally under conditions of severe infestation;
2) the seasonal development of prey and predator populations over a period of several seasons;
3) the feeding capabilities of larvae and adults of *C. stigma* under controlled laboratory conditions.

MATERIALS AND METHODS

Field Study Area. A 15-hectare Scots pine Christmas tree plantation near Martville, Cayuga County, New York, was utilized for field investigations during the period June, 1963 to September, 1965. Trees ranged from 0.5 to 3 m in height, averaging 2 m. The spacing was 1.5 x 1.5 m except in a few open areas where replanting was not undertaken after selective harvesting. Stocking was approximately 3000 trees per hectare. All trees were sheared annually during July and August to obtain the dense branching required for Christmas tree market quality. This practice provides very dense foliage and hence a bountiful food source for the pine needle scale.

Pine Needle Scale. The seasonal development of the pine needle scale at Martville was only generally known prior to the study. Herrick (1931) and Gambrell (1938) reported that in New York the pine needle scale may have either one or two generations annually depending upon elevation and temperature. Accordingly, each of the life stages were carefully sampled and recorded for the duration of the three-year study to determine seasonal development patterns. Scale population densities as related to foliage injury levels are based on random samples of 100 needles taken from five branches on each of 100 severely infested trees. A rating system of infestation intensity was then determined to relate population denisty to tree vigor (DeBoo and Weidhaas,

1973).

The reproductive potential for the pine needle scale was estimated from counts of apparently viable overwintering eggs under each of 100 female scales (Fig. 1) on May 14, 1963, April 25, 1964, April 20, 1965, and September 12, 1965. The average number of overwintering eggs per needle was calculated from gross counts of eggs on 500 needles selected randomly from trees on each date mentioned above.

The percentage of infested trees in the plantation was determined each year from a random survey of approximately 10% of the total number of trees in the 1 to 3 m height range. Infestation levels were classified as:

I. Light -- trees with scales present on only a few branches of the lower crown quarter.

II. Moderate -- trees with abundant scales on most of the lower half of the crown.

III. Severe -- trees with abundant scales throughout the whole crown.

Trees from each of these infestation categories were then selected for controlled predator feeding tests in the field.

Twice-stabbed Lady Beetle. Because of the mobility of this coccinellid predator, estimates of its density per scale infestation category were obtained by visual counts

of larval and adult beetles on every branch of 100 radomly-selected trees each years. In addition, conical cages of framed aluminum window screen were placed around four trees (1.3 to 1.5 m tall) in each of the three scale infestation categories on May 20, 1965. After each tree was carefully examined and all predators removed, each cage was closed and sealed. Adults of *C. stigma* then were introduced at the rate of 10, 50, 100, and 150 individuals per cage for each pine needle scale infestation category (i.e. 4 predator density treatments replicated 3 times according to prey density). Cages were removed on September 5, 1965, and counts were made of living beetles and adult scales to determine both predator and prey survival for the different initial levels of prey abundance.

Three isolated mugho pines (*P. mugho* Turra) 2 - 3 m tall near Willard Straight Hall at Cornell University, Ithaca, N. Y., were selected for unrestricted release of *C. stigma*. These trees had also sustained severe attack by the pine needle scale for at least 3 years, but coccinellids were not as numerous as at Martville. Collections of adult lady beetles from the Martville plantation were transported to Ithaca and released on June 14, 1965, at the rate of 10, 50, and 100 per tree. The trees were thoroughly examined 96 days later to determine the degree of predation on the scale population, if any, and to assess the practicability of release under conditions of plentiful but localized prey supply.

Laboratory Feeding Studies. In the laboratory, scale-infested Scots pine needles were placed in 6-dram vials containing a single adult *C. stigma*. Estimates of scales attacked and consumed were made hourly at intervals of 1 to 10, 24, 48, 72, 96 and 120 hours after placement in the vials. All beetles used in the test were starved prior to adding infested needles for at least 6 hours in vials containing strips of moist filter paper. The open end of each vial was covered with a small square of cheese cloth and secured by a rubber band.

Each feeding trial included 10 replicates of one beetle per vial, and five trials were conducted for each time period. With the exceptions of the 1 and 2 hour trials, fresh beetles and scales were used each time. The number of mature female scales placed in each vial varied from 50 to 60 for each of the first 10 hourly periods. For the 24 to 96 hour feeding tests, at least 100 scales were used. Because of a limited supply of scales at the time of the 120 hour tests, an average of only 65 scales per vial (beetle) was used. At the termination of each selected time period, the number of surviving adult scales was recorded. Although eggs also were consumed, separate counts of these were not maintained.

An abbreviated series of feeding tests using 34 late-instar *C. stigma* larvae and immature scales (92-130 per larva) was established to determine predation by this stage after 24 and 72 hour periods. Counts were made after each

time period as for the adult series. Similarly, 11 adult beetles were selected to determine predation efficiency on immature scales over a 24 hour period.

RESULTS

During the period of the investigations in the field, two generations of the pine needle scale occurred each year at Martville (Fig. 2). The insect overwintered in the egg stage until mid to late May. First-instar crawlers were active for a period of about one week, until they settled on the one-year-old foliage amidst their parents. Once settled, the crawlers commenced feeding and reached maturity by early to mid-July. Eggs were deposited beneath the scale covering until late July when crawlers of the second generation appeared and migrated to the foliage of new shoots. After settling, scale feeding and growth to maturity continued until late August and September. Eggs were deposited again during late August, September and October. Females deposited an average of 19 eggs (range 0 - 49). As many as 118 mature scales were observed crowded together on a single 10 cm long Scots pine needle.

Chilocorus stigma was the most common predator found in the Scots pine plantation at Martville and accounted for at least 90% of all predator collections during the three year period. Other coccinellids observed were:

Common - *Scymnus* spp.

Rare - *Coccinella transversoguttata* Fld.

- *Anatis quinquedecimpunctata* Oliv.

In addition to these coccinellids, an unidentified species of a mirid, a chrysopid, and a hemerobiid were observed occasionally preying on the sedentary scale.

The twice-stabbed lady beetle also was found to have two generations each year (Fig. 2). First springtime activity was noted on April 20 (1965). Mating was observed at this time, and continued for at least three weeks afterwards. Eggs were first observed in the field on May 30, 1965, but first and second-instar larvae also were actively feeding at this time. The eggs were located on the bark of branches towards the inner crown and on exposed buds. Overwintering adults continued to feed through late June and early July. In fact, they may be easily confused with the next adult population (first generation) emerging at about this time. Second-generation larvae were found for the first time on July 5, 1965. Larval development and feeding continued until late August and September. Pupae were found on dead foliage of the inner tree crown. Adult of the second generation were found during the first week of September, and overwintered in ground litter and beneath loose bark with the advent of freezing temperatures.

Approximately 86% of the total number of surveyed trees supported scale populations each year. Most trees were moderately infested, with scales occuring in large numbers only on branches of the lower crown quarter. Counts of the numbers of live overwintering eggs per female and per needle showed a relatively consistent average number per female, but a decreasing number per needle from 1963 to 1965 (Fig. 3). Population densities for both pine needle

scale and the predator, *C. stigma* (Fig. 4), indicated clearly the classic lapse in peak occurrances; the numerical peak observed for the scale was approximately one year before that of the lady beetle.

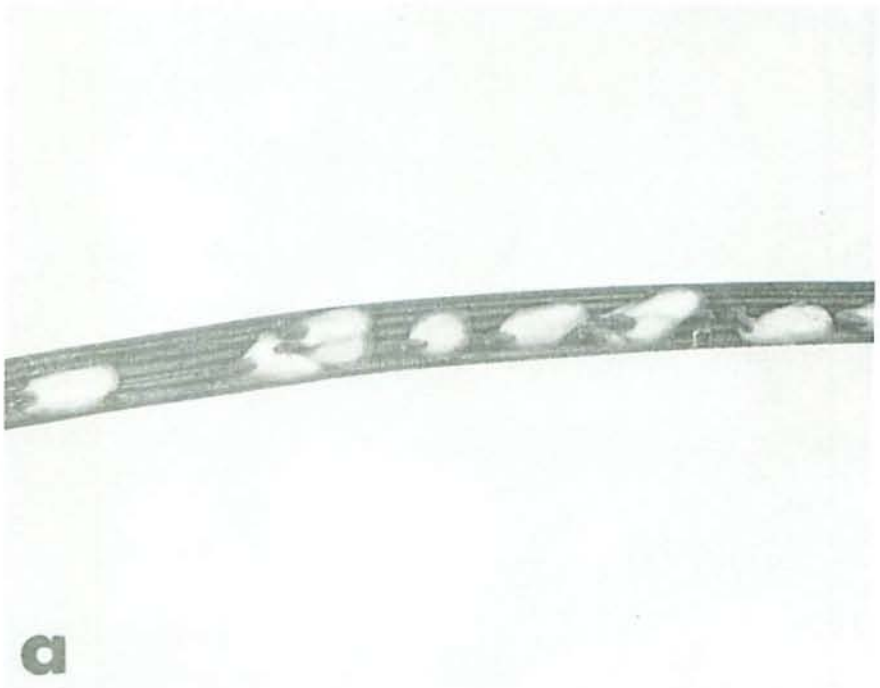
Results of the field cage experiments indicated that approximately 99% of the enclosed scale populations were killed by the predators regardless of infestation intensity. Reproduction of lady beetles occurred on three caged trees supporting moderate infestations of the scale and on all four trees which were severely infested. However, not more than 10 larva and adults were found after more than six weeks of restricted feeding in cages and no live beetles were found on those caged trees having light populations of pine needle scale.

Thorough examination of the mugho pines on the Cornell campus indicated that predation on the large number of scales was minimal (<10% consumed by predators). Only four larvae and one adult of the twice-stabbed lady beetle were found on September 17, 1965, 96 days after predator release.

Laboratory studies of adult feeding behavior showed that the beetles rapidly adapted to confined conditions in the vials. Beetles moved over infested needles to commence feeding very shortly after their introduction into the vials and brief forced starvation period. With intermittent resting periods, consumption of scales (and eggs) continued at a steady

rate (Table I). Hourly consumption was greatest during the first two hours of feeding with an average of slightly more than four scales consumed per beetle.

Voracity of attack was most evident in the feeding trials using immature scales as prey. Both adults and larvae of the twice-stabbed lady beetle consumed an average of nearly 100 small scale nymphs over the two-hour duration of the trials.



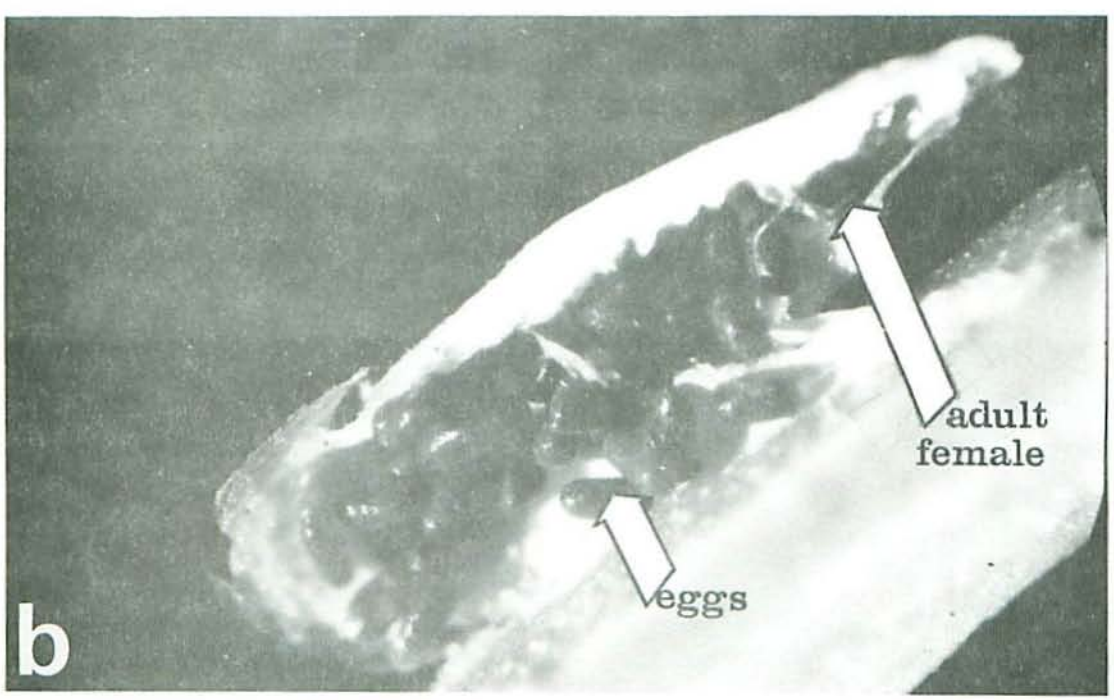


Figure 1. a. Mature pine needle scales (♀) on pine needle.
b. Eggs and adult ♀ under scale secretion.

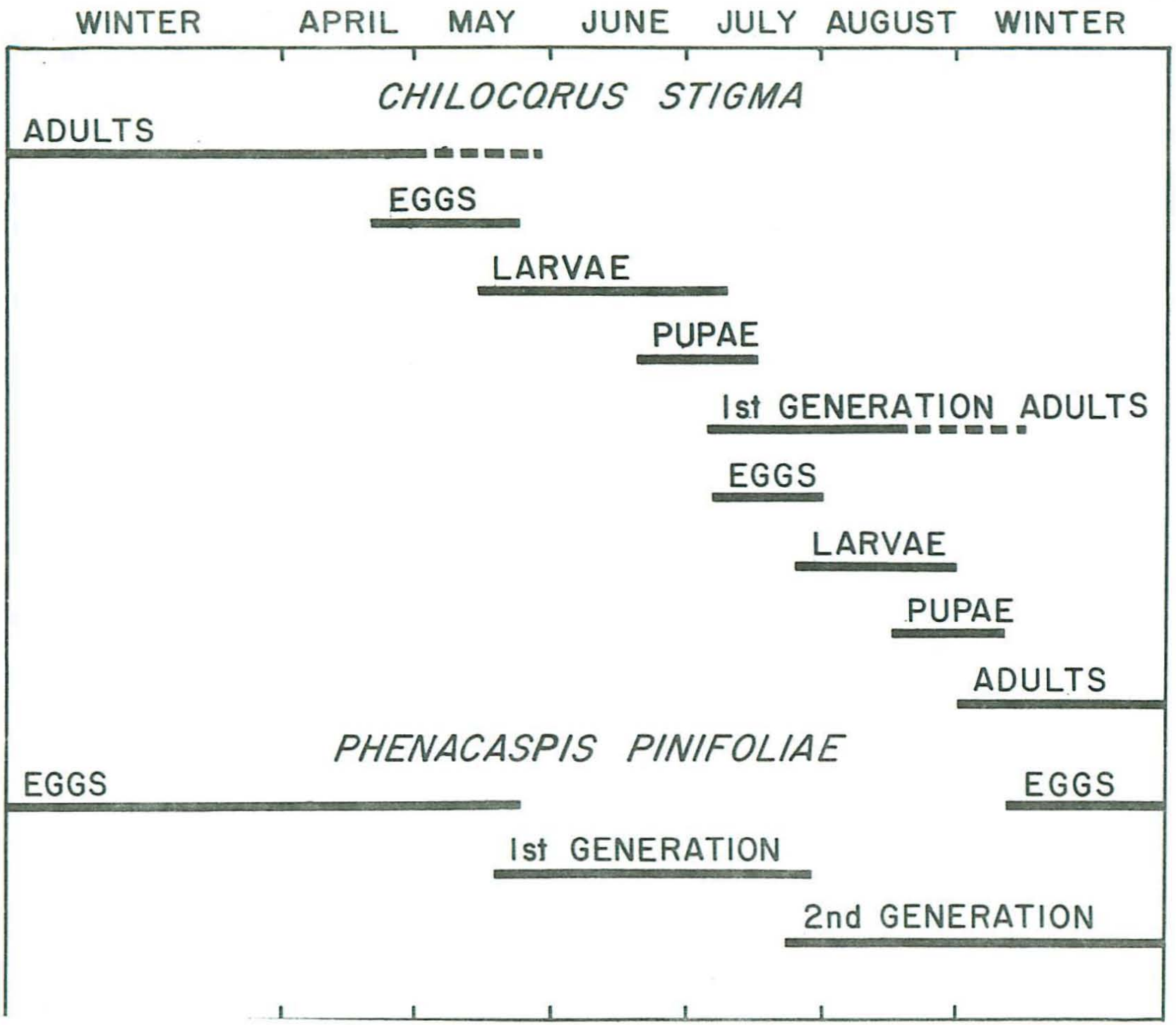


Figure 2. Life cycles for the scale, *Phenacaspis pinifoliae*, and its coccinellid predator, *Chilocorus stigma*.

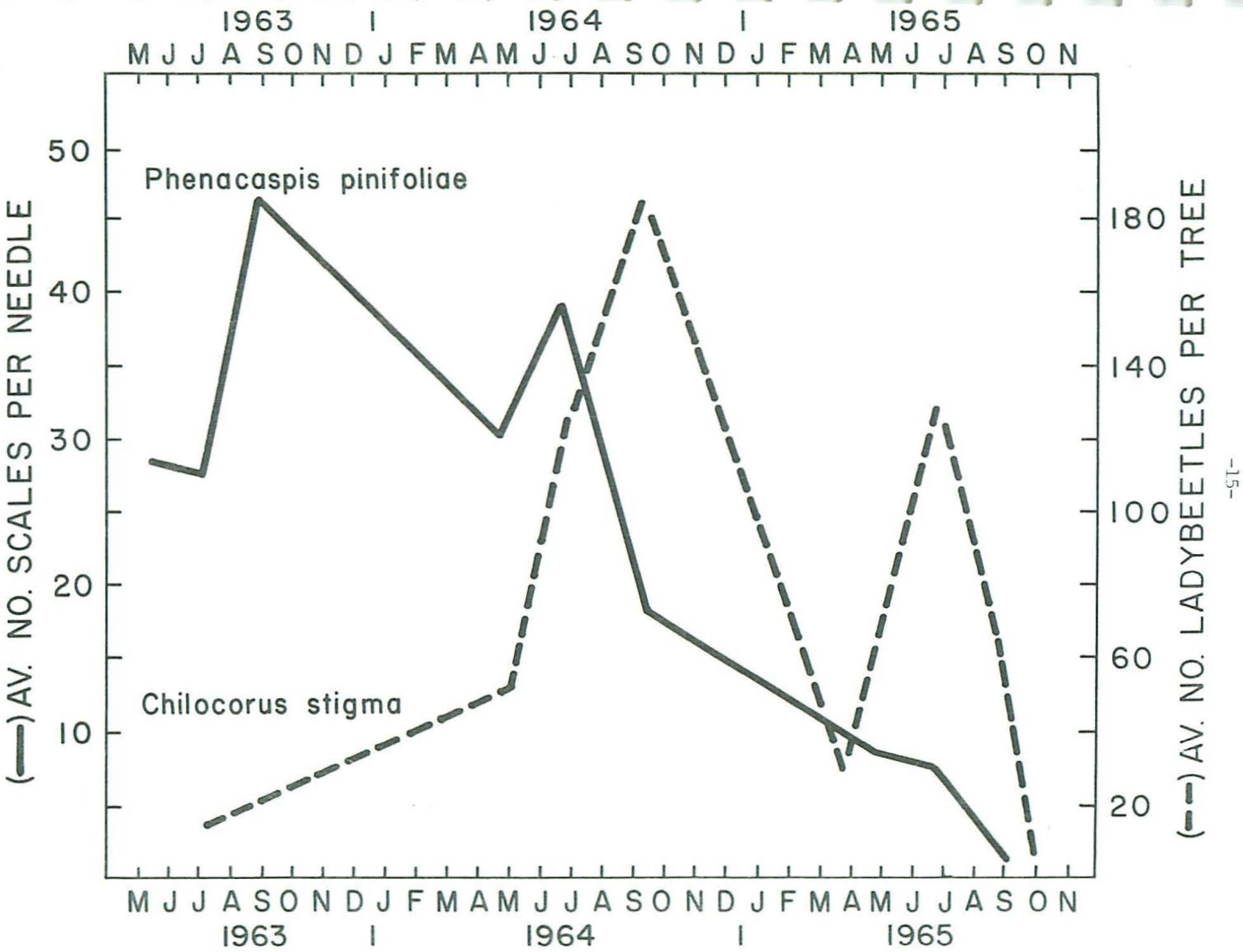


Figure 3. Population levels of the scale, *Phenacaspis pinifoliae*, and the coccinellid predator, *Chilocorus stigma*, 1963 - 1965.

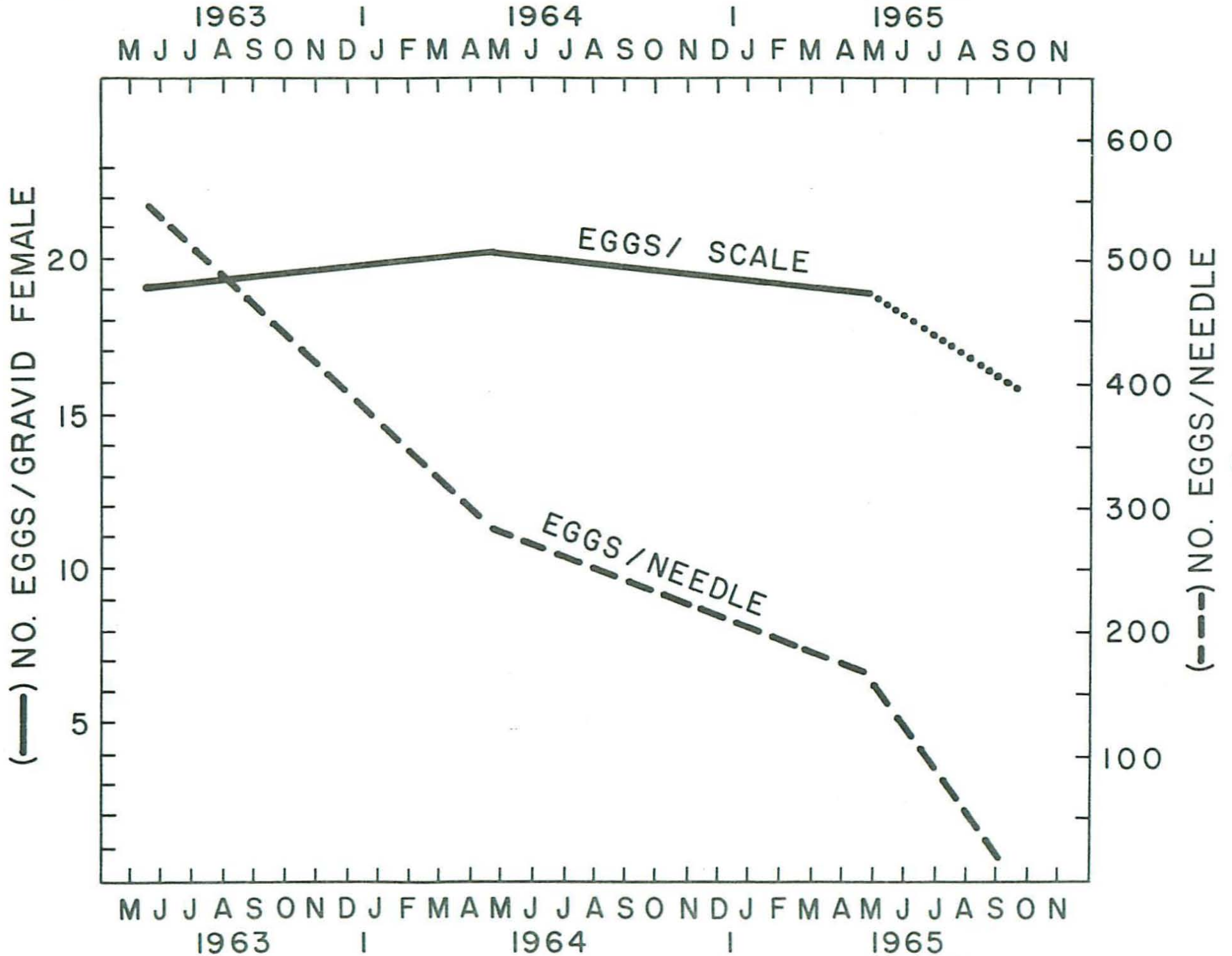


Figure 4. Eggs per female and per needle of the scale, *Phenacaspis pinifoliae*, 1963-1965.

Table I. Predation of *Phenacaspis pinifoliae* by adult *Chilocorus stigma* under controlled laboratory conditions.

Duration of test (hours)	Average No. Scales Destroyed/Adult (Test No.)[1]					No. Scales Consumed/Adult	
	1	2	3	4	5	MEAN	RANGE
1	3.8	2.7	3.0	2.2	3.1	2.9	0 - 9
2	10.2	6.6	8.0	8.4	8.6	8.3	3 - 25
3	11.4	6.9	8.5	8.2	8.8	8.7	3 - 32
4	9.7	10.4	8.7	9.8	9.0	9.5	0 - 22
5	11.3	14.6	10.3	10.7	11.0	11.0	4 - 31
6	13.2	15.1	10.7	13.3	15.0	13.7	6 - 20
7	18.9	17.6	18.9	15.2	16.5	17.5	4 - 36
8	17.2	22.7	14.8	20.7	21.8	19.3	6 - 46
9	27.0	19.5	19.8	23.1	20.0	21.7	0 - 43
10	25.1	27.2	18.9	29.3	27.0	25.7	10 - 37
24	32.6	24.3	28.9	36.2	31.7	32.8	3 - 55
48	52.0	52.1	57.7	48.7	55.1	53.1	23 - 94
96	60.9	54.7	59.9	63.8	67.7	60.2	11 - 90
120	*	*	*	*	*	63.4	58 - 101

* Insufficient no. prey introduced into vial for evaluation. Nearly 100% of all prey (ave. 65 scales/beetle) consumed.

[1] Ten adult *C. stigma* per test time period.

DISCUSSION

The life cycle of *C. stigma* at Martville, N.Y., was well correlated with that of the pine needle scale. As the population densities of pine needle scale increased, so did those of *C. stigma*. The abundance and mobility of the predator were found to be the most important factors contributing to drastic reductions in population levels of the scale in 1964 and 1965 (Fig. 3, 4). Populations were reduced from an average of 46.2 scales per needle in August, 1963 to 0.2 per needle in September, 1965. Those few surviving scales were mostly wedged between needle pairs near the sheath (and protected from predator attack) or located on isolated long branches at the lowest crown whorl that were untrimmed in the shearing operations.

Populations of *C. stigma* increased rapidly from an average of 6 per moderately-infested tree in July, 1963, to an average of 185 adults and larvae in September, 1964. A low initial population of less than 9 *C. stigma* per tree was recorded in April, 1965, due to severe mortality (75%) of pupae during September of the previous year. A rapid population increase was noted during June, 1965, however, on those trees moderately and severely infested by the scale. Apparently, the searching ability of adults of *C. stigma* results in their accumulation on those trees having the greatest number of prey, thereby indicating a distinct

preference for the scale when abundant throughout a monocultural plantation. Conversely, when prey were abundant only on a few isolated trees as at Cornell, the beetles did not remain (or reproduce) in numbers sufficiently high to have significant impact on scale density and resultant damage to host trees. It was suspected that alternative phytophagous prey on nearby deciduous and herbaceous plants may have been sufficiently abundant to prevent congregation of this mobile predator on the pine trees. Thus, the unique and intensive situation created by planting monocultures may not only result in severe infestation of pest species such as the pine needle scale, but also may produce sufficient numbers of biological control agents (such as the influx of twice-stabbed lady beetles) to ultimately contain the spread and severity of the pest infestation.

The feeding capacity of *C. stigma* was best illustrated during laboratory tests, when adults and larvae were fed on immature scales having little or no wax covering. The attack on the immature stages probably also was the most efficient period of predation in the field. Many more individual scales were consumed as immatures in comparison to the similar impact of the predators on wax-covered adults.

The implications of this study on predation of *P. pinifoliae* by *C. stigma* are many, particularly in view of this documentation of the predator as the most important factor

in the population collapse of an important plantation pest. Two applications of the results for possible practical use in the future are:

(1) Artificial introduction of *C. stigma* in large numbers as has been practiced in fruit orchards (Hagen and Tassam, 1965) during the peak period of pine needle scale infestation.

(2) Selective spraying of those severely infested individual trees ready to be marketed during the period of general scale infestation. This would allow for a population increase of the resident density-dependent predators such as *C. stigma* on nearby infested trees not ready for marketing. Chemical insecticide treatment of scattered individual trees should have no impact on overall predator population densities.

CONCLUSIONS

Chilocorus stigma effectively reduced injurious populations of the pine needle scale to extremely low levels in an average-size Scots pine Christmas tree plantation in upstate New York. Contrary to previous reports, it was evident that this coccinellid can be an important natural ememy of a scale insect. The rate of feeding of the twice-stabbed lady beetle, both as larvae and adults, is great, and suggests that biological control of the pine needle scale (and related pest species) may be feasible if an artificial rearing and release program or field collection and re-distribution technique can be developed. Also, application of insecticides to scattered but marketable trees infested with

the scale insect should have insignificant impact on overall predator density, thereby permitting the grower to harvest all trees selected for market. Survival of the scale insect under conditions of severe predation was more related to a few individuals located in protected feeding locations, between the needles near the fascicle, than to chance. In fact, concurrent studies of control with insecticides indicated that some scales located in the same place usually survive the sprays also.

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Weyerhaueser Co., Hot Springs, Ark., and Dr. J.A. Armstrong and Mr. G.W. Taylor of C.C.R.I. reviewed the manuscript.

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