

Mortality of Eggs of Colorado Potato Beetle (Coleoptera: Chrysomelidae) from Predation by *Coleomegilla maculata* (Coleoptera: Coccinellidae)

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ABSTRACT Mortality to the egg stage of Colorado potato beetle, *Leptinotarsa decemlineata* (Say), from endemic predators was assessed in unsprayed plots within commercial potato fields in western Massachusetts in 1986 and 1987. Direct measurement of recruitment into the egg stage and of losses to predation gave estimates of total stage-specific mortality for each generation of Colorado potato beetle and daily mortality rates. Abundance of endemic egg predators was measured through direct observation and trapping. *Coleomegilla maculata* (DeGeer), a coccinellid, was the most abundant predator and the only one consistently present whenever Colorado potato beetle eggs were in the field. Total mortality to eggs from predation was 39.9% in the second generation of 1986 and 37.8% and 58.1% in the first and second generations of 1987, respectively. Daily mortality rate did not change significantly during large fluctuations in prey density. Results suggest that *C. maculata* can contribute to the control of both early and late generations of Colorado potato beetle and efforts to conserve this natural enemy will help reduce the need for chemical control.

KEY WORDS Insecta, *Coleomegilla maculata*, *Leptinotarsa decemlineata*, stage-specific mortality

IN COMMERCIAL POTATO FIELDS in Massachusetts, management of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say) depends almost exclusively on repeated applications of insecticides. Consequently, natural enemy populations have remained low and their contribution to pest control has been negligible. In the absence of insecticides, or with use of compatible insecticides, predators and parasites may reach densities capable of suppressing Colorado potato beetle populations below economically damaging levels (Ferro 1985).

In western Massachusetts, *Coleomegilla maculata* (DeGeer) migrates into potato fields shortly after plant emergence in June and is visible on plants throughout the season. This polyphagous coccinellid readily feeds upon Colorado potato beetle eggs as well as on aphids and pollen and aggregates in patches where food is plentiful (Codre et al. 1987, Wright & Laing 1980). If *C. maculata* colonizes potato fields in sufficient numbers, its effect on the survival of Colorado potato beetle eggs may be significant. Other predators that may contribute to egg mortality include *Podisus* spp., *Lebia grandis* Hentz, other carabids, phalangids, and spiders.

Quantifying the mortality caused by field populations of predators or parasites is an essential step in the development of management strategies which include the action of natural enemies. Larval predation by *Podisus maculiventris* (Say) and *Perillus bioculatus* (F.) and parasitism by *Myiopharus do-ryphorae* (Riley) have received attention (Drum-

mond et al. 1984, Tamaki & Butt 1978, Horton & Capinera 1987, Tamaki et al. 1983). However, the impact of endemic predators upon the egg stage of Colorado potato beetle has not yet been quantitatively evaluated.

The three objectives of this study were: (1) to assess the abundance of *C. maculata* and other endemic predators; (2) to measure the daily predation rates on Colorado potato beetle eggs; and (3) to determine mortality of successive egg cohorts and of each full generation of Colorado potato beetle eggs from native predators.

Materials and Methods

This study was conducted at Taft Farm in Great Barrington, Massachusetts, which is a diversified vegetable farm where potatoes were grown in rotation with sweet corn, bush beans, and other vegetables and with a history of relatively low insecticide use. Cropped fields were surrounded by weedy uncultivated areas which provided alternate food sources and refugia for *C. maculata* and other mobile predators. *C. maculata* was relatively abundant throughout the farm and aggregations of *C. maculata* adults overwintered close to potato fields.

Egg Recruitment and Mortality. Measuring the total mortality occurring in a life stage during one generation of a field population requires estimates of total numbers entering the stage in the generation, and estimates of numbers lost to the mortality

factor over the entire generation. Because the period of Colorado potato beetle oviposition is long relative to the developmental time of the egg, eggs begin to hatch before egg laying as a whole has ended. Therefore, no single sample reflects the total numbers entering the egg stage or total generational mortality of eggs (Van Driesche 1983). These totals can be obtained by measuring two rates: the rate of recruitment of the insect into the stage of interest, and the rate of deaths from the mortality factor, for the duration of the generation. This method was used by Van Driesche & Bellows (1988) to evaluate losses to parasitism in field populations of *Pteris rapae* L. attacked by the parasitoid *Cotesia glomerata* L.. Values of these rates were obtained for each interval between successive sample dates. When these were summed, they estimated total numbers entering the stage in the generation and total numbers dying in the stage from parasitism.

In the present study, the approach of Van Driesche and Bellows (1988) was modified for a predator-prey system. Because Colorado potato beetle eggs are an immobile prey, they can be marked as they enter the population in the field and their survival can be determined by repeated observation. Application of the recruitment method of sampling enables measurement of the numbers of eggs laid in each inter-sample interval and the predation on these cohorts of eggs. Total eggs laid and total numbers eaten by predators are found by summing all cohorts in the generation. This method also provides a measure of the rate of predation on the total prey available (of all ages) during any given time interval, which may be expressed as a daily predation rate.

In June 1986, a 0.3-ha plot (A) was established within a 14-ha field of potato ('Russett Burbank') at Taft Farm. However, the density of Colorado potato beetle eggs was so low in the first generation that it was not possible to collect enough samples to estimate predation. A second 0.2-ha plot (B) with higher Colorado potato beetle densities was established in the same field for study of the second generation. Conventional commercial practices were used for weed and disease control, fertilization, and tillage. No insecticide treatments were made to the study plots or to the surrounding field.

Sampling for first-generation eggs began after plant emergence, on 19 June. Sampling for second-generation eggs began on 4 August, when oviposition by summer Colorado potato beetle adults was first observed. One hundred randomly selected plants (first generation) or stalks (second generation) were marked with stakes and searched twice each week for new egg masses. All newly recruited egg masses were labeled with a date-specific code of colored paint on the upper side of the leaflet and the eggs in each new mass were counted. All masses were reexamined on each successive sampling date to determine the number of eggs damaged or intact. Missing eggs were assumed to have

been removed by predation, except during the interval when hatch occurred.

In 1987, a 0.16-ha study plot (C) was established in the center of one edge of a 10.2-ha potato field ('Russett Burbank', planted 13 May) and was not treated with any insecticides. Sections of the surrounding field were treated with one or more insecticides (*Bacillus thuringiensis* subsp. *san diego*, fenvalerate, azinphos-methyl, carbaryl, or oxydemeton-methyl) for control of Colorado potato beetle and other insect pests, except for a 10-row border around the study area to minimize drift into the plot. The entire planting was subject to conventional commercial weed and disease control and hilling, as in 1986. Egg predation was measured in the same manner as in 1986 except that observations were made three times per week and masses were marked with colored surveyor's tape tied to the petiole nearest the leaflet with eggs. One hundred plants were marked on 5 June at plant emergence, but this was reduced to 50 plants on 22 June because egg density was too high to allow all eggs on 100 plants to be observed on every sample date.

Because of heavy defoliation by Colorado potato beetle larvae and adults in plot C, the study was moved at the beginning of the second generation (24 July) to an area (D) previously protected by insecticides. This 0.08-ha plot was located ≈ 100 m from plot C, in the same potato field. Fifty complete stalks were permanently staked, egg masses were marked, and their fate was recorded.

In both 1986 and 1987, no attempt was made to quantify predation which occurred during the interval when eggs hatched. Egg damage from chorion feeding or cannibalism by Colorado potato beetle larvae, which commonly occurs during hatch, cannot be reliably distinguished from that caused by chewing predators. Therefore, if first instars were found on the mass or the adjacent leaflets or stalk, then changes in the egg mass during that interval were not attributed to predation. The number of eggs surviving up to the time of hatch was assumed to be the same number that were present on the previous observation date. Thus, mortality from larval cannibalism during and just after hatch was not measured in this study, and predation was underestimated to the extent that it occurred during the interval when hatch took place. Cannibalism has been estimated in the field (Harcourt 1971) and in the laboratory (Van Driesche et al. 1989) to kill $\approx 15\%$ of Colorado potato beetle eggs during hatch.

Plant densities in study plots were as follows: Plot B, 7.8 stalks/m²; Plot C, 2.54 plants/m²; Plot D, 7.8 stalks/m². All samples were converted to numbers per m².

Natural Enemies. Abundance of *C. maculata* and other diurnal predators was monitored by recording the number observed on marked plants or stalks during examination of Colorado potato beetle eggs. Sampling took place between 1100 and 1400

hours. In 1986, *Podisus* spp. were also monitored by traps baited with three species-specific pheromones provided by J. Aldrich (USDA, Beltsville, Md.). In 1987, on three occasions, staked plants were searched four times during the night (1900–2100, 2230–2400, 0130–0300, and 0530–0700 hours) for nocturnal predators. On 15 June, 56 plants (with 101 egg masses) and on 30 June 90 plants (99 egg masses) were searched in Plot C. Fifty stalks (57 egg masses) were observed on 27 July in Plot D.

The presence of carabids in Plot C was also assessed using burlap "traps" which consisted of pieces of burlap (50 by 150 cm) wrapped around potato plants, placed on the ground, or wrapped around wire hoops touching potato foliage. These designs have been effective in capturing *L. grandis* in potato (Grodon 1989). These were checked every 2–5 d from 5–22 June. Carabid species and abundance were monitored in Plot D by placing ten pitfall traps at random from 27 July to 24 August and checking them every 2–5 d.

Specimens of all species captured in pitfall traps were tested for consumption of Colorado potato beetle eggs. They were returned to the laboratory and held in screened plastic boxes (7 by 7 by 8 cm) at 25°C and 75% RH with 2–3 cm of pasteurized soil mix (1:1 [loam:sand]). All were given fresh Colorado potato beetle eggs and moistened dental wicking, and eggs were checked daily for signs of predation. Species that consumed eggs were further tested in large screened cages (36 by 36 by 48 cm) to determine their foraging range on a potato plant. Each cage contained a potted potato plant and sterilized potting soil covering the floor of the cage to a depth of ≈ 4 cm. On each plant, one egg mass was pinned to a leaf near the top of the plant, one half-way up the plant, and one to a leaf that touched the ground. Egg masses were checked daily for predation.

Analytical Methods. For each observation date, information was obtained on the fate of all remaining previously marked egg masses and on the number of new eggs laid since the last sample date. The daily egg recruitment rate was calculated by dividing number of eggs recruited per interval by the number of days (n) in that interval ($n = 3$ or 4 in 1986; $n = 2$ or 3 in 1987). The sum of eggs recruited over all intervals of each egg generation is the total generational egg recruitment. All eggs laid in a given interval constitute, for analysis purposes, an even-aged cohort whose mortality rate is $1 - S$, where S equals the proportion of cohort eggs surviving to hatch.

The rate of predation on all eggs present in an interval, regardless of when they were laid, was also calculated from the data recorded for each interval. This rate was expressed as the absolute numbers eaten per m^2 per interval or as the proportion of available prey that were eaten per day during the interval.

The estimate of available prey must take into account the dynamic interaction of eggs entering

the population via oviposition and those leaving it via hatch or predation. The density of eggs present on each sampling date reflects the sum of these processes for a given moment in time. The number of eggs available to predators during the interval between two sampling dates was taken to be the average of the number present at the beginning and the end of the interval. The proportion of eggs surviving the interval (S), is the ratio of numbers surviving the interval over total number available. The daily mortality rate for an interval with n days is then given by $1 - \sqrt[n]{pS}$.

For statistical analyses, a linear regression model (SAS Institute 1987) was used to test for a relationship between egg density (number of eggs available) as the independent variable and the daily mortality rate. Similarly, the consumption rate of each predator (eggs eaten per predator per day) was regressed against egg density.

Results

Natural Enemies. No carabids were seen in the potato foliage at night. Total predators observed on plants at night, on the three sampling dates, were as follows: adult *Coleomegilla maculata*, 13; phalangids, 5; spiders, 3; *Chrysopa* spp., 2; *Podisus* spp., 1; and other hemipteran predators, 6. The reason for the absence of *Lebia grandis* is unknown but may be the result of herbicide use in these fields. *L. grandis*, especially the soil-dwelling immature stages, is readily killed by certain herbicides (Grodon 1989).

Burlap and board traps placed in Plot C captured only 14 carabids in all, primarily *Agonum plactidum* Say. No *L. grandis* were captured. During this period, potato plants were small and most of the soil was bare and exposed.

Pitfall trap catches in Plot D included four species which subsequently were found to consume eggs: *L. grandis*, *Pterostichus lucublandus* Say, *P. melanarius* Illeger, and *Anisodactylus sanctaecrucis* F. (Fig. 1). One other species captured, *Harpalus pensylvanicus* DeGeer, consumed leaf tissue but not eggs in the laboratory. Both *L. grandis* and *P. lucublandus* consumed all or most of the eggs provided in small cages, whereas *P. melanarius*, *A. sanctaecrucis*, and *A. plactidum* ate eggs sporadically. In large cages where egg masses were placed at three levels in the potato foliage, only *L. grandis* foraged in the foliage. *A. sanctaecrucis* and *P. melanarius* ate eggs on the leaf that touched the ground but not on leaves in the canopy. In this group of carabids, only *L. grandis* possesses adhesive setae on the tarsomeres which permit adhesion to plant stems (G. Ball, personal communication). Thus, in this plot, the egg-consuming carabids that were present in significant numbers could only have fed upon eggs on leaves touching the ground.

Pheromone traps used in 1986 failed to capture any *Podisus* spp., although identical traps used at

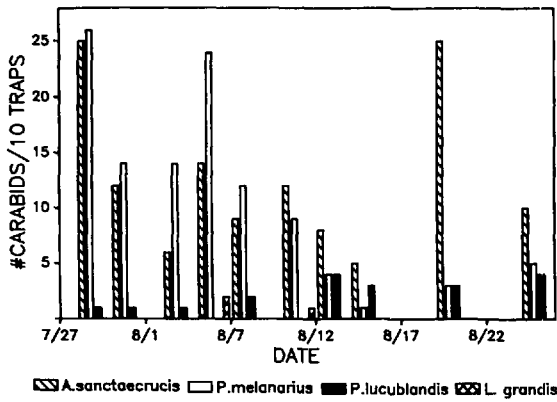


Fig. 1. Number of carabid adults caught in ten pit-fall traps placed in study plot in potato field during July and August 1987, Gt. Barrington, Mass.

another potato field in western Massachusetts did capture *Podisus* spp.

The most abundant predator observed on plants during both day and nighttime sampling was *C. maculata*. Other predators found in the foliage during daytime observations were nymphs and adults of *Podisus* spp., phalangids, and spiders. *Podisus* and phalangids were seen more frequently in the latter half of the season in both 1986 and 1987. Only *C. maculata* was consistently observed on all sample dates when Colorado potato beetle eggs were present in the field.

Coleomegilla maculata was more abundant during the second generations of 1986 and 1987 than during the first generation of 1987, reaching a maximum mean density of 1.56 individuals/m² in both years (Fig. 2E, 3E, and 4E). In the second generation in 1986, these samples included larvae, but in 1987 larvae were seen only in the first generation. The number of *C. maculata* larvae did not exceed the number of adults except on one occasion. In the first generation of 1987, *C. maculata* density peaked when Colorado potato beetle egg abundance was increasing, whereas in the second generation the density of *C. maculata* was highest after peak egg abundance (Fig. 2E, 3E). Between the sampling dates of 3 and 5 August 1987, the density of *C. maculata* increased fivefold just after maximum egg availability and remained high for about a week, then declined to zero (Fig. 3E).

Egg Recruitment and Mortality. In 1986, colonization of the early season study plot by overwintered Colorado potato beetle adults was delayed and reduced by rotation of potato fields from one side of the Housatonic River to the other. First-generation egg densities were too low to conduct the planned study. Because of late colonization by overwintered adults, emergence of first-generation adults was also delayed. Oviposition of second-generation eggs began around 1 August (Fig. 2A) and lasted 17 d. The rate of recruitment peaked at 69.8 ± 8.6 eggs/m²/d in the 7–11 August interval and

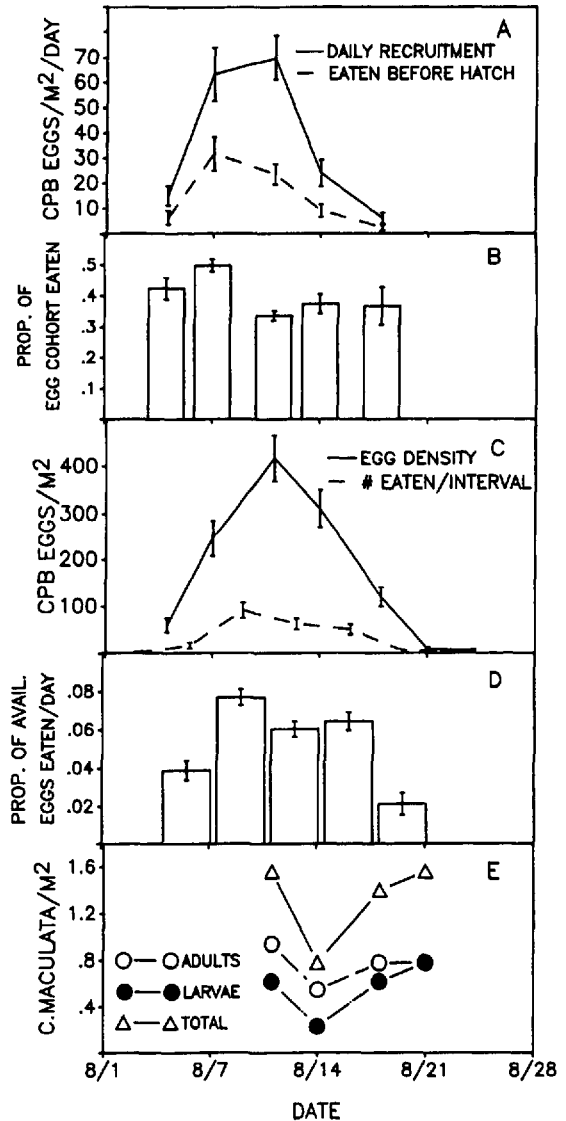


Fig. 2. Recruitment, density and mortality of second-generation Colorado potato beetle eggs, 1986. Error bars for egg counts (Fig. 2A and 2C) indicate standard error of the mean; those for proportions (Fig. 2B and 2D) indicate 95% confidence intervals. (2A) Daily recruitment of eggs per m² during the preceding time period, and the corresponding number of eggs in that cohort that were eaten by predators before hatch; (2B) Proportion of each egg cohort that was eaten by predators; (2C) Total egg density on each observation date, and the number eaten by predators during the period between successive observation dates; (2d) Daily mortality rate, the number of eggs eaten/number available/day; (2E) *Coleomegilla maculata* adult and larval density (number per m²), from visual observation of the marked stalks on which eggs were traced.

then ended one week later. A total of five egg cohorts that originated during successive 3- or 4-d intervals were evaluated for predation. Mortality of cohorts (proportion killed by predation) was rel-

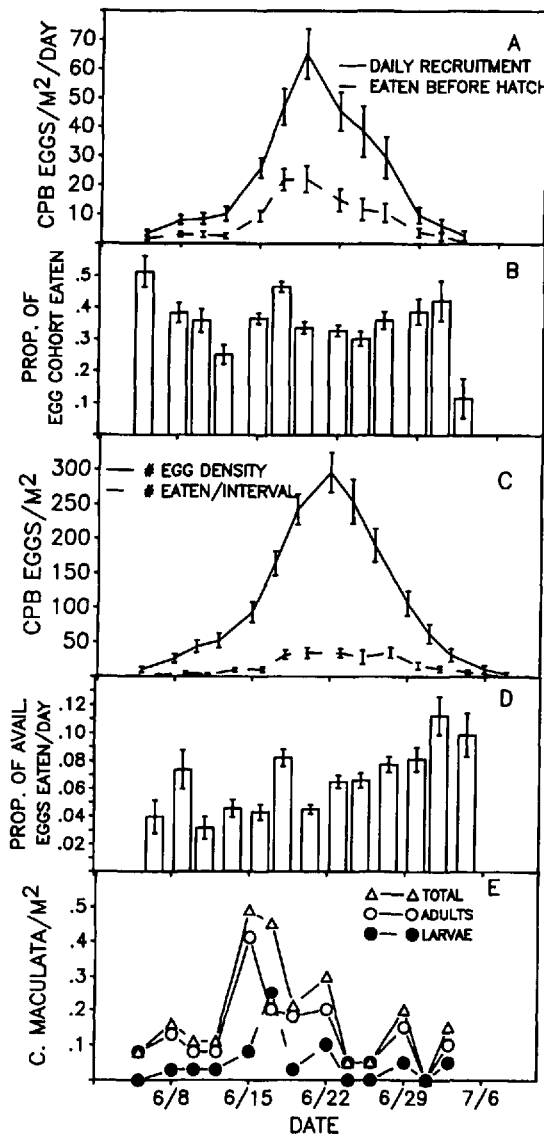


Fig. 3. Recruitment density and mortality of first-generation Colorado potato beetle eggs, 1987. See legend for Fig. 2 for explanation of each graph.

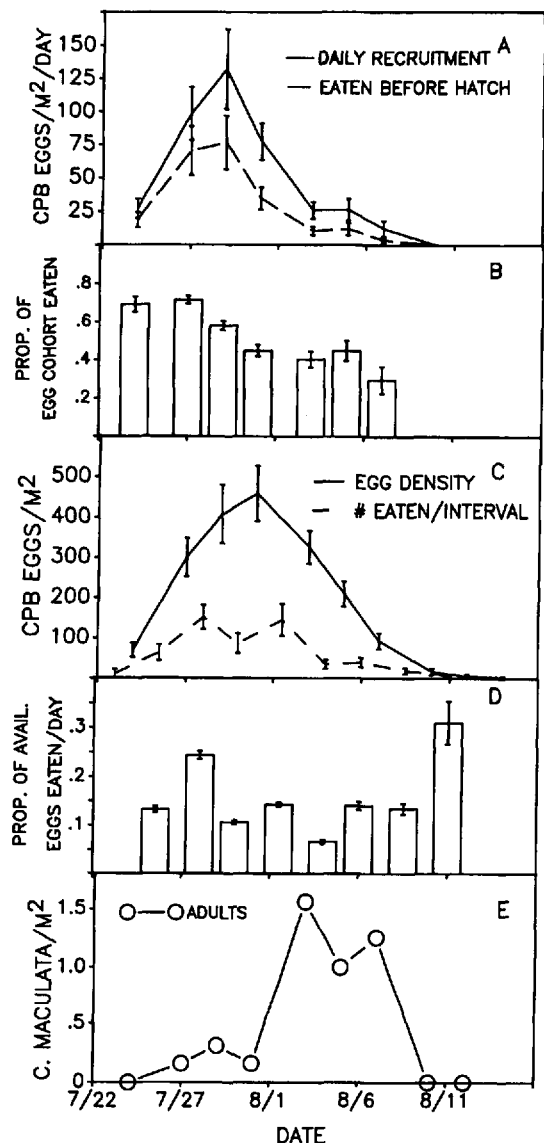


Fig. 4. Recruitment, density and mortality of second-generation Colorado potato beetle eggs, 1987. See legend for Fig. 2 for explanation of each graph.

actively uniform, with rates being perhaps higher in the first two cohorts as compared to the last three (Fig. 2B). Total recruitment for the generation was 625 eggs/m², of which 39.9% (249 eggs/m²) were eaten by predators before hatch (Table 1).

Egg recruitment declined rapidly after 11 August and the date of maximum recruitment coincided with maximum egg density (Fig. 2C). Egg density peaked at 417.8 ± 49.5 eggs/m² on 11 August. Some eggs remained in the field for about one week after the last new oviposition, and were observed until 24 August for damage from predation. The daily mortality rate (eggs eaten/eggs available/day) was highest during the three periods

of highest density (0.077, 0.061, and 0.065 for intervals preceding 7, 11, and 14 August, respectively) (Fig. 2D).

In 1987, because the study field was close to the previous year's potatoes and to overwintering sites of Colorado potato beetle, adult beetles colonized the field as soon as plants emerged. Oviposition was first observed on 5 June. The egg-laying period lasted 28 d, with the last new eggs marked on 3 July. Peak recruitment rate was 70.4 ± 9.2 eggs/m²/day, during the interval of 17–19 June (Fig. 3A). Thirteen egg cohorts were marked and traced to hatch. Predation on three successive cohorts originating from 10–17 June rose from 25.2 to 46.6%.

Mortality then fell to 33.7% for the 19 June cohort and remained relatively constant for succeeding groups (Fig. 3B). Total recruitment for the first generation was 749 eggs/m², of which 37.8% (280 eggs/m²) were eaten by predators (Table 1).

Peak egg density was 296.0 ± 28.9 eggs/m² and occurred 3 d after maximum recruitment (Fig. 3C). The daily mortality rate exhibited a gradual increase over the course of the generation. From 8 June to 22 June, while the number of prey rose tenfold (from 26.9 ± 6.3 to 286.0 ± 34.7 eggs/m²), the proportion of available prey eaten per day did not decline (Fig. 3D).

Recruitment of second-generation eggs began on about 21 July, earlier than in 1986, and lasted 17 d. High rates of egg deposition from 27 to 31 July produced higher egg densities in a shorter period of time than in the first generation (Fig. 4A). Unlike the two previous generations described, cohort mortality rate declined steadily from initial levels of 69.2% and 71.6% for the first two cohorts to 29.6% for the seventh and final cohort (Fig. 4B). Total recruitment was 988 eggs/m², of which 58.1% (574 eggs/m²) were eaten by predators.

Egg density reached a maximum of 458.5 ± 68.2 eggs/m² two days after peak egg recruitment (Fig. 4C). The number of eggs eaten was highest when the availability of eggs was greatest (intervals ending on 29 and 31 July and 3 August). However, the proportion eaten increased in correspondence with a density increase only during the first two intervals (Fig. 4D).

The daily rate of mortality showed no relationship to egg density in the first generation ($n = 13$, $R^2 = 0.002$, $P = 0.8962$) or second generation in 1987 ($n = 8$, $R^2 = 0.142$, $P = 0.3577$) and showed a positive though not significant relationship to egg density in 1986 ($n = 5$, $R^2 = 0.758$, $P = 0.0546$). For prey such as Colorado potato beetle eggs, which undergo large and rapid fluctuations in density, maintenance of a relatively stable mortality rate represents a significant positive relationship between predator foraging behavior and prey density.

The rate of predator attack on eggs (eggs eaten per predator per day) showed a positive linear relationship with prey density in both the first ($R^2 = 0.582$; $F = 15.3$; $df = 1,10$; $P = 0.0024$, $y = 0.473x$) and second ($F = 6.8$; $R^2 = .526$; $df = 1,6$; $P = 0.0416$, $y = 0.665x$) generations of 1987. This suggests that the functional response to prey density which has been demonstrated for *C. maculata* under laboratory conditions is also operating in the field.

Discussion

Coleomegilla maculata was both the most abundant predator and the only one consistently present when Colorado potato beetle eggs were available as prey. Colonization of early-season potatoes by adult *C. maculata* occurred shortly after plant

Table 1. Total recruitment of Colorado potato beetle eggs for 1986 and 1987 and generational mortality to the egg stage from predation by *C. maculata*

Beetle generation	Eggs tracked	Total recruitment, eggs/m ²	Eggs eaten, eggs/m ²	Stage-specific mortality (% eaten)
1986				
Generation 2	8,011	625	249	39.9
1987				
Generation 1	17,999	740	280	37.8
Generation 2	6,097	988	574	58.1

emergence in 1987 and was well synchronized with the first occurrence of Colorado potato beetle eggs. In potato fields in Rhode Island and Michigan, Groden et al. (1990) also found the numbers of *C. maculata* to be well synchronized with populations of first-generation Colorado potato beetle eggs. No other endemic predator or parasitoid of egg and larval stages has been shown to cause significant early-season mortality to Colorado potato beetle eggs or larvae, with the exception of *L. grandis* (Groden 1989). However, *L. grandis* was not a significant predator in our study fields. Mortality to early life stages of the first generation of Colorado potato beetle is especially significant because it prevents feeding damage during the plant growth stage when potato yield is most affected (Ferro et al. 1983).

Estimates of total mortality occurring before the larval stage should include the influence of cannibalism during hatch. If the estimate of mortality rate from cannibalism of 15% made by Harcourt (1971) and Van Driesche et al. (1989) is added to mortality from predation, total mortality in these fields is estimated to be 54.9% for 1986, and 52.8% and 63.1%, respectively, for first and second generations of 1987.

Fluctuations in the numbers of *C. maculata* observed in foliage may be caused by adult immigration and emigration from the plot, reproduction, or variation in foraging activity in the plant canopy. Movement of adults between potato, other crops, and field borders probably occurs constantly throughout the growing season in response to changing prey populations. Groden (1990) found that *C. maculata* was present in plots of sweet corn, alfalfa, green beans, cole crops, and cucurbits next to potato plots in Rhode Island and Michigan, with highest densities occurring in sweet corn after tasselling (pollen shed). Numerical response of *C. maculata* via immigration of adults into a patch of abundant food can occur rapidly. Gross et al. (1985) found that adult *C. maculata* density increased significantly within 1 h and peaked by 8 h after application of lepidopteran larval homogenate as a food source to corn plots. Wright & Laing (1980) saw a numerical response of *C. maculata* to density of corn leaf aphid. In the latter two cases, adult

arrival was associated with deposition of eggs. Reproduction occurs in potato fields as well, as evidenced by presence of larvae in samples (Fig. 2E, 3E). However, its contribution to fluctuation in total *C. maculata* numbers may be small relative to adult movement, as larvae comprised no more than half of any sample and frequently were absent from samples altogether. This may be explained in part by the fact that Colorado potato beetle eggs are not the optimal food for oviposition or larval development (Hazzard & Ferro 1991).

Ambient temperature, time of day, and predator hunger influence foraging activity and therefore numbers observed in samples. Benton & Crump (1981) found that locomotor activity of *C. maculata* was greatest in early morning in sweet corn in New York State, and that beetles foraged in the upper levels of corn only in the early morning hours and descended to lower levels before noon. Mack & Smilowitz (1980) studied sampling methods for *C. maculata* in potato and found 0900–1115 hours to be the time during daylight hours when sampling variability was lowest, although the time period from 1115 to 1535 hours gave the highest means. The numbers of coccinellids observed foraging may be several times fewer than the absolute numbers present because satiated individuals rest at the base of plants in cracks in the soil (Frazer & Gill 1981). Thus, samples derived from foliage observations may significantly underestimate the absolute density of *C. maculata* present, and attempts to correlate those sample numbers with other phenomena must recognize the degree of error associated with patterns of foraging behavior in this coccinellid.

The combined records of egg recruitment and egg survival provide insight into the relationship between the rate of mortality occurring in the egg stage and the number of prey entering and leaving the stage. In 1986, egg recruitment was relatively low (625 eggs/m²) and generational mortality to eggs was 39.9%, resulting in survival of 376 eggs/m². In 1987, total egg recruitment was greater in the second generation (988 eggs/m²) than in the first (740 eggs/m²) and stage-specific mortality of eggs was also higher (59.1% as compared to 37.8% in the first generation). The net outcome was that the number of eggs surviving to hatch was lower (414 eggs/m²) in the second generation than in the first (460 eggs/m²) (Table 1). Larvae from the eggs that survived in the first generation of 1987 caused more severe defoliation than those of the second generation, in part because potato foliage biomass was less at the time of the first generation than at the time of the second. Because it is the interaction of pest numbers, stage-specific mortality rate, and plant susceptibility that determines whether economic thresholds are exceeded, a rate of predation that is adequate for economic control at a certain pest density and plant growth stage may not be adequate under other conditions.

Coleomegilla maculata can contribute substan-

tially to the control of both early and late generations of Colorado potato beetle in Massachusetts and efforts to conserve this natural enemy will help reduce the need for chemical control. The synchrony of adult immigration into potato fields with the expansion of Colorado potato beetle egg populations represents a valuable mechanism for early-season control. However, native populations of *C. maculata* will not be sufficient to manage Colorado potato beetle population unless other practices, such as field rotation and use of compatible pesticides, are included in the management program.

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