Effects of Aerial Application of Insecticide on the Survival Rate of *Monochamus alternatus* (Coleoptera: Cerambycidae) within *Pinus densiflora* Logs

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Pine logs on which caged *Monochamus alternatus* insects had deposited eggs were placed in a *Pinus densiflora* stand, and a carbamate insecticide, carbaryl, was aerially sprayed for a 2-year period, and survival rates were studied. Life tables were constructed from samplings conducted 5 times a year in which the mortality rates and agents were examined at each developmental stage. The survival rate from egg to adult emergence was 0.55 during the year before the spraying, and 0.37 and 0.54 in the 2 years when spraying was conducted. For populations (cohorts) established by June-July oviposition, however, the survival rate was 0.56 in the year before application and 0.87 in the 2 years with application. The comparison of mortality agents and life tables suggested that the insecticide application had suppressed the general activity of predaceous insects when and after *M. alternatus* reached the 3rd larval instar.

INTRODUCTION

Monochamus alternatus HOPE adults transmit the pinewood nematode, *Bursaphelenchus xylophilus* (STEINER et BUHRER) NICKLE, which is the causative agent of the pine wilt disease of *Pinus thunbergii* PARL. and *P. densiflora* SIEB. et ZUCC. in Japan (KIYOHARA and TOKUSHIGE, 1971; MAMIYA and ENDA, 1972; MORIMOTO and IWASAKI, 1972). To control the vector beetles insecticides are applied from the air twice during the period of beetle emergence. This chemical control technique has various ecological disadvantages such as environmental pollution and destructive changes in pine forest ecosystems. Furthermore, it is possible that the aerial application of insecticides actually raises the reproduction rate of the vector beetle by killing its natural enemies (TANAKA, 1979). Although it is important to elucidate this indirect effect of insecticide application on *M. alternatus*, there have been no studies on this problem.

In our study, *M. alternatus* populations established within *P. densiflora* logs were placed from 1979 through 1982 in a *P. densiflora* stand which was sprayed with insecticide from 1980. Life tables were constructed for one year before the insecticide application, and continued for 2 years after its commencement in order to evaluate its effect on *M. alternatus* reproduction.

MATERIALS AND METHODS

Study site. The *P. densiflora* stand used in this study is in the mountains at Tatsunokuchi, Ishikawa Prefecture. Trees were 13–15 years old, and averaged 7.6 m ht and 9.9 cm dbh in 1978. The stand density was 2,100 trees/ha. Since the pine wilt disease occurred about 750 m southwest of the study site in the autumn of 1979, a carbamate insecticide, carbaryl, was aerially applied to the study stand twice during the period of beetle emergence; on June 13 and 26, 1980, and on June 17 and 30, 1981. Ultra-low volume spray was made with a formulated concentrate of carbaryl (active ingredient of 40%), which was sold by Izutsuya Co. as “Sevimol”. The first and second applications were 7 l/ha and 6 l/ha, respectively. The pine wilt disease did not occur in the study stand from June 1978 to May 1982.

Insects and sampling methods. Ten pairs of newly emerged adults were introduced into an outdoor cage (0.9 m × 0.9 m × 2.0 m) in the Ishikawa Forest Experiment Station at Tsurugi. These were the adults and progeny which emerged from dead *P. thunbergii* trees collected at Oshimizu in Ishikawa Prefecture. Three cages were used in 1979 and 2 cages in 1980 and 1981. They were supplied with *P. densiflora* logs (1 m length, 6.4 cm average dia) as oviposition sites. The logs, which were taken from trees felled 3–15 days before, were renewed at weekly intervals. Further details of rearing methods are described in TOGASHI and MAGIRA (1981). One to 6 days after being taken out of cages, the logs were transferred to the study site and placed on a mountain ridge 140 m above sea level. The logs were sampled at the 5 different times: about 4 weeks after placement, just before overwintering in November, just after overwintering in March, during the pupation period in June, and after adult emergence in August–September. However, to avoid the incidence of pine wilt disease due to beetle emergence, all the remaining logs were transported to the Ishikawa Forest Experiment Station and placed in outdoor cages in late April or early May.

The number of live and dead eggs, larvae, pupae, teneral adults and emergences, and, when possible, causes of death were recorded. Larval instars were separated by measurements on the head capsule (KOJIMA and KATAGIRI, 1964; OCHI, 1975). The location of individuals was also recorded, defined as under bark, in tunnels or in pupal chambers in the xylem.

Some eggs, which caged populations deposited on logs, hatched before the logs were placed in the study site. So, to examine the hatchability of eggs under field conditions, fresh *P. densiflora* logs, which were cut from the trunks of trees felled 2–17 days before, were placed in the study site and exposed to the wild beetle population. The logs were transferred to the station 9–22 days (usually 14 days) after their placement in the study site and egg hatchability was examined within 10 days after the transfer.

A preliminary survey on the mortality agents was conducted in 1978–1979 by a method similar to 1979–1982 studies except that sampling times were arbitrary.

Data analysis. *M. alternatus* lives within pine logs before adult emergence. Thus, all corpses must be found by carefully surveying under bark, in tunnels or pupal chambers after adult emergence. Larval feeding activity makes it difficult to find corpses in young stages, especially during high larval densities. The mortality rate of a given developmental stage was therefore calculated using the data taken in a specified sampling time (Table 1). With i ($i=1, 2, \dots, \omega$), j ($j=1, 2, \dots, \gamma$), D , and L denoted

Table 1. Times of sampling and developmental stages of *M. alternatus*

Time of sampling	Developmental stage (for estimation of mortality rate)
About 2 weeks after placing logs which had not yet been oviposited.	Egg stage ^a
About 4 weeks after placing logs containing <i>M. alternatus</i>	The 1st and 2nd larval instars
Just before overwintering in November	The 3rd and 4th larval instars prior to the construction of pupal chamber
Just after overwintering in late March-early May	—
During pupation period in June	—
After adult emergence in August-September	The 3rd and 4th larval instars inside pupal chamber in xylem, and pupal and adult stages inside pupal chamber

^a When the wild population of *M. alternatus* did not oviposit on fresh pine logs, the mortality rate at egg stage was estimated from the data obtained from the pine logs which were placed in the study stand for about 4 weeks after the 1-week oviposition by the caged population.

as developmental stage, factor responsible for mortality, and numbers of deaths and survivors, respectively, total number of deaths in a given developmental stage x , D_x , is

$$D_x = \sum_{j=1}^r D_{xj}.$$

The number of individuals in the later developmental stages is

$$\sum_{i=x+1}^{\omega} (L_i + D_i).$$

Consequently, the mortality rate at the developmental stage, q_x , is represented as

$$q_x = D_x / \{D_x + \sum_{i=x+1}^{\omega} (L_i + D_i)\}.$$

When there were survivors at the developmental and younger stages, death probability was assumed to be q_x at the developmental stage, although the stage was decided for a sampling time so that the number of those survivors was as small as possible.

Using the q_x data, a life table was constructed on 2 assumptions: that a standard cohort began with 1,000 eggs deposited and that its members were exposed throughout life to these particular mortality rates. Thus the life tables constructed in this way sometimes dropped some mortality agents which were found in different sampling times. Groups which required 2 years to complete one life cycle were not included in the calculation of mortality rate in the 3rd larval instar and the later stages because of their delayed development. Consequently, the life tables made in this study refer only to the univoltine populations.

RESULTS

A total of 277 corpses were taken from pine logs. Table 2 gives 15 causes of mortality which were identified on 67 corpses. Table 3 gives the life tables for each generation from 1979 to 1982 and Fig. 1 shows their survivorship curves.

Table 2. Mortality factors, developmental stages, generations, and oviposition times of *M. alternatus* established within *P. densiflora* logs

Causes of mortality	No. of <i>M. alternatus</i> corpses															in populations ^c established in			
	at developmental stage ^a										in generation ^b					Jun.	Jul.	Aug.	Sept.
	E	L ₁	L ₂	L _{1,2}	L ₃	L ₄	L _{3,4}	L	P	A	Total	I	II	III	IV				
Conspecific bites	0	0	0	1	2	0	1	8	0	0	12	4	7	0	1	0	10	1	0
<i>Serratia</i> spp.	0	2	0	2	0	0	0	0	0	0	4	4	0	0	0	0	3	1	0
<i>Beauveria bassiana</i>	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	0
<i>Atanycolus initiator</i>	0	0	0	0	2	0	1	0	0	0	3	1	0	0	2	0	1	2	0
<i>Spathius</i> sp.	0	5	6	1	0	0	0	0	0	0	12	5	2	2	3	0	3	9	0
<i>Dolichomitus</i> sp.	0	0	0	0	2	0	0	0	0	0	2	0	0	0	2	0	0	2	0
<i>Cleonymus</i> sp.	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	1	0
<i>Sclerodermus nipponicus</i>	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	0	0
Parasitic wasps ^d	1	0	1	0	0	0	0	0	0	0	2	1	1	0	0	0	1	1	0
<i>Stenogostus umbratilis</i>	0	0	0	0	2	6	0	0	3	0	11	0	4	7	0	0	5	6	0
<i>Carcinophora marginalis</i>	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0
Insect predation	0	0	0	0	0	4	3	1	3	2	13	- ^e	11	2	0	2	5	6	0
Bird predation	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	0	0
Resin	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0
Compression	0	0	0	0	1	0	1	0	0	0	2	0	2	0	0	0	1	1	0
Unknown	46	13	25	5	46	42	8	9	6	10	210	79	42	28	61	2	70	108	22
Total	48	20	32	9	55	53	16	19	12	13	277	96	72	40	69	4	101	141	22

^a E, L, P, and A represent egg, larval, pupal, and adult stages, respectively. Subscripts beside L indicate larval instars. ^b Generations I to IV represent 1978–1979, 1979–1980, 1980–1981, and 1981–1982 generations, respectively. ^c Populations within pine logs were established by oviposition in June, July, August, or September. ^d Not determined. ^e Not recorded.

Fig. 1. The survivalship curves of *M. alternatus* subjected to aerial application of insecticide. *P. densiflora* logs, on which caged populations of *M. alternatus* oviposited, were placed in a *P. densiflora* stand at Tatsunokuchi, Ishikawa Prefecture. Aerial applications of carbaryl began in 1980, and were conducted 2 times in June for 2 years. Solid and broken lines in figures show *M. alternatus* populations at one year before application and for 2 years with application, respectively.

Egg stages

The female beetle deposits eggs in the inner bark. Tree resin sometimes kills eggs by partial or complete enclosure in *P. thunbergii* trees killed by the pine wilt disease (TOGASHI, 1990). In this study, however, only one egg was killed this way.

An empty cocoon of an unknown parasitic wasp was found near a dead host egg. The egg mortality rate was extremely small for each generation (Table 3).

First and 2nd larval instars

Identified mortality agents were conspecific bites, *Serratia* spp. (bacteria), *Spathius* sp. (Hymenoptera: Braconidae), and another parasitic wasp (Table 2).

Mortality by conspecific bites was observed in young larval stages. A Y-shaped feeding trace made by 2 young larvae indicated that one larva survived after the encounter. In this case, there was no sign showing activity of any other insects in the surroundings.

Serratia spp. were found on four 1st or 2nd instar larvae with purple-red bodies.

Spathius sp. larvae appeared from the 1st or 2nd instar host larvae and then spun cocoons. There were 1 to 4 cocoons near host corpses. There was a correlation between the number of cocoons and host size.

A black pupa of a parasitic wasp was near a host corpse of a 2nd larval instar. It failed to emerge as an adult, but was possibly *Cleonymus* sp. judging from the shape, size, and color.

The mortality rate in the 1st and 2nd larval instars varied from 6.8 to 25.0% (Table 3). The average rate was 12.6%.

Table 3. Life tables for each generation of *M. alternatus* within *P. densiflora*

Age class (x)	Causes of mortality ($d_x F$)	1979-1980 generation					1980-1981 generation				
		l_x	$100q_x$	d_x	l_A	l_B	l_x	$100q_x$	d_x	l_A	l_B
Egg		1,000.0					1,000.0				
	Unknown		1.3	1				0.0	0		
	Total		1.3	1	76	2		0.0	0	8	0
L _{1,2}		987.0					1,000.0				
	<i>Spathius</i> sp.		3.4	2				7.1	2		
	Parasitic wasp		1.7	1				0.0	0		
	Unknown		1.7	1				17.9	5		
	Total		6.8	4	55	39		25.0	7	21	0
L _{3,4} (before com- pletion of PC)		920.1					750.0				
	<i>A. initiator</i>		0.0	0				0.0	0		
	Unknown		17.5	7				7.4	2		
	Total		17.5	7	33	14		7.4	2	25	7
L _{3,4} (in PC)		759.1					694.4				
	<i>B. bassiana</i>		0.9	1				0.0	0		
	Insect predation		6.3	7				19.2	5		
	Unknown		8.1	9				11.5	3		
	Total		15.3	17	94	13		30.8	8	18	7
Pupa (in PC)		642.8					480.8				
	Insect predation		5.3	5				0.0	0		
	Unknown		5.3	5				0.0	0		
	Total		10.6	10	84	0		0.0	0	18	0
Adult (in PC)		574.4					480.8				
	Insect predation		1.2	1				11.1	2		
	Unknown		3.6	3				11.1	2		
	Total		4.8	4	80	0		22.2	4	14	0
Adult (in flight)		547.1					373.9				

L_{1,2}, L_{3,4}, and PC in age class column represent the 1st-2nd and 3rd-4th larval instars, and predation by *S. umbratilis* and *C. marginalis*. l_A shows the number of insects in more advanced age and dead insects in the age class concerned. Mortality rate ($100q_x$) was calculated as $\{d_x/(l_A +$

Third and 4th larval instars

Seven mortality factors were determined: conspecific bites, *Beauveria bassiana* (a fungus), *Atanycolus initiator* (FABRICIUS) (Hymenoptera: Braconidae), *Dolichomitus* sp. (Hymenoptera: Ichneumonidae), *Sclerodermus nipponicus* YUASA (Hymenoptera: Mutilidae), *Stenagostus umbratilis* (LEWIS) (Coleoptera: Elateridae), insect predation, bird predation, and compression (Table 2).

Some larvae were killed by conspecific bites, determined from observations of single living larva near the injured, moribund or dead individuals of the same species. Insect predation was not assumed due to the absence of predators in these cases. The injured portion of the body was usually only the head, but sometimes the thorax or the end of the abdomen was also damaged. Of 11 larvae killed this way, 10 were under bark,

logs placed in a *P. densiflora* stand at Tatsunokuchi, Ishikawa prefecture

1981-1982 generation					1979-1982 generations combined				
l_x	100 q_x	d_x	l_A	l_B	l_x	100 q_x	d_x	l_A	l_B
1,000.0	3.3 ^a	2			1,000.0	1.2	1		
	3.3 ^a	2	58	0		1.2	1	84	2
966.7	3.6	2			988.2	4.2	6		
	0.0	0				0.7	1		
	8.9	5				7.7	11		
	12.5	7	49	2		12.6	18	125	41
845.8	4.3	2			863.8	1.8	2		
	21.7	10				16.8	19		
	26.1	12	34	16		18.6	21	92	37
625.2	0.0	0			703.3	0.5	1		
	0.0	0				6.4	12		
	8.0	4				8.6	16		
	8.0	4	46	1		15.5	29	158	21
575.2	0.0	0			594.2	3.2	5		
	2.2	1				3.8	6		
	2.2	1	45	0		7.0	11	147	0
562.7	0.0	0			552.9	2.0	3		
	4.4	2				4.8	7		
	4.4	2	43	0		6.8	10	137	0
537.7					515.3				

pupal chamber in xylem, respectively. In causes of mortality, insect predation includes the classes than the age class for estimation of mortality rate. l_B and d_x show the numbers of live d_x) $\times 100$. ^a determined by the method described in the footnote in Table 1.

and one in a xylem tunnel.

B. bassiana was detected in a 3rd or 4th instar larva.

A singular larva of *A. initiator* emerged from a 3rd or 4th instar larva under bark. A cocoon of *Dolichomitus* sp. was found inside a tunnel constructed by a host larva in xylem. The host larvae died at the 3rd instar. A *Cleonymus* sp. pupa was near a host corpse (possibly 2nd or 3rd larval instar—impossible to determine due to the absence of head capsule). Eleven *S. nipponicus* larvae had attached their heads into a 4th instar larva body which was under bark.

S. umbratilis larvae were found within the host pupal chambers with a host corpse. Some *S. umbratilis* larva exuviae remained inside other pupal chambers with the head capsule of the dead host larva. Insect predation was assumed when the pupal chambers

had loose wooden fiber entrance plugs, a host corpse was present, and predators were absent.

Bird predation was identified from feeding scars on wood.

When dead uninjured larvae were found laterally flattened with the intestine protruding from the anus, the mortality factor was judged to be compression. This possibly occurred during the transportation of logs.

At the 3rd and 4th instars, the larvae construct tunnels within xylem and plug the entrance with wooden fiber. We refer to this as the pupal chamber (PC) in this article. The 3rd and 4th larval instars were accordingly divided into 2 stages in the life tables: before and after the completion of pupal chambers (Table 3). The mortality rate varied from 7.4 to 26.1% with the average of 18.6% for the 3rd and 4th larval instars before pupal chamber completion. It fluctuated from 8.0 to 30.8% with the average of 15.5% in the same larval instars after pupal chamber completion.

Table 4. Effects of aerial application of insecticide (carbaryl) on *M. alternatus* populations, established by June-July oviposition on *P. densiflora* logs

Age class (<i>x</i>)	Causes of mortality (<i>d_xF</i>)	1979-1980 generation					1980-1982 generations				
		<i>l_x</i>	100 <i>q_x</i>	<i>d_x</i>	<i>l_A</i>	<i>l_B</i>	<i>l_x</i>	100 <i>q_x</i>	<i>d_x</i>	<i>l_A</i>	<i>l_B</i>
Egg		1,000.0					1,000.0				
	Unknown		0.0	0				3.1 ^a	1		
	Total		0.0	0	33	2		3.1 ^a	1	31	0
L _{1,2}		1,000.0					968.8				
	Unknown		0.0	0				3.3	1		
	Total		0.0	0	41	39		3.3	1	29	1
L _{3,4} (before com- pletion of PC)		1,000.0					936.5				
	Unknown		14.7	5				2.6	1		
	Total		14.7	5	29	8		2.6	1	37	4
L _{3,4} (in PC)		852.9					911.8				
	Insect predation		7.5	4				0.0	0		
	Unknown		11.3	6				5.1	2		
	Total		18.9	10	43	0		5.1	2	37	1
Pupa (in PC)		692.0					865.1				
	Insect predation		9.3	4				0.0	0		
	Unknown		2.3	1				0.0	0		
	Total		11.6	5	38	0		0.0	0	37	0
Adult (in PC)		611.5					865.1				
	Insect predation		2.6	1				0.0	0		
	Unknown		5.3	2				0.0	0		
	Total		7.9	3	35	0		0.0	0	37	0
Adult (in flight)		563.3					865.1				

No insecticide was applied in 1979. Insecticide was applied twice in June of 1980 and 1981. ^a determined by the method described in the footnote of Table 1. See Table 3 for further explanation.

Pupal stage

Insect predation was also observed in the pupal stage (Table 2). A *S. umbratilis* larva was found feeding on a host pupa inside pupal chamber and *S. umbratilis* exuviae were found to be with host corpses in other pupal chambers. No other mortality factors were identified. The mortality rate in the pupal stage averaged 7.0%.

Adult stage before emergence

A *Carcinophora marginalis* (DOHRN) (Dermaptera: Anisolabididae) nymph was found to be in a pupal chamber with a dead host adult. Insect predation was confirmed in 2 pupal chambers, each containing a dead host adult. The mortality rate in the adult stage fluctuated from 4.4 to 22.2%. The average rate was 6.8%.

Other life tables were made by rearranging the data to clarify the effect of insecticide.

Table 5. Effects of aerial application of insecticide (carbaryl) on *M. alternatus* populations, established by August oviposition in *P. densiflora* logs

Age class (x)	Causes of mortality ($d_x F$)	1979-1980 generation					1980-1982 generations				
		l_x	100 q_x	d_x	l_A	l_B	l_x	100 q_x	d_x	l_A	l_B
Egg		1,000.0					1,000.0				
	Unknown		2.3	1				0.0	0		
	Total		2.3	1	43	0		0.0	0	8	0
L _{1,2}		977.3					1,000.0				
	<i>Spathius</i> sp.		11.1	2				7.4	4		
	Parasitic wasp		5.6	1				0.0	0		
	Unknown		5.6	1				16.7	9		
	Total		22.2	4	18	0		24.1	13	41	1
L _{3,4}		760.1					759.3				
(before completion of PC)	<i>A. initiator</i>		0.0	0				5.7	2		
	Unknown		20.0	1				31.4	11		
	Total		20.0	1	4	5		37.1	13	22	16
L _{3,4} (in PC)		608.1					477.2				
	<i>B. bassiana</i>		1.7	1				0.0	0		
	Insect predation		5.2	3				13.5	5		
	Unknown		5.2	3				13.5	5		
	Total		12.1	7	51	6		27.0	10	27	6
Pupa (in PC)		534.7					348.3				
	Insect predation		2.0	1				0.0	0		
	Unknown		7.8	4				3.7	1		
	Total		9.8	5	46	0		3.7	1	26	0
Adult (in PC)		482.3					335.4				
	Insect predation		0.0	0				7.7	2		
	Unknown		2.2	1				15.4	4		
	Total		2.2	1	45	0		23.1	6	20	0
Adult (in flight)		471.8					258.0				

Refer to Tables 3 and 4 for explanation.

ticide application on mortality of *M. alternatus* populations which were established in different months within pine logs.

For the populations established by June-July oviposition, the percent survival from egg to adult emergence was much lower in the 1979-1980 generation (no insecticide application) than in the 1980-1982 generations (insecticide applied; see Table 4 and Fig. 1). The difference reached 30%. The lower survival rate in the 1979-1980 generation was caused by the increased mortality rate between the 3rd larval instar and the adult stage. Remarkably, insect predation was observed in the generation without insecticide application, whereas it was not observed in the 2 generations with insecticide application.

A reversed relationship was observed for the populations established by August oviposition: the percent survival was higher in the 1979-1980 generation than in the 1980-1982 generations (Table 5 and Fig. 1). The difference in survival was 21%, and caused by the different mortality rates both in the 3rd-4th larval instars and in the adult stage. All generations were parasitized by wasps such as *Spathius* sp. and all generations except 1981-1982 were preyed upon by insects such as *S. umbratilis*, regardless of the insecticide applications.

DISCUSSION

METCALF (1986) pointed out 7 ecological effects of insecticide application: the suppression of target pest population, selection of resistant pests, destruction of natural enemies, promotion of pest resurgences including the development of secondary pests, destruction of pollinators, contamination of food webs, and general ecotoxicity.

In Japan, aerial application of 2 kinds of insecticides, carbaryl and fenitrothion, has been undertaken for the control of pine wilt disease by killing the insect vector, *M. alternatus* adults. Environmental pollution, destructive changes to pine forest ecosystems, and a supposed increase in the reproduction rate of *M. alternatus* caused by the destruction of natural enemies are bases of objection against the aerial application of insecticide.

However, there has been no clear evidence of an increased reproduction rate of *M. alternatus*. TANAKA (1979) pointed out a possibility that a beetle population increased after an aerial spraying of carbaryl, judging on the basis of 16 beetles captured by 2 traps in a pine forest where the insecticide had been sprayed one year but not in the following year. He did not prove that the destruction of natural enemies caused the increased reproduction rate of the beetle population.

KOBAYASHI et al. (1983) added eggs or 2nd-3rd instar larvae of the pine caterpillar, *Dendrolimus spectabilis* BUTLER, to some *P. densiflora* forests in order to examine a possibility of resurgence of the caterpillar after aerial application of carbaryl for the control of pine wilt disease. They showed no correlation between mortality rate of young larvae and aerial application of carbaryl, and did not observe an obvious suppression of spiders and ants, the natural enemies of pine caterpillar. They did not conclude that the resurgence of pine caterpillars always occurs after the aerial application of carbaryl.

The survival rate of immature stages is a component of reproduction rate. In our study, this was determined by placing pine logs containing *M. alternatus* in a *P. densiflora* stand. Unexpectedly, the aerial application of carbaryl was started during this study period. Consequently, data were obtained to study the effect of insecticide

application on *M. alternatus*. After the beginning of the insecticide application, insect predation had a tendency to decrease (Table 2), but there was no large difference in the survival rate from egg to adult emergence among the 3 consecutive generations (Table 3 and Fig. 1). That is, it was not indicated that carbaryl had an adverse effect on the natural enemies of *M. alternatus* sufficient to enhance the pest's survival rate. But, the populations (cohorts) established by June-July oviposition had much lower survival rates in the year before insecticide application (0.56) than in the 2 years with insecticide application (0.87) (Table 4 and Fig. 1). Only the former populations were found to be preyed upon by insects. In the case of populations established by August oviposition, the survival rate was higher for the year before application (0.47) than for the 2 years with application (0.26) (Table 5 and Fig. 1). Insect predation occurred for the year before application and in the first year after its initiation. These facts suggest that predaceous insects contributed to a reduced survival rate of the *M. alternatus* population. The timing of insecticide application appears to be a key variable in causing or avoiding the incidental destruction of the insect predators of *M. alternatus*. Accordingly, different cohorts displayed different responses to applications.

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