attractive than Rocket Red, Horizon Blue, blue 871 and white. Saturn Yellow (Peak RI = 527 nm), Signal Green (Peak RI = 518 nm) and yellow 776 (Peak RI = 550 nm) were equivalent in attraction, but significantly more attractive than Arc Yellow (Peak RI = 595 nm). These results compare favorably with those of Vaishampayan *et al.* (1975) who found *T. varporariorum* was most attracted to surfaces with peak RI in the "yellow-green" region (520–610 nm), and that the "blue-violet" (400–480 nm) and "red" (610–700 nm) spectral regions were not attractive and possibly inhibitory to alightment. Our work also compares with that of Affeldt *et al.* (1983), who found that fluorescent Saturn Yellow and Signal Green traps were not significantly different in catches of *T. vaporariorum,* and that these colors were not significantly better than non-fluorescent yellow traps.

These data indicate that blue, yellow and white colored traps are adequate for trapping *F. occidentalis*, and that traps with peak RI between 520–550 (green-yellow) are most attractive for trapping *T. vaporariorum* in greenhouse. Where a single trap is desired for sampling both species, a yellow hue with high RI between 530–550 is preferred. Fluorescent paints, which are more expensive than non-fluorescent paints, would not contribute significantly to the trapping of either species in greenhouses.

LITERATURE CITED

Affeldt, H.A., R.W. Thimijan, F.F. Smith and R.E. Webb. 1983. Response of the greenhouse whitefly (Homoptera: Aleyrodidae) and the vegetable leafminer (Diptera: Agromyzidae) to photospectra. J. Econ. Ent. 76:1405–1409.

Brodesgaard, H.F. 1989. Coloured sticky traps for *Frankliniella occidentalis* (Pergande) (Thysanoptera, Thripidae) in glasshouses. J. Appl. Ent. 197:136–140.

Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics 11:1–42.

Gillespie, D.R. and R.S. Vernon. 1990. Trap catch of western flower thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae), as affected by color and height of sticky traps in greenhouses. J. Econ. Entomol. 83:971–975.

Vaishampayan, S.M., M. Kogan, G.P. Waldbauer and J.T. Woolley. 1975. Spectral specific responses in the visual behaviour of the greenhouse whitefly, *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). Entomol. Exp. Appl. 18:344–356.

Vernon, R.S. and D.R. Gillespie. 1990. Spectral responsiveness of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) determined by trap catches in greenhouses. Environ. Entomol. 19:1229–1241.

Observations on the biology of the bronze flea beetle *Altica tombacina* (Coleoptera: Chrysomelidae) in British Columbia

J.P. MICHAUD
DEPARTMENT OF BIOLOGICAL SCIENCES
SIMON FRASER UNIVERSITY
BURNABY, B.C. V5A 1S6

ABSTRACT

Populations of *A. tombacina* were monitored for 2 years at three field sites of varying elevation on Vancouver Island. In 1988, population densities of overwintered adults were greatest at the middle elevation (615m) followed by the highest (830m) and lowest at the low elevation (185m). Egg densities remained below 10/m^2 at 185m but exceeded 200/m^2 in places at 615m and 400/m^2 at 830m. Egg mortality was exceedingly high at all sites ranging from 98% at 185m, 95% at 615m and 99% at 830m; very few larvae appeared to survive. Only 2 adults were counted the following spring at the lowest elevation where eggs and larvae were exceedingly difficult to find. No life stages could be found at either of the higher elevation sites. Cold weather early in June, 1988, appeared to be responsible for this population decline. Overwintered adults of *A. tombacina* were also reared in the laboratory at constant temperatures of 18° and 25°C. The rate of oviposition was greater by a factor of 2 at the higher temperature. The egg-adult survival rate was approximately 15% at 25°C and there was no completed development at 18°. Each larva surviving to pupation consumed a mean of about 28mg. dry weight of leaf.

INTRODUCTION

The bronze flea beetle, *Altica tombacina* Mannerheim (Coleoptera: Chrysomelidae), is a common inhabitant of early successional communities of the Pacific northwest from Oregon to British Columbia. Its natural host is fireweed, *Epilobium angustifolium* L. (Onagrcaeae), but it has also been described as a pest of strawberry and roses (Dirks-Edmunds 1965). The *Altica-Epilobium* relationship is probably a very ancient one. Closely related species, *e.g. A. lythri* Aube, *A. oleracea* L. and *A. palustris* L., are also found in the old world associated with various *Epilobium* spp. (Phillips 1977, Port & Guile 1986).

In temperate regions the Alticinae are almost exclusively monovoltine and overwinter as adults in the plant litter. Phillips (1977) noted that a second period of oviposition sometimes occurred in various old-world species. Dirks-Edmunds (1965) stated that the progeny of lab-reared *A. tombacina* collected in Oregon began reproduction without diapause, a fact suggesting that bivoltinism may be facultative in this species. Adult sex ratios commonly range from 5:1 to >15:1 in favor of females according to my own observations. Skewed sex ratios apparently occur frequently in the Alticinae. Port & Guile (1986) have reported sex ratios exceeding 6:1 for *Altica britteni* (Sharp) and *A. ericeti* (Allard) in Great Britain.

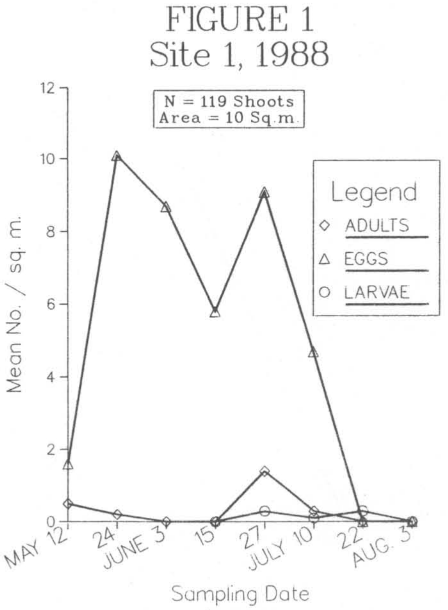
The life history of *A. tombacina* has been described by Dirks-Edmunds (1965) and is not dissimilar from that of other new world Alticinae (Woods 1918). There are three larval instars; both adults and larvae feed in exposed locations on the foliage of their host plant. Under optimal conditions eggs hatch in 3 to 5 days and the larvae feed for 12 to 14 days before pupating. Pupation requires another 10 to 14 days after which adults eclose and feed briefly before dispersing. In late summer, the quality of fireweed foliage declines and aggregations of beetles can sometimes be found feeding on the buds and tender bark of red alder, *Alnus rubra* L.

A common feature of most *Altica* species appears to be marked and unpredictable fluctuations in population density (Woods 1918, Port & Guile 1986). Large populations occasionally result in severe defoliation of the host plants, primarily as a result of feeding by larvae. In the case of *A. tombacina* this has been cause for concern among apiarists in British Columbia who rely upon fireweed for a valuable midsummer honey flow. Defoliation by larvae can inhibit flowering (Michaud 1990) and reduce nectar secretion (Michaud 1989), even causing the die-back of entire shoots (Atkins 1964).

The following study was designed to observe the trajectories of three field populations over 2 years and to establish techniques for rearing the flea beetles in the laboratory. I also wanted to test the effects of temperature on oviposition rate and the survival of eggs, larvae and pupae and to estimate larval consumption.

MATERIALS AND METHODS

Three sites varying in elevation were selected for study near Lake Cowichan, Vancouver Island. Quadrats of $2m^2$ were staked out in early May, 1988, as the first over-wintered adults emerged. Site 1 was at an elevation of 185m a.s.l. near the lake shore and five quadrats were located here. Sites 2 and 3 were located 20 km west of the lake at elevations of 615m and 830m, respectively. Ten quadrats were placed at each of these two sites. All three sites were relatively recent clear-cuts that had been replanted to Douglas fir, *Pseudotsuga menziesii* (Mirb.) Franco within the last 3 years. All quadrats were examined at 10–12 day intervals and the beetle's life stages were tallied (adults, eggs and larvae). Pupation is subterranean and pupae were not counted.



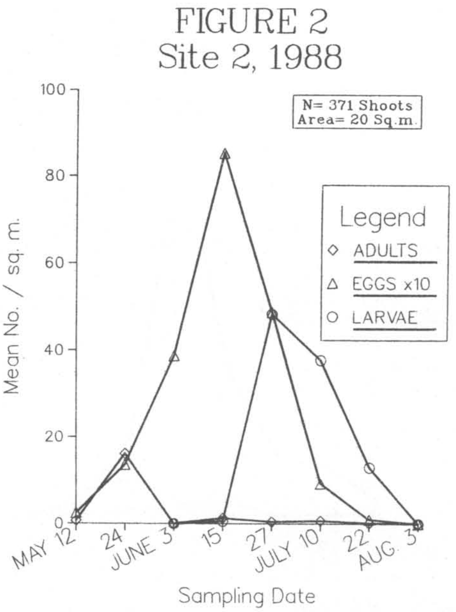


Fig. 1. Population trajectory of *A. tombacina* at site 1 (el. 185m) in 1988 showing emergence of over-wintered adults, oviposition, and appearance of larvae.

Fig. 2. Population trajectory of *A. tombacina* at site 2 (el. 615m) in 1988 showing emergence of over-wintered adults, oviposition, and appearance of larvae.

Several hundred overwintered adults were collected during the last week of April at a number of roadside sites in Burnaby, B.C. Specimens of *A. tombacina* were identified by L. LeSage of the Biosystematics Research Institute, Ottawa, Ontario, where voucher speciments were consigned. A number of different enclosures were tested for suitability in rearing the insects. Large ventilated plastic petri dishes were finally employed with a layer of moist sand covered by filter paper. Fresh leaves were provided every 2 days and appeared to remain acceptable as food over this time. There remained the problem of containment while food and filter paper were being changed. This procedure was best accomplished within the confines of a conventional plexiglass insect cage so that escapees could be readily caught and returned to their respective containers. Larvae were reared in similar containers and they pupated in the moist sand beneath.

To assess the influence of temperature on reproductive rate, two separate colonies of overwintered adults were established. Beetles were sexed on the basis of size (males are generally much smaller) and by separating pairs observed in copula. Each colony was adjusted to contain 35 females and 15 males. One colony was maintained in a greenhouse where the temperature averaged 25° (± 4°) and the other in a growth chamber at 17° (± 2°). RH was maintained as close as possible to 80% in both treatments but sometimes dropped as low as 60% in the greenhouse. Fresh leaves of fireweed were provided every 2 days, and all eggs removed and counted. This experiment was begun on April 29 and ended on May 27.

Some of the eggs were collected, placed into separate dishes, and maintained under the same thermal regime as their respective parental colonies. As the larvae hatched, they were transferred to a series of dishes with fresh leaves. Mature larvae usually found their way under the filter paper to burrow and pupate in the moist sand, although some did so directly on the surface of the paper. As the adults eclosed, they were transferred to another series of dishes, also provisioned with fresh leaves.

FIGURE 3
Site 3, 1988

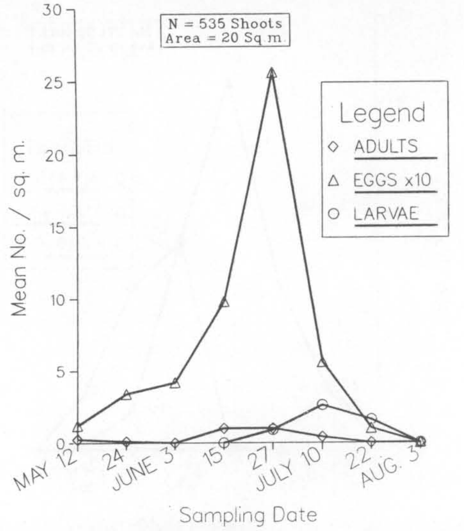


FIGURE 4

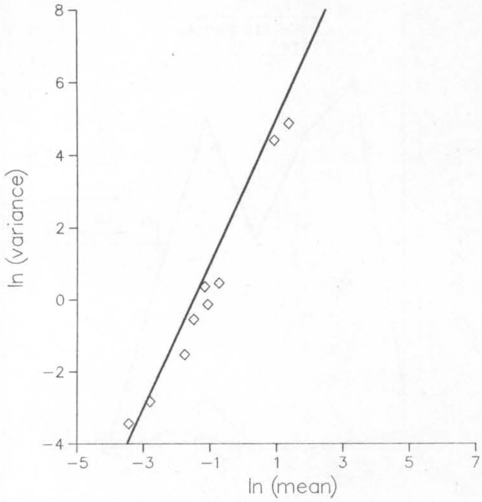


Fig. 3. Population trajectory of *A. tombacina* at site 3 (el. 830m) in 1988 showing emergence of over-wintered adults, oviposition, and appearance of larvae.

Fig. 4. Data for site 2 (el. 615m) on May 25, 1988 plotted as ln(variance) #'s of adults/shoot against ln(mean) showing a significant departure from random distribution (regression line slope = 2).

To assess larval consumption, 60 1st-instar larvae were segregated into various dishes immediately upon hatching. Fresh leaves were weighed before they were given to the larvae, and again upon removal 2 days later. The 25° temperature regime was used because it appeared to be the most favorable for development. Fresh leaves lost 24.6% of their original weight due to moisture loss over the 2 day period under these conditions. Fresh leaves contained a mean of 78.2% water by weight. Mean consumption per larvae surviving to pupation was then determined according to the following equation:

$$\Sigma[(wi - wo \times mlc^{-1}) \times dwc](\#1)^{-1}$$

wi = weight in (grams)
wo = weight out (grams)
mlc = moisture loss constant = .754
dwc = dry weight conversion factor = .218
#1 = number of larvae alive

RESULTS AND DISCUSSION

The patterns of emergence of overwintered adults, oviposition and appearance of larvae in 1988 are represented in Figs. 1–3 by mean densities for each sampling date on a site by site basis. The exact numbers of adults, eggs and larvae respectively counted on each sample date, quadrat by quadrat, are reported in the Appendix. It should be noted that counts of '0' adults occurred for all quadrats on June 3 because wind and rain during the previous 24 hours drove all insects to seek shelter in the litter.

Adults displayed a highly clustered distribution on shoots. For example, at quadrat 4 on May 24, 159 adults were counted. Of the 40 shoots of fireweed in quadrat 4, site 2, only 22 had beetles residing on them. Of these 22 shoots, one had 71 adults, one 16, and one 12. The remainder had fewer than 10 per shoot but only 3 had a single occupant. Likewise at quadrat 3, site 2 on the same sampling date, of the 110 adults counted on 43

FIGURE 5

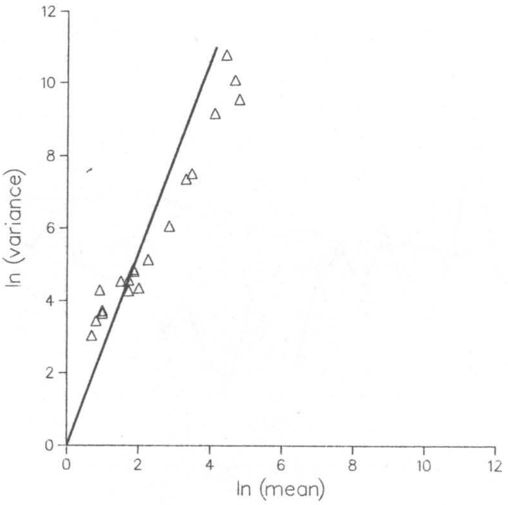


Fig. 5. Data for sites 2 (el. 615m) & 3 (el. 830m) on June 15, 1988 plotted as ln(variance) of #'s of eggs/shoot against ln(mean) showing a significant departure from random distribution (regression line slope = 2.26).

---

shoots, 85 occurred on 2 plants. Fig. 4 illustrates the clumping of adults with a plot of ln(variance) vs ln(mean) using data from each quadrat at site 2 in which adults were counted on May 25, 1988. The slope of the regression line is 2 and indicates a distribution significantly more clumped than random (slope = 1). This clumping of adults may be related to the low frequency of males that forces females to congregate. A sex ratio estimate based on a dissected sample of some 200 beetles collected on the same date indicated that females out-numbered males 15:1 in this population. This skew in the sex ratio must dictate a polygamous mating system, which in turn results in a highly clumped distribution of overwintered individuals.

Ovipositing females similarly appeared to favor particular shoots. On June 3, 1988, 2704 eggs were counted quadrat 4 of site 2. Of these, 1900 (70%) occurred on only 17% of the 40 available shoots. On June 14, 4791 eggs were counted in this quadrat, 88% of which occurred on 18 shoots. Fig. 5 illustrates the clumping of eggs on shoots with a plot of ln(variance) vs ln(mean) using data from sites 2 and 3 on June 15, 1988. The regression line slope is 2.26 and indicates a distribution significantly more clumped than random.

Dividing the total numbers of eggs by total numbers of 1st-instar larvae provided a rough estimate of the mortality rate of eggs: 95% in site 1, 99% in site 2, and 98% in site 3. The primary cause of mortality appeared to be cold weather. Many eggs never hatched but eventually darkened and decayed. The remainders of egg casings adhering to leaves provided evidence of some predation, while other eggs had been drained of their contents, presumably by some insect with sucking mouthparts.

Most larvae appeared to die in the first instar and left only small feeding scars on the undersides of leaves. I again suspected that cold weather was the primary cause of mortality. Apart from direct effects on survival, cold weather seemed to slow the development and growth of both eggs and larvae, probably rendering them more vulnerable to predation. Fig. 6 charts the trajectory of mean daily temperature during the period of egg and larval development. During the last week of May and the first week of

FIGURE 6

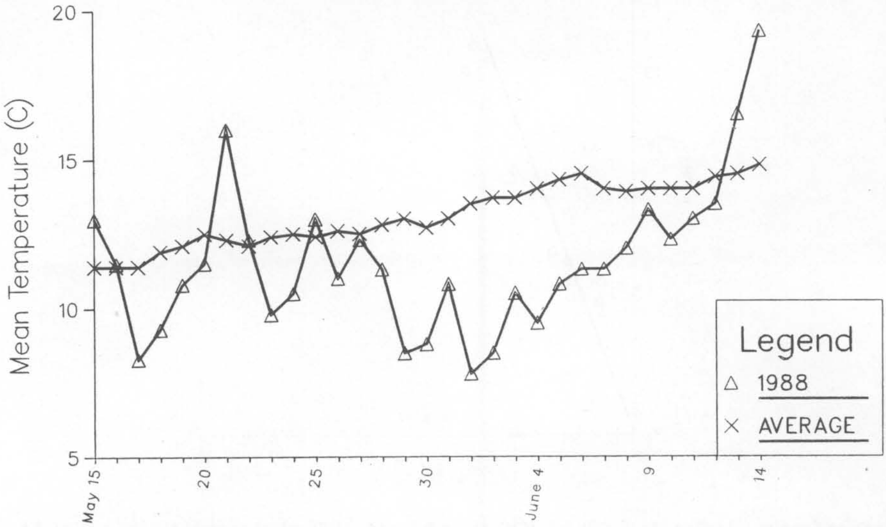


Fig. 6. Trajectory of mean daily temperature in °C for Lake Cowichan during spring of 1988 plotted with normal values for the period.

June, mean temperatures averaged some 3–4°C below normals and daily maxima remained below 19°.

No adults were observed after July 22, indicating that by this time the overwintered cohort was dead. However, the possible emergence of some callow adults may have gone undetected. Based on laboratory observations these tend to be reclusive and spend most of the time hiding under leaf litter, emerging occasionally to feed. This is also the stage when most dispersal appears to occur and during which adults can occasionally be found feeding on alternate hosts such as *Alnus rubra*. In 1989, only two adults were observed at site 1 and, subsequently, a few eggs and larvae. No life stages were encountered at sites 2 or 3 despite extensive searches. Cursory observation of roadside populations on the B.C. lower mainland over some 4 years revealed that mainland populations did not appear to undergo population fluctuations similar to those observed on Vancouver Island, but appeared to remain stable at very moderate densities.

Ovipositing beetles in the laboratory colonies laid slightly more than twice as many eggs (2954) at 25° as they did during the same period at 18° (1390) (one-way ANOVA, $P < 0.01$). Greenhouse temperature oscillated by ± 4° about a mean of 25° so it may be concluded that temperatures up to 30° are stimulatory to oviposition relative to lower temperatures.

A total of 650 eggs was incubated at 18° but only four of these hatched, for a survival rate of < 0.1%. Many became covered with a white mycelial growth, although it could not be determined if fungal infection was the cause of death. The four larvae that hatched were transferred to a clean dish and given fresh leaves but they fed little and grew slowly, dying in the second instar.

A total of 457 eggs was incubated at 25°C of which 160 hatched for a survival rate of 35%. Of the 120 newly hatched, 1st instar larvae reared at 25°, 77 survived to pupation for a survival rate of 64%. Of these, 53 (68%) eclosed as viable adults, giving an egg-adult survival rate of about 15%. These values suggest that the egg is probably the most vulnerable life stage. The principal source of mortality in the pupal stage appeared to result from fungal infection, but a number of adults eclosed with marked elytral deformities and were presumed non-viable. This may have been an artifact of the constant temperature regime under which the insects were reared. Such an effect of constant temperatures on development has been noted for other Chrysomelid beetles. Mason & Lawson (1980) were unable to rear any normal adults of the american aspen beetle, *Gonioctena americana* (Schaeffer), under constant temperature conditions, whereas development was normal in oscillating temperature.

A total of 35 larvae pupated in the larval consumption assay. The mean consumption per larva surviving to pupation was estimated to be 27.6 mg dry weight of leaf. Larvae feed selectively on the undersides of leaves, leaving behind several layers of cells on the upper leaf surface that subsequently senesce. Therefore the amount of leaf actually consumed underestimates foliar damage by as much as 50%.

Callow adults eclosing in the laboratory behaved very differently from the overwintered adults collected in the spring. They responded photonegatively and tended to aggregate underneath the filter paper in the dishes, remaining relatively inactive, emerging only at night to consume small amounts of the leaves provided. They were also observed to consume portions of alder leaves, *Alnus rubra*, when these were made available together with fireweed. Larvae would not accept alder, even in a no-choice situation. On several occasions, pairs in copula were observed, and a few eggs were eventually deposited on the leaves and filter paper. This was apparently less ovipositional activity than that observed by Dirks-Edmunds (1965) in 1st-generation adults reared in Oregon. This author concluded that two complete generations may occur in that region. It is possible, nevertheless, that a partial second period of oviposition may occur in B.C. under suitable conditions.

Of six overwintered adults collected on May 22, 1987, near Shawnigan Lake on Vancouver Island, two were parasitized and yielded pupae that were incubated until eclosion. The emerging parasite adults were identified[1] as males of the genus *Medina* Robineau-Desvoidy (tribe Blodeliini), probably *M. barbarta,* although identification to species could not be made with certainty.

---

[1] J.E. O'Hara, Dept. of Entomology, Univ. of Alberta, 255 Earth Sciences Building, Edmonton, Alberta, T6G 2E3.

ACKNOWLEDGEMENTS

Thanks are due to Dr. M. Mackauer for supervising this research and providing advice on sampling techniques and to Dr. J. Borden for his editorial advice. This research was sponsored, in part, by G.R.E.A.T. Award #73 (GC-8) from the Science Council of British Columbia and by the British Columbia Honey Producers Association.

REFERENCES

Atkins, M.D. (1964). *Altica tombacina* Mannerheim (Coleoptera: Chrysomelidae); a serious pest of fireweed. Proc. Ent. Soc. B.C. 61:44–45.

Dirks-Edmunds, J.C. (1965). Habits and life history of the bronze flea beetle, *Altica tombacina* Mannerheim (Coleoptera: Chrysomelidae). Northw. Sci. 39(4):148–158.

Mason, M.L. & F.A. Lawson (1980). Laboratory rearing of the American aspen beetle (Coleoptera: Chrysomelidae: *Gonioctena americana* [Schaeffer]). J. Kan. Ent. Soc. 53(2):421–422.

Michaud, J.P. (1989). Nectar accumulation in flowers of fireweed, *Epilobium angustifolium* L. (Onagraceae), in response to simulated defoliation. J. Apic. Res. 28(4):181–186.

Michaud, J.P. (1990). Biomass allocation in fireweed, *Epilobium angustifolium* L., (Onagraceae), in response to simulated defoliation. Bot. Gaz. (in press).

Phillips, W.M. (1977). Observations on the biology and ecology of the chrysomelid genus *Haltica* Geoff. *in* Britain. Ecol. Ent. 2:205–216.

Port, C.M. & C.T. Guile (1986). Outbreaks of flea beetles, *Altica* spp., on heather and other flowering plants. Plant Path. 35:575–577.

Woods, W.C. (1918). Biology of the Maine species of *Altica*. Maine Agr. Exp. St. Bull. 273:149–205.

APPENDIX

Numbers of *A. tombacina* Adults—1988

	May 12	May 24	June 3	June 15	June 27	July 10	July 22
SITE 1							
Q1	2	1	0	0	1	0	0
Q2	0	1	0	0	2	1	0
Q3	3	0	0	0	0	9	0
Q4	0	0	0	0	9	0	0
Q5	0	0	0	0	3	0	0
SITE 2							
Q1	2	7	0	4	0	1	0
Q2	1	5	0	1	1	0	0
Q3	1	110	0	1	0	0	1
Q4	4	159	0	0	1	2	0
Q5	2	11	0	4	0	0	2
Q6	1	11	0	0	1	0	0
Q7	1	16	0	2	3	1	0
Q8	0	0	0	6	0	3	0
Q9	0	3	0	5	1	4	0
Q10	1	1	0	3	3	3	0
SITE 3							
Q1	0	0	0	1	0	0	0
Q2	0	1	0	3	1	0	0
Q3	0	0	0	5	0	2	0
Q4	0	0	0	0	1	2	0
Q5	2	0	0	0	2	0	0
Q6	0	0	0	2	13	1	0
Q7	1	0	0	0	0	1	0
Q8	1	0	0	2	1	0	0
Q9	1	0	0	6	0	0	0
Q10	0	0	0	1	2	0	0

Numbers of *A. tombacina* Eggs—1988

	May 12	May 24	June 3	June 15	June 27	July 10	July 22
SITE 1							
Q1	0	5	9	0	20	11	0
Q2	5	1	2	0	12	1	0
Q3	9	82	47	15	30	24	0
Q4	0	9	19	26	24	7	0
Q5	2	4	10	17	5	4	0
SITE 2							
Q1	46	215	300	3287	926	92	11
Q2	25	163	117	936	684	78	9
Q3	101	819	1882	3565	626	35	0
Q4	226	746	2704	4791	1300	22	0
Q5	24	176	421	883	904	113	0
Q6	28	387	1560	2066	679	16	0
Q7	21	63	266	174	362	19	0
Q8	4	41	179	324	670	266	0
Q9	0	89	232	847	2932	970	9
Q10	24	22	88	173	675	254	0
SITE 3							
Q1	9	15	38	127	388	51	0
Q2	20	106	115	318	551	73	0
Q3	14	69	134	276	808	118	0
Q4	78	220	180	208	586	130	0
Q5	10	40	63	122	567	95	0
Q6	6	21	50	154	830	281	2
Q7	30	39	79	97	285	94	0
Q8	12	65	44	47	189	59	0
Q9	14	18	86	358	671	132	0
Q10	36	77	49	244	236	78	5

Numbers of *A. tombacina* Larvae—1988

	June 27	July 10	July 22	Aug 3
SITE 1				
Q1	0	0	3	0
Q2	0	0	0	0
Q3	3	1	0	0
Q4	0	0	0	0
Q5	0	0	0	0
SITE 2				
Q1	6	3	1	0
Q2	3	21	0	0
Q3	460	46	5	0
Q4	212	121	2	0
Q5	121	37	0	0
Q6	131	112	1	0
Q7	0	0	0	0
Q8	0	34	23	0
Q9	33	300	212	0
Q10	0	80	14	0
SITE 3				
Q1	0	0	1	0
Q2	13	0	1	0
Q3	0	6	7	0
Q4	5	14	7	0
Q5	0	8	0	0
Q6	0	8	0	0
Q7	0	8	3	0
Q8	0	7	5	0
Q9	0	0	0	0
Q10	0	0	12	0