The Occurrence and Population Dynamics of Adult *Anoplophora glabripennis* (Coleoptera: Cerambycidae)*

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Abstract. The bait-tree method was used to predict the seasonal occurrence of adult *Anoplophora glabripennis* (Motsch.) (Coleoptera: Cerambycidae). A close relationship was observed between the adult population of *A. glabripennis* and poplar variety, poplar age, and index of climate integral. Results showed that 2.7- and 14.5-fold more eggs were laid on *Populus × euramericana cv.* 'Luisa-Avanzo' than on *Populus × euramericana* (Dode) Guineir *cv.* 'I-214' and *P. deltoides cv.* 'Lux'(I-69/55), respectively. The number of eggs on 3-yr old trees was 8-fold higher than on 5-yr old trees, on *P. deltoides cv.* 'Lux' (I-69/55). Early instar survival prior to winter was positively correlated with the index of climate integral for June through September. We concluded preliminarily that *A. glabripennis* has a five-year population cycle.

KEY WORDS: *Anoplophora glabripennis*, adult occurrence, forecasting, population dynamics

Anoplophora glabripennis (Motsch.) (Coleoptera: Cerambycidae) is an important woodborer commonly found in north, northwest, and central China, causing serious damage to trees such as *Populus* spp., *Salix* spp., *Ulmus* spp., and many other broad-leaf tree species. Although there are some studies on the biology and management of this pest [1-6], few focus on population dynamics and forecasting [7]. The identification of key factors in adult occurrence and population dynamics in this study was based on the understanding of the biological characters of this pest and hence should be instructive to the management practice.

Materials and Methods

This study was conducted at Yihe Forest Farm in Yinan county, Shandong province and County Forest Farm of Zhongmu in Henan province. The main poplar varieties at the Yihe Forest Farm were *P. deltoides cv.* 'Lux'(I-69/55), *Populus × euramericana* (Dode) Guineir *cv.* 'I-214', *Populus × euramericana cv.* 'Luisa-Avanzo', and *P. cv. simopyramidalis;* trees ranged from 3 –12 years old. The poplars at County Forest Farm consisted of 3-15 year old *Populus × euramericana cv.* 'Sacrau-79' and *P. deltoides cv.* 'Lux'(I-69/55).

Adult Occurrence. Numbers of adult *A. glabripennis* were determined daily from June to September on *Acer negundo* L. bait trees.

Population Dynamics.

Population vs. Poplar Variety. A total of 30 trees were selected from each of the following poplar varieties to serve as sample trees: *P. deltoides cv.* 'Lux'(I-69/55), *Populus ×*

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euramericana (Dode) Guineir *cv.* 'I-214', *Populus × euramericana cv.* 'Luisa-Avanzo'. Numbers of egg sites, larvae, and adults were determined at regular intervals.

Population vs. Tree Age. The number of egg sites was observed periodically on trees of different age.

Population vs. Climate Factors. The number of egg sites on each sample tree was observed every 5 d from June to September. The number of larvae surviving within each marked egg site was also determined and analyzed relative to local climate information in mid October.

Results and Analyses

Forecasting *A. glabripennis* adult populations. Adult *A. glabripennis* were baited with *A. negundo*, its preferred food, by taking advantage of the supplemental feeding habits. Adult numbers on the bait tree were recorded daily from June to September in 1993 and 1995. Generally speaking, the development of insects in any life stage can be sub-divided into starting period, peak period, and ending period when 16, 50, and 84% of the population reaches this stage, respectively [8]. According to this, the starting period of adult *A. glabripennis* fell in between July 10 and 15, when 13 to 16% individuals became adults. The peak and ending periods were observed on July 30 (48-55% adults emerged) and between August 19 and 24 (80-84% adults emerged), respectively. The first *A. glabripennis* adult in the field was observed on June 16; the last adults emerged between September 18 and 23. It took 25 to 30 d to reach the starting period from its first appearance, 15 to 20 d from starting period to the peak, 20 to 25 d from peak to the ending period, and 30 d from ending period to its last appearance, respectively (Fig.1).

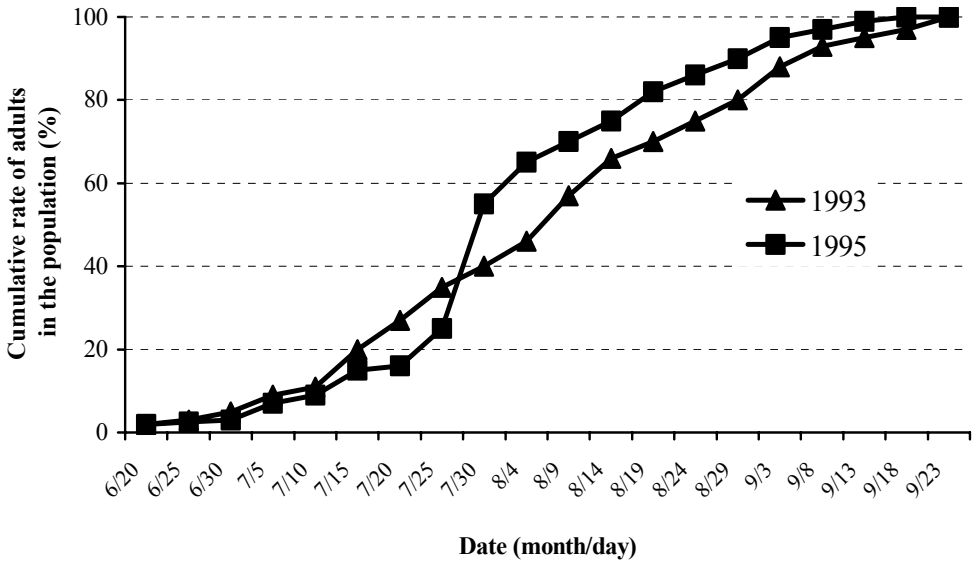

Fig. 1. Occurrence of adult *A. glabripennis* (estimate figure, see original for details).

Population Dynamics.

Population vs. Poplar Variety. The occurrence of *A. glabripennis* eggs, larvae, and adults on three poplar varieties was observed from 1991 to 1995. Field data showed that the average percentage of trees containing *A. glabripennis* eggs was 53.7, 50, and 16% for *Populus × euramericana cv.* 'Luisa-Avanzo', *Populus × euramericana* (Dode) Guineir *cv*. 'I-214', and *P. deltoides cv.* 'Lux'(I-69/55), respectively. The average number of adult *A. glabripennis* observed from 30 sample trees of *Populus × euramericana cv.* 'Luisa-Avanzo', *Populus × euramericana cv.* 'I-214', and *P. deltoides cv.* 'Lux'(I-69/55) was 37.3, 2.0, and 2.7, respectively. There was a significant difference between the number of egg sites and poplar variety within 99% confidential intervals (CI) (Table 1); there was both adult feeding and

Table 1. The correlation between *A. glabripennis* population and poplar variety

Poplar Variety	Studied Item	Year of observation						Arc sine transformed percentage data					
		1991	1992	1993	1994	1995	Ave.	1991	1992	1993	1994	1995	Ave.
	Trees with eggs (%)	16.7	76.7	93.3	76.7	23.3	53.74	24.1	61.1	75.0	61.1	28.9	50.04**
	Egg sites/tree (ave)	0.27	4.33	8.70	8.60	0.50	4.48						
Luisa	Trees with larvae (%)	3.3	3.3	0	10.8	0	3.48	10.5	10.5	0	19.2	0	8.04
	Larvae/tree (ave)	0.03	0.03	0	0.11	0	0.03						
	Adults/30 trees (n)	-	-	107	4	1	37.33**						
	Trees with eggs (%)	46.7	66.7	90.0	23.3	23.3	50.00	43.1	54.8	71.6	28.9	28.9	45.46**
	Egg sites/tree (ave)	1.40	2.23	3.73	0.93	0.47	1.75						
I-214	Trees with larvae (%)	3.3	3.3	3.3	6.2	0	3.22	10.5	10.5	10.5	14.4	0	9.18
	Larvae/tree (ave)	0.03	0.03	0.03	0.06	0	0.03						
	Adults/30 trees (n)	-	-	5	1	0	2.0						
	Trees with eggs (%)	3.3	30.0	46.7	0	0	16.00	10.5	33.2	43.1	0	0	17.36
	Egg sites/tree (ave)	0.03	0.47	1.06	0	0	0.31						
I-69	Trees with larvae (%)	0	0	0	0	0	0	0	0	0	0	0	0
	Larvae/tree (ave)	0	0	0	0	0	0						
	Adults/30 trees (n)	-	-	8	0	0	2.67						

** indicates significant difference under 99% CI.

oviposition preference for *Populus × euramericana cv.* 'Luisa-Avanzo'. However, no significant differences were found among poplar varieties when both egg sites and larvae were concerned.

Population vs. Tree Age. There was a significant difference in the number of egg sites for two different age class trees of *P. deltoides cv.* 'Lux'(I-69/55) within the same study year (Table 2). In 1993, 88.9% of the 3-yr old trees contained egg sites, compared to 47.6% on the 5-yr old trees. Additional study demonstrated that branches grown the previous year on trees over 5 years old were preferred for oviposition. Thus, egg sites were found higher in older trees because aging of the bark lower on the trunk reduces numbers of adults chewing indentations and laying eggs.

Table 2. The correlation between the number of eggs of *A. glabripennis* and tree age for *P. deltoides cv.* 'Lux'(I-69/55)

Date	Tree age	Trees with eggs (%)	Arc sine transformed percentage data	Egg sites/tree (ave)
Oct. 11, 1993	3	88.9	70.5*	8.0
	5	47.6	43.6	1.0
Oct. 10, 1994	4	22.2	28.1*	0.4
	6	0	0	0

* indicates significant difference under 95% CI.

Population vs. Climate Factors. The survival of *A. glabripennis* larvae from eclosion to mid October was affected by the joint action of temperature, precipitation, and raining days. A positive correlation was observed between the survival rate of *A. glabripennis* larvae and the index of climate integral based on the analysis on climate data collected before the overwintering of larvae each year from 1992 to 1995 (Tables 3 and 4). The correlation index $r = 0.986$ under 99% CI.

Table 3. Climate data of July, August, and September from 1992 to 1995

Year	Precipitation (mm)			Temperature (ºC)			Raining days (d)		
	July	Aug.	Sept.	July	Aug.	Sept.	July	Aug.	Sept.
1992	147.3	60.3	103.9	27.4	24.8	20.1	10	9	8
1993	195.3	170.3	21.0	23.7	24.1	21.6	14	11	7
1994	245.5	386.3	58.3	26.1	25.6	21.8	13	13	4
1995	120.2	345.3	37.0	25.7	25.7	20.1	15	16	8

Generation time and population dynamic cycle.

Generation. Studies of *A. glabripennis* growth rate in 1992 and 1993 in Yinan County, Shandong Province revealed that 85.7% completed development in one year while 14.3% required two years. In this study, larvae were marked and released, and adult emergence holes were periodically recorded during the summers.

Population Dynamic Cycle. A dynamic cycle was found for *A. glabripennis* populations based on systematic field observation from 1991 to 1995. For example, there was a five-year dynamic cycle in egg populations. In 1991, 22.2% of the trees contained eggs, increasing to 57.3% in 1992, peaking at 76.7% in 1993, then decreased to 33.3 and 15.5% in 1994 and 1995, respectively (Fig. 2). A similar cycle was also observed in adult populations, with a half cycle from 1993 to 1995. The average number of adults observed was 40, 2, and 1 for 1993, 1994, and 1995, respectively.

Table 4. Correlation between survival rate of *A. glabripennis* larvae and the comprehensive climate index

Year	Egg sites (n) (July – Aug.)	Larvae (n) (mid-Oct.)	Larval survival (%)	Climate indices[a] between July and Sept.			Comprehensive climate index (Q)[b]
				Precipitation ∂_{x1}	Ave. Temp. ∂_{x2}	Raining dates ∂_{x3}	
1992	1000	179	17.9	2.92	0.125	10.98	4.675
1993	1000	139	13.9	1.67	0.048	3.73	1.816
1994	1000	123	12.3	1.71	0.078	2.36	1.383
1995	1000	135	13.5	1.29	0.111	3.65	1.664

[a.] $\partial_{x1} = X_1/\sigma_1$, $\partial_{x2} = X_2/\sigma_2$, $\partial_{x3} = X_3/\sigma_3$. Where X_1, X_2, X_3 and σ_1, σ_2, σ_3 represents the average and standard error of precipitation, temperature, and raining dates from July to September.

[b.] $Q^{[9]} = (\partial_{x1} + \partial_{x2} + \partial_{x3})/3$.

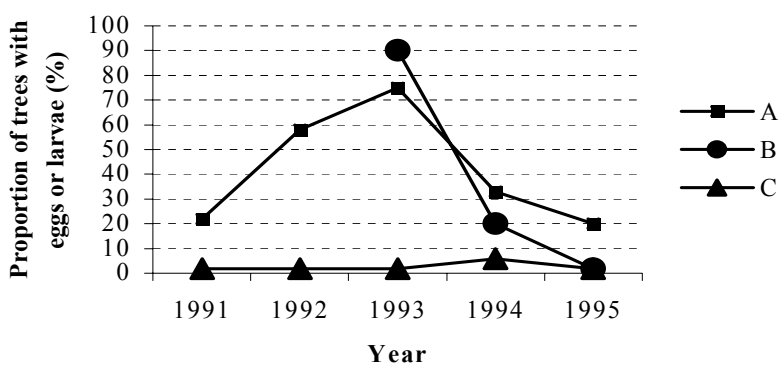

Fig. 2. Population dynamics in egg and larval stages of *A. glabripennis*.
A: proportion of trees with eggs in plot I; B: proportion of trees with eggs in plot II;
C: proportion of trees with larvae in plot I. (estimate figure, see original for details)

Conclusions and Discussions

1. The forecasting of egg, larval, and pupal populations of *A. glabripennis* is difficult to determine because these stages reside inside trees. However, adult populations can be readily monitored with the use of bait trees due to adult feeding preference for *A. negundo.* The starting, peak, and ending period of *A. glabripennis* adult stage was between July 10-15, July 25-August 4, and August 19-24, respectively.

2. There was a close correlation between *A. glabripennis* population and poplar variety. With poplar varieties such as *Populus × euramericana*, *Populus × dakuanensis* Hsu, and *Populus × simopyramidalis* being replaced by *Populus × euramericana cv.* 'I-214' and *P. deltoides cv.* 'Lux' (I-69/55), *A. glabripennis* population was higher on *Populus × euramericana cv.* 'Luisa-Avanzo' and *Populus × euramericana cv.* 'I-214' when compared with that on *P. deltoides cv.* 'Lux' (I-69/55). There was also a correlation between *A. glabripennis* population and tree age, with a higher population observed on 3-yr than on 5-yr old trees, and a higher population on 4-yr than on 6-yr old trees. Climate factors were positively correlated with *A. glabripennis* population. The comprehensive index of climate integral from July to September directly affected the survivorship of *A. glabripennis* larvae.

3. Either one generation/year or one generation/two years were found for *A. glabripennis* in Yinan county of Shandong province, with the former accounted for 85.7% and the later 14.3%. Based on this study, we concluded preliminarily that *A. glabripennis* has a 5-year dynamic cycle.

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