Life Table Study of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) Natural Populations

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Abstract  The average life table of *Anoplophora glabripennis* natural populations on *Populus pekinensis* and *P. dakuanensis* was studied using a combined method of repeated survey and trace survey from 1987 to 1990. Regular patterns and key influential factors for the population dynamics of *A. glabripennis* were revealed. Findings of this study provide the scientific basis for population monitoring and integrated management of this pest.

Key Words  *Anoplophora glabripennis*; Natural populations; Life table

Material and Methods

Stage Determination and Survey Time. The life history of *A. glabripennis* was divided into five stages based on its biological and ecological characteristics: egg, early larval (bark stage), later larval (sapwood stage), pupal, and adult. The survey time for the eggs, early stage larvae, later stage larvae, pupae and adults was late October and late April, late May, early June, and late August each year, respectively.

Mortality Factors for Each Stage. The mortality factors for each stage were determined using the outlined criteria based on results of field investigation, laboratory dissection and identification, and laboratory rearing (Table 1).

Survey Methods. Field populations of *A. glabripennis* were sampled periodically from the study plots through the dissection of standard trees using repeated and trace survey methods. Mortality factors were determined based on the symptoms of dead individuals. Mortality rate caused by each factor was calculated for every developmental stage.

Results and Analysis

Construction of the Life Table. The average life table of two generations of *A. glabripennis* on *P. pekinensis* and *P. dakuanensis* in Changzhi prefecture of Shanxi province was constructed based on the information obtained from continuous field investigation from 1987 to 1990 (Table 2, 3).

Population Survival Curves. The survival curves for both populations were very similar (Fig. 1), with a sharp decline in the survival rate of early larval stage, indicating this was the most vulnerable life stage.

Mortality Factors and Rates between Populations. *A. glabripennis* populations on *P. pekinensis* and *P. dakuanensis* shared the same mortality factors at the same stages (Table 1, 2). Natural enemies, mechanical damage, and low temperature were the key mortality factors in the life history of both populations, although difference in mortality rate was detected. Significant higher mortality rate in egg and early larval stage was attributed to mechanic damage and low temperature on *P. pekinensis* population compared with that of *P. dakuanensis* population, whereas parasitism and predation were responsible for the higher mortality rate in later larval stage of *A. glabripennis* population on *P. dakuanensis*. *P. pekinensis* has smooth bark and grows fast in its early days, leaving eggs and young larvae vulnerable to mechanical damage and low temperatures, whereas *P. dakuanensis* has thicker and cracked bark which benefits the action of natural enemies. However, no
significant difference in accumulated mortality for the whole generation was observed between these two populations, with a mortality rate of 64.53% and 62.06% for populations from *P. pekinensis* and *P. dakuanensis*, respectively.

**Table. 1. Criteria used to determine mortality factors in the life cycle of *A. glabripennis***

<table>
<thead>
<tr>
<th>Developmental stage</th>
<th>Symptoms</th>
<th>Mortality Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>Presence of elongated oval egg pit, no egg hole or unblocked egg hole</td>
<td>Empty egg pit</td>
</tr>
<tr>
<td></td>
<td>Healed cambial tissues along with desiccated egg</td>
<td>Mechanical damage</td>
</tr>
<tr>
<td></td>
<td>Dead and desiccated egg after overwintering, with partial development</td>
<td>Low temperature</td>
</tr>
<tr>
<td></td>
<td>Minute emergence hole(s) in chorion</td>
<td>Parasitism</td>
</tr>
<tr>
<td></td>
<td>Decomposed egg contents with unhealed cambial tissues</td>
<td>Atrophy</td>
</tr>
<tr>
<td></td>
<td>Decomposed larval cadaver or remains inside healed cambial tissues</td>
<td>Mechanical damage</td>
</tr>
<tr>
<td></td>
<td>Frozen stiff larva</td>
<td>Low temperature</td>
</tr>
<tr>
<td></td>
<td>White dry larva or dark brown decomposed larva</td>
<td>Fungal or bacterial infection</td>
</tr>
<tr>
<td>Early larval</td>
<td>No larva, but with frass inside the pit, and small hole on pit surface</td>
<td>Predation</td>
</tr>
<tr>
<td></td>
<td>Presence of parasitoid(s) inside or only exoskeleton of the insect remains</td>
<td>Parasitism</td>
</tr>
<tr>
<td></td>
<td>Cracks on the pit, or presence of scales and spiders</td>
<td>Desiccation</td>
</tr>
<tr>
<td>Later larval</td>
<td>Woodpecker feeding hole(s)</td>
<td>Woodpecker predation</td>
</tr>
<tr>
<td></td>
<td>White dry larva or dark brown decomposed larva</td>
<td>Fungal or bacterial infection</td>
</tr>
<tr>
<td></td>
<td>Presence of parasitoid(s) or only insect exoskeleton and head remains</td>
<td>Parasitism</td>
</tr>
<tr>
<td>Pupal</td>
<td>White and dry pupa</td>
<td><em>Beauveria bassiana</em> infection</td>
</tr>
<tr>
<td></td>
<td>Decomposed dark brown pupa</td>
<td>Bacterial infection</td>
</tr>
<tr>
<td>Adult</td>
<td>Adult fails to emerge from the exit hole</td>
<td>Atrophy</td>
</tr>
<tr>
<td></td>
<td>Adult contains white and dry mycelia inside</td>
<td><em>B. bassiana</em> infection</td>
</tr>
</tbody>
</table>
# Table 2. Average life table of *A. glabripennis* natural population on *P. pekinensis* (1987-1990)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Starting Number</th>
<th>Key mortality factor</th>
<th>Mortality (d, F)</th>
<th>% Mortality (d, F)</th>
<th>Survival rate (S)</th>
<th>% Mortality against N (q', F)</th>
<th>Accumulated mortality (Q)</th>
<th>Accumulated survival rate (S')</th>
<th>K -value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg (N&lt;sub&gt;i&lt;/sub&gt;)</td>
<td>1,500</td>
<td>Atrophy</td>
<td>65</td>
<td>4.33</td>
<td>0.0433</td>
<td>0.1453</td>
<td>0.8547</td>
<td>0.0682</td>
<td>0.0192</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical damage</td>
<td>103</td>
<td>6.87</td>
<td>0.0687</td>
<td>0.1453</td>
<td>0.8547</td>
<td>0.0324</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low temperature</td>
<td>31</td>
<td>2.06</td>
<td>0.0206</td>
<td>0.1453</td>
<td>0.8547</td>
<td>0.0102</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Natural enemy</td>
<td>19</td>
<td>1.27</td>
<td>0.0206</td>
<td>0.1453</td>
<td>0.8547</td>
<td>0.0064</td>
<td></td>
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<tr>
<td></td>
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<td>Total</td>
<td>218</td>
<td>14.53</td>
<td>0.8547</td>
<td>0.1453</td>
<td>0.8547</td>
<td>0.0682</td>
<td></td>
</tr>
<tr>
<td>Early larval</td>
<td>1,282</td>
<td>Low temperature</td>
<td>101</td>
<td>7.88</td>
<td>0.0673</td>
<td>0.1521</td>
<td></td>
<td>0.1521</td>
<td>0.0356</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fungi / bacteria</td>
<td>74</td>
<td>5.77</td>
<td>0.0493</td>
<td>0.1521</td>
<td></td>
<td>0.1521</td>
<td>0.0281</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mechanical damage</td>
<td>139</td>
<td>10.84</td>
<td>0.0927</td>
<td>0.1521</td>
<td></td>
<td>0.1521</td>
<td>0.0583</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Natural enemy</td>
<td>286</td>
<td>22.31</td>
<td>0.1907</td>
<td>0.1521</td>
<td></td>
<td>0.1521</td>
<td>0.1521</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>600</td>
<td>46.80</td>
<td>0.5320</td>
<td>0.4547</td>
<td>0.4547</td>
<td>0.2741</td>
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</tr>
<tr>
<td>Later larval</td>
<td>682</td>
<td>Fungi / bacteria</td>
<td>14</td>
<td>2.05</td>
<td>0.0093</td>
<td>0.0640</td>
<td>0.6093</td>
<td>0.3907</td>
<td>0.0659</td>
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<tr>
<td></td>
<td></td>
<td>Natural enemy</td>
<td>68</td>
<td>9.97</td>
<td>0.0453</td>
<td>0.0640</td>
<td>0.6093</td>
<td>0.3907</td>
<td>0.0466</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Woodpecker</td>
<td>14</td>
<td>2.05</td>
<td>0.0093</td>
<td>0.0640</td>
<td>0.6093</td>
<td>0.3907</td>
<td>0.0102</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>96</td>
<td>14.08</td>
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<td>0.4547</td>
<td>0.4547</td>
<td>0.2741</td>
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<tr>
<td>Pupal</td>
<td>586</td>
<td>B. bassiana</td>
<td>7</td>
<td>1.19</td>
<td>0.0047</td>
<td>0.0073</td>
<td></td>
<td>0.0073</td>
<td>0.0052</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bacteria</td>
<td>14</td>
<td>2.39</td>
<td>0.0093</td>
<td>0.0073</td>
<td></td>
<td>0.0073</td>
<td>0.0106</td>
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<tr>
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<td></td>
<td>Total</td>
<td>21</td>
<td>3.58</td>
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<td>0.0140</td>
<td>0.6233</td>
<td>0.3767</td>
<td>0.0158</td>
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<tr>
<td></td>
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<td>B. bassiana</td>
<td>11</td>
<td>1.95</td>
<td>0.0073</td>
<td>0.0073</td>
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<td>0.0073</td>
<td>0.0085</td>
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<tr>
<td>Adult</td>
<td>565</td>
<td>Atrophy</td>
<td>22</td>
<td>3.89</td>
<td>0.0147</td>
<td>0.0147</td>
<td></td>
<td>0.0147</td>
<td>0.0176</td>
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<td></td>
<td></td>
<td>Total</td>
<td>33</td>
<td>5.84</td>
<td>0.9416</td>
<td>0.0220</td>
<td>0.6453</td>
<td>0.3547</td>
<td>0.0261</td>
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<tr>
<td>Total</td>
<td>532</td>
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<td></td>
<td></td>
<td>0.6453</td>
</tr>
</tbody>
</table>

1
Table 3. Average life table of *A. glabripennis* natural population on *P. dakuanensis* (1987-1990)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Starting Number</th>
<th>Key mortality factor</th>
<th>Mortality factor</th>
<th>% Mortality (d&lt;sub&gt;x&lt;/sub&gt;, F)</th>
<th>% Mortality against N&lt;sub&gt;i&lt;/sub&gt; (q&lt;sub&gt;x&lt;/sub&gt;)</th>
<th>Survival rate (S&lt;sub&gt;x&lt;/sub&gt;)</th>
<th>Accumulated mortality (Q&lt;sub&gt;x&lt;/sub&gt;)</th>
<th>Accumulated survival rate (S'&lt;sub&gt;x&lt;/sub&gt;)</th>
<th>K -value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg (N&lt;sub&gt;i&lt;/sub&gt;)</td>
<td>1,500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atrophy</td>
<td>63</td>
<td>4.20</td>
<td></td>
<td>0.0420</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0192</td>
</tr>
<tr>
<td>Mechanical damage</td>
<td>65</td>
<td>4.33</td>
<td></td>
<td>0.0433</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Low temperature</td>
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<td>1.00</td>
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<td>0.0100</td>
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<td>0.045</td>
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<tr>
<td>Natural enemy</td>
<td>15</td>
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<td></td>
<td>0.0100</td>
<td></td>
<td></td>
<td></td>
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<td>0.0045</td>
</tr>
<tr>
<td>Total</td>
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<td>0.1053</td>
<td>0.8947</td>
<td>0.0483</td>
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<tr>
<td>Early larval</td>
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<td></td>
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</tr>
<tr>
<td>Low temperature</td>
<td>66</td>
<td>4.92</td>
<td></td>
<td>0.0440</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0219</td>
</tr>
<tr>
<td>Fungi / bacteria</td>
<td>67</td>
<td>4.99</td>
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<td>0.0447</td>
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<td>0.0234</td>
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<tr>
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<td>0.0379</td>
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<tr>
<td>Natural enemy</td>
<td>281</td>
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<td></td>
<td></td>
<td>0.1270</td>
</tr>
<tr>
<td>Total</td>
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<td>0.6162</td>
<td>0.3433</td>
<td>0.4486</td>
<td>0.5514</td>
<td>0.2103</td>
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<tr>
<td>Later larval</td>
<td>827</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fungi /bacteria</td>
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<td>Total</td>
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<tr>
<td>Pupal</td>
<td>618</td>
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<td></td>
<td></td>
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<td>B. bassiana</td>
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<td>0.0080</td>
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<td></td>
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<tr>
<td>Adult</td>
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<td>B. bassiana</td>
<td>11</td>
<td>1.84</td>
<td></td>
<td>0.0073</td>
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<td></td>
<td></td>
<td></td>
<td>0.0081</td>
</tr>
<tr>
<td>Atrophy</td>
<td>17</td>
<td>2.85</td>
<td></td>
<td>0.0113</td>
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<td></td>
<td></td>
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<td>0.0128</td>
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<tr>
<td>Total</td>
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<td>0.9531</td>
<td>0.0186</td>
<td>0.6206</td>
<td>0.3794</td>
<td>0.0209</td>
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<tr>
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<td>569</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|                |                |                      |                  |                  |                               |                      |                   | 0.6206                     | 0.3794   | 0.4210 |
Fig. 1 Survival curves of *A. glabripennis* on two species of poplar. X-axis represents the developmental stages (egg, early larval, later larval, pupal, and adult), Y-axis represents the accumulated percent survival rate.

----- on *P. pekinensis*, ------ on *P. dakuanensis*

**Forecasting Future Populations using Data from the Average Life Tables.** The size of the future population at different stages was readily estimated based on the accumulated survival rates, sex ratio (1:1), average fecundity (27.4 eggs/female), and the empty egg pit rate (8.3 and 2.93% for the population on *P. pekinensis* and *P. dakuanensis*, respectively) from the average life tables (Table 4). The size of any other stage can be forecasted if the size of one stage was determined through field investigation.

**Table 4.** Forecasting of future population for *A. glabripennis*

<table>
<thead>
<tr>
<th>Stage</th>
<th><em>P. pekinensis</em></th>
<th><em>P. dakuanensis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg</td>
<td>0.7839N</td>
<td>0.5685N</td>
</tr>
<tr>
<td>Early larval</td>
<td>0.4170N</td>
<td>0.5352N</td>
</tr>
<tr>
<td>Later larval</td>
<td>0.3683N</td>
<td>0.3999N</td>
</tr>
<tr>
<td>Pupal</td>
<td>0.3455N</td>
<td>0.3863N</td>
</tr>
<tr>
<td>Adult</td>
<td>0.3253N</td>
<td>0.3682N</td>
</tr>
<tr>
<td>Egg in next year</td>
<td>4.4564N</td>
<td>5.0445N</td>
</tr>
</tbody>
</table>

Note: N represents the number of new egg pits of the current year.
Conclusion and Discussion

Results in this study showed that the key mortality factors for *A. glabripennis* on *P. pekinensis* and *P. dakuanensis* were natural enemies, mechanical damage, and low temperature. However, mortality caused by mechanical damage and low temperature was higher in the *P. pekinensis* population compared with that of *P. dakuanensis*, whereas mortality caused by natural enemies was higher in the *P. dakuanensis* population than that of *P. pekinensis*. The early larval stage was the most vulnerable stage in the life cycle, and hence the best time for implementing integrated management. In practice, fast growing tree species in a well-managed multi-culture forest will cause significantly higher mortality to *A. glabripennis* population through the action of mechanical damage and natural enemies. Population forecasting based on data from the life table provides scientific basis for the integrated pest management. Forecasting itself will become more accurate as population data is accumulated in the coming years and life tables are gradually improved.

References Cited


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