An Outbreak of the Cryptomeria Bark Borer, *Semanotus japonicus*
LACORDAIRE (Coleoptera: Cerambycidae) in a Young Japanese
Cedar (*Cryptomeria japonica* D. DON) Plantation.
I. Annual Fluctuations in Adult Population Size
and Impact on Host Trees¹

Kensuke ITO and Kazumi KOBAYASHI²

Kansai Research Center, Forestry and Forest Products Research Institute,
Momoyama, Fushimi, Kyoto 612, Japan

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(1) The number of adults of the cryptomeria bark borer, *Semanotus japonicus* LACORDAIRE, was examined for each generation in a young plantation of Japanese cedar, *Cryptomeria japonica* D. DON, in Kyoto, Japan, throughout a period of population increase and decline from 1976 to 1985. Annual occurrences of damaged and killed host trees caused by the borer were also recorded. (2) The borer established its population in the study plantation 5 years after planting. It increased continuously in number, reached a peak abundance (about 34,000 adults/ha) 6 years later, and subsequently declined rapidly. Such a gradual outbreak occurring only once in early plantation ages was suggested to be a characteristic common to the infestation of the borer in susceptible host plantations. (3) The annual fluctuation in the number of trees from which adult borers emerged coincided with the yearly trend of the number of emerged adults in the whole plantation. The number of damaged trees in the study plantation amounted to 50.5% of the total population. Nearly 37% of these damaged trees were killed by the borer. The larger, dominant trees were more vulnerable to borer infestation and mortality. Tree diameter or growth rate is proposed as an indicator of the favourability of each host tree as a food resource for the borer. The abundance of the borer in host plantations was considered to be limited by the availability of favourable host trees.

Key words: *Semanotus japonicus*, *Cryptomeria japonica*, host age, host size, host susceptibility

INTRODUCTION

The cryptomeria bark borer (*Semanotus japonicus* LACORDAIRE) is an important wood-damaging insect of 2 major commercial conifers in Japan, Japanese cedar (*Cryptomeria japonica* D. DON) and Japanese cypress (*Chamaecyparis obtusa* ENDL.). Borer larvae

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² Present address: Forestry and Forest Products Research Institute, Tsukuba Science City, Ibaraki 305, Japan

feed on the phloem and wood of the trunk of living host trees, causing serious deterioration of timber quality and occasional mortality. A large number of plantations have been heavily infested by the borer (KOBAYASHI, 1985). Although extensive surveys of damage levels have been conducted throughout infested areas (KOBAYASHI, 1985), there have been no intensive studies on borer population fluctuations and impact upon host tree populations.

Since 1979, we have been studying a borer population in a cedar plantation. This paper describes the annual fluctuations in the abundance of adult borers and the impact on host trees throughout the course of an infestation.

MATERIALS AND METHODS

1. *Life history of the cryptomeria bark borer.* Adults make elliptical holes in the bark and emerge from host trees in late March and April. Females then copulate and deposit their eggs under bark crevices from April to early May. Each female can produce from 10 to more than 400 eggs, the potential fecundity being proportional to her weight (INOUE, 1981; ITO, 1986). The larvae feed on the phloem and sapwood, forming irregular galleries densely filled with their frass. At the end of summer the fully developed larvae penetrate the wood, wherein each larva makes a pupal chamber and overwinters in the callow adult stage. There is normally 1 generation a year.

2. *Study site.* The study was carried out in a young Japanese cedar plantation covering an area of 950 m², in Kyoto, central Japan. The plantation was located on a flat section of a south-facing slope at an elevation of 70 m. Five hundred eighty seedlings were planted in March 1972. The plantation was surrounded by a residential area, a field of vegetables and fruits, and woods composed of evergreen broad-leaved trees. There were also middle-aged plantations of Japanese cedar and cypress nearby. Some of these surrounding cedar and cypress plantations had been heavily infested by the borer, suggesting its presence in the vicinity.

At the first census of standing trees conducted in December 1979, there were 452 living trees and 7 newly dead trees which were presumed to have died after the spring of 1979. Hence, 459 trees were living in the spring of 1979. The locations of the trees are shown in Fig. 1.

The size distribution of the trees is shown in Fig. 2. The diameter at breast height (DBH) of each tree was measured in December 1979. It varied widely, ranging from

Fig. 1. Map of host trees in the study plantation in December 1979. ○: live tree, ●: dead tree.

Fig. 2. Frequency distribution of tree diameter sizes in the host population in December 1979.

1.0 cm to 15.3 cm with an average of 7.0 cm. In this paper, we used DBH data obtained in December 1979 as a relative measure of tree size.

The trees lost between planting and the spring of 1979 (121 trees) seemed to die from damage by the white-spotted longicorn beetle (*Anoplophora malasiaca* (THOMSON)) (KOBAYASHI and OKUDA, 1981) or from suppression under intraspecific competition among cedar trees. Although some of the trees that had died shortly after planting had been replaced by newly planted seedlings, replanting records had not been kept. Consequently, all trees were assumed to be planted in 1972.

3. *Census methods.* The number of dead trees and the number of adult emergence holes on each tree were recorded annually from 1979 to 1986 in the plantation. Tree mortality was examined in February and March (just before the adult emergence season) except in 1979. Adult emergence holes were counted between May and November (after the adult emergence season).

The adult borer population size was determined annually by counting the current-year emergence holes on every host tree. At the first census in December 1979, we looked for adult emergence holes on the trunks of all trees. For each hole discovered, we estimated time of formation according to the degree of trunk-surface deformity developed by callus formation around the larval gallery. Temporal development of the external deformity caused by borer's feeding is described by KOBAYASHI and SHIBATA (1985). Thus, we judged 4, 7, and 8 holes to be formed in the spring of 1977, 1978, and 1979 respectively. Since 1980, emergence holes formed in the current year on all trees were examined every year. To avoid double-counting, every recorded hole was marked with paint or notched. As trees grow higher, the upper limit of the vertical distribution of emergence holes on the trunks moves upward (NISHIMURA, 1984). Since 1982, a ladder was used in order to examine points on trunks as high as possible.

Numerous adults often emerge from not only the lower but also the upper trunk of newly deceased host trees (KOBAYASHI, 1978; ITO et al., 1983). For this reason, the trees that died in the previous year were cut down, and the entire trunk was searched for emergence holes.

Following the above procedure, census work was carried on until the autumn of 1986. After that, borer density appeared to decrease considerably, and less emergence holes were discovered. Consequently, the census work was terminated.

The sequence of insect generations and plantation ages was described as follows. Plantation age was defined as 1-year-old from planting in 1972 to March 1973. One year was added to the age each April. Secondly, the year of adult emergence (or formation of an emergence hole) was assumed to be the year of birth (the year before it actually emerged), because most of the adults emerging in a particular year arise from the egg population oviposited in the previous year. Finally tree mortality that occurred in a particular year was grouped with mortalities occurring from April in a given year through March of the following year.

RESULTS

1. *Annual fluctuation in adult population size*

The annual fluctuation in the number of emerged adults is shown in Fig. 3. Four adult borers successfully emerged on 2 trees in the plantation's fifth year (1976). Thereafter the population size increased rapidly and reached a peak density of 3,225 adults

Fig. 3. Annual fluctuation in the number of adult borers emerged in the study plantation.

Fig. 4. Annual fluctuation in the number of trees from which adult borers emerged each year. Hatched and crosshatched bars represent trees that were alive and dead when the adult borers of each generation emerged, respectively.

(about 34,000 adults per hectare) in 1982. Such a high borer density has not been previously reported. In 1983, however, the population collapsed and only 189 adults emerged. Since then it has continued decreasing. Thus, 3 phases—build-up, peak, and decline—were distinguished in the observed population fluctuation (Fig. 3).

2. Impacts on host trees

The occurrence of the trees both damaged and killed by the borer during its outbreak is described below. For the sake of simplification, trees were considered damaged after the first emergence holes were formed on them. The wounds caused by the borer to the wood persist even though they can be concealed by the callus formation. The injuries accumulate in the wood year by year, with stain and decay growing. Although feeding by larvae which failed to mature also can cause damage to hosts, such damage was not recorded here.

The annual fluctuation in the number of trees from which adult borers emerged each year (Fig. 4) coincided with the yearly trend of the number of emerged adults in the whole plantation. The peak level of infestation occurred in 1982, when the largest number of adults emerged from these infested trees.

Figure 5 shows the annual accumulation of damaged trees, which followed a sigmoidal growth curve. The occurrence of newly damaged trees increased slightly during the build-up phase of the borer population. Then it increased rapidly both in 1981 and in 1982, and dropped to a slightly increasing rate in the decline phase. The borer infestation seemed to reach a saturation point when nearly 50% of the trees had been damaged. Overall, 232 trees were damaged during the study period. Figure 6 shows the percentage of the trees damaged during the study period in each DBH class. It is obvious that the larger the tree, the more susceptible to the infestation by the borer it was.

One hundred twelve trees died during the study period. Figure 7 shows the annual decrease in the number of living trees in April of each year, that is the number of trees available to the borer population as potential food resources for each generation. The number of dead trees peaked in 1982 ($N=54$). The next most severe mortality rates occurred in 1981 and 1983. At other times, annual mortality was fairly constant, with only 6 or 7 trees dying each year. Total mortality was 24.4% of the initial tree population ($=112/459$).

Not all of these trees, however, were killed by the borer. When a dead tree had emergence hole(s) formed in the year of its death or when it had been alive, it was

Fig. 5. Annual accumulation of the number of trees damaged by the borer.

Fig. 6. Percentage of trees damaged by the borer in each tree diameter class.

Fig. 7. Annual decrease in the number of trees living in April of each year. Hatched bars represent the number of trees that died by April of the following year.

Fig. 8. Total tree mortality caused by the borer in each diameter class during the study period. Solid, crosshatched, and hatched bars represent tree mortality during the build-up, peak, and decline phase, respectively.

regarded as being killed by the borer. Eighty five trees were thus assumed to be killed by the borer. The remaining 27 trees had no emergence hole. Seventy percent (19 trees) of them were small (DBH less than 6 cm). The cause of their deaths was presumed to be suppression by dominant trees and/or lingering damage by the white-spotted longicorn beetle. Some of the other larger trees fell with wind or snow. Thus, 36.6% of the damaged trees ($=85/232$) were killed by the borer, and the mortality due to the borer accounted for 75.9% of the total mortality in the host tree population ($=85/112$). Figure 8 shows the percentage of the killed trees in each DBH class. It is apparent that larger trees had larger risks of mortality and that large, dominant trees were killed exclusively in the peak phase of the borer population.

DISCUSSION

1. *Pattern of temporal abundance of the borer in susceptible host plantations*

Although this is the only long-term study based upon the complete census of borer abundance, some aspects of the population dynamics of the borer have been studied by other workers. Here, combining our results with others', we consider the temporal abundance pattern of borer populations.

Ito et al., (1981) surveyed borer's damage levels and site characteristics of 153 cedar plantations and noticed that heavy borer infestations tended to be prevalent among south-facing small plantations isolated from large-scale plantations. SHIBATA (1988) has shown that the borer usually attacks host plantations which are at a low elevation, especially those lower than 200 m. Our study plantation has the same site conditions that they note. This suggests that the host tree population we observed was highly susceptible to the borer.

NISHIMURA (1984) sampled several borer-damaged trees from 5 cedar plantations and examined the annual fluctuations in the number of pupal chambers, which remain within the wood. He found that in all of the plantations the pupal populations exhibited a very similar pattern of temporal abundance: pupal chambers began to occur 6 to 10 years after planting and then pupal populations continued to increase for a period of about 5 years before reaching a constant decline phase. The generation curve of the adult population described in this paper (Fig. 3) shows the same pattern.

On the other hand, in older plantations exceeding the plantation age of 20 years where the borer had already attained high densities, borer populations exist at extremely low densities or are completely absent (KOBAYASHI and SHIBATA, 1985). Although the borer can attack cedar trees as old as 90 years (MATSUO, 1987), there has been no report of outbreaks or mass adult emergence of the borer in such old plantations.

Therefore, we conclude that the generation curve obtained in our study plantation (Fig. 3) is representative of the pattern of yearly fluctuations in population size of the borer infesting susceptible host plantations. With this conclusion, we can expect that outbreaks of the borer will never recur in our study plantation. Such an incremental outbreak occurring only once in the early ages of plantations is probably a characteristic common to the infestation of the borer in susceptible host plantations.

2. *Hypothesis for the cause of observed population fluctuation*

The larger and faster-growing the tree was, the more vulnerable to the borer it was (Fig. 6). The same phenomenon has been reported by many other authors (e.g.

YAMADA, 1968; ITOYA, 1982; NISHIMURA, 1983; SHIBATA, 1986). In addition, we found that among the trees which survived the outbreak in the study plantation, there was a significantly positive correlation between tree size (DBH measured in 1979) and the total number (log-transformed number) of adult borers that emerged from each tree during the study period (ITO and KOBAYASHI, unpublished). These indicate that DBH or the rate of diameter growth has a close relationship to factors determining the favourability of each tree as a food resource for the borer.

The borer population attacked and killed most of the large, dominant trees, the more favourable food resources, during its peak phase (Fig. 8). This suggests that the abundance of the borer is limited by the availability of favourable food resources.

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