Life history of the oak borer, *Platypus quercivorus* (Murayama) (Coleoptera: Platypodidae)

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**Abstract**

We studied the life history and the seasonal changes in the number of individuals inhabiting galleries of the oak borer, *Platypus quercivorus* (Murayama) (Coleoptera: Platypodidae), during the period from May 1994 to August 1996. Adult males started the formation of galleries in June. Adult females began to deposit eggs at the terminal parts of tunnels two to three weeks after the commencement of gallery formation. The number of individuals per gallery increased with the development of galleries throughout September. About 50 and 60 individuals, on average, inhabited a gallery in the 1994–1995 and the 1995–1996 generations, respectively. The maximum number of individuals was 161 and 136 in these two generations. About 40% of the broods reached the adult stage during August and September. The majority of new adults left their maternal galleries in September and October but some new adults remained in the galleries until spring and then died. The rest of the broods attained the 5th larval stage by the end of November and overwintered in pupal chambers. Pupation started in May, and adults emerged again in June and July. Mortality rates were low for all stages in the galleries.

**Key words:** Oak borer, *Platypus quercivorus*, life history

**INTRODUCTION**

The oak borer, *Platypus quercivorus* (Murayama) (Coleoptera: Platypodidae), is an ambrosia beetle and a pest of oak and other broad-leaved trees. Infestations by this insect were observed on a total of 28 species of trees (Saito, 1959; Sueyoshi, 1990; Nobuchi, 1990; Sato et al., 1993; Soné et al., 1995b). In Japan, infestation by this species on *Quercus* trees was first recorded in the 1930’s in southern Kyushu (Nobuchi, 1990). Subsequently, mass mortality of oak trees was recorded in Hyogo Prefecture in the 1940’s (Matsumoto, 1955) and in Yamagata Prefecture in the 1950’s (Saito, 1959) and 1970’s (Yamasaki, 1978). Recently, the mass mortality of oak trees has reoccurred in southern Kyushu and some localities along the Japan Sea (Sueyoshi, 1990; Ishiyama, 1993; Nunokawa, 1993; Sato et al., 1993).

Male-initiated monogamy is a rule in Platypodidae (Kirkendall, 1983) and a pair of parent beetles of *P. quercivorus* make only one gallery system in their lifetime and die there (Nobuchi, 1994). After copulation, the female *P. quercivorus* extends the gallery and lays eggs, while the male plugs the entrance with its body. The female carries bored dust and frass to the entrance which the male discards outside the gallery (Nobuchi, 1994). Despite the curious biology of this species compared to other ambrosia beetles, we know little about its life history and biology. This species attacks not only felled logs but also living trees. All studies on this species have been conducted for populations attacking living trees. Some workers (Hijji et al., 1991; Ishiyama, 1993; Sato et al., 1993) have reported a seasonal pattern of attacks to living trees and the emergence pattern of adult beetles. Sueyoshi (1990) reported the developmental stages of this species in autumn and spring. However, there have been no reports on the seasonal changes in the numbers and developmental stages of individuals in galleries mainly due to difficulties in digging up the complex galleries in the wood. By using computer tomography, Soné et al. (1995a) surveyed galleries in fresh logs. Periodical surveys are more practical for galleries in fresh logs than for those in living trees. In this paper, we report the
seasonal changes in the number and the developmental stages of individuals inhabiting galleries formed in fresh logs throughout the year and an outline of the life history of this species in Kagoshima.

**STUDY SITE**

We conducted this study in the Takakuma Experimental Forest of Kagoshima University, Tarumizu City, Kagoshima Prefecture, during the period from May 1994 to August 1996. We established a study site of about 2 ha in an evergreen broad-leaved forest in May 1993. Soné et al. (1995b) gave a detailed description of the study site. A brief description of the vegetation in the study site was as follows. *Pasania edulis* (Makino) Makino was the most dominant species, constituting about 40% of the dominant trees. Other dominant tree species were *Castanopsis cuspidata* (Thunberg) Schottky, *Machilus thunbergii* Sieb. et Zucc., *Neolitsea sericea* (Blume), *Distylium racemosum* Sieb. et Zucc., *Quercus acuta* Thunberg, and *Q. salicina* Blume. *Cleyera japonica* Sieb. et Zucc., *Symphysocosis lucida* Sieb. et Zucc., *Camellia japonica* L., and *Illicium anisatum* L. were dominant in the understory vegetation. The ground of the forest was covered with a thin layer of leaf litter of the dominant tree species, and *N. aciculata* (Bl.) Koidzumi, *Hydrangea scandens* (L.f.) Seringe, *I. anisatum*, and *Damnocanthus indicus* Gaertn. f. distributed patchily on the ground surface.

**METHODS**

Infestation of logs. We cut down living trees of *P. edulis* which had not been previously infested in the Takakuma Experimental Forest of Kagoshima University and prepared fresh logs, 12–20 cm in diameter and 40 cm long. The cross-sections of each log were coated with paraffin to protect them from desiccation. We set a total of 24 and 21 logs horizontally about 50 cm above the ground in an evergreen broad-leaved forest at intervals of about 3–5 m in the westernmost part of the study site on 25 May 1994 and 24 May 1995, respectively. We counted the number of new attacks at intervals of 10 to 14 days until 25 October 1994 and 5 December 1995, respectively. On each census occasion, we marked the entrances of new galleries with different colored paints.


On each census occasion, we brought one to three logs with galleries back to the laboratory and traced each gallery using computer tomography. Soné et al. (1995a) gave the details of the application of computer tomography. Based on the trace, we dug up each gallery with a chisel and completed the trace. We measured the total length of the tunnels and recorded the numbers of eggs, larvae, pupae, and adults with their positions on the trace. We measured the width of the head capsule of each larva to the nearest 0.025 mm under a binocular microscope. Based on the width of the head capsule, we specified the stage of the individual larvae. We surveyed a total of 244 and 45 galleries for the 1994–1995 and 1995–1996 generations, respectively.

Adult emergence. On 12 May 1995, we brought a log with 30 galleries formed in 1994 (log No. 94-21) back to the laboratory, and set an emergence trap made up of a nylon netting bag, 2.5 cm in diameter and 12 cm long, at the entrance of each gallery. We kept the log in the shade, and counted the number of adults caught in each trap at intervals of one to three days during the period from 19 May to 21 July. On 15 August, we also set emergence traps at nine galleries formed in the logs in July, and counted the number of adults caught in each trap at intervals of about 10 days until 5 December at the study site.

On 2 May 1996, we brought a log with 11 galleries formed in 1995 (log No. 95-17) back to the laboratory, and covered the entrance of each gallery with an emergence trap. We kept the log in the shade, and counted the number of adults caught in each trap almost daily until 16 August. We counted the number of adults caught in each of 31 traps on the log (log No.
95-15) at intervals of about 10 days during the period from 2 May to 16 August at the study site.

Besides the traps on the logs, we set 80, 94, and 59 emergence traps at galleries in living trees of *P. edulis* formed in early summer of the previous year on 24 May 1994, 23 May 1995, and 2 May 1996, respectively. On 5 December 1995, we also set nine emergence traps at galleries formed in the autumn of 1995. We counted the number of adults caught in each trap at intervals of 10 to 14 days during the period from the end of May to mid-August.

RESULTS

Infestation of logs

Figures 1 and 2 show the seasonal patterns of infestation of the logs in 1994 and 1995. In 1994, the beetles infested 19 out of 24 logs. The infestation started during the period from 4 June to 15 June and ceased by 25 July. In 1995, the beetles attacked six out of 21 logs. Infestation was observed during the periods from 15 June to 15 August and from 6 to 18 October. In both years, most infestations were concentrated within the first three weeks of the entire period, during which time about 97% and 87% of all infestations were recorded in 1994 and 1995, respectively (Fig. 1). Although a considerable number of logs were infested at each census in June and July, the total number of infested logs did not increase greatly after the first census when the infestations were observed (Fig. 2). The logs which had previously been infested were more frequently found to be infested at subsequent censuses than those which had not been infested at the first census (14/18 vs. 1/6, Fisher’s exact probability test $p=0.0147$ in 1994; 4/5 vs. 0/16, $p=0.0008$ in 1995).

Development of gallery systems

Figure 3 shows the schemes of the development of galleries in the logs in 1994. Table 1 shows the seasonal changes in total length of the tunnels of a gallery where the beetles had successful brood production (reproductive galleries) with a maximum number of strata of horizontal tunnels.

Galleries continued to develop throughout the end of September but, even in the log with 31 galleries, they did not intersect. On 27 June,
Fig. 3. Development of galleries of *P. quercivorus* in logs. Numbers in figures are gallery numbers. ▲: heart; ○: vertical tunnels. The strata of horizontal tunnels in (C') and (D') were derived from vertical tunnels, A and B in (C') and A, B, and C in (D'), which extended from A and B in (C) and A, B, and C in (D), respectively.
two to three weeks after the commencement of gallery formation, all galleries consisted of only a main tunnel, and were not branched. On 25 July, some well-developed galleries contained as many as four tunnels branched horizontally from a main tunnel (secondary tunnels). All tunnels lay in one plane at right angles to the long axis of the logs. During August, galleries developed well and had as many as three strata of horizontal tunnels. These strata were connected by tunnels branched vertically from a main and/or secondary tunnels. Pupal chambers about 1 cm long were excavated parallel to the grain of the wood in the wall of the tunnels. On 27 September, the development of galleries was nearly complete. The most developed gallery had six strata of horizontal tunnels and the total length of the tunnels was 302.9 cm. After that date, galleries showed no apparent development. On 26 April, we dug up a well developed gallery which had seven strata of horizontal tunnels with a total length of 387.3 cm.

In 1995, a new gallery was initiated on the log during the period from 6 to 18 October, but this gallery did not develop at all.

**Number and development of insects in galleries**

Figure 4 shows the frequency distribution of the head capsule width of larvae. Five peaks can be seen at 0.35 mm, 0.475 mm, 0.65 mm, 0.90 mm, and 1.05–1.15 mm, indicating the five larval stages. From the 1st to the 4th stage, larval size increased at a constant ratio, 1.35–1.38, between successive stages, and the ratio decreased to 1.22 between the 4th and the 5th stages.

Figure 5 shows the seasonal changes in the number and age structure of individuals in galleries. For the 1994–1995 generation, parent beetles inhabited about 75% of all galleries, and adult females deposited a cluster of one to seven eggs at the terminal part of a main tunnel in about 50% of all galleries on 27 June. On 25 July, adults, eggs, and larvae of the 1st to the 5th stage were observed in 55% of all galleries, and on 26 August, the population consisted of individuals of all stages. Eggs were deposited in groups of as many as 30 eggs at the terminal parts of tunnels. Newly emerged adults were observed in about 50% of reproductive galleries.

![Fig. 4. Frequency distribution of larval head capsule width.](image-url)
In September, new adults emerged in 10 out of 11 reproductive galleries. Fifth stage larvae became more dominant in autumn (64% in September and 76% in October) and occupied more than 90% of the population during winter. Pupation started again in May and pupae occupied 43% of the population on 24 May.

The mean number of individuals per gallery with living individuals (the number of individuals per gallery) increased from 3.8 ± 2.5 (S.D.) \((n=31)\) to 50.9 ± 32.7 \((n=17)\) during the period from 27 June to 26 August, remained at this level in September, and then showed about a 40% decline during October. During winter, the number of individuals per gallery did not decrease drastically. On 26 April, we examined only two well-developed galleries, and the number of individuals per gallery was much greater than those on other census occasions. A maximum of 161 individuals were inhabiting a gallery on 25 September.

For the 1995-1996 population, both the age structure of individuals in galleries and the number of individuals per gallery were similar to those in 1994. On 12 September, all stages of individuals were inhabiting galleries and the age structure was similar to that on 26 August 1994, and 59.6 ± 42.8 \((n=5)\) individuals, with a maximum of 136 individuals inhabiting one reproductive gallery. On 24 November, 5th stage larvae were dominant and occupied about 90% of the population. The number of individuals per gallery decreased about 33% from mid-September to late November. This decline was equivalent to the number of newly emerged adults which left their maternal galleries.
Mortality in galleries

Adults suffered mortality just after the beginning of gallery construction; 6 and 11% of adults were dead in galleries where they failed to produce broods in July and August, respectively. Table 2 shows the percentages of adults and larvae that died in reproductive galleries. In reproductive galleries, the percentage of dead adults was high in September (about 10%) and May (about 18%). In September, adults which died in reproductive galleries were parents, and we did not find any mortality in newly emerged adults. Mortality of larvae was extremely low at all censuses. On 24 November 1995, three shriveled dead 5th stage larvae were found in a gallery. Some inquilines, adults and larvae of *Rhizophagus japonicus* Reitter and larvae of *Hymenopteran* and *Dipteran* (Chironomidae?) insects, were observed in galleries irrespective of life or death of larvae. Pupal exuviae of Tipilidae insects was found at the entrances of galleries of this species on the trunks of *P. edulis* trees.

Adult emergence

Figure 6 shows the seasonal patterns of adult emergence from galleries in logs in 1995 and 1996. In all cases, males emerged earlier than females. In 1995, adult emergence started at the period from 5 to 8 June, showed a peak in mid-June, and ceased on 18 July. An average of 29.3±23.0 adults emerged from 7 out of 28 galleries in a log (No. 94-21). The sex ratio of emerged adults did not deviate from 1:1 (105♂ : 99♀, χ² = 0.176, p > 0.05). At the end of August, newly emerged adults began to fly out of galleries in the study site. Adult emergence showed a peak in mid-September and early October, and ceased in early November. A total of 23 males and 37 females were caught in five out of nine emergence traps. The sex ratio did not differ significantly from 1:1 (χ² = 3.267, 0.10 > p > 0.05). Twenty three ± 5.7 adults were captured in two emergence traps set on a log (No. 95-16). No new adults flew out of galleries in the log (No. 95-14) before it was brought back to the laboratory on 12 September.

In 1996, 18.5±19.5 adults were caught in eight out of 11 traps on a log (No. 95-17) during the period from 3 June to 30 July, with a peak in late June and early July. The sex ratio of the adults was significantly biased towards males (101♂ : 58♀, χ² = 11.269, p < 0.01). At the

<table>
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Fig. 6. Seasonal patterns of adult emergence from logs in 1995 and 1996. ●: males; ○: females. Adult emergence in autumn was surveyed only in 1995.
study site, only four males and two females were caught in four traps on a log (No. 95-15) during the period from 1 June to 11 July. Therefore, we could not compare the seasonal patterns of adult emergence between the study site and Kagoshima City.

In three out of the 80 emergence traps set on living trees in May 1994, a total of 21 males and 10 females were caught during the period from 4 June to 25 October 1994 with a peak in late July. In one out of the three traps, five, one, and three adults were caught again on 25 July, 6 September, and 12 September 1995, respectively. No adult was caught in emergence traps set on living trees in 1995 and 1996.

DISCUSSION

This study revealed some characteristics of the life history and biology of *P. quercivorus*, which are expected to be of importance for studies on population dynamics in Kagoshima. Firstly, this insect successively infested fresh logs which had been previously infested, resulting in concentrated infestation of some logs. Mori et al. (1995) reported the same tendency for infestation of living trees at the study site. Possibly, some chemical attractants to male adults emanate from host trees, as reported by *Platytypus flavicornis* (F.) (Coster, 1969) and by *P. subgranosus* Schedl. (Elliott et al., 1983). This species prefers debilitated trees and fresh logs to vigorous living trees (Nobuchi, 1994). These profitable resources were usually less abundant and sparsely distributed in forests. In these habitat conditions, concentrated infestations may promote efficient utilization of sparsely dispersed resources.

Secondly, this insect developed fast in summer, and about 30–40% of the broods reached the adult stage from August to October. The rest of the broods overwintered at the 5th larval stage and began to emerge in mid-June. Most new adults left their maternal galleries to form their own galleries in autumn. Nobuchi (1990) noted that this species was univoltine, but the results of this study clearly showed that adults emerged twice a year. Sueyoshi (1990) also observed pupae and newly emerged adults in galleries on 29 September. These results show that the life cycle of this species is partially bivoltine in Kagoshima; parts of the population take one year to complete a life cycle and the other may have two generations a year. However, the adults which left their maternal gallery in autumn did not succeed in brood production in their own galleries, and we could not examine whether they could complete two generations. Some adults that emerged in autumn remained in their maternal galleries and died there the next spring. After October, only a few eggs were observed in galleries. These results suggest that they may engage in keeping their galleries clean without producing their own broods. If such is the case, then it can be said that this insect has eusocial characteristics.

Thirdly, adult beetles emerged in July 1994 and again in July 1995 from a gallery system formed in July 1993. This suggests that some individuals spent two years to complete their life cycle, or that adults that emerged in the trap in 1994 eventually returned to their maternal gallery and used it for reproduction. In the latter case, they should inbreed. This also shows that the gallery was maintained for at least two years. However, this was the only gallery used for two or more years throughout the study site. Some parts of sapwood of the fresh logs deteriorated considerably, and no individuals inhabited in the galleries two years after gallery formation (Soné, unpublished). Therefore, individual galleries of this species may not be maintained for a long period, especially in logs, contrary to the galleries of *Austroplatypus incompertus* (Schedl) which has a long life cycle (Harris et al., 1976).

The other important characteristics of bionomics was that this species has a high reproductive potential. A maximum of 161 individuals were inhabiting a gallery in the log. About 30, 20, and 20 adults per gallery, on average, emerged in early summer in 1995, autumn in 1995, and early summer in 1996, respectively. These results suggest that reproductive success was much higher for galleries in logs than those in living trees; 40–50 adults vs. 5.5–7.9 (Sueyoshi, 1990) and 3.5–9.7 adults per gallery in living trees (Sato et al., 1993). High brood production and low mortality in galleries due to parental care may contribute to their high reproductive success.
Sap was secreted into almost all galleries formed in living trees and flown out of galleries with frass at the study site. The percentage of traps which caught adults was much lower on living trees than on the logs. Therefore, it can be concluded that the poor reproductive success in living trees is due to strong resistance of host trees by secreting sap into the galleries. Harris et al. (1976) also stated that the most important mortality factor of the galleries of *A. incompatus* in *Eucalyptus* trees was the secretion of kino resin by host trees. The results of this study suggest that the loss of vigor or felling of many host trees by climatic and biological factors, such as disease or severe defoliation by herbivorous insects, resulting in the cessation or decline of sap secretion by host trees seems to be a trigger for sudden outbreaks of this insect. The dispersion of new adults in autumn may facilitate the exploitation of host plants when there are many profitable host plants for gallery formation. Concentrated attacks of adult beetles and parental care may also promote outbreaks of this species.

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