Change in the Activity of Adult *Monochamus alternatus* HOPE (Coleoptera: Cerambycidae) in Relation to Age

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Age-related changes in the mobility of adult *Monochamus alternatus* was analysed by repeated weekly marking and recapture in a stand of *Pinus thunbergii*. During periods of adult emergence in 1980–1983, 1–5 day old adults, which had emerged in field cages, were released. The proportion of beetles recaptured a week after release decreased with ages up to 17 days after emergence. After the age of 17 or 24 days they were caught at an almost constant rate. Wild beetles were also caught, marked individually, and released in the same stand. The proportion of wild beetles recaptured a week after release was about 10% in June and July, and about 20% in August and September. These results suggest that the beetles' mobility rose from the time of emergence to the time of reproductive maturation, at which point it dropped.

INTRODUCTION

Adults of the Japanese pine sawyer *Monochamus alternatus* HOPE transmit the pine wood nematode *Bursaphelenchus xylophilus* (STEINER et BUHRER) NICKLE, the causal agent of the pine wilt disease (MAMIYA and ENDA, 1972; MORIMOTO and IWASAKI, 1972). Their behavior must greatly affect the disease's spread.

YAMANE (1976) classified the behavior of beetles into 3 age-dependent stages—postemergence dispersal, maturation feeding, and oviposition—based on observations of caged populations (YAMANE and FUSHIMI, 1974). The postemergence dispersal stage occurs between emergence and initial feeding on twig bark, and includes long-distance dispersal of individuals. After the less active stage of maturation feeding, activity, which includes flight, increases again during the oviposition stage. Another study using tethered beetles (ITO, 1982) indicated that long-distance movements occurred before reproductive maturation which required 16–30 days of feeding for females (ENDA and NOBUCHI, 1970) and 5–15 days of feeding for males (NOBUCHI, 1976), and that subsequent activity was negligible. No studies have been conducted in the field to clarify these conflicting hypotheses.

This paper deals with the change in the recapture rate of beetles in a pine stand in relation to their age and season based on the repeated marking-recapture method.

MATERIALS AND METHODS

Materials and methods are as in the previous paper (TOGASHI, 1988). The study was conducted at the landward fringe of a large coastal forest of Japanese black pine

Fig. 1. Study stand map showing 3 substands (A, B, and C) and the distribution of healthy *P. thunbergii* trees (early June, 1980).

Pinus thunbergii PARL. at Oshimizu, Ishikawa Prefecture. A rectangular 9.18 a (15–17 m $\times$ 58 m) study stand was used. The stand consisted of 249 healthy trees averaging 8 m ht. and 9.2 cm dbh at the beginning of the study, June 1980 (Fig. 1). The stand was divided into 3 substands, which contained almost equivalent areas and tree populations. No aerial applications of insecticide were made during the study. All dead trees had been removed from the stand before the start of beetle emergence.

We sought to clarify the relation of beetles' activity and age. Individually-marked beetles, which had emerged from pine logs placed in field cages at Tsurugi, Ishikawa and had been individually reared in plastic cases (8.5 $\times$ 17.5 $\times$ 4.0 cm), were released at weekly intervals during emergence periods from 1980 to 1983. The pine logs had been collected at Oshimizu or supplied to Oshimizu beetles for oviposition the previous year. The released beetles rarely carried the pine wood nematodes due to the desiccation condition of the logs caused by barking and dry storage conditions (TOGASHI, 1988). The numbers of beetles released were as follows: 123 beetles on tree #124 in Substand B (Fig. 1) in 1980, 96 on #39 and 30 on #215 in 1981, 102 on #53 and 100 on #214 in 1982, and 95 on #69 and 94 on #215 in 1983. Average beetle age at time of release was 3 days, ranging from 1 to 5 days. Releases were conducted after completing beetle capture.

Weekly capture of beetles was carried out between June and September from 1980 to 1983 for all individual trees in the study stand except June 1980 when only Substand B was sampled. Trees were coded and then shaken in order to capture beetles. Beetles were coded and released on the trunks of trees from which they had fallen. When unmarked (wild) beetles were captured, many of them were immediately marked and then released in the same way as the released-recaptured beetles. A few females were dissected to investigate the presence or absence of eggs.

RESULTS

Activity of released beetles

Age-related mobility of adult *M. alternatus* was evaluated on the basis of the change of recapture rate of different ages of beetles released weekly into Substand B (tree #124) in 1980. In the 123 young 3 day old beetles, 24% were recaptured a week after the release (Fig. 2). Thereafter the proportion of recaptures uniformly decreased until the 3rd week, shifting to a low, relatively steady percentage. Ten and three percent of the 10 day old beetles were caught 1 and 2 weeks after their release, respectively. They were not subsequently captured except on the 5th week. In the aged, 17 day old beetles, the proportion of recaptures stayed at around 5%.

The proportions of recaptures a week after the release were 24, 10, and 0% for beetles aged 3, 10, and 17 days, respectively. This indicated enhanced activity with age. In addition, the beetles aged over 24 days were recaptured at a relatively uniform proportion, suggesting movement within a limited range.

From 1981 to 1983, the released beetles were placed on tree trunks in Substands A and C. As only a few beetles were caught a week after the release, the results are shown only for the 3 day old beetles (Figs. 3-5). In each substand, as well as the study stand, the proportion of recaptures decreased with time. The proportion of recaptures tended to stabilize from the 2nd or 3rd week after the first release, as shown in the beetles placed on tree #39 in 1981 and tree #214 in 1982. The proportion of recaptures was 0 to 5% smaller in each substand than in the study stand in all weeks during the study period.

Even when the proportions of recaptures were calculated combining beetles released

Fig. 2. Temporal changes in the proportion of recaptured *M. alternatus* adults which were released at different ages in Substand B in 1980. The arrow mark and numerals in each figure represent date of beetle release, average age and number of beetles released. Open and solid circles represent females and males, respectively.

Fig. 3. Temporal changes in the proportion of recaptured *M. alternatus* adults which were released at the average age of 3 days in 1981. Left: The proportion of recaptures in the substand containing a tree on which beetles were released. Right: The proportion of recaptures in the whole study stand. The numerals in each figure are code numbers of trees on which beetles were released and the number of beetles released on the tree. Open and solid circles represent females and males, respectively.

Fig. 4. Temporal changes in the proportion of recaptured *M. alternatus* adults which were released at the average age of 3 days in 1982. See Fig. 3 for further explanation.

Fig. 5. Temporal changes in the proportion of recaptured *M. alternatus* adults which were released at the average age of 3 days in 1983. See Fig. 3 for further explanation.

Fig. 6. Temporal changes in the proportion of recaptured wild *M. alternatus* adults which were caught and released at various times in 1981. Left: The proportion of beetles recaptured in the substand in which they were caught and released before. Right: The proportion of beetles recaptured in the whole study stand. The month and numerals in each figure represent beetle capture and release times and numbers of beetles caught and released during the month, respectively. Open and solid circles represent females and males, respectively.

on 2 trees, temporal patterns were similar to those for the beetles released onto each tree: in 1981 and 1982, the proportion of recaptures decreased until the 2nd or 4th week after release and was thereafter constant. In 1983, no beetles were caught after the 4th week, possibly because of rapid dispersal. There was no marked sexual difference in the temporal recapture pattern.

This 4 year study indicates that beetle mobility increased until the age of 15–19 days after emergence and thereafter decreased.

Activity of wild beetles

Beetles emerge from dead pine trees between June and July in Ishikawa (TOGASHI, 1989), indicating that the average age of beetles increases through the season. Comparisons between recapture rates of different months therefore indicate the difference in the mobility of beetles at different ages.

In 1980, 26 wild beetles (12 females and 14 males) were caught and released.

Table 1. Seasonal change in the proportion of *M. alternatus* females with mature eggs (1980–1984)

Month	June	July	Aug.	Sept.
No. of females examined	3	7	7	3
No. of females with mature eggs	2	6	7	3
Females with mature eggs (%)	67	86	100	100

Two of these were recaptured. In 1982, 57 wild beetles (28 females and 29 males) were captured. Only one beetle of the 44 released was caught again. In 1983, 19 beetles (13 females and 6 males) were caught. Three of the 14 released were captured again. The numbers recaptured in those years were too small to classify into groups captured in different months.

In 1981, the proportions of wild beetles recaptured are shown for both the substand and the whole stand (Fig. 6). In all months, the proportion was larger in the 1st week after release than in any subsequent week. The average proportion of recaptures in the 1st week was about 10% in June and July and about 20% in August and September in the stand, whereas the value was 3 to 10% in June and July and 10 to 17% in August and September in the substand. This seasonal difference in recapture rate may be caused by the younger, reproductively immature beetles included in the June and July populations (Table 1).

DISCUSSION

YAMANE (1976) and ITO (1982) present different explanations of the temporal activity pattern of *M. alternatus*. Based on the observations of caged beetles (YAMANE and FUSHIMI, 1974), YAMANE (1976) states that the beetles practice long-distance dispersal during a period between emergence and initial feeding on twig bark, decrease their mobility until reproductive maturation, and enter an oviposition stage of renewed mobility. ITO (1982), in contrasting observations based on flight durations of tethered beetles, states that beetles fly long distances before reproductive maturation and that they repeat smaller flights after that.

In our study, the recapture rate of released beetles indicated that the beetles increased their mobility with age during periods from the age of 1–5 days to 15–19 days. In addition, it showed that mobility decreased with further aging.

The beetles are reproductively immature at emergence. They need to feed on pine-twig bark for maturation, which takes 16–30 days for females (ENDA and NOBUCHI, 1970) and 5–15 days for males (NOBUCHI, 1976) under rearing conditions. The age of 15–19 days corresponds to the time of reproductive maturation. Thus, the results of this study can be defined as follows: the mobility of beetles increased with the age between emergence and reproductive maturation, and then decreased. Consequently, our results agree with ITO's (1982) rather than YAMANE's (1976).

Weakened trees are the oviposition and mating sites for beetles. Such trees are supposed to have occurred rarely and unpredictably in time and space before the introduction of pine wilt disease to Japan (TOGASHI, unpublished). It is therefore difficult to accept the notion that beetles have a long-distance dispersal stage only before reproductive maturation as proposed by YAMANE (1976). It is easier to assume

that reproductively mature beetles still have a large flight capacity, even if there is a significant difference in the duration of flight between 5 and 40-day-old beetles (ITO, 1982), and that the prolonged period of stay in a limited area with many weakened trees results in a seemingly reduced mobility or enhanced settlement.

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