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Dispersal distance of adult Japanese horntail *Urocerus japonicus* (Hymenoptera: Siricidae) which causes wood discoloration damage

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Abstract
The dispersal distance of adults of the Japanese horntail, *Urocerus japonicus*, was studied in the field by the mark-recapture method. Twenty-two attractant-traps were set up on 3 transect belts which were set spokewise from a fixed release point in a *Chamaecyparis obutusa* stand. Traps were 10–150 m apart from the release point. Adults emerging in cages were released at the release point after being marked on the thoraces with paint. Traps were examined weekly. Two hundred and eighty males and 56 females were released, and a total of 22 males and 16 females were recaptured. The recapture ratio was significantly higher for females than for males. All males were recaptured in the traps at 10 m from the release point, although some females were captured over 30 m from the release point. One female was captured in a trap 90 m from the release point and the longest dispersal distance of females was estimated to be 105 m. Thus, the dispersal distance of females is concluded to be farther than that of males.

Key words: Japanese horntail, dispersal distance, mark-recapture method, attractant-trap

INTRODUCTION

The Japanese horntail *Urocerus japonicus* (Hymenoptera: Siricidae) causes wood discoloration of Japanese cedar *Cryptomeria japonica* and hinoki cypress *Chamaecyparis obutusa* through the transmission of symbiotic fungi *Amylostereum* spp. at the time of oviposition (Okuda, 1989; Tabata and Abe, 1997). It has recently been elucidated that wood discoloration of *C. japonica* and *C. obutusa* caused by siricid woodwasps occurs widely throughout Japan (Okuda, 1985; Yoshioka, 1996; Hosoda et al., 1998; Miyata, 1999), and in western Japan, most of the damage is caused by *U. japonicus* (Sano, 1992; Miyata, 1999).

Most *U. japonicus* require one year to complete development (Fukuda, 1997), whereas a few require two years (Okuda, 1989; Miyata, 1999). The period of adult emergence is June to October (Okuda, 1989). Female adults of *U. japonicus* usually oviposit in the sapwood of *C. japonica* and *C. obutusa* trunks. Larvae feed on wood tissue infected by *Amylostereum* spp. (Fukuda, 1997) and molt about 10 times before pupation (Okuda, 1989). Adults are sexually mature by the time of emergence and copulate soon after emergence (Okuda, 1989).

To avoid damage by *U. japonicus*, trees felled for thinning are simultaneously removed from the stand of *C. japonica* and *C. obutusa* (Sano, 1991; Miyata, 1999), because the woodwasp reproduces on newly felled trees left in the stand. In addition, people are advised to fell trees during winter for thinning, because such felled trees become inadequate for *U. japonicus* oviposition by the beginning of the reproductive season (Sano, 1991; Fukuda, 1997).

However, *U. japonicus* emerging in adjacent stands may fly into a controlled stand. To avoid damage by *U. japonicus*, we must not only consider taking control measures in the target stand but also evaluating the intrusion of *U. japonicus* from bordering stands. The dispersal distance of adult *U. japonicus* has not been studied hitherto, and thus it is unknown how far they disperse from the emerging sites. Here we estimated the dispersal distance of adult *U. japonicus* using the mark-recapture method with attractant-traps.

MATERIALS AND METHODS

The mark-recapture experiment of *U. japonicus* was carried out from July to September 1998 in a stand of *C. obutusa* mixed with some *C. japonica* in Tosayamada Town, Kochi Prefecture (33°40′N, 133°41′E), Japan. The study site was 400–440 m above sea level and the stand was about 30 years old. The stand density was about 2,000 trees per ha with the crown closure. The average height of the trees was about 12 m and the average diameter at breast height was about 15 cm. Some trees of *C. obutusa* and *C. japonica* had been cut down by the previous winter and were left on the ground in the stand with the crown during the study period. The density of felled trees was about 400 per ha in the stand. The stand was surrounded by the stands of broad-leaved trees, which were about 5–10 m tall and about 10 cm of diameter at breast height.

Three belts were set spokewise from a fixed release point in the study stand. On each belt, traps were fixed singularly at 10, 30, 50, 70, 90, 110 and 130 m apart from the release point. An additional trap was fixed 150 m from the release point on a specified belt. On each trap point an attractant-trap was set. Twenty-two traps in total were set in the stand (Fig. 1). Column-shaped attractant-traps, which had been developed for the capture of the siricid woodwasps (Yamazaki and Mineo, 1991; Kanasugi et al., 1995), were used. Hodoron® (produced by Izutsuya Chemical Industry Inc., Kumamoto) was set as the attractant in the plastic column of each trap. Five adhesive sheets of Kamikiri-hoihoi® (produced by Earth Chemical Inc., Tokyo) were attached rolling outside of the column on each trap. The structure of this trap was illustrated in the figure by Yamazaki and Mineo (1991). This trap is reported to attract both sexes of adult *U. japonicus* (Yamazaki and Mineo, 1991).

Trees were felled in July and November 1996 and in March and July 1997 on a stand of *C. japonica* in Otoyo Town and on a stand of *C. obutusa* in Nankoku City, Kochi Prefecture. The felled trees were left on the ground of the original stands until the spring of 1998 to allow *U. japonicus* to oviposit. The trees were hauled to Shikoku Research Center, Forestry and Forest Products Research Institute, Kochi City, and to Kochi Prefectural Forestry Experimental Station, Tosayamada Town in the spring of 1998. They were soon cut into logs of 1 m length, resulting in 600 logs for each tree species and placed in outdoor cages. The average diameter of the logs was about 10 cm.

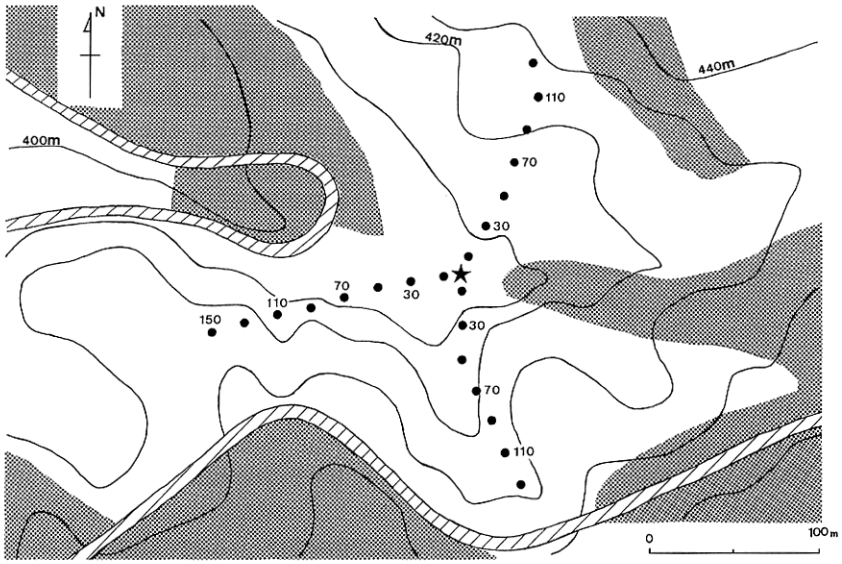

Fig. 1. Map of attractant-traps set in the study stand. Solid lines, hatched belt and dotted area represent contour lines, paved roads and stands of broad-leaved trees, respectively. Asterisk and solid circles indicate the release point of *U. japonicus* and attractant-traps, respectively. Figures show the distance from the release point.

U. japonicus adults emerging from the logs were collected every 2 or 3 days from July to September 1998. They were individually placed in small containers and marked on the pro- and/or mesonotum with synthetic resin paint within one day after collection. They were released at the release point twice a week. Insects were 1–7 days old when released. All adults released on a given date were painted with the same mark, to allow identification of the date of release. The painted marks on *U. japonicus* had been ascertained to remain for at least a week by a preliminary experiment in the field. Five to 41 adults were released at every release time and a total of 280 males and 56 females were released. The released adults may have copulated before release. Attractant-traps were examined every week to record recaptured *U. japonicus*. Adhesive papers were renewed every 2 or 3 weeks.

An approximately simple relationship is found in the spatial distribution of animals subject to random dispersal. The relationship is represented as follows,

$$\ln(N+0.5)=a-b(\pi d^2) \qquad (1)$$

where N is the density of animals which moved distance d from the release point, and a and b are parameters (Itô and Miyashita, 1965; Itô, 1975). The values of the parameters were determined by the least squares method. Then we estimated the upper limit of the dispersal distance by placing $N=0$ into the Eq. (1).

RESULTS

A total of 38 released individuals were recaptured. The ratio of recaptures was 7.9% (22/280) for males and 28.6% (16/56) for females, showing a significant difference between the sexes ($\chi^2=19.9$, $p<0.001$). Along with the marked wasps, 10 males and 40 females of unmarked *U. japonicus* were captured by the attractant traps.

All 22 recaptured males were in 3 traps located 10 m from the release point (Fig. 2). On the other hand, 9 females were recaptured in 3 traps 10 m from the release point, and the remaining 7 females in 5 traps 30 m or more away. One female was trapped 90 m from the release point (Fig. 2). Thus, the distance from the release point was significantly different between females and males (Mann-Whitney U test, $p<0.05$).

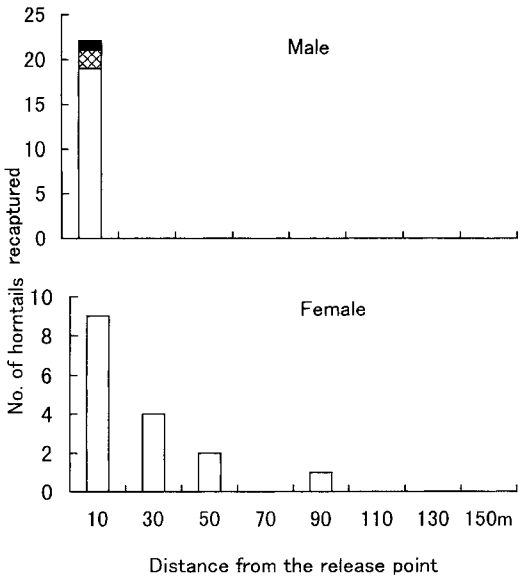

Fig. 2. Frequency distribution of dispersal distance in *Urocerus japonicus*. Distance is represented by the length from the release point to the traps in which marked *U. japonicus* were recaptured. Open bars, crosshatched and solid bars show adult horntails recaptured within 6 days after release, 5–11 days after release and 12–18 days after release, respectively.

Most *U. japonicus* were recaptured within 6 days after release, while one male was recaptured 12–18 days after release and two males 5–11 days after release. On the other hand, all females were recaptured within 6 days after release (Fig. 2).

Parameter values were determined by using the results of the mark-recapture study of *U. japonicus*. The equation for males is

$$\ln(N+0.5)=3.59-15.1\pi d^2 \quad (r=0.980,\ p<0.01),$$

thus the upper limit of dispersal distance was estimated to be 30 m.

For females, equation is

$$\ln(N+0.5)=1.61-0.663\pi d^2 \quad (r=0.545,\ p<0.05).$$

The females are estimated to move as far as 105 m from the release point.

DISCUSSION

Sexual difference in effectiveness of attractant-trap

The ratio of recaptures was higher for females

than for males, which suggests that the attractant-trap used in this study is more effective for females than for males of *U. japonicus*. Hodoron®, which was used as an attractant in this study, is registered as an attractant pesticide for siricid woodwasps and its effective components are benzoic acid and eugenol (Kanasugi et al., 1995). Sano (1989) suggested that the attractive effect of Hodoron® was higher for females than for males. Our findings also showed the same tendency. The major component of Hodoron® is a volatile oil extracted from coniferous woods. Thus, it is suggested that female adults of *U. japonicus* are attracted by such compounds when searching for suitable trees for oviposition.

On the other hand, there were 5 traps in which only males were captured in our study. These cases indicate that males were not lured by the previously captured females. It is likely that Hodoron® attracts both sexes of *U. japonicus*, although the effectiveness is lower for males than for females.

Dispersal distance of adult *U. japonicus*

U. japonicus males were only captured in traps 10 m from the release point. Some females were captured in traps over 30 m from the release point (Fig. 2). Females were ascertained to fly at least 90 m and the longest dispersal distance of females was estimated to be 105 m, which might be underrated because *U. japonicus* could not fly once they were captured in the traps.

The results of our study show that males stay in the vicinity of the release point while females disperse widely. Females of *U. japonicus* probably fly further than males because they are looking for a suitable substrate for oviposition such as weakened and wind-broken trees.

No detailed observations have been made on the behavior of adult *U. japonicus*, except for the copulation and oviposition behavior reported by Okuda (1987). However, both sexes of newly emerged *Sirex noctilio* fly to tree tops where they aggregate. After mating, the original photopositive response of the female is replaced by a host-location response (Madden, 1988), and males remain near the site of emergence (Morgan, 1968). In the present study, we found that the dispersal distance of adult *U. japonicus* differs significantly between the sexes. The behavior of *U. japonicus* adults might be similar to that of *S. noctilio*.

Our results indicate that female *U. japonicus* may traverse over more than one stand. In order to avoid the damage by *U. japonicus*, control should be carried out not only in the target stand but also in surrounding stands, which requires total management of small and mosaic plantations.

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*Titles are tentative translations from the original Japanese titles by the authors of this paper.