

環動昆

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Mass-trapping Trials of the Fall Webworm, *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae), with Synthetic Sex Pheromone in Urban Street Trees

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合成性フェロモン製剤を用いたアメリカシロヒトリ *Hyphantria cunea* (Drury) (Lepidoptera: Arctiidae) の大量誘殺法 山中武彦¹⁾・里田史朗²⁾・千田修治²⁾・田付貞洋¹⁾(¹⁾ 東京大学大学院農学生命科学研究科、²⁾ 日東電工株式会社)

アメリカシロヒトリ (*Hyphantria cunea* (Drury)) に対する合成性フェロモン製剤を用いた大量誘殺法の有効性を確かめるために、1994年から1996年にかけて東京都江東区豊洲の街路樹を用いて野外実験を行った。大量誘殺法の効果を確かめるためのつなぎ雌実験では、条件によっては大量誘殺試験区で交尾の阻害効果が示された。しかし、1994年の第2世代を除いて、幼虫による街路樹の食害を無処理区に対して低く押さえることはできなかった。これらの結果から、大量誘殺法のみでは、本種を防除することが難しいものと思われた。

To investigate the efficacy of mass-trapping trials with synthetic sex pheromone as a method for controlling the fall webworm (*Hyphantria cunea* (Drury)), field experiments in street trees in a Tokyo urban area were conducted from 1994 through 1996. Separate experiments, employing tethered females, indicated that mass-trapping techniques could disturb the mating of female moths. However, we could not reduce the damage occurring in the treated areas compared to the control areas, with the exception of second generation in 1994. We concluded that it is difficult to reduce the damage caused by the fall webworm by the mass-trapping method, only.

Key words : Mass-trapping, Tethered female, Synthetic sex pheromone, *Hyphantria cunea* (Drury)

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Introduction

The fall webworm (*Hyphantria cunea* (Drury)) was accidentally introduced into Tokyo from North America in 1945, eventually extending its northern and southern distribution to become one of the most serious insect pests of street and garden trees in urban areas of Japan (Ishii, 1966). Heavy damage by the larvae has been observed every year in Tokyo, even though extensive spraying of insecticides has been performed (Koto-Ku and Edogawa-Ku, personal communications). In addition, Konno (1998) reported that *H. cunea* larvae in an Ibaraki-prefecture population have acquired resistance to some insecticides such as Fenitrothion (dimethyl 4-nitro-m-tolyl phosphorothioate), Isoxathion (diethyl 5-phenyl-3-isoxazolyl phosphorothioate), and DEP (dimethyl 2, 2, 2-trichloro-1-hydroxyethylphosphonate), which were commonly used for *H. cunea* controls.

Sex pheromones consist of chemicals that have virtually no toxicity and act upon the target insect with a minute amount. Pest control programs using sex pheromone result in little damage to the ecological system, relative to those using more toxic pesticides. It could be advantageous to employ a mass-trapping method in street trees, in order to control *H. cunea* better. *H. cunea* serves as an excellent subject with which to examine the effects of a mass-trapping system because: (1) After mating, female moths lay egg masses without dispersal (Masaki, 1975), i. e. we can omit the baneful danger of fertilized females migrating into the treated areas, (2) We can use a highly effective synthetic sex pheromone, (3) The synthetic pheromone, however, is quite costly to use a large quantity, such as in the mating disruption experiments, (4) There are many obstacles such as tall buildings and crowded roads prohibiting male moth dispersal. This may

minimize the risk of immigration from non-target areas.

In this study, we tested whether the mass-trapping method could reduce the damage to street trees by *H. cunea*. Because we did not know the exact density of this insect pest in the study field, we conducted our mass-trapping experiments with the maximum density of traps we could use as the first step to apply this method in actual streets.

Materials and Methods

Trap and lure

The sex pheromone of *H. cunea* is composed of five components (Hill *et al.*, 1982; Toth *et al.*, 1989). The lure used in our experiments (NITTO-LURE-AMESHIROR, Nitto Denko Corp. Co., Osaka), however, contained three of these components, (3Z, 6Z)-3, 6-9, 10-epoxyheneicosadiene, (9Z, 12Z, 15Z)-9, 12, 15-octadecatrienal and (3Z, 6Z)-1, 3, 6-9, 10-epoxyeicosatrien and was proven in the field experiments to be as effective as the lure which contained the five components (Zhang and Schlyter, 1996; Zhang *et al.*, 1996). The lure was a sheet of laminated plastic made of polyester and PET, and was centered on the underside of the trap's ceiling. The traps were sticky delta-traps (with a sticky surface of 30.0 × 18.5 cm, Nitto Denko Corp.).

Study field

The experiments were conducted on a 1.2 km stretch of Harumi Street located in Toyosu, Koto-Ku, Tokyo (Fig. 1). This area is in a man-made island isolated from other areas by narrow creeks. Street trees were regarded as the main habitat of *H. cunea* larvae, but we found some colonies in other areas such as parks or a school ground. When *H. cunea* larvae fed on the street trees voraciously during our experiments, extensive controls with insecticide were sometimes applied in this area by

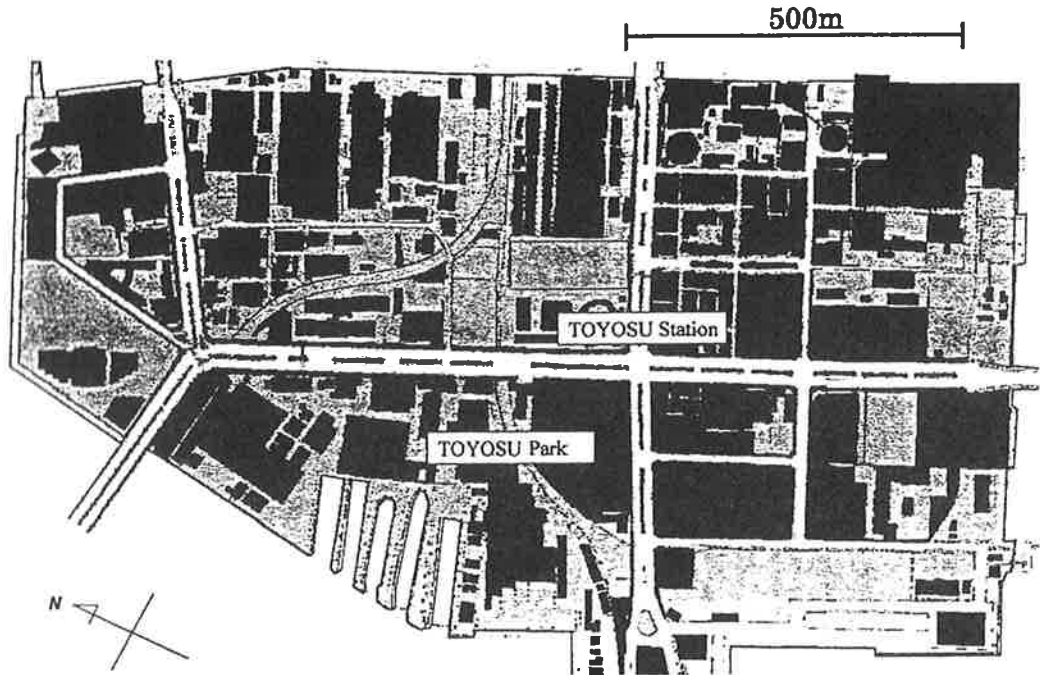


Fig. 1 Detailed map of the study field, Toyosu Koto-Ku, Tokyo. Black areas mean buildings or factorial plants. Light gray shaded areas mean open fields covered with concrete. Dark gray shaded areas mean places in which *H. cunea* larvae can live.

Koto-Ku government. Insecticides were sprayed during the 2nd larval period (in early August) every year.

Seasonal occurrence of moths and larvae

Experiments in 1994 and 1995

We divided the study field into 4 experimental areas, and named as Area-1, Area-2, Area-3 and Area-4 from north to south (Fig. 2 (a)). There were buffer areas between the neighboring experimental areas. Though buffer areas were thought to be non-treated areas which were not using for testing in our trials, buffer areas have their own meaning. In previous mass-trapping experiments, it was suggested that the existence of pheromone traps would affect the spatial distribution of male moths (Nemoto *et al.*, 1980; Trammel *et al.*, 1980). Therefore, buffer areas were allocated in the non-treated areas to reduce the effect of pheromone

traps in treated areas from biasing our results.

Each area had twenty plane trees (*Platanus acerifolia*) (ten trees in each side) and was about 150 m length. We placed a pheromone trap on each tree in Area-2 and Area-3 (Treated areas). The average distance between trees was about 6 m (ranging from 4 m to 30 m). We used Area-1 and Area-4 for non-treated controls. We counted the number of male catches over 5-9 d period which encompassed the greatest amount of male presence. During the larval period (in mid June, early August and mid September), we counted the number of webs both in the treated areas and in the non-treated areas. However, broad deviations in larval occurrence, as well as adult moth occurrence, were observed. Therefore, we assessed the number of webs twice in every generation and selected the larger number of webs to represent the maximum number of webs in

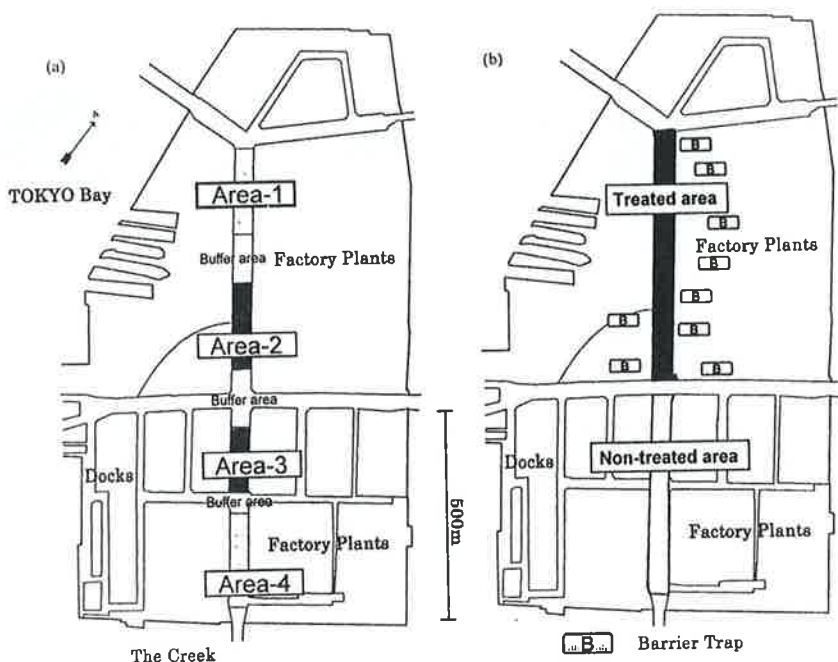


Fig. 2 (a) : Map of the study field in 1994 and 1995. Area-1 and Area-4 are the non-treated areas. Area-2 and Area-3 are the treated areas. (b) : Map of the study field in 1996. B means a barrier trap.

a single generation. The experiment began April 21st in 1994 and 1995, and concluded October 14th in 1994 and October 13th in 1995.

Experiments in 1996

We extended the experimental areas to eliminate interference between areas as in 1994 and 1995. Namely, we divided the study field into two experimental areas, one treated area and the other non-treated area. We placed barrier traps to prevent male moth immigration into the treated area (Fig. 2 (b)). The treated area had 88 plane trees (44 trees in each side) and each tree was treated with a pheromone trap. The non-treated area had 64 plane trees (31 trees in east side and 33 trees in west side). We counted the number of male catches every 7-10 days. We counted the larval webs in the same manner as in 1994 and 1995. The experiments began April 2nd and concluded November 7th.

Tethered-female experiment

Tethered-female experiments were conducted around the peak period of male catches. Three-day-old virgin females reared in the laboratory (15L : 9 D, 25 °C) were used. They were collected as larvae in Ibaraki prefecture, and fed artificial diets (Insecta L. F. ; Nihon-Nosan Corp.). Females were tethered by fine polyester threads (50 grade, approximately 30 cm long) near the base of a forewing. The other end of the thread was tied to the branch of each plane tree in the experimental areas. The height of the tethered female position was 1.5 m to 2.0 m. The above procedures allowed the females to move freely on the leaf near the branch and, also, to call and mate. In 1994 and 1995, 20 virgin females were placed in each of Area-1 (non-treated area) and Area-2 (treated area) in each area. One female was put onto each tree. In the

1996, 40 virgin females were placed in each of the treated and the non-treated areas. Females that survived were collected one or two days later and dissected in the laboratory to examine spermatophores in the bursa copulatrix.

Results

Seasonal prevalence of male catches

Captures of males by the traps are shown in Fig. 3. As reported previously (Gomi, 1997), it was confirmed that *H. cunea* completes three generations a year in Tokyo. In the overwinter generations, fewer males were captured every year and the duration of adult moth occurrence was longer than in other generations. In 1994 and 1996, the largest numbers of males were captured in the first generations, whereas in 1995 more males were captured in

the second generation.

The average number of males captured in 1996 was considerable less in every generation, relative to males captured in 1994 and 1995. However, we did not see this as a sign of decline in *H. cunea* population; since more than four times larger number of traps were used in one treated area in 1996 than in 1994 or 1995, the traps might scramble more intensively for male moths.

Degrees of larval occurrence

The degrees of larval occurrence are determined by counting the number of webs. Heavy damage was observed in the study field through 1994 to 1996. This occurred to the greatest extent in the second generations, with many plane trees being defoliated by *H. cunea* not only in the non-treated areas but also in the treated areas.

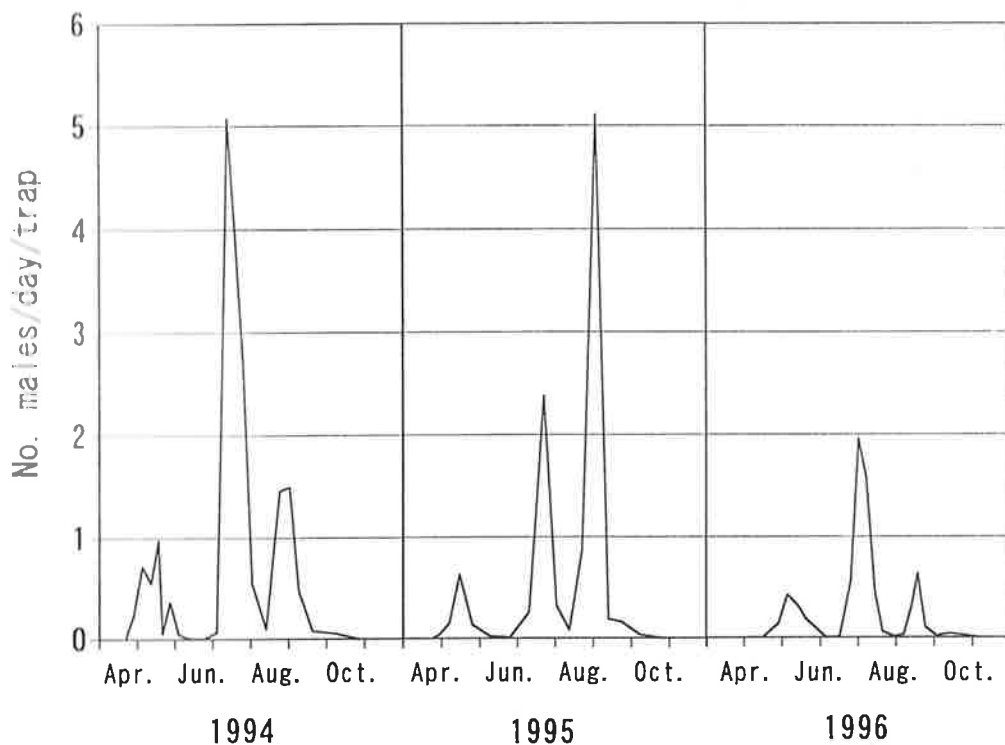


Fig. 3 Seasonal prevalence of males captured by pheromone traps in the treated areas from 1994 to 1996.

The number of webs per tree is summarized in Fig. 4. Only in the 2nd generation of 1994, did we observe fewer webs in the treated areas than in the non-treated areas. In the second generation of 1995 and in the second generation of 1996, many more webs were found in the treated areas. However, no significant differences were observed between the treated areas and the non-treated areas in every generation (Kruskal-Wallis test; $P > 0.05$).

Mating rate of tethered females

The results of the tethered-female experiments are summarized in Table 1 and Table 2. We could not recapture all of the females, because some of them slipped out of threads or were probably eaten by predacious birds. The percentage of mating was calculated based on the females that survived. In the experiments of September 8th in 1994 and July 19th

in 1995, the percentage of mating in the treated area (Area-2) was lower than that in the non-treated area (Area-1). On the other hand, in the experiments of September 12th in 1994 and September 8th in 1995, the percentage of mating was higher in the treated area (Area-1). However, there were no significant differences observed in mating between in the treated and non-treated area ($P > 0.05$, by Fisher's exact probability test) though all experiments.

In the three experiments conducted in 1996, the percentages of mating in the treated area were lower than those in the non-treated area. Nonetheless, there were no significant differences except for the experiment of 20th July 1996 ($P > 0.05$, by Fisher's exact probability test).

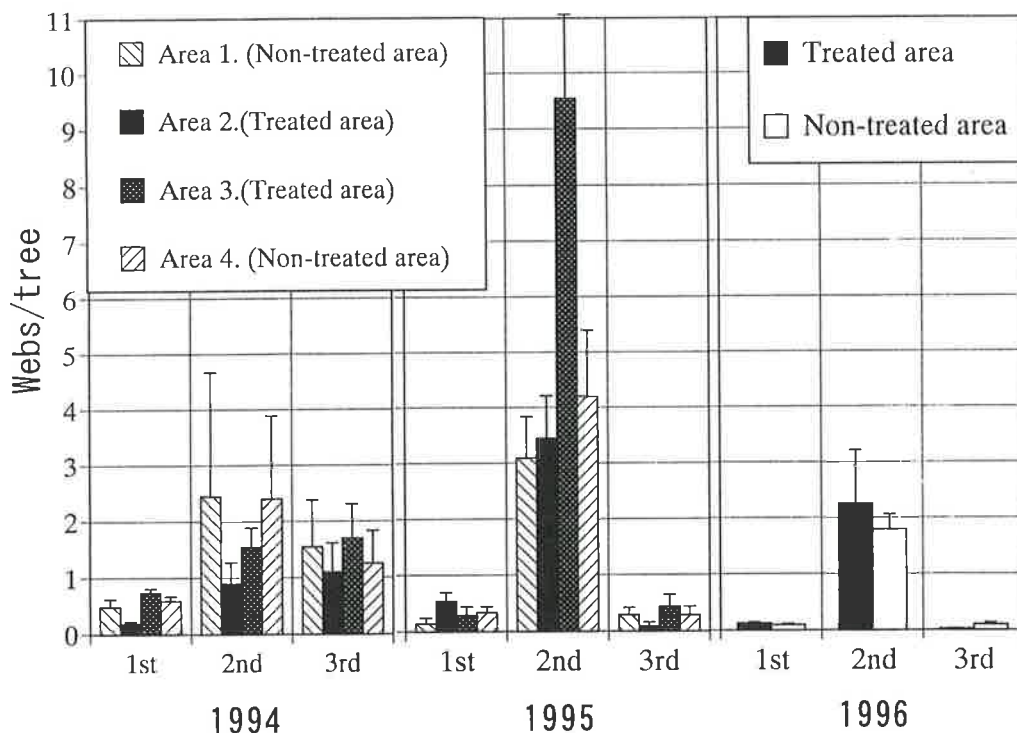


Fig. 4 Seasonal occurrence of webs of *H. cunea* larvae in the experimental areas from 1994 to 1996. Error bars indicate standard error of the mean.

Table 1 Effect of mass-trapping on mating of tethered females of *H. cunea* in 1994 and 1995

Date (Generation)	% females mated (No. recaptured females) ¹⁾	
	Treated area (Area-2)	Non-treated area (Area-1)
8 Sep. 1994 (2 nd)	13.3 (15)	26.3 (19)
12 Sep. 1994 ²⁾ (2 nd)	14.3 (7)	11.1 (9)
19 July, 1995 (1 st)	47.4 (19)	69.2 (13)
8 Sep. 1995 (2 nd)	46.2 (13)	22.2 (9)

1) Twenty virgin females were tethered with one on every tree in each of the treated and the non-treated areas.

2) Virgin females were collected after 2 days, while they were collected after 1 day in other trials

Table 2 Effect of mass-trapping on mating of tethered females in 1996

Date (Generation)	% females mated (No. recaptured females) ¹⁾	
	Treated area	Non-treated area
20 July, 1996 ²⁾ (1 st)	35.7 ³⁾ (28)	80.8 (20)
25 July, 1996 (1 st)	30.0 (30)	46.7 (30)
8 Sep. 1996 (2 nd)	32.4 (37)	45.9 (37)

1) Forty virgin females were tethered with one on every tree in each of the treated and the non-treated areas.

2) Virgin females were collected after 2 days, while they were collected after 1 day in other trials.

3) Means significant difference from the non-treated area by Fisher's exact probability.

Discussion

Fukuyama (1996) showed that the increasing damages by *H. cunea* are caused by the lack of the natural enemies as environmental conditions become increasing urbanized. *H. cunea* outbreaks occur every year in Tokyo and conventional control of this insect using pesticides does not seem very effective (Konno, 1998). Therefore, we anticipated positive results from our mass-trapping experiments using synthetic sex pheromone through 1994 to 1996. However, we could not significantly reduce the population density of *H. cunea* in street trees (as reduction of larval webs) in every treated area and generation compared with those in the non-treated areas. In addition, we could not detect significant decline in *H. cunea* population from year to year. From these results, we suggest that it is difficult to control this insect population only by the mass-

trapping method.

Many mass-trapping attempts have been performed in other lepidopterous insects, but only a few of them have shown positive results, e. g. in the red banded leafroller (Trammel *et al.*, 1974), the codling moth (MacLellan, 1976) and the cotton leafworm (Sato and Fujiwara, 1978). Jones (1998) pointed out some difficulties in achieving the efficacy in mass-trapping using sex pheromone, as follows: (1) Lack of attraction of females by the attractant source used, (2) Lack of highly efficient traps, (3) Problems of high insect population size and trap saturation, (4) Need for a high density of traps per unit of surface area, which in turn renders the technique too costly.

We used a highly efficient lure compared to the virgin females (Zhang and Schlyter, 1996; Zhang *et al.*, 1996) with the maximum density we could use in our experiments excluding the cost performance.

Therefore, we postulate two major reasons of our failure according to Jones (1998).

Firstly, male moths might immigrate into the treated areas, though we minimized immigration into the treated area in urban conditions. To confirm males' activity in nature, we conducted further experiments; flight-mill experiments, wind-tunnel experiments in the laboratory and mark-recapture experiments in the field (Yamanaka *et al.* unpublished data). From these three experiments, we concluded that *H. cunea* males did not disperse over long distances, and rather the dispersal range is likely to be limited to only several hundred meters within 1 day because of a limited period (30-60 min /d) of male mating activity in nature, although they can potentially fly long distances. Therefore, we cannot take male immigration from outside areas to be the main cause of our method's lack of success.

Secondly, the density of *H. cunea* population emerging in the study field might be too high to control by the mass-trapping method alone. The results in Fig. 3 and Fig. 4 show that there seems to be no relationship between male density and the number of webs of next generation, since the number of webs in non-treated areas were not always larger than those in treated areas in every first generation while number of males captured were small in every overwinter generation in Fig. 3. However, adult moths have sharp peaks of occurrence and the density of male moths will temporarily increase even in overwinter generation. Zhang *et al.* (1996) reported that total flight period of the overwinter generation was about 30 days but the major occurrence might be within 20 days and the male occurrences were clearly affected by the weather conditions such as temperature and rainfall. There might be simultaneous emergence at good weather condition. It must be more eminent in first

and second generation because moths take their random flight simultaneously in crowded groups to find female moths within a short period just before dawn in the first and second generations (Arai and Mabuchi, 1979) while the overwinter generation was reported to have rather large mating period during the night (Masaki, 1975).

In our trial, we could not reduce the damage to street trees by the mass-trapping method only. On the other hand, we can say from the results of the tethered-female experiments that the mass-trapping trials might disturb the matings when the treated area was large enough as in 1996. If we can reduce *H. cunea* population by other methods such as the use of insecticide sprays or by pruning as a subsidiary means of control, then the mass-trapping system may be more effective. Then, the mass-trapping technique still has potential viability in an integrated pest management program even if it cannot reduce the damages drastically by itself.

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References

- Arai, T. and M. Mabuchi (1979) Effects of light conditions on the timing of activities in *Hyphantria cunea* Drury (Lepidoptera: Arctiidae). *Jpn. J. Appl. Entomol. Zool.* 23 : 162-169
- Fukuyama, K. (1996) Relationship between urbanization and defoliation by the fall webworm

- Hyphantria cunea* Drury (Lepidoptera : Arctiidae) on roadside trees. *Jpn. J. Appl. Entomol. Zool.* 40 : 83-84.
- Gomi, M. (1997) Geographic variation in critical photoperiod for diapause induction and its temperature dependence in *Hyphantria cunea* Drury (Lepidoptera : Arctiidae). *Oecologia* 111 : 160-165.
- Hill, A. S., B. G. Kovalev, L. N. Nilolaeva, and W. L. Roelofs (1983) Sex pheromone of the fall webworm *Hyphantria cunea*. *J. Chem. Ecol.* 8 : 383-396.
- Ishii, G. (1966) Biology of *Hyphantria cunea* Drury. *Acta Sericologica* 59 : 40-63.
- Jones, O. T. (1998) Practical applications of pheromones and other semiochemicals. In "Insect Pheromones and their Use in Pest Management" (Howse, P., I. Stevens and O. Jones, eds), pp. 263-355, Chapman & Hall, London.
- Konno, Y. (1998) Comparison of insecticide susceptibility between fall webworm, *Hyphantria cunea* (Lepidoptera : Arctiidae) and its parasitoid fly *Exorista japonica* (Diptera : Tachinidae). *Jpn. J. Appl. Entomol. Zool.* 42 : 167-170.
- MacLellan, C. R. (1976) Suppression of codling moth (Lepidoptera : Olethreutidae) by sex pheromone traps in an isolated apple orchard. *J. Econ. Entomol.* 69 : 597-599.
- Masaki, S. (1975) Biology of *Hyphantria cunea* Drury (Lepidoptera : Arctiidae) in Japan : A review. *Rev. Plant. Protec. Res.* 8 : 14-28.
- Nemoto, H., K. Takahashi and A. Kubota (1980) Reduction of the population density of *Spodoptera litura* (F.) (Lepidoptera : Noctuidae) using a synthetic sex pheromone. I. Experiments in taro field. *Jpn. J. Appl. Entomol. Zool.* 24 : 211-216.
- Sato, Y., H. Fujiwara, (1978) A dry pheromone trap for capturing males of *Spodoptera litura* (F.). *Appl. Entomol. Zool.* 15 : 27-35.
- Toth, H. R., H. R. Buser, A. Pena, H. Arn, K. Mori, T. Takeuchi, L. Nikolaeva, and B. G. Kovalev (1989) Identification of (3Z, 6Z)-1, 3, 6-9, 10-epoxyheneicosatriene and (3Z, 6Z)-1, 3, 6-9, 10-epoxyeicosatriene in the sex pheromone of *Hyphantria cunea*. *Tetrahedron Letters* 30 : 3405-3408.
- Trammel, K., W. L. Roelofs and E. H. Glass, (1974) Sex-pheromone trapping of males for control of red banded leafroller in apple orchards. *J. Econ. Entomol.* 67 : 159-164.
- Zhang, Q. H. and F. Schlyter (1996) High recaptures and long sampling range of pheromone traps for fall web worm moth *Hyphantria cunea* (Lepidoptera : Arctiidae) males. *J. Chem. Ecol.* 22 : 1783-1796.
- Zhang, Q. H., F. Schlyter, D. Chu, X. Y. Ma and Y. Ninomiya (1996) Female calling behaviour and response of males to synthetic pheromone and virgin females in spring and summer generations of *Hyphantria cunea* (Lepidoptera : Arctiidae) in northeastern China. *J. Appl. Entomol.* 120 : 467-476.

Occurrence of the Ladybird Beetle *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) in Osaka, Japan.

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大阪におけるツマアカオオヒメテントウ *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) の発生。大橋和典 (京都大学大学院農学研究科生態情報開発学研究室)

オーストラリア原産のカイガラムシ食テントウムシの一種、ツマアカオオヒメテントウ *Cryptolaemus montrouzieri* Mulsant の発生を1999年および2000年に大阪府で観察した。本種は、コナカイガラムシ防除を目的として1931年および1979年に日本への導入が試みられたが、小笠原諸島を除いて定着に失敗し、日本本土には分布していなかった。また、本種は日本本土で越冬できないと考えられていたが、2年連続で観察されたことから定着の可能性が示唆された。

In 1999 and 2000, I confirmed the occurrence of the predatory ladybird beetle, *Cryptolaemus montrouzieri* Mulsant, native to Australia, in Osaka Pref., central Honshu, Japan. This species was introduced into Japan for the biological control of mealybugs in 1931 and 1979, but had failed to establish a population in Japan, except on the Bonin (Ogasawara) Islands. Although it has been believed to be impossible for the beetle to overwinter in Japan, the present observation indicates that the beetle can establish itself in Japan proper.

Key words: *Cryptolaemus montrouzieri*, Coccinellid, Mealybug predator, Biological control, introduced species.

The mealybug predator *Cryptolaemus montrouzieri* Mulsant (Fig. 1) is a ladybird beetle native

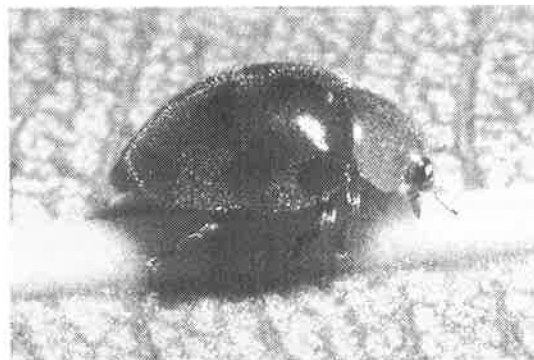


Fig. 1 An adult *C. montrouzieri* walking on a leaf of an oleander plant.

to Australia (Hodek and Honek, 1996). This beetle was first carried into California in 1891, and the introduction was successful for the biological control of mealybugs attacking citrus (Booth and Pope, 1986). Since the first introduction into California, the beetle has been introduced into warmer areas throughout the world (Booth and Pope, 1986). Similar attempts were made in Japan in 1935 and 1979 (Mori and Murakami, 1981). However, the beetle did not establish a population in Japan, except on the Bonin (Ogasawara) Islands located in a subtropical district (Sasaji, 1971; Sasaji, 1998). According to Bartlett (1973), the winter of Japan proper seem to be too cold for the beetle to survive.

However, I observed the occurrence of this beetle in 1999 and 2000 at the same place in Osaka. This observation is a new record in Japan proper. In addition it also suggests that the beetles had overwintered successfully. The successful overwintering might be due to global warming (Harrington and Stork, 1995) and/or acquisition of cold toler

ance (Bartlett, 1973). If the colony survives a severe winter, it may be able to expand its distribution in Japan proper.

Specimens examined: On 14 May 1999, I collected one adult from an oleander plant, *Nerium indicum*, infested by scale, *Pulvinaria aurantii*, in Takatsuki City, Osaka Prefecture, Japan. On 19 June 2000, I also collected 5 adults, 3 pupae and 6 larvae from the same plant where the beetle had been previously collected. Larvae and pupae on shoots heavily infested with coccids were brought to the laboratory, and were reared at 20°C, under a 16L: 10D condition until adults emerged. These adults were identified as *C. montrouzieri montrouzieri* Mulsant based on a key to species by Booth and Pope (1986).

I thank Prof. A. Takafuji of the Laboratory of Ecological Information of Kyoto University for his helpful comments on this manuscript.

References

- Bartlett, B. R. (1974) *Envir. Entomol.* 3 : 553-556.
- Booth, R. G. and R. D. Pope (1986) *Bull. Ent. Res.* 76 : 701-717.
- Harrington, R. and N. E. Stork (eds.) (1995) *Insects in a Changing Environment*. Academic Press, London.
- Hodek, I. and A. Honek (1996) *Ecology of Coccinellidae*. Kluwer Academic Publishers, Netherlands.
- Mori, H. and Y. Murakami (1981) In "*Recent Advances in Entomology*" (Ishii, S. ed), pp. 279-295, The University of Tokyo Press, Tokyo.
- Sasaji, H. (1971) *Fauna Japonica Coccinellidae* (Insecta: Coleoptera). Academic Press, Tokyo.
- Sasaji, H. (1998) *Natural History of the Ladybirds*. The University of Tokyo Press, Tokyo.

「里山」は、狭義には薪炭林あるいは農用林（以下、里山林）をさすが、それらは水田や採草地などと一体となってわが国の田園の景観（広義の里山）を形づくってきた。里山は、生態学的には二次的自然にすぎないが、日本的な生物の温床となっていた。しかし、近年、農業を取り巻く情勢の変化から各地で里山の崩壊が進行し、そこに生息する動植物の衰退が顕著になってきた。本研究は、里山の昆虫類の生物多様性を明らかにするとともに、それらが里山の半自然環境の中で維持されてきたメカニズムを解明し、今後の保全方法を探ろうとするものである。本稿では、大阪周辺で行ったチョウ類群集の多様性調査の結果を紹介する。トランセクト調査の結果、里山林のチョウ類群集の種構成や種多様度は都市緑地のものとは明確に異なることが明らかになった。すなわち、里山林では1化性、ササ類食のチョウ類が多いのに対して、都市緑地では訪花性、移動性のものが多かった。また、種多様度は、高い方から里山林、照葉樹林、都市緑地の順であった。里山林の昆虫類の生物多様性は長い時間をかけて醸成されたものと考えられ、その保全には残された里山林を現在の位置で維持・管理する必要があるだろう。

はじめに

「里山」は、狭義には薪炭林あるいは農用林（以下、里山林という）をさすが、それらは水田や茅場（採草地）などと一体となってわが国の田園の景観（広義の里山）を形づくってきた（図1）。里山は稲作農業を支える基盤として、長いあいだ農民により維持されてきた半自然環境ではあるが、日本的な生物の温床となっていた。しかし、近年、農業を取り巻く情勢の変化から各地で里山の消失、変質、分断化が進行し、そこに生息する動植物の衰退が顕著になっている（守山，1988，1997；石井，1993；石井，2000，2001など）。

本研究は、昆虫類を指標として里山の生物群集の多様性を明らかにするとともに、その生活史の組み立てを究明することによりそれらが里山の半自然環境の中で維持されてきたメカニズムを推定し、今後の保全方法を探ろうとするものである。なお、本稿では、紙面の関係で大阪周辺で行ってきたチョウ類群集の調査結果の概要のみを紹介することとした。

本研究では、トランセクト調査を実施すること

により、大阪府内の能勢町三草山の里山林、貝塚市馬場の広義の里山などのチョウ類群集を大阪城公園、服部緑地、大泉緑地などの都市緑地のものと比較した（石井ら，1991，1995；石井，1996；Ishii，1996）。チョウ類を指標として選んだ理由は、まず第1に昼行性で捕獲しなくても種の同定が可能であるうえ、種数が適当で、各種の寄主植物や成虫の食物などの生活史に関する情報が蓄積しているなど、総合的にみて植生の状態をよく反映する生物群と考えられるからである（Kudrna，1986；石井，1996）。

里山のチョウ類の優占種

この調査の結果、里山のチョウ類群集の種構成や種多様度は都市緑地のものとは明確に異なることが示された。表1は三草山の里山林、貝塚市馬場の広義の里山、大泉緑地のチョウ類群集の優占種（上位10種）とその密度（トランセクト1km当たりの個体数）を示したものである。三草山では上位10種すべてがヒカゲチョウ類やミドリシジミ類などの森林性の種で占められていたのに対して、大泉緑地では造成した里山的な樹林があるにも関

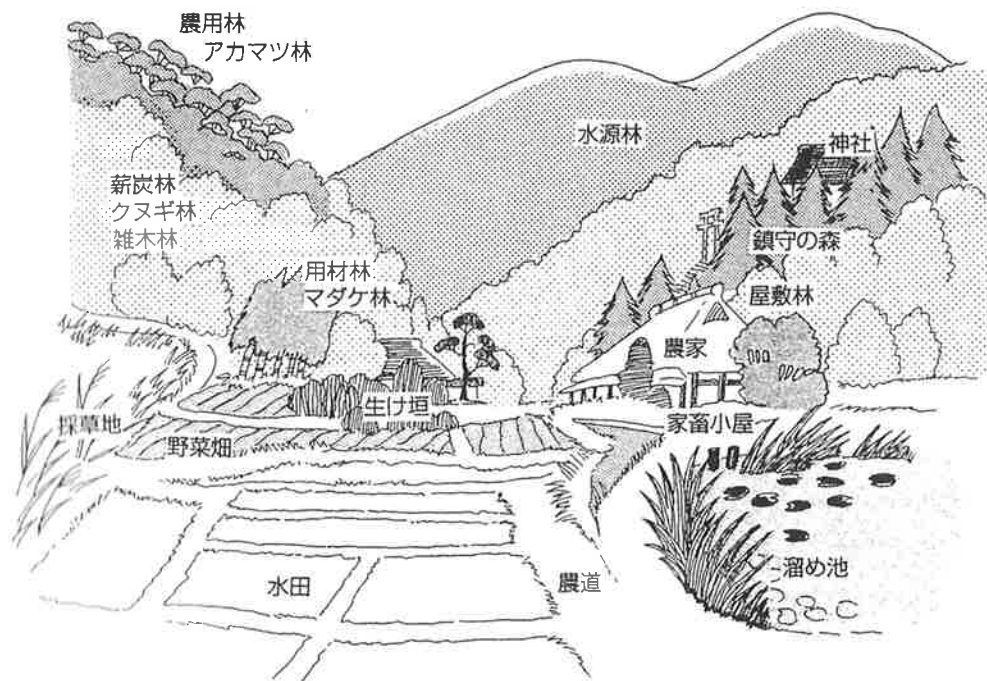


図1 広義の里山を構成する要素 (大阪自然環境保全協会里山委員会 (1996) より)。

むすず、上位10種のうちキチョウ、アオスジアゲハ、ナミアゲハを除く7種は草索性であった。キチョウはハチ類、アオスジアゲハはクスノキ、ナミアゲハはミカン類などの園芸植物を利用できるために都市緑地でも生息が可能なためと思われる。

一方、貝塚市馬場地区では里山林、植林、水田、ため池、水路などを含む広義の里山部分を調査ルートに設定したが、優占種は草索性と森林性が半々で構成されていた。しかし、この調査地の特徴のひとつは、森林性でもヒメウラナミジャノメやキチョウ、コミスジのような林縁性の種が優占していることで、ヒカゲチョウ類のような樹林内を好む種はむしろ少なかった。草索性の種についても、イチモンジセセリ、モンシロチョウ、ヤマトシジミ、ベエシジミなどが大泉緑地のような都市緑地と共通していたが、密度は低かった。このように優占種の構成からみると、農耕地を含む広義の里山のチョウ類群集は、里山林と都市緑地の中間的であることがわかる。

里山のチョウ類の性格

次にこれら3ヶ所の調査地で確認されたチョウ類を食性、化性、移動性などの性格により分類し、比較を行った。ここでは、成虫の食性として花蜜食かそれ以外か、幼虫の寄主植物がササ類かそれ以外か、年間経過世代数について1化性か多化性か、成虫の移動性が知られているか否かをとりあげ、各調査地における種数と個体数の割合を求めた(表2)。

訪花性の種の割合については、種数では80%前後で調査地による違いはなかったが、個体数では大泉緑地が約98%と極めて高かったのに対して、三草山の里山林は約半数程度であった。これはコナラやクヌギなどの落葉樹林を主体とする里山林には、樹液や果実、獣糞など花蜜以外の食物も豊富で、それらに依存する種も生活が可能なためと考えられる。貝塚市馬場地区の広義の里山では、里山林のみの三草山の調査地と異なり、訪花性チョウ

表1 三草山の里山林, 貝塚市馬場地区の里山, 大泉緑地におけるチョウ類の優占種と1km当たり個体数(確認個体数)

順位	三草山(里山林) ¹⁾		貝塚市馬場(里山林・農地) ²⁾		大泉緑地(都市緑地) ³⁾	
1	ナミヒカゲ	6.33 (140)	ヒメウラナミジャノメ	4.60 (91)	ヤマトシジミ	5.63 (161)
2	キマダラヒカゲ類	2.35 (52)	キチョウ	3.48 (69)	イチモンジセセリ	5.28 (151)
3	クロヒカゲ	2.12 (47)	イチモンジセセリ	3.33 (66)	モンシロチョウ	3.74 (107)
4	コムスジ	1.76 (39)	モンシロチョウ	3.03 (60)	キチョウ	3.50 (100)
5	ウラナミアカシジミ	1.45 (32)	ヤマトシジミ	2.32 (46)	ツバメシジミ	3.11 (89)
6	オオチャバネセセリ	1.36 (30)	コムスジ	1.97 (39)	ベニシジミ	2.52 (72)
7	ミズイロオナガシジミ	1.32 (29)	ウラギンシジミ	1.41 (28)	モンキチョウ	2.31 (66)
8	メスグロヒョウモン	1.04 (23)	ベニシジミ	1.36 (27)	アオスジアゲハ	2.20 (63)
9	イチモンジチョウ	1.00 (22)	テングチョウ	1.21 (24)	ヒメアカタテハ	1.15 (33)
10	ヒロオビミドリシジミ	0.86 (19)	スジグロシロチョウ	1.11 (22)	ナミアゲハ	0.94 (27)
上位10種の合計		19.6 (433)	23.8 (472)		30.4 (869)	
全種の合計		27.4 (607)	36.9 (730)		32.3 (923)	
全個体数に占める割合		71.1%	64.7%		94.1%	

- 1) 石井ら(1995)より
- 2) 石井(1996)より
- 3) 石井ら(1991)より

表2 大阪府内の里山と都市公園のチョウ類群集の比較. 成虫の食性, 幼虫の食性, 化性, 移動性について, それぞれ訪花性の種, ササ類を食草とする種, 1化性の種, 移動性の高い種の種数および個体数の割合を示した

調査地	類型	確認種数	訪花性の種		ササ食の種		1化性の種		移動性の種		文献
			種数%	個体数%	種数%	個体数%	種数%	個体数%	種数%	個体数%	
三草山	里山林	49	85.7	53.2	12.2	46.5	30.6	24.2	4.1	1.0	石井ら(1995)
貝塚馬場	里山	45	77.8	84.4	8.9	4.9	13.3	6.0	8.9	19.2	石井(1996)
大泉緑地	都市緑地	22	81.8	97.5	-	-	4.5	0.1	18.2	31.7	石井ら(1991)

ウ類の個体数の割合は80%以上と高かった。

幼虫がササ食のチョウの割合については, 種数, 個体数ともに三草山が最も高く, 貝塚市馬場地区の里山では低く, 大泉緑地ではそのような種は認められなかった。近畿地方の落葉樹林を特徴づける林床のネザサ群落は, 人間の営力による管理や攪乱の程度を反映して発達したり衰退したりするが, この結果はその状態を示すものと考えられる。

一度表土を剥ぎ取って造成され, 徹底的に下草管理がなされる大泉緑地のような都市緑地では, 三草山において個体数の約4割を占めるヒカゲチョウ類のようなササ食者が生息できないのであろう(表1参照)。

このことは1化性の種についても同様である。すなわち, 1化性の種は生活史のどこかの段階で長期間の休眠を行うが, あまりにも管理の行き届

いた都市緑地ではその発育段階を安全に過ごす環境が乏しいと言える。たとえば、早春に成虫が現れるツマキチョウは夏秋冬の約10ヶ月間を蛹の状態ですぐの中などで過ごす。ツマキチョウは三草山と貝塚市馬場地区では見られたが、大泉緑地では確認できなかった。

1化性のチョウには当然、比較的定住性の強いものが多いが、逆に多化性の種は程度の差こそあれ移動性を備えている。なかでも、イチモンジセセリやヒメアカタテハ、モンシロチョウ、ウラナシジミといった草原性の種ではこれまでに移動の記録や副翅がある (Williams, 1958; 中筋・石井, 1988; 石井, 2000など)。大泉緑地で特に移動性の種の割合が高いのは、人間による攪乱が頻繁な都市緑地では、草原的で一時的な環境が多いためと思われる。

このように都市緑地との対比の中で浮かび上がってくるのは、里山林のチョウ類には1化性や定住性で、落葉樹林の植生と結びついた食性の種が多いということである。一方、貝塚市馬場地区のような里山林と農耕地が入り組んだ広義の里山では、里山林特有の種と林縁的な種、都市緑地でも見られる草原的な種などが混生していることがわかった。チョウ類群集の多様性を維持するという観点に立つと、里山林と農耕地を今後とも継続的に維持する必要性を指摘することができる。

里山のチョウ類の種多様度

表1には3ヶ所の調査地におけるチョウ類の平均密度と上位10種の個体数の占める割合を、また表2には確認種数を示した。これらの数値から見ると、大泉緑地のチョウ類群集は、三草山の里山林や貝塚市馬場地区の里山と比較して種数(22種)が少なく、上位種が突出した(約94%)、多様性の乏しいものであることがわかる。

このことを確かめる意味で、図2には日浦(1973, 1976)によるデータも含めた近畿地方のさまざまな緑地におけるチョウ類群集の種多様度(ここでは平均多様度H'を使用)と平均密度(トランセ

クト1km当たりの個体数)を示した。これを見ると、チョウ類群集の種多様度は、里山のものが最も高く、照葉樹林のものがそれに次ぎ、都市緑地の群集は、中程度の服部緑地から極めて低い大阪城公園までまちまちであることがわかる。服部緑地のチョウ類群集の種多様度が高いのは、郊外に立地し、一部に旧来の里山を残した半造成の公園であるためと考えられる。これに対して、大阪城公園は都心に造られた植栽による緑地であり、除草などの管理が徹底している(みどり生き物のマップづくり会議, 1992)ことがチョウ類群集の多様性低下に関係していると思われる。チョウ類群集の平均密度については、里山や都市緑地で高く、照葉樹林で低いという傾向が認められた。

里山林のチョウ類の多様性が高いのはなぜか

近畿地方の植生の極相が照葉樹林であるにも関わらず、落葉樹林からなる里山林よりチョウ類群集の種多様度が低い点について、筆者は最近、日本の森林文化との関係からの考察を試みた(石井, 2001)。花粉化石の分析によれば縄文時代の中期頃は大阪の低地は照葉樹林で覆われ(安田, 1980; 高原, 1998など)、人口密度も極めて低かった(佐々木, 1993など)、現在、南紀地方で見られるような照葉樹林帯の多様なチョウ類がそろっていたと考えられる。しかし、その後西日本に伝来した照葉樹林文化は、祖先に照葉樹林の中で生きるすべを教え、それをきっかけにして原生林の破壊と人口の増加が始まったのではないだろうか。さらに弥生時代に始まる水田稲作農業は大阪低地の風景を一変し、この頃までには照葉樹林のチョウ相の衰退が決定的なものとなったと考えられる。

一方、落葉樹林のチョウ類は、近畿地方の低地においてはウルム氷期の終結から縄文時代の前半にかけて繁栄していたものと思われる。この時代には、まず冷温帯林、続いて暖温帯林が大阪の低地を覆っていたことが、花粉化石の分析結果からわかっているからである(安田, 1980; 高原, 1998など)。やがて、上記のように、縄文時代中期