

VERTICAL AND HORIZONTAL DISTRIBUTION OF *CULEX PIIPIENS* COMPLEX MOSQUITOES COMPARED WITH *AEDES ALBOPICTUS* IN AN INLAND CLIMATE MOUNTAIN AREA, JAPAN

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Abstract Yamanashi Prefecture, an inland climate mountain area of Japan, extends widely north and south, with altitude that varies greatly by location. Mosquitoes transmitting infectious disease have a diversity of habitats in Yamanashi, and many species can be expected there. However, there have been few reports about mosquito fauna; in particular, little information is available on mosquitoes such as *Culex pipiens pallens*, *C. pipiens* form *molestus*, and *Aedes albopictus*. In this study, we investigated the mosquito fauna to clarify their vertical and horizontal distribution patterns, focusing especially on *Culex pipiens* complex, i.e., *C. pipiens pallens* and *C. pipiens* form *molestus*, compared with *Aedes albopictus* in 7 areas from August to September in 2015 and 2016. We set up CDC traps in several temple and shrine precincts in each area. Although *C. pipiens* complex was not captured in the Minobu Area, it was captured in the other 6 areas. *C. pipiens* complex was collected at 851 m asl. which was the maximum altitude, while *Ae. albopictus* was collected at a maximum altitude of 799 m asl. That means habitat of *C. pipiens* complex was distributed more widely than that of *Ae. albopictus*. The mean air temperature of the site at 799 m was estimated to be 10.07 degrees Celsius and that of the site at 851 m was estimated to be 9.67°C. There was an altitude differences of 52 m in vertical distribution between the two species, with a difference in annual mean air temperature of 0.4°C.

Key words Altitude, annual mean air temperature, CDC trap, fauna of mosquitoes, temple and shrine

INTRODUCTION

Culex pipiens pallens Coquillet, *C. pipiens* form *molestus* Forskal, and *Aedes albopictus* (Skuse) are the most common mosquitoes in urban as well as rural areas of Japan (Tsuda et al., 2006). These females are primarily avian feeders but also vicious biters of humans and other mammals (Tanaka et al., 1979). In the summer season, biting females of the former two *Culex* species often enter dwellings and become a target of indoor control, while *Ae. albopictus* bites humans outdoors. These *Culex pipiens* mosquitoes are considered to be the most important potential vector of West Nile virus, and *Ae. albopictus* is an important as a disease vector of dengue and dengue hemorrhagic fever in Japan (Knudsen, 1995; Knudsen et al., 1996). Vector control is an essential measure for controlling the outbreak of viral disease. Thus, collecting information about the distribution and ecology of vectors might be the most important and essential/effective method of vector control. The vertical and horizontal distribution ranges of these mosquitoes are an important factor determining the risk area for transmission of vector-borne diseases. However, there have been no attempts to evaluate the distribution of *C. pipiens* mosquitoes in Japan.

Yamanashi Prefecture in Japan comprises an inland climate mountain area that extends widely north and south, with an altitude that varies greatly by location. Therefore, mosquitoes transmitting infectious diseases have a diversity of habitats in Yamanashi, and many species can be expected there (Kamimura, 1968; Saito, 1968). However, there have been few reports on mosquito fauna in that area. Saito (1968) investigated the mosquito fauna in Kofu using a light trap from July to December, 1961. He reported collecting 6 species including only two individuals of *Ae. albopictus*. Takahashi et al. (2005) investigated three mosquito species, i.e., *Ae. albopictus*, *C. pipiens pallens* and *C. tritaeniorhynchus* Giles, in Kofu using a light trap from May to November in 2005, and the total number of these three mosquitoes collected was 142, including 76 *Ae. albopictus* (53.5%).

We attempted to clarify vertical and horizontal distribution patterns by investigating the fauna of mosquitoes, especially focusing on *C. pipiens* complex (*Culex pipiens pallens* and *C. pipiens* form *molestus*) as compared with *Ae. albopictus*, in 7 areas from August to September in 2015 and 2016. We set up CDC traps in several temple and shrine precincts in each area.

MATERIALS AND METHODS

Mosquito surveys were carried out from the end of August to early September 2015 and 2016 in 7 areas (Hokuto Area, Nirasaki Area, Kofu Area, Koushyu, Fuefuki and Yamanashi Area, Fujiyoshida and Kawaguchiko Area, Minobu Area and Nanbu Area; including 8 cities and 2 towns) in Yamanashi Prefecture (Figure 1). Adult mosquito collections were conducted at a total of 26 sampling sites, including temples and shrines. Table 1 lists study areas, sampling sites, locations (longitude; 138°18' 07.54" E - 138°47' 37.36" E), environmental conditions (annual mean air temperature in each area over 10 years from 2007 to 2016) of the mosquito collection sites, and the investigation periods/days. The latitude ranged from 35°17' 41.57" N to 35°52' 08.89" N, and altitude was 164 - 974m, respectively.

For adult collections, CDC traps without a bulb and baited with 1 kg dry ice were used and operated from 15:00 to 10:00. Mosquitoes were collected every morning for identification following the keys of Tanaka et al. (1979). *C. pipiens* complex (i.e., *C. pipiens pallens* and *C. pipiens* form *molestus*) and *Ae. albopictus* samples were identified and counted. CDC traps were set up at 26 sites (a total of 26 nights) in Yamanashi Prefecture.

Table 1. Environmental conditions of *Culex pipiens* complex and *Aedes albopictus* collection areas in Yamanashi Prefecture, Japan.

Study area	Sampling site	altitude*	10 years annual mean	Sampling days of adult collection by CDC trap (s)	Total No. of collecting mosquitoes (<i>C. pipiens</i> com., <i>Ae. albopictus</i>), <Average of individual No. / night by CDC trap>
		(m)	air temperature (\pm SD) ^{°C} **		
Hokuto	12 sites (12 temples)	867	11.4 (\pm 0.4)	12 sites (12 nights)	244 (13, 29), <Ave. Ind./night by CDC: 20.3 (1.1, 2.4)>
Nirasaki	3 sites (2 shrines, 1 temple)	341	13.5 (\pm 0.3)	2 sites (2 nights)	22 (2, 1), <Ave. Ind./night by CDC: 11.0 (1.0, 0.5)>
Kofu	3 sites (3 temples)	273	15.2 (\pm 0.3)	3 sites (3 nights)	128 (5, 9), <Ave. Ind./night by CDC: 42.7 (1.7, 3.0)>
Koushyu, Fuefuki and Yamanashi	3 sites (2 temples and 1 shrine)	394	14.1 (\pm 0.3)	3 sites (3 nights)	66 (17, 37), <Ave. Ind./night by CDC: 22.0 (5.7, 12.3)>
Fujiyoshida and Kawaguchiko	2 sites (2 temples)	860	11.1 (\pm 0.4)	2 sites (2 nights)	6 (5, 0), <Ave. Ind./night by CDC: 3.0 (2.5, 0.0)>
Minobu	2 sites (2 temples)	226	14.1 (\pm 0.4)	2 sites (2 nights)	4 (0, 2), <Ave. Ind./night by CDC: 2.0 (0.0, 1.0)>
Nanbu	2 sites (2 temples)	141	15.2 (\pm 0.3)	2 sites (2 nights)	68 (5, 13), <Ave. Ind./night by CDC: 34.0 (2.5, 6.5)>
Total	27 sites (3 shrines and 24 temples)			26 sites (26 nights)	538 (47, 91), <Ave. Ind./night by CDC: 20.7 (1.8, 3.5)>

* altitude of the meteorological station in the study area, ** annual mean air temperature at each area during 10 years (2007–2016)

RESULTS AND DISCUSSION

A total of 538 individual adult mosquitoes were collected during the investigation periods, including 47 *C. pipiens* complex and 91 *Ae. albopictus* (Table 1). Although *C. pipiens* complex was not collected in the Minobu Area, it was captured in the other 6 areas in Yamanashi Prefecture. *C. pipiens* complex were collected from the Koushyu, Fuefuki and Yamanashi Area, with a total of 17 individuals and an average of 5.7 individuals/night/CDC trap, followed by the Fujiyoshida and Kawaguchiko Area, and Nanbu Area with 5 individuals and an average of 2.5 individuals/night/CDC trap. Meanwhile, *Ae. albopictus* were collected from the Koushyu, Fuefuki and Yamanashi Area, with a total of 37 individuals and an average of 12.3 individuals/sampling, followed by the Nanbu Area with 13 individuals and an average of 6.5 individuals/sampling point. Figure 2 shows individual number of *C. pipiens* complex by CDC trap/night in Yamanashi Prefecture. Many adult mosquitoes were collected in the northeast part of Yamanashi Prefecture. Figure 3 shows the proportion of main mosquito fauna, *C. pipiens* complex and *Ae. albopictus*, in each site in Yamanashi Prefecture. Depending on the site, these mosquitoes were widely distributed in all of Yamanashi Prefecture.

Figure 4 shows the relationship between the number of individual *C. pipiens* complex by CDC trap/night and the altitude of the CDC trap site. At an investigation site with an altitudes of more than 900 m (only 1 site), no adult *C. pipiens* complex were captured. Two individual adult mosquitoes were collected at Doukiin Temple (asl. 851 m) in the Hokuto Area, which was the maximum altitude at which *C. pipiens* complex was collected in this study. On the other hand, Figure 5 shows the relationship between the number of individual *Ae. albopictus* by CDC trap/night and the

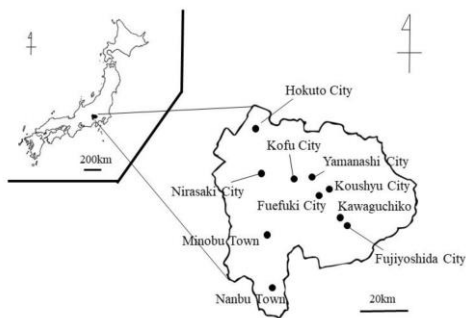


Figure 1. Distribution of the 7 studied areas in Yamanashi Prefecture.

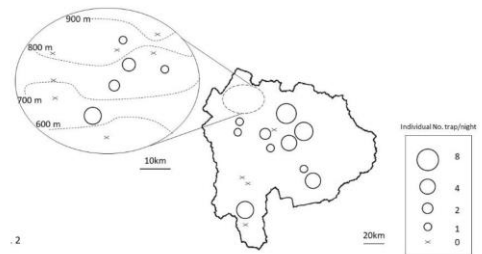


Figure 2. Number of *Culex pipiens* complex by CDC trap/night in Yamanashi Prefecture.

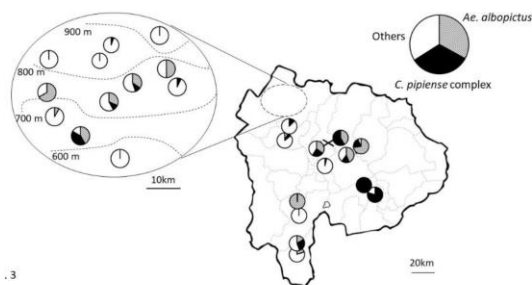


Figure 3. Proportion of main mosquito fauna, *Culex pipiens* complex and *Aedes albopictus*, in each site in Yamanashi Prefecture.

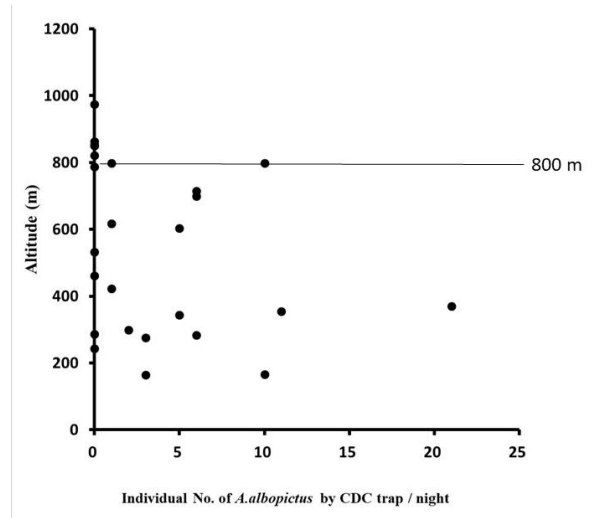
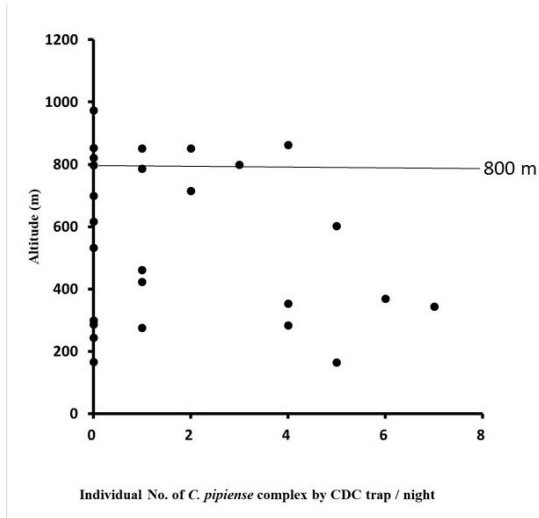


Figure 4 and 5. Relationship between number of *C. pipiens* complex by CDC trap/night and altitude of CDC trap site. Relationship between number of *Ae. albopictus* by CDC trap/night and altitude of CDC trap site.

altitude of the CDC trap site. At investigation sites with altitudes of more than 800 m (6 sites), no adult *Ae. albopictus* were captured. Ten individual adult mosquitos were collected at Ryutakuji Temple (asl. 799 m) in the Hokuto Area, which was the maximum altitude at which *Ae. albopictus* was collected in this study. Thus, *Ae. albopictus* was collected at a maximum altitude of 799 m asl. while *C. pipiens* complex was collected at a maximum altitude of 851 m asl. That means the habitat of *C. pipiens* complex was more widely distributed than that of *Ae. albopictus*. A strong negative correlation was found between the altitude of the meteorological station in this study area ($y = -123.79x + 20.48$) and the annual mean air temperatures at each area during the 10 years (x) ($r^2 = 0.84$). The mean air temperature of the site at 799 m was estimated to be 10.1°C and that of the site at 851 m was estimated to be 9.7°C. There was a difference in altitude of 52 m of vertical distribution between the two species, and a difference of 0.4°C in annual mean air temperature. According to Kobayashi et al. (2002), there is a strong correlation between *Ae. albopictus* mosquito-infested areas and annual mean air temperature above 11°C. In our study, *Ae. albopictus* was not collected in mountainous areas, with an altitude of 821-974 m (4 sites) and annual mean air temperature of 8.6±9.0°C. At altitudes of 800 m and under annual mean air temperature was 10.1°C, and *Ae. albopictus* was captured. Thus, our results partly agree with those of Kobayashi et al. (2002).

This is the first report with quantitative data on *C. pipiens* complex and *Ae. albopictus* by CDC traps in Yamanashi Prefecture. Further follow-up field investigations will be necessary to collect more adults using a combination of several sampling methods and may well further improve our understanding of the mosquito fauna in Yamanashi Prefecture.

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