Distribution of the mosquitoes, *Culex tritaeniorhynchus*, in relation to disposition of sound traps in a paddy field*

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Abstract: The spatial and temporal distributions of *Culex tritaeniorhynchus* were studied with sound traps at an unisolated 1.7 ha area of a paddy field in Chikugo City from Jul. 23 to Aug. 4. Fourteen traps were placed on black cloth swarm markers at 20–50 m distance from each other, and a 370 Hz, 100 or 110 dB sound was emitted for 20 min during the swarming time, 19:42 to 20:02. As the results, 20,141 males and 1,116 females in total were caught. There was a sex-biased spatial distribution; males evenly distributed over the breeding paddy, but some males nightly migrated out to a pigpen nearby. The females, on the contrary, took the host appetent flight and heavily concentrated in the vicinity to the pigpen. The significant reduction of blood-fed females trapped and resting in vegetation was observed towards the end of experiment. This reduction would be attributed to the decreased emergence of mosquitoes due to the mid-season water drainage in the paddy or the increased rates of virgin females due to the possible mating disruption by sound, or both.

INTRODUCTION

Khan and Offenhauser (1949) and Belton (1967) have experimented sound traps for attraction of male *Anopheles albimanus* and *Aedes stimulans* in the fields. They have never evaluated the sound traps in a population scale and never attempted the utilization for mosquito control. Ikeshoji *et al.* (1985) investigated the impact of sound traps, which were placed around a small isolated population of *Culex tarsalis* at a hill

slope in California. Removal of 3,600 males during 2 weeks reduced the insemination rate of resting unfed females from 22% to zero.

The objective of the present work is to investigate further on the spatial and temporal distributions of *Culex tritaeniorhynchus* so that disposition of the sound traps is optimized at an unisolated paddy field.

MATERIALS AND METHODS

Experimental field: Approximately 1.7 ha area of a rice paddy field in the midst of the large rice-growing plain in Chikugo City was selected for the experimental field (Fig. 1). Rice plants grew from 20 to 40 cm in height during the experimental period from July 23 to August 4, 1985. The paddy was irrigated

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Fig. 1 Paddy field used for the experiment.

until July 28, then dried completely to the end of experiment for the practise of the mid-season water drainage. A pigpen accommodating about 300 pigs which were the major blood sources for mosquitoes was located at the west end of the field. During the experiment, one or two hand sprays of insecticides and herbicides were made by farmers for the plant protection purpose, which however seemed not to affect the mosquito population.

The larvae of *Culex tritaeniorhynchus* Giles with very few of *Anopheles sinensis* Wiedemann bred mostly in the paddy, but scarcely in the creek where water flowed slowly and fish inhabited. No larval breeding was observed in the sewage and fish ponds.

Mosquito trapping: Fourteen sound traps were distributed irregularly to 15 stations at 20 to 50 m distance from each other. The stations were set at the roadsides of paddy and at the open spaces beside the pigpen where male mosquitoes were expected to swarm. The sound traps were the same as those tested previously (Ikeshoji *et al.*, 1985); a 9.3-cm diam. speaker connected to a hand-made sound generator was rolled around with a 30-cm long polyethylene sheet to form

Fig. 2 A sound trap placed on a tripod over a black cloth swarm marker.

a cylinder. The trap was placed on a 1-m high tripod, which was then set on a 1×2 or 1×3 m wide black cloth as a swarm marker (Fig. 2). A 370 Hz sound of either sinusoidal, rectangular or saw-tooth wave was emitted in 100 or 110 dB SPL at the orifice of the cylinder in a cycle of 6-sec on and 5-sec off. The 20-min sound emission

Fig. 3 Male mosquitoes responding to sound.

Fig. 4 Mosquitoes stuck onto the inside wall of a sound trap.

from 19:42 was set with a clock disregarding a slight change in the commencement time of swarming depending on the weather and the advancement of sunset time. Morning swarms also occurred at dawn around 4:45 (sunrise at 5:45) and ended at 5:00, but the swarm size was only one fiftieth or even one hundredth as small as that of the evening swarm. Thus, the sound trappings were made only at evening swarms.

The males of *Cx. tritaeniorhynchus* stuck with tangle foot onto the inside wall of a sound trap (Fig. 4) were counted in the next morning. The traps also caught large numbers of other species such as tiplids, chironomids, psychodas and some moths. These catches will be reported elsewhere.

Sampling the resting mosquitoes and the larvae: The resting mosquitoes were sampled by sweeping 20 times with a 30-cm diam. insect net on rice plants and grasses around each station at 15:00 to 17:00, albeit they were resting at the lower parts of vege-

tation at this time of the day and hence the catches were small.

Three larval samples were taken in paddy and creek with a 12-cm diam. dipper each on July 22 and 27. The figures were averaged for each station.

RESULTS

Numbers of mosquitoes caught by sound traps

Numbers of male and female mosquitoes caught at 15 stations from Jul. 23 to Aug. 4 are shown in Table 1 (The female numbers are in the parentheses). The catches were smaller on Jul. 24 and 25 than on other days, because of the thunder storm hit at the time of evening swarm. Some traps stopped emitting the sound on Jul. 30 because the sound generators were wet by rain before the swarming time. On other evenings, the weather was generally fine and calm.

By excluding the mosquito catches on Jul. 24 and 25 and at stations 2, 3', 5, 12 and 14, and by estimating the 3 missing data at station 1 on Aug. 4, station 4 on Aug. 2 and station 9 on Jul. 30 according to Snedecor (1962), the statistical analysis was made for the catches on the remaining 9 days at 10 stations. First, the numbers of male and females (N) were transformed to $\log(N+1)$ and ANOVA II was applied. The significance of the mean catches were tested for days and stations by F values. Differences among all means of $\log(N+1)$ were tested according to the Turkey's 5% significant difference $D=Q_{s\bar{x}}$.

As the results, the mean catches among stations and among days were significantly different with females at 1% level, but not with the males at 5% level. The mean catches at station 1, 3 and 4 were significantly different from those at other stations. There were no significant differences among the mean catches at the three stations neighboring the pigpen and among those at other seven stations. The mean female catch on Jul. 4 was significantly different from those on Jul. 23, 30 and Aug. 1.

Mosquito catches by net sweep

The numbers of mosquitoes caught at 11

Table 1 Numbers of male and female mosquitoes caught by the sound traps (females in parentheses).

Stn.	Dates caught											Sum	No./night
	Jul. 23	24	25	26	27	29	30	Aug. 1	2	3	4		
1	516 (31)	29 (21)	188 (21)	323 (21)	487 (16)	353 (16)	15 (41)	131 (25)	148 (18)	299 (21)	—	2,489 (222)	248.9 (22.2) ^d
2	26 (26)	0 (13)	1 (20)	—	—	301 (3)	—	—	39 (10)	250 (2)	7 (2)	1,128 (76)	161.1 (10.8)
3	638 (25)	50 (19)	50 (54)	32 (76)	34 (23)	389 (30)	19 (35)	56 (30)	11 (23)	594 (10)	105 (0)	1,978 (325)	179.9 (29.5) ^d
3'	55 (7)	29 (7)	26 (29)	—	—	—	—	—	—	—	—	110 (43)	36.7 (14.3)
4	190 (24)	110 (16)	15 (49)	173 (44)	40 (24)	354 (46)	2 (56)	2 (28)	—	278 (12)	4 (2)	1,388 (301)	138.8 (30.1) ^d
5	447 (2)	40 (1)	19 (4)	8 (0)	18 (7)	5 (2)	—	12 (0)	—	—	—	689 (16)	98.4 (2.3)
6	93 (0)	65 (0)	60 (21)	31 (0)	99 (0)	26 (0)	85 (0)	149 (1)	195 (0)	164 (0)	20 (0)	987 (22)	89.7 (2.0) ^e
7	259 (2)	60 (0)	9 (1)	105 (1)	152 (0)	304 (0)	170 (0)	24 (0)	9 (0)	283 (0)	26 (0)	1,401 (4)	127.4 (0.4) ^e
8	28 (0)	189 (0)	7 (0)	258 (0)	838 (0)	194 (3)	168 (0)	158 (0)	172 (1)	4 (0)	14 (1)	2,030 (5)	184.5 (0.5) ^e
9	204 (2)	88 (2)	26 (6)	21 (0)	112 (3)	39 (0)	—	2 (2)	5 (1)	95 (0)	392 (3)	985 (18)	98.5 (1.8) ^e
10	478 (10)	47 (0)	10 (4)	43 (2)	98 (6)	72 (0)	8 (1)	15 (7)	60 (0)	83 (0)	124 (0)	1,268 (30)	115.3 (2.7) ^e
11	430 (0)	125 (3)	28 (1)	211 (0)	286 (0)	55 (0)	134 (2)	115 (2)	75 (0)	18 (1)	53 (0)	1,527 (9)	138.8 (0.8) ^e
12	96 (0)	175 (0)	22 (2)	21 (2)	73 (2)	128 (2)	—	—	—	64 (1)	47 (0)	819 (9)	102.4 (1.1)
13	371 (5)	95 (0)	76 (2)	609 (0)	150 (17)	194 (0)	—	334 (10)	394 (0)	255 (0)	74 (0)	2,552 (34)	255.2 (3.4) ^e
14	—	—	—	—	—	11 (0)	300 (0)	149 (0)	209 (0)	45 (0)	74 (1)	788 (1)	131.3 (0.2)
Sum	3808 (134)	1,102 (82)	537 (214)	2,028 (146)	2,387 (98)	2,565 (102)	1,131 (135)	1,147 (105)	1,317 (53)	2,432 (38)	1,690 (9)	20,141 (1,116)	
No./Stn.	272 (9.6) ^a	78.7 (5.9)	38.5 (15.3)	169 (12.2)	198.9 (8.2)	183.2 (7.3)	125.7 (15.0) ^b	95.6 (8.8) ^c	119.7 (4.8)	187.1 (2.9)	140.8 (0.8) ^{a,b,c}		147.0 (8.1)

The figures with the same letter a, b or c differ significantly at 5% level. The figures with the same letter d or e not differ at 5% level.

Table 2 Numbers of male and female mosquitoes caught by a 20-net sweeps (females in parentheses).

Stn.	Dates caught				Sum	No./20 sweeps
	Jul. 22	26	29	Aug. 3		
1	0 (882)	0 (197)	0 (30)	0 (40)	0 (1,149)	0 ^b (287.3) ^d
2	1 (32)	0 (5)	—	0 (0)	1 (37)	0.3 ^c (12.3) ^e
3	9 (75)	0 (227)	3 (80)	0 (30)	12 (412)	3.0 (103.0) ^d
6	1 (1)	0 (0)	0 (0)	1 (1)	2 (2)	0.5 (0.5) ^e
7	0 (1)	0 (0)	9 (3)	0 (0)	9 (4)	2.3 (1.0) ^e
8	—	0 (0)	1 (1)	3 (0)	4 (1)	1.3 (0.3) ^e
9	—	5 (2)	2 (0)	6 (5)	13 (7)	4.3 ^b (2.3) ^e
10	2 (1)	2 (0)	5 (3)	11 (0)	20 (4)	5.0 ^b (1.0) ^e
11	2 (2)	0 (1)	—	5 (3)	7 (6)	2.3 (2.0) ^e
12	15 (4)	4 (0)	13 (6)	1 (0)	33 (10)	8.3 ^{b,e} (2.5) ^e
13	5 (0)	1 (1)	5 (4)	3 (1)	14 (6)	3.5 (1.5) ^e
Sum	35 (998)	12 (433)	37 (128)	30 (80)	114 (1,639)	
No./Stn.	3.9 (110.9)	1.1 ^a (39.4)	4.1 ^a (14.2)	2.7 (7.3)		2.9 (41.0)

The figures with the same letter a, b or c differ significantly at 5% level. The figures with the same letter d or e do not differ at 5% level.

stations on each of 4 occasions are shown in Table 2. The catches were analyzed by ANOVA II as above after inserting the 4 missing data at stations 8 and 9 on Jul. 22, and stations 2 and 11 on Jul. 29. As the results, the *F* values were significantly larger for stations in both sexes at 1% level and for days in males but not in females at 5% level. The mean male catch at station 1 was not equal to those at stations 9, 10, 12 and the catch at station 2 was not so to that at station 12, respectively. The mean female catches at stations 1 and 2 were not equal to those at other stations.

The total catch of male and female mosquitoes at each station is illustrated in Fig. 5. There are three lines drawn for each station which is shown on the abscissa with the

distance from the pigpen; the 1st line for the catch of the sound traps, the 2nd for that of net sweeps and the 3rd for the dipping count of larvae. The percentages of males, 82–92%, shown on tops of the 1st lines were apparently smaller at stations 1, 2, 3 and 4 compared with those at other stations, 98–100%. In reverse, the higher percentages of females were obtained at the pigpen stations. The male percentages of the net-sweep samples shown on tops of the 2nd lines were lower at the pigpen stations; they were only 0–3% compared with 60–85% at the paddy stations. The dipping counts shown by the 3rd lines were not proportional against the station distance; it was the highest at station 7, otherwise even more or less over the experimental field.

Fig. 5 Means of male and female mosquitoes caught by a sound trap (the 1st line of a set of three at each station) and by a 20 net-sweep collection (the 2nd line), and the means of larvae caught by a 3 dipping collection (the 3rd line) at each station.

The figures on tops of the 1st and 2nd lines are the percentages of males in the catches.

DISCUSSION

Spatial distribution of the mosquitoes and disposition of the sound traps

If the catches of sound traps are proportional to the densities of males in their habitat, the male distribution in the paddy is considered uniform over the paddy field as the male catches were not significantly different among the stations. Then, some males emerged in the paddy would have dispersed to the pigpen stations where they waited for the arrival of virgin females to mate. The migration behavior of males to the vicinity of hosts is common among the males of *Stegomyia* species. However, the smaller catches of resting males in the daytime at these pigpen stations than at the paddy stations indicate the nightly migration of the

swarming males there.

The heavy concentration of females around the pigpen and the scarcity at the paddy stations was the contrast to the uniform male distribution. Apparently, the females made the appetent flight to the blood sources. The wider dispersal or migration of female mosquitoes than males is well known (Gillies, 1961 for *Anopheles gambiae*; Lindquist *et al.*, 1967 for *Cx. p. fatigans*; Milby *et al.*, 1983 for *Cx. tarsalis*).

For a future male annihilation programme, disposition of the sound traps may need to cover all larva-breeding paddy and nearby blood sources at a distance of 20–50 m, since no large swarmings were noticed between any two traps under the present condition.

Temporal distribution of mosquitoes

The temporal distribution of male mos-

quitoes were uniform during the experimental period. In other words, the present intensive but yet inefficient catches of males seemed not to affect the male populations. The female catches, on the contrary, decreased towards the end of experimental period in the sound-responding and resting populations, although the latter was statistically not significant due to the large variations of the mean catches. Nevertheless, the decreasing trend was apparent especially in the blood-fed female population resting at stations 1, 2 and 3.

The reason for the decrease of blood-fed populations would be twofold; one is the decreasing emergence of mosquitoes in the paddy due to the mid-season water drainage since July 28. In this case, the male population would have remained without appreciable mortality in the paddy, while the females emigrated for blood feeding and the resulted gravids did not return to the dried paddy. The other reason might be that males have lost their mating chance and mate-searching energy on response to the sound trap at the swarming site and time. Their intensive response to a sound trap is shown in Fig. 3. The time and site are critical for successful mating of some *Anopheles* spp. whose mating occurs precisely at swarming in erection of their antennal flagella (Ikeshoji, 1981a, b). The possible decrease of mated females might have reduced the numbers of pigpen-visiting and blood-fed females. In this connection, Ikeshoji *et al.* (1985) have demonstrated the drastic decrease of the insemination rates of female *Cx. tarsalis* resting in a small isolated batches of fleabane in California after the 2-week sound trapping of males.

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摘 要

水田におけるコガタアカイエカの分布と音響トラップの設置

1985年7月23日から8月4日まで筑後市の1.7 haの水田で、音響トラップを使ってコガタアカイエカの空間、時間的分布を調べた。20~50 m 間隔に群飛標識として黒布を敷き、その上に14個のトラップを設置した。蚊の群飛時刻 19:42 から 20:02 の20分間に、370 Hz, 100/110 dB, 6/5 秒の断続音を発信した。その結果、合計雄 20,141 匹、雌 1,116 匹を誘殺した。蚊は性によって分布を異にし、雄は水田全面で均等に分布し、一部は夜ごとに豚舎へ移動した。反対に雌は、常に豚舎周辺に集中していた。実験後期には吸血雌の著しい減少がみられた。この原因は水田の中干しによる羽化数の減少か、あるいは飛群での音による交尾妨害で、処女雌が増加したことよると思われる。