Dispersal Experiment of *Culex tritaeniorhynchus* in Nagasaki Area (Preliminary Report)

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Abstract

To make clear the dispersal of *Culex tritaeniorhynchus* females in rather hilly Nagasaki area, a mark-and-recapture method was applied in summer, 1967. From 3 points, differently marked 156,500 females in total were released at 4 AM, July 29, and recapture catches were made by light traps at 19 points in the area of 8 km x 10 km on 7 succeeding nights from the release. From the results obtained, it is seen that (1) the females disperse generally along valleys and seacoast; (2) usual flight range seems to be at least 1.0 km; (3) some of the females have an ability to fly at least 2.0 km without landing, and to disperse at least 8.4 km. Also a method of estimating daily loss rate of the released females by the daily recapture data was described.

Introduction

Culex tritaeniorhynchus is known as the most important vector of Japanese encephalitis in Japan, and therefore the dissemination of the causative virus in an area seems to have a close relation to the dispersal pattern of this mosquito. On this point, there were some

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questions in Nagasaki area that (1) not a few Japanese encephalitis cases occurred every year in Nagasaki City where the breeding places of *C. tritaeniorhynchus* were rarely found, and (2) in some villages where swine, which are considered very important amplifying animals for the disease, were not kept within 1 km, infected mosquitoes were found nearly simultaneously with in other neighboring villages keeping many swine (Takahashi et al., unpublished). Uemoto et al. (1967) made a dispersal experiment of *C. tritaeniorhynchus* by a mark-and-recapture method and found that this mosquito was an unexpectedly strong flier in Kyoto area, which is quite level in topography. However, our Nagasaki area is rather hilly. The above is the reason why this experiment was made.

We are indebted to Drs. O. Maeda and K. Uemoto who kindly let us know some techniques they used in the dispersal experiment in Kyoto area.

Place and method

The experimental area was situated at the northeast of Nagasaki City. Marked females of *C. tritaeniorhynchus* were released from three points and recapture catches were made at 19 points including the three release points. These release and recapture points are given in a map with topography in Fig. 1. The area is hilly, and along small valleys and seacoast there are scattered farm villages with some paddy-fields. The nearest recapture point No. 19 to Nagasaki City is about 2 km apart from the outskirts of the city.

C. tritaeniorhynchus females to be released were collected on two nights of July 26 and 27, 1967 by dry ice traps and at a horse shed, and kept in the laboratory with 2% sugar solution. The mosquitoes were marked on July 28 by spraying water solutions of three kinds of fluorescent dye, 1.0% Yellow 8G, 0.1% Rhodamine 6G and 1.0% Kaycoll BZ, so that recaptured mosquitoes could be distinguished as for the release points. Around 4 AM on July 29, differently marked mosquitoes of 51,300, 19,000 and 86,200 were released respectively from the three release points No. 4, 7 and 16, which were in open spaces near paddy-fields. At the time of the release, it was fine, nearly windless and about 26°C, and still dark as the sunrise of that day was 5:32 AM.

Recapture catches were made on succeeding

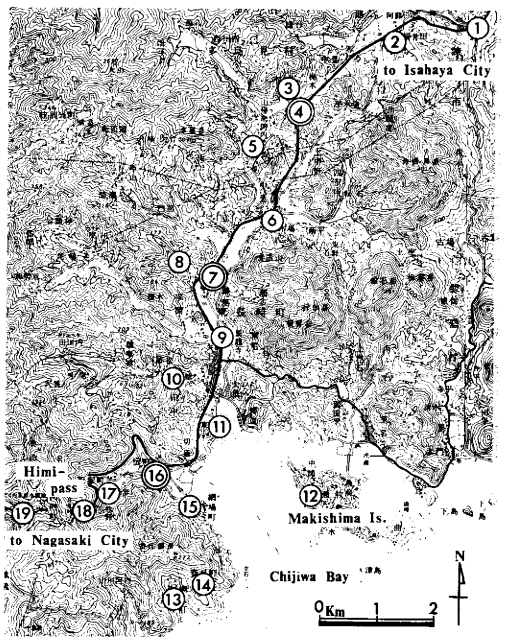

Fig. 1. Map of the area for the dispersal experiment of *Culex tritaeniorhynchus* females, showing 3 release points and 19 recapture points. Double circles indicate the points for release and recapture, single circles those for recapture only. Numerals within the circles represent point numbers.

seven nights after release at 19 points scattering within an area of 8 km by 10 km. The catches were made at six points by light traps combined with dry ice traps from 7 : 30 PM to 9 : 30 PM and at the other 13 points by light traps set in cow or swine sheds from 7 : 30 PM to next morning. The light traps were fitted with 6 watt fluorescent black lamps.

The mosquitoes collected by the light trap at each recapture point were examined for the marking with a fluorescence-examining-lamp, and the marked specimens were recorded by release point and day.

Results

Numbers of recaptured *C. tritaeniorhynchus* females released from the three points are shown in Table 1 by recapture point and day. Out of 51,300, 19,000 and 86,200 females released at No. 4, 7, and 16, 20 (0.039%), 44 (0.232%), and 167 (0.194%) individuals were respectively recaptured in total. In any cases of the releases, it is seen from Table 1

Table 1. Numbers of recaptured *C. tritaeniorhynchus* females by recapture point and day.

Release point No. (No. ♀♀ released)	Days after release	No. ♀♀ recaptured at the indicated recapture points																			Total	% recaptured
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
4 (51,300)	1			13			3				1										17	0.033
	2																					
	3	1					1								1						3	0.006
	4																					
	5																					
	6																					
	7																					
	Total	1		13			4				1				1						20	0.039
7 (19,000)	1			1				34											1		36	0.190
	2						1	1				1									3	0.016
	3						2	1	1												4	0.021
	4																					
	5														1						1	0.005
	6																					
	7																					
	Total			1			3	36	1			1			1				1		44	0.232
16 (86,200)	1										2	6	1	4	9	15	5	32	12		86	0.100
	2					1					1		1	1	1		17	16	3		41	0.048
	3						1							1	5	2		9	4	1	23	0.027
	4									2	1				1	1	1	1			7	0.008
	5													1			3	1			5	0.006
	6														1	1					2	0.002
	7														1	1	1				3	0.004
	Total					1	1			2	4	6	2	7	18	20	27	59	19	1	167	0.194

Table 2. Total recapture rates and dispersal range by day of *C. tritaeniorhynchus* females released at 3 points.

Days after release	Recaptured		Mean distance	Maximum distance
	No.	%		
1	139	0.089	0.9km	5.1km
2	44	0.028	0.8	5.8
3	30	0.019	1.7	8.4
4	7	0.004	1.6	2.7
5	6	0.004	1.4	5.4
6	2	0.001	1.5	2.0
7	3	0.002	1.0	2.0
Total, Mean or Max.	231	0.148	1.0	8.4

that the nearer the recapture point is to the release point, the larger the number of recaptures is in general.

Total recapture rates and dispersal ranges of *C. tritaeniorhynchus* females released from 3 points are shown by day in Table 2. Mean dispersal distance during seven days was 1.0km, which should be considered as a usual flight range of this mosquito. Maximum dispersal distance on day 1 was 5.1 km and that during seven days was 8.4 km (on day 3).

In Figs. 2, 3, and 4, the states of dispersals of *C. tritaeniorhynchus* females released from points No. 4, 7, and 16, respectively, are illustrated with supposed dispersal routes. From these figures, it is seen that the dispersal occurred to all directions from the release points. However, if there exists a hill between a release point and a certain point for recapture,

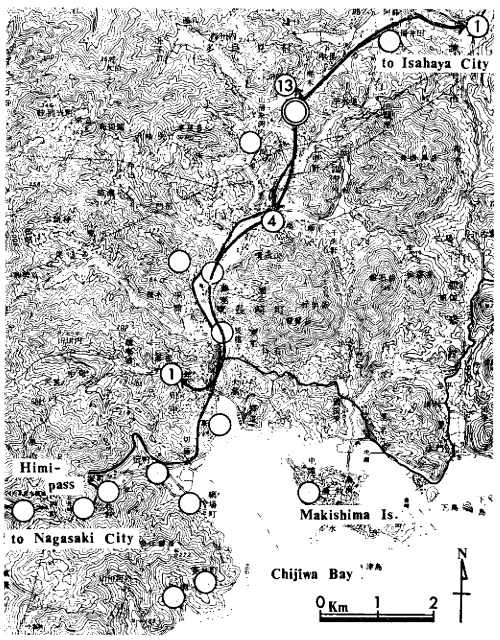

Fig. 2. Dispersal of *Culex tritaeniorhynchus* females released from point No. 4 indicated by a double circle (51,300 females were released). Numbers of recaptured females are shown within circles at respective recapture points. Supposed dispersal routes are indicated by arrows.

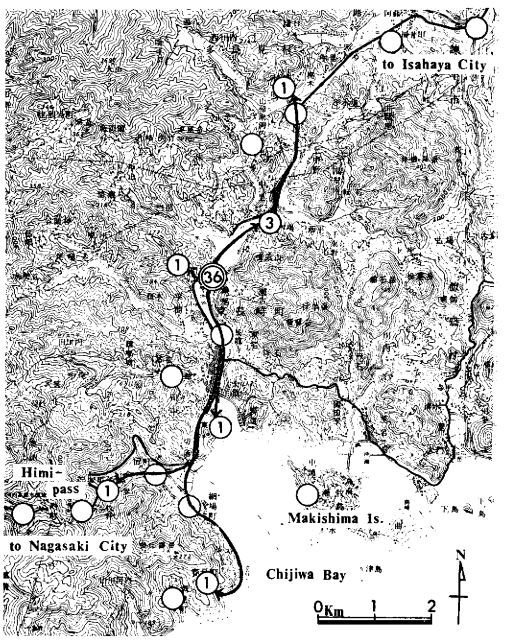

Fig. 3. Dispersal of *Culex tritaeniorhynchus* females released from point No. 7 indicated by a double circle (19,000 females were released). Numbers of recaptured females are shown within circles at respective recapture points. Supposed dispersal routes are indicated by arrows.

it seemed difficult for released mosquitoes to reach the point over the hill. For example, there is a hill between points No. 4 and 5 which are only 1.0 km apart each other, and none of released mosquitoes from No. 4 was recaptured at No. 5. On the other hand, one individual of released ones from No. 16 reached No. 5 on day 2 (see Figs. 2 and 4, and also Table 1). The distance was as long as 5.8 km which was extended along a main valley and a small side valley. Other examples are that the numbers of recaptures were relatively small at No. 8 from No. 7 point and at No. 11 from No. 16 point probably because of existing small hills between the release and recapture points (see Figs. 3 and 4 and Table 1).

Two of the released mosquitoes from No. 16 were recaptured at No. 12 on Makishima-Islet (Fig. 4) showing that these mosquitoes dispersed over sea (about 2 km) directly. This indicates that *C. tritaeniorhynchus* females have the ability to fly at least 2 km without landing. One of the released mosquitoes from No. 16 was recaptured at No. 19. The dispersal route from No. 16 was probably through a valley and Himi-pass (altitute : 210 m) to No. 19 (the distance between the two points was 2.3 km) which is situated about 2 km east of the outskirts of Nagasaki City. Considering the long flight range of this mosquito shown by this experiment, mosquitoes breeding out in the outside of Nagasaki City seems to invade easily the city.

Now, the survival rate of released mosquitoes will be estimated by the tendency of the decrease of the number of recaptures with the progress in days after release. Supposed that the daily survival rate of released females is constant during the experimental period, and let p daily survival rate, N the total number of released females, A the number of females recaptured on the nth day after release, and a a recapture rate, then

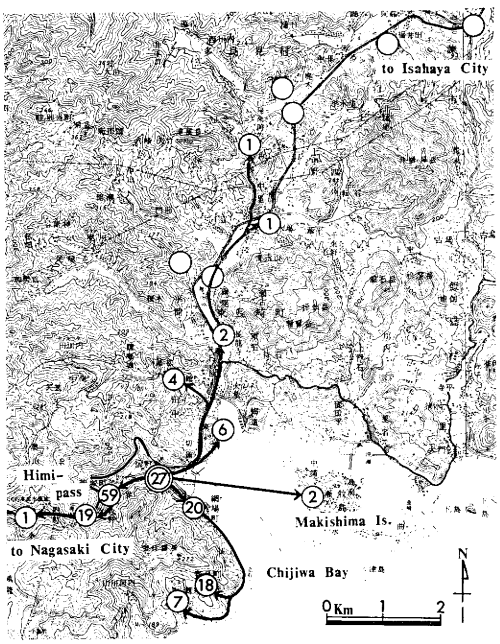

Fig. 4. Dispersal of *Culex tritaeniorhynchus* females released from point No. 16 indicated by a double circle (86, 200 females were released). Numbers of recaptured females are shown within circles at respective recapture points. Supposed dispersal routes are indicated by arrows.

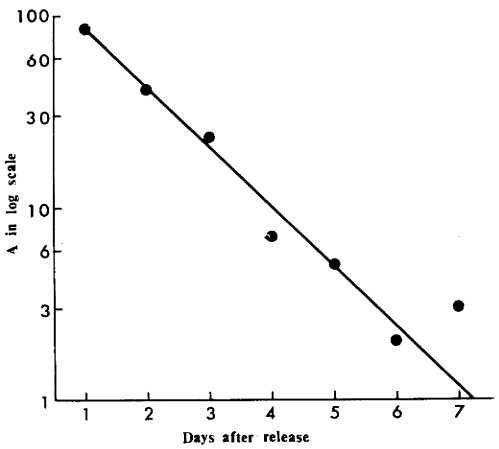

Fig. 5. Decrease after the release in number (A) of recaptured *Culex tritaeniorhynchus* females released from point No. 16.

$$A = Nap^n$$

and accordingly

$$\log A = n \log p + \log Na.$$

Thus, the linear relation between $\log A$ and n is expected. It is seen from Fig. 5 that the above supposition holds true for the present data, as the relation between A in log scale and n is represented by a linear regression line. The slope of the regression line, -0.3109, is an estimate of $\log p$, therefore daily survival rate p is estimated as 0.4888. However, the daily survival rate thus obtained is perhaps rather under-estimated, because some released females are considered to have gradually dispersed to the outside of the area where recapture catches were being made.

Discussions

Provost (1952, 1957, 1960) studied very extensively the dispersal of a salt-marsh mosquito, *Aedes taeniorhynchus*, in Florida, and said that the dispersal can be ascribed to two phases, an initial non-appetential or non-searching migration, which occurs from 1 to 4 days after emergence, and subsequent appetential or searching flights. With an ecologically quite different mosquito, *Culex tarsalis*, Dow et al. (1965) reported the dispersal experiment in California, and said that the dispersal seemed to be simply the results of successive appetential flights, and there probably was little if any migratory flight, which would occur at an early stage after emergence, since the dispersal of the freshly-reared releases was similar to that of the field-trapped releases.

Asahina and Noguchi (1968) expressed the view that it is perhaps reasonable to separate the dispersal of *C. tritaeniorhynchus* into the exodus flight during some 2 days after emergence and the subsequent appetential flight. They also recorded the long-distance flight; two females were collected on a weather ship about 500 km south of Shionomisaki-cape, Honshu, Japan.

In the present dispersal experiment of *C. tritaeniorhynchus*, the migratory flight could be excluded, because field-collected females were released and therefore at the time of the release they were considered to have passed the migratory stage during a few days after emergence. However, as seen from Tables 1 and 2, the speed of the dispersal on day 1 after release seems to have been, in general, larger than that on day 2 or later. This may indicate that there occurred two types of dispersal; initial long-distance dispersal and subsequent short-distance dispersal. The short-distance dispersal, which was probably appetential in nature, seems to have occurred any day during the experimental period, but the long-distance dispersal mostly on day 1 after release. This long-distance dispersal is, of course, not the same as migratory flight of Provost and others. It may be a rather unusual flight possibly caused, to some extent, by the effect of collecting, confining in cages, marking, and releasing. However, it seems to be certain that *C. tritaeniorhynchus* can disperse long distance under natural conditions, as indicated by the fact that a considerable number of females were collected by a light trap in Tokyo City at Shinagawaku, which was at least 10 km apart from the nearest significant breeding places (Asahina and Noguchi, 1968), and also by the fact that a tremendous number of mosquitoes, mostly *C. tritaeniorhynchus*, attacked many villages located 2 km to 8 km down

the river or along its tributary from the Sakuma reservoir dam where an outbreak of the mosquito larvae appeared after a flood (Sakakibara, 1965).

Garrett-Jones (1962) discussed the possibility of active long-distance migrations by *Anopheles pharoensis*, and gave an opinion that the non-appetential migratory flights are not necessarily undertaken only by very young mosquitoes, but also by mosquitoes after taking at least one blood meal. In the case of this anopheline mosquito, the stimulus to induce the migratory flight appear to be connected with the occurrence of a full moon, but he also added that the followings can be thought as such stimuli: the age of the insect, its density at the breeding site, scarcity of food, and so on.

In consideration of the above all together, it seems reasonable to assume that there are two types of flights in the dispersal of *C. tritaeniorhynchus*, appetential and migratory. If this view is right, the migratory flight would not necessarily be limited to the young stage of mosquitoes after emergence. This suggests that the migratory flight is facultative in *C. tritaeniorhynchus*, while it is obligatory in *Aedes taeniorhynchus*. The stimuli to induce the migratory flight of *C. tritaeniorhynchus* may be high population density of larvae or adults, or lack of suitable hosts, or others.

References

1) **Asahina, S. & Noguchi, K.** : Long-distance Flight of *Culex tritaeniorhynchus*. Jap. J. Sanit. Zool., 19(2) : 110, 1968 (in Japanese).

2) **Dow, R. P., Reeves, W. C. & Bellamy, R. E.** : Dispersal of Female *Culex tarsalis* into a Larvicide Area. Amer. J. Trop. Med. Hyg., 14(4) : 656-670, 1965.

3) **Elmore, C. M. Jr. & Schoof, H. F.** : Dispersal of *Aedes taeniorhynchus* Wiedemann near Savannah, Georgia. Mosquito News, 23(1) : 1-7, 1963.

4) **Garrett-Jones, C.** : Migratory Flight in Anopheline Mosquitoes in the Middle East. Bull. Endem. Dis., 2 : 79-87, 1957.

5) ——— : The Possibility of Active Long-distance Migrations by *Anopheles pharoensis* Theobald. Bull. Wld Hlth Org., 27 : 299-302, 1962.

6) **Gillies, M. T.** : Studies on the Dispersion and Survival of *Anopheles gambiae* Giles in East Africa, by Means of Marking and Release Experiments. Bull. Ent. Res., 52(1):99-127, 1961.

7) **Haeger, J. S.** : Behavior Preceding Migration in the Salt-Marsh Mosquito, *Aedes taeniorhynchus* Wiedemann. Mosquito News, 29(2) : 136-147, 1960.

8) **Nielsen, E. T. & Nielsen, A. T.** : Field Observations on the Habits of *Aedes taeniorhynchus*. Ecology, 34(1):141-157, 1953.

9) **Provost, M. W.** : The Dispersal of *Aedes taeniorhynchus*. I. Preliminary Studies. Mosquito News, 12(3) : 174-190, 1952.

10) ——— : The Dispersal of *Aedes taeniorhynchus*. II. The Second Experiment. Mosquito News, 17(4) : 233-247, 1957.

11) ——— : The Dispersal of *Aedes taeniorhynchus*. III. Study Methods for Migratory Exodus. Mosquito News, 20(2):148-161, 1960.

12) **Sakakibara, S.** : Outbreak of Mosquitoes in the Sakuma Reservoir Dam after a Great Flood Caused by Heavy Rains in Ina Valley on June, 1961. Endem. Dis. Bull. Nagasaki, 7(2) : 130-141, 1965 (in Japanese with English Abstract).

13) **Takahashi, K.** et al. : Unpublished.

14) **Uemoto, K.** et al. : Dispersal Experiment of *Culex tritaeniorhynchus* by Mark-and-Recapture Method. Jap. J. Sanit. Zool., 18 (2/3) : 150-151, 1967 (in Japanese).

長崎地方におけるコガタアカイエカの分散実験（予報）

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摘　　要

長崎県は一般に平地に乏しく，海岸近くや小さな谷に沿って村落や水田が発達している所が多い．このような地形の複雑な地方でのコガタアカイエカの分散状況を明らかにするために，長崎市街地の東北に隣接する東西約8Km南北約10Kmの地域で，記号放逐法による分散実験を行った．上記地域に合計19地点を選び，その中の3ケ所から異った螢光色素でマークしたコガタアカイエカの雌成虫計約156,500個体を7月29日午前4時に放逐し，その夜から7日間毎夜全地点において畜舎に或いはドライアイスと共に野外に設置したライトトラップを用いて採集し，その中に含まれているマークされた蚊を放逐地点別に記録した．その結果は次のように要約される．(1) 放逐した約156,500個体の中231個体(0.15%)が回収された．(2) 放逐蚊は，岡をさけて谷間沿いに或いは海岸沿いに飛翔分散する個体が多い．(3) 放逐第1日の最大飛翔距離は5.1Kmであり，回収全期間7日間の最大は8.4Km平均は1.0Kmであったことから，コガタアカイエカの飛翔能力はかなり大きく，少なく共1Kmは通常の行動範囲内に入るものと思われる．(4) 海岸近くで放逐したものの1個体が標高210mの峠を越えて2.3Km離れた，長崎市街地のすぐ近くの1地点で回収されたことは，峠を越えて市街地へ侵入するコガタアカエカの数が少なくないことを想像させるものである．(5) 回収個体数の経日的減少状況から，日生存率の推定値として0.4888を得た．こゝでは調査地域外へ移動した，或いは吸血により採集対象外となったものは死亡として計算したので，上記の値は多少過少評価されている．