Ecological Studies on Mosquitoes Collected by Light Traps

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Abstract

Collection of mosquitoes by light traps was projected to examine the effectiveness of different light colors, the structure of age distribution of mosquitoes attracted to the light, and the rate of fed females against the total ones collected. As a result, it was found that the effectiveness is greatly varied with the difference in light color. It was also found that the females of *C. p. pallens* and *C. tritaeniorhynchus* attracted to the light are subjected to a great variation in follicular stage and that the structure in age distribution of the females seems to have close relation to the nocturnal activities displayed by them in relation to the searching for carbohydrate meal, for blood meal, for breeding places to lay eggs, and so on. Only the females having developing follicles i.e. those with follicles of stages II, III, and IV may be very much inactive in nocturnal activity. The rate of females of each of the two species fed once or more times against the total females collected by light traps is nearly as high as that in those collected by usual collecting method in dwelling houses or cattle-sheds. The reason is that by light traps a great number of females fed and having mature eggs are peculiarly collected as an offset to the great number of nulliparous pre-feeding females which are collected as they are unfed, contrary to the cases in females collected in dwelling houses or cattle-sheds by the usual collecting method.

Introduction

There have been many publications on the collection of mosquitoes by using the light trap. However, we have few of them on the effectiveness of different light colors at least

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in the field of medical entomology, much less on the age distribution of the females attracted to the light. Accordingly, the collection of mosquitoes by light traps was projected to examine the effectiveness of different light colors and also to investigate the structure of age distribution of the females against the total ones attracted to the light especially with the epidemiologically important species, *Culex pipiens pallens* and *Culex tritaeniorhychus*.

The experiments were carried out by the author during her staying at the Department of Medical Zoology, Nagasaki University School of Medicine as a Visiting Research Scientist from National Institute of Agricultural Sciences.

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Experimental place and method

Collection of mosquitoes by light traps was carried out at the school campus of Nagasaki University School of Medicine and at the grounds of Nagasaki Agriculture and Forest Experiment Station (NAFES). The school campus including the buildings of the Basic Sciences of the School of Medicine, The Institute for Tropical Medicine, and a playground of the school, was surrounded by residental guarters in the city of Nagasaki. Within the campus and the residental quarters there were some number of breeding places of mosquitoes especially of *C. p. pallens* and *C. tritaeniorhynchus*. NAFES is located in the farm district about 25 km apart from Nagasaki City, at the foot of low hills facing to a large ricefield area where active breeding of ricefield breeding mosquitoes was expected.

Mosquitoes collected by light traps were classified and the females of *C. p. pallens* and *C. tritaeniorhynchus* were kept in deep freezer at about -20°C to be dissected later for examination of follicular stages.

Effect of light colors to attract mosquitoes

Four types of light traps emitting different light colors as described in Table 1 were used to collect mosquitoes at the school campus on four night in June, 1966. The traps were randomly set in each day on four points which were fixed 1.5 meters above the ground, at intervals of 7 meters, along a school building in a line about 4 meters away from it. All night catches were carried out by operating the traps from sunset through sunrise. The total numbers of mosquitoes collected on four nights by each trap were tabulated in Table 1. The results of catches clearly show that the collected number of mosquitoes was the

Table 1. Number of mosquitoes collected by light traps of different color types at the School[1] Campus. All night catches were made four times during from June 16 to 25, 1966.

Light trap[2] / Sex / Species[3]	BLB FL			BL FL			Incand. L			DL FL			Total
	♀	♂	Total	♀	♂	Total	♀	♂	Total	♀	♂	Total	
An. sinensis							1		1	1		1	2
Ae. albopictus				2		2							2
C. bitaenio.	1		1										1
C. p. pallens	65	115	180	38	34	72	3	8	11	2	1	3	266
C. tritaenio.	9	6	15	3		3	1	1	2				20
Total	75	121	196	43	34	77	5	9	14	3	1	4	291
%	25.8	41.6	67.4	14.8	11.7	26.5	1.7	3.1	4.8	1.0	0.3	1.4	100.0

1) Nagasaki University School of Medicine.
2) BLB FL : 6w. Black Light Blue Fluorescent Lamp which emits ultraviolet light and much less visible light than BL FL.
BL FL : 6w. Black Light Fluorescent Lamp which emits ultraviolet light but a little lighter than BLB FL.
Incand. L : 20w. Frosted Incandescent Lamp which is commonly being used for the light trap of New Jersey type.
DL FL : 60w. Day light Fluorescent Lamp which emits white fluorescent light.
The lamps are lighter in the order of upper to lower.
3) Full species names are given in Table 2.

greatest in BLB FL, next came in BL FL and Incand. L in that order, while it was the least in DL FL. Among five species collected *C. p. pallens* was the greatest in number and *C. tritaeniorhynchus* came next though very small in numbr, while others were few. The school campus including the buildings and a playground was surrounded by residential quarters where some number of breeding places for the former species and a few of them for the latter were thought to be located. In the campus, close to the school building, there were animal houses keeping dogs, cats, hens, and other small animals, and some number of large earthen jars in which some number of mosquitoes of the above two species were breeding. From the result of the above experiment, two types of light traps were chosen for the subsequent experiments: BLB FL, the most efficient one and Incand. L, the most popular one.

Comparison of catches of mosquitoes by BLB FL and Incand. L light traps at the school campus and NAFES

The total numbers of mosquitoes collected by the two light traps on 41 nights at the school campus were given in Table 2. Among 14 mosquito species collected, the most predominant species were *C. p. pallens* and *C. tritaeniorhynchus*, while others were small or rare in number. The two species are most common and important in connection with Bancroftian Filariasis and Japanese Encephalitis in Japan and therefore discussions on the nocturnal activity will be made mainly with these two species.

Table 2 shows that greater number of species and much greater number of mosquitoes were attracted to BLB FL than to Incand. L, clearly showing that the light trap of the for-

Table 2. Total number of mosquitoes collected by light traps on 41 nights during from June to October, 1966 at the School Campus. Catches were made from sunset through sunrise.

Speceis \ Trap / Sex	BLB FL					Incand. L				
	♀	♂	Total	%	♂/♀	♀	♂	Total	%	♂/♀
An. lind.[1] *japonicus*	1	0	1	0.1						
An. sinensis	14	19	33	1.8	1.4	19	22	41	7.0	1.2
An. sinoroides	1	0	1	0.1						
Ae. albopictus	14	4	18	1.0	0.3	13	1	14	2.4	0.1
Ar. subalbatus	14	19	33	1.8	1.4	8	8	16	2.7	1.0
C. bitaeniorhynchus	6	1	7	0.4	0.2	1	2	3	0.5	2.0
C. hayashii	1	0	1	0.1						
C. infantulus	1	1	2	0.1	1.0	1	0	1	0.2	
C. p.[2] *pallens*	392	918	1310	72.6	2.3	28	139	167	28.5	5.0
C. sinensis	0	2	2	0.1						
C. tritaeniorhynchus	167	211	378	21.0	1.3	118	214	332	56.7	1.8
C. vishnui	8	10	18	1.0	1.3	6	4	10	1.7	0.7
C. vorax						1	0	1	0.2	
C. whitmorei						1	0	1	0.2	
Grand total	619	1185	1804	100.0	1.9	196	390	586	100.0	2.0

1) : *lindesayi* 2) : *pipiens*

mer type is much more effective in collecting mosquitoes than that of the latter type. Precisely speaking, however, mosquitoes of *C. p. pallens* were much more numerous in BLB FL than in Incand. L, while those of *C. tritaeniorhynchus* were only a little more numerous in the former than in the latter. Thus, the BLB FL light trap is much more efficient in collecting mosquitoes but at the same time it is inconvenient in a point that it is not easy to pick out mosquitoes from among a tremendous mass of attracted insects. On the contrary, Incand. L light trap is only a little less effective in collecting *C. tritaeniorynchus* and not so difficult in picking out of mosquitoes from among the mass of attracted insects because the number of attracted insects other than mosquitoes is not so numerous as in BLB FL light trap.

At the school campus, the males were collected in relatively great numbers in *C. p. pallens* and *C. tritaeniorynchus* especially in the former. This seems to be due to some breeding places of the two species especially of the former being existed in the near vicinity of setting places of the light traps.

Similar experiment was carried out at Nagasaki Agriculture Forest Experiment Station (NAFES) but only on a night. The station is located at the foot of low hills, facing a large ricefield area on the south, 500 meters or more away from scattered farm houses on the east and west. Total numbers of mosquitoes collected are tabulated in Table 3. As was expected, *C. tritaeniorhynchus* breeding mainly in paddy-fields was the greatest in number and *An. sinensis* which is also breeding in the similar places came next, while *C. p. pallens* breeding mainly in cesspools and ditches near farm houses was rather small in number. In most species, collected numbers of mosquitoes were larger in BLB FL light trap, but the relative abundance was the

Table 3. Total number of mosquitoes collected by light traps from sunset through sunrise on a night of September 3-4, 1966 at Nagasaki Agriculture and Forest Experiment Station (NAFES).

Species \ Trap / Sex	BLB FL					Incand. L				
	♀	♂	Total	%	♂/♀	♀	♂	Total	%	♂/♀
An. sinensis	33	33	66	21.5	1.0	6	10	16	12.4	1.7
M. uniformis						1	0	1	0.8	
Ae. vexans	8	1	9	2.9	0.1	3	0	3	2.3	
Ar. subalbatus	7	4	11	3.6	0.6	7	3	10	7.8	0.4
C. bitaeniorhynchus	2	0	2	0.7						
C. p. pallens	16	4	20	6.5	0.3	0	3	3	2.3	
C. tritaeniorhynchus	178	6	184	59.9	0.0	84	6	90	69.8	0.1
C. vishnui	12	3	15	4.9	0.3	4	1	5	3.9	0.3
C. whitmorei						1	0	1	0.8	
Total	256	51	307	100.0	0.2	106	23	129	100.0	0.2

Table 4. Comparison of the catches of mosquitoes per night at the School Campus and NAFES, and by BLB FL and Incand. L traps (Rearranged from Tables 2 and 3).

Place	Species	Trap \ Sex	♀	♂	Total	♂/♀
School campus	*C. p. pallens*	BLB FL	9.6	22.4	32.0	2.3
		Incand. L	0.7	3.4	4.1	4.9
		BLB/Incand.	13.7	6.6	7.8	
	C. tritaen.	BLB FL	4.1	5.1	9.2	1.2
		Incand. L	2.9	5.2	8.1	1.8
		BLB/Incand.	1.4	1.0	1.1	
	Others	BLB FL	1.5	1.4	2.8	0.9
		Incand. L	1.2	0.9	2.1	0.8
		BLB/Incand.	1.3	1.6	1.3	
NAFES	*C. p. pallens*	BLB FL	16	4	20	0.3
		Incand. L	0	3	3	
		BLB/Incand.		1.3	6.7	
	C. tritaen.	BLB FL	178	6	184	0.0
		Incand. L	84	6	90	0.1
		BLB/Incand.	2.1	1.0	2.0	
	Others	BLB FL	62	41	103	0.7
		Incand. L	22	14	36	0.6
		BLB/Incand.	2.8	2.9	2.9	

highest in *C. tritaeniorhynchus* in Incand. L light trap. The reason of being very small in number of males in general seemed to be due to the breeding places being rather remote or widely distributed.

Comparison of night catches between the different light traps, setting places, and mosquito species is made in Table 4. The number of mosquitoes collected per night by a light trap was very small at the school campus which was located in the city, Nagasaki, while the number was exceedingly large at NAFES located in an agricultural district. BLB FL attracted much more numerous mosquitoes of most species than Incand. L did. *C. p. pallens* was attracted to BLB FL much more powerfully than to Incand. L, while *C. tritaeniorhynchus* was done to the former only a little more so than to the latter. From the above results it can be concluded that BLB FL is more effective for collecting mosquitoes but Incand. L is also useful when the main object is to collect *C. tritaeniorhynchus*. The males appear to be collected by a light trap in larger number when the trap is set up at a near site of breeding places of the mosquitoes.

Hourly prevalence of mosquitoes collected by light traps

Hourly catches of mosquitoes by light traps were made at the school campus on two nights: June 25-26 (Sunset:19:32, Sunrise:5:14) and August 25-26 (18:56, 5:50), 1966. The total numbers of mosquitoes collected on two nights are tabulated in Table 5, by species and sex, light trap, and hour. The similar night catches were made at NAFES on a night of September 3-4 (18:44, 5:56), of the same year with the result shown in Table 6. From Tables 5 and 6, the trend of nocturnal activity of female mosquitoes is roughly summarized

Table 5. Hourly catches of mosquitoes made by light traps, on two nights, June 25-26 and August 25-26, 1966 at the School Campus.

Trap	Species / Sex / Hour	*C. p. pallens* ♀	*C. p. pallens* ♂	*C. p. pallens* Total	*C. tritaen.* ♀	*C. tritaen.* ♂	*C. tritaen.* Total	Others ♀	Others ♂	Others Total
BLB FL	19-20							1	0	1
	20-21	1	14	15	5	0	5	2	0	2
	21-22	4	8	12				2	0	2
	22-23	4	8	12	2	0	2			
	23-24	1	6	7	3	0	3			
	0-3	9	11	20	2	0	2	1	0	1
	3-6	1	2	3						
	Total	20	49	69	12	0	12	6	0	6
Incand. L	19-20									
	20-21	0	1	1	2	0	2			
	21-22	0	1	1	1	0	1			
	22-23									
	23-24	0	1	1						
	0-3	1	0	1	2	0	2	1	0	1
	3-6	0	2	2				0	1	1
	Total	1	5	6	5	0	5	1	1	2

Table 6. Hourly night catches of mosquitoes at NAFES (Rearranged from Table 3)

Trap	Species / Hour / Sex	*C. p. pallens* ♀	*C. p. pallens* ♂	*C. p. pallens* Total	*C. tritaen.* ♀	*C. tritaen.* ♂	*C. tritaen.* Total	Others ♀	Others ♂	Others Total
BLB FL	19-20	11	3	14	107	1	108	20	17	37
	20-21	5	1	6	52	3	55	25	16	41
	21-22				5	0	5	6	3	9
	22-23				1	1	2	0	1	1
	23-24				4	1	5	1	3	4
	0-3				6	0	6	6	0	6
	3-6				3	0	3	4	1	5
	Total	16	4	20	178	6	184	62	41	103
Incand. L	19-20				24	3	27	4	4	8
	20-21	0	2	2	31	2	33	6	7	13
	21-22	0	1	1	5	0	5	1	0	1
	22-23				3	0	3	1	2	3
	23-24				5	0	5	1	0	1
	0-3				4	1	5	3	0	3
	3-6				12	0	12	6	1	7
	Total	0	3	3	84	6	90	22	14	36

as below: On becoming dark mosquitoes of most species become very active, gradually decreasing in activity towards mid-night, increasing, however slightly towards dawn. It is difficult to find out from these tables any trend in nocturnal activity of males.

Age grouping of mosquitoes attracted to the light

Examination of age grouping of mosquitoes especially of *C. p. pallens* and *C.tritaeniorhynchus* collected by light traps seems very important for learning the nocturnal activity of females of different follicular stages, and also for learning the structure in age distribution of the females which may be used as materials for detecting the natural infection with the parasite of mosquito-borne diseases.

On preliminary examination, it was found that the females attracted to the light were very much variable in follicular stage: Some females had the follicles of the earliest stage; some ones had mature eggs; and others each had those of any transitional stage between the above two. Accordingly, close examinations for follicular stages of the females collected by light traps were carried out after the classifications which are being proposed for *C. p. pallens* by Mr. T. Oda and for *C. tritaeniorhynchus* by Mr. S. Kawai of the Department of Medical Zoology Nagasaki University School of Medicine as shown in Table 7.

The result of the examinations with the available females for dissection among those collected at the school campus on from August through October is presented in Table 8. In the case of *C. p. pallens*, follicular stages were classified as No_1~I, II, III, IV, and V, and in *C.tritaeniorhynchus* as No_1~I-II, II, III, IV, and V. Here the females being in stages No_1~I in the former species and No_1~I-II in the latter can

Table 7. Developmental stages of the first follicles of females of C. *p. pallens* and C. *tritaeniorhynchus* at 27°C (After Mr. T. Oda for the former species and Mr. S. Kawai for the latter)

Stage	Description
Before taking blood meal.	
No_1	The follicles of newly emerged females are not apparent and included within germaria which are therefore, a little larger than the germaria at the time of the separation of the first follicles.
No_2	The first follicles become first recognizable by the constriction marked on the pear-shaped germaria by about 12 hours after emergence in *C. p. pallens* and 36 hours after in *C. tritaeniorhynchus*. This stage lasts until the follicles approach N stage.
N	By about 36 hours after emergence in *C. p. pallens* and 60 hours after in *C. tritaeniorhynchus*, the first follicles become larger and to have 8 undifferentiated cells and to be surrounded by large epitherial cells.
I	The egg cell can be recognized from other 7 nurse cells by about 48 hours after the emergence in *C. p. pallens* and 72 hours in *C. tritaeniorhynchus*.
N～I	Usually, however, the distinction between N and I is very difficult and so in this paper these stages are put together in stage N～I.
I-II	In some follicles of a female of *C. tritaeniorhynchus* which is reared on sugar solution for 96 hours or more, yolk granules become faintly recognizable.
After taking blood meal.	
II	About 6 hours after the meal, yolk granules appear sparsely. By about 12 hours after, the egg cell takes up about 1/3 of the follicle and yolk granuales are deposited all over the cell. By about 24 hours after the egg cell occupies 1/3 to 1/2 of the follicle. The nucleus becomes invisible by the dense deposition of yolk.
III	24～36 hours after, the egg cell occupies 1/2～4/5 of the follicle.
IV	About 48 hours a ter, the egg cell occupies nearly the whole follicle taking very long oval shape. Nurse cells are now pushed up above the egg cell.
V	About 60 hours after, the egg cell gains its maximum length, and chorion and micropylar cap become visible.
Oviposition	72 hours after the meal, in most females eggs are oviposited.

be referred to the females being in pre-feeding stages; the females being in stages II, III, and IV are referred to those having premature eggs; and those being in stage V to those having mature eggs.

Table 8 shows that the females attracted to the light are mainly consisted of those being in pre-feeding stages and those having mature eggs, and that nulliparous females are the largest in number and uniparous ones come next, while triparous ones are very rare. This hold roughly true of the both mosquito species and also in the cases of different light colors.

Similar examination was made with *C. tritaeniorhynchus* collected hourly by light traps at NAFES on September 3-4, 1966 from sunset through sunrise with the result as shown in Table 9. The general trend of age distribution is nearly similar to the result obtained at the school campus (cf. Table 8). Here, however, it is of interest that the females in pre-feeding stages appear in fair numbers already at dusk reaching maximum in number one or two hours after dark, coming out thereafter though small in number continuously or intermittently throughout the night. On the contrary, the females with mature eggs appear suddenly in a large number at dusk decreasing abruptly thereafter.

As stated above, the females being in pre-feeding stages are variable in follicular stage. To analyze the age distribution of the females shown in the leftmost columns in Tables 8 and 9, the number of females being in each of different follicular stages are tabulated in Table 10. Here, the follicles of the stage No_1 are under 0.5 and 1.5 days old after emergence of the

Table 8. Age grouping of *C. p. pallens* and *C. tritaeniorhynchus* females collected by light traps on from August through October at the School Campus, showing in number of females being in different parity and follicular stages.

C. p. pallens

Trap	Parity / Stage of follicle / Month	0-parous					1-parous					2-parous					Total No. females examined
		No_1 ~ I-II	II	III	IV	V	N~I	II	III	IV	V	N~I	II	III	IV	V	
BLB FL	Aug.	41				51	36	1	1		17	6		1			154
	Sept.	6				20	6		1		2						35
	Oct.	1				13	7				3						24
	Total	48				84	49	1	2		22	6		1			213
Incand. L	Aug.	4				6	4				1	1					16
	Sept.																
	Oct.					1	2										3
	Total	4				7	6				1	1					19

C. tritaeniorhynchus

		No_1 ~ I-II	II	III	IV	V	N~I-II	II	III	IV	V	N~I-II	II	III	IV	V	
BLB FL	Aug.	37	1	1		45	32	1	1		13	2				1	134
	Sept.	1				1					1						3
	Oct.																
	Total	38	1	1		46	32	1	1		14	2				1	137
Incand. L	Aug.	38		1	2	30	21		1		5	2				1	101
	Sept.	1					1					1					3
	Oct.						1				2						3
	Total	39		1	2	30	23		1		7	3				1	107

females respectively in *C. p. pallens* and *C. tritaeniorhynchus*. Those of the No_2 are under 1.5 and 2.5 days old respectively. Those of the stage N~I are further old and found in nulliparous and parous females which are ready to take the blood meal. Those of the stage I-II are occasionally found only in *C. tritaeniorhynchus* females searching for blood.

Table 10 shows that in nulliparous females, the total number of females with follicles of stages No_1 and No_2 are larger in *C. p. pallens*, while, it is smaller in *C. tritaeniorhynchus* than the number of females which are ready to take blood meal. At any rate, it is of interest that a number of such young females as those being in stages No_1 and No_2 are attracted to the light. This seems to show that the young females become active at night probably in searching for carbohydrate meal. The females having follieles of stage N~I in *C. p. pallens*, and N~I and I-II in *C. tritaeniorhynchus* are attracted to the light in a great number. These females become active at night, as a matter of course, in searching for blood meal.

Table 10 also shows that the females with sac-like follicular tubes and those of having just engorged with blood are attracted to the light in some number. These are summarized

Table 9. Age grouping of *C. tritaeniorhynchus* females collected hourly by light traps on a night, September 3-4, 1966 at NAFES. The females dissected are from among those shown in Table 6.

Trap	Parity	0-parous					1-parous					2-parous					Total No. females examined
	Stage of follicle / Hour	No ~ I-II	II	III	IV	V	N ~ I-II	II	III	IV	V	N ~ I-II	II	III	IV	V	
BLB FL	19-20	8		1		43	18		1		18	3				2	94
	20-21	14	1			4	23	1			2	4					49
	21-22						4					1					5
	22-23					1											1
	23-24	1				1	2										4
	0-3					2	1	1				2					6
	3-6	1					2										3
	Total	24	1	1		51	50	2	1		20	10				2	162
Incand. L	19-20	4				8	5		1		6						24
	20-21	5				3	10				3	4					25
	21-22	2				1	1										4
	22-23	2									1						3
	23-24						2	1				1					4
	0-3	1					2					1					4
	3-6	1	1				2										4
	Total	15	1			12	22	1	1		10	6					68

in Tables 11 and 12. Table 11 shows that the percentage of females with sac-like tubes i. e. those having just laid eggs is higher in C. *p. pallns* and in BLB FL than in C. *tritaeniorhynchus* and in Incand. L. It is of interest because no such females are usually found to come to bite man or cattle.

Table 12 shows that only in *C. tritaeniorhynchns*, the females of having just engorged with blood are attracted to the light though very small in number.

Consideration on the relation between the nocturnal activity of female mosquitoes and their being attracted to the light

The structure of age distribution of the females attracted to the light seems to have close relation to the nocturnal activities displayed by them in relation to the searching for carbohydrate meal, for blood meal, and for breeding places to lay eggs; and also to the flying on the way back to resting places after oviposition and, only in *C. tritaeniorhynchus*, just after feeding. In this meaning, the females which have growing eggs may be thought to remain inactive till the day of maturity of eggs.

Table 10. Age distribution of the females being in pre-feeding state attracted to the light.

The figure gives the numbre of females having follicles of each developmental stage. The number of females with sac-like follicular tubes and that of those having just fed are given parentheses and in double parentheses respectively.

Trap	Parity / Stage / Time	O-parous					1-parous			2-parous		
		No_1	No_2	N～1	I-II	Total	N～I	I-II	Total	N～I	I-II	Total
C. p. pallens at the School Campus (cf. Table 8)												
BLB FL	Aug.	12	12	17		41	36(11)		36	6(4)		6
	Sept.	1	3	2		6	6(3)		6			
	Oct.			1		1	7(4)		7			
	Total	13	15	20		48	49(18)		49	6(4)		6
Incand. L	Aug.	2	1	1		4	4(1)		4	1		1
	Sept.											
	Oct.						2(1)		2			
	Total	2	1	1		4	6(2)		6	1		1
C. tritaeniorhynchus at the School Campus (cf. Table 8)												
BLB FL	Aug.	6	3	27	1((1))	37	29(9)	3((2))	32	2(1)		2
	Sept.		1			1						
	Oct.											
	Total	6	4	27	1((1))	38	29(9)	3((2))	32	2(1)		2
Incand. L	Aug.	7	6	24((2))	1((1))	38	19(2)	2((1))	21	2(1)		2
	Sept.		1			1	1(1)		1		1	1
	Oct.						1		1			
	Total	7	7	24((2))	1((1))	39	21(3)	2((1))	23	2(1)	1	3
C. tritaeniorhynchus at NAFES (cf. Table 9)												
BLB FL	19-20		1	7		8	17(1)	1	18	3(2)		3
	20-21		5	9((2))		14	21(4)((1))	2((1))	23	4		4
	21-22						4(4)		4	1(1)		1
	22-23											
	23-24			1		1	2(1)		2			
	0-3						1(1)		1	2(2)		2
	3-6			1		1	2(2)		2			
	Total		6	18((2))		24	47(13)((1))	3((1))	50	10(5)		10
Incand. L	19-20		2	2		4	3	2	5			
	20-21		1	4(1)		5	8(2)	2	10	4(2)		4
	21-22			2(1)		2	1		1			
	22-23			1	1	2						
	23-24						2(2)		2	1		1
	0-3			1		1	2(2)		2	1		1
	3-6			1		1	2		2			
	Total		3	11((2))	1	15	18(6)	4	22	6(2)		6

Table 11. Number of parous females attracted to the light, and the number and percentage of those with sac-like follicular tubes (From Table 10)

Trap / No. & % / Species	BLB FL			Incand. L		
	No. of females examined	No. of females with sac	% of females with sac	No. of females examined	No. of females with sac	% of females with sac
C. p. pallens	55	22	40.0	7	2	28.6
C. tritaen.	94	28	29.8	54	12	22.2

Table 12. Number of females having current follicles of stage N~I in *C. p. pallens* and N~I-II in *C. tritaeniorhynchus*, and the number and percentage of the females attracted to the light just after taking blood meal (From Table 10)

Trap / No. & % / Species	BLB LL			Incane. L		
	No. of females examined	No. of females having just fed	% of females having just fed	No. of females examined	No. of females having just fed	% of females having just fed
C. p. pallens	75	0	0.0	8	0	0.0
C. tritaen.	140	7	5.0	91	6	6.6

Consideration on the feeding rate of mosquitoes Collected by light traps

In the case of the examination of mosquiotes for the natural infection with the parasite of a mosquito-borne disease, it is desirable to choose a collecting method to get a female population including as many fed females as possible.

The feeding rates of *C. p. pallens* and *C. tritaeniorhynchus* collected by light traps calculated from the data shown in Tables 8, 9, and 10 are 77.6% and 77.2% respectively. The rates are nearly the same as or only a little lower than those obtained with the two mosquito species collected by a sucking tube and hand net in dwelling houses and cowsheds in a village in 1964 and 1965(Omori et al. unpublished). The reason is that by the light trap a great number of nulliparous females being in pre-feeding stages are collected as they are unfed, and peculiarly the females once fed and having mature eggs are collected in a great number too, while, by the usual collecting method in houses and cattlesheds the nulliparous females being in pre-feeding stages are collected mostly after feeding but the females having mature eggs are collected only in a very small number. Consequently, it can be said that collecting mosquitoes by the light trap for the examination of natural infection with the parasite of human diseases is not less profitable than the usual collection of them in houses or cattlesheds, except for the trouble in picking up of mosquitoes from among a mass of attracted insects to the light every one or two hours to collect them during they are still alive.

Summary

Collection of mosquitoes by using light traps was carried out at the school campus of Nagasaki University School of Medicine and Nagasaki Agriculture and Forest Experiment Station (NAFES) in 1966. The main objects of the experiment were to compare the effectiveness of different light colors and to examine the structure of age grouping of the females and the rate of fed females attracted to the light.

Among the four light traps used, the one with Black Light Blue Fluorescent Lamp was the most effective obtaining the largest number of species and mosquitoes; the most popular one with Frosted Incandescent Lamp (New Jersey type) was the third in the order of effectiveness but it was only a little less effective than the above one so far as the collected number of *C. tritaeniorhynchus* is concerned.

At school campus located in Nagasaki City, *C. p. pallens* was the greatest and *C. tritaeniorhynchus* came next, and others were very small or few in number, while at NAFES, *C. tritaeniorhynchus* was the greatest, *An. sinensis* and *C. p. pallens* came next, and others were small or few in number.

The result of examinations for hourly prevalence of mosquitoes attracted to the light showed that: On coming dark, mosquitoes of most species bacame very active, gradually decreasing in activity towards mid-night, increasing a little towards dawn.

Age distribution of the females attracted to the light was examined with only the predominant and important mosquitoes, *C. p. pallens* and *C. tritaeniorhynchus*. As a result, it was revealed that the females attracted to the light are very much variable in their follicular stages: Some females respectively have follicles of stage No_1, No_2, N~I, I-II (only and rarely in *C. tritaeniorhynchus*), V; and very much rarely II, III, and IV; and also follicles of sac-like follicular tubes. In C. *tritaeniorhyuchus*, the females are attracted to the light just after taking full blood meal, though small in number. The structure of age distribution of the females attracted to the light seems to have close relation to the nocturnal activities displayed by them in relation to the searching for carbohydrate meal, for blood meal, and for breed ing place to lay eggs; and also to the flying on the way back to the resting place after oviposition, and only in *C. tritaeniorhynchus* just after taking blood. In this meaning the females having follicles of stages II, III, aud IV may be very much inactive in nocturnal activity.

The rate of females attracted to the light which have fed or had fed once or more times is about 77~78 percent against the total ones collected and is not necessarily lower than that seen in females collected in dwelling houses or cattle-sheds by usual collecting method. This seems to be due to the fact that a great number of nulliparous and parous females with mature eggs are peculiarly collected by light traps as an offset to the fact that in houses and cattle-sheds most nulliparous females of being in stages N~I in *C. p. pallens* and N~I-II in *C. tritaeniorhynchus* are collected after taking blood meal.

References

1) **Detinova, T.S.** : Age-grouping methods in Diptera of medical importance, with special reference to some vectors of malaria. W.H.O. Monogr. Ser. 47, **1962.**

2) **Frost, S.W.**: Response of insects to black and White light. J. Econ. Ent. **46**(2): 376-377, **1953.**

3) **Hayashi, S.** and **Kurihara, T.**: Studies on the age of mosquitoes. I. The determination of physiological age of *Culex pipiens pallens* by the relics formed at ovarioles after the oviposition. Jap. J. Sanit. Zool., **16**(1): 29-33, **1965** (In Japanese with English summary).

4) **Inatomi, S.**, **Yamaguti, N.**, **Kumura, M.**, **Mizuoti, O.**, **Otsuka, N.**, **Sakumoto, D.** and **Itano, K.**: On the incidence of Japnnese Encephalitis and the mosquitoes collected by light-trap in Okayama prefecture in 1960. Additional note on the occurrence of *Culex tritaeniorhynchus* at Kurashiki city and its neiborhood in 1958. J. Okayama Med. Ass., **72** (11, 12): 29-34, **1960** (In Japanese with English summary).

5) **伊藤誠喜, 榊原純一, 小林朝雄, 吉岡武雄, 高橋克征**：特殊螢光灯（ライトトラップ）応用による家畜の夏季衛生害虫防除法とその経済性. 畜産の研究, **20** (5): 713～718, **1966.**

6) **Ito, S.**: collection of mosquitoes by light traps at four stations in Nagasaki City. Endem. Dis. Bull. Nagasaki, **6**(4) 231-241, **1964** (In Japanese with English summary).

7) **Ratoh, S.** and **Ohgushi, R.**: The insects crowding on the room lamp and their control. 2. The correlation between the number of crowding insects and the various colour of lamps. Ins. Ecology, **8**(1): 22-25, **1959** (In Japanese).

8) **Kitaoka, S.** and **Ito, K.**,: Attractiveness of black light to biting midges and mosquitoes. Jap. J. Sanit. Zool. **15**(3): 208-209, **1964** (In Japanese with English summary).

9) **Nakata, G.** and **Ito, S.**: Ecological studies on mosquitoes about Kyoto City (2). On the annual succession of the mosquitoes captured by the light trap. Jap. J. Sanit. Zool. **6**(2):82-93),: **1955** (In Japanese with English summary).

10) **Oda, T.**: Observations on the mosquitoes visiting the fowers of spindle trees, *Euonymus japonica*. Endem. Dis. Bull. Nagasaki, **6**(4): 242-246, **1964.**

11) **Oda, T.** and **Omori, N.**: Changes in ovarioles following oviposition of *Culex pipiens pallens*. *Jap.* J. Sanit. Zool. **15**(2): 107, **1964** (In Japanese).

12) **Yamaguchi, S.**, **Inatomi, S.** and **Kimura, M.**: On the incidence of Japanese B Encephalitis and the mosquitoes collected by light trap at Okayama in 1952. Jap. J. Sanit. Zool. **4**(1, 2): 3-4, **1953** (In Japanese).

ライトトラップで採集される蚊の生態学的研究

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摘　　要

ライトトラップによる蚊の採集を1966年の 6 月から 9 月迄の間に長崎大学医学部構内と長崎県農林センターの構内で行なった. 本実験の主な目的は使用した 4 種の異なった着色電球の効果を比較することと, 疫学的に重要なアカイエカとコガタアカイエカの光に誘引される♀個体群についてその年令構成と吸血率とを知ることにあった.

4 種のライトトラップの内, ブラックライトブルー螢光管ライトトラップが採集蚊種及び個体数が最も多いこと及び, 最も普及しているニュージャーシー型の白熱電球ライトトラップでは, 少なくともコガタアカイエカについては上記のものとあまり劣らず採集できることを知つたので, 以後この両型のトラップを使用して採集したものについて生態学的吟味を行なった. 医学部構内ではアカイエカが最も多く, コガタアカイエカがこれに次ぎ, その他のものは採集数が極めて少なかった. 農林センターではコガタアカイ

エカが最多で，シナハマダラカ，アカイエカがこれに次ぎ，他は少ないか稀であった．

夜間の時間的活動をみると，何れの種類も暗くなると急に極めて活潑に活動を始め，真夜中に向って次第に減少する．然し夜明け頃多少多くなる傾向がみられる．

光に誘引される♀個体群の年令をみると，未経産の羽化直後のもの，羽化後種類により 0.5～1.5日経過したもの，吸血可能な状態のもの，Ⅴ期卵を持ったもの，及び1回或るいは2回経産後に，吸血可能となったものや吸血後Ⅴ期卵を持ったもの，更には，普通人家や畜舎では殆んど採集できないような臍胞管尾部のサック状のもの，或るいは（コガタアカイエカのみで見られ個体数は少ないが）吸血直後のものが採集できる．然しⅡ，Ⅲ，及びⅣ期卵を持った♀蚊は極めて稀にしか採集できない．光に集まるこの両種蚊の♀個体群の，このような年令分布の様相は，各年令♀蚊群の夜間の活動性と密接な関係のある事と思われる．即ち，羽化後間もなくから夫々，炭水化物性の食餌を，吸血源を，又は産卵場所を求めて活動するもの，或るいは産卵後に潜伏場所を求めて飛翔するもの又は，コガタアカイエカのみでは，吸血直後飛散するものなどがその活動と関連して光に誘引されるものと考えられる．この意味ではⅡ，Ⅲ，及びⅣ期卵を持った♀群は夜間あまり活動しないのではないかとも考えられる．

ライトトラップで採集される♀蚊の内，既に或るいは嘗て吸血したことのある蚊の割合，即ち採集蚊の吸血率は約77～78％で，普通人家や畜舎で採集される♀蚊についての吸血率より必ずしも低くはない．その訳は，ライトトラップでは，人家や畜舎で採集する場合とは違って，多数の未経産♀蚊は未吸血のまま採集されるが，これとは逆に，成熟卵を持った♀蚊，即ち既に吸血している蚊が，ライトトラップの場合だけに特別に多く採集されることによって埋め合わせられる結果となるためである．