Seasonal Abundance of Immature Stages of *Aedes togoi* at Fukue Island, Nagasaki (Diptera: Culicidae)

Yoshito WADA[1], Sumiyo ITO[2] and Tsutomu ODA[3]

[1]*Department of Medical Entomology, Institute of Tropical Medicine, Nagasaki University, 1−12−4 Sakamoto, Nagasaki 852, Japan*
[2]*Osaka Seikei Women's Junior College, 3−10−62 Aikawa, Higashiyodogawa−ku, Osaka 533, Japan*
[3]*Department of General Education, School of Allied Medical Sciences, Nagasaki University, 1−7−1 Sakamoto, Nagasaki 852, Japan*

Abstract: The seasonal prevalence of immature stages of *Aedes togoi* in coastal rock pools was studied at Abumize, Fukue Island, Nagasaki by estimating the absolute number of larvae (pupae inclusive) in each pool by the modified removal method. The method we used was justified by the fact that the seasonal trend of larvae coincided very well with the trend of adults. The seasonal abundance of larvae was different in years but generally lower in summer. It was shown that the important factors influencing the abundance include (1) drying up of pools by direct sunshine and little rain fall, (2) water quality that is changeable by rain fall, sprays of sea water by strong wind, and the succession of microorganisms, and (3) natural enemies such as dytiscids (Coleoptera) and notonectids (Hemiptera).

Key words: *Aedes togoi*, mosquito, seasonal abundance, immature stages, coastal rock pool

INTRODUCTION

Aedes togoi is a medically important mosquito that it is a main vector of malayan filariasis in Korea and China and susceptible to bancroftian filaria and *Dirofilaria immitis*. However, only a very few studies on the seasonal prevalence of immature stages of this mosoquito were reported so far. The breeding place is rock pools on the sea coast, which are very unstable in their size due to water evaporation and rain fall. The abundance of the mosquito is greatly influenced by the change in the size of the breeding pools, therefore it is necessary to know not the relative but the absolute number of mosquitoes in every pool in a particular area for the study of the seasonal prevalence.

To know the absolute number of immature *Ae. togoi*, Nakamura *et al.* (1988) pumped up all water in a pool and counted the number of immatures in it, but it needs too much time to apply this method especially when the size of the pool is large. Mori (1989) proposed to stir the water well then to dip in a pool for estimatiing the absolute density of immature *Ae.*

togoi, but the size of pools are sometimes too small to dip. However, we could estimate the absolute density of immatures in pools of various sizes by using the modified removal method (Wada, 1962), and obtain quite properly the seasonal prevalence of immature *Ae. togoi* in 1961−1962 on the sea coast at Abumize on Fukue Island, where bancroftian filariasis was endemic (Wada, 1963). The method we used was justified by the fact that the prevalence of immatures coincided very well with that of adults. The results are herewith reported with the discussion on the influencing factors of the density.

PLACE AND METHODS

The seasonal prevalence of immature *Ae. togoi* was studied on the sea coast of Abumize, Fukue Island, Nagasaki Prefecture. Fukue Island is located in the temperate region, and the mean monthly temperature in 1931−1960 shows 7.1℃ in January (coldest month) and 26.8℃ in August (hottest month). Bancroftian filariasis was endemic in Abumize where the microfilarial prevalence rate was 8.3% in 1961, and epidemiological and entomological studies were being carried out (Wada, 1963, 1966). This study was a part of them.

Careful examination revealed that *Ae. togoi* was breeding nearly exclusively in rock pools on the sea coast and not found inside the village at all, therefore the seasonal prevalence of immature stages was studied in coastal rock pools. Distribution of rock pools in Abumize was limited mainly in two adjacent areas of 13×8 and 9×8 m. The target rock pools were well above the sea level even on the high tide and not usually disturbed by sea water. However, strong wind could sometimes influence the pools by waves and sprays of sea water. Salinity of water often increased after strong wind and shiny days, but gradually decreased by rain fall and the disintegration of salt.

In each examination, the surface area, depth and temperature of the water were recorded and the catch of mosquito larvae (pupae inclusive) by one-minute pipetting or one dip was repeated five times in all the 18 pools located in the two areas. The absolute number in each pool was estimated by the modified removal method, the estimation error being expected to be within 10% (Wada, 1962). Meteorological data on Fukue Island was obtained from the Nagasaki Marine Observatory.

RESULTS AND DISCUSSION

The mosquitoes found in the pools were mostly *Ae. togoi*, and an extremely samll number of other mosquitoes were only temporarily encountered. They were *Anopheles sinensis, Culex tritaeniorhynchus* and *Cx. halifaxii*. Table 1 shows the pools examined for the number of immature *Ae. togoi* in 1961−1962. The size of water varied in pools and in time, and the maximum value of the surface area of each pool ranged from 0.05 to 8.84 m² and that of the depth from 5 to 37 cm. The number of days with water when examined was also

Table 1. Pools examined for the number of immature *Aedes togoi*, 1961−1962

Group*	Pool No.	No. (%) of days with water	Max. size of water area (m²)	depth (cm)	Total number(%) of immatures**
A	16	25 (100)	8.84	37	315,691 (70.03)
	17	25 (100)	1.92	31	66,344 (14.72)
B	7	23 (92)	0.64	16	18,500 (4.10)
	8	24 (96)	0.32	12	17.573 (3.90)
	14	24 (96)	1.05	9	9,970 (2.21)
	10	19 (76)	0.45	7	6,028 (1.34)
C	18	22 (88)	0.96	14	3,482 (0.77)
	13	21 (84)	0.43	8	3,002 (0.67)
	4	20 (80)	0.09	9	2,117 (0.47)
	5	15 (60)	0.20	8	2,003 (0.44)
	1	24 (96)	0.06	5	1,956 (0.43)
	3	15 (60)	0.12	5	1.339 (0.30)
	2	15 (60)	0.44	5	896 (0.20)
	15	17 (68)	0.51	6	895 (0.20)
	9	15 (60)	0.20	7	469 (0.10)
	6	16 (64)	0.05	7	233 (0.05)
	12	15 (60)	0.10	7	165 (0.04)
	11	13 (52)	0.19	5	99 (0.02)

*Pools were grouped as A, B and C according to the total number of immature *Ae. togoi*.
**Total number in 25 days during the whole observation period.

variable in pools from 25 (100%) to 13 days (52%). The mosquito productivity differed very greatly in pools, and the total of the number of immatures estimated by the modified removal method in 25 days during the whole observation period ranged from 315,691 (70.03% to the total number for all pools) in No. 16 pool to 99 (0.02%) in No. 11 pool. As the mosquito productivity was higher and the number of days with water was larger (water was less frequently dried up) generally in pools of larger size. The 18 pools were grouped as A, B and C as in Table 1 according to the mosquito productivity and the seasonal trend was examined separately.

The seasonal changes in 5-day precipitation and water surface area in pools of group A, B and C (in % to the total in a year) in 1961 and 1962 are shown in Fig. 1 and 2, respectively. It is clearly indicated that the water surface area was less stable in group C pools of smaller size. In 1961 (Fig. 1), water in group C pools was dried up very often in summer due to high temperature by direct sunshine, while in group A pools of larger size the water area was relatively stable and always filled with water throughout the year (see also Table 1). The water surface area of pools was influenced by precipitation, and it was more stable in 1962 in which there were more rain falls than in 1961.

Fig. 3 and 4 show respectively the seasonal change in 1961 and 1962 in the number of larvae (pupae inclusive) together with the water surface area given in Fig. 1 and 2. The seasonal trend in the number of the larvae was generally in parallel with that of the water surface area. This clearly shows that the seasonal abundance of the larvae in rock pools depended greatly on precipitation. However, there are other factors influencing the seasonal abundance. Among them, the activity of natural enemies and the change of water quality are important.
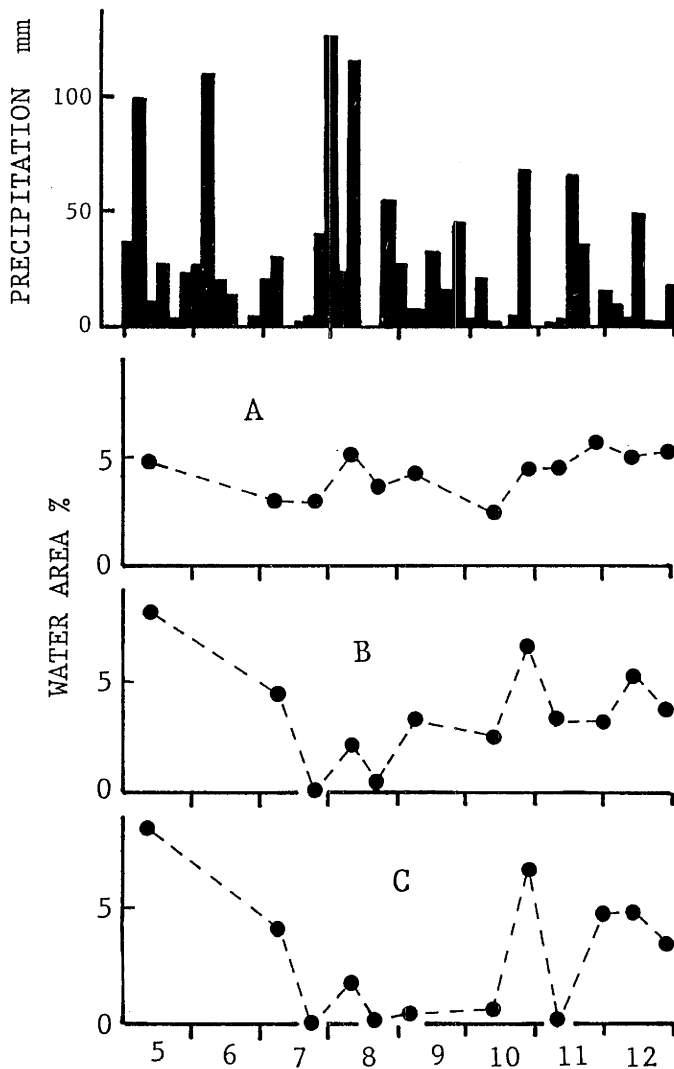
Fig. 1. Seasonal change of 5-day precipitation and water surface area in all pools of group A, B and C, at Abumize, Fukue Island, in 1961. For A, B and C, see Table 1.

Important natural enemies of immature *Ae. togoi* included dytiscids (Coleoptera), dragonfly larvae (Odonata), and notonectids (Hemiptera). Two species of dytiscids were found, *Liodessus megacephalus* and *Eretus sticticus. L. megacephalus*, a typical inhabitant of coastal rock pools (Sato, 1964), was common from April to October, but *E. sticticus* was found only once and as Sato and Matsuura (1964) indicated, this seemed not to be a true halophilous species. Notonectids were common throughout the year in lage and middle-sized pools. Dragonfly larvae were only found in large pools from May to October in 1962 with more precipitation than in 1961.
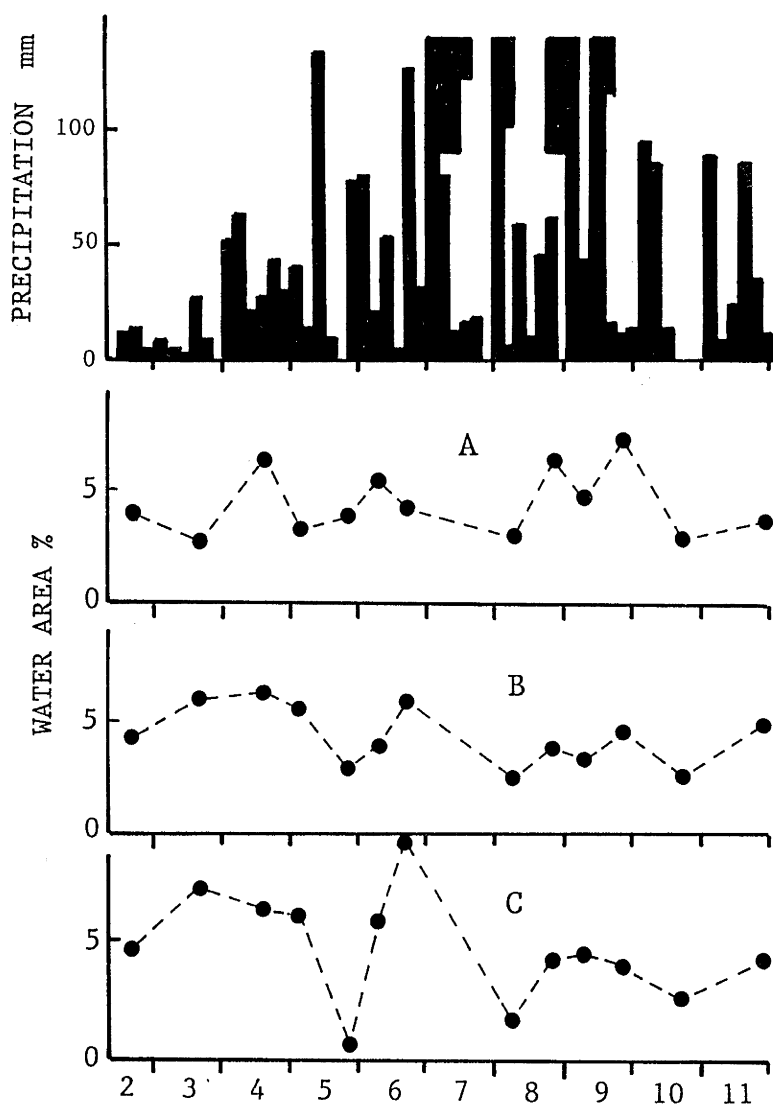
Fig. 2. Seasonal change of 5-day precipitation and water surface area in all pools of group A, B and C, at Abumize, Fukue Island, in 1962. For A, B and C, see Table 1.
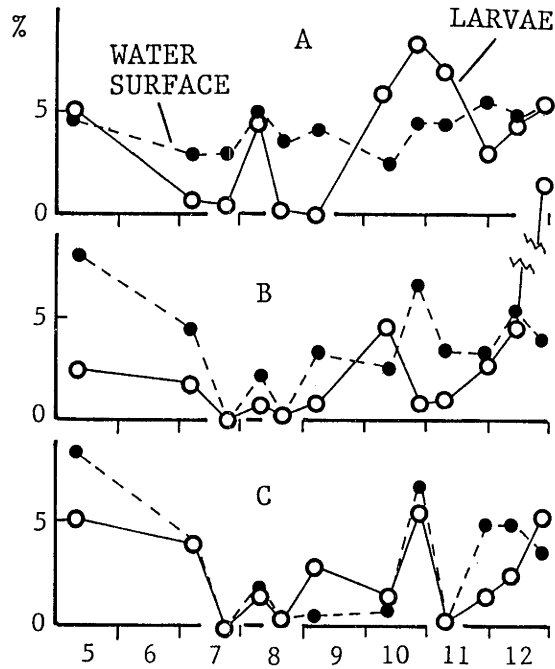
6

Fig. 3. Seasonal change of the number of larvae (pupae inclusive) and water surface area in the pools of group A, B and C, at Abumize, Fukue Island, in 1961. For A, B and C, see Table 1.
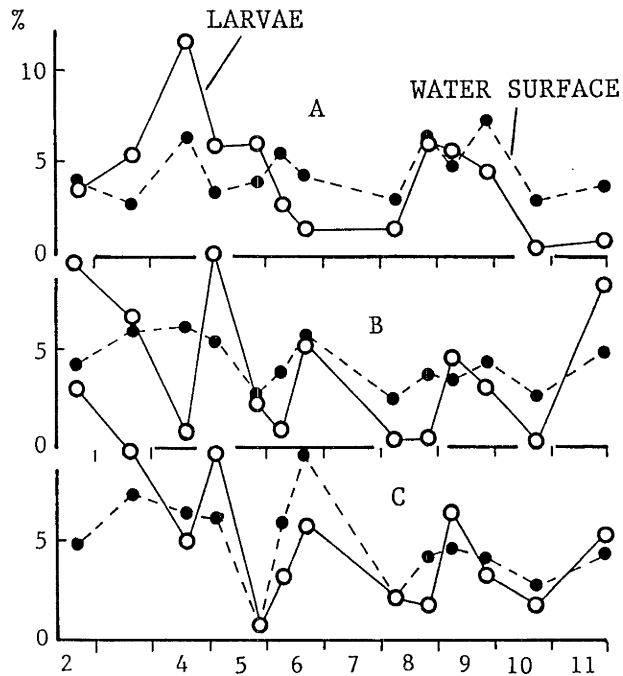

Fig. 4. Seasonal change of the number of larvae (pupae inclusive) and water surface area in all pools of group A, B and C, at Abumize, Fukue Island, in 1962. For A, B and C, see Table 1.

Shoji (1955) studied the succession of microorganisms in coastal rock pools and found that the larval density of *Ae. togoi* was closely related to the microorganism association. The present study demonstrated that the succession of microorganisms influenced not only *Ae. togoi* larvae but also their natural enemies.

On May 11 in 1961 when the present study was started, the water in the pools of large size (group A) was nearly transparent and the density of *Ae. togoi* larvae was high. It was apparent that some time before that day the pools had received the influence of sea water, as indicated by scattered fragments of sea brown algae in the pools. On July 7 and 23 many *L. megacephalus* were found and the decrease of larval density was thought to be due partly to the activity of this dytiscids. The water quality also became turbid by propagation of some microorganisms (species not determined) and unsuitable for the breeding of the larvae. The larvae on August 11 consisted mainly of young ones and the temporal rise in the density on that day was probably caused by hatching of larvae after rainfall. The extremely low density of larvae on August 21 and September 8 was apparently due to the unsuitable quality of water for the mosquito breeding and the activity of many notonectids. Then the attack of typhoon changed the condition of the pools, and the water quality became nearly transparent again by the inflow of sea water and notonectids disappeared. As a result, on October 12 and 27, the density of immature *Ae. togoi* was very high. On November 10, notonectids reappeared and the density of *Ae. togoi* began to decline.

On the contrary to the pools of large size (group A), in the pools of small size (group C), and to a lesser extent in those of medium size (group B), the influence of natural enemies was not so remarkable and the seasonal trend of immature *Ae. togoi* was affected very greatly by the change in the surface area and the quality of water.

In comparison with 1961, there was more rain in 1962 (Fig. 1 and 2), therefore pools were less frequently dried up even in the pools of small (group C) and medium (group B) size. Breeding of dragonfly larvae in 1962 was probably due to relatively stable water of the pools.

Table 2 shows examples of water temperature in pools in summer and winter. Omori and Fujii (1953) reported the decrease of larval density of *Ae. togoi* in summer in Fukui Prefecture, and Nakamura *et al.* (1988) observed the same phenomenon and stated that the rise in water temperature might be an important factor to reduce the larval density in summer. In fact, high temperatures of water (maximum 38.8℃ in July 7 and 39.2℃ in August

Table 2. Examples of water temperature in pools in summer and winter

Date	No. of pools	Weather at observation	Temperature ℃	
			Range	Mean
Jul. 7, 1961	16	shiny	30.3 — 38.8	35.7
Aug. 21, 1961	5	shiny	33.1 — 39.2	37.1
Dec. 27, 1961	16	cloudy	7.2 — 11.5	9.7
Feb. 21, 1962	17	shny	15.0 — 24.2	19.8

21) were recorded in pools under direct sunshine in the daytime in Abumize (Table 2). However, various instar larvae and pupae were found in all the pools examined, therefore the high water temperature itself may not be an important limiting factor of the density, though it contributes to dry up the water in pools.

The rise in water temperature by sunshine was recognized also in winter. Mean water temperature was 19.8 ℃ in pools on a shiny day (February 21), while it was 9.7 ℃ on a cloudy day (December 27), as given in Table 2. This implies that immature *Ae. togoi* can develop slowly even in winter.

The age structure of immature *Ae. togoi* in winter is given in Table 3. All instar larvae and pupae were found throughout the winter, though each proportion changed with time. Mogi (1981) experimentally demonstrated that the Nagasaki strain of *Ae. togoi* undergoes either larval or embryonic diapause in response to a rather small difference in photophase and observed that the alternative diapause actually functions under natural conditions in Nagasaki. Nakamura (1964) collected fourth instar larvae in the end of November at Abumize and reared them in the laboratory of 25−27 ℃ but the majority pupated about two weeks later and the resulting adults were abnormally large. This suggests that they were in larval diapause. The present study also suggested the presence of egg and larval diapause in the field.

As shown in Table 3, the number of fourth instar larvae very much increased from November 30 to December 27, while the decrease in the number of pupae was remarkable during the same period. This is probably due to the larval diapause. The number of first instar larvae increased from November 30 to February 21, and this can be ascribed to the hatch of eggs, which were probably in the state of diapause.

The continuous hatch of larvae from eggs in the winter was shown by Table 3, but this was more directly demonstrated in Table 4, in which the change of the number of immatures in pools 11 and 15 is given. In these two pools, water was completely dried up on December 27, but 46 first instar and 64 second instar larvae were observed on February 21, indicating the hatch from eggs.

Fig. 5 shows the seasonal trend in the abundance of larvae (pupae inclusive) in all pools and adults of *Ae. togoi* at Abumize in 1961−1962. Data for adults are at dwelling houses and

Table 3. Age structure in immature *Aedes togoi* in winter, 1961−1962

Date	No. of each instar larvae and pupae*					total
	1	2	3	4	P	
Nov. 30	2,031	2,506	4,153	2,421	2,411	13,522
Dec. 13	3,209	3,167	4,406	8,104	552	19,438
27	9,298	7,656	7,372	10,003	448	34,777
Feb. 21	13,505	3,541	1,610	2,624	12	21,292
Mar. 20	10,533	11,287	1,870	1,020	821	25,531

*Total number in all the 18 pools.

cowsheds in Abumize village (Wada, 1966). The seasonal trend was very similar in larvae and adults, except for the period from February to April when only a small number of adults were emerging. The similar seasonal trend in larvae and adults implies that the method of larval survey used in the present study is reliable.

The seasonal trend of larvae was fairly different by groups of pools according to their size as shown in Fig. 3 and 4, but the seasonal trend in all pools (Fig. 5) was nearly the same as in group A pools of large size. This means that the total production of the mosquitoes in the area depends largely on that in large-sized pools only.

The larval density differed in years but was low generally in summer. The abundance of larvae is influenced by many factors, which can be summarized as follows. Lack of rain fall easily makes pools to be dried up particularly when the pool size is small. The quality of

Table 4. Change of the number of immature *Ae. togoi* in pools 11 and
15 in winter, 1961−1962

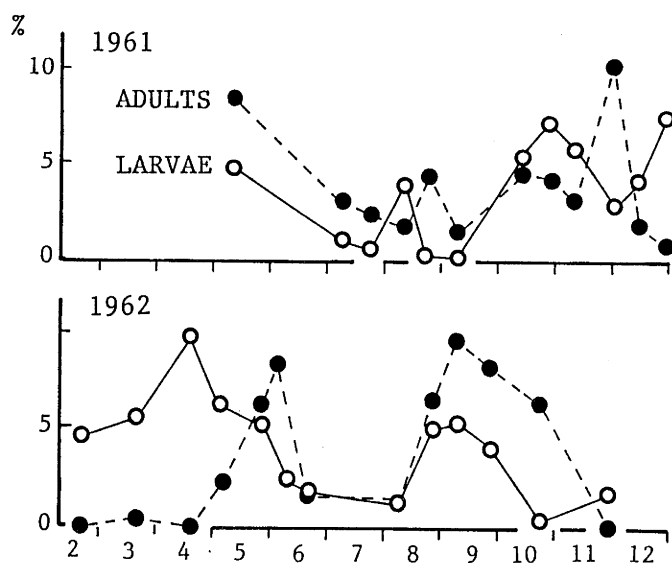| Date	No. of each instar larvae and pupae				
	1	2	3	4	P
Nov. 30	0	0	2	2	0
Dec. 13	4	8	2	0	1
27	pools were dried up				
Feb. 21	46	64	0	0	0

Fig. 5. Seasonal trend of the abundance of larvae (pupae inclusive) and adults
of *Ae. togoi*, at Abumize, Fukue Island, in % to the total in two years
of 1961 and 1962. Data for adults are from Wada (1966).

water in pools vitally affects the breeding of *Ae. togoi*. The water quality is influenced by rain fall and sprays and waves of sea water by strong wind. It changes also by the succession of microorganisms in pools. Natural enemies often play an important role in reducing the density of the larvae particularly in pools of large size.

ACKNOWLEDGMENT

REFERENCES

1) Mogi, M. (1981): Studies on *Aedes togoi* (Diptera: Culicidae) 1. Alternative diapause in the Nagasaki strain. J. Med. Entomol., 18, 477−480.

2) Mori, A. (1989): A simple method for sampling the immature stages of *Aedes togoi*. Trop. Med., 31, 171−174.

3) Nakamura, S., Miyagi, I. & Toma, T. (1988): Seasonal appearance of immature populations of *Aedes* (*Finlaya*) *togoi* (Theobald) in Okinawa. Jpn. J. Sanit. Zool., 39, 91−96 (in Jpn., Engl. summary).

4) Nakamura, Y. (1964): Experimental studies on the role of *Aedes togoi* in the transmisision of bancroftian filariasis. 1. Numer of microfilariae taken up by the female and their movement in her body. Endem. Dis. Bull. Nagasaki, 6, 25−33 (in Jpn., Engl. summary).

5) Omori, N. & Fujii, S. (1953): On the feeding habits of *Aedes togoi* and other species of mosquitoes. Yokohama Med. Bull., 4, 23−31.

6) Sato, M. (1964): Studies on the marine beetles in Japan, Ⅳ. Some remarks on the fauna of marine beetles in Japan. J. Nagoya Jogakuin College, No. 10, 76−81.

7) Sato, M. & Matsu-ura, K. (1964): Studies on the marine beetles in Japan, Ⅲ. Some ecological notes on *Bidessus megacephalus* Gschwendtner. J. Nagoya Jogakuin College, No. 10, 72−75.

8) Shoji, S. (1955): On the synecological observation of micro-organism communities in some tidewater rock-pools with special reference to the morphological variation of the larva of a mosquito, *Aedes togoi* Theobald. Ecol. Rev., 14, 91−98.

9) Wada, Y. (1962): Studies on the population estimation for insects of medical importance 2. A method of estimating the population size of larvae of *Aedes togoi* in the tide-water rock pool. Endem. Dis. Bull. Nagasaki, 4, 141−156.

10) Wada. Y. (1963): Epidemiology of bancroftian filariasis in Nagate and Abumize Villages, Nagasaki Prefecture, especially in relation to vector mosquitoes 1. Endemicity of the filariasis. Endem. Dis. Bull. Nagasaki, 5, 136−151.

11) Wada, Y. (1966): Epidemiology of bancroftian filariasis in Nagate and Abumize Villages, Nagasaki Prefecture, especially in relation to vector mosquitoes 3. Ecology and natural infections of mosquitoes. Endem. Dis. Bull. Nagasaki, 8, 45−53.