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The Seasonal Abundance of *Aedes albopictus* in Nagasaki

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Abstract: The seasonal abundance of *Aedes albopictus* was observed for three years. From the results, following things were made clear. Only eggs can survive through winter in Nagasaki. When the larval density is high in mid-summer, high mortality and delay of development are found during the larval period. While the larval density is low in spring and early summer, the survival and developmental period are as normal as under the optimal experimental condition. Since the number of daily emerging adults is considered to be kept nearly constant from May to August, the adult population of *Ae. albopictus* in a certain area is dependent largely upon the abundance of larval breeding places.

Aedes albopictus is one of the vector mosquitoes of dengue fever in Southeast Asia, and in Japan there was the epidemic of dengue fever by this mosquito. *Ae. albopictus* prefers small artificial containers and bamboo cuts for its larval breeding. In Japan, Makiya (1973, 1974) observed the population dynamics of larvae breeding in water-holding concavities of gravestones in a graveyard. The population he observed, however, was artificially affected by the renewal of water in the water-holding concavities due to the custom of inhabitants. In order to control this species, it will be necessary also to know the population dynamics in the circumstances without such artificial effects. For this reason, the population dynamics of *Ae. albopictus* was observed for three years in small containers in the field of which water was left to follow a natural process, without removing or adding water artificially.

PLACE AND METHODS

Observations were carried out in a small grove, 50m long and 10m wide, in the campus of Nagasaki University School of Medicine. This grove consisted mainly of camphor trees *Cinnamomum camphora* and was isolated from other groves. Ten glass vials, 7cm in diameter and 500ml in capacity, were placed in the grove and filled up with water on April 17, 1974. The water including all contents in each vial was transferred into a white pan and the numbers

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of different instar larvae and pupae of *Ae. albopictus* were recorded, once a week as a rule for three years after setting the vials. After recording, the mosquito larvae and pupae, water and all other contents were put back into the vial as before. Mosquito larvae were not given any food, except for naturally fallen small animals and plant leaves.

Adult *Ae. albopictus* were collected by a person using a small hand net and a sucking tube at the center of the grove for 30 minutes in 1974 and for 15 minutes in 1975 and 1976 once a week as a rule. Collected were the females which were about to bite the collector and the males which were flying as the swarm around him.

RESULTS

The seasonal changes in abundance of immature stages during three years are given in Fig. 1. In 1974, the vials were placed on April 17, and the first individuals of larvae were encountered as the first instar on June 3. Weekly observations were continued until December 27. In 1975, the observations were made from April 17 to December 26, and in 1976 from April 16 to December 24. In 1975 and 1976, larvae were already present in all the vials when the observations were started in April, and some larvae were older than the first instar. These larvae are considered to have hatched newly in the spring from overwintering eggs, because no larva was found in any vials in the end of January in 1975 and 1976. As the overwintered broods pupated and emerged by the end of May, the immature stages disappeared temporarily until the second broods hatched in early June. Immature stages of the third broods appeared from late June to early July. The fourth and later broods became indistinguishable due to overlapping of generations.

Hight density of immature stages were observed in July and August in all of the three years. The year's maximum number was recorded on July 16 in 1974, August 8 in 1975, and July 15 in 1976. The number of immature stages fell gradually from September and only a few larvae were found in the end of November. Although some of them survived until the end of the year, they died by the end of January in the next year. So, it is not probable that the larvae can survive winter successfully in the Nagasaki area.

To investigate the seasonal changes of the numbers of immature stages in details, the seasonal distributions for each instar larvae and pupae for three years are shown in Fig. 2, 3 and 4. When the observation was resumed in the middle of April in 1975 and 1976, some larvae originated from overwintering eggs were already in the third or fourth instar. Since the young instar larvae disappeared from the end of April to late May from the vials, and in another experiment the eggs oviposited in the preceding fall began to hatch around March 10, overwintering eggs probably hatch from the middle of March to the middle of April in the field.

The remarkable increase in the number of young instar larvae can often be noticed, when the density of larvae and pupae was very high. For example, on August 8, 1976, the greater part was the first instar larvae, and it seems that most of the newly hatched larvae died off without developing even a little, because there was no increase in the number of the

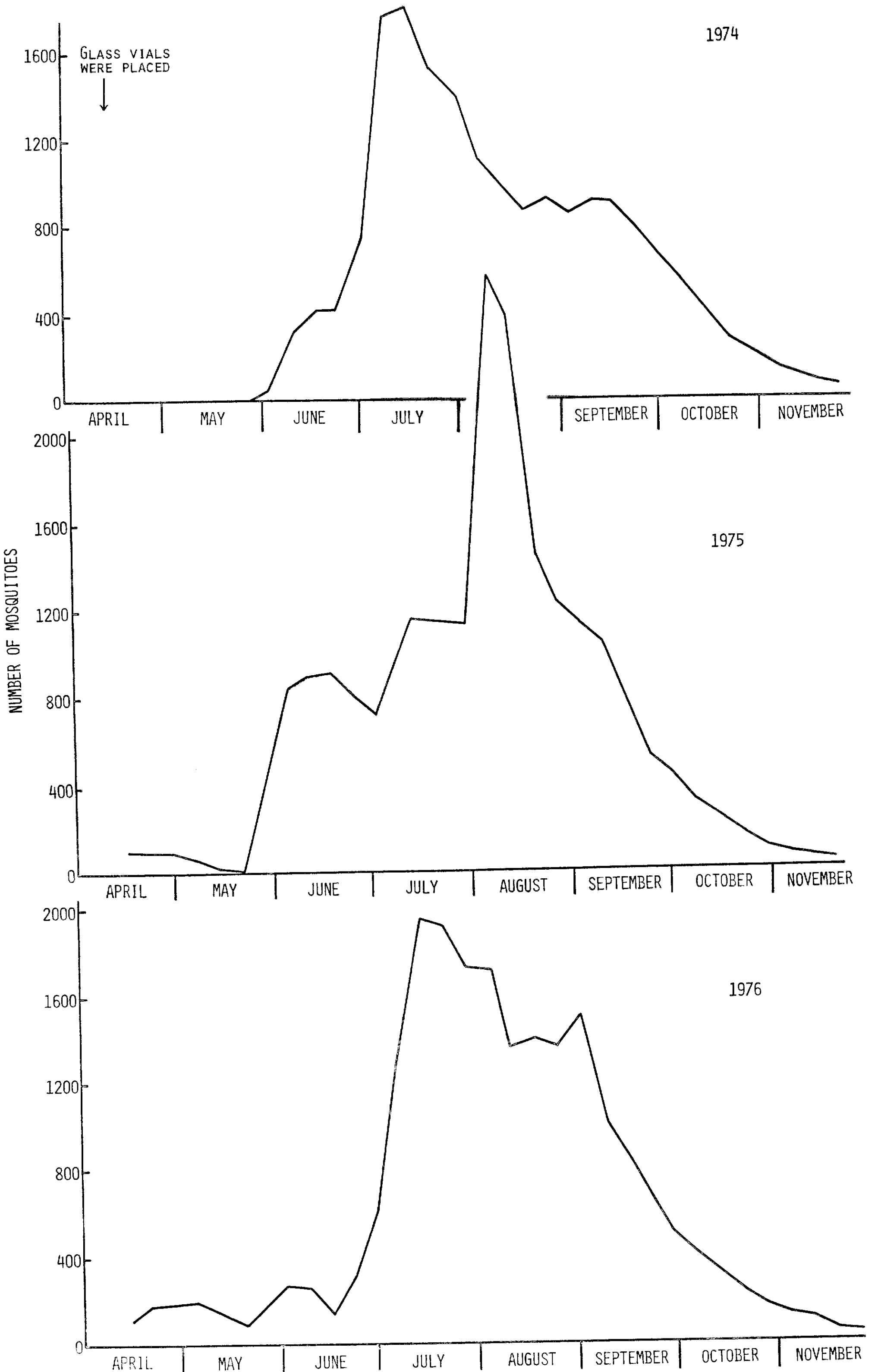

Fig. 1. Seasonal prevalence of larvae plus pupae of *Aedes albopictus* in Nagasaki, 1974–1976.

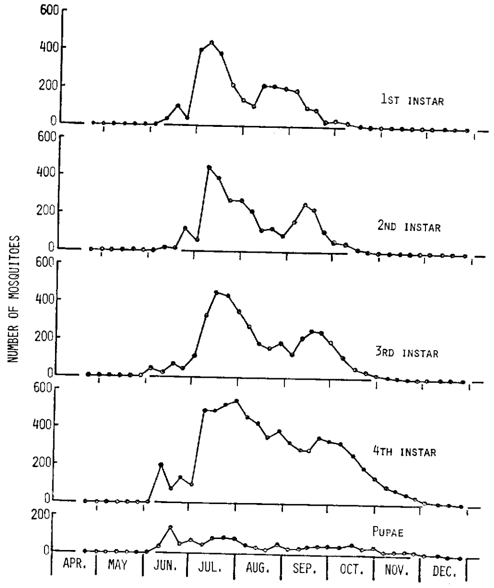

Fig. 2. Seasonal prevalence of each instar larvae and pupae of *Aedes albopictus* in Nagasaki, 1974.

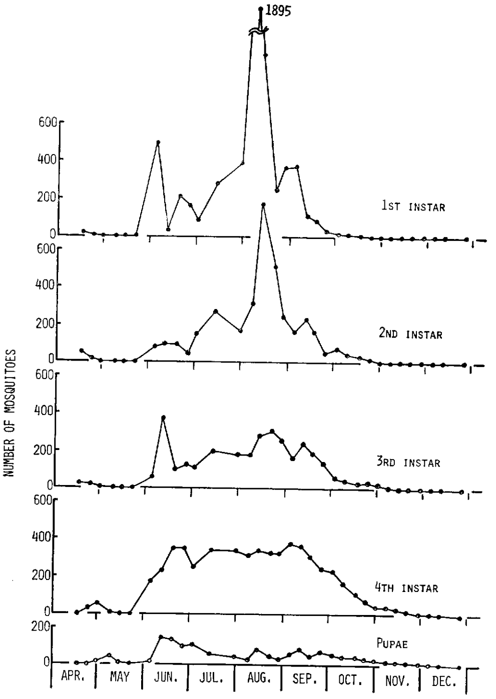

Fig. 3. Seasonal prevaleuce of each instar larvae and pupae of *Aedes albopictus* in Nagasaki, 1975.

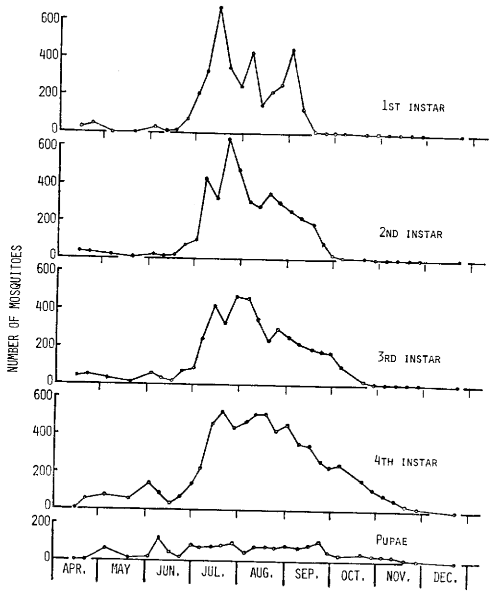

Fig. 4. Seasonal prevalence of each instar larvae and pupae of *Aedes albopictus* in Nagasaki, 1976.

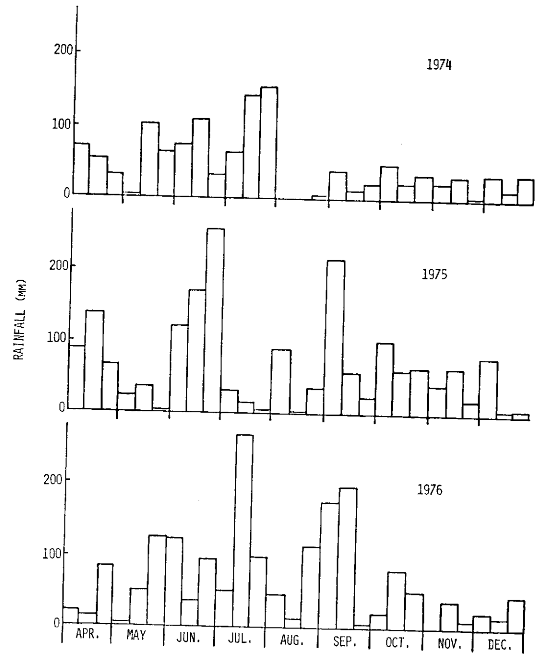

Fig. 5. Ten-day rainfall totals in Nagasaki, April through November, 1974, 1975 and 1976.
Obtained from the Nagasaki Marine Observatory.

third instar or older larvae or pupae corresponding to these first instar larvae, though only a slight increase in the number of the second instar larvae was recognized a week later. The fact that only a very small part of newly hatched larvae were able to develop to the second instar in a week under suitable temperatures of August shows that the development of larvae delayed very much.

The first instar larvae disappeared by the middle of September and the second instar larvae by early October, though, of course, there were minor differences in the time of disappearance among the years. This fact well agrees with the result by another experiment that the diapausing eggs begin to be laid from the middle of September, and do not hatch until next spring.

Since it was considered that the volume of water in the vial greatly influence the population dynamics of the larvae, rainfalls on which the water volume depended were given for three years in Fig. 5. It can be seen that the number of young instar larvae was apparently influenced by rainfalls, that is, many larvae hatched from the eggs deposited on the inside wall of the vial above the water surface, when they were soaked in the water after rain.

The largest number of pupae was observed in early May when the larvae from overwintering eggs pupated. After that, the fluctuations of the number of pupae were far less remarkable than those of the number of larvae.

The proportions of pupae to all immature stages during three years are given in Fig. 6. The proportions were very high in May and June, but low through June to August.

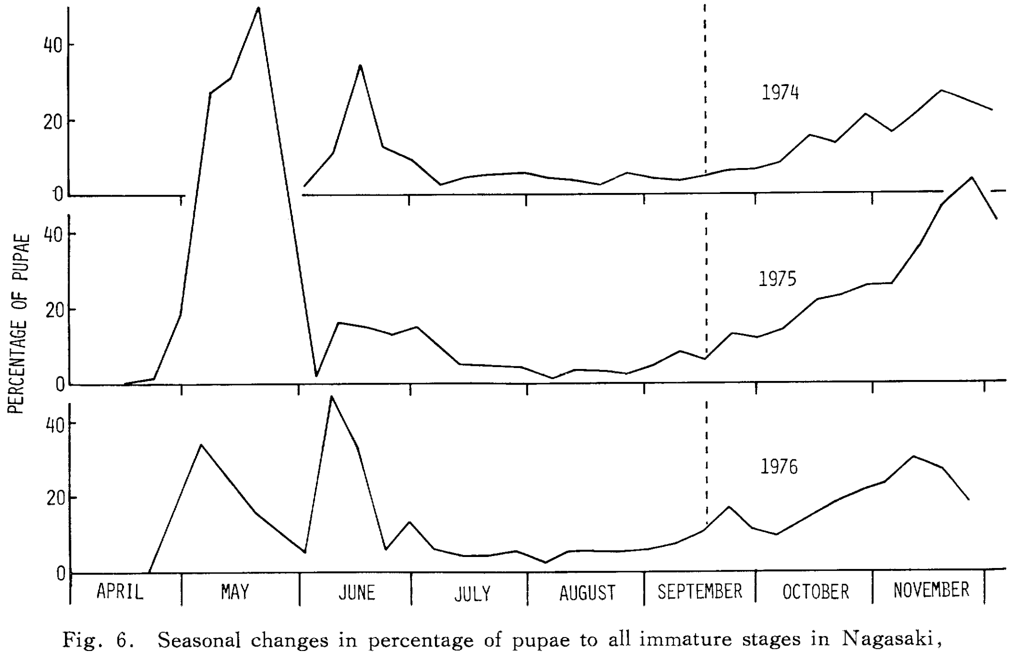

Fig. 6. Seasonal changes in percentage of pupae to all immature stages in Nagasaki, 1974, 1975 and 1976.
Broken line shows the time when the firat instar larvae stopped hatching from eggs due to egg diapause.

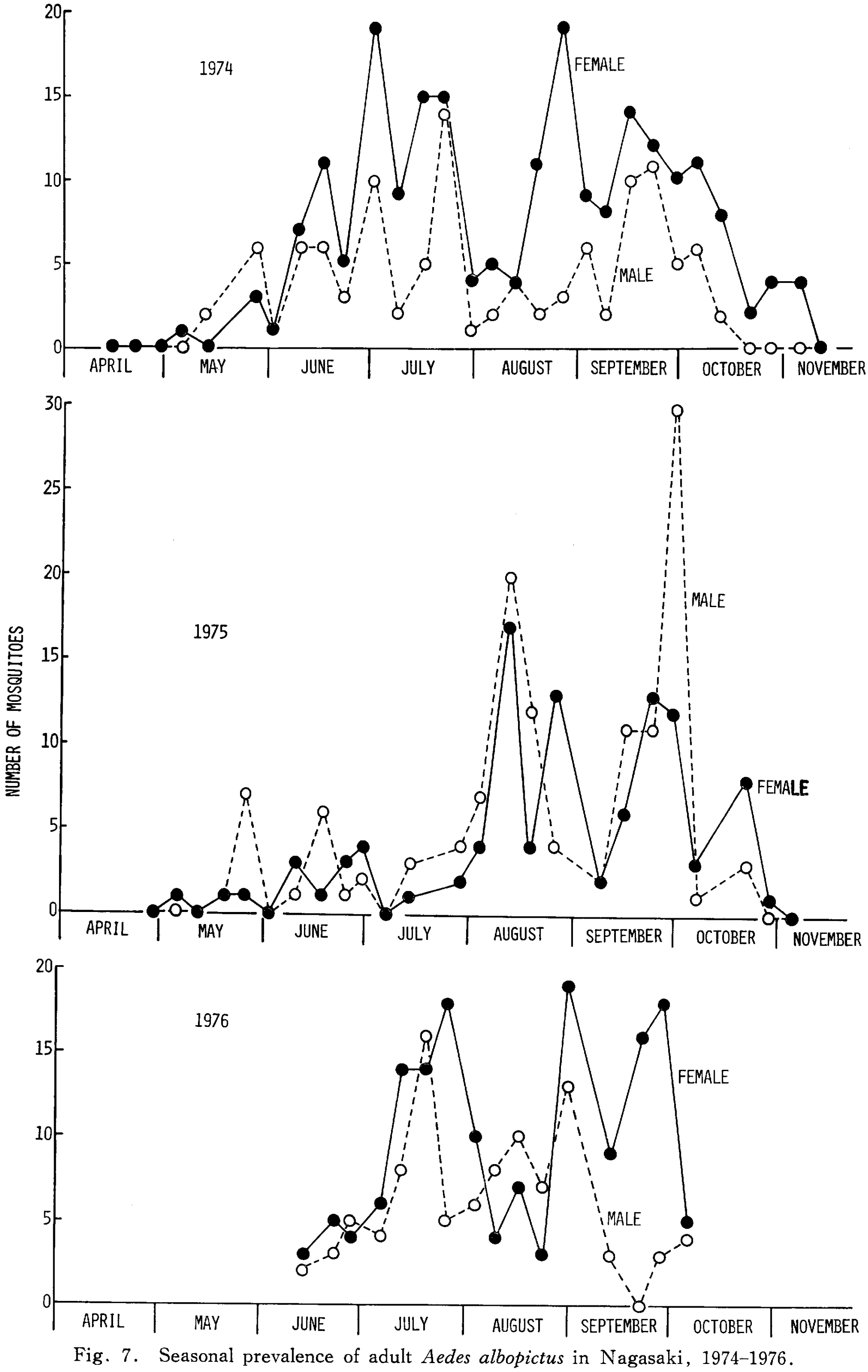

Fig. 7. Seasonal prevalence of adult *Aedes albopictus* in Nagasaki, 1974-1976. Number of mosquitoes collected for 30 minutes in 1974 and for 15 minutes in 1975 and 1976 by human baite catch is shown.

This mid-summer low porportion, which showed nearly the same value in three years, indicates that the survival rate of immature stages in this period was kept lower than in May and June. Since the eggs stopped hatching from September, the proportion of pupae became high again.

To compare the change of the number of immatures stages with that of adults, in Fig. 7 were shown the results of biting collections in the same grove as the immature stages were observed. As most of females of *Ae. albopictus* came to bite or swarm in the first few minutes from the begining of collection, it seems that there were practically no differences between the numbers in the 30 minute and the 15 minute collection. Therefore, the abult density in 1974 (30 minute catch was made) can be compared with that in 1975 or 1976 (15 minute catch).

The first adult during the three years was collected on May 7 in 1974 and 1975, and the last one was on November 7 in 1974. The seasonal changes in the abundance of adults were in agreement with those of pupae only in a general trend. There were some discrepancies between seasonal changes of adults and pupae. This may be due to the reason that only the adults resting within a short distance from the collector were capured, and also the efficiency of collection was greatly influenced by the weather on the day of collection.

DISCUSSION

Aedes albopictus is widely distributed in Asia, from the tropics to Japan in the north. It breeds throughout the year in the tropics, and the seasonal fluctuation of immature stages is closely related with the raintall (Ho *et al.*, 1971). In Japan, this species is distributed in Miyagi Prefecture, located in the northern part of Honshu Island, and southward (Kamimura, 1968). Although it may be possible experimentally for this species to survive through winter in the larval stage in the middle part of Honshu (Ishii *et al.*, 1954), the successful overwintering in the field can be attained only in the egg stage in Japan proper (Abe, 1941; Nakata, 1953; Makiya, 1968). In Amami-Oshima Island, situated in the south of Kyushy Island, the larvae overwintering in the field were found (Takenokuma, 1966), and, in addition, even the adult emergence occurs in winter (Wada *et al.*, 1976).

In the Nagasaki area in Kyushu Island where the present study was carried out, only the eggs can overwinter. The overwintering eggs in the state of diapause are laid by females under a short photoperiod in autumn (Wang, 1966; Imai, 1976), and do not hatch unless they experience winter (Ito, 1959). Therefore, the rain in autumn dose not give any effect on the hatch of eggs. On the contrary, it was often observed that after the rain following several fine days in summer the larvae simultaneously hatched from eggs.

Since the supply of organic matter as food for *Ae. albopictus* larvae is limited in the aquatic habitat like small containers, the larvae eat up the food and fall into an underfed condition readily when the larval density is high (Mori and Wada, unpublished). Ikeshoji and Mulla (1970) showed that harmful substances are producted by the larvae of *Culex pipiens quinquefasciatus* in the overcrowded condition. Also in the case of *Ae. albopictus*, such substances probably exist under high larval density.

Udaka (1959) and Matsuzawa and Kitahara (1966) reported the developing period of *Ae. albopictus* and the developmental zero point of each stage from the results under different temperatures. Udaka (1959) estimated that this species repeats five generations in a year in the Shikoku districts judging by the theory of temperature summation. However, it seems that Udaka's estimate is the maximum number of generations in a year and this is only very rarely realized in the field, because the larval density is usually so high in each container that the developmental period is greatly delayed.

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ヒトスジシマカの季節的消長

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長崎大学医学部構内の独立した林の中に，ガラス容器を自然のままに放置し，3年間にわたって毎週1回それぞれの容器に発生したヒトスジシマカの発育段階と数を調べると共に，同じ林の中で人を囮として成虫の採集を行った．その結果次の事が明らかとなった．長崎では卵のみで越冬し，それは3月中旬から4月中旬にかけてふ化し，羽化は5月上旬から中旬に見られた．第2世代の幼虫は6月上旬，第3世代は6月下旬－7月上旬に現れた．第4世代以降は明確に区別し得なかった．7月中旬から8月上旬に幼虫数は急激に増加し，年間最大の山が形成された．9月中頃からふ化幼虫は減少し，11月からは成虫の羽化もみられなくなり残っていた幼虫，蛹は冬の寒さで死滅した．幼虫数の変動，特にふ化幼虫数には雨量が大きく影響していると考えられる．また幼虫数と発育との関係をみると，春や初夏の低密度の時には幼虫期間は短く生存率が良いのに対し，夏の高密度の時には幼虫期間は長く生存率は低い．これは高密度においては餌の不足あるいは発育阻害物質の生産が密度を抑制するよう働いているものと思われる．その結果，蛹の数には幼虫数のように大きな変動はみられず，一年を通してほぼ安定している．成虫数の変動は蛹の数の変動にほぼしたがっている．野外では夏の高密度期には，好的条件で飼育したよりはるかに長い幼虫期間を要するので，発育零点と有効積算温度から推定された年間世代数は過大評価されていると思われる．

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