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A Study on Seasonal Prevalence of the Populations of the Mosquito Larvae and Other Aquatic Invertebrates in Rice Fields in Korea

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水畓棲息 모기幼蟲 및 其他 無脊椎動物 個體群密度에 關한 調査

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要 約

水畓棲息의 主要 모기幼蟲과 기타 昆蟲의 個體群密度를 調査하기 위하여 京畿道 高陽郡 條里面 廣탄 3里의 一個 自然部落을 調査地域으로 選定하여 1980年 6月부터 9月末까지 週別로 채집을 實施하였다.

1. *Culex tritaeniorhynchus* 幼蟲 個體群密度의 계절적 변동은 다량의 降雨후에 급격한 증가 현상을 보였고 살충제 살포에 대해서 어느정도의 감소 영향을 받았다.

2. *Anopheles sinensis* 幼蟲의 個體群密度는 계절적으로 안정되어 있어 큰 변동을 나타내지 않았으며 강수량과 살충제 살포에 영향을 받지 않았다.

3. Odonata와 Ephemeroptera의 경우는 살충제 살포가 결정적인 억제 요인으로 작용하여 Odonata는 6월 중순의 첫 살포후에, Ephemeroptera는 7월 중순의 두번째 살포후 각각 완전히 자취를 감추었고 그 후 個體群密度의 회복은 불가능 하였다.

4. Coleoptera의 個體群密度는 週別 변동이 심하였으며 이는 主로 살충제 살포에 의한 결과로 해석된다. 살충제 살포 前週와의 비교에 의한 감소율을 보면 Coleoptera는 69.5% (幼蟲 75%, 成蟲 58.3%)였고, Hemiptera의 경우는 75.5%였다.

5. 水畓에 棲息하는 planaria 1種의 個體群密度는 강수량에 영향을 받으며 살충제 살포에 對한 억제효과는 없는 것으로 나타났다.

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INTRODUCTION

Culex tritaeniorhynchus, the vector of Japanese encephalitis and *Anopheles sinensis*, the vector of both malaria and inland-filariasis breed mainly in rice fields, and their feeding habits highly zoophilic so that their vector efficiency totally relies on high population densities. It has shown that there is no effective control measures against adult mosquitoes mainly because of their outdoor feeding and resting habits and the socio-geographical condition. Therefore, studies on population dynamics of immature stages of the vectors are an urgent need, which is considered to be essential for the effective control, and it is of importance to understand the factors regulating natural populations, particularly agricultural pesticides (density independent mortality factor) and predators (density dependent factor) such as fishes, adults and/or larvae of Coleoptera, Hemiptera and Odonata, planaria and many others, which are found in rice fields in Korea.

It is apparent that some natural enemies play an important role in regulating the population densities of the moquito larvae. Wada (1975) carried out the experimental study, showing that either Odonata nymphs or Notonectidae (Coleoptera) larvae, or both are important in reducing *C. tritaeniorhynchus* larvae. Service (1977) collected large numbers of potential aquatic predators from the rice fields and their predatory feeding habits were identified by serological techniques. Quite many species of aquatic animals were found as predators of mosquito larvae, such as 3 species of tadpoles, 4 species of Araneida, 12 species of Coleoptera, 9 species of Hemiptera, 5 species of Odonata and 8 species of Diptera. Among them, the most abundant predators were Coleoptera and Hemiptera which had probably the greatest impact in reducing the *A. gambiae* population. Yu *et al.* (1977, 1979) experimentally proved that native fish *Aphyocypris chinensis* which is very common in rice fields in Korea is an effective predator of mosquito larvae and potential control agent.

The main study objectives were to establish seasonal population density patterns of both the vector mosquitoes and the other aquatic invertebrates including predators, with relation to the agricultural insecticide application, which may provide an essential information on developing effective vector control measure such as biological or innovative control.

MATERIALS AND METHODS

The rice fields, located in front of village of Gwangtan-samri, Byeogje-myeon, Goyang-gun, approximately 15 km north of Seoul were selected for the study area. The fields were divided by plots of various sizes, 735 m^2 in average, and 40 plots of the rice fields (294 m^2 in total) were decided to be studied and each plot was numbered, and of them, 10 plots were randomly selected each time of the survey which was carried out once every week from June to September. In May all the rice fields were dry as not irrigated and in October the water of the rice fields was completely drained out, so that the collections were not carried out. The collections were principally made by two persons each time, but in some occasions done by one person or three. Twenty dips and 3 quadrats were sampled in each of 10 selected plots, so that total 200 dips and 30 quadrats were done each survey, but recording was made by 20 dips and a quadrat bases. Twenty dips were made by dipping once two steps (about 1 meter intervals) along the edge of each plot, starting from a corner. Three quadrats were made at the same edge of each plot, one at a corner and two successive samples with about 10 meter intervals respectively. Each samples collected by 20 dips and a quadrat were all late instar larvae of Dyticidae and Hydrophilidae which were kept in other cups, in order to prevent them from killing and/or eating mosquito larvae during transportation to the labortory.

RESULTS

The result of the seasonal prevalences of aquatic organisms including *C. tritaeniorhynchus* and *A. sinensis* were summarized in Table 1 which was presented by the averagae number per 20 dips and per one quadrat and Figure 1 which was drawn by using total number.

Besides *C. tritaeniorhynchus* and *A. sinensis* which are main target species of the present study, *A. sineroides*, *C. pipiens pallens*, *C. bitaeniorhynchus* and *Aedes vexans* were collected in rice fields during the survey period. They were not dealt here, as their densities were not significant compared to the main two vector species.

The larvae of *C. tritaeniorhynchus* were found from the second week of July and disappeared in the first week of October which was resulted from the complete drainage of the water from rice fields. As shown in figures, the population increases of this species during 13~19 July and 10~16 August were occurred soon after heavy rainfall, which provides much wider and more favorable breeding places. Considerable decreases of the density were shown in the first and fourth week of August, which was probably due to the insecticide application.

The population of *A. sinensis* larvae appeared from the last week of June which was much earlier than *C. tritaeniorhynchus* and kept rather constant seasonal prevalence, showing very small peak in the last week of August and not influenced either by precipitation or insecticide application.

Chironomidae collected in rice fields includes many genera such as *Chironomus*, *Polypedilum*, *Cricotopus*, *Procladius*, *Tanypus* and some others, and most common species found were *Chironomus kiiensis*, *Ch. flaviplumus*, *Cricotopus sylvestris*, *Ablabesmyia monilis*, *Tanypus punctipennis* and some unidentified species. As most of them live at bottom, some of them making nesting tubes in the mud, the number collected by dipping and quadrat should be

Table 1. Seasonal prevalence of mosquito larvae and other aquatic animals by dipping and quarat in rice fields in Korea, 1980

Species	June				July				
	1-7	8-14	15-21	22-28	29-5	6-12	13-19	20-26	27-2
C. tritaeniorhynchus	0	0	0	0	0	1.9	4.8	45.5	39.7
A. sinensis	0	0	0	0.7	2.2	6.0	8.0	26.8	23.6
Chironomidae	5.0	13.1	0.5	3.0	9.7	14.0	6.7	8.5	2.3
Coleoptera	2.5	2.4	0.8	0	1.7	5.5	2.0	0.8	3.5
Hemiptera	3.1	2.7	0.5	0	0.2	0.6	0	0.5	0.3
Ephemeroptera	0	0.4	0	0	0.1	0	0	0	0
Odonata	2.5	3.6	0.2	0	0	0	0	0	0
Fishes	0.2	0.1	0	0.2	0.3	0.1	0.2	0	0.2
Planaria	0	0	0.1	0.1	2.3	2.3	13.6	2.6	0.7
Snails	0	0	0	0.3	0.5	1	4.3	0	4.5

Species	August				September				
	3-9	10-16	17-23	24-30	31-6	7-13	14-20	21-27	Total
C. tritaeniorhynchus	19.3	33.7	180.0	68.5	131.9	71.8	4.3	0.3	618.7
A. sinensis	21.5	25.8	30.9	44.5	19.8	29.8	2.7	0.3	242.6
Chironomidae	0.5	5.0	1.7	3.4	2.6	4.7	0.7	0.4	81.8
Coleoptera	0.9	1.2	4.0	2.4	4.6	4.6	0.5	0.4	37.8
Hemiptera	0	0.3	3.3	0.4	0	0.1	0.3	0.1	12.4
Ephemeroptera	0	0	0	0	0.3	0	0.1	0	0.9
Odonata	0	0	0	0.2	0	0	0	0	6.5
Fishes	0.1	0.3	0.5	0.2	0.6	0.2	0.1	0	3.3
Planaria	0.2	3.0	2.5	0.7	0	1.1	1.0	0.1	30.3
Snails	0	0	6.3	0.5	0.5	0	0	1.3	19.2

* Numbers are indicated by total numbers collected by 20 dips and a quadrat

small proportion compared to the actual density, and is only reliable for the relative density for the seasonal comparison, as the collection methods were uniformly carried out every week. Seasonal change of the population dentity of Chironomidae well coincides with the pressure of the insecticide applications. Each insecticide application causes sharp decrease of the density as shown in Figure 1. The density rapidly increased at the second week of June and sharply decreased next week, which was clearly due to the insecticides, and then began increasing again reaching the peak at the second week of July. The decrease in the third week of July was probably due to the natural pattern of the prevalence, and continuous decrease from the third week of July, the decrease at the early August and the last decrease at the second week of September apparently resulted from the insecticide applications.

The following species in Coleoptera were collected in the rice field habitat during the study period: Dytiscidae-*Cybister japonicus*, *Rhantus sp.*, *Hydaticus* sp., *Agabus* sp., *Laccophilus difficilis;* Hydrophilidae-*Hydrophilus affinis*, *Hydrocyclus* sp., *Enochrus* sp.; Haliplidae-*Peltodytes* sp.. Because the number of each species collected was very low, the population was not observed to species level but to the higher taxon, Order level. Though the seasonal prevalences of larvae and adults observed separately, they were recorded together as their prevalence patterns showed very similar. Both adults and larvae of Coleoptera seemed very susceptible to the insecticide application as densities were markedly decreased whenever the insecticides were applied to the rice fields. The recovery of the population was more rapid in the larvae than adults.

Among Hemiptera, *Sigara substriata* in Corixidae, *Ranatra chinensis* and *Laccotrephesis japonensis* in Nepidae, *Gerris* (*Aquarius*) *paludum* in Gerridae and several species in Notonectidae were collected in rice fields, of which *Sigara substriata* was the most common species. As shown in Table 1 and Figure 1, high density shown in early June was decreased sharply after the first application of pesticides. Thereafter, slow recovery of the populations was shown, but suppressed by the successive applications of pesticides.

Among Ephemeroptera, several species of Baetidae were found. Total 17 species in 5 families (Agrionidae, Lestidae, Gomphidae, Aeschnidae and Libellulidae) in Odonata were collected in rice fields, and most common species with high densities were *Orthetrum triangulare malania*, *Sympetrum striolatum imitoides* and *Sympetrum* sp.. The population of both Ephemeroptera and Odonata species were almost disappeared soon after the first application of pesticides in the middle of June, and not recovered thereafter. It can be explained that they are so susceptible to the pesticides that the populations were dramatically suppressed by the first pesticide pressure, and the duration of their life cycles so long (one year or more) that their new generation did not appear until late summer. The young nymphs of Odonata were found again in late August and of Ephemeroptera in early September, but suppressed and kept low density by the application of pesticides.

The species of planaria found in the rice fields is *Dugesia japonica*, the size of which is rather small. The seasonal prevalence of the population of *D. japonica* were not correlated to the applications. It probably means that this species is not susceptible to the pesticides applied to rice fields. Instead, the population prevalence of this species showed very related to precipitation, appearing the first sharp increase in middle July soon after heavy rainfall and the second increase in middle August again immediately after heavy rain, and both peaks appeared during and/or soon after insecticide application.

Fishes such as *Aphyocypris chinensis*, *Aplochilus latipes*, *Lefua costata* and *Misgurmus* spp. were collected on low number as shown in Table 1 and Figure 1. It is not clear whether the density itself is low or the collection methods are inadequate for fish populations.

Further studies for the fish population densities will be neccessary qualitatively as well as quantitatively. There are some difficulties to be considered for the sampling of

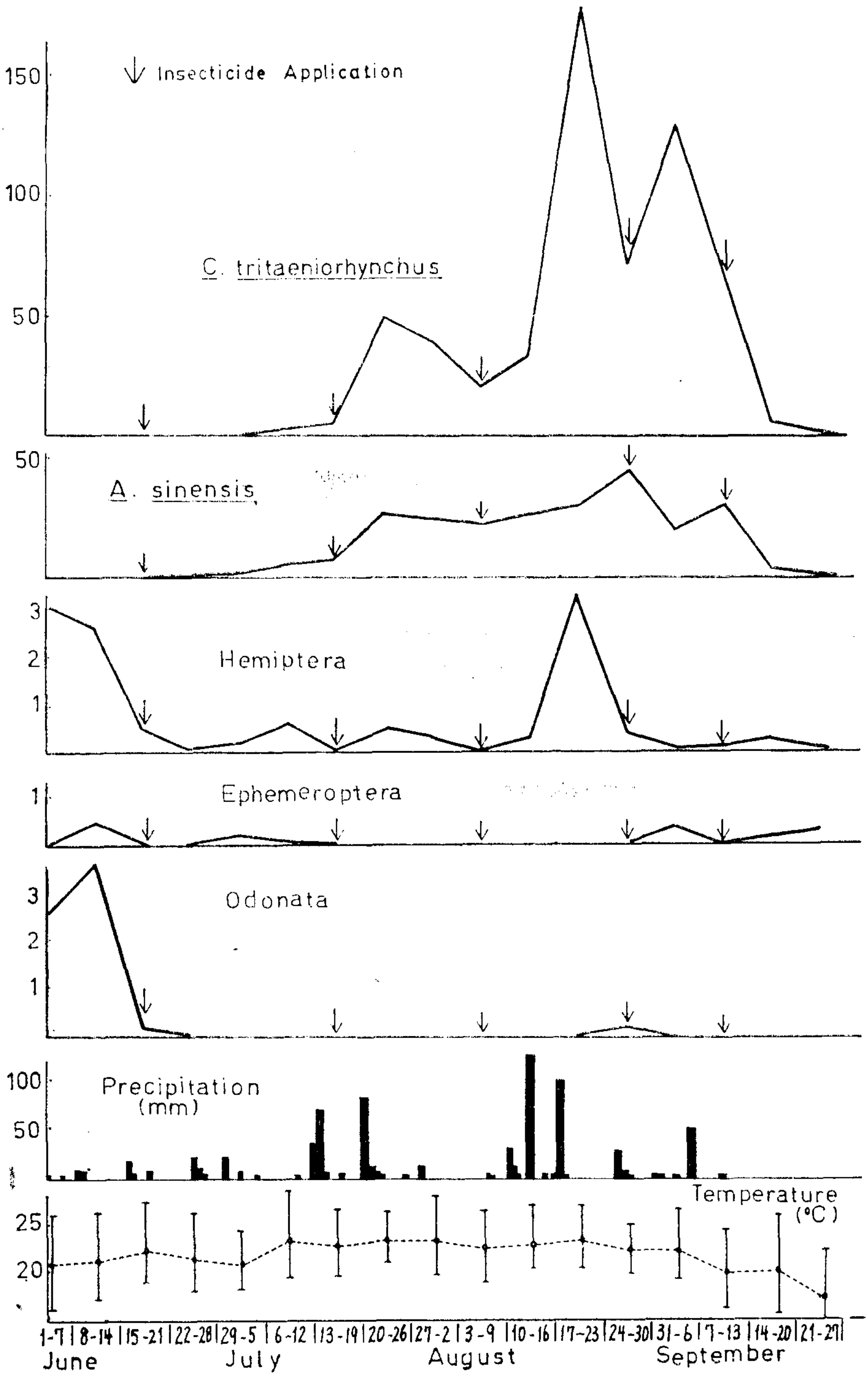

Fig. 1. Seasonal prevalence of aquatic animals in rice paddies

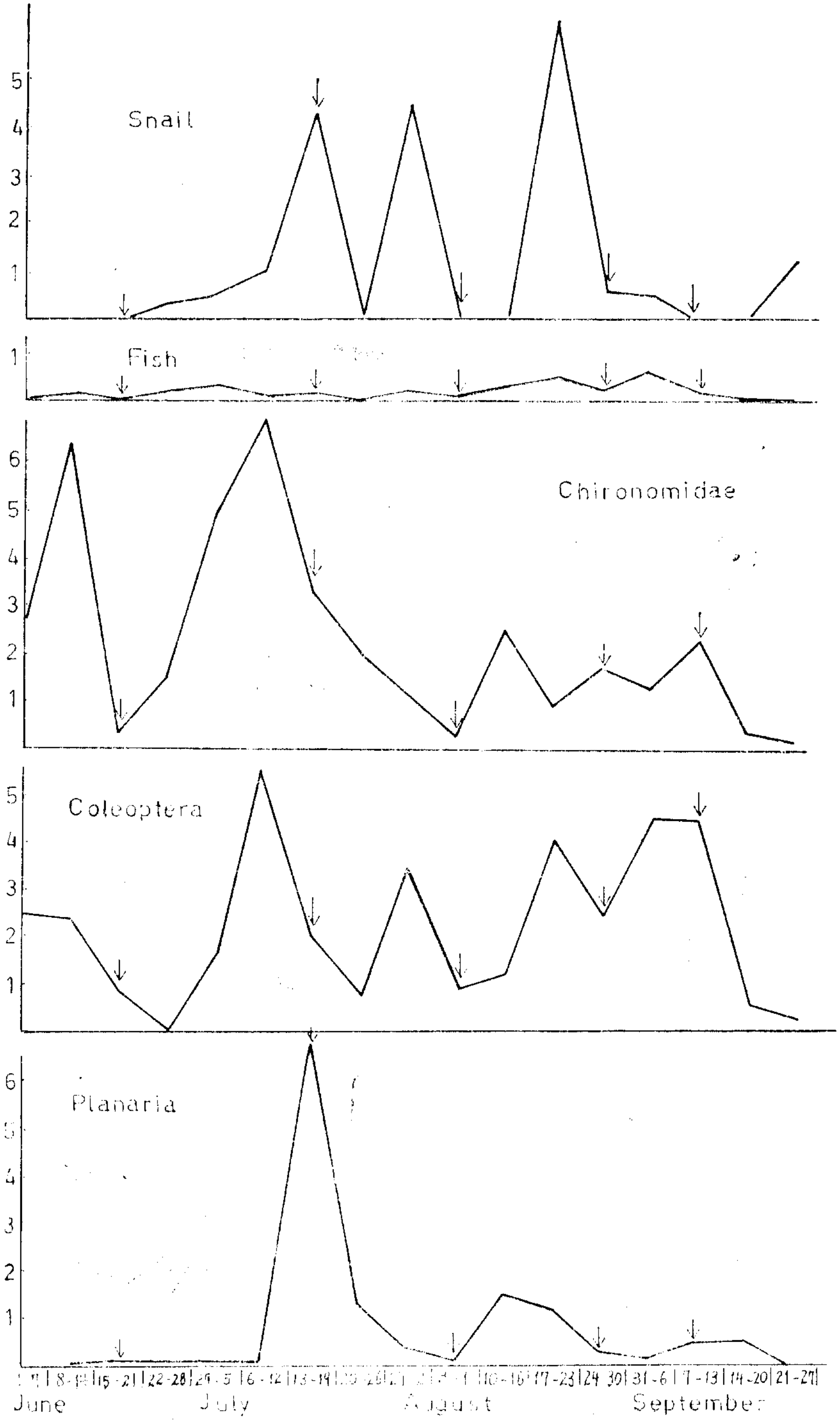

Fig. 1-Continued

fish populations such as gregarious movement, sensitive response to sound of foot steps, etc.

The population density of snails showed great fluctuation as shown in Figure 1. It is not clear whether the fluctuation was due to insecticide pressure or due to the inadequate sampling methods, because of poor knowledge on taxonomy, life cycle, behaviour, susceptibility to pesticides, etc. However, it would probably be resulted from the insecticide treatments, as every decrease of the density was generally correlated to the period of insecticide applictions. Further studies are required.

DISCUSSION

The survey was not aimed to detect changes in larvae abundance or distribution associated with physico-chemical characters of water in rice fields, such as shaded, weedy, pH, DO, etc. Ikemoto and Sakaki (1979) studied that there was only a positive correlation between the number of larvae and the concentration of NH_4-H in the water, among the characters of water such as temperature, water quantity, pH, DO content and NH_4-H concentration. The correlation relations between the larvae density and the other characters of the water were not observed. During the survey, minimum, maximum and average of the temperature and daily precipitation were recorded and compared with the seasonal prevalences of the each taxon, which were not related to the weekly change of temperature.

Both species *C. tritaeniorhynchus* and *A. sinensis* have developed high resistance to most of the pesticides which have been applied to the rice field for many years, so that their prevalences are generally not influenced by the pesticide pressure. However, in case of the former species the pesticide application may act as one of the mortality factors in some degree, as they show still susceptible to some of the common insecticides such as Padan, chlorophyriphos, Quratel and carbaryl (Ree *et al.*, 1979; Ree *et al.*, in press).

There are very few reports on population dynamics of aquatic invertebrates other than mosquitoes, particularly related to the insecticide application in rice fields. Washino *et al.* (1968) evaluated the effects of low volume application of chlorophyriphos (Dursban) on mosquito populations in the rice fields, and aquatic insects other than mosquito larvae such as Hydrophilidae and Dytiscidae of Coleoptera, Corixidae and Noctonectidae of Hemiptera, Baetidae of Ephemeroptera and Odonata were also studied to observe possible effects on them. Their preliminary survey showed that Dursban applied low volume by air for mosquito control, had little or no obvious effects on populations of the non-target aquatic insects. It is not clear whether this was due to low volume application by air, low toxicity of the chemical, or some unknown factors. Service (1977) studied mortalities of *A. gambiae* larvae and other aquatic insects in rice fields in Kenya before and after spraying Dimecron [0, 0-dimethyl-0-(diethylamido-1-chloro-crotnyl) phosphate] applied

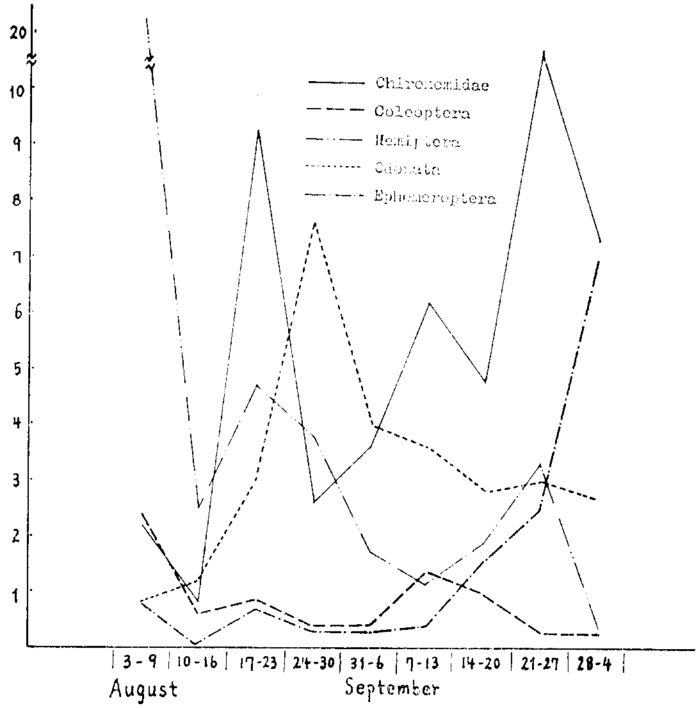

Fig. 2. Seasonal prevalence of aquatic insects in the experimental rice field in NIH.

for the control of rice stem borer. Whereas before spraying there was a very rich and numerous aquatic fauna, exceedingly few live invertebrates remained after spraying. The larval densities of *A. gambiae* 14 days after spraying were significantly larger than prespray densities, whereas aquatic invertebrates were not as earlier. Despite the lack of quantitaive data it is clear that spraying with Dimecron drastically reduced the numbers of aquatic insects and that whereas recolonization was rapid with *A. gambiae*, it was generally less so with other invertebrates.

The results showed that the population of other aquatic invertebrates in rice fields were seriously suppressed by pesticide application, and their recovery was not as same as the previous level or not at all; particularly the population of Ephemeroptera and Odonata nymphs were drastically decreased by the first application of insecticides and never recovered throughout season. This was supported Table 2 and Figure 2 which are the study result of population densities of aquatic insects in the experimental rice field, artificially made in NIH, Seoul. The collection method was not as same as in natural fields, the locality is different and the habitat would not be exactly identical, particularly the size of the experimental rice field not comparably small (2.5 m×2 m), so that the study results of between the natural and experimental rice fields can not be directly compared. Nevertheless, it can be treated as the control field, for pesticides had never been

Table 2. Seasonal prevalence of aquatic insects in the experimental rice field in NIH, August-September 1980 (Number/20 dips)

Species	August					September				
	3-9	10-16	17-23	24-30	31-6	7-13	14-20	21-27	28-4	5-11
C. tritaeniorhynehus	6.2	2.8	5.4	12.8	6.5	7.5	28.2	12.8	12.6	9.6
A. sinensis	21.6	3.2	2.4	9.5	25.1	17.0	26.0	7.3	3.0	0.2
Chironomidae	2.2	0.8	9.3	2.6	3.6	6.2	4.8	10.7	7.3	3.9
Coleoptera	2.4	0.6	0.9	0.4	0.4	1.4	1.0	0.3	0.3	0.2
Hemiptera	22.2	2.4	4.7	3.8	1.7	1.1	1.9	3.3	0.3	0.4
Odonata	0.8	1.2	3.0	7.6	4.0	3.6	2.8	3.0	2.7	3.6
Ephemeroptera	0.8	0	0.7	0.3	0.3	0.4	1.6	2.5	7.0	7.8

applied. The population density of Odonata in the experimental rice field showed sharp increase from middle August and the peak at the last week of August, indicating that the new generation began appearing during this season; the density of Ephemeroptera also showed similar pattern but the increase began from early September, during which the new generation appeared.

SUMMARY

The field studies on the seasonal population prevalences of the vector mosquito larvae and other aquatic invertebrates were weekly carried out in the rice fields located in front of a village of Kwangtan-samri, Byeogje-myeon, Goyang-gun, Gyeonggido throughout mosquito breeding season (June-September) in 1980, and the results are as follows.

The population of *C. tritaeniorhynchus* larvae increased soon after heavy rainfall, and decreased to some extent during the period of the insecticide application.

The seasonal prevalence of *A. sinensis* was rather stable, not being affected by insecticide pressure at all.

The population densities of other aquatic invertebrates in rice fields were seriously suppressed by the pesticide application, and their recovery was not as same as the previous level or not at all: (1) The populations of Odonata and Ephemeroptera nymphs were drastically decreased by the first application of insecticides and never recovered through out season. (2) Coleoptera seemed very susceptible to the insecticide application, as densities were markedly decreased whenever the insecticides were applied. (3) The high density of Hemiptera shown in early June were decreased sharply after the first application of pesticides, and thereafter, some degree of recovery was shown, but suppressed by successive each application of pesticides. (4) A native species of planaria was exceptionally not influenced by the insecticide pressure, and two peaks of the density were appeared during the heavy rainfall.

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