Geo-Eco-Trop, 1977, 3, 169-188

INVESTIGATIONS ON THE AQUATIC FAUNA OF TROPICAL RICEFIELDS WITH SPECIAL REFERENCE TO SOUTH EAST ASIA.

C.H. FERNANDO *

RESUME

Recherches sur la faune aquatique des rizières tropicales, en particulier celle de l'Asie du Sud-Est.

L'Asie du Sud-Est compte environ 70 millions d'hectares de rizières. La plus grande partie de cette surface est irriguée. La présente note envisage la faune aquatique des rizières observées en Inde, Birmanie, Sri Lanka, Malaisie (orientale et occidentale), Indonésie et aux Philippines. Les rizières sont le plus fréquemment des marécages transformés. Elles héritent leur faune de ces marécages, ainsi que des apports saisonniers de celle des systèmes d'irrigation. Les variations de densités et de composition spécifique sont plus marquées dans les rizières que dans les étangs et les marécages. Cette différence résulte des variations du plan d'eau. D'autre part l'utilisation de fertilisants et le nettoiement de la végétation permettent à des espèces d'eau libre ou habitant le sol d'atteindre des densités élevées. Les rizières ont favorisé la propagation des Ostracodes et des Cladocères.

Des études détaillées, à long terme, relatives à l'écologie de la faune aquatique des rizières tropicales sont nécessaires. Elles permettront de dégager des indications précieuses pour l'agriculture et la rizipisciculture.

ABSTRACT

South East Asia has about 70 million hectares under rice cultivation. Most of this area is irrigated. The paper deals with aquatic fauna of ricefields observed in India, Burma, Sri Lanka, Malaysia (East and West), Indonesia and the Philippines. Rice fields are in most cases converted marshes. They inherited the fauna of these marshes and also receive fauna via irrigation system seasonally. The fluctuations in density and species composition are more marked in ricefields than in ponds and marshes, due to fluctuations of the water level. On the other hand the use of fertilizers and the clearing of vegetation enables some open water and soil inhabiting forms to reach high densities. Rice cultivation has resulted in the spread of Ostracoda and Cladocera.

* Department of Biology, University of Waterloo, Waterloo, Ontario, Canada.

Detailed long term studies on the ecology of the aquatic fauna of tropical rice fields are needed. These studies will give data useful to agriculturists and fish culturists.

INTRODUCTION

Rice cultivation is perhaps man's oldest form of intensive agriculture. In South East Asia rice farming is the major agricultural occupation. Rice farming originated in this region and has now spread to other tropical and sub-tropical regions. In 1971 (according to FAO statistics) 70 million hectares were under rice cultivation in South East Asia (roughly the Oriental Region of Zoogeographers). Ricefields have a marked impact on the ecosystem if only because of the high proportion of land occupied and the concomitant irrigation system of canals and reservoirs. However we know very little about the ecology of the aquatic fauna of ricefields apart from cultured fish. Ricefields besides producing rice, yield fish, prawns and crabs for human consumption. This production is essentially aquatic. Also the attention of epidemiologists has been drawn to ricefields because they often serve as breeding grounds for disease carrying mosquitoes, snails and crabs. The job of the epidemiologist is to eliminate if possible or at least reduce these animals to benign levels.

Man has altered marshes and low-lying land into ricefields. As irrigation for this wet crop becomes more sophisticated and cultivation more intensive land at higher elevation is brought into production. The original marshes which could serve as refuges for fauna may be completely eliminated and the colonization of ricefields seasonally may be interrupted. This situation exists in parts of South India and Java. In South India the arid climate has further reduced the fauna in all probability. In Fig. 1. I have shown diagrammatically three stages in rice cultivation from primitive rainfed ricefields to sophisticated irrigation.

The aquatic fauna of ricefields has come from a number of sources. A proportion of the original marsh fauna has survived. However the species composition and abundance of individual species may be changed radically. Thus pest outbreaks of marsh dwelling crabs, tadpole shrimps and Chironomidae have been reported. The use of lift and reservoir irrigation brings into ricefields both running and open water species not normally found in marshes. Forms adapted to temporary habitats may find ricefields which dry regularly very suitable. Ricefields have also received foreign species with imported rice seeds. Tropical species have been reported many times in subtropical ricefields. However there does not seem to be a reverse movement. It is possible that ricefields in the sub-tropics resemble tropical ricefields more than their latitude warrants. This view has been stated by MORONI (1961).

There has been relatively little study of the aquatic ecology of tropical ricefields on a broad basis. In sub-tropical regions however some detailed studies on this aquatic ecosystem have been made e.g. Italy, Jugoslavia, Soviet Union, Hungary

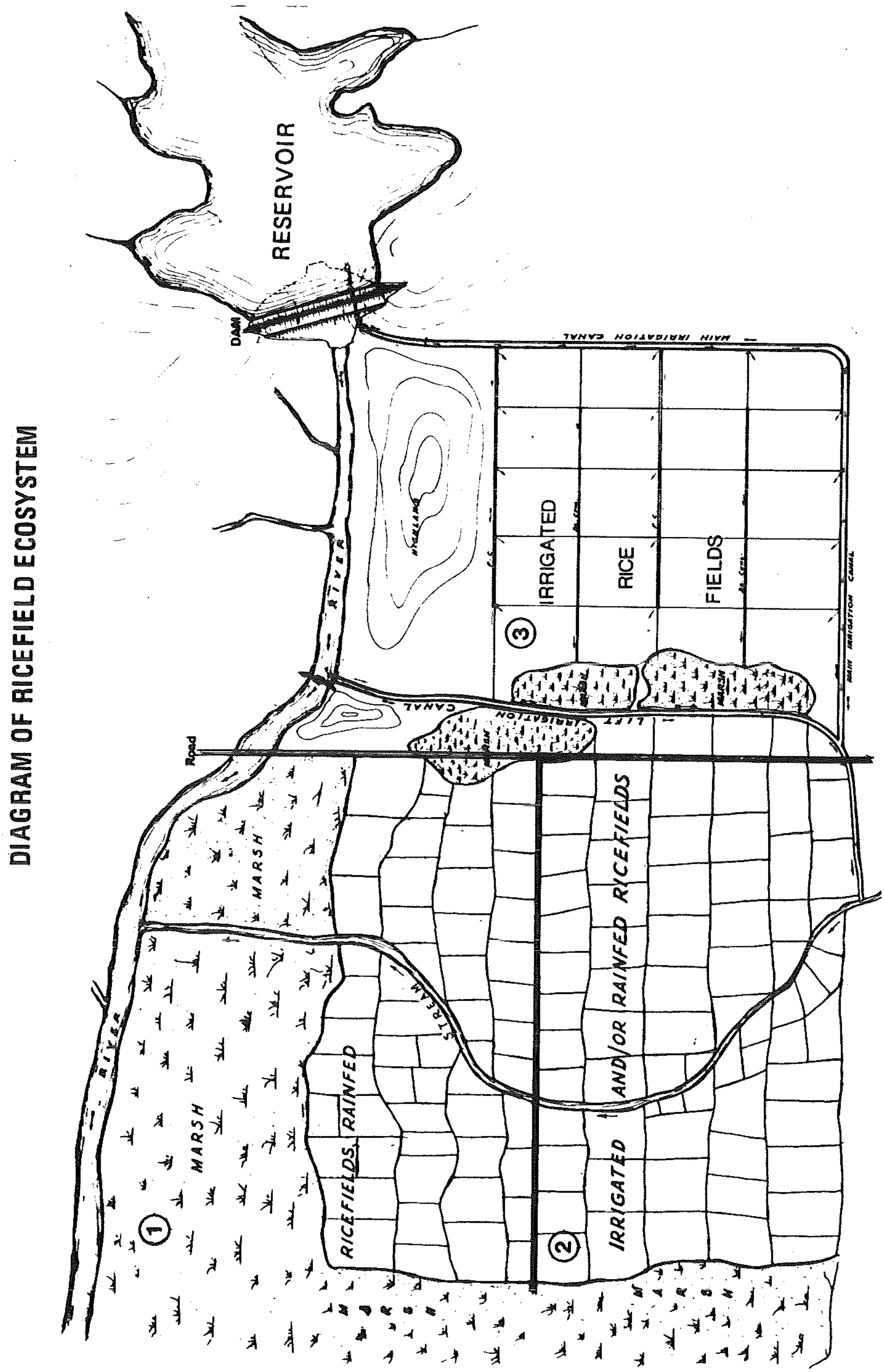


Figure 1 : Diagram of Ricefield ecosystem. 1. Primitive rainfed system 2. Water supplied from river via lift irrigation and 3. Irrigation from stored reservoir supply.

and U.S.A. Although some of these studies are comprehensive workers in one country do not seem to be aware of research done in other regions. There are good reviews of work in the Soviet Union (MUKHAMEDIEV 1960), Italy (MORONI 1961) and Hungary (BERCZIK 1973). FERNANDO and FURTADO (1975) have prepared a provisional bibliography on the aquatic fauna of ricefields.

Most of the literature on the aquatic fauna of ricefields is concerned with pest control. Ricefields have the doubtful distinction of being treated with pesticides and weedicides by agriculturalists and insecticides by vector and biting fly control workers. Both terrestrial and aquatic organisms are targets and most of the chemicals end up in the water where the aquatic fauna (if any survive) live precariously.

Review of Literature

Before passing on to my own investigations I would like to review very briefly some previous work so as to focus on a few important aspects of the aquatic ecology of ricefields. As I have already indicated the literature on the aquatic fauna of ricefields can be divided into those on general ecology and faunal studies, fish culture and pest control. Of the ecological and faunal studies the most comprehensive are studies by MUKHAMEDIEV (1960), MORONI (1961) and BERCZIK (1973). These studies cover most of the fauna and deal with the ecological peculiarities of the ricefield. The "Zooplankton" has been studied, quantitatively by SZABO (1949), KURASAWA (1956), MUKHAMEDIEV (1960), MORONI (1961) and ARIPOV and MUKHAMEDIEV (1966). The dominance of Cladocera and the rapid turnover has been noted. Of the benthic fauna Chironomidae have been studied by DARBY (1960) in the USA, BERCZIK (1973) in Hungary, THIENEMANN (1954) in Sumatra and WEEREKOON and SAMARASINGHE (1958) in Sri Lanka. MUKHAMEDIEV (loc. cit.) and BERCZIK (loc. cit.) deal with the ecology of all the aquatic mesofauna. The little known paper by WEEREKOON and SAMARASINGHE (loc. cit) is the only broad based quantitative study of the benthos of ricefields. The benthos (or wet soil) fauna is rich in Chironomidae, Ceratopogonidae (Heleidae) and Oligochaeta. WEEREKOON and SAMARASINGHE (1958) found an unusually high density of Ceratopogonidae larvae and the dominance of Chironomidae was not so marked in this ricefield as elsewhere. These ricefields had no insecticide treatment and perhaps the low relative density of Chironomidae was due to predation by fish and invertebrates. Generally aquatic oligochaetes are abundant in ricefields. In a personal communication, Dr. Y. KURIHARA of Tohoku University Seqndae, Japan, mentioned that high densities of aquatic oligochaetes are encouraged by organic fertilizers and at high densities oligochaetes can reduce weed growth markedly while increasing the zooplankton production. It is interesting to note that Chironomidae have been recorded as pests in ricefields only in sub-tropical regions (see JONES 1968, BERCZIK 1973). Perhaps natural predators are less effective or not adapted to the ricefield ecosystem in these latitudes.

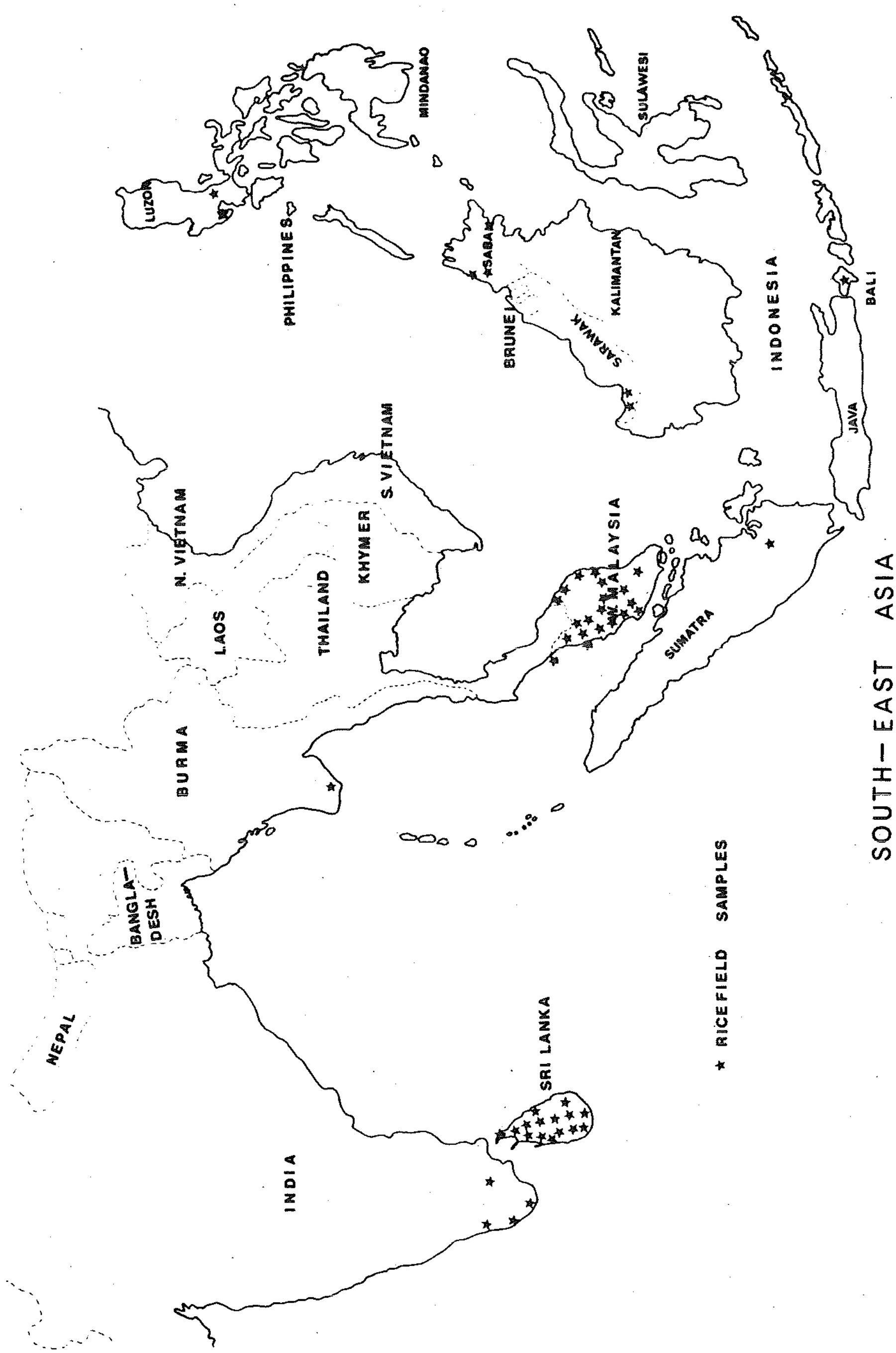


Figure 2 : Areas in South East Asia where samples were collected for study. Each locality marked includes many individual ricefields sampled.

There is a profuse literature on fish culture in ricefields. Most of the important work has been reviewed by COCHE (1967). FERNANDO (1956) gave a bibliography of references to fish in ricefields and noted the great diversity of the fish fauna and the role of the ricefield as a nursery for fish in Sri Lanka. The literature on mosquitoes in ricefields is voluminous but little of this work is ecological in nature. A few papers on ricefield mosquitoes contain useful ecological data. SANDOSHAM (1965) has compiled the data on ricefield mosquitoes for Malaya and PASHISTNOWA (1929, 1935) made a detailed study of the ecology of ricefield mosquitoes. I shall make no attempt to summarize the voluminous work on this subject except to say that some of this literature is useful to aquatic ecologists working on ricefields. Some aquatic pest species have received attention from agriculturists who have used chemicals in an attempt to control them : Crabs (LIM, SAMY and PHANG 1971), Tadpole shrimps (GRIGARICK, LANGE and FINFROCK 1961), Water weevils (BOWLING 1961). FERNANDO (1958) investigated the ecology of fresh-water crabs (Potamonidae) in Sri Lanka ricefields.

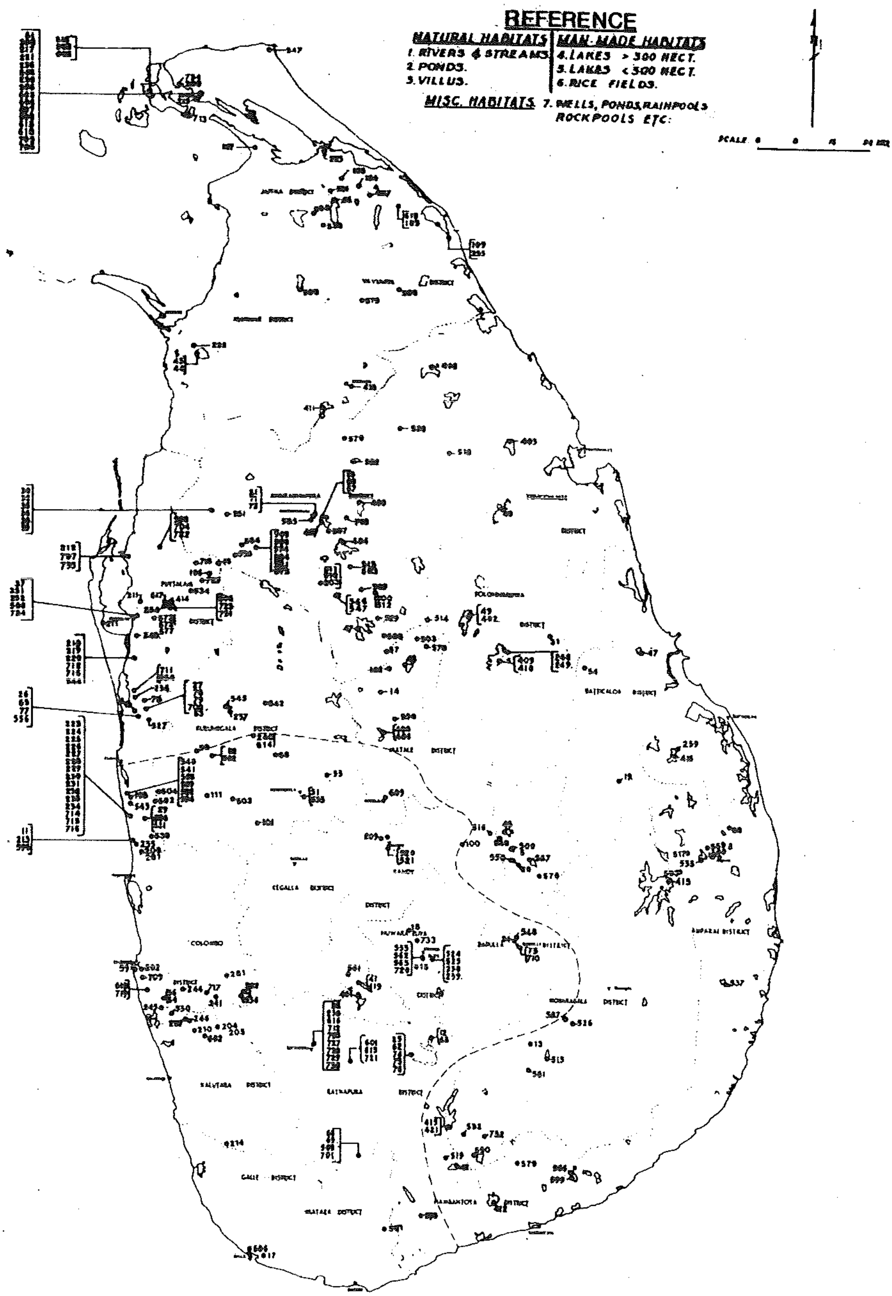
A group of organisms which has received an unusually high degree of attention are the Ostracoda (FOX 1965, MORONI 1966 and GHETTI 1970, 1973 a, 1973 b). Although this work is restricted to the Mediterranean and a small region of Africa, it seems likely that Ostracoda survive the effects of chemicals and intensive cultivation with machinery better than some other groups of aquatic organisms and are therefore abundant and easily available for study. Also GHETTI (1973 b) has found that parthenogenesis is predominant in the Ostracods of ricefield giving a high biotic potential.

Present study

After this brief and very incomplete review of the literature on ricefield aquatic ecology I shall pass now to consider my own investigations. This study was designed to obtain data on the diversity of the aquatic invertebrates of ricefields in comparison to that of other aquatic habitats in the same area. Sampling was done over a wide area in South East Asia in the hope that comparisons of faunal diversity could be made between regions of less and more intensive rice cultivation and human densities. Regular sampling of individual ricefields was done to obtain data on seasonal variation in the diversity of the aquatic fauna and the effects of insecticide use on the aquatic invertebrates in ricefields.

Materials and Methods

The areas where samples were collected are shown in Fig. 2. for the whole of South East Asia and Figs 3 and 4 for Sri Lanka and Malaysia. Samples of aquatic invertebrates were collected using plankton nets with a circular mouth 20 cm in diameter. Two mesh sizes 25 (64μ) and 10 (157μ) were used. Where clogging of the smaller meshed net occured additional samples were taken with the greater one. Fauna was collected usually in shallow water among vegetation and in the



HABITATS SAMPLED SRI LANKA

Figure 3 : Sampling sites in Sri Lanka. Each circle represents a site of collection from rice-fields or other freshwater habitat. In some instances more than one sample was collected at a site at different times of the year.

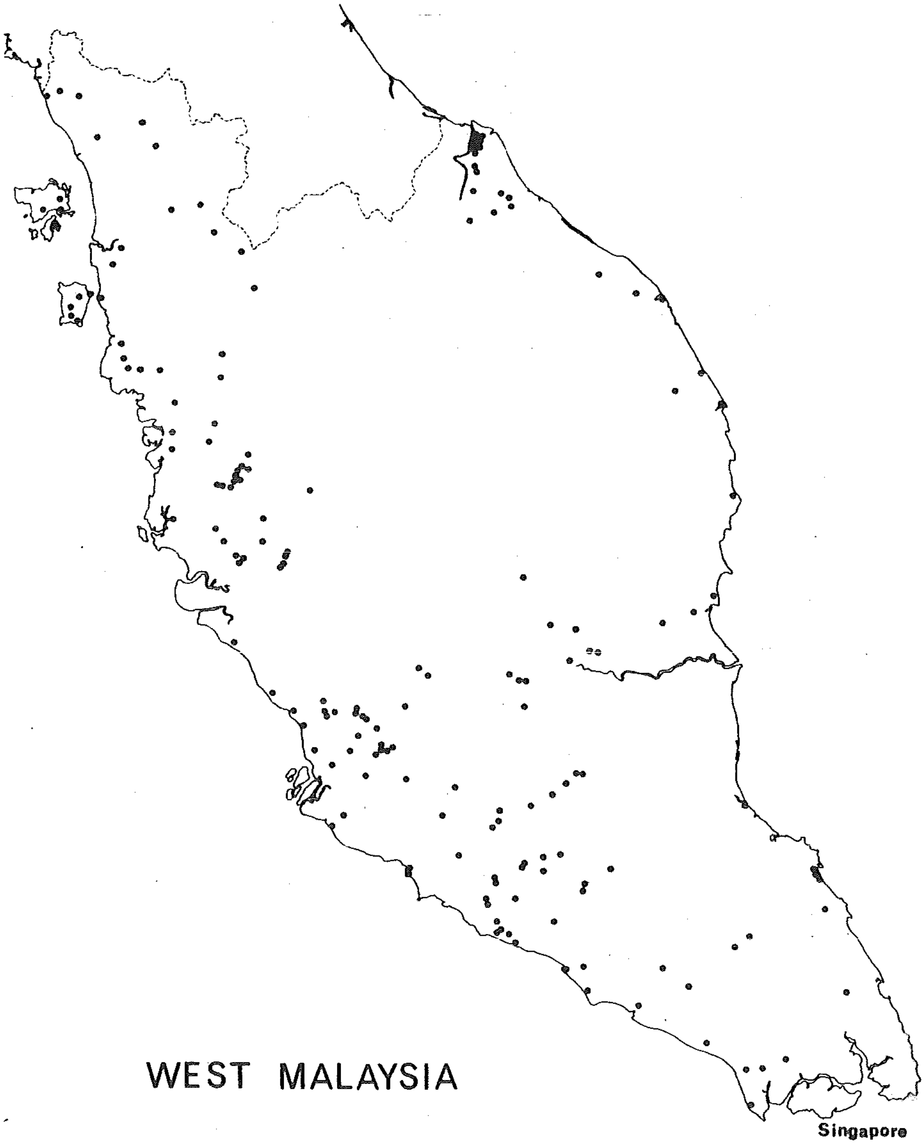


Figure 4 : Sampling sites in West Malaysia. Sites sampled include other types of freshwater habitat besides ricefields. Individual circles often represent more than one sampling site.

open areas. The net was dragged close to the bottom but excessive stirring of the mud was avoided. This sampling technique gives a qualitative sample of shallow water invertebrates living on the mud, among vegetation and in the water column – a situation similar to ricefields. In the case of lakes, reservoirs and rivers plankton nets with the same mesh sizes but with a 25 cm diameter mouth were hauled through the water.

Table 1 : Aquatic Faunal Composition of Ricefields and Other Habitats in Sri Lanka – (Data 1968 – 1973)

Occurrence of species of Rotifera, Cladocera and Copepoda and groups (Phyla) of non Arthropoda eg. Protozoa, Annelida and Arthropoda groups : other Crustacea eg. Conchostraca, Palaemonidae, and Arthropoda orders eg. Coleoptera, Hydracarin.

Habitat / No. Species and Groups		ROTIFERA	CLADOCERA	CYCLOPOIDA HARPACTICOIDA	CALANOIDA	NON-ARTHROPOD PHYLA (GROUPS)	ARTHROPODS OTHER CRUSTACEA AND ORDERS	SAMPLES EXAMINED	% SPECIES AND GROUPS	
									HABITAT	SAMPLE
Villus (marshes)	Total	35	23	4	4	5	6	9	33	
	Av. Range	9.6 4-21	7.2 4-11	1.5 1-2	1.2 0-3	2.2 0-4	2.0 1-4			10.1
Ponds	Total	86	46	10	7	5	7	71	68	
	Av. Range	9.4 0-30	5.5 0-13	2.1 0-5	0.7 0-3	1.2 0-5	1.6 0-6			8.7
Rice Fields	Total	67	38	14	3	4	6	49	56	
	Av. Range	8.0 0-36	6.6 1-15	2.6 0-8	0.3 0-2	1.2 0-4	2.2 0-5			9.0
Lakes >300h	Total	56	25	8	7	5	7	90	46	
	Av. Range	8.8 0-25	4.1 0.13	1.6 0-4	1.3 0-3	0.4 0-4	0.6 0-5			7.1
Lakes <300h	Total	107	41	8	8	6	7	122	76	
	Av. Range	8.9 0-29	3.9 0-16	1.4 0-4	0.9 0-4	0.9 0-6	0.6 0-4			7.1
Misc. Habitats (Man Made)	Total	72	34	10	3	5	6	32	55	
	Av. Range	8.8 1-21	4.6 0-14	2.4 0-6	0.4 0-2	1.3 0-5	1.5 0-3			8.1
Rivers, Streams	Total	37	12	4	1	3	6	6	27	
	Av. Range	9.8 2-19	2.8 0-6	1.7 0-2	0.5 0-1	1.0 0-2	1.3 0-5			7.3
								Total	Average	
Total No. SPP/Group Sri Lanka		136	51	15	9	12	11	379	52	8.1

The species in each sample were listed individually in the case of Rotifera, Cladocera and Copepoda. The other fauna was listed as a group : (a) Non – Arthropod Phyla eg. Protozoa, Annelida, Ectoprocta (b) Arthropod groups : Other Crustacea, orders of insects and Hydracarina.

A rough diversity index was obtained for each type of habitat using this system of listing (Tables 1–3).

Results

Tables 1 and 2 show the diversity of the aquatic invertebrate fauna of ricefields in Sri Lanka and West Malaysia compared to other aquatic habitats. The ricefield fauna has a species diversity very similar numerically to ponds and small lakes (Reservoirs). Ricefields share with these two types of habitats an extensive littoral region but the water in ricefields is shallower and less permanent than in ponds and small lakes. Ricefields are particularly rich in Cladocera and cyclopoid Copepoda. Almost all the species of cyclopoids recorded in these two countries occur in ricefields. A very high proportion of Cladocera also occur in ricefields. Chydoridae are dominant while Sididae like *Pseudosida bidentata* Herrick and *Latonopsis australis* Sars are relatively common. Monidae, Macrothricide and Daphnidae are also relatively common when compared with other habitats. The "typical" zooplanktonic Cladocera like *Draphonosoma excisum* Sars., *Moina micrura* Kurz and *Ceriodaphnia cornuta* Sars are however relatively rare in ricefields.

The rotifer fauna of ricefields is fairly diverse but a closer look shows that apart from common cosmopolitan and cosmotropical forms like *Lecane bulla* Gosse, *Lecane luna* (Muller), *Euchlanis dilatata* Ehrenberg and *Brachionus patulus* (Muller) most of the others are fugitive species. One Conchostracan, *Cyclestheria hislopi* (Baird) a cosmotropical form occurs in ricefields. In most of wet regions of South East Asia this is the only conchostracan recorded. Another feature of ricefields is the high diversity of other non–arthropods (besides Rotifera) and arthropod fauna (besides Cladocera and Copepoda). In this respect ricefields are closely similar to marshes (Tables 1 and 2). Hydracarina were common in ricefields during the fallow period when vegetation is abundant.

Table 3 shows the diversity of the aquatic invertebrate fauna of ricefields in different parts of South East Asia. The most diverse faunas were recorded in West Malaysia, Burma and Sri Lanka. All these areas have abundant natural marshes and relatively high precipitation. The Indonesian and North Borneo samples are few in number and do not reflect the faunal diversity adequately. Also most of the North Borneo samples came from regions where there is little standing water. The faunal diversity is not as great as in the areas mentioned earlier. The Philippines samples from untreated ricefields show a low species diversity except for Rotifera and arthropod groups exclusive to *Cladocera* and Copepoda (Table 3). This suggests a recovery from insecticide treatment. The South Indian ricefields had the lowest species diversity. This is due to the almost complete lack of marshes

Table 2 : Aquatic Faunal Composition of Rice Fields and Other Habitats in West Malaysia (Data 1973–1974)

Occurrence of species of Rotifera, Cladocera and Copepoda and groups (Phyla) of non Arthropoda eg. Protozoa, Annelida and Arthropoda groups : other Crustacea eg. Conchostraca, Palaemonidae and Arthropoda orders eg. Coleoptera, Hydracarina.

Habitat \ No. Species and groups		Rotifera	Cladocera	Cyclopoida Harpacticoida	Calanoida	Non–Arthropod Phyla (Groups)	Arthropods : Other Crustacea and Orders	No Samples examined	°/o Species and groups: Habitat	°/o Species and groups: Sample
Marshes	Total	54	34	10	3	6	7	37	57	
	Av.	7.0	6.7	2.4	0.1	2.0	2.1			10.0
	Range	0-16	0-14	0-6	0-2	0-4	0-5			
Ponds	Total	69	51	13	9	7	7	125	79	
	Av.	6.0	6.1	2.0	0.2	1.6	1.9			9.0
	Range	0-17	0-20	0-6	0-2	0-4	0-5			
Rice Fields	Total	56	40	10	3	6	7	45	62	
	Av.	7.6	8.1	2.8	0.1	2.2	2.5			11.8
	Range	1-29	1-17	1-6	0-1	0-4	0-5			
Reservoirs	Total	41	33	6	6	6	6	19	49	
	Av.	5.1	6.2	1.7	0.6	1.1	1.1			8.0
	Range	0-11	0-15	0-4	0-2	0-3	0-4			
Mining Pools	Total	61	31	7	5	5	6	139	57	
	Av.	5.0	3.7	1.5	0.5	1.0	0.9			6.4
	Range	0-19	0-11	0-3	0-1	0-4	0-3			
Misc. Habitat (Man Made)	Total	52	26	6	1	7	6	18	49	
	Av.	5.7	2.9	1.8	0.1	1.0	1.6			6.6
	Range	0-25	0-13	0-5	0-1	0-4	0-4			
Rivers, Streams	Total	25	30	5	1	6	6	18	37	
	Av.	3.1	4.6	1.6	0.1	1.0	1.4			6.0
	Range	0-11	0-15	0-4	0-1	0-3	0-4			
								Total	Average	
Total SPP Malaysia		92	56	15	11	12	11	401	55	8.2

Table 3 : Faunal Composition of Rice Fields in South-East Asia (Data 1968-1974)

Occurrence of species of Rotifera, Cladocera and Copepoda and groups (Phyla) of non Arthropoda eg. Protozoa, Annelida and Arthropoda groups : other Crustacea eg. Conchostraca, Palaemonidae and Arthropoda orders eg. Coleoptera, Hydracarina.

Area / No. Species and Groups		Rotifera	Cladocera	Cyclopoida Harpacticoida	Calanoida	Non-Arthropod Phyla (Groups)	Arthropoda : Other Crustacea and Orders	No. Samples Examined	REMARKS
Philippines a) Insecticide	Total	2	2	2	0	3	3	13	Fauna Poor, Ostracoda Dominant
	Av.	0.3	0.1	0.5	0	0.5	1.1		
b) No Insecticide	Total	39	11	6	1	3	8	20	Cladocera Few
	Av.	10.1	1.8	1.7	0.1	1.2	2.7		
Burma (Rangoon)	Total	9	14	5	1	3	5	2	Fauna Diverse
	Av.	6.5	10.5	2.5	1.0	2.0	4.0		
Indonesia	Total	24	20	6	2	7	6	11	Fauna Average
N. Borneo	Av.	6.6	3.9	1.7	0.5	2.4	1.8		
S. India	Total	14	11	4	2	4	5	8	Fauna Not Diverse
	Av.	3.0	2.9	1.7	0.3	2.3	2.3		
W. Malaysia	Total	56	40	10	3	6	7	45	Fauna Diverse
	Av.	7.6	8.1	2.8	0.1	2.2	2.5		
Sri Lanka	Total	67	38	14	3	4	6	49	Fauna Diverse
	Av.	8.0	6.6	2.6	0.3	1.2	2.2		

in the area and also the low precipitation. High densities of human population with its concomitant pollution may also be an important factor indirectly reducing species diversity. Hydracarina seem to be adversely affected by the elimination of marsh land resulting from intensive cultivation of rice. Together with the Heleidae they comprise an important group of predators on chironomid larvae. The potential of these and other invertebrate predators for control of aquatic pests in ricefields merits further study.

One group of organisms which perhaps merits mention here are the Ostracoda. In the Philippines samples from insecticide treated ricefields Ostracoda were

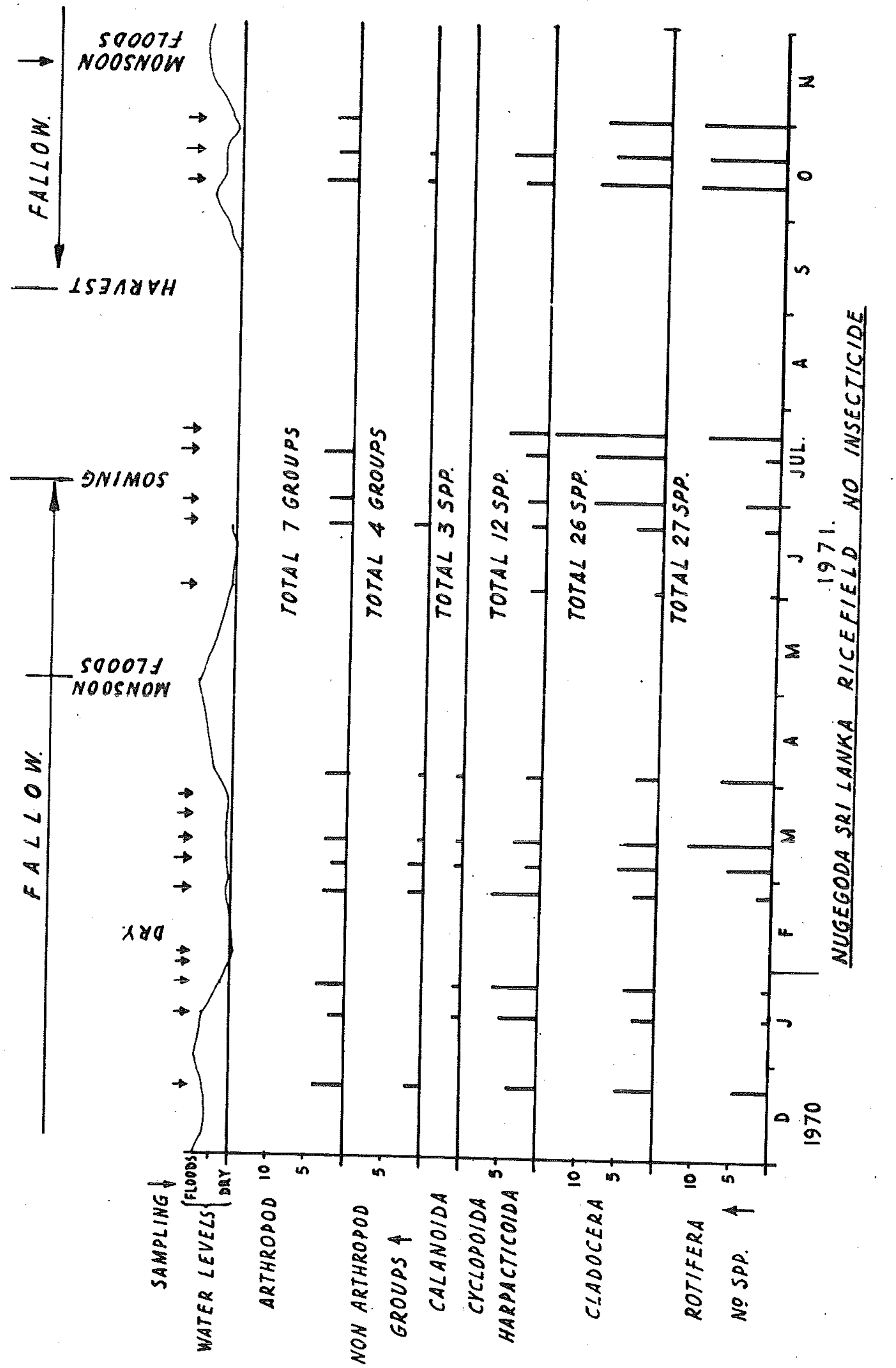


Figure 5 : Seasonal changes in aquatic fauna. Number of species of zooplankton and group of non-arthropods (Phyla) and arthropods : other crustacea, insect orders and Hydracarina.

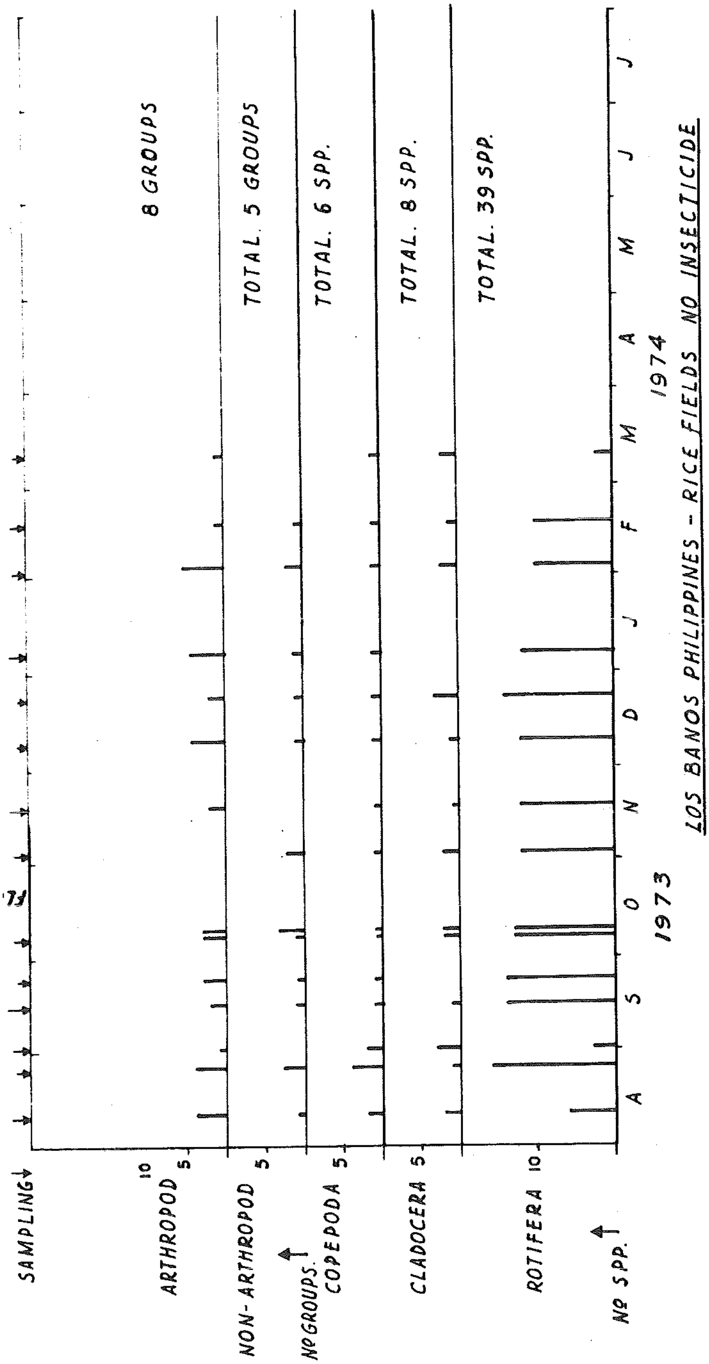


Figure 6 : Seasonal changes in aquatic fauna. Number of species of zooplankton and groups of non-arthropods (Phyla) and arthropods : other Crustacea, insect Orders and Hydracarina.

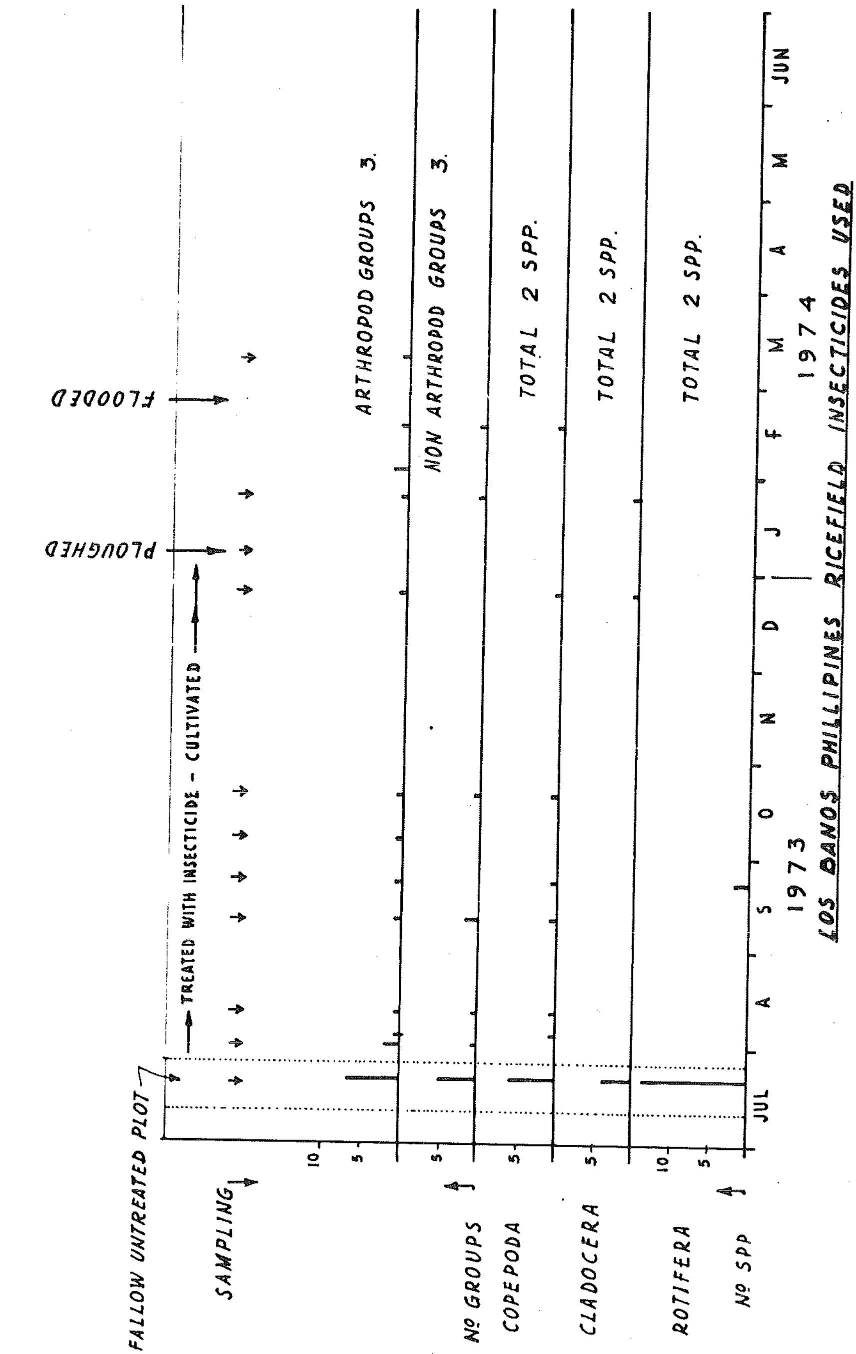


Figure 7 : Seasonal changes in aquatic fauna. Number of species of zooplankton and groups of non-arthropods (Phyla) and arthropods : other Crustacea, insect Orders and Hydracarina.

the only numerous forms recorded. Perhaps they are more resistant to chemicals used for weed and pest control. Unfortunately the Ostracoda in the samples have not yet been identified. Dr. J.W. NEALE of Hull University England has noted 16 species in the ricefield material from Sri Lanka sent to him. He thinks about 10 of these species are new.

Figs 5–7 illustrate the results of regular sampling of individual ricefields in Sri Lanka and the Philippines. The Sri Lanka ricefield was located in Nugegoda, Western Province and is in the wet zone with a precipitation of about 200 cms annually and two monsoons. No chemicals had been used to control pests or weeds. The aquatic fauna is quite diverse considering the number of samples taken (Fig. 5). Drying up of the ricefield eliminated most of the active stages (except in the moist soil) and floods dispersed the fauna so that no sampling was possible. Unfortunately no samples were taken when the rice plants were in the field. The Philippines samples were taken in Los Banos. One of the ricefields sampled was fallow during the sampling period. No insecticides were used at the time of sampling but ricefields in the vicinity were being treated with insecticides. The faunal diversity is not high except in the Rotifera and other crustacean groups besides Cladocera and Copepoda. In fact Ostracoda were the dominant Crustacea. Aquatic insects and non arthropod groups were common. It is likely that this ricefield was recovering from insecticide or receiving residual insecticides from the neighbouring ricefields (Fig. 6). In the ricefield where insecticides were used together with machinary for ploughing, the fauna was very sparse. The only group which was at all numerous was the Ostracoda. (Fig. 7, Table 3). Perhaps I should mention here that I received six samples from insecticide treated ricefields in New South Wales, Australia kindly taken by Dr. Kathleen BOWMER of CSIRO. Only two species of Rotifera and one of Protozoa were found and these appeared to have been dead when the samples were taken.

I have some information on the possible introduction of foreign species into ricefields. Among material sent to me for examination from ricefields in Sendai, Japan I found a tropical calanoid *Tropodiaptomus australis* Sars. Professor N.N. SMIRNOV identified a macrothricid Cladoceran from Sri Lanka I sent him as *Macrotrix shadini* Mukhamediev which had been recently described and recorded in Southern USSR. In both these instances rice seeds could have been a means of transport of tropical forms to subtropical regions.

Summary and Discussion

In general it can be stated that ricefields are converted marshes. Where conditions are favourable and some marsh areas remain the fauna is similar to a marsh fauna. Ricefields also receive and retain faunal elements from flowing and standing waters used for irrigation via rivers and reservoirs. Faunal diversity is adversely affected by elimination of marshes, intensive cultivation and the use of chemicals for control of weeds, pests, vectors and biting insects. From the literature it is clear that a great deal of "chemical control" is in progress. There is however little data on the effects of these chemicals on the fauna. The present investigation has shown that the effects on the aquatic invertebrate are drastic. In West Malaysia a flourishing ricefield fishery has declined very rapidly with the use of insecticides and double cropping (TAN *et al* 1973). A better understanding of the ecology of the aquatic fauna may provide practical means of controlling pests, weeds, and vectors without resorting to drastic chemical remedies.

The impact of introduced fauna (and flora) on ricefields needs further investigation. KOCH (1952) noted that 11 foreign species of flowering plants had been introduced into Italian ricefields. FOX (1965) recorded and commented upon 8 non-European ostracod species in Italian ricefields. More recently GHETTI (1973) recorded 11 additional extra-European Ostracod species in Italian ricefields. MUKHAMEDIEV (1951, 1956) considers that seed rice has been one means of transporting tropical Cladocera into sub-tropical regions of the USSR. MIZUNO and MORI (1970) note the presence of tropical zooplankton species in Japan. These could well have entered Japan with rice seeds. HARDING and PETKOVSKI (1963) discussing the specific status of the sidid Cladoceran *Latanopsis australis* mention that two recently described species of the genus in Japan and Jugoslavia proved to by synonyms of *L. australis*. It seems quite likely that *L. australis was* unfamiliar to Japanese and Jugoslavian workers because it had been introduced recently. Birds have been considered an important agency for the dissemination of microcrustaceans in freshwaters (THIENEMANN 1950, LOFFLER 1963). Perhaps ricefields besides attracting aquatic birds migrant also provide more tropical conditions than the sub-tropical latitude normally warrants.

It has been shown quite clearly that the ricefield aquatic fauna could be as diverse as the natural habitats in the area under certain conditions. Presumably the fauna is also highly productive in biomass. This productivity could be harvested in the form of fish. Also some faunal components have a direct or indirect effect on increasing the yield of rice. This has been demonstrated for fish and oligochaetes. Besides some vertebrate and invertebrate predators can control pests and vectors.

There are many interesting aspects of the ecology of the aquatic ecosystem of ricefields both from purely biological and practical aspects. In view of the importance of rice as a food crop and the potential for fish culture in ricefields the past neglect of ecological studies should be remedied.

Acknowledgements

Many scientists and friends helped in the arduous task of collecting and transporting material from South East Asia. Facilities for my work were provided by many institutions through colleagues. Special mention must by made of the Department of Fisheries, Sri Lanka and the Deputy Director (Research), Mr. A. S. MENDIS; The School of Biological Sciences, University of Malaya and Dr. J. I. FURTADO of that institution; Facultas Perikanan, Institut Pertanian, Bogor, Indonesia and Mr. PONG SUWIGNYO and Dr. A.J. HANSON of this Institute; The Department of Biological Sciences, University of Madurai and Dr. R.G. MICHAEL of the University; The Department of Zoology, University of the Philippines and Professor CARMEN VELASQUEZ and Miss L.B. SILVA of the University; The Department of Fisheries of Sabah and Sarawak, East Malaysia and their respective directors Messrs. CHIN PHUI KONG and ONG KEE BIAN. Individual help in collecting was provided by Dr. ANG KOK JEE, Mardi, Penang; Messrs. LEE KONG THIAN, NASIR MOHAMED ALANG and LIEW KIM SENG, University of Malaya, Kuala Lumpur; Messrs. P.B. KARUNARATNE, P.B. FERNANDO and Mrs R. SELVARAJAH, Sri Lanka and Mr. A.A. SEBASTIAN and Dr. AUNG ZEYA of Rangoon.

Assistance in identification was given by Dr. N.M. SMIRNOV, Moscow; Professor D. G. FREY, Indiana University, Bloomington, Mr. R. CHENGALATH of my laboratory and Dr. J.W. NEALE, University of Hull, England.

Professor Antonio MORONI, Universita di Parma, Italy and Professor O. N. BAUER and Dr. I. AMOSOVA, Leningrad helped with literature. Professor Y. KURIHARA, Tohoku University, Sendai, Japan and Dr. KATHLEEN BOWNER, CSIRO, N.S. W. Australia, sent material from ricefields. Some of the illustrations were prepared by Mr. R.C. K. PIERIS, Toronto, Canada.

Funds for part of this research came from the International Development Research Center, Ottawa under a Research Associateship and the Ford Foundation office in Jakarta through the good offices of Dr. A.J. HANSON. The excellent facilities at the University of Waterloo were a great help in my work.

I wish also to thank the many other people who gave their time and went through considerable inconvenience and expense to help in my work through kindness and tolerance of my unexplained interest.

REFERENCE

ARIPOV, D.A. and MUKHAMEDIEV, A.M., 1966. [Moist weight of the components of the rice fields of the lower reaches of the Amu-Darya river] (Russian). *Vestn. Kara-Kalpak, Filiale Akad. Nauk Uzbek SSR* 1, 47-52.

BERCZIK, A., 1973. Periodische Aspektenveranderungen der zoozonosen aus resifeldern in *Ungarn. Verh. int. Ver. Limmol*, 18, 1742-1750.

BOWLING, C.C., 1961. Chemical control of the rice water weevil. *J. econ. Ent.*, 54, 710-712.

COCHE, A.G., 1967. Fish culture in rice fiels : A worldwide synthesis *Hydrobiologia*, 30, 1-44.

DARBY, R.E., 1962. Midges associated with California rice fields, with special reference to their ecology (Diptera, Chironomidae), *Hilgardia*, 32, 1-206.

FERNANDO, C.H., 1956. The fish fauna of paddy-fields and small irrigation ditches in the Western lowlands of Ceylon; and a bibliography of references to fish in paddy-fields. *Ceylon J. Sci.*, (c) 7, 225-227.

FERNANDO, C.H., 1960. The Ceylonese freshwater crabs (Potomonidae). *Ceylon J. Sci.* (Bio. Sci.), 3, 191-322.

FERNANDO, C.H. and FURTADO, J.I., 1975. A Provisional bibliography of references to the aquatic fauna of ricefields. Waterloo, Canada (Mimeo).

FOX, H.M., 1965. Ostracod Crustacea from ricefields in Italy. *Mem. Ital. Idrobiol. Marco Marchi*, (Pallanza), 18, 205-214.

GHETTI, P.F., 1970. The taxonomic significance of ostracod larvae stages : With examples from the Burundi ricefields. *Boll. Zool.*, 37, 103-119.

GHETTI, P.F., 1973. Dynamique des populations d'ostracodes de douze rizières Italiennes, notes d'écologie. *Ann. stn. Biologique Besse-en-Chandesse*, No 8, 273-294.

GRIGARICK, A.A., LANGE, W.H. and FINFROCK, D.C., 1961. Control of the tadpole shrimp, *Triops longicaudatus*, in California ricefields. *J. econ. Ent.*, 54, 36-40.

HARDING, J.P. and PETKOVSKI, I., 1963. *Latonopsis autralis* Sars (Cladocera) in Jugoslavia with notes on its synonomy and distribution. *Crustaceana*, 6, 1-4.

JONES, E.L., 1968. Bloodworms, pests of rice. *Agric. Gaz. N.S.W.* (Agr.), 79, 477-478.

KOCH, W., 1952. Zur flora der oberitalienischen reisfeldern. *Ber Schweiz. ital. Sci. Nat.*, 71, 179-200.

KURASAWA, H., 1956. [The weekly succession in the standing crop of plankton and zoobenorthos in the paddy field]. (Japanese) Misc. Report Research Institute Natural Resources Tokyo No's 41-42, 86-98.

KURIHARA, Y., 1974. Personal communication.

LIM, G.S., SAMY, J. and PHANG, C.C., 1971. A preliminary study on the control of paddy field crabs with insecticide. *Mardi Crop Protection Research Bulletin* (Kuala Lumpur, Malaysia) 1, 12 pp.

LOFFLER, H., 1963. [Bird migration and the spread of Crustacea] *Verh. dt. zool. Ges.*, 27, 311-316. (Freshwater Biological Assn. Translation).

MIZUNO, I. and MORI, S., 1969. Preliminary hydrobiological survey of some Southeast Asian inland waters. *Biol. J. Linn. Soc.*, 2, 77-117.

MORONI, A., 1961. L'ecosistema di risaia (Monographia). *Ann. Fac. Agraria dell' UCCS*, 31, 1-53.

MORONI, A., 1967. Ostracodi delle risaie Italiane. Studium Parmense 79 pp.

MUKHAMEDIEV, A.M., 1951. [Composition and origin of the faune of Crustacea in paddy fields in the Fergana valley.] (Russian) *Zool. Zh.*, 30, 376-378.

MUKHAMEDIEV, A.M., 1956. [Tropical and sub-tropical species of *Entomostraca Cladocera* from paddy fields in northern Tadzhikistan]. (Russian) *Dokl. AN Tadzh. SSR.*, 17, 25-29.

MUKHAMEDIEV, A.M., 1960. [Contributions to the hydrobiology of the ricefields of the Fergana valley]. (Russian) *Sci. Notes Uzbek. State Pedagogical Inst. Fergana* (Biol.), 6, 1-82.

NEALE, J.W., 1975. Personnal communication.

PASHITNOWA, Z.A., 1929. [Materialen zur erforschung der mikrofauna der reisfeldern und die biologie der *Anopheles*-larvae auf den reisfeldern]. (Russian, German summary). *Acta Univ. Asiae Mediae*, 10, 1-40.

PASHITNOWA, Z.A., 1935. [Micro fauna of a typical ricefield in Samarkand Oasis]. (Russian, German Summary). *Acta Univ. Asiae Mediae*, 18, 1-64.

SANDOSHAM, A.A., 1965. Malariology with special reference to Malaya. Univ. Malaya Press. 349 pp.

SZABO, G.M., 1949. Qualitative and quantitative verteilung der plankton organismen auf reisfeldern. *Rev. suisse d'Hydrobiologie* (1949), 618–622.

TAN, C.E. *et al.*, 1973. A report on paddy and paddy field fish production in Krian, Perak Ministry of Agriculture and Fisheries, Malaysia, Kuala Lumpur. 57 pp.

THIENEMANN, A., 1950. [The transport of aquatic animals by birds]. *Binnengewasser*, 18, 156–159 (Freshwater Biological Assn. Translation)

THIENEMANN, A., 1954. *Chironomus* leben, verbreitung und wirtsschaftliche bedeutung der chironomiden. *Binnengewasser*, Stuttgart 834 pp.

WEEREKOON, A.C.J. and SAMARASINGHE, E.L., 1958. Mesofauna of the soil of a paddy field in Ceylon, Preliminary Survey. *Ceylon J. Sci.* (Bio. Sci.), 1, 155–170.