Applying Four Numerical Methods to Analyze Aquatic Insects Diversity In Rice Fields*

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Abstract: From March 6 to June 5, 1998, aquatic insects were sampled from a biologically controlled rice field (B. F.) and a chemical controlled rice field (C. F.) in Dasha town, Sihui County, Guangdong Province, P. R. China. Forty-three species of aquatic insects were collected. Four numerical methods, Jaccard's coefficient of similarity, coefficient of difference, values of global covering and coefficient of development, were used to evaluate the pollution. The result showed that fauna in B. F. is different from those of C. F. in species richness and abundance. It is suggested that coefficient of development and global covering be more reasonable to assess the water quality of rice fields.

Key words: biodiversity; rice fields; aquatic insects; pollution

CLC: Q968 **Document code**: A **Article ID**: 0529-6579 (2002) 05-0073-04

Benthic invertebrates have often been used to evaluate river or stream pollution. The organisms most commonly used in monitoring quality of stream water are benthic macroinvertebrates, fish and periphyton. Among these organisms, aquatic insects were put in an important position and frequently used to evaluate water quality. In natural streams, there are large number of aquatic insects. These insects function as an important link in the food chain. Aquatic insects may feed on both antochthonous and allochthonous food resources, and they are in turn, feed upon by many fishes[1]. Rice fields, however, are not the same condition. Water in rice fields is shallower than stream and was often drained off. Only those macroinvertebrates with short life circles can live in the paddy fields. The major animal community is macroinvertebrates and microinvertebrates. The water quality, as well as the status of rice fields, can be reflected from invertebrate community. The purpose of this paper is to introduce some numerical methods used in stream pollution studies for evaluating the water quality of rice fields.

1 Materials and Methods

Sampling sites were selected at Dasha town in Sihui county. Dasha is the field experimental station of Zhongshan University for biological control and integrated management of rice pests. Studies for biological control there has been lasting over 20 years and no pesticide was used in biological control fields (B. F.). One patch of B. F. was selected as sampling site. A chemical controlled field in the same area was selected as comparative site (C. F.) in which chemical pesticide was used over two times every years. The two sites were irrigated by the same irrigation canal and the two fields were watered in the same day. The canal sites beside a little village so that some life sewage flows into the canal. As the result, the water for irrigation was somewhat polluted preliminary. In this paper, the pollutant resources are considered only pesticide.

Sampling started from March 6, 1998 after watering the fields and before transplanting rice seedlings. Aquatic insects were sampled with a round collecting net (0.05 m^2, depth 5 cm) which is only for aquatic invertebrates. Fifty nets were taken at one site each time. The died insects and terrestrial insects that fell into water from the rice accidentally were removed. All specimens (larvae, pupae and adults) were preserved in 80% denatured ethyl alcohol. These specimens were made within 48 hours after collecting. The specimens were identified to species and some larvae were identified to general and family level based on keys to aquatic insects in Morse, Yang and Tian[3] and literatures.

Four numerical methods used in the study are as follows: Jaccard's coefficient of similarity was calculated according to the equation:

$$J = \frac{c}{a+b+c}$$

* 收稿日期：2002－03－12
基金项目：生物防治国家重点实验室开放基金资助项目（9707）
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where c is the number of common species in two sampling sites in each collecting time, b is the number of species at site b at each collecting time, and a is the number of species at site a.

The main advantage of Jaccard's coefficient is that sampling sites are compared only qualitatively and avoiding of quantitative data which are difficult to obtain. It also avoids the differences in biomass due to the growth and structure of individual species. Therefore, the coefficient of difference is used here to compare with Jaccard's coefficient

$$\Omega = \sqrt{\sum_1^n (F_{ai} - F_{bi})^2}$$

where n is the total number of species at site a and b at each collecting time; F_{ai} is the percentage of occurrence of species i at site a and F_{bi} is the percentage of occurrence of species i at site b.

Values of global covering (GC) and the coefficient of development (CD) are calculated according to the following equations:

$$GC = 2 \arcsin \sqrt{F}$$

$$CD = \frac{n}{100} \sum_1^n F''_1 * AC_i$$

$$F''_i = 2 \arcsin \sqrt{F_i}$$

where n is the total number of species, F is the percentage of covering of all species at each collecting time for the site considered; F_i is the percentage of covering of species i at each collecting time for the site considered, and AC_i is the number of species accompanying species i.

2 Results

From the two sampling fields, forty-three species of aquatic insects (including larvae, pupae and adults) were collected in which species of Coleoptera are in dominance. Diptera holds the second place. However, it is very interesting that there are 3 species of Ephemeroptera in the two fields. Thirty-one individuals belonging to two genera of Ephemeroptera on April 4 were collected in the filed of B. F., but no one was collected in the field of C. F.. As one of the most important biological indices of monitoring water quality, the collected individuals of Ephemeroptera perhaps indicated that the water in B. F. was unpolluted and no larvae of mayflies suggested that the water in C. F. be polluted.

There was no significant difference in individual number on each sampling date from March 6 to April 4. However, from April 15 to June 5, the difference of the numbers of individuals was significant. The numbers of individuals in C. F. was notably fewer than those in B. F. This suggested that pesticide affect not only the species richness of aquatic insects but also their abundance.

In all samples from the two fields, the following species were only found in the field of B. F. after March 22: *Pantala* sp., *Crocothemis* sp., *Amphiops pedestris*, *Sternolophus rufipes*, *Cybister* sp., *Dytiscus* sp., *Laccophilus* sp., *Coelostoma fabricii*, *Laccophilus flexuosus*, *Rhantus* sp., *Agabus* sp., *Ephemerella* sp., *Cloeoa* sp., *Boreochlus* sp. The following species were only found in the field of C. F. after March 22: *Guignotus licenti*, *Guignotus trassearti*. *Enithares* sp. *Sphaerodema rusticus*, *Chironomlus* sp., *Culex* sp. 1 and *Beroechlus* sp. were common species in both fields.

The similarity of the two fields was overally decreased from time to time and was lowest in April 4 (Fig. 1). This is due to a large number of Ephemeroptera species occur. Considering the similarity index and the coefficient of difference together, the two indices gave the similar result. As the time passing the similarity going reduce and the difference getting increase overally (Fig. 1).

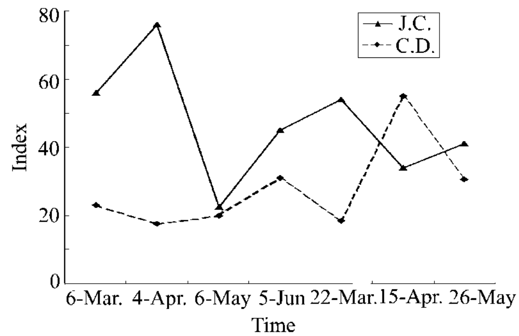

Fig 1 Coefficient of similarity and difference
J. C. for Jaccard's coefficient of similarity
C. D. for coefficient of difference

The values of GC and CD in the field of B. F. were higher than those in C. F. at each sampling time (Fig. 2, 3). In the first two sampling dates (March 6 and March 22) the values of CD in B. F. were only a little bit higher than in C. F.. However, from April 4 to June 5 the values of CD in B. F. were conspicuously higher than in C. F.. The two analyzing results along with the results of analyses of Jaccard's coefficient of similarity and coefficient of difference showed that the conditions for aquatic insects in B. F. is better than those in C. F., which suggested the C. F. were polluted by the pesticide.

3 Discussion

Lenat[2] divided the aquatic insects tolerance values (modified from work of Hilsenhoff) to 10 levels. In his division Hemiptera and most Coleoptera are not assigned tolerance values "because of their mobility and their air-breathing ability, which make their presence in a waterway somewhat independent of the presence of pollutants". To adults of Coleoptera, the thought perhaps is right.

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Tab. 1 The species and numbers of aquatic insects in the two fields (from March to June, 1998)

Species	Mar. 6		Mar. 22		Apr. 4		Apr. 15		May. 6		May. 26		June 5	
	B. F.	C. F.	B. F.	C. F.	B. F.	C. F.	B. F.	C. F.	B. F.	C. F.	B. F.	C. F.	B. F.	C. F.
ODONATA														
Neurobasis ap.	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Coelicca sp.	2	0	1	0	0	0	0	0	0	0	0	0	0	0
Pantala sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Crocothemis sp.	0	0	0	0	0	0	1	0	0	0	0	0	0	0
COLEOPTERA														
Berosus chinensis	2	5	1	3	0	0	0	0	0	0	0	0	0	0
B. japonicus	0	4	1	2	0	0	0	0	0	0	0	0	0	0
B. pulchellus	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydrochus annamita	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Enochrus sp.	4	9	1	3	0	0	0	0	0	0	0	0	0	0
Regimbartia attenuata	3	0	3	1	0	0	2	1	1	0	3	0	1	0
Helochares sp.	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Paracymus orientalis	12	5	1	4	0	0	0	0	0	0	0	0	0	0
Canthydrus sp.	3	1	2	0	0	0	0	0	0	0	0	0	0	0
Guignotus licenti	2	15	8	12	0	1	0	0	0	0	0	0	0	0
Amphiops pedestris	0	0	0	0	1	0	0	0	5	0	0	0	0	0
Sternolophus rufipes	0	0	0	0	0	0	5 (P.)	0	2	0	0	0	0	0
Cybister sp.	0	0	0	0	4 (L.)	0	0	0	0	0	0	0	0	0
Dytiscus sp.	0	0	0	0	2 (L.)	0	0	0	0	0	0	0	0	0
Laccophilus sp.	0	0	0	0	1 (L.)	0	0	0	0	0	0	0	0	0
L. flexuosus	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Rhantus sp.	0	0	0	0	2 (L.)	0	0	0	0	0	0	0	0	0
Agabus sp.	0	0	0	0	0	0	1 (L.)	0	0	0	0	0	0	0
Guignotus trassearti	0	0	0	0	0	0	0	0	0	1	0	0	0	0
G. regimbarti	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Coelostoma fabricii	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Carabidae 1 sp.	1	2	0	1	0	0	0	0	0	0	0	0	0	0
HEMIPTERA														
Diplonychus rusticus	0	1	0	0	0	2	4	1	1	7	4	4	0	0
Enithares sp.	0	0	0	0	0	0	32	12	25	15	51	8	4	2
Nepa sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Sigara sp.	0	0	0	0	0	0	0	0	1	3	0	1	3	1
EPHEMEROPTERA														
Ephemerella sp.	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Cloeon sp.	0	0	0	0	29	0	0	0	0	0	0	0	0	0
Baetis sp.	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Ephemeridae sp.	0	0	0	0	0	0	0	0	3	2	0	0	0	0
DIPTERA														
Chironomus sp.	18	4	12	3	16	29	0	0	3	0	0	0	0	0
Kiefferulus sp.	2	0	0	0	12	17	0	0	0	0	0	0	0	0
Chironomidae sp. 1	0	0	0	0	0	0	5 (P.)	3 (P.)	0	0	0	0	0	0
Chironomidae sp. 2	0	0	0	0	0	0	0	0	10	2	2	8	0	0
Tampus sp.	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Culex sp. 1	4	0	2	1	21	26	0	0	0	0	0	0	0	0
Culex sp. 2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Anopheles sp.	0	0	0	0	0	8	0	0	0	0	0	0	0	0
Tipula sp.	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Total individuals	46	49	36	31	90	85	52	17	55	34	60	21	13	3
Species number	14	12	11	10	10	7	9	4	13	10	4	4	4	2

B. F. = Biologically controlled field; C. F. = Controlled field; (L.) = Larvae; (P.) = Pupae

Larvae and pupae, however, are usually affected seriously by pollutants due to their living in a relative small stagnant water area. Usually, larvae don't move from one water area to another. There is no doubt that the pollutants in the water in which larvae live affect their hatching, growing and the rate of death. Pupae and eggs are the same as larvae. In this study, 4 pupae of *Sternolophus rufipes*, 4 larvae of *Cybister* sp., 2 larvae of *Dytiscus* sp., 1 larva of *Laccophilus* sp., 2 larvae of *Rhantus* sp. and 1 larva of *Agabus* sp. are collected in the field of B. F. but no any larva or pupa of Coleoptera is found in the field of C. F..

Another factor that is different in rice fields from in rivers and streams is that each rice field is separated from

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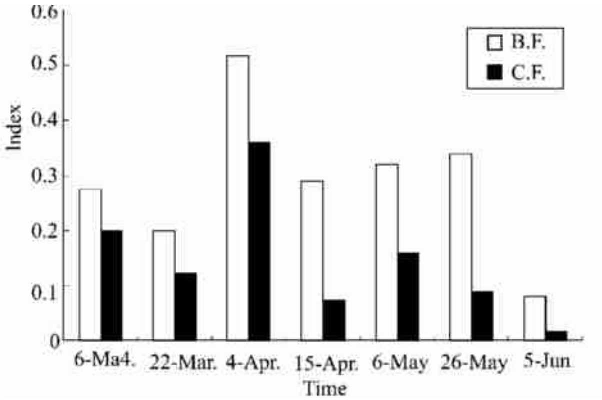

Fig. 2 Values of global covering

B. F. for biological control field; C. F. for chemical control field

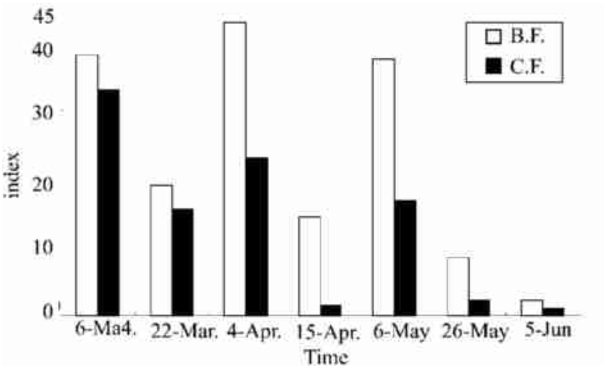

Fig. 3 Values of coefficient of development

B. F. for biological control field; C. F. for chemical control field

another field by a low bund between fields. These low bund prevent the larvae moving from one field to another field. Each small field closed by low bund has a relative stable fauna of aquatic insects unless heavy rain falls and irritations. As a result, every small field keep its own fauna of aquatic insects for a relatively long time. During this period, individuals including larvae, pupae, eggs and adults rarely have chance to move to another field. In this condition, Hemiptera and Coleoptera can be acted by pollutants even though they have mobility and air-breath ability.

A popular hypothesis is that polluted streams often exhibit a reduced number of species with great abundance and unpolluted streams exhibit the converse. This is not the same in rice fields. The numbers of aquatic insects in C. F. is only somewhat fewer than in B. F. and the numbers of species in C. F. is 3 species fewer than in B. F. on March 4. In B. F. there is 5 species of Coleoptera, 2 species of Ephemeroptera, and 3 species of Diptera. In C. F. there is only 1 species of Coleoptera, 1 species of Hemiptera, and 5 species of Diptera. Converse to B. F. with more species of Coleoptera and Ephemeroptera, C. F. has more abundant of Diptera in both species and quantity. This indicated that larvae of Coleoptera and nymphs of Ephemeroptera be more sensible to pollutants and the larvae of Diptera are more resistant to pollutants. From April 15 to June 5, the species from B. F. are more than species from C. F. and the popular species, Enithares sp. has greater abundance in B. F. than in C. F. The difference in number of other species between the two fields is small.

Rivers and streams are dominantly polluted by organic materials which have lower toxicity than pesticide. The species with high tolerance to organic pollutants have opportunities to develop their population. Rice fields are dominantly polluted by pesticide. The species, such as *Cloeoa* sp., *Cybister* sp. (larvae) and *Sternolophus rufipes* (larvae and pupae), which are sensible to these pollutants can't live in the fields when the concentration of pesticides gets to some degree. These pollutants also kill many individuals of species which are relatively tolerated to pesticides. This may be the reason that the numbers of individuals of *Enithares* sp. are distinctly fewer in C. F. than in B. F.

Although the 3 figures clearly reflect the C. F. is polluted more serious than B. F., the analyses are not always regular in all studies. It is possibly affected by the rains and irritations. The affection will be further studied in the future.

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应用四种数值法研究稻田水生昆虫多样性

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摘 要：对 1998 年 3 月 6 日至 6 月 5 日从广东省四会县大沙镇生物防治稻田和化学防治稻田采集到的 43 种、519 只水生昆虫的分析研究。用 Jaccard 相似性指数、相异性指数、总体覆盖指数和发展相关指数四种生物多样性指数进行分析。结果显示，生物防治稻田和化学防治稻田在物种丰富度和总体丰富度上均有不同。分析显示，用总体覆盖指数和发展相关指数评价稻田水质更好。

关键词：生物多样性；稻田；水生昆虫；污染 中图分类号：Q968

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