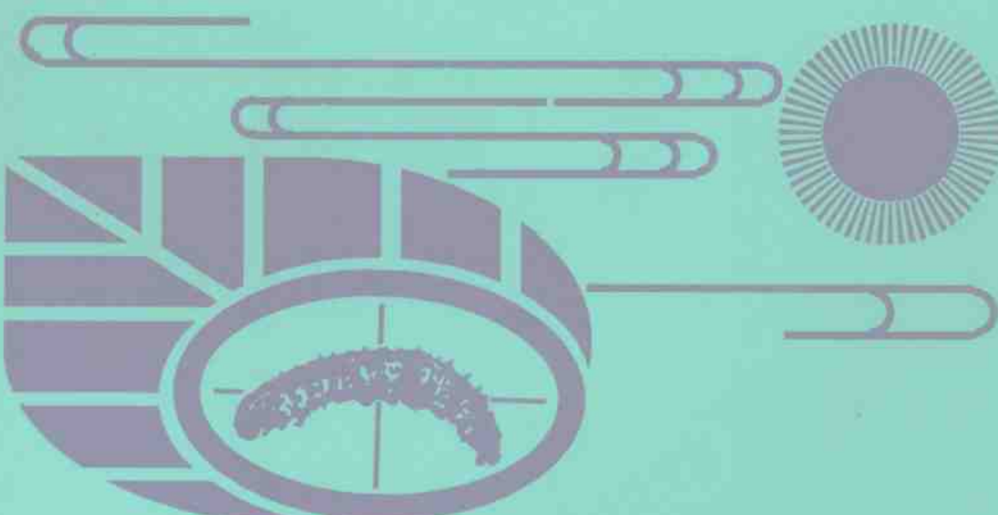
青年生态学者论丛(二)
TRANSACTIONS OF THE ECOLOGICAL SOCIETY OF CHINESE YOUTHS Vol. 2

昆虫生态学研究

SPECIAL ISSUES ON INSECT ECOLOGY

中国生态学会 青年研究会
北京农业大学有害生物综合防治研究所 编



中国科学技术出版社

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内 容 提 要

本文收集了昆虫群落生态学、种群生态学、个体生态学、植物—昆虫相互关系、 作物抗虫性、昆虫迁飞、经济阈值、昆虫种群数量研究技术、昆虫数学生态学、 医学昆虫生态学、专家系统等有关领域的研究论文和专题综述69篇， 反映了我国近年来昆虫生态学研究的前沿内容。本书对于昆虫生态学研究人员、高等院校师生及植物保护工作者都有重要的参考价值。

(京)新登字175号

《青年生态学者论丛》(二)

昆虫生态学研究

主　　编：万方浩　夏云龙
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中国科学技术出版社
(北京海淀区白石桥路32号)
科农胶印厂　印刷

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开本：787×1092毫米 1/16　印张：23　字数：686千字
1992年12月第1版　1992年12月第1次印刷
印数：1～1500册　定价：16.80元

ISBN 7-5046-0812-2/Q · 29

TRANSACTIONS OF THE ECOLOGICAL SOCIETY OF CHINESE YOUTHS

Volume 2

SPECIAL ISSUES ON INSECT ECOLOGY

Published by: CHINA SCIENCE & TECHNOLOGY PRESS
32, Bai Shi Qiao Rd., Beijing 100081, P.R. China

First Published 1992
ISBN 7-5046-0812-2/Q•29
Printed in Beijing

序

中国生态学会青年研究会与中国昆虫学会昆虫生态专业委员会，于1991年10月29日至 11月2日在长沙联合举办“全国昆虫生态学研讨会”，参加该会的代表绝大多数是青年生态学工作者。此辑印出的69篇论文，主要是从这次会议收到的论文中选编的。

此辑论文包括的内容相当广泛，既涉及宏观和微观领域的生态学基础理论， 又涉及农、林、牧、医、及环境等方面应用生态学问题。其中，害虫种群系统的动态研究、 害虫天敌作用的评价和方法、植物抗虫性的研究、害虫复合经济阈值及动态防治指标的研究、 害虫综合治理及其决策模型的研究等，表明我国青年生态学者学术思想非常活跃， 具有勇于创新和进取精神，旨在从理论上探讨昆虫的生态适应及其机制， 并从应用的角度着重研究害虫综合治理与益虫综合利用的理论和实践，显示了各自的见解。

应当指出：讨论植物防御的文章虽多偏重抗虫机制的探讨， 但也有论及植物次生物质对其抗逆性增强的意义，这方面的深入研究， 有可能引起植物保护科学向植物医学的方向进一步渗透和发展。近年来，国际上相当热衷于植物与有害生物之间相关关系的研究， 已从化学生态学、理论生态学、遗传生态学和物理生态学等方面获得一些进展， 植物防御机理以及进化生态学和遗传生态学的研究是值得注意的动向。

90年代生态科学发展的趋势，可从以下事实看出其格局：(1) 1987年联合国42 届大会通过的“我们的未来”，指明协调工业发展、资源利用、环境保护、 人口控制和缓解自然支持系统危机中生态学的任务；(2) 国际地圈、生物圈规划(IGBP)是IBP的扩大，强调了人类活动对全球变化的影响；(3)生态工程可能成为发展中国家振兴经济的一个重要手段，被誉为“21世纪工程之壮举”；(4)分子生态学及生物技术在生态学中的应用，将对人类社会污染问题的缓解发挥作用，并将促进生物大分子及其有关生物活性物质的化学生态学研究的发展。 可见现代生态学的发展只有联系社会实际，了解问题本质， 并不断地从其它自然科学和社会科学中吸取营养，才能在基础理论和方法论上取得突破性进展。

本辑即将付印出版，目的在于交流信息，互通情报，一些概念和观点可能给人以启发，一些结论和实践可能对理论生态学的研究和促进经济建设有其积极作用。 但其中也难免有不足之处，希望读者本着热情鼓励和爱护的精神，提出中肯的批评， 帮助我国青年生态学者的成长，促进我国生态学为经济建设服务事业的发展。

一九九二年十月

前 言

昆虫是动物中的最大类群，世界上估计有百万种之多。 大多数昆虫是对人类无害或有益的，但有不少种类对人类本身或人类的生产实践活动产生重大的危害。 昆虫生态学是研究昆虫与环境关系的一门学问，它揭示昆虫个体、同种之间、不同种之间， 以及昆虫群落间的相互关系及与包括寄主在内的环境的关系， 是人类认识昆虫并利用有益昆虫或防治有害昆虫的理论依据。

近年来，国内的昆虫生态学工作者在昆虫生态学的不同领域进行了大量的研究工作， 取得了可喜的成绩。1991年10月29日至11月2日，中国生态学会青年研究会与中国昆虫学会昆虫生态专业委员会，在长沙联合举办了"全国昆虫生态学学术研讨会"。 参加该会的代表绝大多数是青年生态学工作者，并提交了大量高水平的研究论文或综述文章。 为了更好地交流研究成果和收获，积极扶持和提携青年昆虫生态学工作者，促进我国昆虫生态学的发展， 中国生态学会青年研究会与北京农业大学有害生物综合防治研究所联合编辑出版了这本《昆虫生态学研究》专辑。此辑收入的69篇论文，是在此次会议收到的优秀论文的基础上， 经向全国昆虫生态学工作者征稿或约稿后，请有关专家审阅， 并按《生态学报》的要求从中精选编辑的。

此辑论文包括的内容相当广泛，既涉及宏观和微观领域的生态学基础理论， 又涉及农、林、牧、医、资源及环境等方面应用生态学问题。其中，害虫种群系统的动态研究、 害虫天敌作用的评价和方法、植物抗虫性的研究、害虫复合经济阈值及动态防治指标的研究、 害虫综合治理及其决策模型的研究等，表明我国青年生态学者学术思想非常活跃， 具有勇于创新和进取精神，不但从理论上探讨昆虫的生态适应及其机制， 而且从应用的角度着重研究害虫综合治理与益虫综合利用的理论和实践，显示了各自的见解。

本书的出版得到老一辈昆虫生态学家和广大中青年昆虫生态学工作者的热情关怀和支持。同时，北京农业大学有害生物综合防治研究所所长张青文博士、 福建农学院植保系尤民生博士、华南农业大学植保系梁广文博士、福建农科院植保所刘波博士、 中国农科院生防所郭玉杰博士、莱阳农学院植保系沈长朋先生、吉林农业大学生防所张帆女士、 山西农科院植保所董晋民先生、中科院动物所盛承发博士等提供出版经费， 北京农业大学植保系植保软件工程研究室和中国农科院生防所、 植保所无偿提供大量机时和人力使本书的计算机排版工作得以顺利完成，在此一并致以衷心的感谢。

由于时间较紧、业务水平有限，编委会成员都是利用业余时间开展这项工作，加之利用计算机进行科技书籍的激光照排工作缺乏经验，书中错误和不足之处在所难免， 敬请广大读者批评指正。

编 者

一九九二年十二月

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1992年12月 青年生态学者论丛 (二) Vol. 2
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POPULATION SYSTEM AND POPULATION SYSTEM APPROACH TO RICE BROWN PLANTHOPPER

Xiong-fei Pang, Guang-wen Liang, Ling Zeng & Wei-jian Wu
(South China Agricultural University, Guangzhou)

ABSTRACT

Population system means that a subject population is considered as a control system, grouped by several states, connecting with survival rates and productivities, and its environmental acting factors are regarded as the spatial limit, to study the population dynamics and population dynamics control. in this paper, the rice brown planthopper, *Nilaparvata lugens* (BPH), is taken as an example to construct the population system model. Based on the space-state equation of cybernetics, the state vector "X" is constructed by developmental process from egg to adult per day, the system matrix "A" is constructed by the average life table data, the control matrices B'RR and B"IC are construct by resistant varieties of various damage rates and "selective" or "wide-spectrum" insecticides:

$$X(t_1) = [A + B'RR + B''IC]X(t_0).$$

In this model, the interference indices of population control(IIPC) are used as an inputting information operators. With the output equation, the population dynamics and the population dynamics control of BPH can be discussed by the results.

Key words:population system, *Nilaparvata lugens*, population dynamics control

INTRODUCTION

The application of systems science, including cybernetics and large scale system theory and methods, to investigating the human population is a recent development in China. In this case a term "population system" is used to study the population dynamics control. The population system approaches to insect and animal populations were discussed by Pang et al.[1-3] In this paper, rice pest insect, rice brown planthopper *Nilaparvata lugens*(BPH) is taken as an example to construct the population system model and discussed for this problem.

POPULATION SYSTEM

A population system means that a subject population is considered as a system, grouped in several states, connecting by several rates and productivities as the state to state transfers, the environmental effecting factors are regarded as the spatial limit, in order to study the population dynamics and the population dynamics control.

The population system approach carried forward the population ecology methods. Before the development of system science, the life table method, Volterra mathematical models, Leslie population matrix model etc. were founded as the methodological base of population systems studies.

A life table for BPH

Life table was first applied to study human populations, grouped in age states of equal time intervals, constructed by Graunt in 1662 and Halley in 1693. It has long been used in demography and later in animal population ecology. Morris and Miller[4] constructed another form of life table, grouped in stage for the insect population. on purpose to study the effectiveness of t he acting factors, Pang et al.[5,6] suggested that the life tables may be grouped also in various factors(Table 1).

Table 1 Average life table for 2nd generation of BPH (Hailing Island, Guangdong Province, 1976-1990)

stage and instar (x)	Factor (f)	Survival rate at f (Sf)	EIPC $x(=1/S_i)(Sx)$	Survival rate of per day (a_{ji})	Survival rate
Egg	predators	$S_1=0.561$	1.78	$S_E=S_1S_3S_3$	$a_{2,1}=0.893$
	parasites	$S_2=0.949$	1.18	$=0.453$	$a_{3,2}=0.893$
	others	$S_3=0.951$	1.05		.
					$a_{8,7}=0.893$
Nymph instar 1-2	prd. etc	$S_4=0.336$	2.98	$S_S=S_4$ $=0.336$	$a_{9,8}=0.804$
					$a_{10,9}=0.804$
					.
					$a_{13,12}=0.804$
Nymph instar 3-5	prd. etc	$S_5=0.324$	3.09	$S_L=S_5S_6$	$a_{14,13}=0.849$
	parasites	$S_6=0.835$	1.20	$=0.271$	$a_{15,14}=0.849$
					.
					$a_{21,20}=0.849$
Adult		$P_{fi}(SA_a)i=0.178$	5.62		$a_{22,21}=0.800$
		$f=1000$	-		$a_{23,24}=0.800$
		$P_f=0.246$	-		.
		$P=0.728$	-		.
		$P_h=0.390$	2.56		$a_{32,31}=0.800$

F - the proposed maximum fecundity(per female);
P_f - the proportion of F that can be achieved by the females of the given population;
P - tne proportion of female adult;
P_h - the proportion of habitant adults after flying;
$(SA_a)^i$ - survival rate of adults per day(i);
$(SA_a)^i$ = [.8 .64 .41 .328 .262 .21 .168 .134 .107 .086 .069]
P_{fi} - the proportion of fecundity per day(i)
P_{fi} = [0 0 0 .003 .058 .149 .202 .198 .160 .113 .073 .044]
EIPC - exclusion index of population control, for analyzing the important factors;
$a_{j,i}$ - state per day, equal time interval, for constructing matrix model.

Index of population trend and index of population control

A mathematical model was constructed for the index of population trend (I) by Watt[7]. According to the life table grouped in stage intervals and factors (Fig. 1) for BPH, this model can be expanded as follows:

$$I = S_E\ S_S\ S_L\ F\ P_F\ P\ P_h\ \Sigma P_{fi}(S_{Aa})^i \quad (1)$$
$$I = S_1\ S_2 ... S_K\ F\ P_F\ P\ P_h\ \Sigma P_{fi}(SA_a)^i \quad (2)$$

On the purpose of investigating the population system as a control system, indices of population control(IPC) and the exclusion analysis method, the addition analysis method and the interference analysis method were developed by Pang et al.[1,5,6,8,9] and Pang[2,3].

Index of population control(IPC)

$IPC = I'/I$ (3)

where: I - index of population trend in the normal condition

I'- index of population trend in the changed condition

According to the equation(2), let us suppose that the factor "I" is excluded, correspondently, survival of this factor becomes $S_i=1$. In this case, we shall have an exclusion index of population control(EIPC).

$$EIPC = \frac{S_1\ S_2 ... 1 ... SK\ F\ PF\ P\ P_h\ \Sigma P_{fi}(SA_a)^i}{S_1\ S_2 ... S_i ... SK\ F\ PF\ P\ P_h\ \Sigma P_{fi}(SA_a)^i} = 1/S_i \quad (4)$$

Supposing that a factor "a" is added, in this case, the survival rate of this factor "S_a" will be inserted into the equation. We shall have an addition index of population control(AIPC):

$$AIPC = \frac{S_1\ S_2 ... S_i S_a ... SK\ F\ PF\ P\ P_h\ \Sigma P_{fi}(SA_a)^i}{S_1\ S_2 ... S_i ... SK\ F\ PF\ P\ P_h\ \Sigma P_{fi}(SA_a)^i} = S_a \quad (5)$$

Supposing that the factor "j" is interfered, the survival rate of this factor "S_j" will be changed to "S'_j". We shall have an interference index of population control(IIPC):

$$IIPC = \frac{S_1\ S_2 ... S'_j ... SK\ F\ PF\ P\ P_h\ \Sigma P_{fi}(SA_a)^i}{S_1\ S_2 ... S_j ... SK\ F\ PF\ P\ P_h\ \Sigma P_{fi}(SA_a)^i} = S'_j/S_j \quad (6)$$

In case of more than one factor are excluded, added or interfered, the sum of the indices of population control is equal to the product of these indices.

Population system model

The population control system model was described as a state- space analysis model of cybernetics by Pang et al.[1] as in Fig. 1 and equation 1.

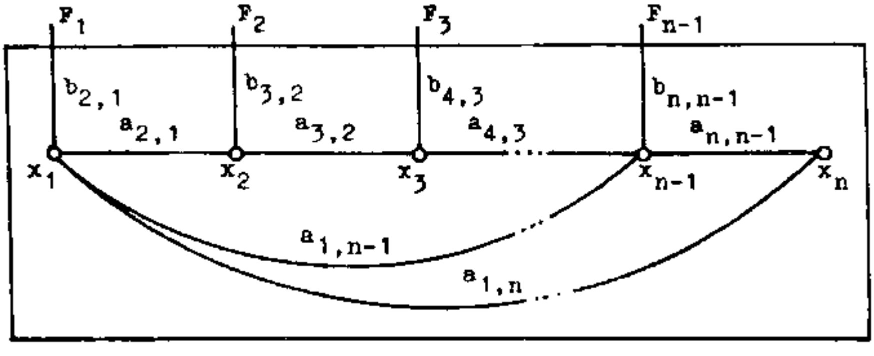

Fig. 1 Network model of a population control system

x_i - state i(i=1,2,3,...n); $a_{j,i}$ - survival rate of state i to state j (j=i+1)

$a_{1,i}$ - fecundity of adult state i; $b_{j,i}$ - input of the effect of effecting factor i

F_i - factor i.

The state space equation for a population control system will be

$$X(t_1) = (A+B)X(t_0) \qquad (7)$$
$$Y(t) = CX(t)$$

where

$X^T = [x_1\ x_2\ x_3\ \ldots\ x_{n-1}\ x_n]$ State variable

$$A = \begin{bmatrix} 0 & 0 & 0 & \cdots & a_{1,n-1} & a_{1,n} \\ a_{2,1} & 0 & 0 & \cdots & 0 & 0 \\ 0 & a_{3,2} & 0 & \cdots & 0 & 0 \\ \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ \cdot & \cdot & \cdot & & \cdot & \\ \cdot & \cdot & \cdot & & \cdot & \\ 0 & 0 & 0 & & a_{n-1,n-1} & 0 \end{bmatrix}$$ System matrix

$$B = \begin{bmatrix} 0 & 0 & 0 & \cdots & b_{1,n-1} & b_{1,n} \\ b_{2,1} & 0 & 0 & \cdots & 0 & 0 \\ 0 & b_{3,2} & 0 & \cdots & 0 & 0 \\ \cdot & \cdot & \cdot & \cdots & \cdot & \cdot \\ \cdot & \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & \cdot & & \cdot & \cdot \\ 0 & 0 & 0 & & b_{n-1,n-1} & 0 \end{bmatrix}$$ Control matrix

$$C = \begin{bmatrix} C_{1,1} & C_{1,2} & C_{1,3} & \cdots & C_{1,n-1} & C_{1,n} \\ C_{2,1} & C_{2,2} & C_{2,3} & \cdots & C_{2,n-1} & C_{2,n} \\ \cdot & \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & \cdot & & \cdot & \cdot \\ \cdot & \cdot & \cdot & & \cdot & \cdot \end{bmatrix}$$ Transmission matrix

The index of population control may be used as the "predators' to decompose and combine the effects of the acting factors. For example in table 1, the addition index of population control(AIPC) of the effecting factor "predators" on egg and "predators etc" on nymph will be AIPC(prd):

$$AIPC(prd) = (0.561)(0.336)(0.324) = 0.061 \qquad (8)$$

By means of the indices of population control(AIPC and IIPC), the network model of the population control may be reconstructed as Fig. 2.

The state-space equation for a population system will become

$$X(t_1) = [A+B_{NE}+B'_{RR}+B''_{IC}]X(t_0) \qquad (9)$$

Where: A - system matrix.

B_{NE} - control matrix of natural enemies

B'_{RR} - control matrix of plant resistance

B''_{IC} - control matrix of insecticide

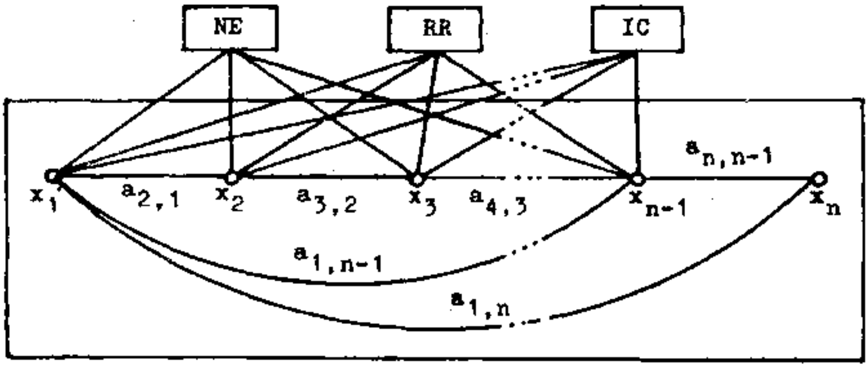

Fig. 2 Network model of a pest population control system
NE - natural enemies as an effecting factor
RR - plant variety resistance to a given pest population
IC - insecticide(if it is used)

The information approach to effecting factor

According to the cybernetics and informatics, the environment factors always affect the control system through the information transfer. Studying on a population system, the effecting factors, such as temperature(°C), moisture(RH%), natural enemies(density), plant resistant) etc. are of the various dimensions. By means of exclusion, addition and interference analysis methods, the effectiveness of a factor will be transferred to EIPC, AIPC as an inputting information into the population system[9,10].

In the equation 9, the elements of the matrix B_{NE}, B'_{RR} and B''_{IC}, $b_{j,i}$, $b'_{j,i}$, $b''_{j,i}$ will be

$b_{j,i} = a_{j,i}(IPC_{j,i-1})$

$b'_{j,i} = a_{j,i}b_{j,i}(IPC'_{j,i-1})$

$b''_{j,i} = a_{j,i}b_{j,i}b'_{j,i}(IPC''_{j,i-1})$

(where $IPC_{j,i}$, $IPC'_{j,i}$ are the IIPC of the factors of the indices of population control)

POPULATION SYSTEM APPROACH TO BPH

As an example herein a population system of BPH is selected to study the effects of rice variety resistance and insecticides. In the population control system model, the state vector X is constructed by 32 state variables (egg-7 states, smaller nymph-5 states, larger nymph-8 states and adult-12 states). The data $a_{j,i}$ and $a_{1,i}$ are used to construct the system matrix A, the interference index of population control of resistant rice varieties and the insecticides are used to construct the control matrices B'_{RR} and B''_{IC} as in the equation 9.

The $a_{j,i}$ and $a_{1,i}$ were showed in Fig. 1. The $b'_{j,i}$, $b'_{1,i}$ and $b''_{j,i}$, $b''_{1,i}$ will be studied as follows.

Information approach to the resistance of rice varieties and the insecticides

The survival rates of the nymph stages (S_S and S_L), the proportion of maximum fecundity (P_f) and the complex coefficient $P_{fi}(SA_a)^i$ are effected by the resistance of rice varieties. A susceptible cultivating variety "B2", a moderately resistant variety "FB2" and a highly susceptible variety "TN1" were selected for the experiment show in Table 2.