DOI:10.6660/TESFE.1992023 台灣昆蟲Formosan Entomol. 12: 183-191 (1992) 研究報告 Research report

Formosan Entomologist
Journal Homepage: entsocjournal.yabee.com.tw

【Research report】

實驗生態系中積穀害蟲與寄生蜂之群聚組成的族群穩定性【研究報告】

賴宗賢、吉田敏治

*通訊作者E-mail :

Received: Accepted: 1992/06/16 Available online: 1992/09/01

Abstract

摘要

由兩種穀物（米、紅豆）、四種積穀害蟲及三種寄生蜂組成的各種生物群聚（community）中，增加寄生蜂種數所引起的多樣性（diversity）可提高寄主族群（population）的穩定性（stability），但增加寄主種數所引起的多樣性卻未必能提高寄主族群自身的穩定性。寄主蜂族群的穩定性在四種寄主的複雜群聚中遠比在僅有一種寄主的單純群聚下穩定，而在僅含一種寄主的群聚中，增加寄生蜂種數時，寄生蜂族群有趨於穩定的趨向，但在四種寄主的複雜群聚中卻出現相反的現象；複雜程度越高，族群的穩定性越差。人為增加室內生態系的多樣性未必能提高群聚的穩定性。

Key words:

關鍵詞: 族群穩定性、多樣性、變異係數、積穀害蟲、寄生者。

Full Text: PDF(0.5 MB)

中華昆蟲 12: 183-191(1992)
Chinese J. Entomol. 12: 183-191(1992)

Population Stability in Laboratory Ecosystem of Stored Product Insects and Parasitoids

Chung-Hsien Lai Faculty of Agriculture, Okayama University, Okayama 700, Japan
Toshiharu Yoshida Okayama University of Science, Ridai-cho, Okayama 700, Japan

ABSTRACT

Experimental ecosystems were studied in growth chamber at 30℃, R.H. 70% in full dark. Biotic factors were combinations of two cereals (rice and azuki bean), four host insects (*Sitophilus oryzae, S.zeamais, Rhyzopertha dominica,* and *Callosobruchus chinensis*), and three parasitic wasps (*Anisopteromalus calandrae, Choetospila elegans* and *Lariophagus distinguendus*). Average population density and coefficient of variation (C.V.) in population fluctuation were compared among the various community complexities. Increase in complexity of parasitoid community increased stability of host population. However, increase in complexity of host community did not always increase stability of host population. Stability of parasitoid populations was higher in a complex host community than in the single host comunity. Furthermore, the stability of parasitoid populations increased as the number of parasitoid species in the simple host community increased; however, this trend was reverse in the complex host community. Therefore, an increase in the complexity of host community may induce instability in the parasitoid population.

Key words: population stability, diversity, coefficient of variation, stored product insect, parasitoid.

實驗生態系中積穀害蟲與寄生蜂之群聚組成的族群穩定性

賴宗賢　日本岡山大學農學部應用昆蟲學研究室〒700日本岡山市津島中
吉田敏治　日本岡山理科大學教養學部〒700日本岡山市理大町

摘　　要

由兩種穀物（米、紅豆）、四種積穀害蟲及三種寄生蜂組成的各種生物群聚（community）中，增加寄生蜂種數所引起的多樣性(diversity)可提高寄主族群(population)的穩定性(stability)，但增加寄主種數所引起的多樣性卻未必能提高寄主族群自身的穩定性。寄生蜂族群的穩定性在四種寄主的複雜群聚中遠比在僅有一種寄主的單純群聚下穩定，而在僅含一種寄主的群聚中，增加寄生蜂種數時，寄生蜂族群有趨於穩定的趨向；但在四種寄主的複雜群聚中卻出現相反的現象：複雜程度越高，族群的穩定性越差。人為增加室內生態系的多樣性未必能提高群聚的穩定性。

關鍵詞：族群穩定性、多樣性、變異係數、積穀害蟲、寄生者。

Introduction

Considering mathematical models of population dynamics and experimental data, Elton (1958) concluded that an increase in complexity of community might enhance community stability. Watt (1964, 1968) examined massive data on population fluctuation of forest insects and concluded that the high stability at a certain level in the food web enhances instability at the next level. The relationship between community complexity and stability is not as simple as concluded by Elton (1958).

Three categories for testing community stability and complexity can be distinguished: (1) field experiments, (2) laboratory ecosystem experiments, and (3) research in mathematical modeling. Among the three, laboratory ecosystem experiments would be most effective because environmental factors can be controlled and biotic performances of each organism can be measured precisely. The complexity of the ecosystem would be dependent on the number of components in the community, the characteristics of individual components, and the relationships between components. Stability of the community could be verified by some properties, such as constancy, predictability, resilience and perpetuity (Kobayashi, 1980).

This report is one of several studies

on an ecosystem composed of a two to three level food web using two cereals, four host insects, and three parasitoid wasps (Lai and Yoshida, 1989). To understand the relationship between community diversity and stability, we investigated the coefficient of variation (C.V.) of individual component population fluctuation in the community as well as the average population density.

Materials and Methods

Experimental ecosystems were established using various combinations of two cereals (rice, *Oriza sativa* and azuki bean *Vigna angularis*), four host insects (*Sitophilus oryzae* (SO), *S. zeamais* (SZ), *Rhyzopertha dominica* (RD) and *Callosobruchus chinensis* (CC)), and three parasitic wasps (*Anisopteromalus calandrae* (A), *Choetospila elegans* (C) and *Lariophagus distinguendus* (L)). All of the four host insect species had been cultured for about 5 years (from 1979 or 1981) in the laboratory of Okayama University on rices or azuki beans under the constant environmental conditions at 30℃ and 70% R.H. The three parasitic wasps had been cultured for 5 years on the larvae of the hosts which fed in the laboratory on rice or azuki bean.

In Experiment 1, 45 g of fresh rice and 10 pairs of 10-day old SO adults were introduced into a plastic cage (100 ml in volume). After 20 days, 6 pairs of emerged adults of a wasp species, or 3 pairs of emerged adults of each of two wasp species, or 2 pairs of each of three wasp species, were introduced simultaneously into the cages. Fresh rice was supplemented every 14 days.

In Experiment 2, 45 g of fresh rice and 3 pairs of each species of SO, SZ, RD adults were introduced into a plastic cage (200 ml in volume). After 5 days, 5 g of fresh azuki beans and 3 pairs CC adults which had emerged within 24 hrs were added. The upper layer of azuki bean was divided from the bottom layer of rice by a metaric net which a mesh size that allowed wasps to pass through. On day 20, parasitic wasps were introduced by the same procedure as mentioned in Experiment 1. Rice was supplemented as it consumed. Five grams of beans were provided every 14 days.

The morphology of SZ is very similar to that of SO. However, the body length of SZ (2.8 mm on average) is longer than that of SO (2.3 mm on average), and the pronotum of the former is wider than that of the latter (Yasutomi and Umeya, 1983). Therefore we could discriminate between them in the experiments.

The host-parasitoid combinations are shown in Figure 1. Two kinds of host populations without parasitoids were established for the control of Experiment 1 and Experiment 2.

All experiments were conducted at 30 ℃, 70% R.H. Population census was made every 14 days. There were three replications for each ecosystem. The population density of each components was averaged during the period until any one of the components became extinct. The coefficient of variation (SD / MEAN, C. V.) was calculated for each number of host or wasp species at each census date. Details of the experimental methods were described by Lai and Yoshida (1989).

Results and Discussion

1. Experiment 1

The average population density of host SO was high in the control population without parasitoids and it tended to decrease with the increase in the number of parasitoid species in the host-parasitoid community (Table 1). The population density of parasitoid A tended to increase when coexisting with other parasitoids. The population density of C was scarcely affected by the existence of other parasitoids. The population density of L decreased when coexisting with other para-

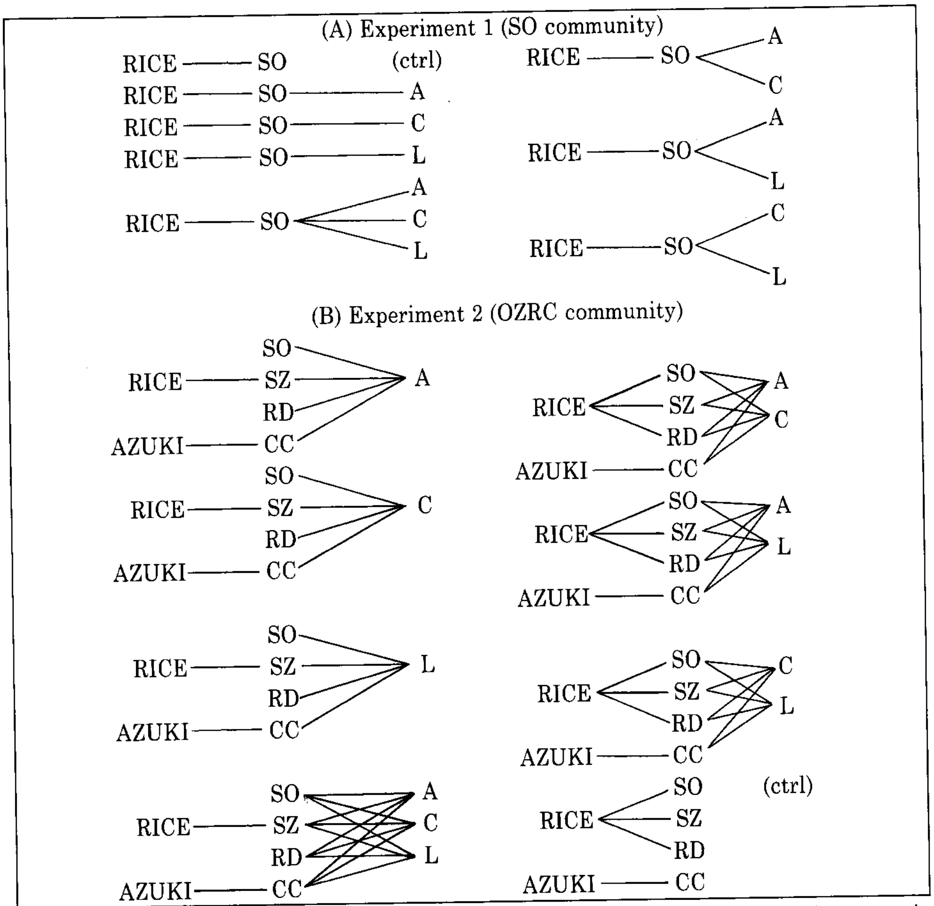

Fig. 1. Various host-parasitoid combinations of the host *Sitophilus oryzae* and three parasitoids (A), and four hosts and three parasitoids (B). SO: *Sitophilus oryzae* (L.); SZ: *Sitophilus zeamais* Motschisky; RD: *Rhyzopertha dominica* (F.); CC: *Callosobruchus chinensis* (F.); A : *Anisopteromalus calandrae* (Howard); C : *Choetospila elegans* *Westood*; *L* : *Lariophagus distinguendus* (Forster).

sitoids.

The C.V. of population fluctuation of SO in the community with parasitoids was smaller than that of the control population without parasitoids except for the SO-C community (Table 1). The C.V. of SO was especially small in the ecosystem with three parasitoids. The C.V. of parasitoids was largest in the ecosystem with one parasitoid.

2. Experimental 2

The average population density of SO and RD tended to decrease when the number of parasitoid species increased (Table 2), The average density of SZ was extremely low whenever parasitoids were introduced into the community. On the other hand, the average density of CC increased when parasitoids were introduced. The average density of all host species decreased more when the parasitoid A introduced than when the other two were introduced. The average density of the parasitoid A scarcely decreased when coexisting with the other two parasitoids. On the other hand, The populations of C and L were affected greatly by the presence of A.

The C.V. of SO populations tended to decrease with the increase of parasitoids

Table 1. The average population density and coefficient of variation (C.V.) of population fluctuation of *Sitophilus oryzae* (SO) and three parasitoids, *A. calandrae* (A), *C. elegans* (C) and *L. distinguendus* (L) in communities of various combinations (Experiment 1).

Combination of host-parasitoid	SO	A	C	L
	Average of population density			—
SO	183.6	—	—	—
SO-A	143.5	29.3	—	—
SO-C	55.5	—	29.8	32.6
SO-L	204.6	—	—	14.4
SO-A,L	97.9	49.9	—	13.6
SO-C,L	148.3	—	30.9	—
SO-A,C	96.8	25.2	31.9	13.4
SO-A,C,L	65.5	61.3	22.9	
	Coefficient of variation (C.V.%)			—
SO	64.2	—	—	—
SO-A	40.4	170.1	—	—
SO-C	82.5	—	157.1	159.8
SO-L	51.3	—	—	118.4
SO-A,L	59.3	109.1	—	161.4
SO-C,L	48.9	—	87.1	—
SO-A,C	58.8	192.0	82.3	93.3
SO-A,C,L	14.0	97.8	80.6	

1) See Fig. 1.

Table 2. The average population density of four host species, *Sitophilus oryzae* (SO), *S. zeamais* (SZ), *R. dominica* (RD), *C. chinensis* (CC) and three parasitoids, *A. calandrae* (A), *C. elegans* (C) and *L. distinguendus* (L) in communities of various combinations (Experiment 2).

Combination of	Average of population density						
host-parasitoid	SO	SZ	RD	CC	A	C	L
OZRC	103.0	132.0	139.7	76.8	—	—	—
OZRC-A	12.9	2.7	4.2	74.8	111.7	—	—
OZRC-C	23.8	3.4	48.3	149.6	—	55.3	—
OZRC-L	42.3	3.8	97.2	147.6	—	—	53.4
OZRC-A,L	6.9	3.9	3.0	69.5	94.5	—	12.5
OZRC-A,C	6.1	2.9	3.1	90.0	81.6	4.9	—
OZRC-C,L	26.1	3.0	32.3	152.6	—	30.8	19.5
OZRC-A,C,L	7.4	4.3	3.8	88.2	86.7	5.7	5.0

1) See Fig. 1.

species (Table 3). The C.V. of parasitoid populations was smallest in the single parasitoid community, becoming larger as the number of parasitoids increased. This trend was quite reverse from that in the single host population (Table 1).

When the population fluctuation of SO in OZRC community was compared

Table 3. The coefficient of variation of population fluctuation of four host species, *Sitophilus oryzae* (SO), *S. zeamais* (SZ), *R. dominica* (RD), *C. chinensis* (CC) and three parasitoids, *A. calandrae* (A), *C. elegans* (C) and *L. distinguendus* (L) in communities of various combinations (Experiment 2).

Combination of host-parasitoid	Coefficient of variation (C.V. %)						
	SO	SZ	RD	CC	A	C	L
OZRC	100.6	90.9	54.2	154.1	—	—	—
OZRC-A	61.2	66.7	71.4	71.0	41.5	—	—
OZRC-C	53.8	61.8	115.3	58.0	—	100.5	—
OZRC-L	82.0	69.3	150.9	71.8	—	—	68.5
OZRC-A,L	31.9	33.3	63.3	96.4	55.9	—	149.1
OZRC-A,C	28.2	68.6	41.1	105.2	80.3	147.8	—
OZRC-C,L	103.8	68.3	125.2	70.1	—	111.2	116.3
OZRC-A,C,L	42.0	39.0	46.7	91.4	84.2	116.6	185.6

1) See Fig. 1.

with that of the single host population (Tables 1 and 2), the average population density of SO in the former was about one half that in the latter; however, the C.V. of the former was larger than that of the latter (Tables 1 and 3).

The average population density of parasitoids in the complex host community was higher than that in the simple one (Table 2). The C.V. of parasitoid populations in the complex host community was lower than that in the simple one, except for C in a population with parasitoid competitors (Tables 1 and 3).

The three hosts, SO, SZ and RD, used in the present study feed on rice. The bean weevil (CC) can not feed on rice, but feeds on azuki bean. However, three parasitoids, A (Okamoto, 1971; Williams, 1971; Dhaliwal and Battu, 1976; Press, 1988), C(Sharifi, 1972; Doanhaye, 1974; Palmer, 1977) and L (Kashef, 1959; Gonen, 1970, 1973; Bellows, 1988), can feed on all of the four hosts mentioned above, although host preference of each parasitoid was difference (Utida, 1956; Fujii, 1983). The parasitoids A and L preferred SZ to SO and C preferred SO to SZ. Parasitoid A also preferred CC, however, parasitoid C scarcely develops in CC. In order to diversify the ecosystems in the present study, the host CC was added to the three rice feeders.

In order to simplify the relationship between the complexity of the community and the stability of the population fluctuation of each component, the means of the both density and C.V. of population fluctuation of SO and parasitoids (Tables 1, 2 and 3) were evaluated according to degree of complexity in the community (Table 4). The population density of SO in the single host community decreased as the number of parasitoids species increased (Table 4). The average density of SO under the existence of three parasitoids was as low as one third of that in the single host population. The C.V. of the population of SO also decreased with increase of the parasitoid species. The population of SO was regulated well at a low density and stable in population fluctuations by the multiple parasites. When the number of host species was four in the community, the population densities of SO decreased more than those in single host community probably became of competition or interference among stored product feeders at the same food level. However, the C.V. values of SO fluctuation became rather large under the

Table 4. Comparison of the means of average population density and of C.V. of *S. oryzae* (SO) and parasitoids among the differient complexities of the community.

Complexity of community	Average density		C.V.	
	Host(SO)	Parasitoid[1)]	Host(SO)	Parasitoid[1)]
One host	183.6	—	64.2	—
One host+one parasitoid	134.5	30.6	58.1	162.3
One host+two parasitoids	114.3	27.7	55.7	125.1
One host+three parasitoids	65.5	32.5	14.0	90.6
Four hosts	103.0	—	100.6	—
Four hosts+one parasitoid	26.3	73.5	65.7	70.2
Four hosts+two parasitoids	13.0	40.6	54.6	110.1
Four hosts+three parasitoids	7.4	32.5	42.0	128.8

1) Means per parasitoid species.

complex host conditions (Table 4). These results suggest that the increase in complexity at an upper trophic level increases stability at a lower trophic level. However, the increase in the complexity at a lower trophic level does not always increase stability at that trophic level. This tendency partially supports the theory by Elton (1958), or the multiple introductions of natural enemies in the biological control theory (Huffaker and Kenneth, 1966). On the other hand, Turnbull and Chant (1961) and Zwölfer (1963) predicted that complexity at a higher trophic level brings about unstable fluctuations at a lower trophic level. Fujii (1983) also predicted that random introduction of multiple parasitoid species would not make the system more stable.

The means of the density per parasitoid species did not change with an increase in complexity in the single host and parasitoid communities although it decreased slightly in the four hosts and parasitoid communities (Table 4). The C. V. of parasitoid populations decreased with the increase of parasitoid species in the single host communities. On the other hand, the C.V. of the parasitoid populations rather increased with the increased of parasitoid species in the complex host community. This suggests that the increase in the complexity at a lower trophic level may bring about instability at the upper trophic level. Watt (1964) analyzed the data of the stability of phytophagous lepidopterans in forests in relation to the width of host range of each insect species and concluded that stability at an upper trophic level decrease stability at a lower trophic level and the increase in the complexity increases stability at the same trophic level.

In the community with single host and single parasitoid species, the average densities of parasitoid A, C and L were 29.3, 29.8, 32.6 (Table 1). Although the density of L is slightly higher, there was no substantial difference among them. In combinations of two parasitoids, the population density was as follows: A>L, C>L, and C>A. When using all three parasitoid species, A is more abundant and followed by C and L. When competition occurred among the parasitoids, A tended to be more dominant than the other two, and L was the weakest. Under the condition of no competition among parasitoids, the population fluctuation of A showed only one peak on the 42nd day (Lai and Yoshida, 1989). However, under competition, the population density increased and C.V. decreased as the number of competitors increased (Table 1). In addition the number of population peaks increased to two (Lai and Yoshida, 1989). This suggests that the increase of the number of competitive species in the parasitoid community strengthened stability in the population A.

However, the trends for parasitoid A in the community of four hosts community was different from that mentioned above (Tables 2 and 3). As the number of the competitive parasitoids species increased, the population size of A tended to reduce and C.V. tended to increase. Under the complex host community, the increase in the parasitoid species decreased stability in the parasitoid A.

When other parasitoid species existed in four host communities, the average density of C reduced considerably (Table 2). Its C.V. increased with the number of competitive species (Table 3). When other parasitoid species existed among parasitoids, the average density of L reduced considerably (Table 2). Its C.V. increased with the number of competitive species (Table 3).

As mentioned previously, the parasitoid populations in the complex host community is more stable in a relatively simple parasitoid community than in a complex parasitoid community. If this is true, the population stability of parasitoids might be achieved after competitors were excluded from the system. The population stability of A and C after L went extinct from the OZRC–A.C.L system was compared with the community OZRC–A.C. The C.V. of A and C in the former were 121.4% and 123.7% but 80.3% and 147.8% in the latter. The C.V. of A after L and C went extinct from the OZRC–A.C.L system was 156.7%, which reveals a decrease in stability. Next, we compared the stability of A in the communities OZRC–A.C and OZRC–A.L after the competitor C or L had been excluded from the system. The C.V of A in the former was 132.4% and 81.2% which is higher than 41.5% in the community OZRC–A. Generally speaking, the C.V. of a parasitoid population after extinction of other parasitoids from a complex parasitoid community was higher than that from the originally simple parasitoid community. This reveals that the parasitoid community would not stabilize even when competitors are excluded from the system.

Acknowledgments

We thank Professor F. Nakasuji, University of Okayama, for his critical reading and verbal correction of this manuscript.

References

Bellows, T. S., Jr., and M. P. Hassell. 1988. The dynamics of age structured–parasitoid interaction. Journal of Animal Ecology. 57: 259–268.

Dhaliwal, G. S., and G. S. Battu. 1976. Occurrence of *Anisopteromalus calandrae* (Howard) in the laboratory culture of *Rhizopertha dominica* F. Bull. Grain Tech. 14: 156–157.

Doanhaye, E. 1974. Parasites of stored product insects and their effect on population: C. Parasitization by *Choetospila elegans* Westwood in a column of grain infested by *Sitophilus oryzae* (L.). Min. Agric. Inst. Tech. Storage Agric. Prod. progress Rep. Year. 1973/74: 23–24.

Elton, C. S. 1958. The ecology of invasion by animals and plants. Methuen, London.

Fujii, K. 1983. Resource dependent stabili ty in an experimental laboratory resource–herbivore–carnivore system. Res. Popul. Ecol., Suppl. 3: 15–26.

Gonen, M., and J. Kugler. 1970. Notes on the biology of *Lariophagus distinguendus* (Foerster) (Hym. Pteromalidae) as a parasite of *Sitophilus oryzae* (L.) (Col. Curculionidae). Israel. J. Entomol. 5: 133–140.

Gonen, M. 1973. Parasites of stored product insects and their effect on population: A. Parasitization of *Sitophilus oryzae* by *Lariophagus dis-*

tinguendus in a column of infested by *Sitophilus oryzae*. Agricultural Research Organization Progress for the Year 1972/73: 17–22.

Huffaker, C. B., and C. E. Kenneth. 1966. Studies of two parasites of olive scale, *Parlatoria oleae* (Colvee). IV. biological control of *Parlatoria oleae* (Colvee) through the compensatory action of two introduced parasites. Hilgardia 37: 283–335.

Kashef, A. H. 1959. *Lariophagus distinguendus* Först (Hymenoptera: Pteromalidae) ectoparasite on *Rhizopertha dominica* Fab. (Coleoptera: Bostrychidae). Bull. Soc. Ent. Egypte 43: 165–184.

Kobayashi, S. 1980. The complexity and stability of biological community. Seibutsu Kagaku. 32: 11–24.(In Japanese)

Lai, C. H., and T. Yoshida. 1989. Experimental study on the diversity and stability in the laboratory ecosystem. l. Persistency of community. Chinese J. Entomol. 9: 169–187.(In Chinese)

Okamoto, K. 1971. The synchronization of the life cycles between *Callosobruchus chinensis* (L.) and its parasite *Anisopteromalus calandrae* (Howard). Jap. J. Ecol. 20: 233–237. (In Japanese)

Palmer, T. J. 1977. A new method for culturing hymenopteran parasitoids of beetle infesting stored grain or pulses. J. Stored Prod. Res. 13: 83–84.

Press, J. W. 1988. Movement of a weevil parasitoid Anisopteromalus calandrae (Howard), within a column of wheat in relation to host location. J. Agric. Entomol. 5: 205–208.

Sharifi, S. 1972. Radiographic studies of the parasite *Choetospila elegans* on the maize weevil *Sitophilus zeamaize*. Ann. Ent. Soc. Amer. 65: 852–856.

Utida, S. 1956. Long-term fluctuation of population in the system of host-parasite interaction. Res. Popul. Ecol. 3: 52–59.

Turnbull. A. L., and D. A. Chant. 1961. The practice and theory of biological control of insects in Canada. Can. J. Zool. 39: 697–753.

Watt, K. E. F. 1964. Community stability and the strategy of biological control. Can. Entomol. 96: 1434–1442.

Watt, K. E. F. 1968. Ecology and Resource Management. McGraw-Hill, New York.

Williams, R. N., and E. H. Floyd. 1971. Effect of two parasites, *Anisopteromalus calandrae* and *Choetospila elegans*, upon populations of the maize weevil under laboratory and natural conditions. J. Econ. Entomol. 64: 1407–1 408.

Yasutomi, K., and K. Umeya. 1983. Medically important pests and indoor pests. Zenkoku Nosan Kyoiku Kyokai, Tokyo. 310 pp. (In Japanese).

Zwölfer, H. 1963. Untersuchungen über die Struktur von Parasitenkomplexen beieinigen Lepidopteren. Zeit. angew. Entomol. 51: 346–357.

Received for publication January 30, 1992; revised manuscript accepted June 16, 1992.