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# CANNIBALISM IN *CHRYSOPERLA CARNEA* (STEPHENS) (NEUROPTERA, CHRYSOPIDAE)

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**ABSTRACT**

***Chrysoperla carnea*** **larvae are able to develop to maturity on ten or more conspecific eggs per day. Larval development is shortened with the addition of food, but pupal development is not. The amount of *C. carnea* eggs consumed by the larvae correlated positively with pupal size, but did not correlate with adult size or with fecundity. Young eggs of *C. carnea* are preferred as food over mature ones, and first instar larvae are unable to feed on mature eggs. In larval-larval cannibalism, the larger, the better fed and the elder larvae consumed the smaller, the hungry and the younger larvae. *Chrysoperla carnea* pupae are eaten only by 3rd-instar larvae, whereas younger instars are unable to do so. Egg cannibalism in *C. carnea* can be considered as a means to facilitate survival of hatched larvae in the temporary absence of other prey, whereas larval cannibalism does not seem to be associated with a certain survival mechanism but to occur by chance. *KEY WORDS: Chrysopa,* cannibalism, lacewings, *Chrysoperla carnea.***

## INTRODUCTION

Cannibalism is defined as intraspecific predation (Fox, 1975a; Price, 1975) and is prevalent among insects. In most cases it expresses itself by older instars eating their juniors or eggs. Cannibalism is more pronounced under laboratory conditions than in the field, with hungry and crowded individuals than with well fed ones. Satisfied individuals were usually found to overcome the hungry ones and eat them, in spite of the fact that the latter were more apt to attack (Arzet, 1973; Dimetry, 1976a,b; Duelli, 1981; Fox, 1975a,b).

Cannibalism of larvae upon conspecific eggs has been studied with *Chrysopa perla* (Linnaeus) (Canard, 1970) and *Chrysoperla carnea* (Stephens) (Duelli, 1981; Elbadry and Fleschner, 1965). The latter found that a hatching larva of *C. carnea* can complete its development, feeding only on conspecific eggs, and that such cannibalism can complement immature development when insufficient food is available. Our experiments were intended to complement the above information and determine the suitability of all immature instars as food for development and reproduction of C. *carnea,* in order to understand the role of cannibalism in survival of immature stages. Such information is also useful in laboratory cultures of *C. carnea.*

We wish to dedicate this article to our teacher and colleague, Prof. J. Kugler on the occasion of his 70th birthday.

## MATERIALS AND METHODS

Unhatched eggs of *C. carnea* were collected in the field and allowed to hatch in the laboratory within gelatin capsules. Hatching larvae were transferred to 2.2 x 5.0 cm glass vials fitted with a piece of cotton cloth on which a lid with a 1.5 cm hole was placed. Cannibalism was observed in these vials after the prey, which was obtained from a laboratory stock of *C. carnea* was introduced into them.

Lab conditions were: 25 ± 2°C, 60 ± 5% RH and a photoperiod of 14/10 (L/D). Statistical tests used were Anova and SS-STP significance tests (Sokal and Rohlf 1969). Specific methods are described under the appropriate sections.

## RESULTS

*C. carnea* lays green eggs, each of which is attached to a thread-like pedicel. Shortly before hatching, the eggs lose their green color, turning grey to brown-grey. Three larval instars occur, all of which are predaceous. They pupate in a silken cocoon. In nature, pupation often takes place in a somewhat protected niche, such as between the bracts and the fruiting body of the cotton plant. The female has a preoviposition period of 3-4 days and duration of the various stages, under lab conditions was: egg – 4 days; larva I – 3-4 days; larva II – 3-4 days; larva III – 5-6 days; pupa – 8-9 days (Bar, 1982).

### Egg cannibalism

A starvation test was first conducted, in which larvae of the 3 instars were given no food and timed until death was recorded. The results showed that the higher the instar, the longer the survival ($L_I$: 1-2 days; n = 23; $L_{II}$: 1-5 days; n = 20; $L_{III}$: 3-6 days; n = 20). In the following test between 1 and 5 eggs were given to hatching larvae. The results (Fig. 1) show a significant linear increase in survival with the addition of food.

Once the parameters of starvation had been established, larvae were given daily aliquotes of eggs to feed on. These were, 1, 2, 5, 10, 20 and 40 eggs. In addition, a 20 egg per day quota for the first 2 instars was replaced by an unlimited amount of pupae of *Carpophilus hemipterus* (L.) (Coleoptera, Nitidulidae) during the 3rd instar (Table 1). The latter had previously been shown to be excellent food for *C. carnea* development and fecundity.

Lacewings were able to develop from hatching to maturity on 10 eggs per day or more. However at 10 eggs, only 4 out of 10 individuals reached maturity. Increase in the amount of prey has the effect of increasing survival and shortening the developmental period of each instar. However, the duration of the pupal stage was unaffected by the feeding history of the larvae ($P > 0.5$). Replacement of eggs by *C. hemipterus* pupae as food for 3rd isntar larvae did not alter the developmental duration or success.

Daily predation rate was examined as to its influence on pupal and adult size and on adult fecundity. Measurements were taken of 1 day old pupae and of newly emerged adults, prior to feeding. Fecundity of the females was determined while they were enclosed in screened boxes and given free access to a 1:1 mixture of yeast

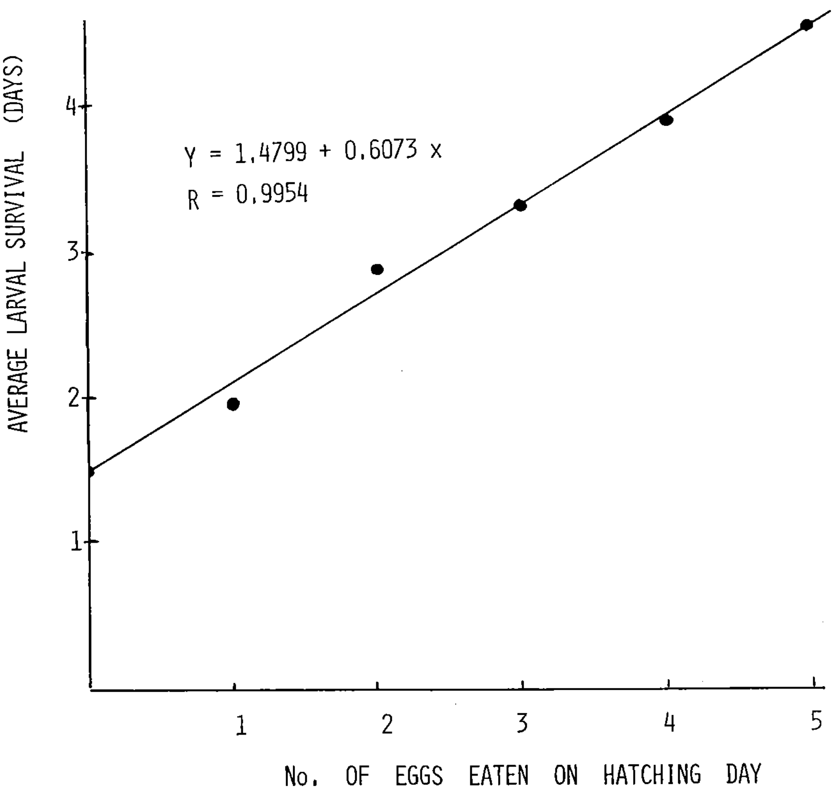


**Fig. 1.** A regression line showing the relationship between the number of *C. carnea* eggs eaten on the hatching day and survival.

hydrolyzate and sugar.

The results (Table 2) showed that pupal size increased significantly with an increase in prey quantity, when the number of prey eggs was increased, and more so when pupae of *C. hemipterus* were used as food ($P < 0.001$). Neither adult sizes nor fecundity were affected by the feeding regimes ($P > 0.5$).

Influence of the age of the developing *C. carnea* egg upon predation success was tested by offering each of the 2 first larval instars green (fresh) eggs and grey (mature) ones. The experiment was run in a free-choice manner, each replicate having 5 eggs of each type, except for 5-day old larvae that were presented wth 10 eggs of each type. In addition, just-hatched larvae were also presented with 10 mature eggs in a no choice situation.

The results (Table 3) showed that hatching *C. carnea* larva had difficulties in feeding upon mature eggs, and when presented with a no-choice situation, 3 out of 10 larvae were unable to feed and died of starvation. Older larvae fed equally well on both kinds.

**Cannibalism of larvae and pupae**

Each experiment included continuous observations for larval behaviour during the first 6 hours. Thereafter, cannibalism was registered 12, 24, 48 and 72 hours from the beginning of the experiment.

TABLE 1. SURVIVAL AND DEVELOPMENT OF *C. CARNEA* LARVAE ON VARYING AMOUNTS OF *C. CARNEA* EGGS

| Daily amount of prey | Group | Number of larvae used | Average larval developmental duration (x ± SE) | | | | Total survival or development |
|---|---|---|---|---|---|---|---|
| | | | LI | LII | LII | Pupa | |
| A. | eggs only | | | | | | |
| 1 | A – survival | 13 | 9.8 ±0.9(12)$^{a}$ | – | – | – | 20.7 ±1.3(13)$^{a}$ |
| 2 | | 12 | 5.8 ±0.3(12)$^{b}$ | 16.0 ±0.5(3)$^{a}$ | – | – | 23.9 ±1.7(12)$^{a}$ |
| 3 | | 11 | 4.7 ±0.1 (11)$^{b}$ | 5.8 ±0.2(11)$^{b}$ | – | – | 37.4 ±3.6(11)$^{b}$ |
| 10 | B – develop. | 10 | 4.7 ±0.2(10)$^{b}$ | 3.4 ±0.3(10)$^{c}$ | 11.8 ±0.6(10)a | 8.3 ±0.3(4)$^{a}$ | 29.5 ± 0.9(4)$^{a}$ |
| 20 | | 10 | 3.7 ±0.2(10$^{b}$ | 3.7 ±0.6(10)$^{c}$ | 6.7 ±0.4$^{b}$ | 8.8 ±0.3(9)$^{a}$ | 22.7 ±0.5(9)$^{b}$ |
| 40 | | 7 | 3.0 ±0.0(7)$^{b}$ | 3.0 ±0.2(7)$^{c}$ | 5.0 ±5(7)$^{b}$ | 8.7 ±0.2(6)$^{a}$ | 19.2 ±0.6(6)$^{c}$ |
| B. | eggs and *C. hemipterus** | 7 | 3.7 ±0.3(7)$^{b}$ | 3.7 ±0.4(7)$^{c}$ | 5.7 ±0.4$^{b}$ | 8.0 ±0.4(6)$^{a}$ | 21.0 ±0.6(6)$^{bc}$ |

* eggs given to LI and LII. *C. hemipterus* pupae given to LIII.

( ) numbers in parentheses mark the number of individuals surviving throughout the stage in question. Only these were used for statistical analysis.

a,b,c, numbers followed by different letters differ significantly at a 5% level SS-STP test in the same column. Total survival was tested separately for survival and for development.

TABLE 2. SIZE OF *C. CARNEA* PUPAE AND ADULTS IN RELATION TO DAILY PREDATION AS LARVAE

| Amount of prey (eggs) | n | Pupal size ±SE | n | Adult size (mm) ±SE | n | Adult fecundity/eggs laid during 40 days ±SE | range |
|---|---|---|---|---|---|---|---|
| 10 | 10 | 2.3 ±0.03[a] | 2 | 7.2 | 0 | | |
| 20 | 10 | 2.9 ±0.03[b] | 6 | 7.9 ±0.2 | 5 | 78.2 ±15.9[a] | 21-119 |
| 40 | 7 | 2.8 ±0.05[b] | 6 | 8.1 ±0.3 | – | No data | |
| 20 + pupae of *C. hemipterus* | 7 | 3.3 ±0.07[c] | 6 | 9.2 ±0.5 | 5 | 69.4 ±16.4[b] | 29-119 |

n = number of surviving individuals that were used at that stage
a,b,c, numbers followed by different letters differ at the 5% significance level in the same column according to an SS-STP test.

TABLE 3. PREDATION OF FRESH VS MATURE *C. CARNEA* EGGS BY *C. CARNEA* LARVAE OF DIFFERENT AGES.

| Predator Age (hours) | Instar | Number used | Number of eggs of *C. carnea* eaten, range, x ±SE | | Remark |
|---|---|---|---|---|---|
| | | | Newly laid eggs | mature eggs | |
| 0-24 | 1 | 20 | (2-5)<br>2.9 ±0.2 | (0-3)<br>1.0 ±0.3 | |
| 0-24 | 1 | 10 | Not given | (0-5)<br>1.9 ±0.5 | 3 larvae starved to death |
| 24-28 | 1 | 10 | (2-4)<br>3.1 ±0.3 | (0-5)<br>2.8 ±0.5 | |
| 48-72 | 1 +2 | 10 | (1-5)<br>2.8 ±0.5 | (0-5)<br>1.9 ±0.5 | 7 larvae molted |
| 72-96 | 1 +2 | 10 | 5.0 ±0 | 5.0 ±0 | 3 larvae molted |
| 96-120 | 2 | 10 | 10.0 ±0 | 10.0 ±0 | |

() = range

TABLE 4. PERCENTAGE OF PREDATION OF *C. CARNEA* LARVAE BY CONFINED CONSPECIFIC LARVAE.

| Instar of prey | The predator LI | LII | LIII |
|---|---|---|---|
| LI | (20)<br>100% | (0)<br>100% | (10)<br>100% |
| LII | – | (10)<br>50% | (10)<br>100% |
| LIII | – | – | (10)<br>100% |
| pupa | (15)<br>20% | (15)<br>20% | (15)<br>100% |

( ) Numbers in parentheses represent the numbers of replicate couples of larvae used.

Larval movement appeared random, and they were not seen to respond to each other's presence even when passing 2 mm from each other. When they chanced upon each other, the larvae immediately withdrew, moving the head sideways, keeping their mouthparts widely separated.

The prey larva is usually held by the predator's mouthparts at the cephalothoracic junction. It is paralyzed within a few minutes and its body fluids can be seen flowing through the predator's mouthparts. On rare occasions predation takes place at the prey's rear end.

In spite of the fact that we used fully fed larvae, cannibalism often reached 100% of the offered prey (Table 4), with a major part of it taking place during the first 6 hours of the experiment. The larger the larva the better a predator it is. In no case did a younger larva feed on an older one.

Feeding upon a *C. carnea* pupa is hampered by its webbing and cocoon formation. First and second instar larvae attempt to penetrate this structure with their mouthparts, but every so often fail and die of starvation, leaving the pupa unharmed. Third-instar larvae are able to feed and develop succesfully upon pupae. In the field, we occasionally found emptied pupal cocoons and near them the full, healthy cocoon of the pupated predator. A frequent meeting place for them was the narrow area between the cotton bracts and the fruiting body, a favourite locus for *C. carnea* pupation.

In order to determine the role of hunger in the larval predator-prey system, we marked with water color 10 fully fed 3rd instar larvae. Each was then presented with a 24 hours starved larva of the same age. The fully fed larva ate the hungry one in all cases.

The suitability of *C. carnea* larvae as food for cannibalistic conspecifics was tested by feeding 1st and 2nd-instar larvae solely upon up to 5 1st-instar *C. carnea*, as compared with identically developed *C. carnea* that were fed *Ephestia* sp. eggs. The *C. carnea* given as prey to the 1st instar larvae were immobilised by pricking them gently with a fine needle before the experiment, to prevent them from eating their future predators. The predators devoured their prey readily, but they were unable to develop upon it. First instar larvae died after 2-3 days, and 2nd instar larvae died after 4-7 days (figs. 2, 3). Supplementing the diet of 1st instar larvae with *Ephestia* eggs provided normal development.

## DISCUSSION

Cannibalism in *C. carnea* is a prevalent phenomenon and can be evaluated as to its significance for the individual and for populations. Nutritionally, the critical period of larval life is from hatching to finding of the first prey (Fleschner, 1950; Brown, 1972). During that period, larval mobility and tolerance of hunger are poor. The habit of scanning the immediate surroundings after hatching increases the chances of finding *C. carnea* eggs. In the absence of other prey, even one or two eggs per day may extend the chances of survival by as much as 20-fold. Thus, larval searching may be considerably extended and with it, its chances of finding other prey.

With decrease in other prey, cannibalism upon eggs increases, reducing the number of developing *C. carnea* larvae in the environment to a level more

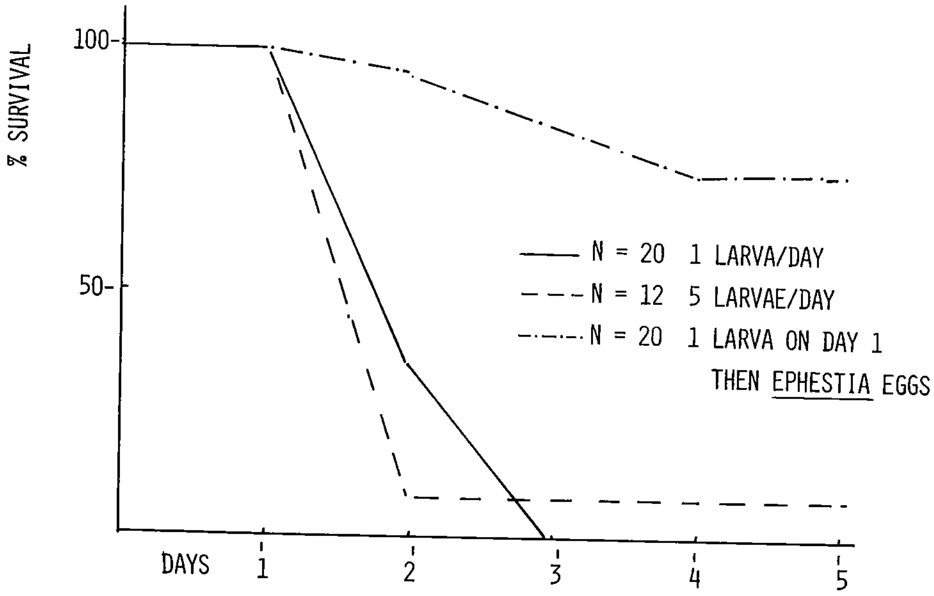


**Fig. 2.** Survival of just hatched *C. carnea* larvae fed on *C. carnea* larvae vs. ones fed on *Ephestia* eggs.

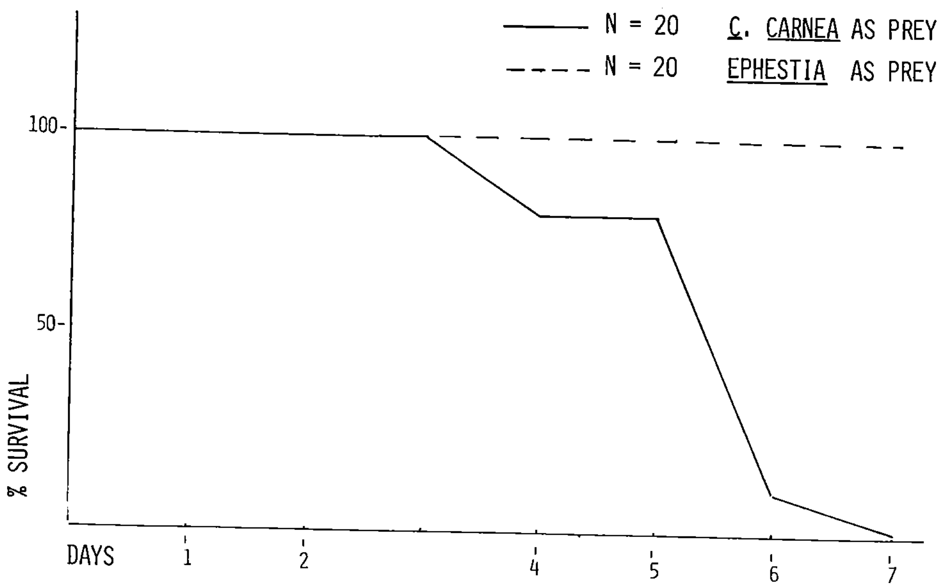


**Fig. 3.** Survival of 2nd instar *C. carnea* larvae feeding on 5, 1st instar, larvae per day.

commensurate with the paucity of prey. Elbadry and Fleschner (1965) found that, in the laboratory, *C. carnea* needed 138 eggs for development from egg to pupation. Our figures are 200 eggs and upward (figuring on at least 10 eggs per day). However, searching for eggs under field conditions is, in itself, an energy-consuming act, and therefore more food is needed under such conditions. Moreover, with larval development and increasing food requirement, this expenditure in energy will grow. Therefore, cannibalism by *C. carnea* larvae should be considered as a mechanism for enabling survival until normal prey is found rather than as providing food for complete development.

In *C. carnea*, the odler larvae ate the younger, the fully fed ate the hungry ones and the larger ate the smaller. Cannibalism was maximal on eggs and minimal on pupae. With a decrease in conspecific prey, larval duration is extended, but the pupal stays constant. This is in accord with other studies on chrysopids and coccinellids (Kehat, 1968; Arzet, 1973; Dimetry, 1974, 1976a,b).

From a population standpoint, the eaten individuals are likely to be those that had less chance of survival, i.e., the embryo, the younger or weaker, sick and even dead larvae (Arbogast, 1979). Therefore, a population in which cannibalism has occurred may be small, but will be composed of strong healthy individuals, with better chances of survival (Fox, 1975a).

Age-differential egg predation is especially interesting, since it spares healthy eggs that are close to hatching time. A similar phenomenon was noted by Canard (1970) in *C. perla* due to hardening of the chorion during egg development. Eggs are also protected by a temporary "paralysis", or cessation of feeding, following cannibalism of eggs. A similar phenomenon was noted by Brown (1972) for coccinellid larvae whose searching activity was reduced following egg cannibalism.

Larval cannibalism is probably a rather rare occurrence in nature, and therefore the lack of developmental success that we noted, or even the occasional developmental success noted by Duelli (1981), reflect upon the relative unimportance of larvae as subjects for cannibalism.

## ACKNOWLEDGEMENTS

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## REFERENCES

**Abrogast, R.T.** 1979. Cannibalism in *Xylocoris flavipes* (Hemiptera, Anthocoridae) a predator of stored-product insects. *Entomologia Experimentalis et Applicata* 25:128-135.

**Arzet, H.R.** 1973. Sauchverhalten der Larven von *Chrysopa carnea* Steph. *Zeitschrift für Angewandte Entomologie* 74:64-79.

**Bar, D.** 1982. Ecology of the green lacewing (*Chrysoperla carnea* Stephens) (Neuroptera, Chrysopidae) in cotton fields of Israel. Ph.D. Thesis, Tel Aviv University. In Hebrew with English summary.

Brown, H.D. 1972. The behaviour of newly hatched conccinellid larvae (Coleoptera: Coccinellidae). *Journal of the Entomological Society of Southern Africa* 35 (1): 149-157.

Canard, M. 1970. L'oophagie des larves du premier stade de *Chrysopa* (Neuroptera, Chrysopidae). *Entomologia Experimentalis et Applicata* 13:21-36.

Dimetry, N.Z. 1974. The consequences of egg cannibalism in *Adalia bipunctata* L. (Coleoptera, Coccinellidae). *Entomophaga* 19:445-451.

Dimetry, N.Z. 1976a. Studies on the cannibalistic behaviour of the predatory larvae of *Adalia bipunctata* L. (Col. Coccinellidae). *Zeitschrift für Angewandte Entomologie* 81:156-163.

Dimetry, N.Z. 1976b. The role of predator and prey density as factors affecting behavioural and biological aspects of *Adalia bipunctata* L. larvae. *Zeitschrift für Angewandte Entomologie* 81:386-392.

Duelli, P. 1981. Is larval cannibalism in lacewings adaptive? (Neuroptera: Chrysopidae). *Research in Population Ecology* 23:193-209.

Elbadry, E.A. and C.A. Fleschner. 1965. The feeding habits of adults of *Chrysopa california* Coquillett. (Neuroptera: Chrysopidae). *Bulletin de la Société Entomologique d'Egypte* 49:359-366.

Fleschner, C.A. 1950. Studies on searching capacity of the larvae of three predators of the citrus red mite. *Hilgardia* 20:233-265.

Fox, L.R. 1975a. Cannibalism in natural populations. *Annual Review of Ecology and Systematics* 6:87-106.

Fox, L.R. 1975b. Factors influencing cannibalism, a mechanism of population limitation in the predator *Notonecta hoffmanni. Ecology* 56:933-941.

Kehat, M. 1968. The feeding behaviour of *Pharoscymnus numidicus* (Coccinellidae) predator of the date palm scale *Parlatoria blanchardi. Entomologia Experimentalis et Applicata* 11:30-42.

Price, P.W. 1975. Insect Ecology. Wiley Interscience, 514 pp.

Sokal, R.R. and F.J. Rohlf. 1969. Biometry. Freeman, San Francisco, 776 pp.