THE PREDATORY CAPABILITIES OF *ORIUS TRISTICOLOR* (WHITE) AND SOME TEMPERATURE EFFECTS ON FEEDING

by

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ABSTRACT

Host preference and consumption rate studies of the six life stages of Orius tristicolor (White) were tested with eight prey. Statistical significance was found between daily consumption of all eight prey in all six life stages. Statistical comparison based on daily consumption of mobile vs. non-mobile prey indicated a general preference tendency for the mobile prey, larval and adult forms, over the non-mobile prey, eggs. Analyses of variance, based on equations for standardizing different prey species, indicated daily prey consumption was highly significant.

Prey consumption differences were analyzed using spider mites at three temperatures, 15°, 20°, and 30° C. Analyses of variance of daily consumption, temperature, and stage of predator indicated that the differences were all highly significant. Temperature did affect daily consumption at all stages with the least consumed at 15° C and the most at 30° C. The overall total lifetime consumption of spider mites was numerically different at the three temperatures. The analysis of the nutritional equivalents of the overall lifetime consumption of mites caused the temperature and temperature-stage of the predator interaction to be non-significant.

INTRODUCTION

Orius tristicolor (White), the minute pirate bug, has been reported in agricultural literature since the late 1800's. Observations often ranked it as the most numerous predator in cotton and alfalfa fields. It can also be found in native vegetation, as well as other agricultural crops. It is an indigenous predator that appears in early spring. Its population expands during the summer months when prey becomes more numerous, and it can be found in the field until late September in most areas. Considering its vast western distribution, its potential population densities, and its migrating habits, relatively little is known about its impact in the field, its predatory capabilities, or its prey preferences.

The objectives of this study were to determine under laboratory conditions, prey consumption rates of both nymphal and adult *O. tristicolor* as affected by temperature and the developmental stage of the prey and to determine host preferences, if they do exist. Since *Orius* had been reported as a good predator and found in high numbers in the field, its potential role in insect pest management was examined.

The greater emphasis being placed on natural control, as a part of the integrated pest management strategy, necessitated the careful examination of the quantitative and qualitative abilities of biological control agents, such as O. tristicolor. In order to clarify Orius' role in a pest management system, its predatory capabilities were examined to estimate impact of its population in the field and to utilize more fully its predatory abilities.

LITERATURE REVIEW

Biology

Information has been limited on *Orius tristicolor* (White); therefore, some information on other species of *Orius* will be included to help more readily define the predatory role of *O. tristicolor*.

O. tristicolor (White) and *O. insidiosus* (Say) are morphologically similar and can be distinguished by the clavus which is entirely black in *O. tristicolor* and dark at the base in *O. insidiosus*. Differences also exist between the male claspers (Kelton 1963). Parshley (1919), Knight (1925), Blatchley (1926), Torre-Bueno (1930), and Marshall (1930) considered *O. tristicolor* a color variation of *O. insidiosus*. However, Barber (1936), Van Duzee (1923), Harris and Shull (1944), and Anderson (1962) considered it a separate species. Kelton (1963) proved its specificity morphologically in 1963.

The genus *Orius* was first described by Wolff in 1811; however, *Orius insidiosus* was placed first in the genus *Reduvius* by Say in 1831. Fieber in 1860 placed it in *Triphleps*, and in 1926 Blatchley placed it in the genus *Orius* (Blatchley 1926).

Blatchley (1926) reported that Orius insidiosus was found all over the United States. Marshall (1930) and Blatchley (1926) reported it as a very common species found in the Pacific states. Anderson (1962) reported O. tristicolor to be the most common species in the Pacific Northwest.

The life history of O. insidiosus has been described by Garman and Jewett (1914), and Marshall (1930). Anderson (1962) described the species Orius tristicolor. Most workers found five nymphal instars. Marshall (1930) found no prominent nymphal change other than size. Askari and Stern (1972b) examined the mating behavior of O. tristicolor and found that the female became receptive shortly after the final molt, and began oviposition two to three days later, laying an average of 129 ± 12 eggs during her life span. Eggs are inserted into plant tissue with the cap protruding (Dicke and Jarvis 1962, Barber 1936, and Askari and Stern 1972b). Marshall (1930) found that female O. insidiosus are positively thigmotropic at the time of oviposition. Barber (1936) reported that female O. insidiosus could live up to 73 days when provided bollworms eggs. Marshall (1930) found that adult O. insidiosus normally live from 15 to 20 days, with the entire length of the life cycle ranging from 35 to 45 days. The life span of adult O. tristicolor was reported to be somewhat longer than at 35 days (Askari and Stern 1972b).

Garman and Jewett (1914), Marshall (1930), Barber (1936), Dicke and Jarvis (1962), and Abdellatif (1965) found that *Orius* spp. overwintered in the adult stage. Anderson (1962) and Abdellatif (1965) stated that only the female of *Orius tristicolor* overwinters.

Sunflowers, safflower, yellow star thistle, grain sorghum, London rocket, corn, cotton, and alfalfa all have served as host plants to *O. tristicolor* (Salas-Aguilar and Ehler personal communication 1978, Fye 1975, van den Bosch and Dietrick 1953, and Lopez and Teetes 1976). Fye (1975), Fye and Carranza (1972), and Lopez and Teetes (1976) reported a shift from native plants to agricultural crops in the early summer months when these crops begin to flower or become succulent. A shift back to native plants and alfalfa occurred when field crops began to senesce. Population densities of *Orius* spp. have been reported to have a close relationship with the presence of agricultural pests, particularly *Lygus* spp. and aphids (Rakickas and Watson 1974, Lopez and Teetes 1976, and Radcliffe et al. 1976).

Predation

Several authors looked into the specifics of *Orius* spp. predation (Barber 1936, Fletcher and Thomas 1943, Irwin, Gill, and Gonzales 1974, and Lopez and Teetes 1976). The information supplied placed *Orius* spp. as a generalized entomophagous predator. The host range is broad. Spider mites, lygus, thrips, lepidopteran eggs and larvae, aphids, and white flies have all been included in *Orius*' spp. diet

(Askari and Stern 1972b, Rakickas and Watson 1974, Ehler, Eveleens, and van den Bosch 1973, Atkins et al. 1957 Knowlton 1949b, van den Bosch and Hagen 1956, and Watve and Clower 1976).

To understand, estimate, and utilize *Orius* in agriculture, Soloman's (1949) two-fold nature of predation must be defined. He stated that first the functional response or the prey consumption must be known, and secondly the numerical response or density of the predator must be calculated. The data collected and presented here along with numerical observations reported by Fye (1971) in Arizona, Orphanides, et al. (1971) in California and Tamaki (1972) in Washington will provide a better understanding of what is eaten, under what conditions, at what densities, and in what kind of a sequence of host plants and seasons *O. tristicolor* can be found.

Irwin et al. (1974) purported *Orius* spp. to be an egg feeder; whereas Orphanides et al. (1971), Ehler et al. (1973), and Lingren and Wolfenbarger (1976) indicated a preference for larvae. Knowlton (1949a) in Utah listed *O. tristicolor* as having a preferred diet of aphids.

Garman and Jewett (1914), Dicke and Jarvis (1962) and Salas-Aguilar and Ehler (1977) contended that this predator is also phytophagous. When studying *O. tristicolor*, Dicke and Jarvis (1962) indicated that corn pollen grains were the principle food of nymphs, as well as adults. Askari and Stern (1972b) found that the life span of O. tristicolor was considerably shorter when fed only lima beans. Salas-Aguilar and Ehler (1977) investigated the diet of O. tristicolor and reported that a diet consisting of thrips and pollen was the most suitable for nymphs, and that a diet of green beans, pollen, and thrips increased adult longevity and total egg deposition. Fauvel (1971, 1974) studied a closely related species, O. vicinus Rib. and determined that nymphal development was possible on pollen alone but that the adult size was diminished by 10 percent and morphological abnormalities appeared. Imaginal life was reduced and the reproduction rate was poor (Barber 1936, and Flauvel 1974). However, these characteristics were reversible when restored to a normal entomophagous diet. He compared his results to other published reports on predators and found that O. vicinus behaved more like those insects linked to animal food.

Insect Pest Management

The usefulness of augmenting and conserving our resident natural control agents was recently reaffirmed by Bottrell and Adkisson (1977) in their review of cotton pest management strategies. They suggested this as only one means of improving pest management schemes. Their review emphasized the need for high levels of beneficial insects, for example Orius, in agricultural fields. They, too, found a definite lack of information that precisely quantified the effectiveness of natural enemies in suppressing pest species below economic thresholds. Current knowledge of the life system of O. tristicolor should make it a good candidate for quantification of its consumptive abilities and prediction of its use in integrated pest management systems.

Ehler, Eveleens, and van den Bosch (1973) evaluated O. tristicolor as a predator for cabbage looper in cotton fields in California. Whitcomb and Bell (1964) quantified O. insidiosus predatory consumption in a field study in cotton in Arkansas. They found 37.5% egg reduction due to Orius.

Ridgway et al. (1967) examined the impact of systemic insecticides on beneficial insects in Texas. They found that hemipterous insects, including Orius, were reduced after applications of systemics. Feese and Wilde (1975) found the same relationship. Lingren and Wolfenbarger (1976) using chlordimeform sprays found that good suppression of H. virescens could be achieved with little affect on O. insidiosus. Shepard and Sterling (1972) examined the effects of early season application of insecticides on the beneficial insect complex and found that some insecticides, such as Bidrin[R] and carbaryl, did affect O. insidiosus but it was able to recover. Lingren and Wolfenbarger (1976) found that Orius was relatively unaffected by insecticide applications and, therefore, could be utilized along with insecticides.

On the whole, selective chemical control has been shown to be compatible with *Orius* in the field, and the two could be employed in pest management systems.

Leigh et al. (1974) have shown that *O. tristicolor* populations can be augmented in cultural control programs within insect pest management programs. They found that *Orius* populations increased in higher plant densities and with more frequent irrigations. Rakickas and Watson (1974) found that *O. tristicolor* adults would migrate along with adult *Lygus* spp. from full-grown cut alfalfa to half-grown uncut alfalfa. This could be used as part of a management system, not only with alfalfa, but in larger areas where cotton and alfalfa were planted. The population densities of *Orius* in alfalfa might supplement populations of *Orius* in cotton fields or serve as a source when deleterious insecticides were used on cotton which killed the beneficials. Planting sorghum next to cotton could also help augment *Orius* populations. Lopez and Teetes (1976) found that *Orius* began to decrease in sorghum when their population levels began to increase in nearby cotton. Radcliffe et al. (1976) established high positive correlations between alfalfa cultivars, aphids, and *Orius*. All of the above cultural practices could prove useful to augment, conserve, and stabilize *Orius* populations in various integrated pest management schemes. Hence, the literature has shown that the genus has been studied in many facets, but particular aspects in the different species need further investigation to be fully understood and utilized in agricultural or in management systems.

METHODS AND MATERIALS

Culture

The culture was maintained at the USDA ARS Cotton Insects Bio-Control Laboratory in Tucson, Arizona. *Orius* adults were kept in a one-gallon jar and supplied fresh green beans every other day as an oviposition site. They were provided pink bollworm eggs (PBW) for food and a 70 percent fructose solution as a moisture and sugar source. The rearing cabinets were kept at 40 percent relative humidity. The green beans with newly oviposited eggs were removed every other day and kept in a one-quart fruit jar. Each jar was dated. These, too, were provided pink bollworm eggs as a food source and fresh green beans as a moisture source; the beans also supplied moisture for a higher relative humidity within the jars. All rearing took place at 30° C and at 14 hours of light. This procedure allowed the segregation of adults and the different instars. Cannibalism was thus relegated to a minor role.

Acceptance Tests

Acceptance tests (ACPT-T) were designed to act as a bottom line in determining how many individuals in the prey categories *Orius* would consume in a 24-hr. and 48-hr. period.

These tests would also tell whether each prey species and what life stages of it would be acceptable as a food source.

To determine if the prey would be acceptable as a food source for Orius, each individual stadium was provided with prey. The numbers consumed were counted and recorded. The daily consumption of these prey would later become the daily minimum number of prey provided for further testing.

Newly-molted Orius were obtained for each test. A minimum of five individual Orius were tested for each acceptance test for each prey and at each of Orius' life stages. Orius was placed with the prey in an inverted 44.42-cm^3 cream cup. Each cup had a 1.5-mm slice of fresh green bean, absorbent tissue, and prey. Tests were repeated if all prey provided in the cup were consumed. The objective was to determine the average number of prey consumed per day for each instar of Orius for all the prey types. This number would then become the minimum number provided per day for the next series of tests. The green bean was provided as a source of moisture in the creamer cups. The acceptance tests were run at 30° C for all prey. Tests were also run at 15° and 20° C for spider mite prey. All tests were held at 14 hours photophase. The tests were checked at 24 hours, and the amount consumed was recorded. Fresh beans and fresh prey were again provided. The tests were concluded on the second 24-hour period. Molts and deaths were also recorded. Individual

Orius that molted or died were not included in acceptance tests when calculating mean daily consumption because these two situations did not represent the normal feeding behavior of the population. After the tests were concluded, the mean consumed per day was determined. If the mean was slightly more than zero, a second series of tests were conducted. It became apparent that some prey was not acceptable the first day but on following days, *Orius* would feed on them. This behavior may have been a tendency for not readily feeding after molting rather than the prey being unpalatable.

Equivalence Tests

Equivalence tests (EQIV-T) were designed to obtain information about each individual life stage of *Orius*. Testing began at the beginning of a molt and lasted until the next molt or until death. The basic intent of the study was to examine the predator capabilities, one of which was daily consumption but other essential information, such as, number of days spent in a life stage was important and could also be obtained through this test.

Newly molted *Orius* were obtained and placed in 44.42 cm^3 inverted creamer cups and provided with 1.5-mm slice of green beans, absorbent tissue paper, and a minimum number of prey above daily consumption as determined from the tests. Extra prey was provided to ensure the predator a complete opportunity at maximum consumption. The tests ran from the first day of the molt until a new molt or until death. Adults and all five instars were tested. The tests were checked at 24-hour intervals, and the number of prey consumed was recorded. Any unusual behavior was also recorded. A minimum of 15 individuals per stadium per prey was maintained for each test, except for a very few cases in which either the prey was so unacceptable that this minimum number was hard to achieve or an error was made such that an individual observation had to be disregarded. With instars one through five, deaths, other than those associated with molting, negated that specific observation's validity, and it was not included in the overall calculations. Disappearances and accidental deaths, which were quite common, were not counted. Prey tested were pink bollworm, *Pectinophora gossypiella* (Saunders); bollworm, *Heliothis zea* (Boddie); cabbage looper, *Trichoplusia ni* (Hubner); cotton aphid, *Aphis gossypii* (Glover); and spider mite, *Tetranychus (Tetranychus) cinnabarinus* (Bois.).

Data were collected to provide quantitative information of *O. tristicolor* predatory capabilities such as: (1) total number of individuals tested per stadium, (2) total number of prey consumed per stadium and per total life stages, (3) mean consumption of prey per stadium and life cycle, (4) mean number of days per stadium and life cycle, (5) mean number of prey consumed per day, and (6) range of days in life cycle and life stages. Analysis of variance tests were conducted to determine significant differences in daily consumption between the different prey in each life stage, the combined life stages between the different species of prey, and between life stages of the same prey species. All these statistical analyses were prepared by Charles Gates, a statistician, and run in an ANOVA computerized program.

Mobility Preference Tests

Prey presented to *Orius* could actually be broken down into three types. These were (1) mobile or larvae, (2) sedentary-mobile or the adult cotton aphids and spider mites, and (3) non-mobile or eggs. Prey was presented to *Orius* in these forms in the EQIV-T tests and, therefore, no separate design was used to examine prey consumption on this basis. However, analyses were conducted on the data collected from EQIV-T tests to determine if differences in daily or total consumption could be a factor in prey consumption due to its mobility type. PIP_I and PIP_T values were calculated based on the mobility form consumption data. Analysis of variance tests were run to determine if significant differences existed between the daily consumption of prey mobility types.

Temperature Effects

To further observe *Orius*' predatory behavior, daily and total lifetime consumption patterns were studied at three temperatures: 15°, 20° and 30° C. Spider mite adults were placed in covered creamer cups. The creamer cups were inverted and snapped onto a creamer lid that had a hole punched through for a cotton seedling which provided a substrate for the mites. Small, six centimeter long vials containing vermiculite and the seedling were snapped into the hole. Cup cages were placed in trays in environmental chambers at the three temperatures at 14 hours photophase and 40 percent relative humidity. However, relative humidity was higher inside the mite cages. The means for individual life stages and for the combined life stages were found. The same ANOVA program was used to analyze these data. Combined total consumption for all stages at the three temperatures were calculated to see if temperature affected total lifetime consumption.

Nutritional Equivalent Values

The nutritional equivalent value of a prey might determine more readily how many prey are consumed than other factors such as, searching abilities or satiation point. Fye (1978) has proposed an equation for finding the nutritional value of prey. This equation may help balance the reported discrepancies in consumption figures and begin to predict Orius effectiveness. The nutritional equivalent of a prey was based on the premise that prey can be standardized by determining the daily consumption of one prey and determining a value for all other prey based on this one prey. This concept was called the prey index profile (PIP) by Fye (1978). For example, it was determined that adult Orius usually ate 0.93 cabbage looper egg (CLE) per day (Table A.6) Therefore, the daily consumption of 0.93 would be the basis for all prey nutritional value calculations for adult Orius. Each instar will have a different value on which to base all nutritional value calculations.

To determine the nutritional equivalent of the prey, the first step was to calculate the point value, PV_a, of one instar of Orius with a particular prey. This value was calculated by using equation 1 and the daily consumption of cabbage looper eggs for the instar being examined.

$$PV_a = \frac{1}{\text{No. of A eaten/No. of CLE eaten}} \quad \text{(Eq. 1)}$$

The PV_a value for adult Orius on cabbage looper eggs was 0.93/0.93 = 1. The number of A (any prey) eaten was determined from the calculated mean consumption per day of that prey in the EQIV-T tests (Tables 5 through 9 pp. 26-30).

PV_a was the point value of Orius at each life stage. There will be six PV_a values for each prey. The mean of these values constitutes the $\overline{X}PV_a$ value in the PIP_I equation. For calculation of the $\overline{X}PV_a$ of cabbage looper eggs was $PV_1 + PV_2 + PV_3 + PV_4 + PV_5 + PV_6 = \frac{6}{6} = 1 = \overline{X}PV_a$. The $\overline{X}PV_a$ was 1.

The next step in determing the nutritional equivalent was to calculate the PIP_I value, prey index profile for one instar.

$$PIP_I = \overline{X}PV_a \times P_e \times \text{No. Days} \quad \text{(Eq. 2)}$$

Equation 2 will determine the procedure for this calculation. P_e was the number of prey consumed per day as determined from the EQIV-T tests, in this example cabbage looper eggs (Table 7 p. 28). "No. Days" was the mean number of days spent in each instar as determined in the EQIV-T tests (Tables 5-9 pp. 26-30). Substituting the numbers appropriate for cabbage looper eggs in Equation 2, the PIP_I value was 12.03. $PIP_I = 1.0 \times 0.93 \times 12.93 = 12.03$. The PV_a values in Table 10 p. 31 were calculated by computer and when calculated by hand, vary sometimes by as much as tenths. The PIP_I values gave the relative rank of the prey nutritional equivalent values.

The PIP_T values were the prey index profile values for one particular prey for the entire six life stages of <u>Orius</u>. These values were also used to rank prey nutritional equivalents in a different manner from the ranking of the PIP_I for individual instars (Table 10 p. 31).

$$PIP_T = PIP_1 + PIP_2 \; . \; . \; . \; . \; PIP_6 \quad \text{(Eq. 3)}$$

The PIP_T value for cabbage looper eggs was 3.20 + 2.79 + 1.53 + 2.27 + 4.13 + 12.87 = 26.79.

PV_a values were calculated to determine PIP_I instar values and PIP_T total life stages values. These values were analyzed by an ANOVA analysis of variance computerized program. This program allowed the data to be approached from two views, the unstandardized raw data and the standardized PIP_I and PIP_T values. It was hoped that these analyses of the PIP_I and PIP_T values would provide an hierarchy of prey preference.

Control

Each prey species was tested as a check to determine the impact of the test environment on its mortality. The control tests were conducted in the same manner as that of the acceptance tests. Fresh prey were placed in the inverted cream cups for a 24-hour period and a 48-hour period, data on mortality of the prey species was recorded to determine the difference between natural and environmentally induced mortality.

RESULTS

Acceptance Tests (ACPT-T)

Data collected from the acceptance tests, ACPT-T, for each life stage of O. tristicolor using the various food sources were used as the daily consumption index for the equivalence tests, EQIV-T. The results from the ACPT-T tests can be found in Table 1. Three food sources, thrips, cotton pollen, and alfalfa pollen, were found to be unsatisfactory and no further tests were conducted.

Equivalence Tests (EQIV-T)

The mean daily consumption of the eight prey used in the EQIV-T tests can be found in Table 2 for all six life stages. Generally, daily consumption for all prey increased from the first instar of O. tristicolor through the adult stage. However, pink bollworm egg and cabbage looper egg consumption stayed relatively the same for all life stages of Orius. The smaller instars of Orius preferred pink bollworm eggs and larvae and cotton aphid adults to the rest of the prey. The larger instars least preferred corn earworm eggs and larvae and cabbage looper eggs and larvae. Pink bollworm larvae were the most preferred prey for all stages of Orius. The number of spider mite adults consumed was

Table 1. Acceptance Tests (ACPT-T) of *O. tristicolor* for Suitable Prey and Mean Daily Consumption

	Mean No. Consumed in 24 Hours					
Prey and Life Stage	Life Stage of Predator					
	N1	N2	N3	N4	N5	Adult
Pink bollworm egg[a]	1.01	2.25	4.67	3.00	2.85	3.82
Pink bollworm N1[b]	3.75	3.20	8.7	12.90	5.12	4.97
Bollworm egg[c]	0.30	0.80	1.2	1.55	2.47	1.34
Bollworm N1[d]	0.80	1.15	0.06	2.75	2.50	2.93
Cabbage looper egg[e]	0.80	0.80	0.92	1.70	0.60	0.8
Cabbage looper N1[f]	1.3	0.87	1.80	1.43	3.36	3.4
Cotton aphid adult	2.09	4.9	3.50	5.80	10.07	9.57
Spider mite adult	1.00	1.7	5.13	10.04	12.50	5.14
Thrips						2.53
Cotton pollen						0
Alfalfa pollen						0

[a]Pink bollworm egg

[b]Pink bollworm first larval instar

[c]Corn earworm egg

[d]Corn earworm first larval instar

[e]Cabbage looper egg

[f]Cabbage looper first larval instar

Table 2. *O. tristicolor* Equivalency Tests (EQIV-T) Indicating Mean Number of Prey Consumed Per Day

Life Stage of *O. tristicolor*	PBW[a] egg	PBW[b] N1	CEW[c] egg	CEW[d] N1	C.[e] Looper egg	C.[f] Looper N1	Cotton Aphid Adult	Spider Mite Adult
N1	4.00	4.21	0.54	1.08	1.04	1.11	2.53	1.23
N2	2.13	3.12	0.64	0.92	1.12	0.93	2.63	1.73
N3	3.94	8.71	1.12	0.99	0.79	2.41	3.17	5.09
N4	4.71	12.03	2.05	1.95	1.04	2.90	4.84	7.06
N5	3.60	19.54	2.20	2.60	1.07	2.75	7.03	8.05
Adult	2.35	25.39	1.19	1.63	0.93	13.49	8.48	6.91

[a]Pink bollworm egg

[b]Pink bollworm first larval instar

[c]Corn earworm egg

[d]Corn earworm first larval instar

[e]Cabbage looper egg

[f]Cabbage looper first larval instar

higher for the larger instars and the adult stage of Orius. Adult Orius ate fewer bollworm eggs, bollworm larvae, and cabbage looper eggs than other prey. The mean daily consumption of the combined life stages of O. tristicolor for the eight prey can be found in Table 3, and the mean daily consumption for all prey combined for the various life stages of Orius can be found in Table 4. Tables 5 through 9 show the mean prey eaten per day for each species of prey for all the life stages of Orius. Tables 1 through 6 Appendix A illustrate most of the information collected on Orius and presented by the individual life stages. The largest mean number of prey consumed was 25.39 PBW larvae by adult Orius. The least mean consumption was by first instar Orius, which ate 0.54 bollworm eggs per day (Table 2). The total consumption for the entire life of Orius ranked these prey in descending order: PBW N1, spider mites, cotton aphids, PBW eggs, CL N1, CEW N1, CEW eggs, and CL eggs (Tables 5 through 9). O. tristicolor lived the longest, 39.34 days, with CEW eggs (Table 6), and the shortest, 21.53, with PBW larvae as prey (Table 5). The nutritional equivalents indicated these prey in descending order as having greater value: Spider mites, CEW eggs, PBW larvae, cotton aphids, CL larvae, PBW eggs, CEW larvae and CL eggs (Table 10).

Significant differences were found between the mean daily consumption of all six of the life stages and all eight

Table 3. Means of the Eight Prey for All Life Stages of *Orius*

Prey	No. Tested	Prey Form[a]	Days Lived	Prey Consumed Per Day	PIP_T[b] Value
PBW egg	92	1	5.98	3.47	6.13
PBW N1	111	2	3.53	10.48	12.72
Bollworm egg	89	1	6.60	1.30	8.89
Bollworm N1	91	2	5.62	1.55	5.98
C. looper egg	89	1	4.51	0.998	4.48
C. looper N1	95	2	5.18	2.33	8.44
Cotton aphids	113	3	5.39	5.20	8.80
Spider mites	98	3	4.46	4.76	9.67

[a]Prey forms: 1 is immobile egg; 2 is mobile larvae; 3 is sedentary-mobile adult.

[b]Prey Index Profile for all life stages of *Orius* for that prey species.

Table 4. Means of All Prey Combined for Each Stage of *Orius*.

No. Tested	Stage of *Orius*	No. Days in Stage	Prey Consumed Per Day	$\bar{X}$ PIP_I^a Value
132	1	2.89	2.21	2.40
133	2	2.73	1.77	1.97
123	3	2.24	3.26	2.89
120	4	2.67	4.53	4.87
135	5	3.98	5.99	8.23
135	Adult	15.57	6.10	28.33

[a]Mean of the Prey Index Profile for one life stage of *Orius*.

Table 5. Equivalency Tests (EQIV-T) for Pink Bollworm Prey Based on Entire Time in Each Life Stage

O. tristicolor	Stage of Prey			
	Eggs		Larvae N1	
	$\bar{X}$ consumed/ day	No. days in stage	$\bar{X}$ consumed/ day	No. days in stage
Adult	2.35	21.67	25.39	7.47
5th	3.60	4.20	19.54	2.60
4th	4.71	2.87	12.03	2.79
3rd	3.94	2.60	8.71	2.13
2nd	2.13	2.87	3.12	3.27
1st	4.00	2.18	4.21	3.27
Total	20.73	36.39	73.00	21.53

Table 6. Equivalency Tests (EQIV-T) for Corn Earworm Prey Based On Entire Time in Each Life Stage

O. tristicolor	Stage of Prey			
	Eggs		Larvae N1	
	$\bar{X}$ consumed/ day	No. Days in stage	$\bar{X}$ consumed/ day	No. days in stage
Adult	1.19	24.80	1.63	15.15
5th	2.20	4.33	2.60	3.93
4th	2.05	2.20	1.95	3.60
3rd	1.12	2.27	0.99	2.13
2nd	0.64	2.53	0.92	2.29
1st	0.54	3.21	1.08	2.75
Total	7.74	39.34	9.17	29.85

Table 7. Equivalency Tests (EQIV-T) for Cabbage Looper Prey Based on Entire Time in Each Life Stage

O. tristicolor	Stage of Prey			
	Eggs		Larvae N1	
	$\overline{X}$ consumed/ day	No. days in stage	$\overline{X}$ consumed/ day	No. days in stage
Adult	0.93	12.93	3.49	13.90
5th	1.07	3.87	2.75	4.60
4th	1.04	2.47	2.90	2.33
3rd	0.79	1.93	2.41	2.00
2nd	1.12	2.50	0.93	1.80
1st	1.04	3.20	1.11	3.53
Total	5.99	26.90	13.59	28.16

Table 8. Equivalency Tests (EQIV-T) for Cotton Aphid Prey Based on Entire Time in Each Life Stage

O. tristicolor	Stage of Prey Adult	
	$\bar{X}$ consumed/day	No. days in stage
Adult	8.48	17.35
5th	7.03	3.70
4th	4.84	1.93
3rd	3.17	2.53
2nd	2.63	2.31
1st	2.53	2.80
Total	28.68	30.62

Table 9. Equivalency Tests (EQIV-T) for Spider Mite Prey Based on Entire Time in Each Life Stage

O. tristicolor	Stage of Prey	
	Adult	
	$\bar{X}$ consumed/day	No. days in stage
Adult	6.91	11.40
5th	8.05	4.87
4th	7.06	3.13
3rd	5.09	2.33
2nd	1.73	3.93
1st	1.23	2.23
Total	30.07	27.89

Table 10. Prey Index Profile (PIP_I)[a] Values for the Six Life Stages of *O. tristicolor* for Eight Prey

Life Stage *O. tristicolor*	Prey PBWE	PBW N1	CEWE	CEW N1	CLE	CL N1	CA	SM
1	2.99	3.76	1.65	1.78	3.20	2.24	1.89	0.97
2	1.92	2.79	1.66	1.28	2.79	1.00	1.44	2.48
3	3.24	5.11	2.75	1.40	1.53	2.84	1.98	4.46
4	4.39	9.20	4.42	4.42	2.27	4.08	2.27	7.98
5	4.86	14.18	9.15	6.70	4.13	7.64	6.50	14.44
Adult	19.78	14.14	33.22	15.97	12.87	26.73	34.04	31.89
Total[b]	37.18	49.18	52.85	31.55	26.79	44.53	48.12	62.22

[a]Same as nutritional equivalents.

[b]Same as Prey Index Profile values (PIP_T) for all life stages of *Orius* for one prey species.

prey. Significant differences were also found between the forms of the prey used, egg, larva, and adult (Table 11).

Mobility Preference Tests

The differences in consumption between the three forms of prey were examined and analyzed as non-mobile eggs, mobile larvae, and sedentary-mobile adults. Table 12 gives the means of the combined eggs as one, combined larvae as two, and combined adults as three for each life stage of *Orius*. The means of the total life stages of *Orius* in the three prey forms are given in Table 13, and Table 14 gives the means of all life stages of *Orius* for prey consumption of mobile vs. non-mobile. Consumption of the various forms of prey had little impact on mean number of days in the life stage; however, it did show numerical differences between the number of forms consumed. Eggs were consumed the least, an average of 1.94 per day; whereas, larvae were the most preferred at 5.14 per day. The adult form consumption was numerically similar at 4.99 per day. The nutritional equivalent values showed the same relationship as actual prey consumption. When the prey forms were further combined to mobile vs. non-mobile forms, the mean number of prey consumed showed the mobile form to be much preferred at 5.08 prey per day to 1.94 prey per day. The nutritional equivalents supported this. Significant differences were found between the prey consumed as egg form and the mobile larval form, and also in the nutritional equiva-

Table 11. Analysis of Variance Tests[a] of the Interactions Between the Six Stages of Predators Against the Eight Prey and the Other Combined Interactions Based on Daily Consumption, Days in the Life Stages, and the PIP_I Values

Variables	Daily Consumption	No. Days in Life Stage	PIP_I[b] Values
Life Stage of <u>Orius</u>	0.01**	0.01**	0.01**
Mobility Type as Prey[c]	0.01**	0.02*	0.07
Prey Species and Mobility Type[d]	0.01**	0.07	0.01**
Mobility Form of Prey-Life Stage of <u>Orius</u>[e]	0.01**	0.01**	0.18
Prey Species-Mobility Type-Life Stage of <u>Orius</u>[f]	0.01**	0.04*	0.01**

[a]Probability of the F values are in percentages and were tested at the one and five percent levels. **Significance was found at the 1% level, and *significance was found at the 5% level.

[b]Prey Index Profile values.

[c]Mobility type is the classification of non-mobile, mobile, or sedentary-mobile forms.

[d]Interaction for each prey species between the daily consumption of that species and the various mobility forms in the same prey species.

[e]Interaction between the daily consumption of the mobility forms of the prey and the life stage of <u>Orius</u> that actually consumed those prey.

[f]Interaction between the individual prey species against the interaction of the various mobility forms within that same prey species, and these two interactions against the six stages of <u>Orius</u>.

Table 12. Means of Mobility Forms[a] for Each of the Six Stages of Orius

No. Orius Tested	Mobility Forms	Stage of Orius	No. Days in Life Stage	Prey Consumed Per Day	PIP_I[b] Value
46	1	1	2.83	1.99	2.65
44	1	2	2.64	1.30	2.11
45	1	3	2.27	1.95	2.51
45	1	4	2.51	2.60	3.69
45	1	5	4.13	2.29	6.05
45	1	Adult	19.80	1.49	21.95
49	2	1	3.27	2.75	2.97
58	2	2	2.60	1.91	1.89
46	2	3	2.09	3.97	3.08
44	2	4	2.91	5.48	5.83
45	2	5	3.71	8.30	9.51
55	2	Adult	12.60	8.79	30.50
37	3	1	2.46	1.76	1.34
31	3	2	3.10	2.19	1.94
32	3	3	2.44	4.07	3.14
31	3	4	2.55	5.99	5.21
45	3	5	4.09	7.37	9.14
35	3	Adult	14.80	7.81	33.12

[a]Mobility forms are: 1 is non-mobile egg; 2 is mobile larvae; 3 is sedentary-mobile adults.

[b]Prey Index Profile value for one instar.

Table 13. Grand Means of the Three Types of Mobility Forms[a] of All Prey Species[b] Tested for All Life Stages (1-6) of Orius.

No. Tested	Forms of Prey	$\overline{X}$ No. of Days in Total Life Stages	$\overline{X}$ Prey Consumed Per Day	$\overline{X}$ PIP_T Value
270	Egg	5.70	1.94	6.50
297	Larvae	4.70	5.14	9.29
211	Adults	4.96	4.99	9.21

[a]The three mobility forms were (1) eggs as a non-mobile form, (2) larvae as one type mobile form, and (3) adult spider mites and aphid as a second type mobile form.

[b]The prey included all eight prey species.

Table 14. Means of Mobility Forms[a] (Mobile vs. Non-Mobile) for Combined Life Stages of *Orius*.

No. Tested	Mobility Form	No. of Days in Total Life Stages	Prey Consumed Per Day	$\overline{X}$ PIP_T[b] Value
270	1	5.69	1.94	6.49
508	2	4.81	5.08	9.25

[a]Mobility forms are (1) non-mobile eggs, and (2) mobile larvae and adults.

[b]Mean of the 8 Prey Index Profile value for each of the prey species.

lents of these same forms, but not in the number of days in the life stages of these same forms. No significant difference was found between the mobile larval forms and the sedentary-mobile adult forms (Table 15).

Temperature Effects Test

The three temperature levels, 15°, 20°, and 30° C, at which prey consumption tests were run, gave great numberical differences in the means. Figure 1 illustrates these differences for spider mite consumption for all six life stages at the three temperatures. The average number of insects eaten per day varied greatly from temperature level to temperature level for the various life stages. The first instar showed little temperature effect on daily consumption; however, all other life stages exhibited greater effects. The fifth instar illustrated the most dramatic temperature effect going from 1.79 at 15° C to 8.05 at 30° C prey per day. The means of the prey consumption of the combined life stages at the three temperatures can be found in Table 16. Highly significant differences were found between the number of prey consumed at the various temperatures, the six life stages of *Orius*, and the temperature-stage interactions. The latter indicated that the daily consumption of the six life stages of the predator were influenced by temperature. However, no inferences could be made from the analyses delineating the effects from either the temperature or the

Table 15. Analysis of Variance Tests[a] for All *Orius* Life Stages in Reference to Mobile vs. Non-Mobile Prey

	Prey Per Day	No. Days in Life Stage	$\bar{X}$ PIP_I[b] Value
Eggs vs. larvae	0.01**	0.12	0.02*
Larvae vs. Adult	0.78	0.60	0.96

[a]Probability of the F values are in percentages and were tested at the one and five percent levels. **Significance was found at the 1% level and *significance was found at the 5% level.

[b]Prey Index Profile values for one instar.

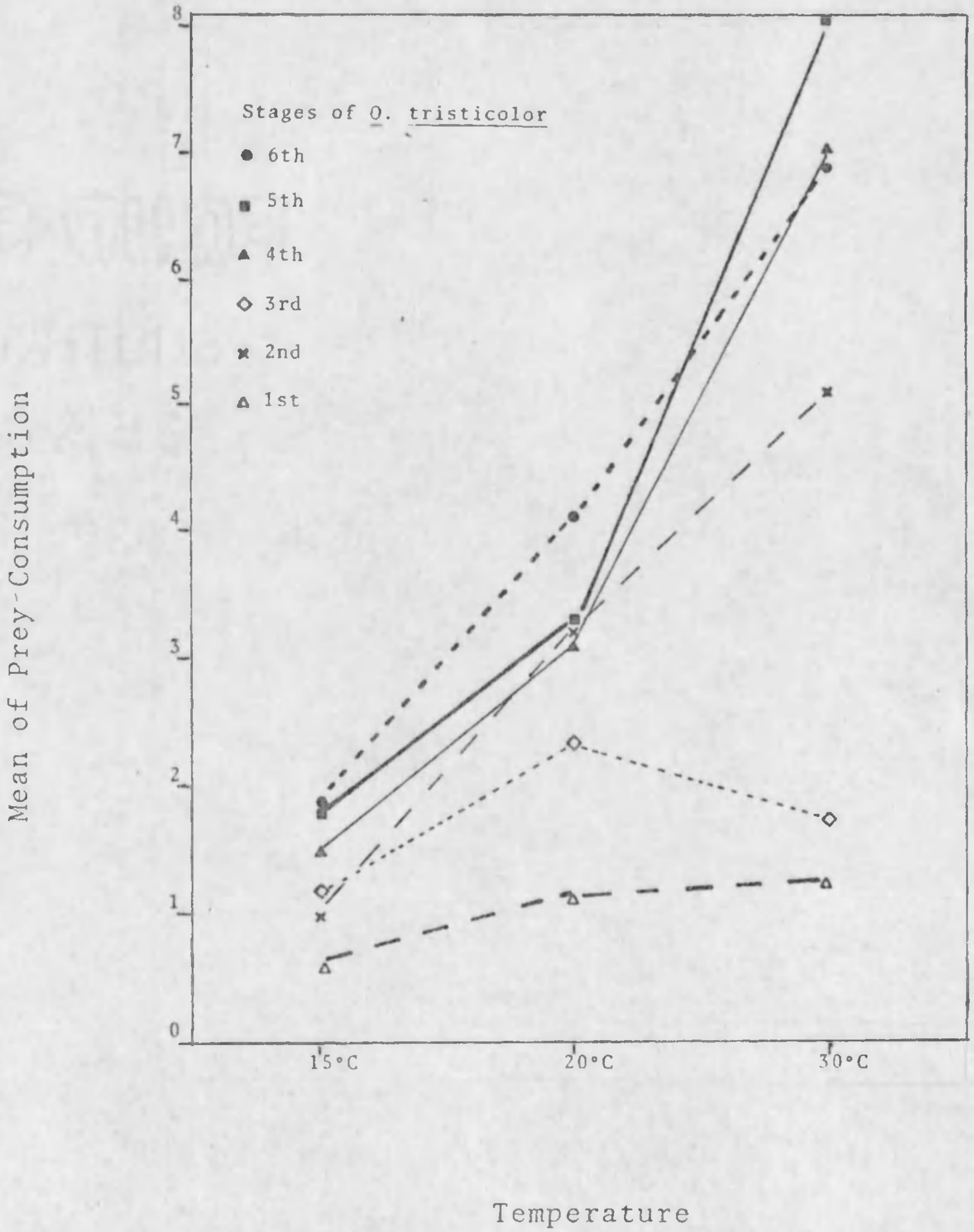

Figure 1. Mean Number of Spider Mites Consumed Per Day for Each Stage of O. tristicolor at Each of the 3 Temperature Levels.

Table 16. Means of the Combined Life Stages of *O. tristicolor* with Spider Mite Adults as Prey at Three Temperatures

No. Tested	Temp.	Total No. Days In Stages	Prey Consumed Each Day	$\overline{X}$ PIP_I Value[a]
98	30° C	4.46	4.76	9.67
87	20° C	5.44	2.78	6.43
93	15° C	14.87	1.39	9.88

[a]Prey Index Profile value for all stages of *Orius* for one prey species.

stage of Orius independently (Table 17). These two variables were analyzed together; and although statistical significance was shown, no further statistical manipulations were available to apply to the data in the manner in which it was collected to further separate these two variables and determine the individual significances.

Due to the procedure used to collect the temperature effects data, no way could be found to statistically analyze the total consumption for the total life stages of Orius. However, there were large numerical differences. Orius consumed 161.43 spider mites at 30° C for its entire life, and at 20° C, it consumed 101.26. This is a dramatic drop and, curiously, there is a rise to 125.05 prey per day at 15° C (Table 18). Either the data collecting technique was flawed or 20° C has detrimental effects on consumption and/or metabolism of spider mites. The nutritional equivalent values expressed this same dip between the three temperatures, but did show less of a gap numerically between temperatures (Table 18). The analysis of variance did show that when daily nutritional equivalent values were analyzed concerning the variables, temperature effect and temperature-stage of predator interaction, no significant differences were indicated. With this in mind, the temperature effect on the entire life cycle of Orius may not be as great as the numerical values indicated.

Table 17. Analysis of Variance Test[a] Results for the Temperature Levels[b] and Life Stages of _O. tristicolor_

	Probability Values of Prey Per Day	No. Days	$\bar{X}$ PIP$_I^c$ Value
Temp.	0.01**	0.01**	0.08[d]
Stage of _Orius_	0.01**	0.01**	0.01*
Temp. Stage of _Orius_	0.01**	0.01**	0.01*

[a]Probability of the F values are in percentages and were tested at the one and five percent levels. **Significance was found at the 1% level, and *significance was found at the 5% level.

[b]15°, 20°, and 30°C.

[c]Prey Index Profile for one instar.

[d]Not significantly different; all other probability values highly significant.

Table 18. Consumption of Spider Mites and Prey Index Profile (PIP_T Value) for Prey Consumed Over Entire Life of *O. tristicolor*

	Temperature		
	30°C	20°C	15°C
Total Prey Consumed[a]	161.43	101.26	125.05
PIP_T Value[b]	62.22	40.73	49.60

[a]Mean daily consumption X mean days lived per life stage, all stages totaled.

[b]Total PIP_I values or total nutritional values for all stages.

DISCUSSION

Equivalence Predator Values

A greater emphasis has been placed on natural control today than since before the introduction of chlorinated hydrocarbons. Therefore, it has become important to be able to quantify the activities of these biological control agents that are present in agroecosystems. The data collected and presented here along with numerical observations reported by Fye (1971) in Arizona, Orphanides et al. (1971) in California, and Tamaki (1972) in Washington will provide a better understanding of what is eaten, under what conditions, at what densities, and in what kind of a sequence of host plants and seasons *O. tristicolor* can be found.

Varying daily consumption figures have been given for *Orius* spp. Whitcomb and Bell (1964) in a field study on bollworms reported a 37.5 percent egg reduction, and Fletcher and Thomas (1943) found 23.3 percent of the egg and 52.3 percent of the larvae of *H. zea* were destroyed. Quaintance and Brues (1905) suggested that up to 50 percent *Heliothis* egg reduction was due to *Orius* spp. However, they failed to give a direct daily quantity consumed. My data indicated an overall consumption of bollworm was 1.30 eggs and 1.55 larvae per day (Table 3). Fifth instar nymphs ate the most at 2.20 eggs and 2.60 larvae per day (Table 2). The daily consumption of O. tristicolor confirmed Ewing and Ivy's (1943) average consumption of 2.8 eggs per day for O. insidiosus. Abdellatif (1965) tested O. tristicolor consumption of bollworm and thrips and found that there were numerical differences but no significant statistical differences. Anderson (1962) also found this relationship. Lingren, Ridgeway, and Jones (1968), in their field study, reported an adult consumption rate of 7 eggs and 4.4 larvae per day; but Orius was a more efficient predator of early instar larvae than eggs. However, of those predators tested, O. insidiosus ranked last. Nielson and Henderson (1959) concluded in predation tests on the spotted alfalfa aphid that O. tristicolor had the lowest consumption rate of those insects tested. Lingren et al. (1968) did find that O. insidiosus destroyed more prey when confined in small containers than when confined on 10-inch cotton terminals. Fye (1978) confirmed this and stated in his searching capacity tests that predators were not particularly efficient. Regarding those findings, my data appear to be in opposition since my daily consumption values were lower than those which were conducted in larger testing cages. My analyses do confirm the preference for larvae over eggs (Table 15).

Pink bollworm predation rate was the greatest found with an overall mean of 3.47 eggs and 10.48 larvae per day (Table 3). Fourth instar Orius had a rate of 12.90 PBW N1 per day, and thé third instar consumed 4.67 eggs per day (Table 2). Lindsey (1970), however, reported higher egg consumption than larval. A greater preference for PBW larvae than eggs was reported by Orphanides et al. (1971). They also rated the consumption of O. tristicolor as the lowest of the six predators they tested. Irwin et al. (1974), however, assigned O. tristicolor to an intermediate predatory position. Orius was reared successfully on PBW eggs, and this would indicate the acceptability of this prey not only on short term, but on a long term basis. Analysis of variance tests indicated a prey preference for the first larval instar over eggs (Table 15). The control test for pink bollworm indicated that there was either high natural mortality, environmentally induced mortality, or escape from the testing cages. Therefore, the daily consumption rates may be somewhat higher than the actual consumption rate.

Cabbage looper prey had rather low equivalency values (Table 2). Larval consumption was numerically higher than egg consumption, and there were significant statistical differences between them (Table 15). The overall value was 0.99 for eggs and 2.33 for larvae (Table 3). Adult Orius showed a greatly increased rate over the other instars at

13.49 larvae per day (Table 2). Looper egg equivalency values were all relatively the same (Table 2). Ehler et al. (1973) reported O. tristicolor to be an effective agent in keeping down looper populations.

Aphids constitute not only food for Orius, but the added aspect of attracting Orius spp. to concentrated areas of aphids (Radcliffe et al. 1976), often away from other host plants. Cotton aphids proved to be one of the prey with the highest consumption rates. The consumption rates increased from 2.53 aphids per day for the first instar to 8.48 aphids per day for adults (Table 8). Adult O. tristicolor lived a longer average number of days on this prey than any other prey (Tables 5-9). The nutritional values (PIP_I) calculated for the instars were intermediate. (Table 10 and Tables A1-A6) Appendix A). Not only was daily consumption high, but the PIP_I values indicated that the prey was a good one for O. tristicolor. Harrison (1960) found that O. insidiosus preferred cotton aphids to Heliothis eggs. Knowlton (1949a and 1949b) suggested a close relationship between the density of O. tristicolor and the number and accessibility of aphids. Ewing and Ivy (1943) concurred and stated that a correlation appeared to exist between Heliothis consumption and the availability of another food source, aphids. They found that Orius ate 16 times more eggs when no aphids were available. Previous observations by the present author of field conditions in alfalfa in Arizona suggested a close relationship between overwintering adults and early spring population increases of Orius to high populations of aphids. Nielson and Henderson (1959) in a laboratory study found O. tristicolor to be an ineffective predator on the spotted alfalfa aphids, consuming an average of five per day; however, Simpson and Burkhardt (1960) working on the same prey, reported Orius' ability to be moderately effective. Nielson and Henderson (1959) observed few instances where Orius attacked spotted alfalfa aphids in the field. Fauvel (1971) presented data that showed O. vicinus ate high numbers of aphids and mites. Barber (1936), van den Bosch and Dietrick (1953), van den Bosch and Hagen (1956) all reported instances of Orius spp. feeding on aphids with many consumption observations in the field.

Spider mites were reported as one prey that Orius biologically controlled by lowering their numbers (Oatman and McMurtry 1966). Others have given evidence of high consumption rates or high correlations with population reductions (van den Bosch and Dietrick 1953; van den Bosch and Hagen 1956; Dicke and Jarvis 1962; Fauvel 1971 and 1974; Tamaki 1972; Askari and Stern 1972a and 1972b; and Salas-Aguilar and Ehler 1977). Butler, Tuttle and Harvey (1952), working with O. tristicolor, found Orius ate 18.17 mites and eggs per day. This figure is well above the average 4.76 mites per day for all life stages (Table 3) or the highest value of 8.05 mites per day for the fifth instar (Table 11). The third instar through the adult stage consumed the most, varying from 5.09 to 8.05 mites per day (Table 11). The first and second instars ate 1.23 and 1.73 mites per day, respectively (Table 11). Askari and Stern (1972b) found that the fourth and fifth instars consumed the highest number of mites. The discrepancy between Butler et al. (1952) data and my data is the consumption of mite eggs. I daily swept clean, with a paint brush, the cotton leaves to eliminate the consumption of mite eggs and nymphs. I did see Orius, particularly the smaller instars, with their proboscis inserted into mite eggs. These incidents probably lowered the mean consumption of all stages, especially the smaller instars, but I cannot estimate to what extent eggs were consumed. However, if Butler (1952) assessed the consumption of eggs, nymphs, and adult mites as being equal, then his mean per day, understandably, would be higher than those which I found. Iglinsky and Rainwater (1949) reported the average adult O. insidiosus consumption to be 16 spider mites per day. The nutritional values (PIP_T) were among the higher values of all prey for all stages of O. tristicolor, indicating that spider mites are good prey for Orius.

Thrips repeatedly were suggested as prey for Orius spp. and much has been reported about the close relationship between numbers of Orius to numbers of thrips (van den Bosch and Dietrick 1953; van den Bosch and Hagen 1956; Dicke and Jarvis 1962; Garman and Jewett 1914; Knowlton 1949b; Tamaki 1972; Robinson, Stannard, and Armbrust 1972). Abdellatif (1965) and Salas-Aguilar and Ehler (1977) used thrips as the food source for their studies on the biology of *O. tristicolor*. I found in the acceptance tests that adult consumption of thrips was 2.53 per day (Table 1). This rate placed thrips at the third lowest consumption value. Due to the mobility of the adult thrips and my technique, I did not pursue their consumption in the equivalency tests. I rated them as one of the least favorable prey, especially when other instars were considered. Other low ranking prey, considering the adult *Orius* values, were found to be good prey for other instars, especially for the lowest instars. I considered thrips to be too active for the smaller instars (Table 1). I compared the mean number of days that *O. tristicolor* lived on thrips spp. as reported by Abdellatif (1965) and Salas-Aguilar and Ehler (1977) to those means of the prey I used and found them all to be relatively the same. Therefore, it appears that *Orius* spp. do utilize thrips as a prey and their consumption has relatively the same effect on growth and development as the five species of prey presented here.

Mobility Preference Values

The preceding discussion on the numbers of prey consumed at 30° C often indicated higher numerical values for mobile prey, such as spider mite adults and pink bollworm larvae, over non-mobile prey, pink bollworm eggs or *Heliothis* eggs (Table 2). Statistical analysis of my data indicated a general trend, if not a preference, for larvae and sedentary-mobile adults (Table 15). Of those mobile prey tested, *H. zea* larvae had the lowest overall consumption values with cabbage looper larvae next, excluding the value for adult *Orius* consumption (Table 2). The nutritional equivalent values also were shown to be significantly different for mobile over non-mobile prey (Table 15). However, there were no significant differences between the mobile larvae over the sedentary-mobile adults. There were great numerical mean-differences between mobile vs. non-mobile prey, and small mean differences between mobile over sedentary-mobile prey (Tables 13 and 14). Analysis of the PIP_T values indicated the same results (Tables 13, 14 and 15). Other scientists reported their estimations of larval preference over eggs (Lingren et al. 1968 and Orphanides et al. 1971) for bollworm, pink bollworm, and mobile adults over eggs (Harrison 1960 and Abdellatif 1965). This data and analyses seemed to add support to those reported consumption trends.

Temperature Effects Tests

Butler (1966) looked at temperature effects on the development of several hemipteran predators, one of which was *O. tristicolor*, and found that *Orius* lived the longest at 68° F and the shortest at 95° F with the optimum in the mid-80's. He did not examine the effects of temperature on food consumption. Abdellatif (1965) also studied temperature effects on the biology of O. tristicolor and noted also that high temperatures caused increased nymphal mortality and development was shorter. He looked at different prey at various temperatures and recorded percentage mortality. The optimum temperature was found to be 82.8° F. He analyzed the effect of the quality of food on the various life stages by examining percentage mortality and found no significant differences in their effects except for the fifth instar. There was a significant difference for the fifth instar between the rearing time on (1) cotton and thrips and (2) alfalfa and thrips and (3) bollworm eggs. Since O. tristicolor is found in alfalfa in early spring in Arizona, the impact on pest species, such as aphids, should be noted. I tried to quantify this impact by looking at mean daily consumption rather than percentage mortality. The mean daily consumption of mites at 30° C for all stages of Orius was 4.76, at 20° C was 2.78, and at 15° C was 1.39 spider mites per day (Table 18). The nutritional equivalent values (PIP_T) were 9.67, 6.43, and 9.88 for 30°, 20°, and 15° C respectively (Table 18). Thus it was seen that temperature over time had little effect at 15° C and at 30° C, but did show an effect at 20° C. This effect at 20° C could be an artifact of the technique. A statistically significant difference was shown at the 0.01 probability level for daily consumption and number of days in the stages to the interaction of temperatures, life stages, and temperature-life stage interactions when unstandardized raw data were used (Table 16). However, the variables of temperature and temperature-life stage were not significantly different when the nutritional values (PIP_I) were analyzed. This indicated that temperature does not readily affect feeding at individual life stages (Table 16). Nonetheless, there are numerical differences between the overall lifetime consumption of spider mites at the three different temperatures, 15°, 20°, and 30° C (Table 17). This increased numerical difference in consumption could very likely be due to the increased respiration rate of *Orius* at higher temperatures. The PIP_T nutritional values are also numerically different; however, there is less difference between 15° and 20° C than at 30° and 20° C or at 30° and 15° C (Table 17). Due to the manner in which the temperature effect data was collected, no statistical analyses could be performed to indicate significant differences.

Pollen

Pollen has been reported as a possible food source for *Orius* spp. by Garman and Jewett (1914), Barber (1936), Dicke and Jarvis (1962), Askari and Stern (1972b), Fauvel (1971, 1974) and Salas-Aguilar and Ehler (1977). Dicke and

Jarvis (1962) indicated that corn pollen grains were the main food source for O. insidiosus; and when corn began to shed pollen, entomophagous predation was reduced. Their findings indicated actual field observations of Orius with its proboscis inserted into pollen grains. They concluded that insect hosts were incidental food, and pollen was their principle food. Fauvel (1971, 1974), and Salas-Aguilar and Ehler (1977) have investigated pollen as a food source or as a supplementary source for Orius spp. and they concluded that it does, indeed, utilize various pollens, but that pollen alone caused either abnormalities or shortened life spans. Since O. tristicolor is found in alfalfa and cotton, and these crops constitute a high percentage of the overall production in Arizona, I investigated the consumption of pollen from cotton and alfalfa. I found in the acceptance tests that no discernible amount of pollen was consumed (Table 1). I never observed Orius with its proboscis in a pollen grain. Orius adults lived up to three days on cotton pollen, and this time approximates the length of time Orius can live without food.

I next tested the utilization of alfalfa pollen as a food source and discovered that the feces did exhibit a change in color and consistency. Again I could not detect any consumption. I allowed Orius adults to live two days on alfalfa pollen before the tests were terminated (Table 1). There was no mortality in these two days. It appears from the literature that *Orius* utilized pollen, but more research needs to be conducted to determine the role of cotton and alfalfa pollen. *Orius* is usually found in the flowering part of plants and, if it utilizes pollen, this could explain its occurrence in this niche. It could be as Salas-Aguilar and Ehler (1977) reported that the nymphs depend heavily on pollen for their growth. Fauvel (1974) reported that pollen, although not essential for normal growth, serves as the first food source for overwintering adults, is important to the early spring population, and has beneficial effects in the dynamics of biocontrol.

CONCLUSION

It has been shown that five common pests in Arizona cotton fields, *Pectinophera gossypiella*, *Heliothis zea*. *Trichoplusia ni*, *Aphis gossypii*, and *Tetranychus* (*Tetranychus*) *cinnabarinus*, served as acceptable prey for *O. tristicolor*. These arthropods served as prey for *Orius* from early spring to early fall when *Orius* migrated back to alfalfa or native plants (Salas-Aguilar and Ehler 1977, Fye 1972, 1975, and Fye and Carranza, 1972). *Lygus* and the false chinch bug probably served as part of the overwintering diet (Fye 1975). Thus the early increases of *Orius* were important in keeping down cool weather pests. The impact of 8.48 aphids consumed per day (Table 8) by female *Orius* could have lasting effects on total season populations of spotted alfalfa aphids or on *Lygus* spp. The PIP_I value for the entire adult life stage was 34.04 which was among the highest, indicating that cotton aphids were well utilized. Early *Orius* populations on March 25, 1974, at the Midvale Farm, Tucson, Arizona, totaled 3,900 *Orius* per acre (personal communication, Fye 1976). Their consumption of aphids, based on this data, would indicate a beneficial impact of 33,072 aphids consumed per day. Thus early season management of *Orius* could eliminate early sprays for cool season pests. Peak *Orius* populations in

July and August in cotton could have an impact, as great as 50,310 aphids per day, 101,394 pink bollworm larvae per day, or 12,578 bollworm eggs per day (Table 3 and personal communication, Fye 1976). All three prey had PIP_T values indicating their utility as good prey.

Lindsey (1970), in his work, indicated that O. tristicolor had potential as a good predator in Arizona, and my data confirm this. O. tristicolor, although consuming small numbers of prey per day as compared to larger predators (Fye 1978), was found in such high numbers (personal communication Fye 1976, Leigh et al. 1974, Lopez and Teetes 1976, and Shepard and Sterling 1972) that overall daily prey reduction in the field could be great. Orius has exhibited migration between several agricultural crops and the ability to change and adapt to those crops which are not only serving as hosts for pests, but also as plant hosts for itself. Keeping this potential in mind, Orius could be used as a tool in pest management. For instance, in a field with 50,000 cotton plants per acre, a 30 percent infestation of bollworm eggs would equal approximately 15,000 eggs per acre. At the peak level in 1974, there were 3,900 Orius per acre, which consumed 12,578 bollworm eggs per acre. By augmenting existing Orius populations, their density could be raised to levels where daily consumption would equal the 15,000 eggs available as food. The problem would be, not so much increasing the *Orius* populations above that peak level in 1974, but synchronizing the *Orius* populations with the crop and at the time that *Heliothes zea* infestations were greatest. The fact that *Orius* makes up only one portion of the entire predator-parasite complex illustrates the usefulness of *Orius* in insect pest management strategies.

The searching capacity of *Orius tristicolor* was not tested; however, inferences can be made on its ability based on the EQIV-T tests and the temperature effects test. *Orius* was a very mobile predator, going everywhere within the small test cages. It searched everywhere on the cotton seedings, in the sponge, and all over the creamer cup in the temperature effects test. I have confidence that under testing conditions, its searching capacity was high. However, under field conditions, *Orius* was normally found at the terminal and within the flowers of cotton and alfalfa. I believe that its searching capacity in the field would be reduced as compared to testing conditions, but the positive value of its searching capacity in the field would be for those insects often found around the cotton terminals, for example, bollworm eggs. Further testing would be necessary to clarify this potential.

It appears that the mobility of prey is a factor in prey consumption and preference. The moderately small, mobile, lepidopterous larvae and sedentary-mobile adult aphids and spider mites were readily consumed by the larger instars and the adult stage of O. tristicolor. The smaller instars tended to prefer the immobile egg stage. Thus the generally higher consumption values of the mobile and sedentary-mobile prey indicated preference for mobile prey.

Temperature was specified as an important factor in prey consumption. Consumption of prey even at a low temperature, 15° C, indicated that Orius did consume spider mites. This low rate of consumption at 15° C had generally the same impact in reducing pest populations as consumption at 20° C. It would take Orius more days at 15° C to reduce a prey population to the same level as it would at 20° C. Orius operated effectively in a cool environment, but reached its maximum consumption at 30° C.

Another important factor in the utility of Orius spp. as biological agents was their small size, and the niche they occupy. Lingren and Wolfenbarger (1976) found that due to their size and their niche Orius was somewhat more protected when insecticides were used. They stated that in the cotton field Orius played a more significant role in tobacco budworm reduction than Trichogramma, even under insecticidal conditions. Thus, it appears that Orius tristicolor has good potential as a biological agent considering its predatory capabilities, its migration habits, its size, and its niche.

SUMMARY

Host preference and consumption rates of the six life stages of *Orius tristicolor* were tested with five prey species exhibiting three types of mobility forms. Statistical significance indicated, not only daily consumption rate differences between prey species, but also differences between consumption rates of the mobility forms. It appeared that mobile larval and adult life stages were preferred to the non-mobile egg stage. No significant differences were detected between daily consumption rates of the adult and larval forms. More larvae were generally consumed than eggs in the three lepidoptern species tested. Daily consumption of all prey generally increased from the first instar through the adult stage. However, all stages of *Orius* consumed relatively the same numbers of pink bollworm eggs and cabbage looper eggs. The smaller instars of *Orius* preferred pink bollworm eggs and larvae and cotton aphids; whereas, the larger instars had higher consumption rates for bollworm eggs and larvae and cabbage looper eggs and larvae. Rates of consumption of pink bollworm larvae were much higher than rates for any other prey. Adult *Orius*, with the highest

consumption rates, ate 19.54 pink bollworm larvae per day, 8.48 cotton aphids per day, and 6.91 spider mites per day. Nutritional equivalent values indicated pink bollworm larvae, bollworm larvae, cotton aphids, and spider mites as the most acceptable prey.

Analysis of temperature effects on daily prey consumption at 15°, 20°, and 30° C indicated that differences were highly significant between (1) the three temperatures, (2) the six life stages of Orius, and (3) the temperature-life stage interactions when unstandardized data were used. Temperature did affect daily consumption at all stages with the lowest rates at 15° and the highest rates at 30° C. Temperature least affected daily consumption by the first instar Orius and most affected the fifth instar Orius. Based on daily consumption rates, the consumption by life stages of Orius were more greatly influenced than consumption due to temperature, consumption of mobility forms, the interaction between prey species and its mobility form, or the interaction between prey species, mobility type, and life stage of Orius. There were no significant differences between the three temperatures and the life stages when standardized nutritional equivalent values were used. There were numerical differences between total lifetime consumption of spider mites at these three temperatures, but statistical tests could not be utilized because of the method of data collection.

The daily consumption values in the lab indicated that *Orius* can have impact on pest populations. All instars of *Orius* were entomophagous, with the larger instars consuming more. The data indicated that smaller instars may consume the eggs and the less mobile prey; whereas, the larger instars and the adults may consume the more mobile prey. Thus *Orius* can have an impact on pest species in their egg and larval stages and on some adult forms. Other studies reported high numbers of *Orius* spp. in field crops. *Orius* population density coupled with their feeding rates indicate their utility as a good predator. Their reported mobility within agricultural crops over the season illustrates the potential to manipulate their numbers with the proper cultural practices. *O. tristicolor* appears to have utility in insect pest management programs.

APPENDIX A

SUPPLEMENTAL INFORMATION ON *O. TRISTICOLOR*

Table A. I. Means for *O. tristicolor* 1st Instar Prey Consumption, Time in Life Stage, Range in Days, and Nutritional Value Equivalents

Prey and Life Stage	No. *Orius* Tested	$\bar{X}$ Consumption Prey Per Day	$\bar{X}$ No. of Days in Life Stage	Range in Days	PIP_I^a Values
Pink bollworm egg	17	4.00	2.18	1-3	2.99
Pink bollworm N1	26	4.21	3.27	2-5	3.76
Bollworm egg	14	0.55	3.21	3-4	1.65
Bollworm N1	8	1.08	2.75	2-3	1.78
Cabbage looper egg	15	1.04	3.20	2-4	3.20
Cabbage looper N1	15	1.11	3.53	2-6	2.24
Cotton aphid A	15	2.53	2.80	1-4	1.89
Spider mite A	22	1.23	2.23	1-4	0.97

[a]Prey Index Profile at one life stage of *Orius* for one prey species.

Table A. 2. Means for *O. tristicolor* 2nd Instar Prey Consumption, Time in Life Stage, Range in Days, and Nutritional Value Equivalents

Life Stage	No. *Orius* Tested	$\bar{X}$ Consumption Prey Per Day	$\bar{X}$ No. of Days in Life Stage	Range in Days	PIP_I^a Values
Pink bollworm egg	15	2.13	2.87	2-5	1.92
Pink bollworm N1	26	3.12	3.27	2-6	2.79
Bollworm egg	15	0.64	2.53	1-5	1.66
Bollworm N1	17	0.92	2.29	1-4	1.28
Cabbage looper egg	14	1.12	2.50	2-3	2.79
Cabbage looper N1	15	0.93	1.80	1-3	1.00
Cotton aphid A	16	2.63	2.31	1-6	1.44
Spider mite A	15	1.73	3.93	1-7	2.48

[a]Prey Index Profile at one life stage of *Orius* for one prey species.

Table A. 3. Means for *O. tristicolor* 3rd Instar Prey Consumption, Time in Life Stage, Range in Days, and Nutritional Value Equivalents

Prey and Life Stage	No. *Orius* Tested	$\bar{X}$ Consumption Prey Per Day	$\bar{X}$ No. of Days in Life Stage	Range in Days	PIP_I[a] Values
Pink bollworm egg	15	3.94	2.60	2-4	3.24
Pink bollworm N1	15	8.71	2.13	1-4	5.11
Bollworm egg	15	1.12	2.27	1-3	2.75
Bollworm N1	16	0.99	2.13	1-5	1.40
Cabbage looper egg	15	0.79	1.93	1-3	1.53
Cabbage looper N1	15	2.41	2.0	1-3	2.84
Cotton aphid A	17	3.17	2.53	1-5	1.98
Spider mite A	15	5.09	2.33	1-5	4.46

[a]Prey Index Profile at one life stage of *Orius* for one prey species.

Table A. 4. Means for *O. tristicolor* 4th Instar Prey Consumption, Time in Life Stage, Range in Days, and Nutritional Value Equivalents

Prey and Life Stage	No. *Orius* Tested	$\bar{X}$ Consumption Prey Per Day	$\bar{X}$ No. of Days in Life Stage	Range in Days	PIP_I^a Value
Pink bollworm egg	15	4.71	2.87	2-5	4.39
Pink bollworm N1	14	12.03	2.79	2-4	9.20
Bollworm egg	15	2.06	2.20	1-3	4.42
Bollworm N1	15	1.95	3.60	2-5	4.42
Cabbage looper egg	15	1.04	2.47	1-4	2.27
Cabbage looper N1	15	2.90	2.33	1-3	4.08
Cotton aphid A	15	4.84	1.93	1-3	2.27
Spider mite A	16	7.06	3.13	2-7	7.98

[a] Prey Index Profile at one life stage of *Orius* for one prey species.

Table A. 5. Means for *O. tristicolor* 5th Instar Prey Consumption, Time in Life Stage, Range in Days, and Nutritional Value Equivalents

Life Stage	No. *Orius* Tested	$\bar{X}$ Consumption Prey Per Day	$\bar{X}$ No. of Days in Life Stage	Range in Days	PIP_I^a Values
Pink bollworm egg	15	3.60	4.20	4-6	4.86
Pink bollworm N1	15	19.54	2.60	1-4	14.18
Bollworm egg	15	2.20	4.33	3-5	9.15
Bollworm N1	15	2.60	3.93	2-5	6.70
Cabbage looper egg	15	1.07	3.87	3-5	4.13
Cabbage looper N1	15	2.75	4.60	3-6	7.64
Cotton aphid A	30	7.03	3.70	1-5	6.50
Spider mite A	15	8.65	4.87	2-6	14.44

[a]Prey Index Profile at one life stage of *Orius* for one prey species.

Table A. 6. Means for *O. tristicolor* Adult Prey Consumption, Time in Life Stage, Range in Days, and Nutritional Equivalents

Prey and Life Stage	No. *Orius* Tested	$\bar{X}$ Consumption Prey Per Day	$\bar{X}$ No. of Days in Life Stage	Range in Days	PIP$_I$[a] Values
Pink bollworm egg	15	2.35	21.67	2-63	19.78
Pink bollworm N1	15	19.54	7.47	2-31	14.18
Bollworm egg	15	1.19	24.80	6-50	33.22
Bollworm N1	20	1.63	15.15	8-38	15.97
Cabbage looper egg	15	0.93	12.93	4-61	12.87
Cabbage looper N1	20	3.49	13.90	8-41	26.73
Cotton aphid A	20	8.48	17.35	3-42	34.04
Spider mite A	15	6.91	11.40	3.26	31.89

[a]Prey Index Profile at one life stage of *Orius* for one prey species.

Table A. 7. Means of Prey as Larvae and Adults with Combined Life Stages of *Orius*

No. Days in Life Stage	4.81 ± 5.57
Prey Consumed/Day	5.08 ± 5.67
$\overline{X}$ PIP_I Value[a]	9.25 ± 16.49

[a]Mean Prey Index Profile for the life stages of *Orius* for the 3 lepidopterous larvae prey species.

Table A. 8. Mean Point Value ($\bar{X}PV_a$)[a] for the Eight Prey

Prey Species	$\bar{X}PV_a$
Pink bollworm eggs	0.32
Pink bollworm larvae	0.27
Bollworm eggs	0.96
Bollworm larvae	0.62
Cabbage looper eggs	1.00
Cabbage looper larvae	0.60
Cotton aphids	0.24
Spider mites	0.38

[a]See Nutritional Equivalent Values in Methods and Materials.

APPENDIX B

KEY CHARACTERISTICS FOR IDENTIFYING *O. TRISTICOLOR* INSTARS

1st Orange bands on abdomen are separated.
Eyes are brown with a thin orange margin.
Body is minute and very elongate.

2nd Bands on abdomen contrasted with brown, but not separated.
Eyes are brown, margins are brown, but more transparent at edges.
Body still is elongate.

3rd Eyes are dark brown with brown margins.
Body is less elongated, more oval.

4th Wing pads appear.

5th Wing pads cover most of the sides of the thorax.
Each instar increases in overall size.

LITERATURE CITED

Abdellatif, A. H. 1965. Life history of O. tristicolor (White) in the laboratory. M.S. thesis, Dept. of Entomol., Univ. of Arizona, Tucson. 43 pp.

Anderson, N. H. 1962. Anthocoridae of the Pacific Northwest with notes on distributions, life histories, and habits (Heteroptera). Can. Entomol. 94: 1325-33.

Askari, A. and V. M. Stern. 1972a. Effect of temperature and photoperiod on Orius tristicolor feeding on Tetranychus pacificus. J. Econ. Entomol. 65(1): 132-5.

Askari, A. and V. M. Stern. 1972b. Biology and feeding habits of Orius tristicolor Hemiptera (Heteroptera) Anthocoridae. Ann. Entomol. Soc. Amer. 65(1): 96-100.

Atkins, E. L., Jr., M. H. Frost, Jr., L. D. Anderson, and A. S. Deal. 1957. The "omnivorous leaf roller" Platynota stultana Wlshm. on cotton in California: nomenclature, life history, and bionomics (Lepidoptera, Tortricidae). Ann. Entomol. Soc. Amer. 50: 251-9.

Barber, G. W. 1936. Orius insidiosus (Say), an importnat natural enemy of the corn ear worm. U.S. Dept. Agric. Tech. Bull. No. 504. 24 pp.

Blatchley, W. S. 1926. Heteroptera or true bugs of eastern North America with special reference to the faunas of Indiana and Florida. Nature Publ. Co., Indianapolis, Ind. p. 637.

Bottrell, D. G. and P. L. Adkisson. 1977. Cotton insect pest management. Ann. Rev. Entomol. 22: 451-81.

Butler, G. D., Jr. 1966. Development of several predaceous Hemiptera in relation to temperature. J. Econ. Entomol. 59: 1306-7.

Butler, G. D., Jr., D. M. Tuttle, and T. Harvey. 1952. Beneficial insects of Arizona. Univ. of Ariz. Dept. Entomol. Doc. 407: 15-37.

Dicke, F. F. and J. L. Jarvis. 1962. The habits and seasonal abundance of Orius insidiosus (Say) (Hemiptera-Heteroptera-Anthocoridae) on corn. J. Kans. Entomol. Soc. 35: 337-44.

Ehler, L. E., K. G. Eveleens, and R. van den Bosch. 1973. An evaluation of some natural enemies of cabbage looper on cotton in California. Environ. Entomol. 2: 1009-15.

Ewing, K. P. and E. E. Ivy. 1943. Some factors influencing bollworm populations and damage. J. Econ. Entomol. 36: 602-6.

Fauvel, G. 1971. The influence of food on the biology of Orius vicinus Heteroptera Anthocoridae. Ann. Zool.-Ecol. Anim. 3(1): 31-42.

Fauvel, G. 1974. Food for a predatory anthocorid Orius (Heterorius) vicinus Rib. Hemiptera. Ann. Zool.-Ecol. Anim. 6(2): 245-58.

Feese, H. D. and G. E. Wilde. 1975. Planting time applications of systemic insecticides on grain sorghum for greenbug control: Interactions with herbicides and effect on predators (Hemiptera (Homoptera): Aphididae). J. Kan. Entomol. Soc. 48: 396-402.

Fletcher, R. K. and F. L. Thomas. 1943. Natural control of eggs and first instar larvae of Heliothis armigera. J. Econ. Entomol. 36(4): 557-60.

Fye, R. E. 1971. Grain sorghum "a source of insect predators for insects on cotton". Prog. Agric. Az. 23(1): 12-3.

Fye, R. E. 1972. The interchange of insect parasites and predators between crops. Cent. Overseas Pest Res. - Pest Art. News Sum. 8(2): 143-46.

Fye, R. E. 1975. Plant host sequence of major cotton insects in Southern Arizona. U. S. Dept. Agric., Agric. Res. Serv. Pub. series W-24. 9 pp.

Fye, R. E. 1978. Cotton insect populations: Development and the impact of predators and other mortality factors. U. S. Dept. Agric., Agric. Res. Serv. Bull. (In Press).

Fye, R. E. and R. L. Carranza. 1972. Movement of insect predators from grain sorghum to cotton. Environ. Entomol. 1: 790-1.

Garman, H. and H. H. Jewett. 1914. The life history and habits of the corn ear worm. Ky. Agric. Expt. Stn. Bull. 187: 511-91.

Harris, H. M. and W. E. Shull. 1944. Preliminary list of Hemiptera of Idaho. Ia. State Univ. J. Sci. 18: 199-208.

Harrison, F. P. 1960. Corn ear worm oviposition and the effect of DDT on the egg predator complex in corn silk. J. Econ. Entomol. 53: 1088-94.

Iglinsky, W., Jr. and C. F. Rainwater. 1949. Observations and life history notes on Orius insidiosus (Say), an important natural enemy of the red spider mite, Spoganychus spp., on cotton in Texas. J. Econ. Entomol. 49: 89-91.

Irwin, M. E., R. W. Gill, and D. Gonzales. 1974. Field-cage studies of native egg predators of the pink bollworm in southern California cotton. J. Econ. Entomol. 67: 193-6.

Kelton, L. A. 1963. Synopsis of the genus Orius Wolff in America north of Mexico (Heteroptera:Anthocoridae). Can. Entomol. 95: 631-5.

Knight, H. M. 1925. A list of Miridae and Anthocoridae from Alberta, Canada (Hemiptera). Can. Entomol. 57: 181-2.

Knowlton, G. F. 1949a. Predacious Hemiptera feeding observation. J. Kans. Entomol. Soc. 22: 37-9.

Knowlton, G. F. 1949b. Orius feeding notes. Bull. Brooklyn Entomol. Soc. 44: 53-5.

Leigh, T. F., D. W. Grimes, W. L. Dickens, and C. E. Jackson. 1974. Planting pattern, plant population, irrigation, and insect interactions in cotton. Environ. Entomol. 3: 492-6.

Lindsey, M. L. 1970. Field and laboratory studies on predation of the pink bollworm Pectinophora gossypiella (Saunders). M.S. thesis. Dept. of Entomol., Univ. of Arizona, Tucson. 25 pp.

Lingren, P. D., R. L. Ridgway, and S. L. Jones. 1968. Consumption by several common arthropod predators of eggs and larvae of two Heliothis species that attack cotton. Ann. Entomol. Soc. Amer. 61: 613-18.

Lingren, P. D. and D. A. Wolfenbarger. 1976. Competition between Trichogramma pretiosum and Orius insidiosus for caged tobacco budworms on cotton treated with chlordimeform sprays. Environ. Entomol. 5: 1049-52.

Lopez, E. G. and G. L. Teetes. 1976. Selected predators of aphids in grain sorghum and their relation to cotton. J. Econ. Entomol. 69: 198-204.

Marshall, G. E. 1930. Some observations on Orius triphleps insidiosus (Say). J. Kans. Entomol. Soc. 3: 29-30.

Nielson, M. W. and J. A. Henderson. 1959. Biology of Collops vittatus (Say) in Arizona, and feeding habits of seven predators of the spotted alfalfa aphid. J. Econ. Entomol. 52: 159-62.

Oatman, E. R. and J. A. McMurtry. 1966. Biological control of the two-spotted spider mite on strawberry in southern California. J. Econ. Entomol. 59: 433-5.

Orphanides, G. M., D. Gonzalez, and B. R. Bartlett. 1971. Identification and evaluation of pink bollworm predators in southern California. J. Econ. Entomol. 64: 421-4.

Parshley, H. M. 1919. Hemiptera of western Canada. Univ. of Mich. Occasional papers. Museum of Zoology, 71, p. 35 (cited by Kelton, 1963).

Quaintance, A. L. and C. T. Brues. 1905. The cotton bollworm. U. S. Dept. Agric. Bur. Entomol. Bull. 50. 155 pp.

Radcliffe, E. B., R. W. Weires, R. E. Stucker, and D. K. Barnes. 1976. Influence of cultivars and pesticides on pea aphid, spotted alfalfa aphid, and associated arthropod taxa in a Minnesota alfalfa ecosystem. Environ. Entomol. 5: 1195-1207.

Rakickas, R. and R. F. Watson. 1974. Population trends of Lygus spp. and selected predators in strip-cut alfalfa. Environ. Entomol. 3: 782-4.

Ridgway, R. L., P. D. Lingren, C. B. Cowan, Jr., and J. W. Davis. 1967. Populations of arthropod predators and Heliothis spp. after application of systemic insecticides to cotton. J. Econ. Entomol. 60: 1012-16.

Robinson, A. G., L. J. Stannard, Jr., and E. J. Armbrust. 1972. Observations on predators of Sericothrips variabilis Beach (Thysanoptera). Entomol. News 83: 107-11.

Salas-Aguilar, J. and L. E. Ehler. 1977. Feeding habits of Orius tristicolor. Ann. Entomol. Soc. Amer. 70: 60-2.

Shepard, M. and W. L. Sterling. 1972. Effects of early season applications of insecticides on beneficial insects and spiders in cotton. Tex. Agric. Exp. Stn. Misc. Publ. 1045. 14 pp.

Simpson, R. G. and C. C. Burkhardt. 1960. Biology and evaluation of certain predators of Therioaphis maculata (Buckton). J. Econ. Entomol. 53: 87-94.

Soloman, M. E. 1949. The natural control of animal populations. J. Anim. Ecol. 18: 1-35.

Tamaki, G. 1972. Biology and ecology of two predators Geocoris pollens Stal. and G. bullatus (Say). U. S. Dept. Agric., Agric. Res. Serv. Bull. 1446. 46 pp.

Torre-Bueno, J. R. de la. 1930. Records of Anthocoridae particularly from New York. Bull. Brooklyn Entomol. 25: 11-20.

van den Bosch, R. and E. J. Dietrick. 1953. Minute pirate bug Orius tristicolor, White. Dept. Entomol., Univ. of Ariz. Doc. 407: 28.

van den Bosch, R. and K. S. Hagen. 1956. Predaceous and parasitic arthropods in California cotton fields. Calif. Agric. Exp. Stn. Bull. 820. 32 pp.

Van Duzee, E. P. 1923. Expedition of the California Academy of Sciences to the Gulf of California in 1921: The Hemiptera. Proc. Calif. Acad. Science Vol. 12: 123-300.

Watve, C. M. and D. F. Clower. 1976. Natural enemies of the bandedwing whitefly in Louisiana. Environ. Entomol. 5: 1075-8.

Whitcomb, W. H. and K. Bell. 1964. Predaceous insects, spiders, and mites of Arkansas cotton fields. Ark. Agric. Expt. Stn. Bull. 690. 83 pp.