Evaluation of the Importance of the Striped Lynx Spider, *Oxyopes salticus* (Araneae: Oxyopidae), as a Predator in Texas Cotton

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ABSTRACT Predation by the striped lynx spider, *Oxyopes salticus* Hentz, on cotton arthropods was studied in an unsprayed field in east Texas. *O. salticus* was the most abundant spider species in cotton (68% of all spiders collected by D-Vac), with population densities of <0.1 spiders per m^2 in June gradually increasing to 7.2 per m^2 in September. This diurnally and nocturnally feeding spider captured prey ranging between 0.1 and 1.1 of its own size. Most prey were small (average body length = 2.61 ± 0.16 mm [SEM]). The natural diet of *O. salticus*, a generalist predator, was diverse, and consisted (by number) mainly of *Solenopsis invicta* Buren (21.9%), leafhoppers (17.2%), dipterans (15.6%), aphids (14.1%), and spiders (14.1%). Predaceous arthropods, including *Geocoris* bugs, and larvae of *Chrysopa* and Syrphidae, composed 42% of the spiders' diet. The proportion of *O. salticus* feeding at any one time was <5% throughout the 1985 season. A subadult/adult spider captured about one prey daily in the middle of the growing season. Based on population density counts and the assessment of the prey capture rate we estimated that in the middle of the growing season ca. 0.12 million prey may have been killed by *O. salticus* per ha cotton land per wk (weekly kill ca. 4.5% of the average arthropod density).

KEY WORDS *Oxyopes salticus*, cotton, prey capture rate, prey preference, phenology

INTEREST IN the role of spiders as natural control agents in agroecosystems is increasing world-wide (review in Nyffeler [1982], Riechert & Lockley [1984]). One of the most common foliage-dwelling spiders in the United States is the striped lynx spider, *Oxyopes salticus* Hentz (Young & Lockley 1985). This vagrant spider hunts among the foliage of various plant species, and has an average adult length of about 6 mm (females) and 5 mm (males) (Brady 1964). *O. salticus* forages throughout the entire plant, at times sitting motionless awaiting prey, at times running over leaves and stems of plants, and occurs in many different types of habitats throughout the United States (Brady 1964). *O. salticus* was found to be the most abundant spider in cotton fields in Arkansas (Whitcomb et al. 1963), Mississippi (Laster & Brazzel 1968), and Texas (Dean et al. 1982), as well as in soybean fields in North Carolina (Deitz et al. 1976) and Missouri (Blickenstaff & Huggans 1962). Because of its abundance, *O. salticus* was suspected of being a major predator of insects in these habitats (Brady 1964, Weems & Whitcomb 1977).

Very little research has been conducted on the feeding ecology of this species, perhaps due to the difficulty of observing predation by these vagrant spiders in the field (Brady 1964). The goal of this paper is to give some insight into the predatory activities of *O. salticus* in a Texas cotton agroecosystem. Studies on the feeding ecology of other spider species occurring in this agroecosystem are presented elsewhere (Nyffeler et al. 1986, 1987a, b,c).

Materials and Methods

During the summer of 1985 (June to mid-September) we evaluated the feeding biology and ecological importance of *O. salticus* by observing certain predatory activities at different times of the day and night in cotton. The investigations were conducted in a cotton field that received no insecticides or other chemicals and was located 8 km west of Austonio, Tex., near Crockett in Houston County. These fields border on meadows (composed of various grasses and low-growing annual Dicotyledoneae) that were mown once during this study. Most of our investigations were carried out in a 6.5-ha cotton field. Half of this field was heavily infested with weeds (Johnson grass); in the other half weeds had been removed mechanically. The lateral distance between rows was 1 m, with a mean of 10.1 cotton plants per m of row. The cotton (var. CAMD-E) was planted on 27 May, and emerged in the first week of June. The fields were cultivated twice. We finished our investigation on 16 September. At that time the fields had not yet been harvested.

Twenty-five semirandom D-Vac suction samples (Dietrick 1961), each of 1 m of row, were taken weekly for 14 wk during the summer of 1985 to assess spider and potential prey densities. Number of spiders per meter of row were converted into number of spiders per square meter. Number of spiders per meter of row equals number of spiders per square meter, since the lateral distance between rows was 1 m. Samples were begun away from the edge of the field and taken in a circular pattern throughout the season. The collected arthropods were returned to the laboratory and later identified and counted under the microscope. In addition, 10 D-Vac samples were taken in an adjacent meadow on five different dates to determine the population density of *O. salticus* in meadows compared with cotton fields.

For evaluation of the diet, during both day and night, the vegetation of cotton fields was thoroughly searched for feeding specimens of *O. salticus*. Such spiders were captured by hand with a transparent plastic cup (7.5-cm upper diameter). Spiders with prey between the chelicerae were killed and preserved in alcohol, and the prey later identified in the laboratory under a microscope.

For evaluation of prey selection, to determine whether *O. salticus* captured its prey randomly or selectively from the range of potential prey, we compared the diet of *O. salticus* with the spectrum of potential prey based upon D-Vac samples. Prey selection was evaluated by Ivlev's electivity index (E), a measure previously used for the estimation of food preference in fish and spiders, which gives a relative value between -1 and $+1$ (Ivlev 1961, Kajak 1965):

$$E = (r_i - p_i)(r_i + p_i)^{-1}, \quad (1)$$

where r_i is the proportion of a certain prey type i in the diet of *O. salticus*, and p_i is the proportion of prey type i in the range of potential prey. Electivity values of $E < 0$ indicate negative selection, $E = 0$ random feeding, and $E > 0$ positive selection.

The prey capture rate (b, number of prey per spider per day) of *O. salticus* can be assessed according to Edgar's (1970) method developed for wolf spiders. We used a formula we modified as follows:

$$b = \frac{(t_f)(60)(w)}{(1)(t_h)(100)}, \quad (2)$$

where t_f is the time (hours per day) available for prey capture and feeding in the field, w is the percentage of spiders with prey in a sample, and t_h is the average handling time (sensu Krebs [1985], in minutes). The handling time was taken as being the period between the initiation of an attack and the cessation of feeding.

In this study we used exclusively the handling time measured for subadult/adult *O. salticus* without differentiating between sexes; the handling time for very small spiders (1–1.9 mm total body length) was not measured. We calculated the prey capture rate for the middle of the cotton-growing season only, because at that time there was a size/age structure in the field, with >90% of the spiders coinciding largely with the size range of adults (adult *O. salticus* ranged from 2–2.9 mm to a maximum size of 8 mm). At other times of the growing season, immatures of 1–1.9 mm in size constituted up to 90% of the *O. salticus* population and without the knowledge of these very small spiders' handling time their prey capture rate could not be calculated.

Table 1. Proportion of *O. salticus* and other predaceous arthropods in the entire arthropod/predator complex of an east Texas cotton agroecosystem (14 June–4 September 1985)

Date	N[a]	% different predators				
		O. salticus	Other spiders	Ants[b]	Other predaceous insects[c]	Total
14 June	935	0.11	0.86	94.55	4.49	100
21 June	318	0	1.57	91.82	6.62	100
26 June	1,887	0.11	0.85	97.40	1.64	100
3 July	1,212	0.33	1.49	91.58	6.60	100
10 July	729	2.33	2.47	69.00	26.20	100
19 July	921	2.28	4.89	77.20	15.64	100
24 July	371	7.01	7.01	46.36	39.62	100
31 July	219	7.31	12.79	20.55	59.36	100
7 Aug.	529	5.67	8.32	56.00	29.11	100
14 Aug.	758	6.86	4.35	58.84	29.95	100
21 Aug.	702	14.10	7.69	49.86	28.35	100
28 Aug.	734	16.76	5.31	61.58	16.35	100
4 Sept.	529	32.51	4.91	49.53	13.04	100
Mean	—	7.34	4.81	66.48	21.30	100

[a] N = total number of predaceous arthropods collected by D-Vac (for each date, 25 D-Vac samples each of 1 m of row).

[b] Primarily *S. invicta*.

[c] *Geocoris*, *Orius*, Coccinellidae, Chrysopidae, Syrphidae, and others.

Feeding frequency (w) and the time available for prey capture and feeding in the field (t_f) were assessed by walking along cotton rows at different times of the day and season and recording the numbers of spiders with and without prey. Night observations were carried out using a head-lamp with white light. The spiders remained motionless when blinded by a beam of white light and could then easily be captured along with prey. These data were also used for the evaluation of changes in the diel and seasonal feeding activity of the spiders. To show if the frequency of feeding in *O. salticus* is dependent on the time of day or season, we used the χ^2 test of association.

To measure the handling time (t_h), 10 specimens of *O. salticus* (subadults/adults) were captured in the field on 8 August, introduced into plastic cages, and fed with leafhoppers of adequate size as the average natural prey.

Results

Numbers, Phenology, and Age Structure. *O. salticus* was the numerically dominant spider species in the cotton field (Fig. 1A). This species composed 68% of the total spiders collected by

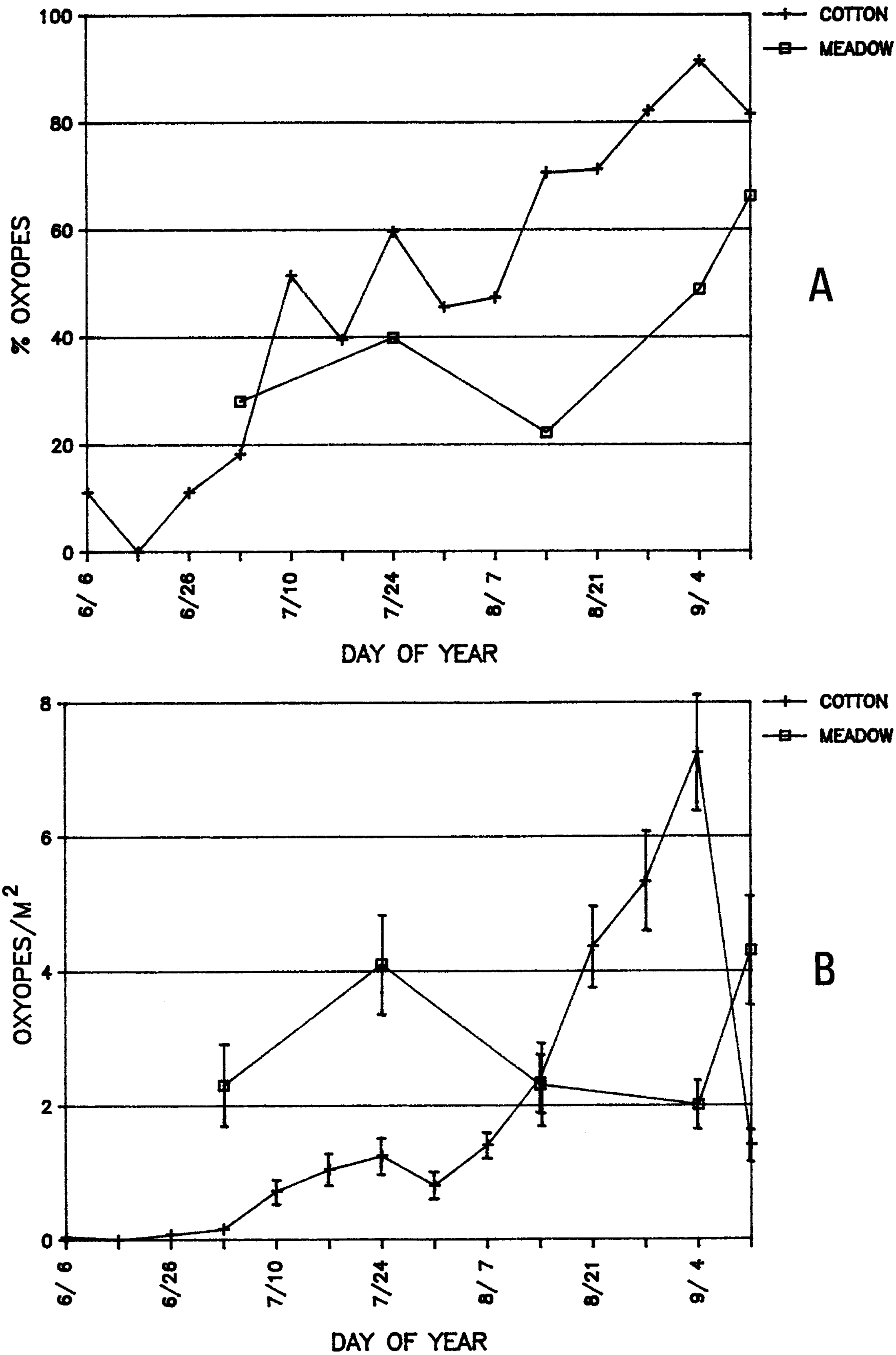
COTTON
MEADOW
% OXYPES
A
DAY OF YEAR
OXYOPES/M²
B
DAY OF YEAR
6/ 6
6/26
7/10
7/24
8/ 7
8/21
9/ 4

Table 2. Size and age structure of *O. salticus* population in an east Texas cotton agroecosystem (mid-June to mid-September 1985)

Date	Range of body length (mm)/carapace width (mm)[a]						Total (all sizes)			
	1–1.9/ 0.4–0.8	2–2.9/ 0.5–1.2	3–3.9/ 0.9–1.9	4–4.9/ 1.0–2.1	5–5.9/ 1.3–2.3	6–6.9/ 1.7–2.3	Immature	♂	♀	Σ
14 June	1						1			1
21 June										0
26 June				2			2			2
3 July	2	1		1			4			4
10 July	3	1	5	6 (1♂)	3		17	1		18
19 July	1	8 (1♀)	10 (1♂)	6 (2♂)	1 (1♀)		21	3	2	26
24 July	2	5	8	10 (3♂)	6 (2♂)		26	5		31
31 July	5	2	2	6 (1♂)	3 (1♂)	2 (2♀)	16	2	2	20
7 Aug.	10	7	7	10 (5♂)	1		30	5		35
14 Aug.	41	3	2	6 (3♂)	7 (3♂) (1♀)	1 (1♀)	52	6	2	60
21 Aug.	86	3	10 (2♂)	7 (5♂)	3 (1♂) (2♀)		99	8	2	109
28 Aug.	116	3	7 (3♂)	4 (3♂) (1♀)	2 (2♀)	1 (1♀)	123	6	4	133
4 Sept.	164	6	2	6 (1♂) (5♀)	2 (1♂) (1♀)	1 (1♀)	172	2	7	181
16 Sept.	25	5	3 (3♂)	1 (1♂)	1 (1♀)		30	4	1	35
Total	456	44 (1♀)	56 (9♂)	65 (25♂) (6♀)	29 (8♂) (8♀)	5 (5♀)	593	42	20	655

Numbers of each date are based on 25 D-Vac samples each of 1 m of row. Numbers in columns give total spiders (immatures plus adults) with number of adults in parenthesis.

[a] Mean carapace width: 0.50, 0.91, 1.27, 1.63, 1.79, 2.05.

D-Vac from June to September. *O. salticus* was also the most abundant spider in meadows bordering on these cotton fields (Fig. 1A).

The proportion of *O. salticus* in the entire arthropod predator complex sampled by D-Vac constituted <1% by the beginning of July, and increased in the course of the growing season up to >10% in the second half of August and later (Table 1).

In June the densities of *O. salticus* in cotton were very low (<0.1 per m^2). From then to mid-July the population density gradually increased to ca. 1 per m^2, and increased to 7.2 per m^2 in early September (Fig. 1B).

In July <40% of all *O. salticus* collected by D-Vac were <3 mm total body length. At the beginning of August about half of the collected spiders were <3 mm total length. After mid-August >70% of the collected spiders reached a total length of <3 mm (Table 2).

Until 3 July only immature *O. salticus* were collected. The proportion of adults increased from 6% on 10 July to ca. 16–20% in the second half of July (adults of both sexes were found since 19 July). In the first half of August, ca. 14% of the spiders were adults and, after 21 August, the proportion of adults was <10% (Table 2).

Potential Prey. The seasonal trend of the potential prey (available arthropods) of *O. salticus* in cotton is shown in Fig. 2. The numbers of potential prey in the cotton field steadily increased from mid-June (46.44 per m^2) with the progressing season up to a peak (348.24 per m^2) on 7 August. After that date, the numbers of potential prey decreased to 92.84 per m^2 in September. At all times predaceous arthropods and aphids were the most abundant potential prey of *O. salticus* in cotton (by numbers together >85%).

Natural Diet. In the cotton field, *O. salticus* killed prey between 0.1 and 1.1 of its own size. Most prey were small (average prey length = 2.61 ± 0.16 mm [$\bar{x}$ ± SEM]; range, 0.6–5.6 mm) relative to the size range of potential prey. We found a low positive correlation ($r^2 = 0.27$) between spider size and prey size.

A total of 64 prey items was collected in 85 h of searching (Table 3). Only one spider (1.6%) was found holding two prey items simultaneously between the chelicerae (multiple prey). Of the observed predation events, 35% were due to immature spiders, 18% due to penultimate/adult males, and 47% due to adult females. The spiders found feeding belonged to the following size classes (total body length): 1–1.9 mm (0% of the spiders), 2–2.9 mm (2% of the spiders), and ≥3 mm (98% of the spiders). The food of *O. salticus* consisted of phytophagous (e.g., leafhoppers and aphids) and predaceous arthropods. Workers of the red imported fire ant, *Solenopsis invicta* Buren, were the most frequent prey of *O. salticus*, constituting 22% of the spiders' diet. Both immature and adult spiders were observed feeding on *S. invicta*. Predaceous arthropods, including spiders; *S. invicta*; the big-eyed bug, *Geocoris punctipes* (Say); and the larvae of *Chrysopa* sp. and Syrphidae, accounted for 42% of the diet of *O. salticus*.

←

Fig. 1. (A) Proportion of *O. salticus* of all spiders in a cotton field and comparative values from an adjacent meadow in 1985 (D-Vac samples). (B) Numbers of *O. salticus* per square meter in a cotton field and comparative values from an adjacent meadow in 1985 (D-Vac samples). Vertical bars indicate SEM.

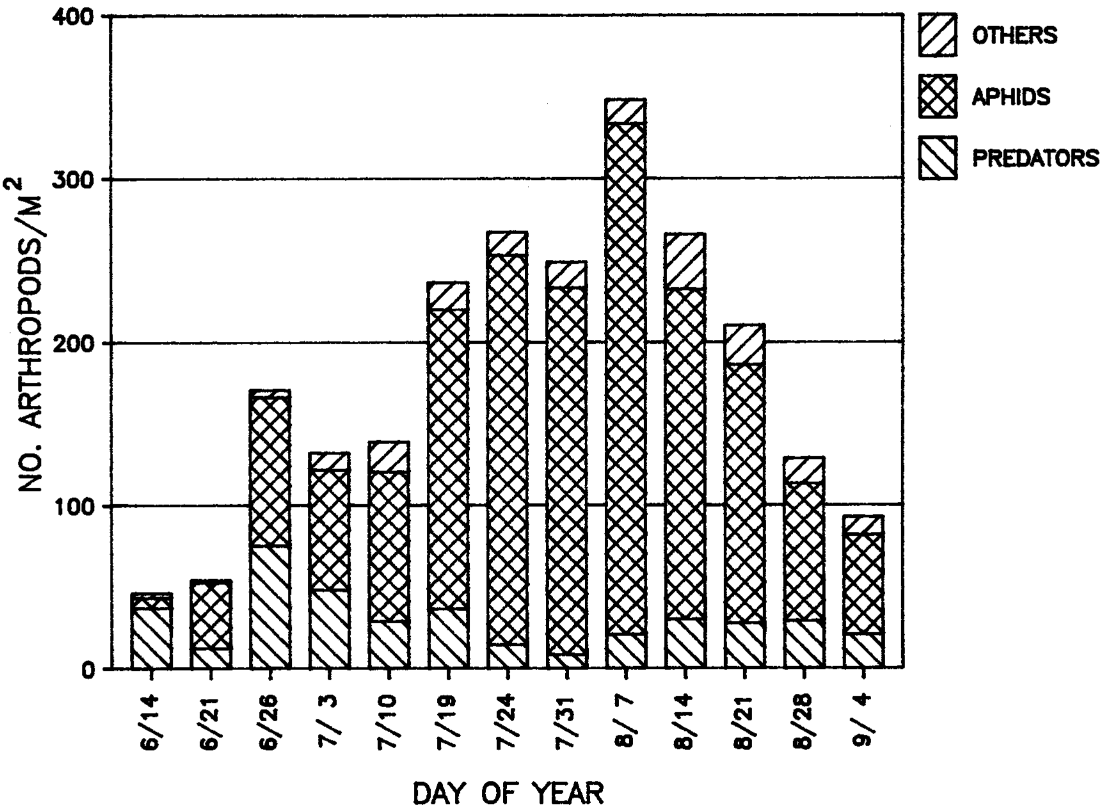

Fig. 2. Seasonal trend of the potential prey of *O. salticus* in an east Texas cotton agroecosystem in 1985 (numbers of arthropods per square meter sampled by D-Vac). Predators include ants, spiders, Heteroptera, Coccinellidae, Chrysopidae, Syrphidae, etc. Others include leafhoppers, Diptera, etc.

Prey Selection. Five major arthropod groups—*S. invicta*, leafhoppers, dipterans, aphids, and spiders—dominated in both the actual and potential prey (Fig. 3) constituting together 84% of the actual prey and 93% of the potential prey. *O. salticus* appeared to prefer spiders ($E = 0.82$) followed by Diptera ($E = 0.77$) and leafhoppers ($E = 0.43$), whereas aphids ($E < 0$) were underrepresented in the striped lynx spiders' natural diet relative to the proportion of these insects in the pool of potential prey.

Diel and Seasonal Changes in Feeding Activity. The proportion of *O. salticus* with prey at different times of the day (Table 4), suggests that this species feeds both day and night. The number of spiders with prey did not depend on the time of day. The percentage of feeding spiders was <5% throughout the 1985 season (Table 5); no dependence of the number of spiders with prey upon the time of the year was found.

Prey Capture Rate. For the estimation of the prey capture rate (b) of *O. salticus* we used formula 2. The following values were put into the formula: $t_f = 24$ (based on Table 4), $t_h = 49.00$ (mean value of 10 measurements on subadults/adults), and $w = 4.72$ (value for 22–28 July from Table 5). On this basis we estimated that a subadult/adult spider captured, in the middle of the cotton-growing season, on the average of a little more than one prey daily. This is, however, a rough estimate that needs to be verified by food-consumption studies under laboratory conditions.

The number of prey killed by *O. salticus* per square meter per week was estimated for the time from 22 to 28 July 1985 (in the middle of the growing season) by multiplying the estimated number of prey captured daily times 7 d times number of spiders per square meter. We estimated that from 22 to 28 July ca. 12 prey per m^2 may have been killed by *O. salticus*. An extrapolation of this value over an entire field leads to the conclusion that approximately 0.12 million prey may have been killed by *O. salticus* per ha cotton land during that week. At that time of the season the number of arthropods per square meter available as potential prey for *O. salticus* was 267.12 (Fig. 2). Thus, in the middle of the growing season the weekly prey kill by *O. salticus* may have been ca. 4.5% of the average arthropod density.

Discussion

During early June, very few spiders were found on the small cotton plants but high densities were already present in the adjacent meadows (based on

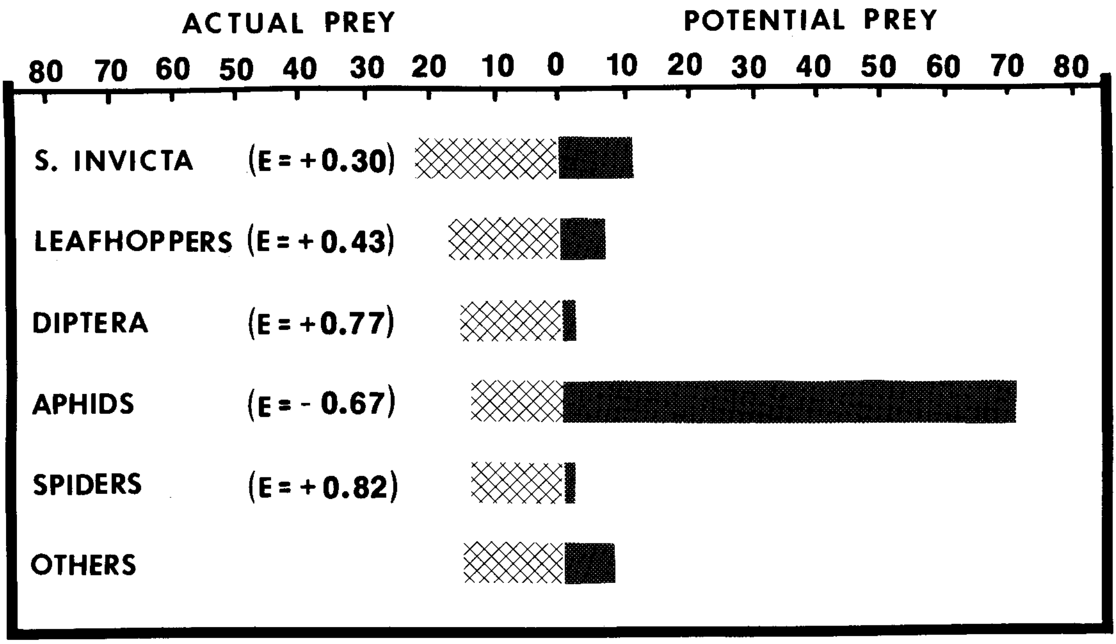

Fig. 3. Comparison of actual and potential prey (percentage by number) of *O. salticus* in a cotton agroecosystem, with calculated electivity indices (*E*).

direct observations and sweep-net samples). Thus, the cotton fields were surrounded by high densities of *O. salticus* and it is likely that those meadows functioned as reservoirs for the colonization of the cotton fields by *O. salticus*. As Dean & Sterling (1985) demonstrated in a study conducted in eastern Texas, this spider is very vagile. The marked increase of the population density of *O. salticus* from mid-August to the beginning of September is likely due to reproduction in the cotton field, because many females guarding egg sacs as well as recently hatched spiderlings were observed in the field during August.

According to the literature, *O. salticus* is a diur-

Table 3. Natural diet of *O. salticus* in an east Texas cotton agroecosystem (summer 1985)

Prey	July		Aug.		Sept.	Total		Prey size range (mm)	Predator size range (mm)	Stage and sex of predator[a]
	1–15	16–31	1–15	16–31	1–15	*N*	%			
Solenopsis invicta Buren worker	0	1	5	7	1	14	21.9	2.1–2.9	3.7–6.8	i, p♂, ♀
Leafhopper sp.	0	2	6	3	0	11	17.2	2.2–3.4	2.6–8.0	i, ♀
Diptera sp.	1	1	7	1	0	10	15.6	1.5–4.1	4.6–5.6	i, p♂, ♂, ♀
Aphid sp.	0	6	3	0	0	9	14.1	0.6–1.3	3.7–7.3	i, p♂, ♂, ♀
Hymenoptera	0	0	1	0	0	1	1.6	2.1	7.4	♀
Grasshoppers	0	0	0	1	0	1	1.6	4.4	5.6	♀
Lygaeidae	0	0	0	1	0	1	1.6	3.9	[b]	[b]
Geocoris punctipes (Say)	0	0	2	0	0	2	3.1	3.6–3.9	5.9–6.8	♀
Chrysopa sp. larvae	0	0	0	1	0	1	1.6	5.6	6.9	♀
Syrphidae larvae	0	1	0	0	0	1	1.6	4.5	[b]	[b]
Oxyopes salticus Hentz	0	0	2	1	2	5	7.8	1.1–5.0	3.9–7.1	i, ♀
Acanthepeira stellata (Walckenaer)[c]	0	0	2	0	0	2	3.1	1.3–1.5	3.6–4.4	i, ♂
Tetragnatha laboriosa Hentz	0	0	1	0	0	1	1.6	3.4	6.4	♀
Pardosa atlantica Emerton	0	0	0	1	0	1	1.6	2.8	6.6	♀
Unidentified[d]	0	1	3	0	0	4	6.3	—	—	—
Total	1	12	32	16	3	64	100	—	—	—

[a] i, immatures; p♂, penultimate males; ♂, adult males; ♀, adult females.
[b] Spider size and stage not identified.
[c] The two *Acanthepeira* found as prey were immatures. In Texas both *Acanthepeira stellata* and *Acanthepeira cherokee* Levi occur, which cannot be separated as immatures. However, because numerous adults captured in east Texas cotton fields all were *A. stellata*, we suppose that the two specimens listed in the table belong to this latter species.
[d] Could not be identified due to spider mastication.

Table 4. Diel change of the percentage of feeding spiders in an *O. salticus* population in an east Texas cotton agroecosystem (summer 1985)

Time of day	Time spent observing (h)	No. spiders observed	No. spiders with prey[a]	% spiders with prey
0800–1155	25	445	16	3.6
1200–1555	17	229	7	3.1
1600–1955	19	480	14	2.9
2000–2355	13	385	15	3.9
0000–0355	3.5	144	7	4.9
0400–0755	7.5	207	7	3.4

[a] $P > 0.05$; χ^2.

Table 5. Seasonal variation of the percentage of feeding spiders in an *O. salticus* population in an east Texas cotton agroecosystem (summer 1985)

Time of year	Time spent observing (h)	No. spiders observed	No. spiders with prey[a]	% spiders with prey
22–28 July	4.5	127	6	4.72
29 July–4 Aug.	14	275	10	3.64
5–11 Aug.	17	379	12	3.17
12–18 Aug.	18.5	388	15	3.87
19–25 Aug.	9	231	4	1.73
26 Aug.–3 Sept.	10	333	9	2.70
4–8 Sept.	4.5	103	2	1.94

[a] $P > 0.05$; χ^2.

nal species (Whitcomb et al. 1963, Brady 1964, Leigh & Hunter 1969), whereas we found that this species feeds day and night. We consider feeding (likewise locomotion, mating, hunting, etc.) as an activity and, thus, define animals that are feeding during the daylight hours as diurnal and those feeding during the period of darkness as nocturnal. The fact that *O. salticus* was observed feeding during the night is not proof for nocturnal foraging, because these spiders may feed during the night on prey that they captured before sunset or during dusk. However, because adult females of *O. salticus* have an average handling time of <1 h (range of 10 measurements for average-sized prey, 8–86 min), one can assume that some of the spiders that were found several hours after sunset feeding on prey of rather small size had foraged nocturnally. This hypothesis of nocturnal foraging in *O. salticus* is verified by an incidental observation from 5 August, when in the cotton field a spider of this species was observed capturing a small fly during the period of darkness (at 2210 hours CST, ca. 1.5 h after sunset).

Our data indicate that *O. salticus* is a generalist. Other oxyopid species also were found to be generalist predators (Furuta 1977, Turner 1979, Nyffeler et al. 1987a). The major food component of *O. salticus* in this Texas cotton agroecosystem was *S. invicta*. Red imported fire ants are themselves aggressive predators and, thus, it is quite interesting that lynx spiders are able to use these insects as a primary food source. We assume that ants at times try to defend themselves against the attacks of spiders, because we observed workers of *S. invicta* biting the legs of *O. salticus*. Spiders of the genus *Oxyopes* have also been observed capturing ants in Asia (Furuta 1977). Other important prey of *O. salticus* in Texas cotton were Diptera, aphids, and leafhoppers. According to Altieri & Whitcomb (1979), *O. salticus* inhabiting Mexican tea (*Chenopodium ambrosioides* L.) in north Florida have also been observed feeding on aphids and leafhoppers. A considerable proportion of the prey of *O. salticus* was spiders (cannibalism and interspecific predation). Other lynx spider species have also been observed to capture spiders. The green lynx spider, *Peucetia viridans* (Hentz), was frequently observed feeding on spiders on cotton and croton plants in east Texas (Nyffeler et al. 1987a), and in the laboratory prey taken by the gray lynx, *Oxyopes scalaris* Hentz, included spiders of the families Clubionidae, Oxyopidae, Salticidae, Thomisidae, and Theridiidae (Cutler et al. 1977).

The key pests in Texas cotton fields are the boll weevil, *Anthonomus grandis* Boheman; the cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter); and *Heliothis* spp. In our study no cases of predation by *O. salticus* on one of these pests were observed, possibly due to the low numbers of the pests. However, during the summer we collected only 64 prey items. Studies of the diets of *Oxyopes scalaris* (Cutler et al. 1977, Carroll 1980) and *Oxyopes sertatus* L. Koch (Furuta 1977) provide evidence that spiders of this genus are able to kill various prey, including different kinds of beetles and moths. As our study in east Texas shows, *O. salticus* captured prey with a total length of up to 5.6 mm (Table 3). Thus, small adults of the boll weevil as well as eggs and larvae of *Heliothis* spp. are in *O. salticus*'s prey range. Also, the cotton fleahopper falls into this prey-size range, and *O. salticus* has been observed feeding on this insect by Kagan (1943), Whitcomb et al. (1963), and D.A.D. and W.L.S. (unpublished data). In previous observational studies on lynx spiders, no insect eggs are recorded as prey of these spiders. However, McDaniel & Sterling (1982) placed radioactive *Heliothis virescens* (F.) eggs in a cotton field and captured radioactive specimens of *O. salticus*, indicating that lynx spiders may be egg predators.

In *O. salticus*, as in other hunting spiders, the average proportion of feeding individuals in a population was <10% (Table 6). The low proportion of feeding spiders seems to be a pattern typical for several species of hunting spiders, whereas in some species of web-building spiders a large proportion of a spider population (>40%) is simultaneously feeding at certain times of the day (see Nyffeler [1982]).

Using Edgar's (1970) method, we estimated for subadult/adult *O. salticus* a prey capture rate of approximately one prey per spider per day (in the middle of the cotton growing season). We com-

Table 6. Percentage of feeding spiders observed in populations of hunting spiders (literature review)

Spider species	Location	Habitat	Authors	% spiders feeding
Oxyopes salticus Hentz[a]	Texas	Cotton field	This paper	3.2
Peucetia viridans (Hentz)[a]	Texas	Cotton field	Nyffeler et al. (1987a)	5.0
Pardosa agrestis (Westring)[b]	Switzerland	Wheat field	Nyffeler (1982)	3.9
Pardosa amentata (Clerck)[b]	Holland	[e]	Edgar (1970)	7.8
Pardosa lugubris (Walckenaer)[b]	Switzerland	Forest	Nyffeler & Benz (1981)	6.0
Pardosa pauxilla Montgomery[b]	Texas	Cotton field	D.A.D. (unpublished data)	8.2
Pardosa spp.[b]	Switzerland	Meadow	Nyffeler (1982)	5.0
Pirata piraticus (Clerck)[b]	Germany	Salt marsh	Schaefer (1974)	8.0
Xysticus cristatus (Clerck)[c]	Switzerland	Meadow	Nyffeler (1982)	8.3
Misumenops celer (Hentz)[c]	Texas	Cotton field	D.A.D. (unpublished data)	1.4
Phidippus audax (Hentz)[d]	Texas	Cotton field	D.A.D. (unpublished data)	3.1

[a] Lynx spiders (Oxyopidae).
[b] Wolf spiders (Lycosidae).
[c] Crab spiders (Thomisidae).
[d] Jumping spider (Salticidae).
[e] Habitat not mentioned.

pared this value with data from the literature. In laboratory experiments confined to small (237 ml) containers, Lingren et al. (1968) showed that adult females of *O. salticus* consumed an average of 93.6 first-instar *Heliothis* sp. per spider per d, but adult spider males consumed fewer larvae (56.7 larvae per spider per d). This experiment by Lingren et al. (1968) indicates that adult *O. salticus* have a high prey-killing capacity, especially if prey are abundant. However, this is a very "unnatural" experiment that may not extrapolate to the much more complex field conditions. Being aware of that, Lingren et al. (1968) conducted a second experiment that provided the larval prey with refugia. Adult *O. salticus* were confined with *Heliothis* sp. larvae on 25.4-cm cotton terminals for 4 d; here the average prey capture rate for adult *O. salticus* was 0.5 larvae per spider per d, which is a much lower value than in the first experiment in small containers. A different approach was chosen by Richman et al. (1980), who assessed the prey capture rate of *O. salticus* by field cage experiments in a Florida soybean field; here *O. salticus* consumed an average of 1.14 soybean looper larvae per spider per d. The results of these experiments do not differ much from our estimate with Edgar's (1970) method. It is probably realistic to assume for subadult/adult *O. salticus* an average prey capture rate of approximately one average sized prey per spider per day. The prey capture rates of adult European wolf spiders, which have approximately the same average adult length as *O. salticus*, were estimated to be of the same magnitude (Edgar 1970, Schaefer 1974, Nyffeler 1982).

From June to the beginning of July the proportion of *O. salticus* in the entire arthropod/predator complex was <1% (Table 1), suggesting that the spiders' impact on cotton insects was very small during that period of the growing season; during the same period, red imported fire ants were very abundant predators in cotton, constituting >90% of the predaceous arthropods (Table 1). After 10 July, the proportion of *O. salticus* in the predator complex increased to ca. 7% in the middle of the growing season and reached >10% in the second half of August and later (Table 1). However, from the significantly increased numbers of *O. salticus* after 14 August one cannot necessarily deduce that the spiders' impact as predators was higher then, because >80% of all *O. salticus* occurring in the cotton field in the second half of August and later had a total body length of <2 mm (Table 2); the food intake capacity and success rates of the very small *O. salticus* stages in capturing certain cotton pests may be limited by the small size of these early instars.

In future research the handling time (t_h) of the various development stages for both sexes of *O. salticus* should be measured, so that the spiders' prey capture rates in the different periods of the cotton growing season can be calculated with Edgar's (1970) method. Due to limitation of time we have chosen a simplistic approach without a differentiation of the foraging parameters between the sexes of *O. salticus*, but we are fully aware that the foraging parameters of males and females may differ (Lingren et al. [1968] and Furuta [1977] found that in adult *Oxyopes* spp. males captured fewer prey than females). Prey capture rates of the various *O. salticus* stages should also be assessed with feeding tests in the laboratory. In addition, the instars of various pest species that can be overcome by very small *O. salticus* should be evaluated to determine the prey-size range of these very small spiders. Currently little is known about the natural diet and prey capture rates of the very small *O. salticus* stages; we assume that they capture small insects, because Whitcomb & Eason (1965) were able to feed second-instar *O. salticus* with the flower thrips, *Frankliniella tritici* (Fitch). The assessment of prey-size range and prey capture rates of these very small *O. salticus* stages is of special importance, because they predominated in the spider fauna in cotton in August and September (Table 2). To understand their impact, one needs to know more about their feeding biology. Another future step in the assessment of the impact of *O. salticus* as a predator of cotton pests should be to evaluate through field experiments the values of mortality of economically important cotton arthropods caused by this spider. A field experiment in that direction was carried out in Arkansas cotton fields by Whitcomb & Eason (1967), who came to the conclusion that in 2 different yr, 11 and 14% of all arthropod predation on second-instar bollworms was due to *O. salticus*.

O. salticus is a predator of cotton pests (Kagan 1943, Whitcomb et al. 1963) and natural enemies (this study). Thus, the positive effect of this spider species as a predator of pests may be counteracted to some extent by its activity in killing natural enemies. The green lynx was also found to be a predator of both pests and beneficial insects (Turner 1979, Randall 1982, Nyffeler et al. 1987a). As the data presented in this paper show, we found low incidence of predation by *O. salticus* on cotton pests, probably because the pests (with the exception of aphids) were relatively rare in the area of Austonio during the period of this study (D.A.D., unpublished data). It would be important to conduct a similar observational study on striped lynx spider predation in a cotton season, when injurious pests (such as cotton fleahoppers, *Heliothis* spp., and boll weevils) are common. Because spiders of the genus *Oxyopes* are abundant in agroecosystems in different parts of the world (review in Young & Lockley [1985]), the evaluation of their role as natural control agents of insect pests is of importance.

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References Cited

Altieri, M. A. & W. H. Whitcomb. 1979. Predaceous arthropods associated with Mexican tea in north Florida. Fla. Entomol. 62: 175–182.

Blickenstaff, C. C. & J. L. Huggans. 1962. Soybean insects and related arthropods in Missouri. Mo. Agric. Exp. Stn. Res. Bull. 803.

Brady, A. R. 1964. The lynx spiders of North America north of Mexico (Araneae: Oxyopidae). Bull. Mus. Comp. Zool. 131: 429–518.

Carroll, D. P. 1980. Biological notes on the spiders of some citrus groves in central and southern California. Entomol. News 91: 147–154.

Cutler, B., D. T. Jennings & M. J. Moody. 1977. Biology and habitats of the lynx spider *Oxyopes scalaris* Hentz (Araneae: Oxyopidae). Entomol. News 88: 87–97.

Dean, D. A. & W. L. Sterling. 1985. Size and phenology of ballooning spiders at two locations in eastern Texas. J. Arachnol. 13: 111–120.

Dean, D. A., W. L. Sterling & N. V. Horner. 1982. Spiders in eastern Texas cotton fields. J. Arachnol. 10: 251–260.

Deitz, L. L., J. W. Van Duyn, J. R. Bradley, R. L. Rabb, W. M. Brooks & R. E. Stinner. 1976. A guide to the identification and biology of soybean arthropods in North Carolina. N.C. Agric. Exp. Stn. Tech. Bull. 238.

Dietrick, E. J. 1961. An improved backpack motor fan for suction sampling of insect populations. J. Econ. Entomol. 54: 394–395.

Edgar, W. D. 1970. Prey and feeding behaviour of adult females of the wolf spider *Pardosa amentata* (Clerck). Neth. J. Zool. 20: 487–491.

Furuta, K. 1977. Evaluation of spiders, *Oxyopes sertatus* and *O. badius* (Oxyopidae) as a mortality factor of gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae) and pine moth, *Dendrolimus spectabilis* (Lepidoptera: Lasiocampidae). Appl. Entomol. Zool. 12: 313–324.

Ivlev, V. S. 1961. Experimental ecology of the feeding of fishes. Yale Univ., New Haven, Conn.

Kagan, M. 1943. The Araneida found on cotton in central Texas. Ann. Entomol. Soc. Am. 36: 257–258.

Kajak, A. 1965. An analysis of food relations between the spiders—*Araneus cornutus* Clerck and *Araneus quadratus* Clerck—and their prey in meadows. Ekol. Polska A 13: 717–764.

Krebs, C. J. 1985. Ecology: the experimental analysis of distribution and abundance, 3rd ed. Harper & Row, New York.

Laster, M. L. & J. R. Brazzel. 1968. A comparison of predator populations in cotton under different control programs in Mississippi. J. Econ. Entomol. 61: 714–719.

Leigh, T. F. & R. E. Hunter. 1969. Predaceous spiders in California cotton. Calif. Agric. 23(1): 4–5.

Lingren, P. D., R. L. Ridgway & S. L. Jones. 1968. Consumption by several common arthropod predators of eggs and larvae of two *Heliothis* species that attack cotton. Ann. Entomol. Soc. Am. 61: 613–618.

McDaniel, S. G. & W. L. Sterling. 1982. Predation of *Heliothis virescens* (F.) eggs on cotton in east Texas. Environ. Entomol. 11: 60–66.

Nyffeler, M. 1982. Field studies on the ecological role of the spiders as predators of insects in agroecosystems. Ph.D. thesis, Swiss Federal Inst. of Technology, Zurich.

Nyffeler, M. & G. Benz. 1981. Some observations on the feeding ecology of the wolf spider *Pardosa lugubris* (Walck.). Dtsch. Entomol. Z. 28: 297–300.

Nyffeler, M., D. A. Dean & W. L. Sterling. 1986. Feeding habits of the spiders *Cyclosa turbinata* (Walckenaer) and *Lycosa rabida* Walckenaer. Southwest. Entomol. 11: 195–201.

1987a. Predation by green lynx spider, *Peucetia viridans* (Araneae: Oxyopidae), inhabiting cotton and woolly croton plants in east Texas. Environ. Entomol. 16: 355–359.

1987b. Feeding ecology of the orb-weaving spider *Argiope aurantia* (Araneae: Araneidae) in a cotton agroecosystem. Entomophaga 32: (in press).

1987c. Prey records of the web-building spiders *Dictyna segregata* (Dictynidae), *Theridion australe* (Theridiidae), *Tidarren haemorrhoidale* (Theridiidae), and *Frontinella pyramitela* (Linyphiidae) in a cotton agroecosystem. Southwest. Nat.: (in press).

Randall, J. B. 1982. Prey records of the green lynx spider, *Peucetia viridans* (Hentz) (Araneae, Oxyopidae). J. Arachnol. 10: 19–22.

Richman, D. B., R. C. Hemenway & W. H. Whitcomb. 1980. Field cage evaluation of predators of the soybean looper, *Pseudoplusia includens* (Lepidoptera: Noctuidae). Environ. Entomol. 9: 315–317.

Riechert, S. E. & T. Lockley. 1984. Spiders as biological control agents. Annu. Rev. Entomol. 29: 299–320.

Schaefer, M. 1974. Experimental studies on the importance of interspecies competition between three wolf spider species (Araneidae: Lycosidae) in a salt marsh. Zool. Jb. Syst. 101: 213–235 (in German).

Turner, M. 1979. Diet and feeding phenology of the green lynx spider, *Peucetia viridans* (Araneae: Oxyopidae). J. Arachnol. 7: 149–154.

Weems, H. V. & W. H. Whitcomb. 1977. The green lynx spider, *Peucetia viridans* (Hentz) (Araneae: Oxyopidae). Fla. Dep. Agric. Div. Plant Ind. Entomol. Circ. No. 181.

Whitcomb, W. H. & R. Eason. 1965. The rearing of wolf and lynx spiders in the laboratory (families Lycosidae and Oxyopidae: Araneida). Ark. Acad. Sci. Proc. 19: 21–27.

1967. Life history and predatory importance of the striped lynx spider (Araneida: Oxyopidae). Ark. Acad. Sci. Proc. 21: 54–58.

Whitcomb, W. H., H. Exline & R. C. Hunter. 1963. Spiders of the Arkansas cotton field. Ann. Entomol. Soc. Am. 56: 653–660.

Young, O. P. & T. C. Lockley. 1985. The striped lynx spider, *Oxyopes salticus* (Araneae: Oxyopidae), in agroecosystems. Entomophaga 30: 329–346.

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