

## Foraging by generalist grasshoppers: two different strategies

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**Abstract.** Observations of foraging activities were conducted on two species of generalist grasshoppers that are cryptic on foliage, *Schistocerca nitens* and *S. shoshone*, which have overlapping distributions in the southwestern region of the U.S.A. Patterns of activity, feed lengths, food choice and switching between host plants were examined by continuous recording of individuals for up to 8 h each in the field. Long feeding bouts and limited locomotion were the norm in both species. Individuals often remained with one plant for most of the day, but then typically fed on more than one tissue type during an observation period. Declining feeding-bout lengths on a single species or tissue were common, as were increased feeding-bout lengths on novel foods. The data from these foliage-cryptic species contrasted with data collected previously on other species that were ground-dwelling or aposematic, and demonstrated different foraging strategies. Possible costs and benefits of the two contrasting foraging strategies are discussed.

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Many studies indicate that polyphagous acridids, like generalists among molluscs and various groups of vertebrates, require a mixed plant diet to achieve maximum growth rates (reviewed in Bernays et al. 1994). Obtaining an appropriate mixture is therefore one task confronting individuals of these generalist species.

Three polyphagous grasshopper species with similar foraging strategies in natural environments have been studied previously. In all three, high levels of locomotor activity and food sampling behaviour were observed. All individuals were polyphagous, feeding on many different plant species within the course of a day and switching frequently between different plants. Individuals commonly fed for a few seconds on several different plant species in succession, or interspersed feeding bouts of a minute or so with many shorter bouts on different foods (Lee 1991; Raubenheimer

& Bernays 1993; Bright et al. 1994). The species represent different taxa and biologies. *Taeniopoda eques* is in the family Romaleidae and *Dactylotum variegatum* is in the subfamily Melanoplinae, family Acrididae. Both are conspicuously coloured and distasteful. The third species, *Brachystola magna*, is also in the family Romaleidae, but is large, brown and ground-dwelling, and is not chemically defended.

In the laboratory, *T. eques* showed similar food-switching behaviour to that found in the field. This behaviour pattern is assumed to prohibit learned associations between flavour and post-ingestive effects, because up to 10 or more different foods are present together in the gut (Bernays et al. 1992). By contrast, laboratory studies of *Schistocerca americana* and *S. shoshone*, which are members of the subfamily Cyrtacanthacridinae in the family Acrididae, had a totally different pattern of activity and feeding; individuals had long bouts of feeding and moved little (Bernays & Lee 1988; Bernays & Raubenheimer 1991; Sword & Chapman 1994). Some other acridids that have been observed continuously for long periods in the laboratory appear to behave similarly (Simpson 1990).

The present study was conducted on two species of *Schistocerca* in the field. Both species are cryptic on their food plants. We first sought to

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clarify whether the feeding patterns found for *Schistocerca* species in the laboratory occurred under natural conditions. Secondly, we wished to determine whether individuals were polyphagous, so that nutritional benefits were possible through food-mixing. We also examined whether individuals showed declining lengths of successive feeding bouts on a particular plant prior to moving to an alternative host plant. This result would be consistent with the patterns of short-term learned aversions to nutritionally inadequate food that has been found in laboratory studies of *S. americana* (Lee & Bernays 1988; Champagne & Bernays 1991).

## METHODS

### Study Organisms and Sites

We observed feeding patterns of *S. nitens* (Thomas) and *S. shoshone* (Acrididae: Cyrtacanthacridinae) in their natural habitats in southern Arizona. We observed single individuals continuously for up to 8 h using a behaviour-recording program on Hewlett Packard HP71B hand-held computers. Line transects (200 points) or metre quadrat sampling (20 quadrats) were used to estimate relative abundance of plant species.

### *Schistocerca nitens*

Solitary *S. nitens* nymphs and adults are found throughout the year in the Sonoran desert of Arizona, usually in canyons, riparian habitats and other areas with woody vegetation. Most hatching occurs in July and August after summer rains, and late nymphal and early adult development occur in the late summer and autumn. Individual adults and nymphs are green or fawn in colour and extremely cryptic on plants.

In 1992, we observed *S. nitens* nymphs and adults in September and October. The site was approximately 400 m<sup>2</sup>, and just west of the Buenos Aires wildlife preserve in an area of grassland at Elkhorn Ranch north of Sasabe, southern Arizona. There were only nine plant species, with small trees of mesquite, *Prosopis velutina*, being dominant (Appendix I). Approximately 75% of the area was bare ground. Herbaceous species were post-flowering and, except *Boerhaavia*, all plants were obviously senescent and somewhat dry.

In 1993, we observed *S. nitens* in August and September in a riparian habitat dominated by mesquite in the Buenos Aires preserve near Arivaca, Arizona. The site was approximately 100 m<sup>2</sup>, with 26 plant species (Appendix II). Most herbaceous plants were still growing and either flowering or pre-flowering. Less than 5% of the ground was bare.

### *Schistocerca shoshone*

*Schistocerca shoshone* eggs hatch over an extended period in the spring and early summer. Late instar nymphs and adults are seen by June, and these gradually die through the late summer. All stages are different shades of green and very cryptic on foliage of various plants. They occur as isolated populations, usually in riparian habitats or areas having more rainfall than the lower Sonoran desert.

Observations on *S. shoshone* were made mainly on adults in an area of mesquite grassland at Portal, Arizona, near the American Museum of Natural History's Southwestern Research Station in September 1992 and June–July 1993. In 1992 the site contained mainly mesquite, the principal food of the insect in this area (Sword & Chapman 1994), but there were several *Acacia constricta* bushes, unidentified grasses and a few herbaceous forbs. In 1993 there were no herbaceous plants, the mesquite was mainly defoliated and the only alternative food was *Ephedra*, a desert gnetopsid.

### Observations

We located individual grasshoppers from early to mid-morning and observed them continuously with binoculars for as long as possible. Both species are easily disturbed, so we observed from a distance of 2–3 m. On some occasions, we carefully touched some individuals with a spot of red paint at the beginning of the observation to help observers to see or relocate them. Sometimes we lost the individual being observed; if this occurred within the first hour, we chose a second individual. All data were from individuals watched at least three hours, mostly for four or more hours, and in some cases for eight hours.

### *Schistocerca nitens*

On arriving at the site, we used the first individual grasshopper found as the observation animal.

When observations began in the morning, at approximately 0830–0930 hours, we usually located individuals on exposed parts of various plants in the sun. As air temperatures increased above 25°C, with body temperatures presumably higher, locomotion and feeding began. For example, on 22 August 1993, observations began at 0815 hours when air and ground temperatures were approximately 23°C. No feeding occurred until 1015 hours when the air temperature was above 25°C. Most feeding occurred between 1230 and 1700 hours, when the average air temperature was 30°C. Feeding ceased late in the afternoon. No studies were undertaken at night, but casual observations indicated that no feeding occurred at night.

In 1992, *S. nitens* did not usually feed on the herbaceous plants (*Amaranthus* spp.) often used for night roosting and early morning basking; individuals moved to *P. velutina* trees before feeding began. In 1993, however, when the vegetation was obviously more lush, feeding commonly occurred on the herbaceous plants used for night roosting and early morning basking; sometimes the insects moved to other plants before feeding. Later in the season, as the herbaceous plants senesced, more feeding occurred on *P. velutina*.

### *Schistocerca shoshone*

This species was mostly found on shrubby, grazed, *P. velutina* bushes, and when we located individuals in the morning at about 0830 hours, temperatures were commonly around 30°C and feeding was sometimes already in progress. Subsequently, we found that, at least on warm nights, there was also nocturnal feeding, although we collected no data at night.

In 1992, we observed mature female adults after the end of the summer rainy season. Although the herbaceous vegetation was beginning to dry out, there was apparently ample acceptable food. In 1993, on the other hand, we made observations earlier, before the summer rain, and there was little vegetation available other than the *P. velutina* bushes on which the insects spent most of the time. Considerable defoliation had already occurred, and the younger, favoured leaves were relatively rare. The observed insects appeared to search for younger foliage on which they readily fed. They bit and rejected older foliage, but chewed damaged remnants of foliage as well as bark.

We mostly began observations in mesquite clumps with a number of *S. shoshone* individuals. We tended to observe those that stayed in such a clump more than those that left. For this reason, and because feeding patterns were complex, and the food substrates were variable and hard to quantify, we made few detailed analyses.

### Recording

We recorded the following behaviour patterns. (1) Locomotion: start and end times of all displacements. These were sometimes intermittent, but often consisted of short walks before or after a period of feeding. (2) Feeding: start and end times of all ingestion activity. (3) Biting or palpating events not followed by feeding.

We identified food plants eaten and rejected to species and the particular tissue of interest noted: old leaf, young leaf, bud, flower, calyx. In the case of mesquite, leaves were usually distinguishable as old or young; these classifications represented leaves from the spring flush versus leaves that had been produced after summer rain. We collected plants at the end of the observation periods for species verification.

We analysed the following data: proportion of time spent moving, proportion of time spent feeding, numbers and lengths of all feeding bouts, numbers and lengths of gaps between all feeding bouts, and rejections; i.e. bites or palpations not followed by feeding, or feeding bouts of less than 10 s.

### Analysis

We examined overall selectivity for foods among available plants by comparing the relative abundance of tissue of different plant species with the number of feeds observed on each plant species. The patterns of feeding were first examined using log-survivor curves of gap lengths (Simpson 1982). These were constructed for each species, pooling data from all individuals for which four or more feeds were recorded (Slater 1974). Obtaining large data sets for any individual was precluded by the few feeds taken by any individual on any day. No individual stood out, however, as being different in any of the parameters examined.

In grasshoppers, log-survivor curves of gap lengths between feeding bouts usually have two

distinct slopes with a break at some point between 2 and 5 mins. (Simpson 1990). To determine this break point objectively, we constructed a program in QuickBasic to fit two regression lines to all possible combinations of points and select the two best-fit regression lines. The point of change between the two regression lines constitutes a bout criterion, below which gaps between feeding bouts could be considered in a different category. This pattern suggests that there are groups of feeding bouts close together, here considered meals. Longer gaps, above the bout criterion, and therefore in a separate category, are the longer resting periods following committed feeds (Simpson 1982). The value at which the fitted lines intersected provided an objective criterion for distinguishing between short gaps within a meal and longer gaps representing periods between meals.

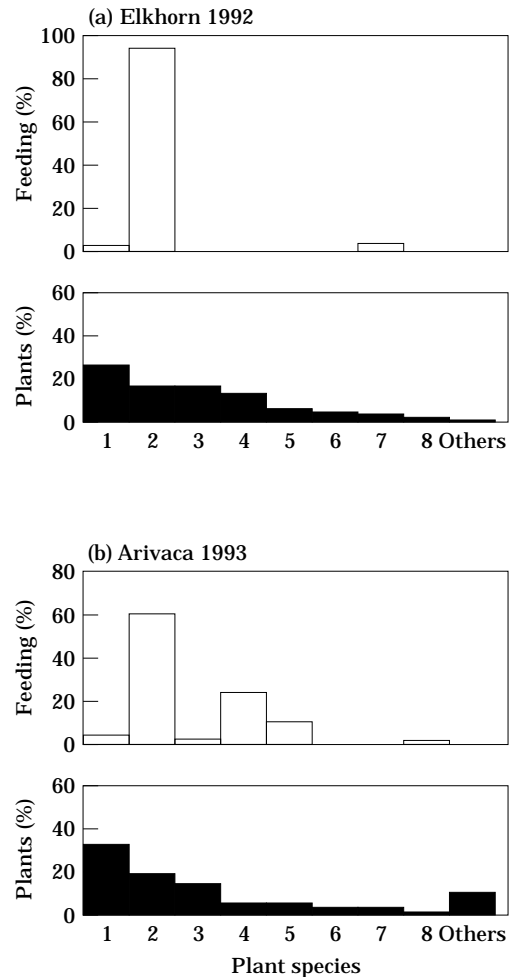
We compared the frequency distributions of feeding bout lengths with data on other species (Bright et al. 1994). Activity budgets were constructed for individuals that had been observed continuously for at least 4 h; the data are presented as mean percentage of time feeding, resting or locomoting.

Individuals often showed declining feeding bout lengths on single plants. They also commonly took relatively long feeds after switching to a new food (a different species, or a different tissue such as leaf and flower, or leaves of mesquite that were either old spring leaves or young summer leaves). To determine whether the pattern was significant, we examined feeding bouts of insects that took three or more feeds. We then counted increases and decreases of successive feed lengths on the same or different foods. A chi-squared test was used to test the null hypothesis that increases and decreases in feed length have equal probability on the same and different plants.

## RESULTS

### Patterns of Feeding: *Schistocerca nitens*

Feeding by *S. nitens* was selective and not in proportion to the relative availability of different plant species, assuming random movement of the insects (Fig. 1). The following plant species were encountered but then rejected: *Amaranthus* spp., *Anoda*, *Conyza*, *Euphorbia* and *Ipomoea*. Approximately 12% of the time was spent feeding, and most of the time was spent quiescent on the plants (Table I).



**Figure 1.** Host plant selectivity in *S. nitens*. (a) Elkhorn ranch 1992, (b) Arivaca 1993. In both (a) and (b), relative abundance of plant species is shown as a percentage of all plant records (■). Relative number of feeds on each plant species (□). The numbers represent plant species from each site listed in Appendices I and II, respectively.

Gap lengths between feeding bouts are shown as the log-survivor functions (Fig. 2). The two best-fit regression lines intersected at approximately 5 min, although only 1993 data showed two significantly different slopes, indicating that feeding bouts were clustered into meals. In 1992, the initiation of feeding did not alter with length of the gap, so that feeding bouts were not clustered into meals. In both years, however, nearly 50% of all gaps were greater than 30 min.

**Table I.** Activity budgets given as the mean  $\pm$  SE percentage of total time observed in locomotion, feeding or quiescence for *S. nitens* and *S. shoshone*, including data for all individuals observed for more than 3 hours

	1992		1993	
	Nymphs	Adults	Nymphs	Adults
<i>S. nitens</i>				
<i>N</i>	18	12	9	5
Locomotion	Low		4 $\pm$ 1	3 $\pm$ 1
Feeding	16 $\pm$ 1	13 $\pm$ 1	10 $\pm$ 1	8 $\pm$ 1
Quiescent	High		86	89
<i>S. shoshone</i>				
<i>N</i>	—	16	3	6
Locomotion	Low		4 $\pm$ 2	4 $\pm$ 2
Feeding	—	8 $\pm$ 1	8 $\pm$ 2	12 $\pm$ 2
Quiescent	High		88	84

Locomotion was not recorded in 1992.

Because we could only distinguish meals for the data collected in 1992, the feeding-bout lengths are presented without any attempt to examine meals. All individuals of *S. nitens* usually had long feeding bouts, commonly lasting several minutes or more, but ranging overall from seconds to 11 min (Fig. 3a,b). *Schistocerca shoshone* showed a similar pattern in 1992 (Fig. 3c), but in 1993 it had a greater proportion of short feeding bouts (Fig. 3d). This difference seemed to be due to shortage of food in the second year, because leaflets were finished and then new ones had to be located. In some cases, feeding-bouts of both species lasted over 20 min.

The mean number of different plant species fed upon per hour was never more than one, and was limited even within long observations. Of 19 nymphs observed for 4–8 h, nine fed on only one plant species, four fed on two, four on three and one on four. Of 14 adults observed, nine fed on one plant species, three fed on two, and two fed on three.

Some dietary mixing occurred that was not detected in these data; grasshoppers sometimes clearly discriminated between plant parts. For example, in 1993 at the Arivaca observation site, where two species of *Acalypha* were flowering, individual grasshoppers chose either species. On several occasions, however, a grasshopper fed on foliage and then, after one or more feeding bouts, moved directly to the inflorescence of the same

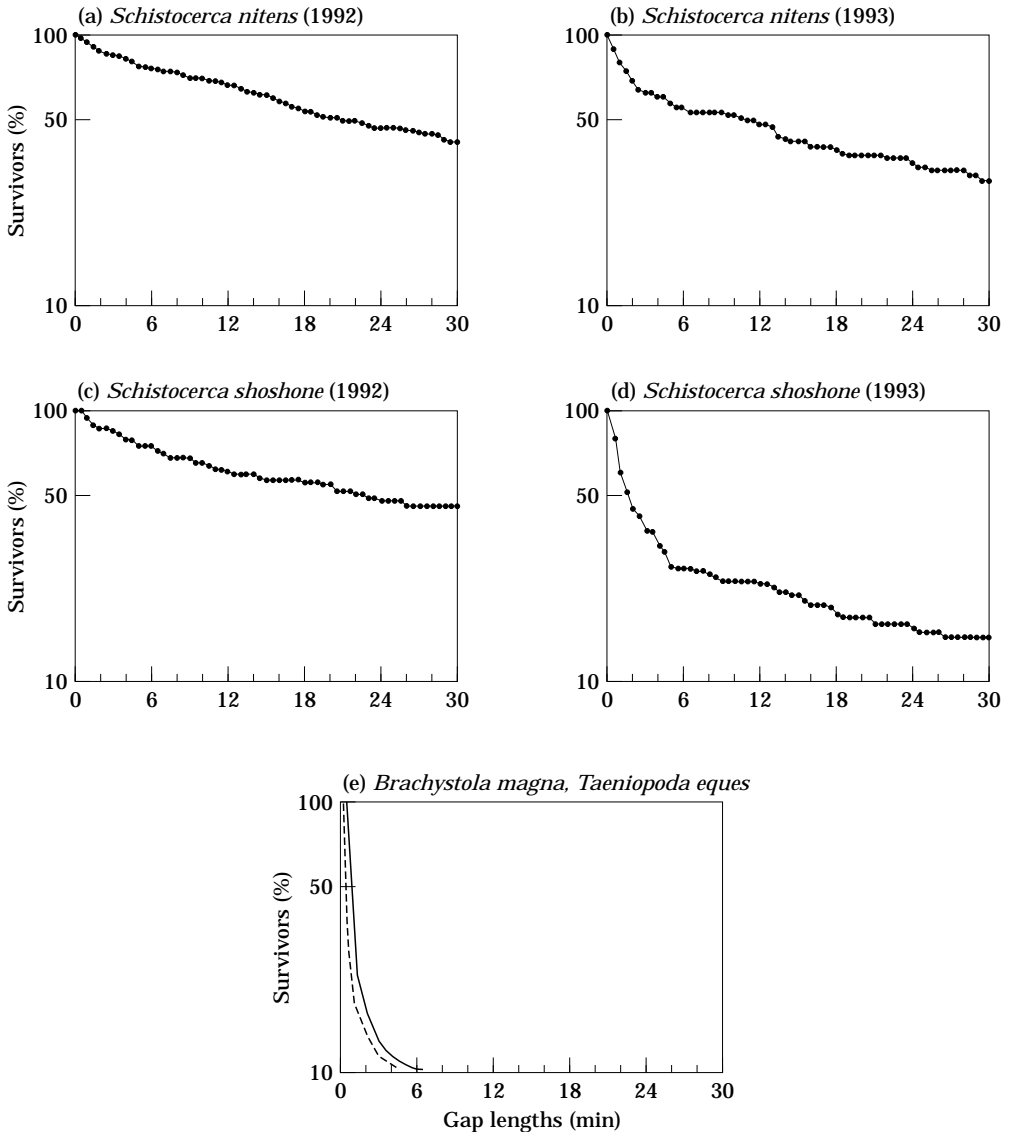
plant and fed on calyx or reproductive tissue. Similarly, in 1992 at the Elkhorn ranch site, individuals fed on either young or old mesquite leaves. Thus, from a nutritional standpoint, food mixing probably occurred within a plant species.

Individuals usually fed exclusively on a single species or tissue type for one or more long bouts. Therefore we analysed whether regular changes occurred in successive feeding-bout lengths. First we plotted the sequences of feeding bouts for each individual over the whole day. Two such sequences from nymphs observed in 1993 are illustrated (Fig. 4). Successive meal lengths were scored as increasing or decreasing. For these two individuals, meal lengths tended to increase following a switch to a new species or tissue, and to decrease if the same species or tissue were eaten. The sequences of feeds for all insects had similar non-random changes in relation to the same or different foods for grasshoppers in both years (Table II). In 1992, the changes were between different-aged leaves of the same species.

The individuals represented in Fig. 4 demonstrate the clustering of feeding bouts into meals. We separately examined the sequences of those feeding bouts that followed short gaps only, and the relatively few data that spanned long gaps between meals for the 1993 *S. nitens* data. No trends suggested that they were qualitatively different.

#### Patterns of Feeding: *Schistocerca shoshone*

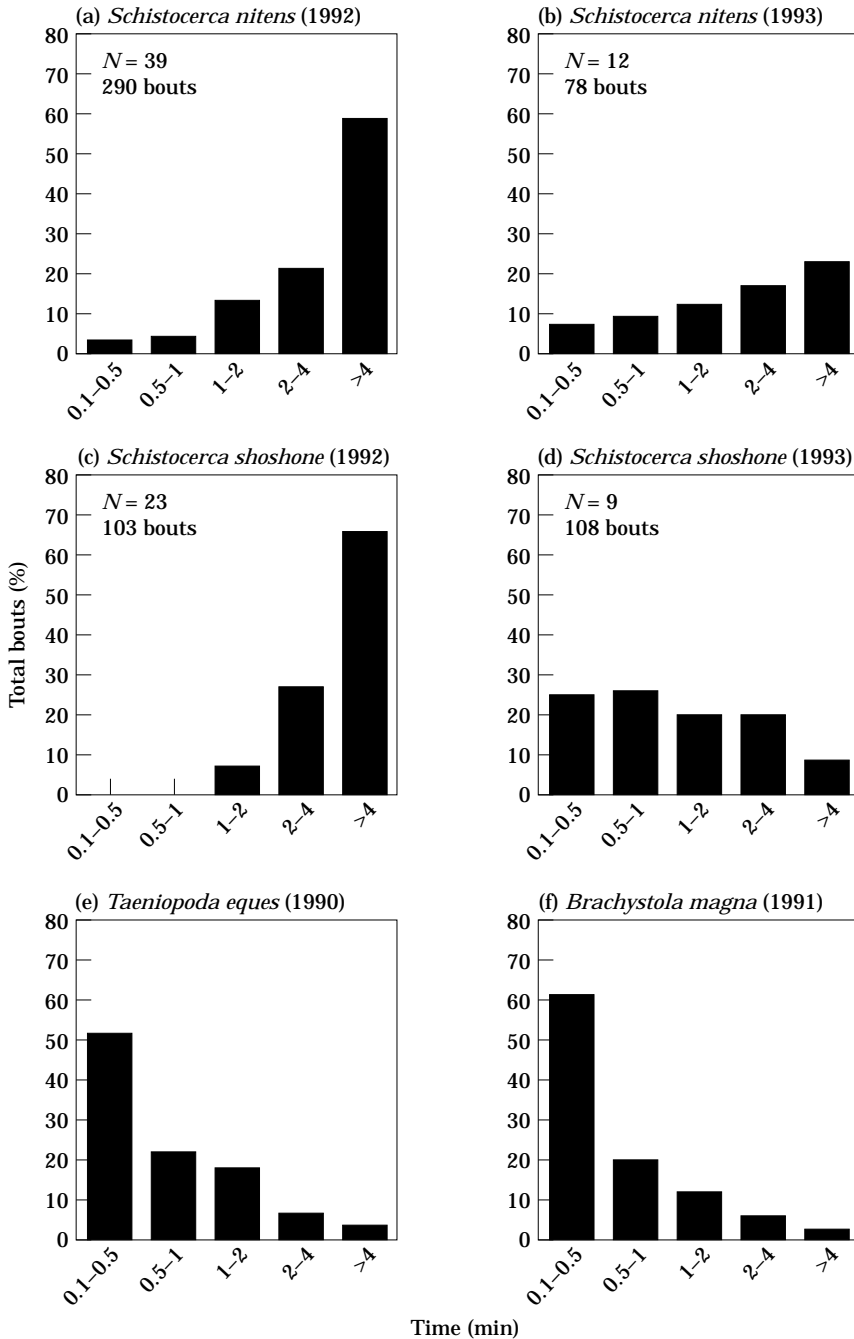
*Schistocerca shoshone* rarely left the *P. velutina* trees, and like *S. nitens* spent most of the time quiescent among the foliage (Table I). In 1992, almost all feeding was on *P. velutina*, in some cases on flowers. Some feeds occurred on *A. constricta*, especially flowers; one feed occurred on an unidentified grass and one on *Marubium vulgare*. Of the 10 individuals observed in 1993, eight fed upon *P. velutina* only, one also fed on *Ephedra*, and another also fed on *A. constricta*. Almost all feeds were on various parts of mesquite, *P. velutina*, including petioles, bark and young shoots. In both years, a few individuals fed on black growths of lichens on the branches of the trees. Continuous observations were usually difficult to obtain. For example, sexual activity of



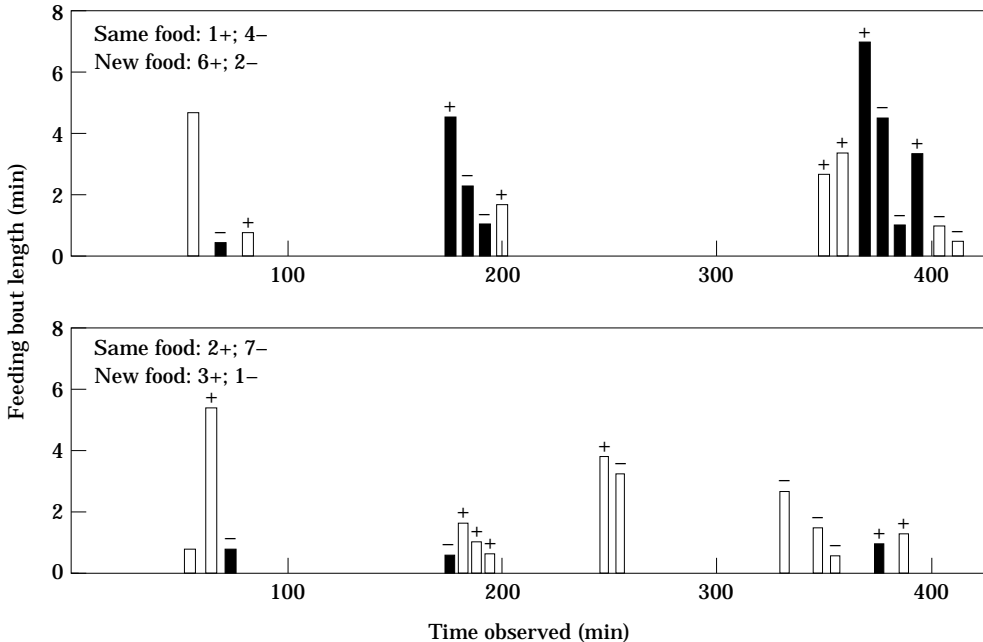
**Figure 2.** Log-survivor functions for gap (inter-feed) lengths. Two regression lines were fitted (see text). The first slope is the regression over the first few minutes, and the second slope is the regression over approximately the next hour. If the first and second slopes differ significantly, the values are given. (a) *S. nitens* 1992, (b) *S. nitens* 1993 (first slope =  $-0.071$ , and second slope =  $-0.014$ ,  $P < 0.05$ ), (c) *S. shoshone* 1992, (d) *S. shoshone* 1993 (first slope =  $-0.14$ , second slope =  $-0.014$ ,  $P < 0.01$ ). (e) For comparison the log survivor functions are shown for *T. eques* and *B. magna* (data after Raubenheimer & Bernays, 1993; Bright et al. 1994).

the insects or attempts to avoid it often led to disruptions and loss of the observation insects. Also, adult insects often fed on a plant for a number of bouts before flying off.

Log survivor analysis of the gap lengths between feeding bouts showed that, as with *S. nitens* the two best-fit regressions intersected at approximately 5 min, but with significantly



**Figure 3.** Feeding-bout lengths as a proportion of the total number of feeding bouts for *S. nitens* in (a) 1992, (b) 1993 and *S. shoshone* in (c) 1992 and (d) 1993. For comparison, data are shown for (e) *T. eques* (Raubenheimer & Bernays 1993) and for (f) *B. magna* (Bright et al. 1994).



**Figure 4.** Feeding sequences for whole-day observations of two nymphs of *S. nitens* at Arivaca in August 1993. Horizontal axis represents time through the day, vertical axis represents feeding-bout lengths. A switch from open to black bars and vice versa represent changes to new foods. The +/– signs indicate that successive meals are longer or shorter, respectively, than the preceding one.

**Table II.** Successive feeds on the same food or on a different food by *S. nitens*

Next feed	Change in feed length	
	Increase	Decrease
<b>1993*</b>		
Same food	2	12
Different food	12	1
	Overall difference: $\chi^2=16.4$ , $P<0.001$	
<b>1992†</b>		
Same food	8	16
Different food	13	4
	Overall difference: $\chi^2=7.4$ , $P<0.01$	

\*Different foods usually means different plant species, but sometimes leaves versus flowers.

†Different foods usually means young or old leaves of mesquite, but sometimes different species.

different slopes only in 1993 (Fig. 2). In 1992, the patterns showed no clustering of feeding bouts into meals and nearly 50% of all gaps were over 30 min. In 1993, many small feeding bouts were

clustered into meals; there was a larger proportion of short gaps.

## DISCUSSION

Both species fed upon several plant species, but rejected others in the environment. They were very sedentary and moved little between foods. They had relatively few feeding bouts on one or a few plant species, and a high proportion of feeding bouts and gaps between them were relatively long. Similar feeding patterns have been found in the laboratory for three other *Schistocerca* species and for *Locusta migratoria* (Blaney et al. 1973; Chapman and Beerling, 1990; Raubenheimer & Simpson 1990; Bernays & Bright 1993; Chapman & Sword 1993, 1994; J. J. Howard, unpublished data). The long feeding bouts and fidelity to particular plants may provide an opportunity for learning by the insects, because post-ingestive effects can be associated with a specific taste or other sensory input.

The results further demonstrate that the pattern of feeding bout lengths by *S. nitens* on the same or

**Table III.** Correlated features of two different feeding strategies in grasshoppers

Type A (seen in <i>T. eques</i> / <i>B. magna</i> )	Type B (seen in <i>Schistocerca</i> )
Extreme polyphagy	Restricted polyphagy
Locomotion high	Locomotion low
Rapid switching between foods	Limited switching between foods
Requirement for novelty/random food selection	Short-term learned aversions on successive foods
Nutritional balance by chance alone	Nutritional balance through feedbacks
Aposematism/ground dwelling	Foliage dwelling/foliage cryptic
Relatively fixed colour patterns	Genetic and phenotypic plasticity of colour patterns/homochromy

different foods is non-random; successive feeds on a single food are likely to get shorter. Feeds on a new food are likely to be longer than the last feeds on previous foods. These patterns of feeding by individual *S. nitens* in the field show notable similarities to the patterns of acquired short-term aversions seen in *S. americana* in the laboratory (Bernays & Lee 1988; Lee & Bernays 1990; Bernays & Raubenheimer 1991; Champagne & Bernays 1991; Bernays 1993). Such patterns suggest that obtaining mixtures of plants that improve performance over single plants might be achieved similarly in nature. Successive short term aversive conditioning on various foods could maximize nutrient balance (cf. Simpson 1990).

The *Schistocerca* feeding patterns differ greatly from those of two ground-dwelling aposematic species (*Taeniopoda eques* and *Dactylotum variegatum*: Lee 1991; Bernays et al. 1992; Raubenheimer & Bernays 1993) and one ground-dwelling, but not warningly coloured or chemically protected species (*Brachystola magna*; Bright et al. 1994). In each case, individuals showed extreme polyphagy, extensive locomotor activity and frequent switching between plant species that almost certainly precluded learning about specific plants from post-ingestive feedbacks (Figs 2, 3).

That two such contrasting foraging strategies exist for different species of generalist grasshoppers suggests that there may be two different approaches to obtaining suitable mixtures of foods (Table III). Aposematism may be relevant in the case of *T. eques* and *D. variegatum*, because there is presumably little need for concealment, but this is not the case with *B. magna*. Obtaining a good mixture of foods for development must have a large element of chance in each of the three species, but if local plants are diverse in their relative levels of particular nutrients, the chances

of obtaining a good mixture could be high. Furthermore, the likelihood of a sustained imbalance of nutrients, with a consequent putative stress from extended feeding on a single unbalanced resource, is reduced.

The genus *Schistocerca* belongs to a different sub-family from the other three species, and the foraging style found may be phylogenetically constrained. *Dactylotum variegatum* is more closely related to *Schistocerca* than to either of the other two species, however, yet shows no similarity to *Schistocerca* species in foraging style. Only a more comprehensive comparison will enable us to distinguish differences based on phylogeny alone from those based on other biological characteristics. None the less, the correspondence between the degree of crypsis on foliage and the restricted movement within and between plants suggests the importance of such crypsis in the foraging patterns observed.

Other cryptic grasshopper species are also relatively sedentary (e.g. Joern et al. 1986) and might be expected to show the patterns found in the present work. Our findings also agree with those of Otte & Joern (1977) that plant-dwelling species, in contrast to those spending most time on the ground, tend to feed on few plant species.

Although both species of *Schistocerca* studied are extremely cryptic on foliage, *S. nitens* nymphs are also variable in colour.

The ability to change colour and also to colour-match their resting places is well known among grasshoppers from a variety of taxa, including *S. nitens* (Rowell 1971; Rowell & Cannis 1972; Dearn 1990) and reduces predation (Isely 1938; Cox & Cox 1974). The *Schistocerca* pattern of feeding may be related to plant-associated crypsis as an avenue for protection from predators. At least some of the time, choice of substrate for crypsis may also over-ride choice of substrate for

feeding. Thus foliage-crypsis could be a constraint on movement, and so a constraint on food choice.

Constraints on movement by individuals could cause an insect to remain on a particular plant until negative post-ingestive feedbacks cause it to seek out a new food. Indeed, any mechanisms that require feedbacks relating to nutrient balance also require extended feeding on one food to produce effects resulting from an imbalance. There may be relatively greater swings in nutrient imbalance in this foraging strategy.

We have identified two contrasting patterns of feeding and food choice in polyphagous grasshoppers. Perhaps there are trade-offs between the two. In one case, long series of feeding bouts by the cryptic species allow learning, and might produce a balanced nutrient mix over time. This type of strategy might also involve greater nutrient imbalance in the periods of hours on single foods, however, when constraints on movement perhaps delay movement to a new food. The alternative strategy of very short feeding bouts and very frequent switching, may result in less extreme swings in nutritional balance status but poorer overall mix of nutrients.

Finally, the two contrasting strategies may be driven by different ways of reducing predation. For individuals cryptic on foliage, movement poses an extreme risk. This risk might constrain them to stay on a plant longer than might be optimal for nutritional balance, but enable them to learn more from nutrient feedbacks. The predation risk with chemically protected species should be less, and the threshold level of nutrient imbalance leading to movement could likewise be less.

## APPENDIX I

### Plant species list for Elkhorn site for observation of *Schistocerca nitens* September–October 1992

Species	Abundance (%)	Family
Poaceae (2 spp)	25	Poaceae
<i>Prosopis velutina</i>	19	Caesalpinaceae
<i>Boerhaavia</i> sp.	19	Nyctaginaceae
<i>Ambrosia confertiflora</i>	16	Asteraceae
<i>Amaranthus</i> sp.	8	Amaranthaceae
<i>Gutierrezia</i> sp.	6	Asteraceae
<i>Lycium</i> sp.	5	Solanaceae
<i>Tidestromia</i> sp.	2	Amaranthaceae

## APPENDIX II

### Plant species list for Arivaca site for observation of *Schistocerca nitens* August–September 1993

Species	Abundance (%)	Family
Poaceae (5 spp)*	35	Poaceae
<i>Acalypha ostryaefolia</i>	20	Euphorbiaceae
<i>Ambrosia confertiflora</i>	15	Asteraceae
<i>Acalypha neomexicana</i>	6	Euphorbiaceae
<i>Prosopis velutina</i>	6	Caesalpinaceae
<i>Euphorbia heterophylla</i>	4	Euphorbiaceae
<i>Anoda cristata</i>	4	Malvaceae
<i>Ipomoea hederacea</i>	1	Convolvulaceae
<i>Mirabilis</i> sp.	1	Nyctaginaceae
<i>Machaeranthera gracilis</i>	1	Asteraceae
<i>Commelina erecta</i>	1	Commelinaceae
<i>Gaura parviflora</i>	1	Onagraceae
<i>Cucurbita</i> sp.	1	Cucurbitaceae
<i>Helianthus annuus</i>	<1	Asteraceae
<i>Erigeron divergens</i>	<1	Asteraceae
<i>Ipomoea coccinea</i>	<1	Convolvulaceae
<i>Conyza canadensis</i>	<1	Asteraceae
<i>Lepidium</i> sp.	<1	Brassicaceae
<i>Xanthium strumarium</i>	<1	Asteraceae
<i>Ambrosia aptera</i>	<1	Asteraceae
<i>Tetramerium nerosum</i>	<1	Acanthaceae
<i>Oxalis</i> sp.	<1	Oxalidaceae

\*Included: *Bromus catharticus*, *Chloris chloridea*, *Eragrostis* sp. *Cynodon dactylon*.

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