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Diversity of Coprophagous Scarabaeidae (Coleoptera) in Grazed Versus Ungrazed Sandhills Prairie in Western Nebraska

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Baited pitfall traps were used to compare the dung-feeding Scarabaeidae (Coleoptera) of a grazed versus an ungrazed sandhills prairie in western Nebraska. Traps yielded 14,832 coprophagous Scarabaeidae over a 4-week sampling period in 1987. *Canthon ebenus* (Say), *C. pilurarius* (L.), *Onthophagous hecate* Panzer, and *O. pennsylvanicus* Harold were the dominant species on both prairies. The Shannon-Wiener diversity index indicated that diversity was slightly higher on the grazed site, whereas the Margalef diversity index showed the diversities to be nearly the same. Activity and foraging by scarabs (as measured by trapping success) were found to be most closely correlated with temperature (activity decreasing dramatically above 35°C) and insolation. Differences in dung beetle abundance and diversity between sampling sites may be due to microclimatological phenomena caused by grazing of cattle.

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INTRODUCTION

Coprophagous Scarabaeidae (Coleoptera) serve as efficient decomposers of fecal matter and are an important component of the prairie ecosystem. Dung beetles (from the subfamilies Scarabaeinae, Geotrupinae, and Aphodiinae) evolved with large grazers and browsers, exploiting an important niche within the grasslands and helping to eliminate an abundance of waste that would otherwise cover the vegetation and inhibit growth of grasses and forbs (Bornemissza, 1970, 1976; Waterhouse, 1974). Not only do dung beetles remove fecal material, but also they increase the rate of nutrient cycling, aerate the soil, and reduce densities of manure-breeding dipterans, many of which are pests (Bornemissza, 1976; Peck and Forsyth, 1982).

Although dung beetles probably evolved with various herbivores in the prairie environment (Halffter and Matthews, 1966), domestic cattle exert constant forces in a limited area, thus possibly degrading potential habitat for dung-burying Scarabaeinae. Grazing by cattle affects the height and density of vegetation and, hence, the relative humidity in the micro-environment (due to sparsity of plant cover). However, at the same time, cattle dung is used by Scarabaeinae for feeding, breeding and rearing of young. This study examines the differences in diversity and abundance between grazed and ungrazed sites, briefly analyzes the effects of grazers and grazing on vegetation and on dung beetle populations, and the effects of abiotic factors on dung beetle activity. The intent of this study was to determine the differences, if any, between the dung-feeding scarab beetle populations of a grazed versus an ungrazed sandhills prairie and the impact of such grazing by domestic cattle.

STUDY SITES AND METHODS

Sampling sites were in the sandhills of Arthur Co., Nebraska, and were similar in soil composition (sandy) and topography (gently rolling hills). The ungrazed site was a 1,280 acre (517 ha) native prairie known as Arapaho Prairie, approximately ten miles (16 km) southwest of Arthur, NE (sec. 31-32, T18N, R39W). The vegetation was abundant and dense, with a thin to moderate layer of accumulated litter. Predominant vascular plants included: POACEAE: *Andropogon scoparius* Michx. (little bluestem), *A. gerardii* Vit. (big bluestem), *A. hallii* Hack. (sand bluestem), *Koeleria pyramidata* (Lam.) (junegrass), *Stipa comata* Trin. & Rupr. (needle and thread), *Eragrostis trichodes* (Nutt.) Wood (sand lovegrass), *Sporobolus*

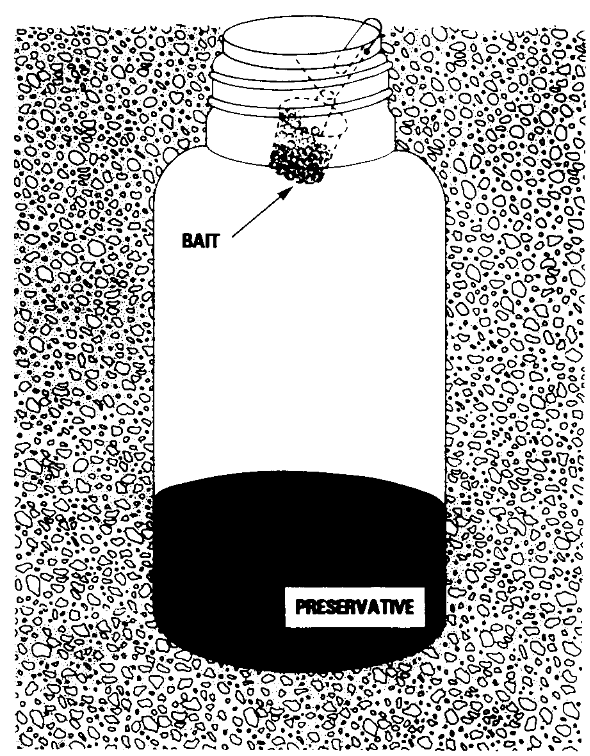

FIGURE 1. Design of baited pitfall trap with preservative.

Table 1. Total number of dung-feeding scarabs collected.

Species	Grazed Site	Ungrazed Site	Total
Onthophagus pennsylvanicus	4,267	6,641	10,908
Canthon ebenus	2,005	774	2,779
Canthon pilularius	353	108	461
Onthophagus hecate	218	85	303
Aphodius lentus	24	115	139
Aphodius rubeolus	62	41	103
Phaneus vindex	49	17	66
Melanocanthon nigricornis	4	46	50
Geotrupes opacus	3	2	5
Copris fricator	14	9	23
Onthophagus orpheus pseudorpheus	1	14	15
Totals	**7,000**	**7,872**	**14,782**

Table 2. Dominant coprophagus Scarabaeidae from each sampling site (in order of abundance).

GRAZED SITE		UNGRAZED SITE	
Species	**Total**	**Species**	**Total**
Onthophagus pennsylvanicus	4,267	*Onthophagus pennsylvanicus*	6,641
Canthon ebenus	2,005	*Canthon ebenus*	774
Canthon pilularius	353	*Aphodius lentus*	115
Onthophagus hecate	218	*Canthon pilularius*	108
Phaneus vindex	49	*Onthophagus hecate*	85

Table 3. Diversity parameters for each site.

	GRAZED SITE	UNGRAZED SITE
Number of species	11	11
Total scarabs collected	7,000	7,872
Shannon-Wiener Diversity (H)	1.494	.905
Margalef's Diversity (α)	1.129	1.115
D_{max}	12.773	12.935
Evenness (E)	.117	.070
Dominance (J)	.883	.930

cryptandrus (Torr.) A. Gray (sand dropseed), *Calamovilfa longifolia* (Hook.) Scribn. (sandreed); LILACEAE: *Yucca glauca* Nutt. (soapweed); CACTACEAE: *Opuntia macrorhiza* Engelm.; ASTERACEAE: *Helianthus* spp. (sunflowers), *Artemisia* spp. (sages) and several other less dominant forbs from the families Commelinaceae, Loasaceae, Rosaceae and Lamiaceae. This sample site had been neither burned, grazed, nor hayed since 1976.

The grazed site was six miles (9.5 km) east of Arapaho Prairie and was moderately grazed by cattle which were not being given internal pesticides (growth and chitin inhibitors that are incorporated into feed and mineral blocks, retained in the digestive system of the animal, and excreted in the feces). This method of pest prevention, aimed primarily at dung-breeding horn flies, can cause the eradication of not only the target pest, but also many other coprophagous insects. Plant cover at this site was considerably less abundant with little or no accumulated litter. Bovine feces covered the vegetation in several areas. The predominant vegetation at this site included: POACEAE: *Andropogon hallii* (sand bluestem), *Calamovilfa longifolia* (sandreed), *Andropyron smithii* Rybd. (western wheatgrass), *Sporobolus cryptandrus* (sand dropseed), *Panicum virgatum* L. (switchgrass); ASTERACEAE: *Cirsium* spp. (thistles); PAPAVERACEAE: *Argemone polyanthemos* (Fedde) GBO (prickly poppy); CACTACEAE: *Opuntia* sp. (cactus).

Five baited pitfall traps were placed in each sample site at 30 foot intervals in a straight line. Traps were installed on 14 July 1987, and specimens were collected twice per week until August 11. To prevent attracting or repelling of scarabs by a preserving fluid (Luff, 1975; Newton and Peck, 1975; Adis, 1979), a 2:1 mixture of commercial ethylene glycol and water was used. The trap measured 5 cm in diameter at the opening and 20 cm in depth (Fig. 1). Bait (ca. 15 cm^3 of human excrement) was placed in the center of the trap in a small container. At each sampling date, contents of the pitfall trap were removed and fresh bait and preservative were added. Specimens from each trap were sorted, identified, recorded, and curated. Voucher specimens were placed at the University of Nebraska State Museum, Lincoln. A weather station at Arapaho Prairie provided data on temperature, humidity, insolation, precipitation and wind velocity (Fig. 2) for both sites.

Species diversity, an estimate combining the number of species and the number of individuals in an area, was calculated using two general indices: the Shannon-Wiener index (Southwood, 1966) and Margalef's index of diversity (Southwood, 1966). These, as well as all other diversity indices, have certain limitations and certain advantages. In comparison to the Margalef's index, the Shannon-Wiener index is more dependent upon sample size and is less sensitive to species represented by few individuals (Burgio, 1983). The Margalef index does not require a large sample size and is more sensitive to rarities in the sample (Southwood, 1966).

Other parameters calculated were the maximum diversity ($D_{max} = \log_2 N$); the equitability or evenness ($E = H/\log_2 N$), and dominance (J = 1-E).

Higher values of alpha and H are interpreted as higher diversity. H may also be compared with D_{max} (the maximum diversity possible given the total number of individuals captured) for each site. Species evenness (E) or relative distribution of abundance among species has a minimal value of 0 (when evenness is low) and a maximal value of 1.0 (when evenness is high) (Nagel, 1979; Schreiber, 1985). Dominance (J) is the influence that one species (due to its predominance) has over the total diversity. A low dominance will have values near 0, and a high dominance will approach 1.0 (Schreiber, 1985).

RESULTS AND DISCUSSION

Trap-yield from Both Sites Combined

Pitfall traps at both sample sites yielded a total of 14,832 dung-feeding Scarabaeidae from 11 species (Table 1), several carrion-feeding insects [such as *Nicrophorus* sp. and *Silpha* sp. (Coleoptera: Silphidae) and Sarcophagidae (Diptera)], predatory arthropods [including Cicindelidae, Carabidae (Coleoptera), and Araneae (Arachnida)], and scavengers [such as Histeridae (Coleoptera)]. Many Orthoptera (Gryllidae, Tettigoniidae, Acrididae) were also collected. The Acrididae from the ungrazed site were greatly attracted to the pitfall traps and accounted for 98.8% (dry weight) of the total Acrididae collected from both sites. No explanation for this difference in acridids between grazed and ungrazed sites is evident.

In the subfamily Scarabaeinae, *Onthophagus pennsylvanicus* Harold, *O. hecate* Panzer, *Canthon ebenus* (Say), *C. pilularius* (L.), *Melanocanthon nigricornis* (Say), *Copris fricator* (F.), and *Phaneus vindex* (Macl.) were collected. In the Aphodiinae, two species were collected: *Aphodius lentus* Horn and *A. rubeolus* Beauvois. One species of Geotrupinae was collected, *Geotrupes opacus* Haldeman.

The dominant species at both sites (Table 2) was *Onthophagus pennsylvanicus*, comprising 73.3% of the overall total. *Canthon ebenus* represented the second-most abundant species (18.7%), *C. pilularius* third (3.1%), *Onthophagus hecate* fourth (2.0%), and the remaining seven species made up 2.9% of the total.

Comparison of Grazed and Ungrazed Sites

Numerically, the ungrazed site yielded slightly more dung- feeding scarabs (7,872 or 53% of the total) than the grazed site (7,000 or 47% of the total). Bartlett's test of homogeneity of variances as well as the F-test showed that there was no significant difference between the variances of the two sites.

The general diversity (Table 3) as calculated by the Shannon-Wiener index suggested that the grazed site had a slightly higher diversity of coprophagous scarabs overall. Hutcheson's T-test for general diversity (H) (Zar, 1974) showed that the scarab beetle diversity at the grazed site was significantly different (alpha=.05) than that of the ungrazed site. The Margalef's diversity index, however, essentially showed that the diversities of the two sites were equal. This difference between the two indices can be attributed to the higher sensitivity o the Margelef's index to species in the sample represented by fev individuals (rare species). Species evenness of the grazed site wa higher and species dominance was lower, indicating a more evenl distributed species component at this site. D_{max} showed that th diversity at both sites was low. The availability of bovine feces an the grazing activity of the cattle may be two factors that contribute to scarab faunal diversity at the grazed site. Grazing by cattle pro duced sparser plant cover that should provide more favorable search ing conditions for Scarabaeinae (Halffter and Matthews, 1966) an more favorable microclimate. By limiting the plant cover by grazing the relative humidity within the environment [humidity having negative effect on scarab activity (Halffter and Matthews, 1966)] decreased. These effects could be produced on the ungrazed prairi with prescribed burning as well as by haying and may be benefici to many invertebrates. If one of these management tools had bee used on the ungrazed site, the diversities may have been even mo similar.

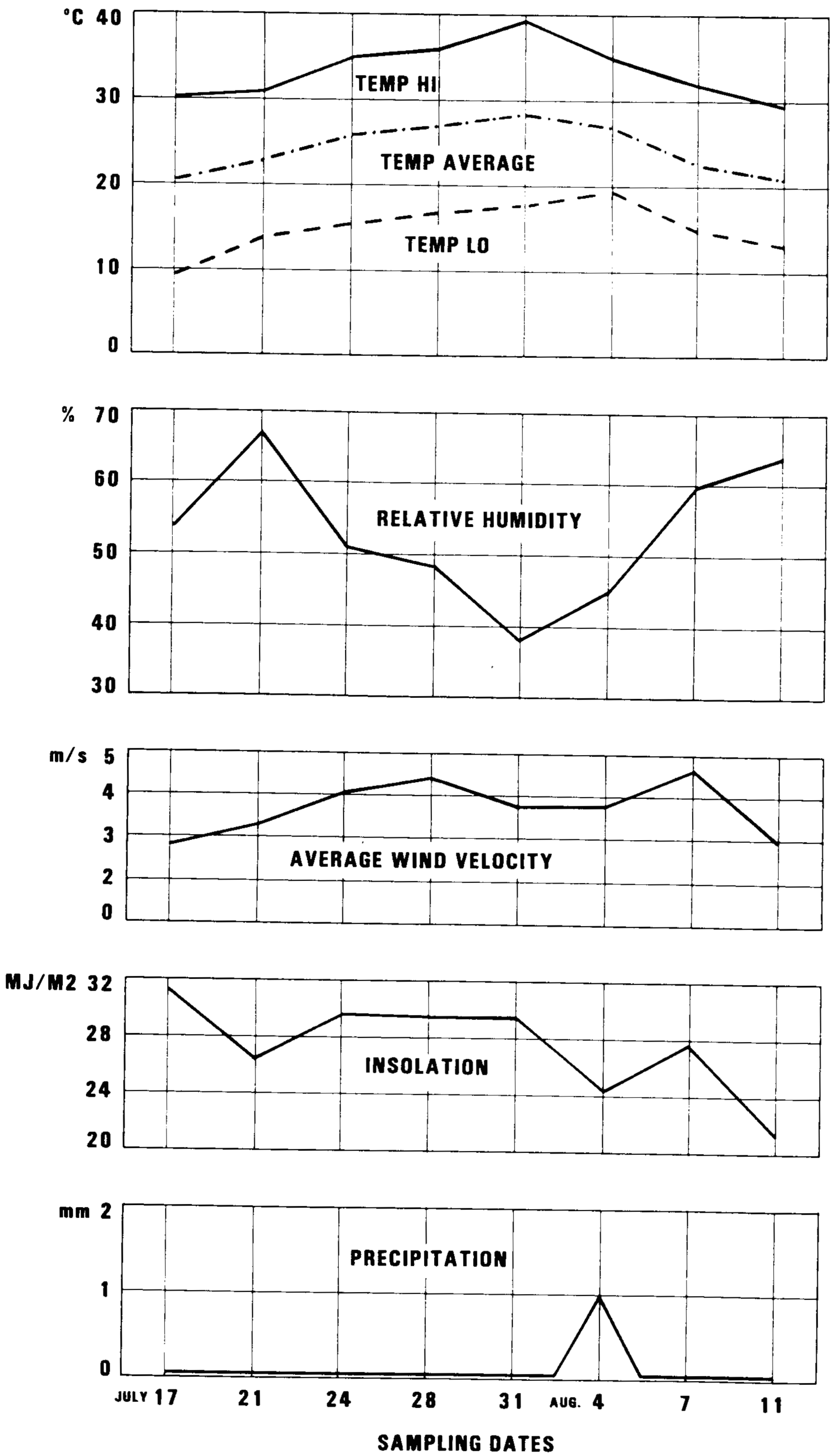

FIGURE 2. Weather data collected from Arapaho Prairie weather station per sampling date. Data shown are for weather variables (averaged) that occurred prior to the sampling date.

Although diversity was slightly lower on the ungrazed site, 872 more dung beetles (5.9%) were captured here than on the grazed site. This could be attributed to normal variation or it could reflect the higher rate of competition for feces on the ungrazed prairie. It may be that the beetles at the ungrazed site did not divide their foraging efforts between bovine feces (which were readily available) and the bait stations as, perhaps, did the beetles of the ungrazed site.

Abiotic Effects on Dung-feeding Scarabaeidae

The rigorous sandhills environment with its hot, dry, windy summers had a dramatic effect on the dung beetles collected from both sampling sites. Consequently, the relation of scarab abundance and physical parameters was examined.

Key elements of microclimate (wind, sun, soil, plant cover, humidity, precipitation, etc.) influenced the quality, availability, and malleability of the dung as a nutritional resource for dung-feeding scarabs. A pat of dung exposed to the sun, wind and other abiotic elements will be prone to faster desiccation and remain a viable food source for a shorter time. Moisture content of the feces is of major importance to coprophagous scarabs. The modified mouthparts of Scarabaeinae allow only for the "sucking" of liquid nutriment rather than chewing or cutting of solid food matter (Halffter and Matthews, 1966). A desiccated pat, because it is firm, is not easily broken into smaller pieces (using the clypeus and foretibiae), detached, and buried for use as a food or brood ball.

Temperature had a pronounced effect on abundance and diversity. Although scarabaeines in general are adapted for xeric conditions, prolonged temperatures above 35°C appeared to substantially reduce activity at both sites (Fig. 3). Halffter and Matthews (1966) noted that temperatures above 30°C reduced activity in temperate grassland Scarabaeinae. At both sites, temperatures averaging in excess of 35°C for a period of 13 days caused a sharp decrease in activity (as displayed by abundance) (Fig. 3). Scarab beetle abundance in traps during this period of excessively high temperatures dropped from a high of 3,387 to a low of 268 overall. The Wilks' lambda statistic (multivariate analysis) showed there was a correlation between species numbers and time at the 90% level. Because temperature, directly or indirectly, is such an important factor in the system, it may be hypothesized that temperature is the leading cause of the correlation between species numbers and time.

While high temperatures deterred activity on both sites, scarab beetle abundance between sites did not respond equally. Activity at the grazed site dropped to 12% of the high, while that of the ungrazed locality decreased to 2.8% of the high (Fig. 4), nearly becoming inactive. This result may be a function of the microclimatological differences between both sites. At the grazed site, the sparsity of plant cover caused by the grazing cattle created a lower relative humidity, whereas the more dense vegetation of the ungrazed prairie created a higher relative humidity within the microenvironment. A higher humidity deters dung beetles (Halffter and Matthews, 1966) and thus may account for the drastic decrease in activity observed at the ungrazed compared to the grazed site.

A decrease in temperature below 35°C and increase in precipitation of 1 mm (August 7) immediately caused an increase in dung beetle activity at both sites (Figs. 3 and 4). The ungrazed site rebounded to 72% of the high and the grazed site to 87% of the high (Fig. 3; August 7, temperature 32°C). Whether this increase was a function (directly or indirectly) of precipitation, temperature, barometric pressure or a combination of factors is unknown. Adults waiting in pupal chambers or estivating until environmental conditions become favorable may respond to any one of these factors as a releasing mechanism.

The amount of solar radiation (Fig. 2) appeared to be correlated with dung beetle activity. High insolation, combined with more benign temperatures, resulted in high rates of scarab activity (Fig. 3; July 17, 30.0°C). However, lower solar insolation and benign temperatures (30°C) were associated with lowered scarab abundance in traps (Fig. 3; August 11, 28.8°C). Halffter and Matthews (1966) considered insolation to be an important factor in Scarabaeinae activity in that activity tends to be reduced when the sun is blocked.

Other abiotic elements such as wind, relative humidity, and precipitation were measured, yet no correlations between these factors and species numbers and abundance were evident. Further study is needed to assess these relations.

CONCLUSIONS

The diversities of the grazed site and ungrazed sites were similar, with the grazed site having a slightly higher diversity. This difference may be a function of both the microclimate created by grazing (shorter, sparser vegetation enabling searching, and lower relative humidity due to sparsity of plant cover) and dung availability.

The abiotic factors of temperature and insolation were correlated with trapping success. Temperatures in excess of 35°C were associated with reduced trapping success, lowering activity at both sites to only 8% of the high. When temperatures dropped to 32°C, activity resumed to 78% of the high. A high insolation was also positively related to dung beetle trapping success.

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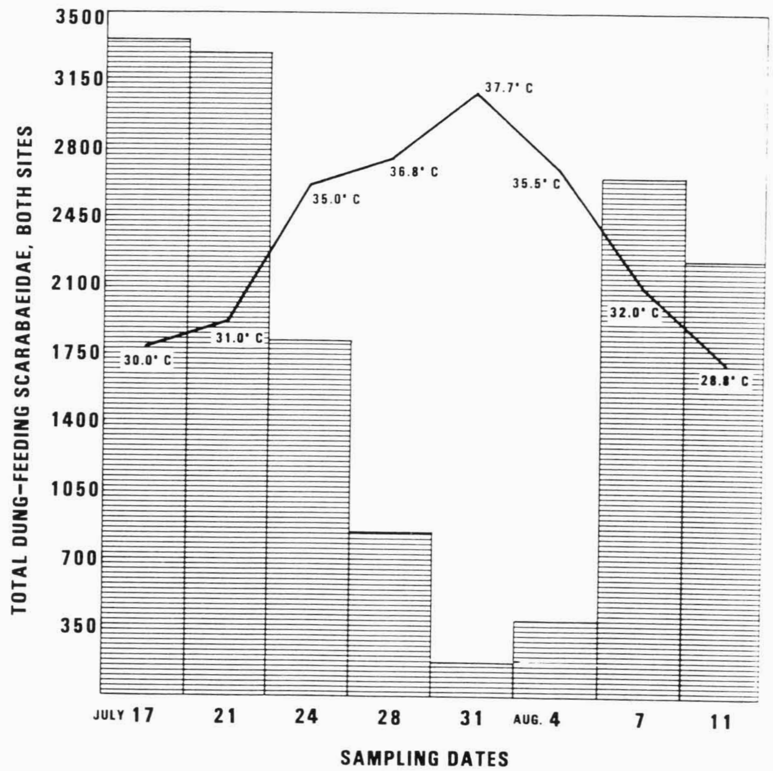

FIGURE 3. Total number of dung-feeding Scarabaeidae (histogram) as correlated with the temperature high (line).

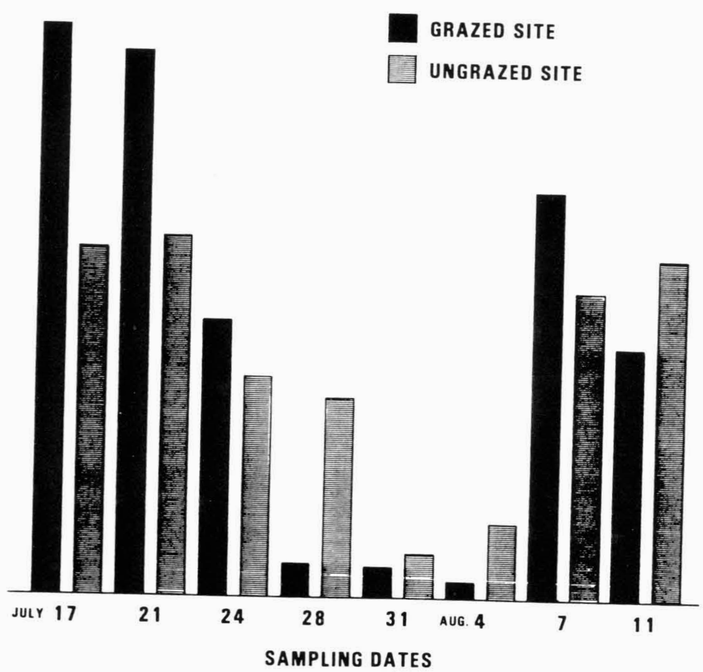

FIGURE 4. Total number of dung-feeding Scarabaeidae at each site.

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