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Abstract. The importance of disturbance in prairie has long been recognized. Increasingly interest and research have focused on the action and interaction of multiple disturbances. The distribution of Flodman's thistle [*Cirsium flodmanii* (Rydb.) Arthur] on ant mounds, badger mounds, buffalo wallows, and potholes and in a lightly and a moderately grazed pasture was compared at the Nature Conservancy's S. H. Ordway Jr. Memorial Prairie in northcentral South Dakota. In the lightly grazed pasture, Flodman's thistle occurred most frequently on hilltops and ridges, but in the moderately grazed pasture it occurred with equal frequency on hilltops and ridges, and low areas surrounding potholes. Flodman's thistle was common on earthen mammal mounds and was less abundant on thatching ant mounds and buffalo wallows. No thistles were sampled in potholes. Relative availability of light may explain the thistle's distribution. Implications of observed patterns are discussed for the evolution of life history traits and the management of prairie remnants.

Key Words. Flodman's thistle, *Cirsium flodmanii,* northern mixed prairie, disturbance, patches, grazing, South Dakota

INTRODUCTION

Historically, many different disturbances have affected and continue to influence North American grasslands. In this paper, disturbance is narrowly defined as the destruction of biomass (Grime 1979), although of equal importance are the past and present temporal and spatial patterns of disturbance (Allen and Starr 1982). Ecologists have long been interested in the effect of disturbance on prairie, studying fire (Higgins 1986, Steuter 1987, Collins 1987, Hulbert 1988), drought (Albertson and Weaver 1946, Albertson *et al.* 1957, Coupland 1958), grazing of bison or cattle (Dix 1959, Ellison 1960, England and DeVos 1969, Collins 1987), prairie dog towns (Bonham and Lerwick 1976, Coppock *et al.* 1983, Archer *et al.* 1987), buffalo wallows (Polley and Collins 1984), and badger mounds (Platt 1975, Platt and Weis 1977). Recent discussions of grasslands and disturbance have emphasized the interaction of disturbances with each other (Collins and Barber 1985, Collins 1987) and with the physical environment (Platt and Weis 1977, Gibson and Hulbert 1987).

Flodman's thistle [*Cirsium flodmanii* (Rydb.) Arthur] is a rosette forming perennial. It is rhizomatous, spreading rapidly in open, bare areas (Wilson and McCarty 1984). In eastern South Dakota, Beebe and Hoffman (1968) found that this species increased in abundance when under moderate to heavy grazing pressure by cattle.

As part of work in progress at the Nature Conservancy's Samuel H. Ordway Jr. Memorial Prairie, the distribution of Flodman's thistle in slightly and moderately grazed stands of three major upland plant communities was compared. The response of Flodman's thistle to different disturbances was examined by recording its presence or absence on the mounds of the western thatching ant (*Formica obscuripes* Forel) (Weber 1935), earthen mounds built by burrowing mammals, and buffalo wallows. While not disturbances in the sense of Grime (1979), ephemeral prairie potholes provide bare areas suitable for colonization and were included.

METHODS

Site Description

The Nature Conservancy's Samuel H. Ordway Jr. Memorial Prairie is a 3,156 ha prairie, located in McPherson County in northcentral South Dakota. It is of the northern mixed prairie type (Singh *et al.* 1983) and has been previously described by Barnes *et al.* (1983). Soils are mostly loams and annual precipitation is about 490 mm (Soil Conservation Service 1981). Since its purchase in 1975, the preserve has been grazed primarily with cattle.

Community Sampling

All community sampling was done in July, 1987 and was divided between a moderately and a lightly grazed pasture. The moderately grazed pasture had been grazed at 1.24-1.98 AUM/ha by cattle as part of a three pasture deferred rotation for 11 of the previous 13 years. The lightly grazed pasture was grazed by cattle for two years (1977 and 1981 at 1.48 AUM/ha) and by bison for the past six years in the fall and winter. The former pasture was burned in April, 1985, and the latter May, 1984.

In each pasture, eight stands of low, mid, and high prairie (Barnes *et al.* 1983) were delineated for a total of 48 stands. Stands were selected to cover a range of soil types and slope aspects and angles. Four 0.5 m^2 quadrats were placed in the center of each stand, using characteristic species for each community to determine stand boundaries. Low prairie was dominated by big bluestem (*Andropogon gerardii* Vitman) and found near potholes. Mid prairie was dominated by bluegrasses (*Poa* spp. L.), green needlegrass (*Stipa viridula* Trin.), and western wheatgrass (*Agropyron smithii* Rydb.) and covered most of the preserve. High prairie was dominated by little bluestem (*Andropogon scoparius* Michx.), plains muhly [*Muhlenbergia cuspidata* (Torr.) Rydb.], and porcupine grass (*Stipa spartea* Trin.) and was found on dry hilltops and ridges. Quadrats were separated by 1 m and placed along a line perpendicular to the slope. Presence of Flodman's thistle (rosettes and flowering adults combined) was recorded for each quadrat and calculated as a percentage (0%, 25%, 50%, or 100%) for each stand.

Visual estimates of aerial cover were made for all species, using a Daubenmire cover class system (Mueller-Dumbois and Ellenberg 1974), slightly modified with the two largest cover classes combined. Designation of a stand as high, mid, or low prairie was verified by group membership in a Bray-Curtis ordination (Beals 1984), using cover data for all species at each stand. Some stands were reclassified.

Patch Sampling

Mounds of burrowing mammals and western thatching ant were selected from a list of mounds compiled from walking surveys of one 22 ha plot in each pasture. Mound size, age, and location were all criteria in selection. A total of 63 earthen mammal mounds (37 in the lightly grazed pasture and 26 in the moderately grazed pasture) and 65 ant mounds (46 in the lightly grazed pasture and 19 in the moderately grazed pasture) were selected. No more than four mounds were located in low prairie in either pasture. Quadrats, 0.5 m^2, were placed 1 m on either side of most mounds. Presence or absence of Flodman's thistle was recorded for mounds and adjacent off mound quadrats. The larger number of mounds sampled in the moderately grazed pasture reflected their greater abundance in that pasture. Mounds were similar in size (mammal mounds mean diameter = 92 cm, s.d. = 19 cm; thatching ant mounds mean diameter = 87 cm, s.d. = 20 cm).

Buffalo wallows were not present in either the lightly or mod-

erately grazed pasture, because these were not grazed by bison during the summer months. Wallows were present in a pasture adjacent to the lightly grazed pasture. This pasture was grazed alternately by cattle and bison at 1.24-1.48 AUM/ha from 1985 to 1987 and at 0.30-1.90 AUM/ha during the previous nine years, primarily by bison. Twelve wallows (mean size = 240 cm, s.d. = 45 cm) were selected for sampling, and all had at least a 10% vegetative cover (visually estimated) and had not been used by bison since the previous year. Each wallow was sampled with two to four 0.5 m^2 quadrats placed along a north-south or east-west transect in each wallow. Quadrats were also placed 1 m on either side of each wallow on the same transect. Presence or absence of Flodman's thistle was recorded for the quadrats in and adjacent to wallows.

Six small openings (4-15 m in diameter) in five small potholes were sampled with 0.5 m 2 quadrats placed on north-south transects through the center of each. At the time of sampling, the openings were dry and contained relatively little (less than 50% live cover, visually estimated) emergent vegetation (*Eleochoris* spp, *Carex* spp). Twenty-four quadrats were sampled for the presence of the thistle.

RESULTS

Prairie Communities

In the lightly grazed pasture, Flodman's thistle was most abundant in high prairie stands; but in the moderately grazed pasture, it occurred with equal frequency in low and high prairie (Figure 1). The thistle was much more abundant in the moderately grazed pasture. Grazing treatments were not replicated, but the increased abundance of Flodman's thistle in the moderately grazed pasture agrees with earlier work by Beebe and Hoffman (1968).

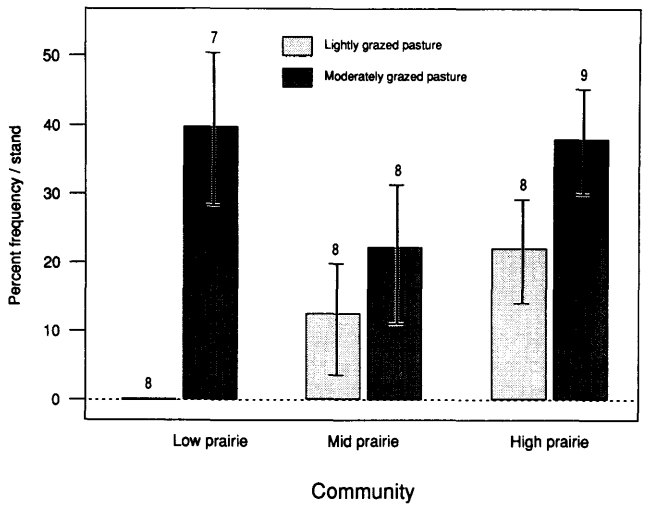

FIG. 1. Mean percent frequency of Flodman's thistle in lightly and moderately grazed stands of three upland communities at the S. H. Ordway Jr. Memorial Prairie. Number of samples is given above each histogram. Vertical bars are plus and minus one standard error of the mean.

Patches

Flodman's thistle occurred on all of the upland patches but was not found in any of the small potholes (Figure 2). Individual plants were observed in dry potholes in 1988. Where it did occur, percent frequency was lowest on the mounds of the thatching ant. Percent frequency was similar for mounds in both the moderately and lightly grazed pastures, despite a doubling in frequency in the adjacent area. Areas next to the earthen mammal mounds showed a similar trend. One-half of the earthen mounds in the moderately grazed pasture had Flodman's thistle, compared to 11% in the lightly grazed pasture. Frequency data for the wallows are best compared with results from the grazed pasture. Thistle abundance adjacent to wallows was most like the grazed pasture. Flodman's thistle was present in only 15% of the samples taken from wallows.

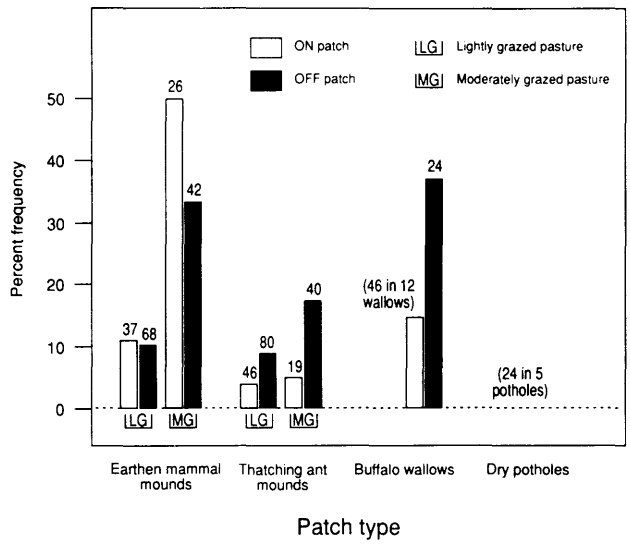

FIG. 2. Percent frequency of Flodman's thistle on and adjacent to different patches in a lightly and moderately grazed pasture at the S. H. Ordway Jr. Memorial Prairie. Number of samples is given above each histogram.

DISCUSSION

Flodman's thistle, in the three upland communities at the Samuel H. Ordway Jr. Memorial Prairie, was present in greatest abundance in the moderately grazed pasture. Its pattern of occurrence on patches suggested a major influence of light. The step-wise decrease in percent frequency of Flodman's thistle from lightly grazed high to low prairie may correspond to a decreasing availability of light. Ungrazed low prairie has a tall, almost continuous canopy and a much greater above-ground biomass than do either mid or high prairies (Barnes *et al.* 1983, Steuter 1987). The vegetation is shorter in ungrazed high prairie and does not form a continuous canopy. Grazing in the moderately grazed pasture reduced live cover, especially in low prairie where cattle reduced the canopy to a height of 1 to 2 cm. Mounds of the thatching ant had a dense cover of grasses, such as western wheatgrass, prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], or green needlegrass, that shaded most of the surface of the mound. Vegetative cover on the earthen mammal mounds, wallows, and potholes was much sparser, although a thick layer of litter occurred in the potholes. Actual measurements of vegetation cover, canopy height, and light availability are needed to confirm these qualitative observations.

Because Flodman's thistle forms rosettes, it may be especially susceptible to shading even though leaves range from prostrate to erect. For example, Givnish (1982) found a positive correlation between forest herb leaf height and vegetative cover in an eastern deciduous forest and discussed the importance of light. Wilson and McCarty (1984) found reduced germination in Flodman's thistle under low light conditions. Shading of young ramets may be equally or more important. Several earthen mounds were excavated, and it was found that the thistles on them originated from rhizomes located below the original ground level.

Factors other than light are critical to the success of this species. Its absence in potholes may reflect an inability of the seeds to survive submersion. Van Der Valk (1981) presented a general

discussion of plant colonization and establishment in potholes and marshes. Ants may directly attack or bury (King 1977) young seedlings or ramets. In creating wallows. bison appeared to remove most roots and rhizomes in the wallow and compact the soil, likely reducing the rate of vegetative colonization. Bison probably destroy young plants in active wallows.

Studies of a single patch type or single disturbance at a single site may not accurately estimate the relative importance of that patch or disturbance to the reproductive success of a species. Percent frequency of Flodman's thistle varied greatly between the different patch types, communities, and pastures examined in this study. This is shown in the difference between on and off patch frequencies for the thistles on earthen mounds (Figure 2). If vegetative colonization is important, higher frequency of Flodman's thistle on earthen mounds in the moderately grazed pasture could be the direct result of higher off patch frequencies. In contrast, thistle frequency on ant mounds was the same in the two pastures despite a two-fold difference in frequency adjacent to mounds. Life history traits such as seed dispersal and rhizomatous growth need to be considered in relation to the range of both the disturbance and environmental factors encountered by individuals of a species before their significance and possibly evolutionary history are to be understood.

While Flodman's thistle is not rare, its distribution raises several important issues for the management of prairies, especially small remnants. Of particular importance may be an understanding of 1) the dependence of plants on disturbance for regeneration and the similarity of different disturbances, 2) how the presence of one type of disturbance affects the probability or abundance of other disturbances, and 3) the need to supplement burn management of prairies with grazing or mowing or creation of artificial mounds and other openings or the importation ants and small mammals.

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