EFFECTS OF GRAZING ON NESTING BY UPLAND SANDPIPERS IN SOUTHCENTRAL NORTH DAKOTA

BONNIE S. BOWEN, U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, ND 58401
ARNOLD D. KRUSE,[1] U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Jamestown, ND 58401

Abstract: Grazing by livestock is often used to reduce litter, improve plant vigor, and alter plant species composition, but additional information is needed on the effects of these management practices on upland-nesting birds. Thus, we conducted an experimental study of the effect of grazing on nest density and nest success of upland sandpipers (*Bartramia longicauda*) in southcentral North Dakota from 1981 to 1987. Our experimental design consisted of 4 treatments and 1 control, each applied to 1 field in each of 3 study areas. The treatments represented options available to grassland managers: spring grazing, autumn grazing, autumn-and-spring grazing, season-long grazing, and control (ungrazed during the study). Nests (n = 342) were found by searching study areas with a cable-chain drag. Nest density was lower (P = 0.006) for treatments where cattle were present (spring, autumn-and-spring, and season-long) than where cattle were not present (autumn and control) during the nesting season. We concluded that grazing during the nesting season reduced the nest density of upland sandpipers. Nest success varied among years (P = 0.01) and was low in the first year of grazing and higher at the end of the study period. We found little evidence that the grazing treatment influenced nest success. We recommend that public lands with breeding populations of upland sandpipers include a complex of fields under various management practices, including fields undisturbed during the nesting season.

J. WILDL. MANAGE. 57(2):291–301

The upland sandpiper is a medium-sized shorebird whose populations have declined during the past 100 years because of market hunting, sport hunting, and loss of native prairie habitat (Mitchell 1967, Kirsch and Higgins 1976). This species has been on the National Audubon Society's Blue List of species of concern for many years (Arbib 1979, Tate 1986). It also was on the U.S. Fish and Wildlife Service's 1982 list of migratory nongame birds of management concern, but was removed in 1987 primarily because of positive population trends indicated by the Breeding Bird Survey (U.S. Fish and Wildl. Serv. 1987). During the past 20 years, populations have increased on Breeding Bird Survey routes in Canada and the Northern Plains states (Robbins et al. 1986), the primary breeding habitat of the upland sandpiper. Continued positive population trends in this region depend partly on successful reproduction.

Upland sandpipers breed in grasslands, which are often grazed for livestock production or are managed by grazing. Upland sandpipers often occur on grazed pastures (Bowen 1976, Ailes and Toepfer 1977, Ailes 1980, Kantrud 1981, Kantrud and Kologiski 1982), but nest success may be lower on annually grazed fields than on ungrazed fields (Kirsch and Higgins 1976).

We evaluated the effects of various grazing practices on the nesting biology of upland sandpipers in southcentral North Dakota. We focused on management practices that are suitable for public lands such as National Wildlife Refuges and Waterfowl Production Areas, where the objective of grazing is to manage the grassland to enhance prairie and wildlife. The grazing treatments we chose are presumed to reduce exotic cool-season grasses, such as Kentucky bluegrass (*Poa pratensis*). We compared the effects of 3 such treatments with the effects of a traditional season-long grazing pattern and ungrazed pastures on nest density, nest success, and vegetation structure. We also investigated the relationship between vegetation structure and nest site selection and whether a long period of non-grazing affected nest density or nest success.

We thank D. H. Johnson, K. M. Kraft, W. M. Newton, T. L. Shaffer, and D. J. Twedt for advice on statistical analyses; J. L. Piehl for help in establishing the field study; staff of the Kulm Wetland Management District for facilitating the field work; B. A. Hanson for preparing the figures; and B. A. Hanson and C. L. Nustad for assisting with data management. Data collection was conducted by many able field assistants, all of whom we thank. J. E. Austin, K. F. Higgins, D. H. Johnson, R. R. Koford, T. L. Shaffer, and

[1] Present address: U.S. Fish and Wildlife Service, Wetland Habitat Office, Route 1, Box 96K, Jamestown, ND 58401.

2 anonymous reviewers provided helpful comments on an earlier version of the manuscript.

STUDY AREAS

We conducted studies from 1981 to 1987 on 3 Waterfowl Production Areas (WPA's) in the Kulm wetland management district of the U.S. Fish and Wildlife Service in southcentral North Dakota. The study sites were in the gently to moderately rolling Missouri Coteau physiographic region (Stewart and Kantrud 1973). The Geisler WPA was located 17.7 km south and 27.3 km west of Kulm in sections 14, 22, 23, and 27 of township 131 north, range 69 west. The Erlenbusch WPA was 22.5 km south of Kulm in sections 3 and 10 of township 130 north, range 66 west. The Lazy-M WPA was located 33.8 km south and 1.6 km east of Kulm in sections 14, 15, and 23 of township 129 north, range 66 west. Study sites were separated by 11–39 km. Each WPA had 5 fields, ranging in size from 25 to 47 ha.

The habitat consisted primarily of mixed-grass native prairie and seasonal and semipermanent wetland basins (Stewart and Kantrud 1971). Vegetation in the native prairie was diverse. Plants with canopy coverage of >5% were upland sedges (*Carex* spp.), needle-and-thread (*Stipa comata*), Kentucky bluegrass, big bluestem (*Andropogon gerardii*), and green needlegrass (*Stipa viridula*). Plants with canopy coverage of 2–5% were western wheatgrass (*Agropyron smithii*), porcupine-grass (*Stipa spartea*), rigid goldenrod (*Solidago rigida*), smallflower aster (*Aster falcatus*), blue grama (*Bouteloua gracilis*), stiff sunflower (*Helianthus rigidus*), prairie sandreed (*Calamovilfa longifolia*), white sage (*Artemisia ludoviciana*), little bluestem (*Andropogon scoparius*), smooth brome (*Bromus inermis*), lead plant (*Amorpha canescens*), and western snowberry (*Symphoricarpos occidentalis*). A small area of exotic grasses on previously farmed land contained predominantly smooth brome with some Kentucky bluegrass and alfalfa (*Medicago sativa*).

The climate in southcentral North Dakota is cool and semi-arid, characterized by cold, dry winters and warm summers. Average temperatures range from −15 C in January to 21 C in July. Average annual precipitation is 44.5 cm, over half of which occurs during April–July. Average length of the frost-free season is 120 days (Jensen 1972).

METHODS

Vegetation

We defined 12 vegetation types, that were mapped on aerial photographs of each field in 1981 and 1987; we mapped 513 ha each year. The 6 most common vegetation types were: grass/forb (61% of total), grass with ≥50% canopy cover and forbs with <50% canopy cover; wetland (19%); grass/brush (8%), western snowberry with <50% canopy cover and an understory of grass; shallow marsh emergent (5%), vegetation characteristic of the shallow marsh zone of wetlands in the prairie pothole region (Stewart and Kantrud 1971); brush/grass (3%), western snowberry with ≥50% canopy cover and an understory of grass; and forb/grass (3%), forbs with ≥50% canopy cover and grass with <50% canopy cover. Vegetation types that each represented <1% of the total area were 100% brush, trees, rock piles, islands, bare ground, and miscellaneous areas not searched for nests.

We ascertained availability of nesting habitat by measuring areas of each vegetation type from the aerial photographs previously described. Because area of each vegetation type changed little between 1981 and 1987, mean values were used. We determined use of available vegetation types for nesting by classifying the vegetation type at each nest site into one of the 6 types. We compared use and availability of vegetation types with a Chi-square goodness-of-fit test and Bonferroni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984, Thomas and Taylor 1990).

We indexed vegetation height and density with the 100% visual obstruction method described by Robel et al. (1970), as modified by Kirsch et al. (1978). Readings were rounded to the nearest 0.5 dm. Height–density readings were grouped into classes: 0–0.49 dm, 0.50–0.99 dm, 1.00–1.49 dm, 1.50–1.99 dm, and ≥2.00 dm.

To assess availability of vegetation height–density classes, we obtained a systematic sample of upland vegetation using transects that bisected each study field. Wetlands and previously farmed areas were avoided. Each transect contained 25 stations, spaced 25 paces apart. Readings were taken twice each year, once in late April to assess the height–density of residual vegetation and again in early June during the peak of the upland sandpiper nesting season. We added June readings to the protocol in 1982.

A vegetation height–density reading was taken at each nest site.

We used the second readings, obtained between 1 and 7 June, to compare the index of vegetation height–density at nest sites with available vegetation. We restricted the analyses to nests found between 24 May and 14 June (±1 week from the extremes of the dates when the transect readings were taken). WPA's were pooled by year. We compared use and availability of vegetation height–density classes for nesting on each treatment using a Chi-square contingency test and Bonferroni simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984, Thomas and Taylor 1990).

Nest Searches

We found nests by flushing birds with a 53-m cable-chain (Higgins et al. 1977) towed between 2 vehicles. Stages of embryonic development were ascertained by egg flotation (Westerskov 1950). We estimated the hatch date by summing the clutch size (assuming 1 egg was laid/day) and the incubation period (21 days; Buss and Hawkins 1939, Harrison 1978), and adding that number to the estimated date of nest initiation. Nests were checked every 3 weeks and after estimated hatch dates to ascertain their fates. We considered a nest successful if it contained recently hatched young or small fragments of eggshell in the bottom of the nest (Higgins and Kirsch 1975). Nest success was calculated by the Mayfield method (Mayfield 1961) with the 40% modification of Johnson (1979).

Grazing Treatments

We applied 4 grazing treatments to each WPA (Appendix). One field on each WPA was left ungrazed as a control. Treatments were assigned randomly to fields on each WPA. All fields were monitored in the 1981 nesting season before grazing began.

Analyses of Treatment and Year

Our measure of nest success was an angular transformation (Steel and Torrie 1980) of daily nest survival rate (Klett et al. 1986), weighted by exposure days. Abandoned nests (2) were omitted from the success analyses. Nest success data were not collected in 1981. Nest success data for 1986 were not used because the criteria for nest fate that year were not consistent with other years of the study. We used the procedures described by Milliken and Johnson (1984:378) for unbalanced data to analyze nest success, because estimates of daily nest survival rates were not available for all fields in all years. Least squares means were calculated for nest success.

We used 2 measures of nest density: annual nest density was the number of nests per field each year divided by the non-wetland area of the field, and the total nest density was the number of nests per field summed over all treatment and post-treatment years (1982–87) divided by the non-wetland area of the field. Pre-treatment year (1981) nest data were not included in the analysis of total nest density.

We analyzed data as a randomized complete block design. Each WPA represented a block. To analyze nest success and annual nest density, we used repeated measures analysis of variance (Milliken and Johnson 1984). We tested for the main effects of treatment and year, as well as treatment–year interaction. To analyze total nest density, we used a randomized block design, testing for the effect of treatment. To test specific a priori hypotheses, we constructed statistical contrasts, which we describe in the Results section. Statistical analyses were performed with SAS programs for microcomputers (SAS Inst. Inc. 1987). A probability level ≤ 0.05 indicated statistical significance.

RESULTS

Nest Initiation and Clutch Size

We found 342 nests during the 7-year study. The earliest date of nest initiation was 8 May (1987) and the latest was 28 June (1986). The median initiation date ranged from 21 May (1982) to 30 May (1983).

Of the 328 completed nests, 306 (93%) contained 4 eggs. Of the remaining 22 nests, two contained 2 eggs, 14 contained 3 eggs, five contained 5 eggs, and one contained 7 eggs. We suspect the 7-egg clutch may have been from 2 laying females.

Nest Density

Grazing treatment marginally affected ($F = 3.73$; 4, 8 df; $P = 0.053$) total nest density. We hypothesized that treatments with cattle during the nesting season would have lower nest density than treatments without cattle, and that among treatments with cattle, those with higher stocking densities would have lower nest density than those with lower stocking densities. To test our

Table 1. Mean values of annual nest density (nests per 100 ha), nest success, and exposure days of upland sandpiper nests relative to block (Waterfowl Production Area), treatment, and year, southcentral North Dakota, 1981–87.

		Nest success[a]		
Effect	Annual density	DNSR	Mayfield (%)	Exposure days
Block				
Erlenbusch	8.2	0.954	30.8	416
Lazy-M	12.6	0.981	61.9	808
Geisler	16.4	0.985	68.5	914
Treatment				
Control	15.9	0.992	81.8	598
Autumn graze	18.5	0.979	58.8	629
Autumn-and-spring	11.6	0.961	37.0	340
Season-long	8.5	0.982	63.5	304
Spring graze	7.5	0.950	27.7	267
Year				
1981	21.8	NA[b]	NA[b]	NA[b]
1982	11.2	0.925	14.2	416
1983	9.8	0.970	46.7	391
1984	10.3	0.992	81.8	424
1985	12.0	0.983	65.1	475
1986	9.8	NA[b]	NA[b]	NA[b]
1987	12.0	0.985	68.5	432

[a] Measures of nest success are daily nest survival rate (DNSR) and the Mayfield estimator $[(DNSR)^{25} \times 100]$.
[b] Estimates of nest success were not available for 1981 and 1986.

hypotheses, we conducted 3 a priori statistical contrasts. We found that fields that were grazed during the nesting season (autumn-and-spring, season-long, and spring) had lower ($F = 14.06$; 1, 8 df; $P = 0.006$) nest density than did fields in which cattle were absent during the nesting season (control and autumn) (Table 1). Fields with spring grazing tended ($F = 0.36$; 1, 8 df; $P = 0.57$) to have lower nest density than those with autumn grazing (Table 1). Nest density in the treatment with high stocking density (spring grazing) did not differ ($F = 0.09$; 1, 8 df; $P = 0.77$) from nest density in the treatment with low stocking density (season-long grazing).

Annual nest density by years ranged from 9.8 to 21.8/100 ha and had an overall mean of 12.4/100 ha (Table 1). The treatment–year interaction was significant ($F = 2.06$; 24, 60 df; $P = 0.013$), which prevented us from interpreting the main effects of treatment and year. A significant treatment–year interaction was not surprising, as grazing was not applied to all fields in all years.

Following our finding of a significant treatment–year interaction, we analyzed years within treatments and treatments within years. We examined year effects within treatments (Fig. 1) by conducting 22 a priori contrasts, 3–5 within each treatment. We hypothesized that annual density in the pre-treatment year differed from annual density in the post-treatment year (1981 vs. 1987), and annual density differed in years with and without grazing. In addition, we tested for linear and quadratic effects throughout the course of the study, and linear effects within each grazing rotation.

There were 6 significant effects. Pre-treatment and post-treatment years differed in the season-long ($t = 3.35$, $P < 0.05$) and autumn-and-spring ($t = 4.46$, $P < 0.05$) treatments, with nest density lower at the end of the study than at the beginning. The spring treatment showed a similar trend in the contrast of pre-treatment and post-treatment years ($t = 1.95$, $0.05 < P < 0.10$). Linear effects in the season-long ($t = 3.13$, $P < 0.05$) and autumn-and-spring ($t = 3.05$, $P < 0.05$) fields also indicated lower density at the end of the study. All treatments that had lower density at the end of the study had been grazed during the nesting season. The 2 remaining significant effects were quadratic effects for autumn ($t = 3.03$, $P < 0.05$) and autumn-and-spring ($t = 2.28$, $P < 0.05$). The quadratic effect in the autumn treatment reflected low nest density in the 3 years following the first autumn grazing year (1981) and exceptionally high nest density in the 3 years following the second autumn grazing year (1984; Fig. 1).

Nest density in the control fields tended to be lower at the end of the study (contrast of pre-treatment and post-treatment years: $t = 1.98$, $0.05 < P < 0.10$). This was due to a decline in nest density to zero nests on 1 WPA (Lazy-M) at the end of the study. The other 2 WPA's had changed little in nest density. None of the a priori contrasts among grazing treatment combinations within years were significant.

Nest Success

Daily survival rate of nests varied among years ($F = 4.08$; 4, 29 df; $P = 0.01$) but not among grazing treatments ($F = 1.58$; 4, 8 df; $P = 0.26$). There was no treatment–year interaction ($F = 0.54$; 16, 29 df; $P = 0.90$). We examined 3 a priori statistical hypotheses regarding the differences among years. We hypothesized that nest success would be lower in years with grazing than in years without and that nest success would be lower during the treatment years than in the post-treatment year. We also hypothesized that there would be a linear trend in nest

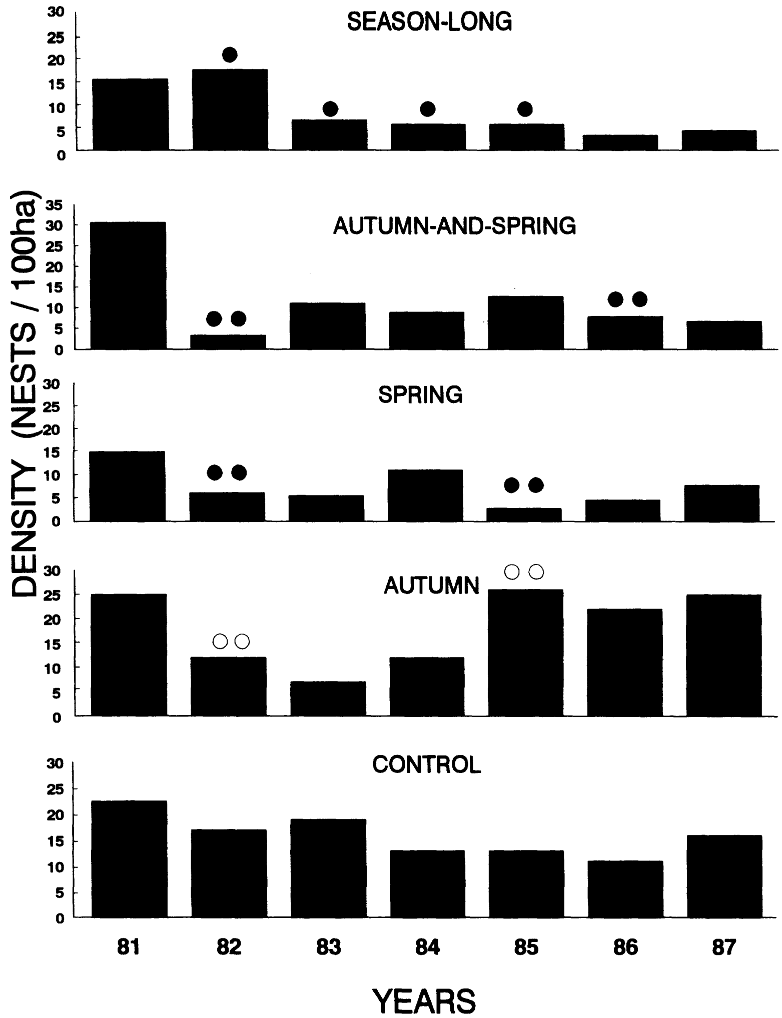

Fig. 1. Nest density of upland sandpipers during spring, southcentral North Dakota, 1981–87. Symbols indicate when grazing occurred: ● = Light spring and summer grazing, June–September. ●● = Heavy spring grazing, May–June. ○○ = Heavy grazing during previous autumn.

success throughout the study. We found that nest success tended to be lower ($F = 3.84$; 1, 29 df; $P = 0.06$) in years with the highest number of grazed fields (1982 and 1985) than in years with the lowest number of grazed fields (1983 and 1984; Table 1). Nest success during the treatment years (1982–85) did not differ ($F = 1.45$; 1, 29 df; $P = 0.24$) from nest success in the post-treatment year (1987). We found a linear trend in nest success: daily nest survival rate increased ($F = 8.04$; 1, 29 df; $P = 0.008$) during the study (Table 1).

We analyzed 4 a priori hypotheses to explore the effects of the grazing treatments on nest success. We hypothesized that treatments with high stocking density and May–June grazing (spring and autumn-and-spring treatments) differed from the control; treatments with high stocking density and May–June grazing differed from the traditional, low stocking density season-long grazing; treatments with high stocking density and May–June grazing differed from autumn grazing; and treatments with nesting-season grazing (spring, autumn-and-spring, and season-long) differed from those without.

Because there was not a significant main effect of treatment in the overall model, we adjusted the critical probability level using the Bonferroni method (Milliken and Johnson 1984, Harris 1985). Contrasts were considered statistically significant only if $P < 0.0125$.

Control fields tended toward higher ($t = 2.40$;

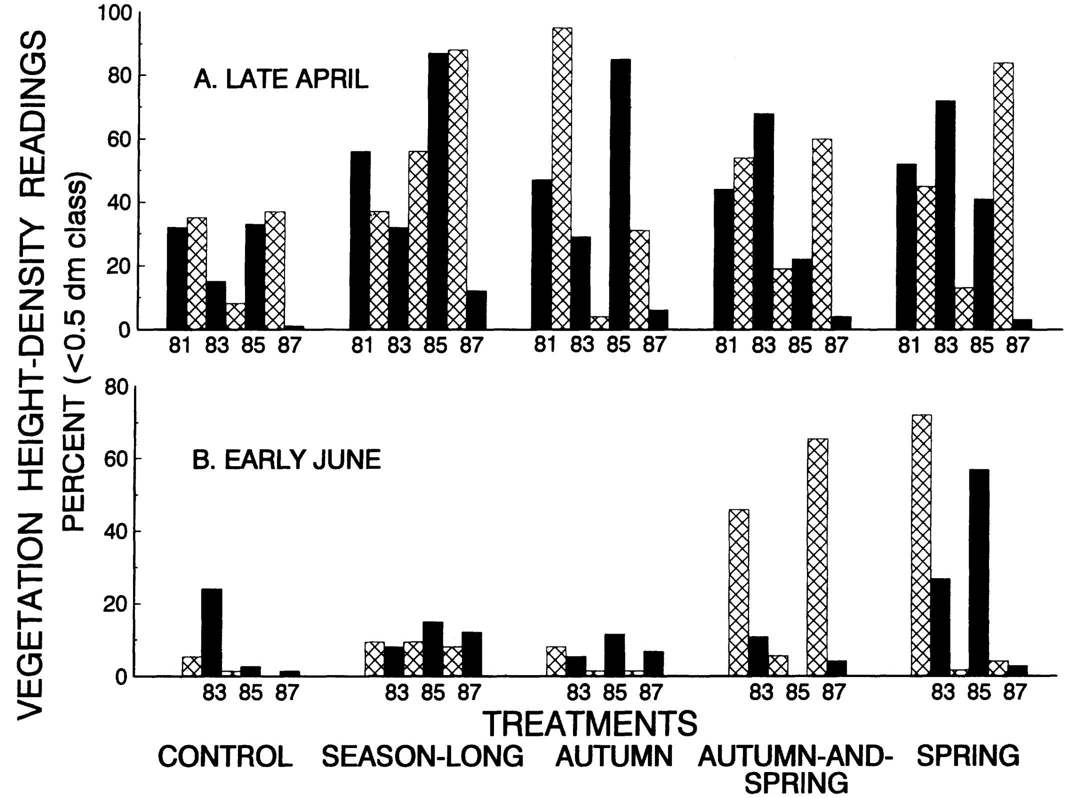

Fig. 2. Percent of vegetation height–density readings in the <0.5-dm class on transects, southcentral North Dakota, 1981–87. Even numbered years are indicated with the cross-hatched pattern. (A) readings from late April; (B) readings from early June.

8.68 df; $P = 0.04$) daily nest survival than fields with high stocking density and May–June grazing (spring and autumn-and-spring), although the difference was not significant. The remaining 3 contrasts revealed no differences among the treatments tested. Daily nest survival did not differ ($t = 1.33$; 15.18 df; $P = 0.20$) between the season-long treatment and the fields with high stocking density and May–June grazing; autumn grazing did not differ ($t = 1.29$; 8.91 df; $P = 0.23$) from treatments with high stocking density and May–June grazing; and treatments with nesting-season grazing (spring, autumn-and-spring, and season-long) did not differ ($t = 1.77$; 9.17 df; $P = 0.11$) from those without nesting-season grazing (autumn and control).

The major source of nest failure was predation. Of 95 nest destructions, predators destroyed 93 nests, and livestock trampled 2 nests.

Grazing and Vegetation Structure

Vegetation height–density in April, which served as a measure of residual vegetation from the previous growing season, changed in years after grazing (Fig. 2). In 1981, when no grazing had occurred in the previous year, the percentage of vegetation height–density stations with April readings <0.5 dm ranged from 32 to 56% (Fig. 2A). In 1987, when only the autumn-and-spring treatment fields had been grazed in spring the previous year, no more than 15% of stations had vegetation height–density readings <0.5 dm. The only years in which >60% of April readings were <0.5 dm were in the springs after many fields had been grazed the previous year (season-long 1985 and 1986; autumn grazing 1982 and 1985; autumn-and-spring 1983; and spring grazing 1983 and 1986). The least residual vegetation occurred in the springs after autumn grazing (1982 and 1985), when 85 to 95% of the stations had April readings <0.5 dm.

By early June, when most upland sandpipers were nesting, the vegetation height–density was higher as a result of new growth. On the autumn grazing fields, only a small percentage of the

Table 2. Comparison of availability and use of vegetation types by nesting upland sandpipers, southcentral North Dakota, 1981–87.

Vegetation type[a]	Availability		Use	
	Hectares	Proportion	Nests	Proportion
Brush/grass	16.4	0.042	1	0.003[b]
Forb/grass	15.0	0.039	7	0.020
Grass/brush	43.3	0.112	47	0.137
Grass/forb	311.2	0.806	287	0.839

[a] Where a combination of life forms is indicated (i.e., brush/grass) the first covers ≥50% of the area; the second covers <50%.
[b] Used less ($P < 0.05$) than expected.

height–density readings were <0.5 dm (Fig. 2B). The fields with high percentages of readings <0.5 dm were those with cattle present in May and early June (autumn-and-spring 1982 and 1986; spring 1982 and 1985) (Fig. 2B).

Nest Site Location and Selection

Vegetation Types.—Most upland sandpiper nests were in the grass/forb vegetation type (Table 2). The most common plants within 1 m of upland sandpiper nests were Kentucky bluegrass, needle-and-thread, green needlegrass, western wheatgrass, smooth brome, upland sedges, and western snowberry.

Nests were found in brush/grass, forb/grass, grass/brush, and grass/forb. The remaining vegetation types were not included in the analyses because the birds did not nest in them or we did not search for nests in them.

Brush/grass habitat was avoided and forb/grass, grass/brush, and grass/forb habitats were used in proportion to their availability (Table 2).

Vegetation Height-Density.—Most (90%) nests of upland sandpipers found between 24 May and 14 June in 1982–87 were in vegetation with height–density readings between 0.5 dm and 2.0 dm in early June (Fig. 3). In our analyses of nesting habitat use and availability, we analyzed grazing years and non-grazing years separately for the spring, autumn-and-spring, and season-long treatments that had cattle present during the nesting period in some years. Only on the control fields was use of nesting habitat different ($\chi^2 = 8.19$, 3 df, $P = 0.04$) from availability. On the control fields, sandpipers avoided vegetation with height–density <0.5 dm and ≥1.50 dm and used vegetation between 0.5 dm and 1.49 dm in proportion to its availability (Table 3).

To determine whether all vegetation ≥1.50 dm was avoided, we expanded the highest

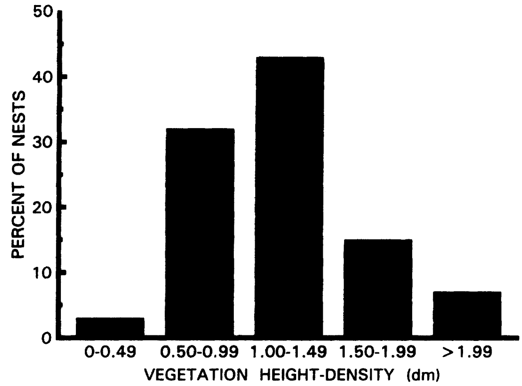

Fig. 3. Nests of upland sandpipers by vegetation height–density classes, southcentral North Dakota, between 24 May and 14 June 1982–87.

height–density class into 2 classes (1.50–1.99 and ≥2.00). Although the probability level was higher ($\chi^2 = 8.67$, 4 df, $P = 0.07$) for the overall use–availability comparison with the expanded classes, the Bonferroni simultaneous confidence intervals indicated that vegetation 1.50–1.99 dm was used in proportion to its availability, and vegetation ≥2.0 dm was avoided (Table 3).

Examination of the data for all treatments revealed that very few nests were in vegetation <0.50 dm. On most fields, little vegetation was available in this class, and the expected number of nests was small. Thus, the power of individual tests was low. Considering all treatment groups together, however, the trend is striking; 16.4 nests were expected in vegetation <0.5 dm, but only 5 nests were found there.

DISCUSSION

Nest Density

The nest densities we observed (8–22/100 ha, mean 12.4/100 ha) are comparable to those reported from other studies (5/100 ha, Lokemoen and Duebbert 1974; 8–17/100 ha, Kirsch and

Table 3. Comparison of availability and use of vegetation height–density classes by upland sandpipers nesting on control fields, southcentral North Dakota, 1981–87.

Height-density (dm)	Availability		Use	
	Transects	Proportion	Nests	Proportion
0–0.49	26	0.05	0	0.00[a]
0.50–0.99	135	0.27	15	0.38
1.00–1.49	194	0.39	20	0.50
≥1.50	138	0.28	5	0.12[a]
1.50–1.99	79	0.16	4	0.10
≥2.00	59	0.12	1	0.02[a]

[a] Used less ($P < 0.05$) than expected.

Higgins 1976), although Buss and Hawkins (1939) reported higher densities (25–75/100 ha). Upland sandpipers sometimes nested semicolonially (Buss and Hawkins 1939, Bowen 1976). Colony sites were fairly consistent among years, but have been known to change (Buss and Hawkins 1939, Bowen 1976). In our study, the Lazy-M WPA control field had high nest density (37 nests/100 ha) during the first year, and the nests appeared clustered in a colony (A. Kruse, pers. observ.). By the end of the study, the density on this field had declined to zero, indicating the temporary nature of the colony. Examination of nest success and vegetation height–density patterns did not reveal any patterns that would explain the decline in density. The field may have become unsuitable for nesting after a long period of non-grazing. However, density did not decline after a similar period of non-grazing on the Geisler and Erlenbusch control fields.

Any explanation for low densities of nests on fields with grazing during the nesting season must account for both grazing years and non-grazing years. In years when cattle were present during the nesting season, upland sandpipers may have avoided nesting on grazed fields because of the physical presence of cattle, or because cattle foraging and trampling altered the vegetation structure, making the grazed fields unsuitable for nesting. The vegetation was altered on fields with spring and autumn-and-spring treatments in grazing years. A large percentage of vegetation was in the shortest height–density category (<0.5 dm) in early June, when the sandpipers were nesting. Such short vegetation was avoided by upland sandpipers for nesting sites even on control fields.

Alteration of vegetation height–density does not explain reduced nest density in the non-grazing years because vegetation height–density readings on grazed fields in the non-grazing years were more similar to readings on fields that were never grazed than to those that were grazed. Other aspects of vegetation structure, such as the presence of litter, may have influenced upland sandpiper nesting density, but we have no data to test this hypothesis.

Reduced nest density in the non-grazing years could have been a result of the movement and settlement patterns of upland sandpipers. Although our knowledge of philopatry is meager, 2 studies have found that breeding upland sandpipers are philopatric. Bowen (1976) documented that 3 of 20 (15%) banded adults returned to previous nesting sites, and Ailes (1980) documented that 5 of 15 (33%) returned. Density may have remained low in the non-grazing years because few birds reproduced successfully in those fields in years of grazing. As a result, few birds were available to return the next year. The fact that few birds colonized these fields in non-grazing years raises the possibility that not many upland sandpipers were looking for breeding sites.

Some researchers who compared nest density on grazed and ungrazed fields found more nests on grazed than ungrazed fields (Skinner 1975, Messmer 1985), or similar densities (Kaiser 1979, Dale 1984). Both results contrast with our findings that nest density was lower on fields with grazing during the nesting season. In the study areas of Dale (1984) and Messmer (1985), vegetation composition was different on grazed and ungrazed fields, suggesting that the ungrazed fields were unacceptable as nesting sites for sandpipers. In the central and southern Great Plains, where some studies of upland sandpipers were conducted (Skinner 1975, Bowen 1976), the vegetation on ungrazed fields may have been too tall and dense for upland sandpipers, but grazed fields, with lower vegetation height, may have offered acceptable nesting sites. Quantitative comparisons of vegetation height in our study area and those studies conducted farther south are not possible because we measured vegetation height–density, and other investigators measured only maximum height of the vegetation.

Another apparent contradiction between our study and previously published studies is that upland sandpipers are often seen in grazed fields during roadside and breeding-bird surveys in prairie habitats (Bowen 1976, Kantrud 1981, Renken and Dinsmore 1987). However, surveys do not indicate how the birds use habitat. Studies of habitat use have found that upland sandpipers use grazed fields for rearing broods (Ailes 1980), foraging (Ailes and Toepfer 1977, Ryder 1980, McNicholl 1988), and loafing (McNicholl 1988), in addition to nesting (Lokemoen and Duebbert 1974, Kirsch and Higgins 1976, Kaiser 1979). Because upland sandpipers are not territorial on their foraging areas (Buss and Hawkins 1939), densities on these areas may be higher than on nesting areas. Such behavior may help explain why this species is sometimes more common on heavily grazed fields than on lightly grazed and idle fields (Kantrud 1981).

Nest Success

Previous researchers (Bowen 1976, Kirsch and Higgins 1976, Kaiser 1979, Ailes 1980) calculated nest success of upland sandpipers as the percentage successful nests of the total found. Mayfield estimates, which we present, are better indicators of true nest success because apparent nest success does not consider the stage at which the nest is found (Mayfield 1961, 1975; Johnson 1979). Green (1989) presented a method to transform apparent nest success to values that can be compared with Mayfield estimates. We calculated a discrete version of Green's estimator (Johnson 1991) for a number of studies that reported apparent estimates of nest success. The lowest value of nest success (41%, 27 nests) was for upland sandpipers in grazed grassland in Kansas (Bowen 1976). In undisturbed, grazed, and burned grasslands in North Dakota, success was 48% (67 nests; Kirsch and Higgins 1976). Upland sandpiper success in grazed grassland in South Dakota was 66% (30 nests; Kaiser 1979), and success in idle and hayed fields in Wisconsin was 74% (13 nests; Ailes 1980). The mean value of nest success in our study was 67% (209 nests).

One previous examiner of the effect of grazing on nest success reported that success was lower on fields with season-long grazing than on ungrazed fields (Kirsch and Higgins 1976), although no statistical tests were conducted. We found a trend toward lower nest success on the fields with May–June grazing and high stocking densities (spring and autumn-and-spring grazing) than on the control fields. The fact that most nest destruction was due to predation suggests that the presence of the cattle did not affect nest success directly, such as by trampling the nests, but rather it may have had an indirect effect on nest success.

Nest success varied substantially among years and tended to increase during the study. Possible explanations for annual variation in nest success include effects from the grazing systems, temporal changes in the predator community, and unexplained environmental variation.

We found little evidence that the grazing systems were responsible for the annual variation in nest success. There was a marginally significant trend toward higher nest success in years with few grazed fields, but we are hesitant to emphasize this finding, because of the possible confounding effect of the increase in success throughout the study. Contrasts among years within treatments revealed no differences in nest success between grazing and non-grazing years. Thus, we conclude that the annual variation in nest success was independent of the treatments in our study.

MANAGEMENT IMPLICATIONS

Managers of grasslands on public lands need to consider a variety of factors when deciding what management tools to use. Increasingly, attention is being given to nongame wildlife such as the upland sandpiper, which are dependent on grassland habitats. Our study indicates that grazing during the late spring and early summer, a traditional grassland management practice, has a detrimental effect on reproduction, especially nesting density, of upland sandpipers in the northern Great Plains.

If managers use grazing to meet management objectives in grasslands in the northern Great Plains, they should consider delaying grazing until after nesting is well underway in mid to late June. Traditional season-long grazing, June–October, at low stocking density, should be avoided on grasslands that are used by upland sandpipers. Autumn grazing at high stocking densities may be a satisfactory option, but additional research is needed to test this possibility. In our study, the density response on the autumn grazing fields was complex. Density of nests was quite low in the 3 years after the first grazing rotation, but high in the 3 years after the second rotation. Leaving native grasslands idle for several years did not have a detrimental effect on nesting upland sandpipers.

In our study, the interval between grazing rotations in the spring and autumn-and-spring treatments was short (3–4 yr), which did not allow us to determine the optimal interval for nesting density to return to the high levels we observed in the pre-treatment years and on the control fields. Further research is needed on timing of grazing rotations.

Nest success varied widely among treatments, blocks, and years. Among treatments, the Mayfield estimates of nest success for the 25-day nesting period ranged from 28 to 82%. Even with such a wide range of nest success values, we found few statistically significant differences in success, due to wide variability among WPA's (blocks) and years. Our findings should caution other researchers about seemingly wide-ranging values that are presented and interpreted as being different without adequate testing.

Our results suggest that upland sandpipers avoided tall, dense vegetation. Studies conducted in the central Great Plains, where precipitation is greater and vegetation height typically is taller, have found that upland sandpipers prefer to nest in grazed fields, rather than ungrazed fields where the vegetation is too tall. Thus, our finding of a negative effect of grazing is applicable primarily to the northern Great Plains.

Management of public lands used by upland sandpipers may require a complex of fields of various management practices. In the mixed-grass prairies of North Dakota, grazed, burned, or hayed fields may provide suitable habitat for feeding, loafing, and brood-rearing, whereas fields undisturbed during the nesting season are required for reproduction.

LITERATURE CITED

AILES, I. W. 1980. Breeding biology and habitat use of the upland sandpiper in central Wisconsin. Passenger Pigeon 42:53–63.

———, AND J. E. TOEPFER. 1977. Home range and daily movement of radio-tagged upland sandpipers in central Wisconsin. Inland Bird Banding News 49:203–212.

ARBIB, R. 1979. The blue list for 1980. Am. Birds 33:830–835.

BOWEN, D. E. 1976. Coloniality, reproductive success, and habitat interactions in upland sandpipers (*Bartramia longicauda*). Ph.D. Diss., Kansas State Univ., Manhattan. 127pp.

BUSS, I. O., AND A. S. HAWKINS. 1939. The upland sandpiper at Faville Grove, Wisconsin. Wilson Bull. 51:202–220.

BYERS, C. R., R. K. STEINHORST, AND P. R. KRAUSMAN. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050–1053.

DALE, B. C. 1984. Birds of grazed and ungrazed grasslands in Saskatchewan. Blue Jay 42:102–104.

GREEN, R. E. 1989. Transformation of crude proportions of nests that are successful for comparison with Mayfield estimates of nest success. Ibis 131:305–306.

HARRIS, R. J. 1985. A primer of multivariate statistics. Second ed. Academic Press, New York, N.Y. 576pp.

HARRISON, C. 1978. A field guide to the nests, eggs and nestlings of North American birds. Collins, New York, N.Y. 416pp.

HIGGINS, K. F., AND L. M. KIRSCH. 1975. Some aspects of the breeding biology of the upland sandpiper in North Dakota. Wilson Bull. 87:96–102.

———, ———, H. F. DUEBBERT, A. T. KLETT, J. T. LOKEMOEN, H. W. MILLER, AND A. D. KRUSE. 1977. Construction and operation of cable-chain drag for nest searches. U.S. Fish and Wildl. Serv. Wildl. Leafl. 512. 14pp.

JENSEN, R. E. 1972. Climate of North Dakota. N.D. State Water Comm., Bismarck. 48pp.

JOHNSON, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96: 651–661.

———. 1991. Further comments on estimating nest success. Ibis 133:205–207.

KAISER, P. H. 1979. Upland sandpiper nesting in southeastern South Dakota. Proc. S.D. Acad. Sci. 58:59–68.

KANTRUD, H. A. 1981. Grazing intensity effects on the breeding avifauna of North Dakota native grasslands. Can. Field-Nat. 95:404–417.

———, AND R. L. KOLOGISKI. 1982. Effects of soils and grazing on breeding birds of uncultivated upland grasslands of the northern Great Plains. U.S. Fish and Wildl. Serv. Wildl. Res. Rep. 15. 33pp.

KIRSCH, L. M., H. F. DUEBBERT, AND A. D. KRUSE. 1978. Grazing and haying effects on habitats of upland nesting birds. Trans. North Am. Wildl. Nat. Resour. Conf. 43:486–497.

———, AND K. F. HIGGINS. 1976. Upland sandpiper nesting and management in North Dakota. Wildl. Soc. Bull. 4:16–20.

KLETT, A. T., H. F. DUEBBERT, C. A. FAANES, AND K. F. HIGGINS. 1986. Techniques for studying nest success of ducks in upland habitats in the prairie pothole region. U.S. Fish and Wildl. Serv. Resour. Publ. 158. 24pp.

LOKEMOEN, J. T., AND H. F. DUEBBERT. 1974. Summer birds for a South Dakota prairie. S.D. Conserv. Digest 41:18–21.

MAYFIELD, H. 1961. Nesting success calculated from exposure. Wilson Bull. 73:255–261.

———. 1975. Suggestions for calculating nest success. Wilson Bull. 87:456–466.

MCNICHOLL, M. K. 1988. Ecological and human influences on Canadian populations of grassland birds. ICBP Tech. Publ. 7:1–25.

MESSMER, T. A. 1985. Effects of specialized grazing systems on upland nesting birds in southcentral North Dakota. M.S. Thesis, North Dakota State Univ., Fargo. 112pp.

MILLIKEN, G. A., AND D. E. JOHNSON. 1984. Analysis of messy data. Van Nostrand Reinhold Co., New York, N.Y. 473pp.

MITCHELL, G. J. 1967. The upland plover and its status in relation to environmental conditions and situations, past and present. Blue Jay 25:58–63.

NEU, C. W., C. R. BYERS, AND J. M. PEEK. 1974. A technique for analysis of utilization availability data. J. Wildl. Manage. 38:541–545.

RENKEN, R. B., AND J. J. DINSMORE. 1987. Nongame bird communities on managed grasslands in North Dakota. Can. Field-Nat. 101:551–557.

ROBBINS, C. S., D. BYSTRAK, AND P. H. GEISSLER. 1986. The breeding bird survey: its first fifteen years, 1965–1979. U.S. Fish and Wildl. Serv. Resour. Publ. 157. 196pp.

ROBEL, R. J., J. N. BRIGGS, A. D. DAYTON, AND L.

C. HULBERT. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. J. Range Manage. 23:295–297.

RYDER, R. A. 1980. Effects of grazing on bird habitats. Pages 51–66 *in* R. M. DeGraff, tech. coord. Proc. workshop management of western forests and grasslands for nongame birds. U.S. For. Serv. Gen. Tech. Rep. INT-86.

SAS INSTITUTE INC. 1987. SAS/STAT guide for personal computers. Version 6 ed. SAS Inst. Inc., Cary, N.C. 1,028pp.

SKINNER, R. M. 1975. Grassland use pattern and prairie bird populations in Missouri. Pages 171–180 *in* M. K. Wali, ed. Prairie: a multiple view. Univ. of North Dakota Press, Grand Forks.

STEEL, R. G. D., AND J. H. TORRIE. 1980. Principles and procedures of statistics. Second ed. McGraw-Hill, New York, N.Y. 633pp.

STEWART, R. E., AND H. A. KANTRUD. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Fish and Wildl. Serv. Resour. Publ. 92. 57pp.

———, AND ———. 1973. Ecological distribution of breeding waterfowl populations in North Dakota. J. Wildl. Manage. 37:39–50.

TATE, J., JR. 1986. The blue list for 1986. Am. Birds 40:227–236.

THOMAS, D. L., AND E. J. TAYLOR. 1990. Study designs and tests for comparing resource use and availability. J. Wildl. Manage. 54:322–330.

U.S. FISH AND WILDLIFE SERVICE. 1987. Migratory nongame birds of management concern in the United States: the 1987 list. Off. Migr. Bird Manage., Washington, D.C. 62pp.

WESTERSKOV, K. 1950. Methods for determining the age of game bird eggs. J. Wildl. Manage. 14:56–67.

Received 20 January 1992.
Accepted 17 October 1992.
Associate Editor: Mannan.

Appendix. Average grazing periods, stocking densities (head of livestock per ha, hd/ha), grazing rates (animal unit months per ha, AUM/ha), and grazing and non-grazing (rest) schedules for each treatment, North Dakota, 1981–87.

	Treatment				
	Spring grazing	Autumn grazing	Autumn-and-spring grazing	Season-long grazing	Control
Grazing period	Early May–mid Jun	Early Sep–mid Oct	Early Sep–mid Oct (F) Early May–mid Jun (S)	Mid Jun–late Sep	none
Stocking density (hd/ha)	3.7	3.11	A: 0.97 S: 2.8	1.0	
Grazing rate (AUM/ha)	3.1	3.2	A: 1.28 S: 2.85	2.45	
Grazing schedule[a]					
1981	Rest	Autumn graze	Autumn graze	Rest	Rest
1982	Spring graze	Rest	Spring graze	Graze	Rest
1983	Rest	Rest	Rest	Graze	Rest
1984	Rest	Autumn graze	Rest	Graze	Rest
1985	Spring graze	Rest	Autumn graze	Graze	Rest
1986	Rest	Rest	Spring graze	Rest	Rest
1987	Rest	Rest	Rest	Rest	Rest

[a] Each of 3 Waterfowl Production Areas received the same grazing schedule.