A SYNTHESIS OF THE EFFECTS OF UPLAND MANAGEMENT PRACTICES ON WATERFOWL AND OTHER BIRDS IN THE NORTHERN GREAT PLAINS OF THE U.S. AND CANADA

David E. Naugle, Kenneth F. Higgins and Kristel K. Bakker

In cooperation with Ducks Unlimited Canada, Prairie Pothole Joint Venture, North American Waterfowl Management Plan, South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University, South Dakota Department of Game, Fish and Parks, U.S. Geological Survey, Wildlife Management Institute, U.S. Fish and Wildlife Service and the University of Wisconsin-Stevens Point.

Wildlife Technical Report 1

ACKNOWLEDGMENTS

Ducks Unlimited Canada provided funding for the synthesis and review. The Prairie Pothole Joint Venture (C. A. Lively-Coordinator), North American Waterfowl Management Plan, funded publication and distribution costs. T. G. Neraasen and D. B. Wark, Ducks Unlimited Canada, initiated this work and provided helpful insights into project objectives. We thank N. A. Gleason, D. H. Johnson, B. L. Kopplin, and C. J. Kopplin for assistance with reference acquisition. A. D. Kruse, R. K. Murphy, and R. H. Pemble granted access to their personal literature files. We also thank W. T. Barker for his help and hospitality during our stay at North Dakota State University. M. G. Anderson, K. J. Forman and R. E. Redmann provided useful comments on earlier drafts. Cooperators with the South Dakota Cooperative Fish and Wildlife Research Unit include: South Dakota State University, South Dakota Department of Game, Fish and Parks, U.S. Geological Survey, Wildlife Management Institute, and the U.S. Fish and Wildlife Service. Manuscript layout and design by Shelley Anderson, Printing & Design Department, University of Wisconsin-Stevens Point.

SDSU

College of Natural Resources

This publication may be cited as:

Naugle, D. E., K. F. Higgins and K. K. Bakker. 2000. A Synthesis of the Effects of Upland Management Practices on Waterfowl and Other Birds in the Northern Great Plains of the U.S. and Canada. College of Natural Resources, University of Wisconsin-Stevens Point, WI. Wildlife Technical Report 1. 28 pp.

Copies of this manuscript can be obtained from the authors free of charge.

2,000 copies printed at a cost of $1.20/copy.

A SYNTHESIS OF THE EFFECTS OF UPLAND MANAGEMENT PRACTICES ON WATERFOWL AND OTHER BIRDS IN THE NORTHERN GREAT PLAINS OF THE U.S. AND CANADA

David E. Naugle
College of Natural Resources
University of Wisconsin-Stevens Point
Stevens Point, WI 54481

Kenneth F. Higgins
South Dakota Cooperative Fish and Wildlife Research Unit
United States Geological Survey
Box 2140B, South Dakota State University
Brookings, SD 57007

and

Kristel K. Bakker
Department of Wildlife and Fisheries Sciences
Box 2140B
South Dakota State University
Brookings, SD 57007

December 2000

A SYNTHESIS OF THE EFFECTS OF UPLAND MANAGEMENT PRACTICES ON WATERFOWL AND OTHER BIRDS IN THE NORTHERN GREAT PLAINS OF THE U.S. AND CANADA

David E. Naugle[1], Kenneth F. Higgins[2] and Kristel K. Bakker[3]

[1]College of Natural Resources, University of Wisconsin-Stevens Point, Stevens Point, WI 54481

[2]South Dakota Cooperative Fish and Wildlife Research Unit, United States Geological Survey, Box 2140B, South Dakota State University, Brookings, SD 57007

[3]Department of Wildlife and Fisheries Sciences, Box 2140B, South Dakota State University, Brookings, SD 57007

SUMMARY

We synthesized effects of upland grassland management on vegetation structure and upland nesting bird use and productivity measures to provide guidelines for managing grasslands in the northern Great Plains of the U.S. and Canada. Agronomic literature focusing mostly on vegetation yield, nutrition, and floristics indicated that litter accumulations and reductions in root biomass are characteristic traits of unmanaged grasslands. Avian research evaluating treatment effects (idle, burn, hay, graze, till) in the treatment year, from annually treated lands, and from idled lands of unknown age indicated that bird use and productivity responded most positively to idling. In contrast, 28 references that incorporated study designs that enabled grassland treatment response to be evaluated over time indicate that periodic treatment of grasslands is required to remove excessive litter. Litter accumulations that negatively affect vegetative stand health, structure, and vigor also negatively affect duck production. References provide broad recommendations suggesting that grasslands can be treated every 1-5 years in the tallgrass prairie zone and every 3-10 years in the mesic mixed grass prairie zone. Although an accurate estimate is unknown, limited information indicates that grasslands in the shortgrass and rough fescue zones require longer recovery periods (>3-10 years) to return to pre-treatment conditions. Ground surface litter is probably the single best vegetation attribute that managers may use to determine when to apply grassland treatments; however, attention also should be given to the abundance of seed and flower stalks, height and density of vegetation, and the abundance of undesirable plant species within stands. Managers should wait 1-2 years (undermanage) rather than treat too frequently (overmanage) when uncertain whether a grassland treatment is required. We recommend periodic treatment (i.e., burning, haying, or grazing) over perpetual idling or annual cropping for the prairie pothole region. When possible, we recommend burning as a primary grassland management treatment because fire provides the fastest and most effective means of litter removal. Based on our synthesis of vegetation recovery intervals and bird nesting studies, we recommend that burns be conducted at 2-5 year intervals in the tallgrass zone, 3-10 year intervals in the mesic mixed and mesic rough fescue zones, and at ±10 year intervals in more xeric mixed grass, shortgrass and xeric rough fescue zones. Grazing is a suitable treatment when managed to primarily benefit grassland structure for wildlife rather than for red meat production, especially on public lands. Unfortunately, grazing has consistently been the most controversial treatment choice in relation to upland nesting bird productivity. Haying is also a management option, but it may not remove litter as effectively as burning or grazing. We remind readers that no single management treatment type or time interval is suitable for all grasslands. Rather, managers must consider the land use history of each grassland when prescribing treatments. We also encourage managers to keep an open mind and consider new treatment options that emerge rather than develop biased or negative attitudes about specific treatments (e.g., grazing is always bad or burning is always good).

INTRODUCTION

The prairie pothole region of North America encompasses 777,000 km^2 of upland and wetland habitats that are vital to duck productivity in the United States (Greenwood et al. 1995) and Canada (Kiel et al. 1972; Fig. 1). Despite drainage efforts designed to place wetland habitats into agricultural production (Pospahala et al. 1974), millions of small wetlands remain in this region that provide breeding habitat for 50-80% of the continental duck population annually (Batt et al. 1989). Although wetland drainage rates have declined dramatically since the early 1900's, grassland habitats surrounding wetlands that are used by ducks as nesting cover continue to be converted to croplands through intensive agricultural practices. Overgrazing has reduced the quality of most remaining native grasslands. In a little over a century, this region has been transformed from expansive grasslands and parklands into a highly fragmented, agricultural landscape that is less conducive to duck production. In response, waterfowl managers have attempted to conserve the remaining native grasslands and to restore croplands back into planted grassland cover. Acquisition efforts are of urgent importance to ensure conservation of remaining native sod. Vegetation management also is needed to maintain stand structure and longevity of native and restored tracts. Proper grassland establishment is the most important aspect of grassland restoration. Guidelines for establishing grasslands have been summarized for the U.S. (Duebbert et al. 1981, Woehler and Kahl 1987) and prairie Canada (Morgan et al. 1995, Wark et al. 1995). Publications by Morgan et al. (1995) and Wark et al. (1995) are most recent and contain supporting color photographs. If these guidelines are adhered to, rarely should managers expect poor stand establishment.

These grassland establishment guidelines enable waterfowl managers to successfully establish an array of native and exotic cool- and warm-season grasses and forbs in a range of soil types. Vegetative health of established stands as well as duck use and productivity of grasslands may be dependent on timing, frequency, intensity, and duration of management treatments. Limited research has been conducted concerning the response of upland grasslands and birds to management treatments. Most research related to grassland production and management has resulted from agricultural interests that focus on forage production. Factors that agriculturalists consider important when prescribing grassland treatments to improve productivity and sustain longevity of upland vegetation also may be used by wildlife managers to enhance duck production. Agriculturalists measure total biomass, basal and canopy cover, and changes in species composition to relate range condition to animal productivity while wildlife scientists measure vegetative height and horizontal-vertical densities of live and residual cover to determine structural characteristics that increase productivity of upland nesting birds. The current challenge is to determine whether vegetative measures from agricultural and wildlife research may be used to determine optimal timing, frequency, intensity, and duration of grassland treatments for upland grassland birds.

The primary objective of this synthesis and review is to evaluate the effects of upland grassland management practices on vegetation structure and upland nesting bird use and productivity in major grassland zones of the northern Great Plains region of the United States and Canada (Fig. 2). An emphasis has been put on interpretation to provide guidance to field personnel managing existing native and planted grassland habitats. Secondary objectives are to suggest treatment intervals for seeded and native grasslands and to identify gaps in current knowledge on which future research or management efforts may be directed.

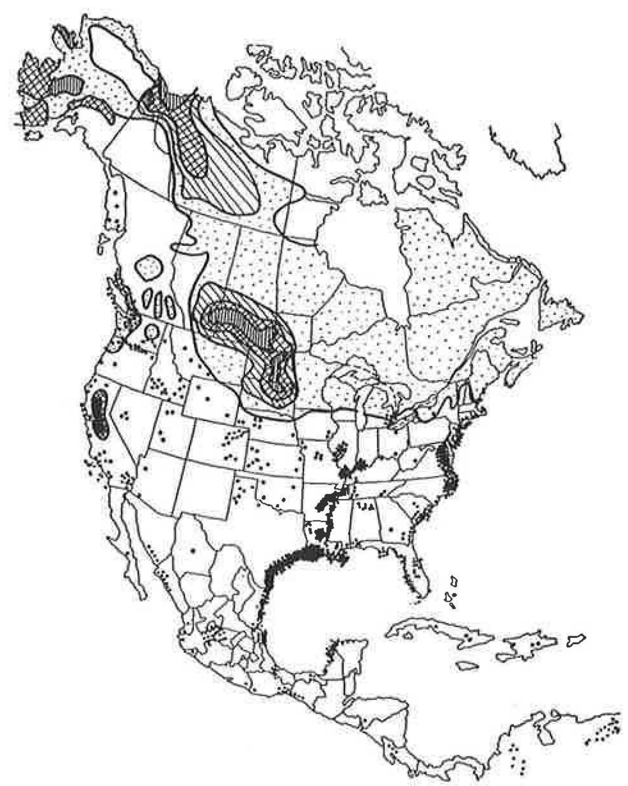

Figure 1. Density of breeding waterfowl in North America (reproduced from Kiel et al. 1972).

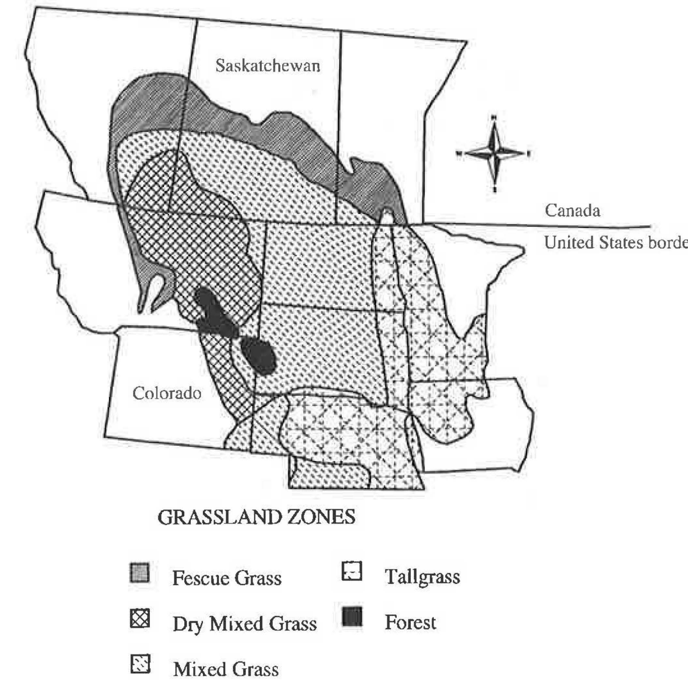

Figure 2. Map of grassland zones in the northern Great Plains region of the United States and Canada (modified from Wright and Bailey 1982).

METHODS FOR CONDUCTING THE SYNTHESIS AND REVIEW

We reviewed ca. 1,700 scientific references from 1950-1997. This review emphasizes upland nesting ducks in the northern Great Plains, but is supplemented with information concerning the effects of grassland management practices on upland gamebirds and nongame passerines. Literature outside the northern Great Plains was used when studies provided findings regarding treatment effects. To avoid using the same information twice (e.g., thesis versus journal articles), we used the reference with the most rigorous peer review.

We synthesized recommendations from research into bird use and productivity response to changes in vegetative structure that result from grassland treatments. References were partitioned across grassland zone, stand type, treatment, recommended interval and faunal group (i.e., ducks, game or nongame birds). We sub-divided treatment interval recommendations to indicate whether they were based on data or expert opinion only.

We constructed two data sets to evaluate treatment intervals. The first data set provides estimates of the time interval required for vegetative attributes to recover to pre-treatment conditions. We recorded intervals as point estimates or as the mid-point of years for references reporting a range. We evaluated these data first by using all intervals for vegetative recovery and secondly by using only recovery intervals for burning treatments. The subsequent evaluation using only burning intervals based on biomass and litter reduced variability in estimates. The second data set provides estimates for burning intervals to enhance vegetative structure or bird use and productivity. We focused evaluation of the second data set on burning intervals because it was the most common treatment reported in literature (80% of recommendations involve burning).

Next, we used references to compare measures of bird use and productivity among upland grassland treatments. Pair use, nest density and success, and number of eggs or young produced/unit area were used as indices of bird responses to treatments. A meta-analysis (Vanderwerf 1992, Fernandez - Duque and Valeggia 1994) could not be conducted to evaluate measures of bird use and productivity among upland grassland treatments or to determine optimal grassland treatment frequencies because references do not report age or interval between management treatments for grasslands (e.g., Kirsch 1969). Rather, references report results of studies conducted only in the treatment year, from annually treated lands (e.g., agricultural interests), or from control (i.e., idled) lands of unknown age. We devised a ranking system to summarize information and present a narrative review of trends in bird use and productivity measures among management treatments. We ranked treatments as positive, negative, or neutral according to their effects on bird use and productivity measures. We assigned positive ranks to treatments with significantly higher values for reported use and productivity measures. Within the same reference, negative ranks were assigned to treatments with lower use and productivity measures. Neutral ranks were assigned to treatments when no significant differences occurred. The number of positive, negative, and neutral ranks within each treatment type was summed for each use and productivity measure to determine directional effects of grassland treatments. Rank sums were converted to percentages by dividing the number of positive, negative, and neutral ranks by the total number of ranks recorded.

VEGETATIVE RESPONSE TO GRASSLAND TREATMENTS

We reviewed 30 references that report a time interval for vegetation to recover to a pretreatment condition (Table 1). The most common measures of vegetative response were yield, floristics, and changes in percent species composition or nutritional qualities. Vegetative recovery also was measured as the time required for vegetation to return to pretreatment structure or as the degree of directional shift of species within a community. The latter measures were largely dependent on litter accumulation and shifts in seral stage. We interpret recovery intervals cautiously because vegetative response measures were intended for use in agronomic studies unrelated to wildlife management objectives. Recommendations for recovery intervals were heavily weighted towards studies with burning as the grassland treatment (Table 1). The range of recommendations (in years) varied widely with geographic area, vegetative attributes,

Table 1. Time intervals for grassland attributes (e.g., litter, mulch, canopy cover, biomass, flowering) to recover to pretreatment condition by grassland zone (i.e., tallgrass, mixed grass).

Grassland Zone	Area	Attribute Type	Stand Type	Treatment	Recovery Interval (years)	Reference
Tallgrass	Iowa	Litter	Native	Burn	2	Ehrenreich and Aikman (1963)
Tallgrass	North Dakota	Biomass/ Canopy cover	Seeded Native	Burn	2	Olson (1975)
Tallgrass	Nebraska	Coverage	Native	Graze	2	Bragg (1978)
Tallgrass	Wisconsin	Canopy cover	Seeded Native	Burn	2+	Howe (1995)
Tallgrass	Illinois	Litter	Seeded Native	Burn	2-3	Hadley and Kieckhefer (1963)
Tallgrass	Minnesota	Litter	Native	Burn	2-3	Tester and Marshall (1962)
Tallgrass	Iowa	Flower stalk height/density	Native	Burn	3	Ehrenreich (1957)
Tallgrass	Missouri	Litter	Native	Burn	5	Kucera (1968)
Tallgrass	Iowa	Litter	Native	Burn	4-6	Ehrenreich and Aikman (1963)
Tallgrass	Iowa	Litter	Native	Burn	4-6	Ehrenreich (1959)
Tallgrass	Wisconsin	Biomass	Native	Burn	4-6	Vogl (1965)
Tallgrass	Wisconsin	Litter	Native	Burn	4-6	Dix and Butler (1954)
Tallgrass	Missouri	Litter/Biomass	Native	Clip	7.8-8.8	Keolling and Kucera (1965)
Tallgrass	Iowa	Litter/Biomass	Native	Clip	10.6	Keolling and Kucera (1965)
Mixed	Saskatchewan	Biomass	Native	Burn	3	Clarke et al. (1943)
Mixed	North Dakota	Litter/Dead biomass	Native	Idle	3	Abouguendia and Whitman (1979)
Mixed	Saskatchewan	Biomass	Native	Burn	3+	Coupland (1973)
Mixed	Kansas	Litter	Native	Idle	3-4	Hopkins (1954)
Mixed	Saskatchewan	Biomass	Native	Graze	3-5	Clarke et al. (1943)
Mixed	North Dakota	Mulch	Native	Burn	4	Dix (1960)

grassland type, and treatment (Table 1). We supplemented recovery interval estimates with 12 studies from Iowa, Wisconsin, Missouri, Illinois, and Nebraska because only two studies from the northern Great Plains addressed grasslands in the tallgrass prairie zone. Vegetation recovery intervals ranged from 2-8.8 years. Vegetation recovery intervals from 16 studies in the northern Great Plains ranged from 3-5 years in mixed and mixed/rough fescue (*Festuca scabrella*) grassland zones, and from 2-32 years in the rough fescue zone (Table 1). Vegetative recovery intervals in tallgrass and mixed grass zones range from 2-6 years when the influence of one clipping study from Iowa and Missouri (Koelling and Kucera 1965) is not considered (Table 1). No recommendations for recovery intervals were found for grasslands in the shortgrass zone of the northern Great Plains. Recovery intervals for vegetation of the shortgrass and rough fescue zones are difficult to interpret because few studies were conducted for a long enough period of time to enable vegetation to fully recover from treatments. However, two references from the central Great Plains reported that recovery intervals for basal cover and biomass were 2-3 years or longer in shortgrass areas of Kansas (Table 1).

Burning.—Vegetative attributes of most grasses and forbs respond positively to burning in tallgrass and mesic mixed grasslands of the northern Great Plains (Table 1). Although research results are generally lacking for areas other than the tallgrass and mesic mixed grasslands, we suggest that plant species responses to fire may sometimes be negative in more western xeric mixed grass, shortgrass and rough fescue grasslands. This interpretation is based on three studies that report that vegetation had not recovered from burning at the end of their study (Table 1). The only study reporting a definitive treatment interval in the fescue grassland zone reported that peak green biomass and total graminoid biomass in *Festuca*-dominated grasslands recovered to the level of unburned plots 2-3 years after burning and that recovery in a *Stipa-Agropyron* community occurred 4-5 years postburn (Redmann et al. 1993); although no information was available pertaining to litter recovery, we suspect that litter build-up in postburn years occurs more slowly in the fescue grassland zone compared to other zones. Negative responses of vegetation to burning in drier climates may result in a longer recovery period for which a precise estimate in years is currently unknown. Long-term recovery periods are usually attributed to reduced litter, soil moisture reduction, increased evapotranspiration rates and solar radiation, less snow retention and poorer water infiltration (Old 1969, Wright and Bailey 1980, Henderson 1982, Hulbert 1986). Exceptions to these generalizations may occur because individual plant species exhibit different responses to fire. A similar increase in recovery period may occur in the grey soil areas of the Canadian prairie pothole region. We speculate that grasslands in grey soil areas may require recovery periods longer than those required in tallgrass and mesic mixed grass zones, but shorter than recovery periods required in xeric mixed, shortgrass, and xeric rough fescue grasslands.

Sixty-six references (marked with * in literature cited) were burning studies that used one or more predetermined intervals to evaluate grassland response to burning (Table 2). Ninety-one percent of these references are from the tallgrass (74%) and mixed grass (17%) prairie zones. The last 8% of references concerned research on shortgrass and rough fescue prairie zones (Table 2). Eighteen percent of references dealt with seasonal effects of fire (e.g., spring versus summer, fall or winter) and 7% of the references involved multiple-year frequencies. Thirty-five percent of references involved post-treatment studies of single-event fires (Table 2). Twenty percent of the references studied the effects of annual fires, most of which were from studies in the tallgrass zone. Eight percent of studies conducted in the tallgrass zone used a 2-year fire interval. Additional references from the tallgrass zone were based on 4-5 year fire treatment intervals (Table 2). Although many references contained a priori treatment interval information, most lacked study designs necessary to evaluate vegetative response relative to grassland age or stage of succession. Many of the earlier studies were single-event wildfires (e.g., lightning set or accidental). References from the tallgrass zone were largely the result of long-term research conducted on Konza Prairie through Kansas State University and the University of Nebraska. We believe researchers were

Table 2. Number of references (identified by an * in the literature cited) that reported information concerning fire intervals using predetermined interval designs.

Number of Years between Fires	Grassland Zone[1] TG	MG	SG	FG	PP	Total
Single-event	23	10	2	1	2	38
1	18	1	0	0	3	22
2	9	0	0	0	0	9
3	1	0	0	0	0	1
4	7	0	0	0	0	7
5	3	0	0	0	0	3
6	1	0	0	0	0	0
>10	1	0	0	0	0	1
Seasonal effects	11	7	1	1	0	20
Multiple years	7	1	0	0	0	8
Total	81	19	3	2	5	110

[1]Grassland zone abbreviations are for tallgrass (TG), mixed grass (MG), shortgrass (SG), rough fescue (FG), and prairie parklands (PP).

attempting to mimic historical fire intervals or seasonal timing of natural fires in references reporting results for a priori treatment intervals ranging from 1-5 years (see estimates by Moore 1972, Bragg 1982, Higgins 1986a). The largest designed experiment of a priori burning and grazing was developed by Hulbert (1973) at the Konza Prairie research site where watersheds were burned at intervals of 1, 2, 4, 10, and 20 years. Additional research related to Hulbert's original work also was conducted at the Konza Prairie (Gibson 1989, Collins and Gibson 1990).

Grazing.—Little information exists in relation to vegetation response to timing and frequency of grazing in the northern Great Plains (Table 1). In prairie Canada, nearly all of the grazing studies have been conducted in xeric mixed grass and rough fescue grasslands, some of which occurred in the aspen parkland zone. Overview studies of Canadian rangelands have been presented by Moss and Campbell (1947), Coupland (1950), and McCartney (1993). Smoliak et al. (1988) presented pictorials of Alberta's pastureland ranges with average yield ranges and stocking rates per range condition classes (excellent, good, fair, poor).

Several authors recommended rotational grazing systems over season-long grazing treatments in tallgrass and mesic mixed grassland zones (Clarke et al. 1943, Owensby et al. 1973, Sedivec 1989, Barker et al. 1990, Sedivec et al. 1990, Sedivec 1994). Rotational grazing systems enable managers to control timing of treatments to enhance range condition. Owensby et al. (1973) found that forage production and range condition were higher on deferred-rotation pastures than on season-long pastures in Kansas. Likewise, in tallgrass prairie in Oklahoma, Cassels et al. (1995) found higher herbage standing crop in September on short-duration grazing plots than on those continuously grazed.

Grasslands are more susceptible to season-long or multiple periods of grazing in areas outside the tallgrass prairie zone. Zhang and Romo (1994) reported that mixed grasslands in Saskatchewan should be grazed only once annually and that grazing should be deferred until peak annual growth had been attained. Similarly, Naeth et al. (1991) found that high intensity and/or early season grazing on mixed and rough fescue grasslands in Alberta decreased dead standing biomass, live biomass, and litter. Willms et al. (1993) recommended grazing practices for mixed prairie in Alberta that conserve litter to stabilize range condition.

Xeric mixed and xeric rough fescue grasslands may be more sensitive to herbage removal than tallgrass and mesic mixed grasslands. Smoliak (1965) and Peake and Johnston (1965) have shown that even light grazing will affect biomass production and condition of mixed and rough fescue grasslands in Alberta. Peake and Johnston (1965) found that at the end of 10 years, heavily grazed rough fescue grasslands in Alberta had degenerated so far that season-long grazing was no longer an option. They also found that mulch biomass declined as grazing intensity increased. Willms et al. (1985) reported that rough fescue was extirpated with increased grazing pressure; this example of extirpation is important to note because less than 5% of this grassland type remains in the prairies and parklands of southern Canada. Time-controlled grazing studies conducted on mixed and rough fescue prairies in Alberta indicated that range condition was reduced in areas managed according to Holistic Resource Management principles with 12, 16, and 17 paddock systems (Willms et al. 1990). Dormaar et al. (1989) also found that grazing negatively effected physical and chemical properties of soil on 17 paddock systems.

The only information pertaining to short grass prairie indicated that plant cover response in southern Alberta and southwestern Saskatchewan was more positive on deferred and rotational grazing systems than on annually grazed pastures (Clarke et al. 1943). Fields that were moderately grazed and burned required at least 3-5 years to recover to pre-treatment productivity.

Timing of herbage removal in xeric mixed and rough fescue may affect grassland response to grazing and haying treatments. Willms et al. (1986), studying mixed grass and rough fescue prairies in Alberta, found that dormant season grazing enhanced rough fescue prairie while decreasing forage yields on mixed prairie. Willms and Fraser (1992), studying rough fescue grasslands in southwest Alberta, found that a single hay harvest in late August at 15 cm height, sustained forage yields while cutting at lower heights decreased yields. Moss and Campbell (1947), studying rough fescue grasslands in Alberta, reported that a standard haying practice was to harvest in alternate years, occasionally after two years of rest.

Mowing/Haying.—Agronomic literature indicated that non-irrigated grasslands generally were hayed only once annually in most of the shortgrass, rough fescue, and mixed grass zones. Moss and Campbell (1947) recommend alternate year haying in more xeric portions of the shortgrass and rough fescue grasslands. Conversely, non-irrigated grasslands with alfalfa (*Medicago sativa)* as a mixture component were mowed at least twice annually throughout much of the tallgrass zone. We found little information pertaining to recovery intervals following haying or mowing treatments. Visual obstruction readings (VOR's) that were lower in mowed than unmowed Conservation Reserve Program (CRP) fields indicated that mowing/haying effectively removed standing biomass (Hays et al. 1989). However, wildlife managers may be concerned that grass growth will not be stimulated following mowing/haying treatments because the litter layer has not been removed. Hover and Bragg (1981), in a Nebraska study of native prairie, considered mowing a viable alternative treatment option when burning was not possible. Similarly, Ehrenreich and Aikman (1963), studying tallgrass prairie in Iowa, reported that mowing at the end of the growing season after plants had made seed was the best treatment other than burning for removing vegetation to prevent harmful accumulations of above-ground organic material without harming native vegetation.

UPLAND NESTING BIRD RESPONSE TO GRASSLAND TREATMENTS

We remind readers that most available studies lack research designs necessary to evaluate bird response to changes in grassland structure. Most studies were only conducted in the treatment year, from annually treated lands, or from idled lands of unknown age or type. For example, many researchers labeled the treatment year as burned or grazed and the following 1-3 years as idled while others referred to subsequent years following treatment as post-treatment year 1, 2, or 3. Furthermore, "idled" lands were often used as a reference area or control on which to compare other treatments. Unfortunately, the assumption that grasslands maintain their health and vigor as stand age increases may be violated. In designing future studies, we suggest that researchers consider idling as a conscious management treatment that has predictable consequences rather than as a control (Kirby et al. 1992).

Information used to evaluate treatment effects on prairie nesting birds in the tallgrass zone included eight references from the northern Great Plains (Tables 3-5). Information from the tallgrass zone in the northern Great Plains was supplemented with references from Iowa (11), Wisconsin (4), Illinois (4), Ohio (2), Nebraska (1), and Missouri (1). The 32 references used to evaluate the effects of treatments on prairie nesting birds in mixed grass prairie were all conducted in the northern Great Plains region (Tables 6-8). Little information was available concerning treatment effects on prairie birds in shortgrass and rough fescue grassland zones. Three references from shortgrass prairies in the northern Great Plains and one reference each from Oregon, Utah, and Colorado were located within the shortgrass prairie zone. Three references from Canada comprised all the information available for treatment effects on grassland birds in the rough fescue prairie zone.

Pair use and nest density and success of prairie birds were most positively influenced by idling grasslands in the tallgrass prairie zone (Table 3-5). Treatments other than idling usually either negatively influenced or did not affect prairie nesting birds (Table 3-5). Information pertaining to the effects of burning on use and productivity of birds was lacking for the tallgrass zone. Effects of grazing and mowing/haying on nest density and success were mostly negative. Tillage treatments had the most negative effects on bird production in the tallgrass prairie zone (Table 3-5).

Prairie nesting bird responses to treatment effects in the mixed grass prairie zone were similar to those reported for tallgrass prairie. Pair use, nest density, and productivity of prairie nesting birds were positively influenced by idling grasslands (Table 6-8). Sparse information indicated that burning had the second highest proportion of positive effects on use and productivity measures. Grazing, mowing/haying, and tillage practices negatively influenced prairie bird use and productivity of grasslands in the mixed grass prairie zone (Table 6-8).

Table 3. References used for positive (+), negative (-), and neutral (o) treatment comparisons for use and productivity measures for waterfowl in the tallgrass zone. Treatments are burning (B), grazing (G), mowing (M), idling (I), and tillage (T).

Pair Use					Nest Density					Nest Success					Productivity					
B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	Reference
							-	+				-	+							Luttschwager et al. (1994)
							+	-				o	o							Kemner and Higgins (1993)
						-	-	+			o	o	o							Fleskes and Klaas (1991)
					-	-	+	-			-	-	+	-						Klett et al. (1988)
							-	+				-	+							Livezey (1981)
					o			o		-			+							Messinger (1974)
											-		+							Krapu et al. (1970)
						-	-	+	-		+	+	-	-						Burgess et al. (1965)
					-		-	+	-			o	o	o						Moyle (1964)
					-	-		+			-		+							Glover (1956)

Table 4. References used for positive (+), negative (-), and neutral (o) treatment comparisons for use and productivity measures for gamebirds in the tallgrass zone. Treatments are burning (B), grazing (G), mowing (M), idling (I), and tillage (T).

Pair Use					Nest Density					Nest Success					Productivity					
B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	Reference
			+	-																King and Savidge (1995)
+	-		+																	Kobriger et al. (1987)
								+	-											Basore et al. (1986)
						-	-	+			-	-	+							Dumke and Pils (1979)
						-	-	+			-	-	+							George et al. (1979)
						-		+	-											Olson and Flake (1975)
							-	+				-	+							Joselyn et al. (1968)
						-		+	-		o		o	o		-		+	-	Trautman (1960)
						-	-	+	-											Leedy and Dustman (1947)

Table 5. References used for positive (+), negative (-), and neutral (o) treatment comparisons for use and productivity measures for nongame birds in the tallgrass zone. Treatments are burning (B), grazing (G), mowing (M), idling (I), and tillage (T).

Pair Use					Nest Density					Nest Success					Productivity					
B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	Reference
-		-	+																	Herkert (1994)
								+				-	+							Bryan and Best (1994)
			+	-																Bryan and Best (1991)
		-	+																	Frawley and Best (1991)
+			-																	Schramm et al. (1984)
-			+																	Halvorsen and Anderson (1983)
						-	-	+			-	-	+							George et al. (1979)
						o		o												Kaiser (1979)
	+	-	-			+	-	-												Skinner (1975)
						-	-	+				-	+							Roseberry and Klimstra (1970)
			+	-																Dambach and Good (1940)

Table 6. References used for positive (+), negative (-), and neutral (o) treatment comparisons for use and productivity measures for waterfowl in the mixed grass zone. Treatments are burning (B), grazing (G), mowing (M), idling (I), and tillage (T).

Pair Use					Nest Density					Nest Success					Productivity					
B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	Reference
							-	+				o	o				-	+		Renner et al. (1995)
													+	-						Greenwood et al. (1995)
					-	-		+	-	+	-		-		-	-		+	-	Higgins et al. (1992)
					-	-		+	-	o	o		o		-	-		+	-	Higgins et al. (1992)
						-		+			+		-							Sedivec et al. (1990)
						-	-	+	-		o	o	o	o						Lokemoen et al. (1990)
								+	-				+	-						Cowardin et al. (1985)
								+	-											Cowan (1982)
						-		+												Rice and Carter (1982)
								+	-				o	o				+	-	Higgins (1977)
					-			+		+			-							Fritzell (1975)
						-	-	+	-		-	-	+	-		-	-	+	-	Duebbert and Kantrud (1974)
					o			o		+	-		-							Kirsch and Kruse (1972)
						-	-	+	-		-	-	+	-						Miller (1971)
							-	+				o	o				-	+		Page and Cassel (1971)
							-	+				-	+							Oetting and Cassel (1971)
	-		+			-		+			-		+							Kirsch (1969)
		o	o				-	+				o	o				-	+		Martz (1967)
	-		+			-		+												Bue et al. (1952)

Table 7. References used for positive (+), negative (-), and neutral (o) treatment comparisons for use and productivity measures for gamebirds in the mixed grass zone. Treatments are burning (B), grazing (G), mowing (M), idling (I), and tillage (T).

Pair Use					Nest Density					Nest Success					Productivity					
B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	Reference
						-		+	-		o		o	o						Keyser (1986)
						-		+								-		+		Rice and Carter (1982)
								+	-				+	-						Higgins (1975)
	-	-	+	-																Kirsch et al. (1973)

Table 8. References used for positive (+), negative (-), and neutral (o) treatment comparisons for use and productivity measures for nongame birds in the mixed grass zone. Treatments are burning (B), grazing (G), mowing (M), idling (I), and tillage (T).

Pair Use					Nest Density					Nest Success					Productivity					
B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	B	G	M	I	T	Reference
			+	-																Johnson and Igl (1995)
																		+	-	Hartley (1994)
						-		+			o		o							Bowen and Kruse (1993)
						-	-	+	-		-	-	+	-						Kantrud and Higgins (1992)
	-		+																	Renken and Dinsmore (1987)
+			-																	Huber and Steuter (1984)
	-		+																	Kantrud (1981)
								+	-											Higgins et al. (1979)
						-		+												Higgins et al. (1969)

Ten references related to shortgrass and rough fescue grasslands of the northern Great Plains indicated that idling was the only management treatment that positively influenced use and productivity measures of prairie nesting birds. Grazing, mowing/haying, and tillage treatments negatively influenced prairie nesting birds in the shortgrass zone. No references contained evaluations of the influence of burning on birds in the shortgrass prairie zone. Four references that evaluated passerine birds in Canadian rough fescue grasslands indicated that treatments other than idling negatively affected productivity of prairie avifauna.

Effects of Idling Grasslands.—Each use and productivity measure in every grassland zone for which adequate information was available indicated that idling was more beneficial than other treatments (Tables 3-8). Idled tallgrass and mixed grasslands in North and South Dakota and Minnesota were the only habitats studied in which nest success consistently approached or exceeded levels necessary to sustain populations (Klett et al. 1988). Similarly, grazing (Gjersing 1975, Mundinger 1976, Maher 1979, Gilbert et al. 1996), mowing/haying (Jarvis and Harris 1971), and tillage (Bartmann 1969) treatments negatively influenced prairie birds in shortgrass zones. The only four references involving rough fescue grasslands in Canada also indicated that treatments other than idling negatively affected productivity of prairie avifauna (Owens and Myres 1973, Driver 1987, Pylypec 1991, Dale 1993).

Effects of Grazing and Mowing/Haying.—Nest density and success, the two most widely reported productivity measures, indicated that grazing and mowing/haying usually negatively influenced reproduction despite their widespread use as management techniques (Tables 3-8). Page and Cassel (1971) reported lower nest densities in hayed than unhayed areas. Furthermore, productivity of nesting ducks was six times greater in unhayed areas compared to hayed areas (Page and Cassel 1971). Similarly, Martz (1967) concluded that duck nests in mowed areas had smaller clutch sizes than nests in unmowed areas at Lower Souris National Wildlife Refuge in North Dakota. Renner et al. (1995) found that average hatchling density (hatchlings/40.5 ha) was twice as high in idled than in hayed sites.

Timing of grazing or haying treatments may play a role in grassland use by nesting ducks. Grazing in spring before nesting begins decreases vegetative height and density without allowing time for regrowth (Kirsch et al. 1978, Sedivec et al. 1990). Short and sparse grasses may be unattractive to upland nesting ducks. When grazing or mowing/haying is permitted, investigators recommend delaying treatments until late July after nesting has been completed (e.g., Oetting and Cassel 1971, Gjersing 1975, Luttschwager et al. 1994).

Effects of Tillage on Bird Use and Productivity.—Tillage had the most negative influence on bird use and productivity in that no positive effects were noted in 55 references (Tables 3-8). Cropland was the least preferred nesting habitat by all ducks except northern pintails (*Anas acuta*) in the glaciated areas of Manitoba, the Dakotas and western Minnesota despite its high availability (Milonski 1958, Moyle 1964, Higgins 1977, Klett et al. 1988). Hatched-clutch duck densities (young/unit area) were 16 times lower in tilled than untilled uplands in North Dakota (Higgins 1977). Duck nest density and success varies among land use treatments within annually tilled croplands. Higgins et al. (1992) found higher duck nest densities and success in growing grain crops compared to standing or mulched stubble fields (also see Milonski 1958). Similarly, Warburton and Klimstra (1984) documented greater bird abundance during the growing season in no-till compared to conventional tillage fields. Cowan (1982) found that total duck production in southern Manitoba was almost four times higher on zero tillage farms than on conventional farms. Higgins (1977) stated that duck production in intensively farmed areas was dependent either on enough precipitation to fill wetlands and delay planting or on good wetland conditions with early establishment of grain to provide cover for late nesting and renesting ducks. Duebbert and Kantrud (1987) concluded that a trend toward increasing planting of no-till winter wheat in the prairie pothole region should increase duck production because nest success is high in fields of growing grain (Higgins 1977).

Effects of Stand Type.—Eurasian plant species in Canadian mixed grass prairie may produce changes in nongame bird species composition (Wilson and Belcher 1989). Upland sandpipers (*Bartramia longicauda*) and Sprague's pipits (*Anthus spragueii*) were more abundant in native prairie while no species surveyed was more abundant in bromegrass (*Bromus* spp.) or Kentucky bluegrass (*Poa pratensis*). Native and introduced stands were correctly classified according to their respective bird communities (Wilson and Belcher 1989). In contrast, numerous investigations have indicated that the structure of idled vegetation is more important than the plant species composition when the goal of grassland management is duck production (e.g., Schranck 1972, Voorhees and Cassel 1980).

Nest density and success were the most widely reported measures used to indicate whether native prairie or seeded plantings are more important to duck production. Nest density and success varied greatly for the seven references that evaluated both grassland stand types. Klett et al. (1988) found that seeded nesting cover was the most preferred nesting habitat while success was highest for ducks nesting in idle prairie grasslands of North and South Dakota and western Minnesota. Lokemoen et al. (1990) reported that seeded nesting cover contained the highest density of mallard (*Anas platyrhynchos*) and gadwall (*Anas strepera*) nests.

Lokemoen et al. (1990) found that the first year seeded nesting cover was available, it composed 2% of the land area but contained 27% of mallard and gadwall nests. Nest success for mallards and gadwalls did not differ among cover types (Lokemoen et al. 1990). Klett et al. (1984) found that seeded nesting cover in which native grasses were dominants or co-dominants with introduced grasses was attractive to nesting ducks and that nest success did not differ from that observed in native prairie or in stands of seeded introduced grasses and legumes. Lokemoen (1984) reported that costs of duck production were higher using native grass plantings than introduced grass plantings because native seed is more expensive than introduced seed. However, seeded native tracts may last longer with proper management, thus reducing the costs of periodic reseeding, which is often necessary with introduced cool-season species. Klett et al. (1984) stressed the importance of site quality and climate to the success of seeded plantings. They suggested that in areas of the prairie pothole region where precipitation is <40 cm, it may be difficult to establish stands of big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Instead, introduced grasses such as intermediate wheatgrass (*Agropyron intermedium*) and alfalfa (i.e., dense nesting cover) were recommended (Klett et al. 1984).

Kemner and Higgins (1993) evaluated duck use of dense nesting cover and found that nest densities and success in northeastern South Dakota were higher in dense nesting cover than in stands of smooth brome grass (*Bromus inermis*) and Kentucky bluegrass. Similarly, duck production in North Dakota was higher on grasslands seeded to dense nesting cover than native prairie (Higgins et al. 1992). Seeded grasslands also produced three times as many ducklings/unit area than adjacent native prairie (Higgins et al. 1992). Rodriguez (1984) also found that nest density was higher in dense nesting cover (0.9 nests/ha) compared to native cool season grasses (0.5 nests/ha). However, hatching success between stand types did not differ (Rodriguez 1984).

Landscape-scale Factors.—Duck production in the western prairie pothole region of Montana was not a function of stand types that produce tall and dense nesting cover (Ball et al. 1995). Rather, high duck productivity was associated with large, unfragmented native grassland tracts with relatively low predator populations. Waterfowl habitat in Montana contrasts other areas of the prairie pothole region where predator populations are high and habitat fragmentation by humans is extensive. For example, nest success reportedly decreased 4% for every 10% of land area that was converted from grasslands to croplands in southern Canada (Greenwood et al. 1995). Ball et al. (1995) suggested that attempts to improve duck nest success at inappropriately small scales may be unproductive when nesting hens and their predators are attracted to the same cover. Clark and Nudds (1991) also recommend that the effects of patch size and predator communities on duck nest success need to be tested experimentally.

Landscape studies that incorporate multiple grassland patches that vary in size, stand type, and juxtaposition should be conducted to evaluate the influence of scale on waterfowl production. Ball et al. (1994) stated that research needs of waterfowl and nongame passerine species are quite similar in that declines in productivity of both groups are largely due to nest predation and parasitism. Although little research has assessed duck production at a landscape-scale, research has addressed the effects of grassland fragmentation on nongame passerine species. Nest predation rates for five nesting passerine grassland species were higher for nests in small (<30 ha) patches, in areas near (<45 m) wooded edges, and in vegetation that had not been recently burned (>3 yrs) (Johnson and Temple 1990). Similarly, Burger et al. (1994) found that predation rates on artificial nests were higher (37.0%) in prairies <15 ha in size compared to larger tracts (13.9%). Herkert (1994) also concluded that habitat fragmentation has likely caused declines in midwestern grassland bird communities in Illinois.

Numerous investigators have reported high duck nesting success in tall, dense, and rank cover (Schranck 1972, Duebbert and Lokemoen 1976, Kirsch et al. 1978, Livezey 1981, Cowardin et al. 1985, Sugden and Beyersbergen 1986, 1987). Similarly, Duebbert and Kantrud (1974) found that large tracts of high quality grassland in an area without predator reduction produced six times as many ducks as lands containing moderate quality cover when predators were reduced. Despite these numerous instances of high nest success in managed cover, other studies have indicated that duck production in managed grasslands was depressed due to high rates of mammalian predation (Balser et al. 1968, Doty and Rondeau 1987, Johnson et al. 1989, Greenwood et al. 1990, Sargeant et al. 1995). Similarly, Clark et al. (1991) found that duck nest success can be unpredictable when predation is a major cause of nest failures even though moderately large (50-200 ha) areas of seeded nesting cover were managed to improve duck production. However, until the public becomes more accepting of lethal methods to control predators (Greenwood and Sovada 1996), establishment and maintenance of duck nesting habitat in areas of good wetland conditions is still the most sound management practice available. Use of multiple stand types including native remnant stands and seeded native and introduced plantings rather than only one type of stand may be important for duck production. Current recommendations for "best management practices" indicate that large grasslands as well as multiple tracts should be managed to provide a mosaic of recently treated and untreated areas to ensure a shifting steady-state of successional stages of suitable habitat (Higgins 1986b, Renken and Dinsmore 1987, Zimmerman 1988, Bowen and Kruse 1993, Herkert 1994). Continual placement of high quality nesting cover is a desired approach to enhance duck production until landscape-level or some other type of research provides a better means of increasing duck productivity.

ESTIMATING A TREATMENT INTERVAL FROM AVAILABLE DATA

Nine references recommended burning intervals to allow vegetation to recover to pre-treatment conditions, of which five were supported by data (Table 9). Treatment intervals in the tallgrass zone ranged from 1-5 years for recommendations based on data and from 1-3 years for those based on expert opinion (Table 9). The two treatment intervals in the mixed grass zone that were based on opinion ranged from 5-10 years (Table 9).

Eight references recommended treatment intervals to enhance grassland structure for birds in the tallgrass prairie zone, of which only one was from the northern Great Plains region.

The other seven references were from tallgrass prairie states outside the northern Great Plains (Table 10). Five recommendations were based on data and three were expert opinion. Six of seven references recommended burning as the treatment of choice. One reference from Missouri recommended haying over burning to periodically rejuvenate grasslands. The treatment interval ranged from 2-5 years for recommendations based on data and from 3-5 years for those based on opinion (Table 10).

Eleven references recommending treatment frequencies were found for grasslands in the mixed grass prairie zone, of which six were supported by data (Table 11). Treatment intervals ranged from 3-10 years for recommendations based on data with the exception of one reference (Kruse and Bowen 1996) that indicated that vegetation should remain idle (Table 11). A similar treatment interval range of 4-10 years was found for recommendations based on opinion (Table 11). No treatment interval recommendations were found for grasslands in the shortgrass or rough fescue grassland zones of the northern Great Plains.

Fire literature provided the most extensive information available for rejuvenating grasslands in the tallgrass prairie zone. Intervals should be interpreted cautiously when burning is used to enhance duck production because most recommendations reported were for gamebird and nongame passerine species from outside the northern Great Plains (Tables 9 and 10). Interval recommendations indicate that grasslands in tallgrass prairie should be burned every 1-5 years. Periodic rejuvenation may be required to increase bird use, nest density and success, and productivity. Westemeier (1973) found that prairie chicken (*Tympanuchus cupido*) nest densities on burned areas two or more years after burning were higher (1 nest/6.0 acres) than nest densities on unburned areas (1 nest/9.3 acres). Vandel and Linder (1981) concluded that numbers of ring-necked pheasants (*Phasianus colchicus*) in South Dakota declined when quality of nesting cover decreased over time without periodic rejuvenation. Wheeler et al. (1984) found that duck nest success in south-central Wisconsin was higher in 4-8 year-old planted cover than in similar cover that was >9 years old. Only one reference was found indicating that burning tallgrass prairie negatively affected prairie nesting birds (Swengel 1996). In this study,

Table 9. Recommended treatment intervals by grassland zone (i.e., tallgrass, mixed grass, shortgrass, rough fescue, parkland). Table sub-headings indicate whether interval recommendations are based on data or expert opinion without data.

Grassland Zone	Area	Stand Type	Treatment	Recommended Interval (yrs)	Reference
Recommendations with Data					
Tallgrass	Wisconsin	Seeded Native	Burn	1-2	Howe (1995)
Tallgrass	Northern Great Plains	Unspecified	Burn	1-5	Collins and Gibson (1990)
Tallgrass	Kansas	Native	Burn	2-3	Abrams (1985)
Tallgrass	North Dakota	Seeded Native	Brun	2-3	Olson (1975)
Tallgrass	Nebraska	Unspecified	Burn	3.5	Bragg (1985)
Expert Opinion without Data					
Tallgrass	Eastern Great Plains	Native	Burn	1-3	Wright and Bailey (1982)
Tallgrass	Wisconsin	Seeded Native	Burn	3	Widstrand (1985)
Tallgrass/ Mixed grass	Prairie Pothole Region	Seeded Native and Exotics	Burn	5-10	Duebbert et al. (1981)
Mixed/ Shortgrass	West Central Great Plains	Native	Burn	5-10	Wright and Bailey (1982)

Table 10. Recommended treatment intervals within bird groups (i.e., ducks, upland gamebirds, and nongame birds) in tallgrass prairie. Table sub-headings indicate whether interval recommendations are based on data or expert opinion without data.

Area	Bird Group	Stand Type	Treatment	Recommended Interval (yrs)	Reference
Recommendations with Data					
Illinois	Prairie Chicken	Seeded exotics	Burn	3-4	Westemeier (1973)
Illinois	Prairie Chicken	Seeded/Native	Burn	3-5	Westemeier and Buhnerkempe (1983)
Missouri	Nongame	Native	Hay	2-3	Swengel (1996)
Minnesota	Nongame	Native	Burn	≤3	Johnson and Temple (1990)
Kansas	Nongame	Native	Burn	3-4	Zimmerman (1988)
Expert Opinion without Data					
North Dakota	Prairie Chicken	Native	Burn	3-5	Svedarsky and Van Amburg (1996)
Wisconsin	Pheasant	Seeded native and exotics	Unspecified	4	Frank and Woehler (1969)
Iowa	Pheasant	Seeded native	Burn or Hay	4-5	George et al. (1979)

higher densities and less fluctuation in numbers of Henslow's sparrows (*Ammodramus henslowii*), dickcissels (*Spiza americana*), and grasshopper sparrows (*Ammodramus savannarum*) were recorded in hayed prairies compared to burned prairies. As a result, Swengel (1996) recommended biennial or triennial midsummer haying instead of burning to manage for prairie nesting birds.

Fire may temporarily remove residual vegetation required for nesting the year of the burn. For instance, Messinger (1974) reported that duck nests in Iowa that were found in fields burned the same year lacked residual cover necessary for concealment. Although the effects of periodic burning to rejuvenate grasslands may be drastic, such effects usually are short in duration compared to the time required to achieve similar treatment effects using grazing, and to a lesser extent with haying. A common misconception is that burning during nesting eliminates production for that year. Depending on timing and severity of the burn, many duck clutches hatch before burning or survive fire (Kruse and Piehl 1986, Kruse and Bowen 1996). Nesting passerines such as Henslow's sparrows and sedge wrens (*Cistothorus platensis*) that prefer tall cover, returned by July to Missouri tallgrass prairies that had been burned in April (Skinner et al. 1984). Similarly, Zimmerman (1988) recommended periodic burning on Konza Prairie in Kansas to remove woody plants and stimulate herbaceous growth despite finding that any management that removed standing dead vegetation excluded Henslow's sparrows.

Burning interval recommendations for rejuvenating grasslands in the mixed grass zone mostly related to burning experiments. References from North and South Dakota provided all the information concerning treatment intervals. Interval recommendations indicate that grassland stands in mixed grass prairie should be burned every 3-10 years (Table 11). As in the tallgrass prairie zone, periodic rejuvenation of grasslands in the mixed grass prairie zone may enhance bird use, nest density and success, and productivity. Although Kirsch (1969) advocated discontinuing any land use practice that removed grassland cover, he still recommended that research be conducted to determine methods (e.g, burning) of creating dense cover for nesting ducks. Miller (1971) reported that duck nesting success in grasslands idled <4 years was 69% whereas nest success in grassland idled >5 years was only 33% in eastern North and South Dakota. Higgins et al. (1992) also found that periodic burning enhanced duck production in south-central North Dakota. Kruse and Bowen (1996) have the best study design of any paper included in this review. This also is the only study that did not indicate that burning enhanced duck production (Table 11). Rather, Kruse and Bowen (1996) reported that idled vegetation remained

Table 11. Recommended treatment intervals within bird groups (i.e., ducks, upland gamebirds, and nongame birds) in mixed grass prairie. Table sub-headings indicate whether interval recommendations are based on data or expert opinion without data.

Area	Bird Group	Stand Type	Treatment	Recommended Interval (yrs)	Reference
Recommendations with Data					
North Dakota	Ducks	Native	Fall burn	3	Higgins (1986b)
North Dakota	Ducks	Seeded exotics	Mow/Hay	3	Voorhees and Cassel (1980)
North Dakota	Ducks	Native and Seeded	Spring burn	3-4	Higgins et al. (1992)
North Dakota	Ducks	Native	Burn, Graze	Remain idle	Kruse and Bowen (1996)
North Dakota	Upland Sandpiper	Native	Spring burn	3	Kirsch and Higgins (1976)
North Dakota	Nongame	Burn	Burn	5-10	Madden (1996)
Expert Opinion without Data					
North Dakota South Dakota	Ducks	Native and Seeded	Unspecified	4	Miller (1971)
South Dakota	Ducks	Seeded exotics	Unspecified	6-7	Duebbert and Kantrud (1974)
South Dakota	Ducks	Seeded exotics	Unspecified	6-10	Duebbert and Lokemoen (1976)
Unspecified	Prairie Chickens	Unspecified	Burn	3-5	Kirsch (1974)
North Dakota	Prairie Grouse	Seeded native and exotics	Burn	3-5	Kirsch et al. (1973)

attractive to nesting ducks throughout nine years of study. However, nest success may not have been affected by treatments in this study (i.e., grazing, burning, and idling) because brush (mainly snowberry [*Symphoricarpos occidentalis*]), the preferred vegetation of nesting mallards and gadwall, was readily available before and after treatments were applied in all fields at Lostwood National Wildlife Refuge, North Dakota.

No recommendations of treatment frequencies were found for grasslands in the shortgrass or rough fescue grasslands; however, literature indicated that prairie birds respond negatively to treatments other than idling in these regions. Upland nesting ducks responded negatively to grazing in shortgrass prairies of eastern Montana (Gjersing 1975, Mundinger 1976). Further west in Colorado, duck nesting success that declined 38% after only a light grazing treatment, was still depressed 17% below pregrazing levels three years after grazing was terminated (Gilbert et al. 1996). Similarly, Pylypec (1991) reported that densities of passerines on a burned rough fescue grassland remained below those on unburned grassland for >3 years. Driver (1987) recorded poor recoveries in breeding bird densities three years after a fire in rough fescue prairie. To enhance duck production, Gilbert et al. (1996) recommended burning or grazing only when residual vegetation is so thick that new growth ceases. We speculate that shortgrass and rough fescue grasslands may recover slower than tallgrass and mixed grasslands because precipitation-evaporation ratios decline to the north and west across the northern Great Plains. Therefore, management practices in shortgrass and rough fescue grassland zones that remove cover may negatively influence nesting grassland birds for a higher number of years than in tallgrass and mixed grasslands. Information from nongame passerine research in rough fescue has indicated that breeding bird densities which decrease after burning may require >3 years to return to pre-burn densities (Owens and Myers 1973, Driver 1987, Pylypec 1991).

SYNTHESIZING RESEARCH INTO MANAGEMENT DIRECTIVES

Grassland management to enhance duck production remains as much an art as a science despite years of research. Scientific and management communities largely agree that continuous idling of grasslands is a poor management choice in comparison to periodic treatment to rejuvenate grasslands. Continuous idling (e.g., >10 years) without periodic treatment as a conscious management decision fails to address long-term grassland health. Although a low-cost management option, continuous idling usually results in a grassland dominated by undesirable grass species and/or undesirable or noxious weeds, many of which are regulated by state and local authorities. Continuous idling may be necessary in some reclamation prescriptions; however, the feasability of long-term idling as a primary management objective should be assessed on its merits for selected species or when other land use options are difficult to accomplish or of high risk to other social properties or ecological functions and values. We advocate periodic treatment of grasslands to remove excessive litter accumulations that negatively affect vegetative health, structure, and vigor. However, managers often are either reluctant to apply grassland treatments or may treat grasslands too frequently because complete guidelines for treatments and intervals do not exist. Wide ranges in recommended treatment intervals are largely due to variations in climate, geographic region, soils, and weather. In this section, we attempt to join scant scientific research with expert opinion as a means of estimating treatment intervals for seeded and native prairie grasslands. We depict probable grassland response to continuous idling and periodic treatments irrespective of specific treatment type (Figs. 3 and 4). Our recommendations are open to criticism where data are lacking because management recommendations throughout this synthesis portray a grassland management philosophy based on our current state of scientific knowledge. Readers should recognize that recommended treatments and intervals may change with scientific advancements and future research.

A goal of many managers is to maintain herbaceous cover at an optimal level where vegetation is always in its tallest and most vigorous form. Unfortunately, vegetative structure of cover cannot be maintained at this level because grassland health and vigor decline with age (Higgins and Barker 1982). Therefore, grasslands must be treated periodically to remove excessive litter that negatively affects stand health and duck production. Our first illustration (Fig. 3) is a hypothetical characterization of the structural decline of a stand of seeded nesting cover located in the mesic mixed grassland zone. Seeded nesting cover (Fig. 3) may be either native or introduced grass mixtures. Volunteer weeds or sweet clover in dense nesting cover may cause an initial peak in height-density readings only two years after establishment (Fig. 3). However, peak structural characteristics in seeded nesting cover generally are attained 3-5 years after establishment (Fig. 3). Litter accumulates rapidly during this 3-5 year period of increased biomass production, after which vegetative structural qualities are much reduced by age five or six. Declines in aboveground measures of productivity (e.g., tiller and culm densities) are largely due to litter that has accumulated over time. Belowground productivity measures (e.g., root and rhizome biomass) also decline without periodic treatment (Seastedt and Ramundo 1990). Stand quality in subsequent years remains low without a grassland treatment designed to remove litter and stimulate growth.

We recommend use of a 2-5 year interval between treatments to rejuvenate grasslands in tallgrass prairie zones. Secondly, we recommend a 3-10 year interval between treatments in the mesic mixed grass and mesic rough fescue zones. A more conservative treatment interval of ±10 years may be appropriate for grasslands in the xeric mixed grass, shortgrass, and xeric rough fescue zones because treatment effects are less well known. Our recommended intervals are not intended to be a substitute for understanding factors that influence treatment intervals. Rather, experienced managers must prescribe treatments on an individual field basis due to the inherent unpredictability in variables (e.g., climate and soils) that influence grassland growth (see Higgins and Barker 1982 for a review). We also recommend that managers wait

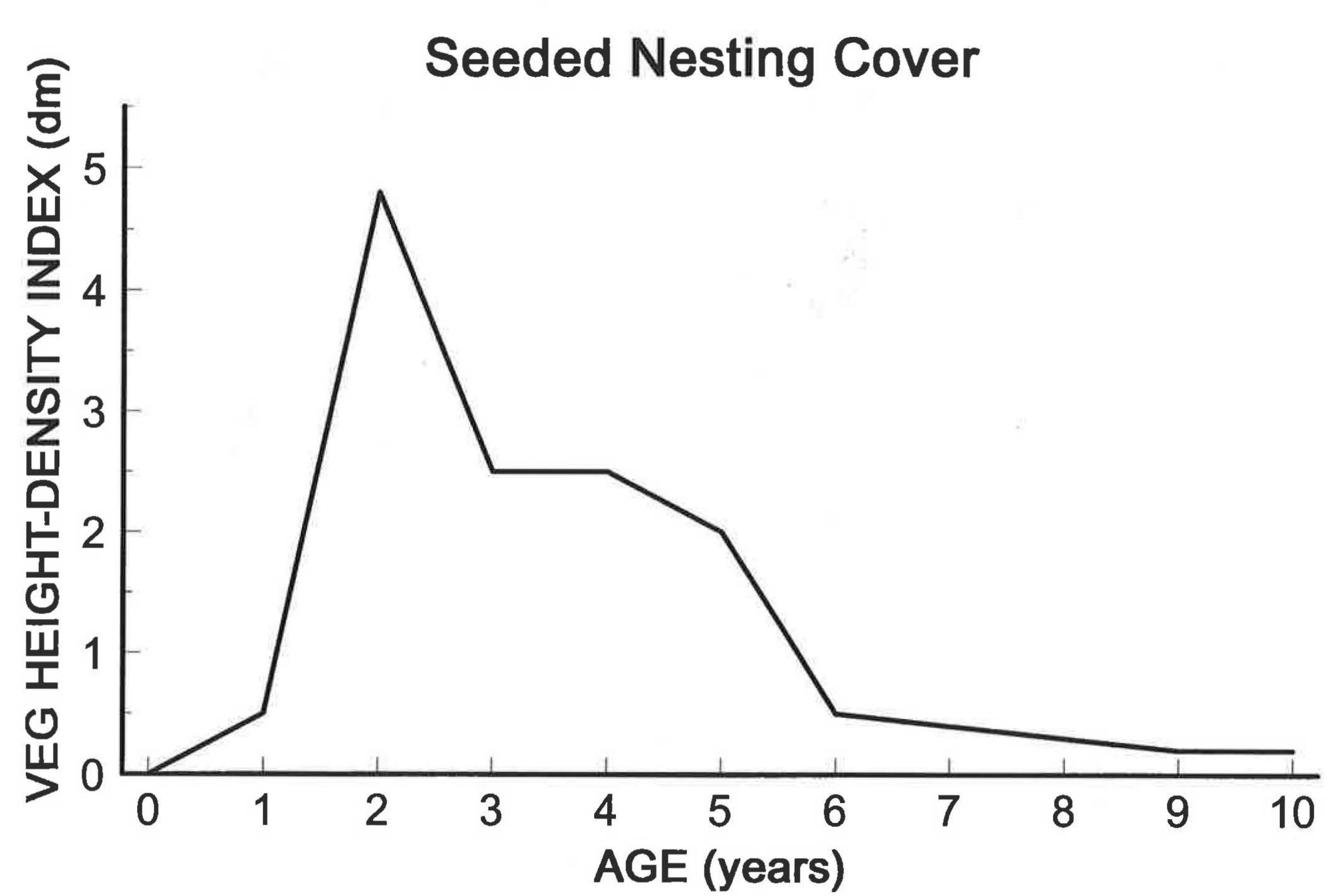

Figure 3. Hypothetical characterization of the structural decline of a stand of seeded nesting cover in the mesic mixed grassland zone of the northern Great Plains.

1-2 years (undermanage) rather than use treatments too frequently (overmanage) when they are uncertain whether or not a grassland requires treatment.

Our second illustration (Fig. 4) depicts probable grassland response when management treatments are applied at 3-year intervals to seeded and native prairie vegetation. Native prairie vegetation height-density readings usually do not exceed those of seeded cover. However, treatment intervals in both stand types coincide with declines in vegetative height-density readings and increases in litter depth (Fig. 4). Native prairie response to management may remain consistent compared to that of seeded vegetation which slowly declines over time (Fig. 4). Treatments enable managers to consistently maintain a cover quality that may be below the maximum potential of a newly established stand but is above that which would occur without periodic stand rejuvenation (i.e., continuous idling).

Litter is probably the single best attribute managers can use to determine when to apply grassland treatments. Litter accumulations accompanied with an abundance of brush and weeds decrease habitat quality for nesting birds by reducing structural stand attributes and grass performance. Grasslands should be treated in as short a time as possible regardless of treatment type to minimize loss of cover. Grasslands should not be treated in years of extreme drought or wetness. Heavy snow or ice pack as well as excessive rodent herbivory over winter also may affect management decisions.

Selection of a specific grassland treatment is a trade-off between treatment effectiveness, reliability and cost. Each treatment type we have discussed is used widely in the northern Great Plains and provides an alternative to continuous idling. Burning provides the fastest and most effective means of litter removal. Burning that can be applied rapidly compared to grazing is cost-effective on larger sites. Burning has become widely accepted with recent advances in fire suppression and ignition equipment and an increase in number of personnel trained in the use of fire. Burning is a poor management choice under the following five conditions: 1) federal, state, provincial, or local regulations prohibit burning, 2) containment and safety are high risk factors, 3) endangered species or natural communities are subject to harm or their status is unknown, 4) fire behavior or fire effects do not meet objectives for the area, or 5) when local residences are in jeopardy.

In the northern Great Plains, haying treatments can be applied more universally than burning and with less risk to people. Haying also can be a useful tool because managers may

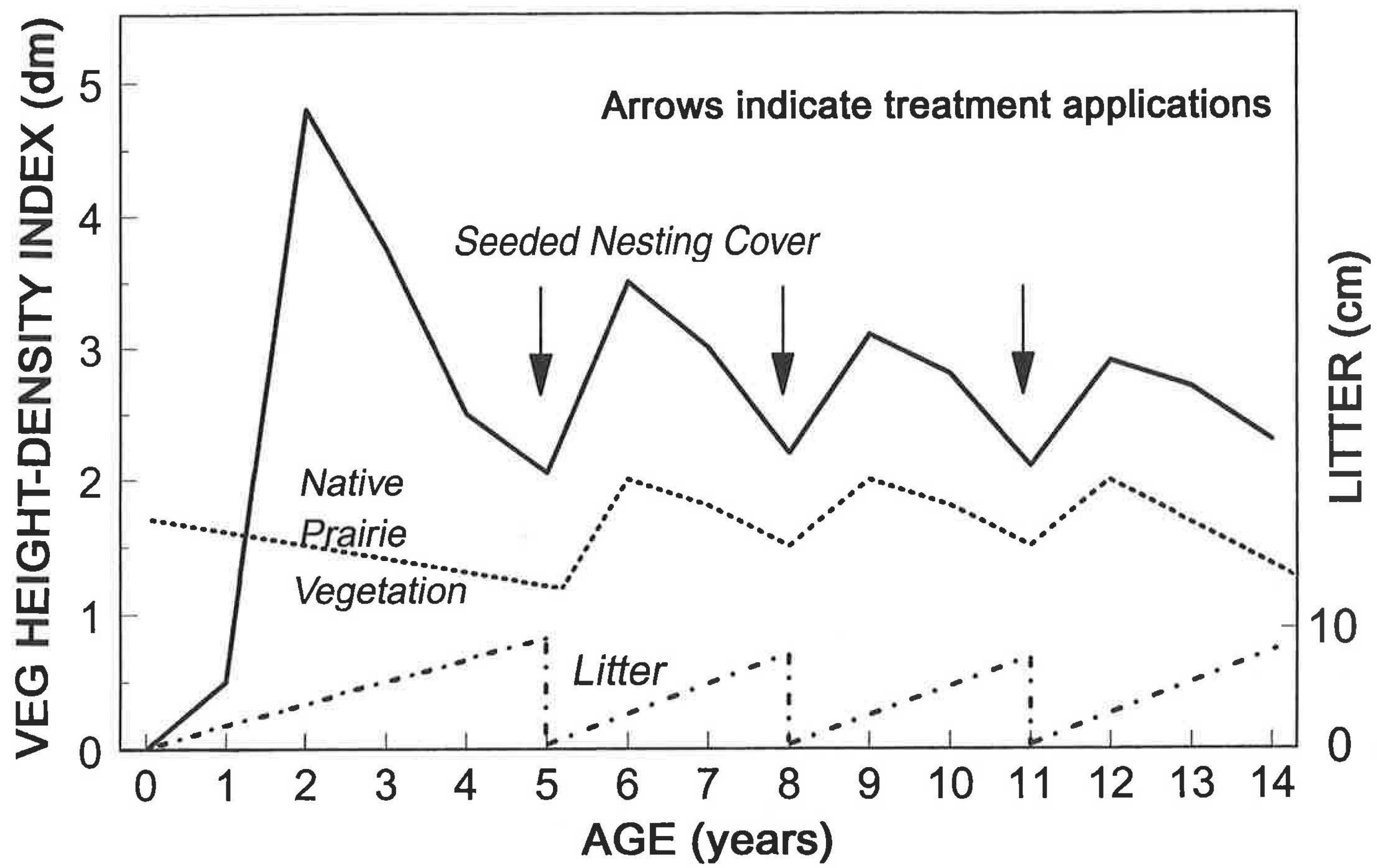

Figure 4. Hypothetical responses of seeded nesting cover and native prairie vegetation and litter to management treatments applied at 3-year intervals, beginning at year 5.

contract with local landowners to treat numerous tracts simultaneously. The concern with haying is that although haying removes some dead standing vegetation, most mowers, swathers, and rakes will not remove litter biomass <1 dm (4 in) above the ground surface. Haying is not a logistically viable option if terrain, rocks, pocket gopher mounds, or brush prohibits use of equipment or cooperators are unavailable. Haying equipment and hay are generally easily transportable, so distance is often less limiting than with livestock treatments, and haying requires no fences or water. The main constraints to permittees are the rental costs and the designated time in which the haying can be done (i.e., usually after July 15 to minimize damage to ground nesting birds in northern latitudes). Landowner concerns usually include small field sizes, large distances that equipment must be transported, and low quantity and quality of late-season hay. Fees for hay may be adjusted as necessary to ensure that grassland treatment goals are met.

Livestock grazing has been the most controversial treatment in relation to upland nesting bird productivity. Grazing can be used to enhance grasslands for wildlife or it can be a force that speeds up grassland degradation. If grazing is chosen as the management tool, managers must maintain control of the grazing treatment, and they should work within a set of obtainable objectives with a long range goal. Livestock grazing removes more litter than haying through consumption of above-ground standing crop and trampling. However, unlike burning and haying that can be completed within 1-2 days, grazing must be conducted for much longer time periods to achieve desired treatment effects. Recent advances in livestock transport equipment and solar-powered generators that provide a cost effective method of partitioning pastures enable managers to use grazing as an option. Multiple-species (e.g., sheep and cattle) grazing is an alternative to chemical application for noxious weed control. We recommend that readers consider new or modified treatment options as they emerge rather than develop generalistic, negative attitudes about specific treatments (e.g., grazing is always bad or grazing is always good).

CURRENT RESEARCH NEEDS

Rapid technological advances continually provide new opportunities in research and management. Communication between wildlife professionals is necessary to ensure that natural resource personnel are informed of new research findings and management strategies. Symposia and synthesis papers are a useful means of communicating such information. Our synthesis has identified several information gaps relative to vegetation and wildlife responses to burning, grazing, haying, idling, and tillage treatments in grasslands of the northern Great Plains region. Research needed to fill these gaps include the following:

1. Future research should incorporate methods into study designs that enable grassland response to multiple treatments to be measured over time. Duck use and productivity measures from grasslands of known age and condition could be used to compare effect sizes among grassland treatments. Permanent research plots throughout the major prairie-soil zones in the northern Great Plains should be established so that research is not terminated before vegetation recovery to pre-treatment conditions has occurred.

2. Research to determine optimal treatment intervals between management treatments is urgently needed in western xeric mixed grass, shortgrass and rough fescue grasslands.

3. More accurate vegetation measurement techniques should be developed for relating quality of cover to duck nesting success. New techniques should focus on increasing precision of estimates to decrease biases currently associated with visual obstruction readings. Measurements that are phenologically coordinated with key plant species would enhance use of techniques. Partnerships between agronomic and wildlife professionals also should be developed that enable researchers to coordinate across vegetation zones to enhance the quality of data collection and analysis.

4. Duck researchers should continue studying landscape-scale factors influencing waterfowl use and productivity measures. Future studies should investigate whether duck productivity is related to quantity or quality (vegetative composition and structure) of available nesting cover. Information concerning minimum area requirements by vegetative stand type (e.g., warm-versus cool-season grasses) for upland nesting passerines also would be useful.

5. Indices reflecting relationships between precipitation-evaporation rates and soil-moisture measurements should be developed to link vegetative performance to long-term moisture regimes. New indices that explain variability in moisture regimes would enhance modelling exercises across extensive landscapes.

6. Research is needed to identify haying and grazing strategies that are beneficial upland nesting birds and economically acceptable to farmers and ranchers. Modifications to current haying and grazing practices designed to increase wildlife production could have a large impact because most grassland habitat is privately owned and operated.

7. Agronomists and plant breeders are encouraged to develop more winter hardy cultivars of fall-planted varieties of wheat and other small grains. Newly developed cultivars would provide residual spring cover to early-nesting ducks. Fall-planted cultivars designed to replace spring-planted varieties throughout the prairie pothole region also would reduce chemical and tillage applications.

LITERATURE CITED

Abouguendia, Z. M., and W. C. Whitman. 1979. Disappearance of dead plant material in a mixed grass prairie. Oecologia 42:23-29.

Abrams, M. D. 1985. Fire history of oak gallery forests in a northeast Kansas tallgrass prairie. Am. Midl. Nat. 114:199-191.

*Abrams, M. D. 1988. Effects of burning regime on buried seed banks and canopy coverage in a Kansas tallgrass prairie. Southwest. Nat. 33:65-70.

*Abrams, M. D., A. K. Knapp, and L. C. Hulbert. 1986. A ten-year record of aboveground biomass in a Kansas tallgrass prairie: effects of fire and topographic position. Am. J. Bot. 73:1509-1515.

*Aikman, J. M. 1955. Burning in the management of prairie in Iowa. Iowa Acad. Sci. 62:53-62.

*Anderson, K. L. 1964. Burning Flint Hills bluestem ranges. Proc. Tall Timbers Fire Ecol. Conf. 3:89-103.

*Anderson, R. C. 1973. The use of fire as a management tool on the Curtis Prairie. Proc. Tall Timbers Fire Ecol. Conf. 12:23-35.

Anderson, M. L., and A. W. Bailey. 1979. Effect of fire on a *Symphoricarpos occidentalis* shrub community in central Alberta. Can. J. Bot. 57:2819-2823.

*Anderson, H. G., and A. W. Bailey. 1980. Effects of annual burning on grassland in the aspen parkland of east-central Alberta. Can. J. Bot. 58:985-996.

Bailey. A. W. 1978. Prescribed burning as an important tool for Canadian rangelands. Pages 15-27 in Proc. Fire and Range Manage. Seminar, sponsored by the Land Use Serv. DREE-PFRA and Lands Branch, Sask. Dep. Agric., Regina.

*Bailey, A. W., and M. L. Anderson. 1978. Prescribed burning of a *Festuca-Stipa* grassland. J. Range Manage. 31:446-449.

*Bailey, A. W., B. D. Irving, and R. D. Fitzgerald. 1990. Regeneration of woody species following burning and grazing in Aspen Parkland. J. Range Manage. 43:212-215.

Ball, I. J., R. L. Eng, and S. K. Ball. 1995. Population density and productivity of ducks on large grassland tracts in northcentral Montana. Wildl. Soc. Bull. 23:767-773.

Ball, I. J., T. E. Martin, and J. K. Ringelman. 1994. Conservation of nongame birds and waterfowl: conflict or complement? Trans. North Am. Wildl. Nat. Resour. Conf. 59:337-347.

Balser, D. S., H. H. Dill, and H. K. Nelson. 1968. Effect of predator reduction on waterfowl nesting success. J. Wildl. Manage. 32:669-682.

Barker, W. T., K. K. Sedivec, T. A. Messmer, K. F. Higgins, and D. R. Hertel. 1990. Effects of specialized grazing systems on waterfowl production in southcentral North Dakota. Trans. North Am. Wildl. Nat. Resour. Conf. 55:462-474.

Bartmann, R. M. 1969. Pheasant nesting on soil bank land in northern Utah. J. Wildl. Manage. 33:1020-1023.

Basore, N. S., L. B. Best, and J. B. Wooley. 1986. Bird nesting in Iowa no-tillage and tilled cropland. J. Wildl. Manage. 50:19-28.

Batt, B. D. J., M. G. Anderson, C. D. Anderson, and F. D. Caswell. 1989. The use of prairie potholes by North American ducks. Pages 204-227 in A. van der Valk, ed. Northern Prairie Wetlands. Iowa State Univ. Press, Ames.

*Becic, J. N., and T. B. Bragg. 1978. Grassland reestablishment in eastern Nebraska using burning and mowing management. Pages 120-124 in D. C. Glenn-Lewin and R. Q. Landers, Jr., eds. Proc. Fifth Midwest Prairie Conf.

*Becker, D. A. 1989. Five years of annual prairie burns. Pages 163-168 in T. B. Bragg, and J. Stubbendieck, eds. Proc. Eleventh North Am. Prairie Conf.

*Blankespoor, G. W. 1987. The effects of prescribed burning on a tall-grass prairie remnant in eastern South Dakota. Prairie Nat. 19:177-188.

Bowen, B. S., and A. D. Kruse. 1993. Effects of grazing on nesting by upland sandpipers in southcentral North Dakota. J. Wildl. Manage. 57:291-301.

*Bragg, T. B. 1978. Effects of burning, cattle grazing, and topography on vegetation of the Choppy Sands Range Site in the Nebraska Sandhills prairie. Pages 248-253 in D. N. Hyder, ed. Proc. First Int. Rangeland Congress.

*Bragg, T. B. 1982. Seasonal variations in fuel and fuel consumption by fires in a bluestem prairie. Ecology 63:7-11.

Bragg, T. B. 1985. A preliminary fire history of the oak/pine forest in northcentral Nebraska. Nebr. Acad. Sci. 95:8.

*Briggs, J. M., J. T. Fahnestock, L. E. Fischer, and A. K. Knapp. 1994. Aboveground biomass in tallgrass prairie: effect of time since fire. Pages 165-170 in R. G. Wickett, P. D. Lewis, A. Woodliffe, and P. Pratt eds. Proc. Thirteenth North Am. Prairie Conf.

Bryan, G. G., and L. B. Best. 1991. Bird abundance and species richness in grassed waterways in Iowa rowcrop fields. Am. Midl. Nat. 126:90-102.

Bryan, G. G., and L. B. Best. 1994. Avian nest density and success in grassed waterways in Iowa rowcrop fields. Wildl. Soc. Bull. 22:583-592.

Bue, I. G., L. Blankenship, and W. H. Marshall. 1952. The relationship of grazing practices to waterfowl breeding populations and production on stock ponds in western South Dakota. Trans. North Am. Wildl. Conf. 17:396-414.

Burger, L. D., L. W. Burger, Jr., and J. Faaborg. 1994. Effects of prairie fragmentation on predation on artificial nests. J. Wildl. Manage. 58:249-254.

Burgess, H. H., H. H. Prince, and D. L. Trauger. 1965. Blue-winged teal nesting success as related to land use. J. Wildl. Manage. 29:89-95.

Cassels, D. M., R. L. Gillen, F. T. McCollum, K. W. Tate, and M. E. Hodges. 1995. Effects of grazing management on standing crop dynamics in tallgrass prairie. J. Range Manage. 48:81-84.

Clark, R. G., and T. D. Nudds. 1991. Habitat patch size and duck nesting success: the crucial experiments have not been performed. Wildl. Soc. Bull. 19:534-543.

Clark, R. G., T. D. Nudds, and R. O. Bailey. 1991. Populations and nesting success of upland-nesting ducks in relation to cover establishment. Can. Wildl. Serv. Prog. Notes No. 193.

Clarke, S. E., J. A. Campbell, and J. B. Campbell. 1943. The effects of climate and grazing practices on short-grass prairie vegetation in southern Alberta and southwestern Saskatchewan. Can. Minist. Agric. Publ. No. 747.

Collins, S. L., and D. J. Gibson. 1990. Effects of fire on community structure in tall-grass and mixed-grass prairie. Pages 81-98 in S. L. Collins and L. L. Wallace, eds. Univ. Oklahoma Press, Norman.

Coupland, R. T. 1950. Ecology of mixed prairie in Canada. Ecol. Monogr. 20:271-315.

Coupland, R. T. 1973. Producers: I. Dynamics of above-ground standing crop. Matador Proj., Can. Int. Biol. Program. Tech. Rep. 27.

*Coupland, R. T., E. A. Ripley, and P. C. Robins. 1973. Floristic composition and canopy architecture of the vegetative cover. Matador Proj., Can. Int. Biol. Program. Tech. Rep. 11.

Cowan, W. F. 1982. Waterfowl production on zero tillage farms. Wildl. Soc. Bull. 10:305-308.

Cowardin, L. M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl. Monogr.92.

*Curtis, J. T., and M. L. Partch. 1948. Effect of fire on the competition between blue grass and certain prairie plants. Am. Midl. Nat. 39:437-443.

*Curtis, J. T., and M. L. Partch. 1950. Some factors affecting flower stalk production in Andropogon gerardi. Ecology 31:488-489.

Dale, B. 1993. Productivity of endemic grassland passerines in haylands. Pages 27-33 in G. L. Holroyd, H. L. Dickson, M. Regnier, and H. C. Smith, eds. Proc. Third Prairie Conserv. Endangered Species Workshop, Occas. Pap. No. 19.

Dambach, C. A., and E. E. Good. 1940. The effect of certain land use practices on populations of breeding birds in southwestern Ohio. J. Wildl. Manage. 4:63-76.

*Diboll, N. 1986. Mowing as an alternative to spring burning for control of cool season exotic grasses in prairie grass plantings. Pages 204-209 in G. K. Clambey, and R. H. Pemble, eds. Proc. Ninth North Am. Prairie Conf.

*Dix, R. L. 1960. The effects of burning on the mulch structure and species composition of grasslands in western North Dakota. Ecology 41:49-56.6

Dix, R. L., and J. E. Butler. 1954. The effect of fire on a dry thin-soil prairie in Wisconsin. J. Range Manage. 7:265-286.

Dormaar, J. F., S. Smoliak, and W. D. Willms. 1989. Vegetation and soil responses to short-duration grazing on fescue grasslands. J. Range Manage. 42:252-256.

Doty, H. A., and A. J. Rondeau. 1987. Predator management to increase duck nest success. Pages 134-139 in Proc. Eighth Great Plains Wildl. Damage Control Workshop. U.S. For. Serv. Gen. Tech. Rep. RM-154.

Driver, E. A. 1987. Fire on grasslands - friend or foe? Blue Jay 45:217-225.

Duebbert, H. F., E. T. Jacobson, K. F. Higgins, and E. B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat in the prairie pothole region. U.S. Fish Wildl. Serv., Spec. Sci. Rep.-Wildl. No. 234.

Duebbert, H. F., and H. A. Kantrud. 1974. Upland duck nesting related to land use and predator reduction. J. Wildl. Manage. 38:257-265.

Duebbert, H. F., and H. A. Kantrud. 1987. Use of no-till winter wheat by nesting ducks in North Dakota. J. Soil and Water Conserv. 42:50-53.

Duebbert, H. F., and J. T. Lokemoen. 1976. Duck nesting in fields of undisturbed grass-legume cover. J. Wildl. Manage. 40:39-49.

Dumke, R. T., and C. M. Pils. 1979. Renesting and dynamics of nest site selection by Wisconsin pheasants. J. Wildl. Manage. 43:705-716.

*Ehrenreich, J. H. 1957. Management practices for maintenance of native prairie in Iowa. Ph.D. Dissertation, Iowa State College, Ames. 159pp.

*Ehrenreich, J. H. 1959. Effect of burning and clipping on growth of native prairie in Iowa. J. Range Manage. 12:133-137.

*Ehrenreich, J. H., and J. M. Aikman. 1957. Effect of burning on seed stalk production of native prairie grasses. Iowa Acad. Sci. 64:205-212.

*Ehrenreich, J. H., and J. M. Aikman. 1963. An ecological study of the effect of certain management practices on native prairie in Iowa. Ecol. Monogr. 33:113-130.

*Engle, D. M., and P. M. Bultsma. 1984. Burning of northern mixed prairie during drought. J. Range Manage. 37:398-401.

Fernandez-Duque, E., and C. Valeggia. 1994. Meta-Analysis: A valuable tool in conservation research. Conserv. Biol. 8:555-561.

Fleskes, J. P., and E. E. Klaas. 1991. Dabbling duck recruitment in relation to habitat and predators at Union Slough National Wildlife Refuge, Iowa. U.S. Fish and Wildl. Serv. Tech. Rep. 32.

*Forde, J. D., N. F. Sloan, and D. A. Shown. 1984. Grassland habitat management using prescribed burning in Wind Cave National Park, South Dakota. Prairie Nat. 16:97-110.

Frank, E. J., and E. E. Woehler. 1969. Production of nesting and winter cover for pheasants in Wisconsin. J. Wildl. Manage. 33:802-810.

Frawley, B. J., and L. B. Best. 1991. Effects of mowing on breeding bird abundance and species composition in alfalfa fields. Wildl. Soc. Bull. 19:135-142.

Fritzell, E. K. 1975. Effects of agricultural burning on nesting waterfowl. Can. Field-Nat. 89:21-27.

*Gartner, F. R., J. R. Lindsey, and E. M. White. 1986. Vegetation responses to spring burning in western South Dakota. Pages 143-146 in G. K. Clambey, and R. H. Pemble, eds. Proc. Ninth North Am. Prairie Conf.

George, R. R., A. L. Farris, C. C. Schwartz, D. D. Humburg, and J. C. Coffey. 1979. Native prairie grass pastures as nest cover for upland birds. Wildl. Soc. Bull. 7:4-9.

* George, R. R., A. L. Farris, C. C. Schwartz, D. D. Humburg, and J. M. Kienzler. 1978. Effects of controlled burning on selected upland habitats in southern Iowa. Iowa Wildl. Res. Bull. No. 25.

*Gibson, D. J. 1988. Regeneration and fluctuation of tallgrass prairie vegetation in response to burning frequency. Bull. Torrey Bot. Club 115:1-12.

*Gibson, D. J. 1989. Hulbert's study of factors effecting botanical composition of tallgrass prairie. Pages 115-133 in T. B. Bragg, and J. Stubbendieck, eds. Proc. Eleventh North Am. Prairie Conf.

Gilbert, D. W., D. R. Anderson, J. K. Ringelman, and M. R. Szymczak. 1996. Response of nesting ducks to habitat and management on the Monte Vista National Wildlife Refuge, Colorado. Wildl. Monogr.131.

Gjersing, F. M. 1975. Waterfowl production in relation to rest-rotation grazing. J. Range Manage. 28:37-42.

Glover, F. A. 1956. Nesting and production of the blue-winged teal (*Anas discors* Linnaeus) in northwest Iowa. J. Wildl. Manage. 20:28-46.

*Graber, L. F. 1926. Injury from burning off old grass on established bluegrass pastures. J. Am. Soc. Agron. 18:815-819.

Greenwood, R. J., P. M. Arnold, and B. G. McGuire. 1990. Protecting duck nests from mammalian predators with fences, traps, and a toxicant. Wildl. Soc. Bull. 18:75-82.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Shaffer. 1995. Factors associated with duck nest success in the prairie pothole region of Canada. Wildl. Monogr.128.

Greenwood, R. J., and M. A. Sovada. 1996. Prairie duck populations and predation management. Trans. North Am. Wildl. Nat. Resour. Conf. 61:31-42.

*Hadley, E. B. 1970. Net productivity and burning responses of native eastern North Dakota prairie communities. Am. Midl. Nat. 84:121-135.

Hadley, E. B., and B. J. Kieckhefer. 1963. Productivity of two prairie grasses in relation to fire frequency. Ecology 44:389-395.

Halvorsen, H. H., and R. K. Anderson. 1983. Evaluation of grassland management for wildlife in central Wisconsin. Pages 267-279 in C. L. Kucera, ed. Proc. Seventh North Am. Prairie Conf.

Hartley, M. J. 1994. Passerine abundance and productivity indices in grasslands managed for waterfowl nesting cover. Trans. North Am. Wildl. Nat. Res. Conf. 59:322-327.

*Haupt, M. L. 1986. Prescribed burning of re-established grasslands on reclaimed mined land in western North Dakota. M.S. Thesis, North Dakota State Univ., Fargo. 124pp.

Hays, R. L., R. P. Webb, and A. H. Farmer. 1989. Effects of the Conservation Reserve Program on wildlife habitat: results of 1988 monitoring. Trans. North Am. Wildl. Nat. Resour. Conf. 54:365-376.

Henderson, R. 1982. Vegetation - fire ecology of tallgrass prairie. Nat. Areas J. 2:17-26.

Herkert, J. R. 1994. Breeding bird communities of midwestern prairie fragments: the effects of prescribed burning and habitat-area. Nat. Areas J. 14:128-135.

Higgins, K. F. 1975. Shorebird and game bird nests in North Dakota croplands. Wildl. Soc. Bull. 3:176-179.

Higgins, K. F. 1977. Duck nesting in intensively farmed areas of North Dakota. J. Wildl. Manage. 41:232-242.

Higgins, K. F. 1986a. Interpretation and compendium of historical fire accounts in the Northern Great Plains. U.S. Fish and Wildl. Serv. Resour. Publ. 161.

Higgins, K. F. 1986b. A comparison of burn season effects on nesting birds in North Dakota mixed-grass prairie. Prairie Nat. 18:219-228.

Higgins, K. F., and W. T. Barker. 1982. Changes in vegetation structure in seeded nesting cover in the prairie pothole region. U.S. Fish Wildl. Serv., Spec. Sci. Rep.-Wildl. No. 242.

Higgins, K. F., H. F. Duebbert, and R. B. Oetting. 1969. Nesting of the upland plover on the Missouri Coteau. Prairie Nat. 1:45-48.

Higgins, K. F., L. M. Kirsch, A. T. Klett, and H. W. Miller. 1992. Waterfowl production on the Woodworth Station in south-central North Dakota, 1965-1981. U.S. Fish and Wildl. Serv. Resour. Publ. 180.

Higgins, K. F., L. M. Kirsch, M. R. Ryan, and R. B. Renken. 1979. Some ecological aspects of marbled godwits and willets in North Dakota. Prairie Nat. 11:115-118.

*Hill, G. R., and W. J. Platt. 1975. Some effects of fire upon a tall grass prairie plant community in northwestern Iowa. Pages 103-113 in M. Wali, ed. Prairie: A Multiple View.

Hopkins, H. H. 1954. Effects of mulch upon certain factors on grassland environment. J. Range Manage. 7:255-259.

*Hopkins, H. H., F. W. Albertson, and a. Riegel. 1948. Some effects of burning upon a prairie in west-central Kansas. Trans. Kans. Acad. Sci. 51:131-141.

*Hover, E. I., and T. B. Bragg. 1981. Effect of season of burning and mowing on an eastern Nebraska Stipa-andropogon prairie. Am. Midl. Nat. 105:13-18.

*Howe, H. F. 1995. Succession and fire season in experimental prairie plantings. Ecology 76:1917-1925.

Huber, G. E., and A. A. Steuter. 1984. Vegetation profile and grassland bird response to spring burning. Prairie Nat. 16:55-61.

Hulbert, L. C. 1973. Management of Konza Prairie to approximate pre-white-man fire influences. Pages 138-142 in L. C. Hulbert, ed. Proc. Third Midwest Prairie Conf.

*Hulbert, L. C. 1986. Fire effects on tallgrass prairie. Pages 138-142 in G. K. Clambey and R. H. Pemble, eds. Proc. Ninth North Am. Prairie Conf.

*Hulbert, L. C., and J. K. Wilson. 1983. Fire interval effects on flowering of grasses in Kansas bluestem prairie. Pages 255-257 in C. L. Kucera, ed. Proc. Seventh North Am. Prairie Conf.

Jarvis, R. L., and S. W. Harris. 1971. Land-use patterns and duck production at Malheur National Wildlife Refuge. J. Wildl. Manage. 35:767-773.

Johnson, D. H., and L. D. Igl. 1995. Contributions of the conservation reserve program to populations of breeding birds in North Dakota. Wilson Bull. 107:709-718.

Johnson, D. H., A. B. Sargeant, and R. J. Greenwood. 1989. Importance of individual species of predators on nesting success of ducks in the Canadian prairie pothole region. Can. J. Zool. 67:291-297.

Johnson, R. G., and S. A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. J. Wildl. Manage. 54:106-111.

Joselyn, G. B., J. E. Warnock, and S. L. Etter. 1968. Manipulation of roadside cover for nesting pheasants-a preliminary report. J. Wildl. Manage. 32:217-233.

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.

Kantrud, H. A., and K. F. Higgins. 1992. Nest and nest site characteristics of some ground-nesting, non-passerine birds of northern grasslands. Prairie Nat. 24:67-84.

Kemner, D. P., and K. F. Higgins. 1993. Response by upland nesting ducks to three rejuvenation treatments applied to two types of seeded nesting cover in eastern South Dakota. Proc. S.D. Acad. Sci. 72:87-109.

Keyser, E. J., III. 1986. Pheasant nesting and vegetation development in dense nesting cover established under the South Dakota Pheasant Restoration Program. M.S. Thesis, South Dakota State Univ., Brookings. 58pp.

Kiel, W. H., Jr., A. S. Hawkins, and N. G. Perret. 1972. Waterfowl habitat trends in the aspen parkland of Manitoba. Can. Wildl. Serv. Rep. Ser. No.18.

King, J. W., and J. A. Savidge. 1995. Effects of the conservation reserve program on wildlife in southeast Nebraska. Wildl. Soc. Bull. 23:377-385.

Kirby, R. E., J. K. Ringelman, D. R. Anderson, and R. S. Sojda. 1992. Grazing on national wildlife refuges: do the needs outweigh the problems? Trans. North Am. Wildl. Nat. Resour. Conf. 57:611-626.

Kirsch, L. M. 1969. Waterfowl production in relation to grazing. J. Wildl. Manage. 33:821-828.

Kirsch, L. M. 1974. Habitat management considerations for prairie chickens. Wildl. Soc. Bull. 2:124-129.

*Kirsch, L. M. 1978. Effects of fire upon wildlife habitat. Pages 47-51 in Proc. Fire and Range Manage. Seminar, sponsored by the Land Use Serv. DREE-PFRA and Lands Branch, Sask. Dep. Agric., Regina.

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.

Kirsch, L. M., and K. F. Higgins. 1976. Upland sandpiper nesting and management in North Dakota. Wildl. Soc. Bull. 4:16-20.

Kirsch, L. M., A. T. Klett, and H. W. Miller. 1973. Land use and prairie grouse population relationships in North Dakota. J. Wildl. Manage. 37:449-453.

Kirsch, L. M., and A. D. Kruse. 1972. Prairie fires and wildlife. Proc. Tall Timbers Fire Ecol. Conf. 12:289-303.

Klett, A. T., H. F. Duebbert, and G. L. Heismeyer. 1984. Use of seeded native grasses as nesting cover by ducks. Wildl. Soc. Bull. 12:134-138.

Klett, A. T., T. L. Shaffer, and D. H. Johnson. 1988. Duck nest success in the prairie pothole region. J. Wildl. Manage. 52:431-440.

*Kline, V. M. 1986. Response of sweet clover (*Melilotus alba*) and associated prairie vegetation to seven experimental burning and mowing treatments. Pages 149-152 in G. K. Clambey, and R. H. Pemble, eds. Proc. Ninth North Am. Prairie Conf.

*Knapp, A. K., and L. C. Hulbert. 1986. Production, density an height of flower stalks of three grasses in annually burned and unburned eastern Kansas tallgrass prairie: a four year record. Southwest. Nat. 31:235-241.

Kobriger, J. D., D. P. Vollink, M. E. McNeill, and K. F. Higgins. 1987. Prairie chicken populations of the Sheyenne Delta in North Dakota, 1961-1987. Paper presented at the Prairie Chickens on the Sheyenne Nat. Grasslands Symp., Univ. of Minn., Crookston.

Koelling, M. R. and C. L. Kucera. 1965. Productivity and turnover relationships in native tallgrass prairie. Iowa State J. Sci. 39:387-392.

Krapu, G. L., D. R. Parsons, and M. W. Weller. 1970. Waterfowl in relation to land use and water levels on the spring run area. Iowa State J. Sci. 44:437-452.

Kruse, A. D., and B. S. Bowen. 1996. Effects of grazing and burning on densities and habitats of breeding ducks in North Dakota. J. Wildl. Manage. 60:233-246.

Kruse, A. D., and J. L. Piehl. 1986. The impact of prescribed burning on ground-nesting birds. Pages 153-156 in G. K. Clambey and R. H. Pemble, eds. Proc. Ninth North Am. Prairie Conf.

*Kucera, C. L. 1968. Ecological effects of fire on tallgrass prairie. Pages 12-19 in P. Schramm, ed. Proc. Symp. on Prairie and Prairie Restor., Knox College, Galesburg, Ill.

*Kucera, C. L., and J. H. Ehrenreich. 1962. Some effects of annual burning on central Missouri prairie. Ecology 43:334-336.

*Kucera, C. L., and M. Koelling. 1964. The influence of fire on composition of central Missouri prairie. Am. Midl. Nat. 72:142-147.

*Launchbaugh, J. L. 1964. Effects of early spring burning on yields of native vegetation. J. Range Manage. 17:5-6.

*Launchbaugh, J. L. 1978. Fire effects on shortgrass vegetation. Paper presented at the Prairie Prescribed Burning Symp. and Workshop, Jamestown, N.D.

Leedy, D. L. and E. H. Dustman. 1947. The pheasant decline and land-use trends, 1941-1946. Trans. North Am. Wildl. Conf. 12:479-490.

Livezey, B. C. 1981. Duck nesting in retired croplands at Horicon National Wildlife Refuge, Wisconsin. J. Wildl. Manage. 45:27-37.

*Lodge, R. W. 1960. Effects of burning, cultivating, and mowing on the yield and consumption of crested wheatgrass. J. Range Manage. 13:318-321.

Lokemoen, J. T. 1984. Examining economic efficiency of management practices that enhance waterfowl production. Trans. North Am. Wildl. Nat. Resour. Conf. 49:584-607.

Lokemoen, J. T., H. F. Duebbert, and D. E. Sharp. 1990. Homing and reproductive habits of mallards, gadwalls, and blue-winged teal. Wildl. Monogr.106.

Luttschwager, K. A., K. F. Higgins, and J. A. Jenks. 1994. Effects of emergency haying on duck nesting in Conservation Reserve Program fields, South Dakota. Wildl. Soc. Bull. 22:403-408.

Madden, E. M. 1996. Passerine communities and bird-habitat relationships on prescribe-burned, mixed-grass prairie in North Dakota. M.S. Thesis, Montana State Univ., Bozeman. 153pp.

Maher, W. J. 1979. Nestling diets of prairie passerine birds at Matador, Saskatchewan, Canada. Ibis 121:437-452.

Martz, G. F. 1967. Effects of nesting cover removal on breeding puddle ducks. J. Wildl. Manage. 31:236-247.

McCartney, D. H. 1993. History of grazing research in the aspen parkland. Can. J. Anim. Sci. 73:749-763.

Messinger, R. D. 1974. Effects of controlled burning on waterfowl nesting habitat in northwest Iowa. M.S. Thesis, Iowa State Univ., Ames. 49pp.

Miller, H. W. 1971. Relationships of duck nesting success to land use in North and South Dakota. Trans. Congr. Int. Union Game Biol. 10:133-141.

Milonski, M. 1958. The significance of farmland for waterfowl nesting and techniques for reducing losses due to agricultural practices. Trans. North Am. Wildl. Conf. 23:215-228.

Moore, C. T. 1972. Man and fire in the central North American grassland 1535-1890: a documentary historical geography. Ph. D. Dissertation, Univ. California, Los Angeles. 155pp.

Morgan, J. P., D. R. Collicutt, and J. D. Thompson. 1995. Restoring Canada's native prairies - a practical manual. Prairie Habitats, Argyle, Manitoba, Canada. 84pp.

Moss, E. H. and J. A. Campbell. 1947. The fescue grassland of Alberta. Can. J. Res. 25:209-227.

Moyle, J. B., ed. 1964. Ducks and land use in Minnesota. Minn. Dept. Conserv. Tech. Bull. 8.

Mueggler, W. F. 1975. Rate and pattern of vigor recovery in Idaho fescue and bluebunch wheatgrass. J. Range Manage. 28:198-204.

Mundinger, J. G. 1976. Waterfowl response to rest-rotation grazing. J. Wildl. Manage. 40:60-68.

Naeth, M. A., A. W. Bailey, D. J. Pluth, D. S. Chanasyk, and R. T. Hardin. 1991. Grazing impacts on litter and soil organic matter in mixed prairie and fescue grassland ecosystems of Alberta. J. Range Manage. 44:7-12.

Oetting, R. B., and J. F. Cassel. 1971. Waterfowl nesting on interstate highway right-of-way in North Dakota. J. Wildl. Manage. 35:774-781.

*Old, S. M. 1969. Microclimate, fire, and plant production in an Illinois prairie. Ecol. Monogr. 39:355-384.

*Olson, W. W. 1975. A study of the effects of controlled burning on vegetation structure and seeding establishment. M.S. Thesis, North Dakota State Univ., Fargo. 136pp.

Olson, R. A., and L. D. Flake. 1975. Nesting of ring-necked pheasants in eastern South Dakota. Proc. S.D. Acad. Sci. 54:126-136.

Owens, R. A., and M. T. Myres. 1973. Effects of agriculture upon populations of native passerine birds of an Alberta fescue grassland. Can. J. Zool. 51:7-713.

*Owensby, C. 1978. Fire's influence on livestock production on the Kansas prairie. Pages 48-54 in C. Bourassa, A. Brackebusch, eds. Proc. 1977 Rangeland Manage. and Fire Symp. Mont. Forest Conserv. Exp. Sta., Univ. Montana School of For., Missoula.

Owensby, C., E. F. Smith, and K. L. Anderson. 1973. Deferred-rotation grazing with steers in the Kansas Flint Hills. J. Range Manage. 26:393-395.

Page, R. D., and J. F. Cassel. 1971. Waterfowl nesting on a railroad right-of-way in North Dakota. J. Wildl. Manage. 35:544-549.

Peake, R. W., and A. Johnston. 1965. Grazing effects of fescue grassland in western Canada. Proc. Ninth Int. Grassland Congr. 2:1627-1630.

*Peet, M., R. Anderson, and M. S. Adams. 1975. Effect of fire on big bluestem production. Am. Midl. Nat. 94:15-26.

*Pfeiffer, K. E., and A. A. Steuter. 1994. Preliminary response of Sandhills prairie to fire and bison grazing. J. Range Manage. 47:395-397.

Pylypec, B. 1991. Impacts of fire on bird populations in a fescue prairie. Can. Field-Nat. 105:346-349.

Pospahala, R. S., D. R. Anderson, and C. J. Henny. 1974. Population ecology of the mallard: II. Breeding habitat conditions, size of the breeding populations, and production indices. Fish and Wildl. Serv., U.S. Bur. Sport Fish. and Wildl., Res. Publ.115.

Redmann, R. E., J. T. Romo, and B. Pylypec. 1993. Impacts of burning on primary productivity of *Festuca* and *Stipa-Agropyron* grasslands in central Saskatchewan. Am. Midl. Nat. 130:262-273.

Renken, R. B., and J. J. Dinsmore. 1987. Nongame bird communities on managed grasslands in North Dakota. Can. Field-Nat. 101:551-557.

Renner, R. W., R. E. Reynolds, and B. D. J. Batt. 1995. The impact of haying Conservation Reserve Program lands on productivity of ducks nesting in the prairie pothole region of North and South Dakota. Trans. North Am. Wildl. Nat. Resour. Conf. 60:221-229.

*Rice, E. L., and R. L. Parenti. 1978. Causes of decreases in productivity in undisturbed tall grass prairie. Am. J. Bot. 65:1091-1097.

Rice, L. A., and A. V. Carter. 1982. Evaluation of South Dakota grassland management practices as they affect prairie chicken populations, 1974-78. S.D. Dep. Game, Fish, and Parks, Pierre. Completion Rep. No.84-11.

*Richards, M. S., and R. Q. Landers. 1973. Responses of species in Kaslow Prairie, Iowa, to an April fire. Proc. Iowa Acad. Sci. 80:159-161.

Rodriguez, E. F. 1984. Dense nesting cover versus native grassland in relation to duck nesting success and density. M.S. Thesis, Colorado State Univ., Fort Collins. 61pp.

Roseberry, J. L., and W. D. Klimstra. 1970. The nesting ecology and reproductive performance of the eastern meadowlark. Wilson Bull. 82:243-267.

Sargeant, A. B., M. A. Sovada, and T. L. Schaffer. 1995. Seasonal predator removal relative to hatch rate of duck nests in waterfowl production areas. Wildl. Soc. Bull. 23:507-513.

Schramm, P., D. S. Schramm, and S. G. Johnson. 1984. Seasonal phenology and habitat selection of the sedge wren (*Cistothorus platensis*) in a restored tallgrass prairie. Pages 95-99 in G. K. Clambey and R. H. Pemble, eds. Proc. Ninth North Am. Prairie Conf.

Schranck, B. W. 1972. Waterfowl nest cover and some predation relationships. J. Wildl. Manage. 36:182-186.

Seastedt, T. R., and R. A. Ramundo. 1990. The influence of fire on belowground processes of tallgrass prairie. Pages 99-117 in S. L. Collins and L. L. Wallace, eds. Fire in North American tallgrass prairies. Univ. Oklahoma Press, Norman.

Sedivec, K. K. 1989. Effects of specialized grazing systems on upland nesting waterfowl in southcental North Dakota. M.S. Thesis, North Dakota State Univ., Fargo. 125pp.

Sedivec, K. K. 1994. Effects of two grazing treatments and habitat use on upland nesting birds on privately owned rangeland. Ph.D. Dissertation, North Dakota State Univ., Fargo. 124pp.

Sedivec, K. K., T. A. Messmer, W. T. Barker, K. F. Higgins, and D. R. Hertel. 1990. Nesting success of upland nesting waterfowl and sharp-tailed grouse in specialized grazing systems in southcentral North Dakota. Pages 71-92 in Society for Range Manage. symposium: Can livestock be used as a tool to enhance wildlife habitat?

Skinner, R. M. 1975. Grassland use patterns and prairie bird populations in Missouri. Pages 171-180 in M. K. Wali, ed. Prairie: A Multiple View.

Skinner, R. M., T. S. Baskett, and M. D. Blenden. 1984. Bird Habitat on Missouri Prairies. Missouri Dept. Consn, Jefferson City, Missouri. Terrestrial Series #14. 37pp.

Smoliak, S. 1965. A comparison of ungrazed and lightly grazed Stipa-Bouteloua prairie in southeastern Alberta. Can. J. Plant Sci. 45:270-275.

*Steuter, A. A. 1986. Fire behavior and standing crop characteristics on repeated seasonal burns-northern mixed prairie. Pages 54-59 in A. Koonce, ed. Symp. on Prescribed Burning in the Midwest: State-of-the-Art. Univ. Wisconsin, Stevens Point.

*Steuter, A. A.. 1987. C3/C4 production shift on seasonal burns-northern mixed prairie. J. Range Manage. 40:27-31.

Sugden, L. G., and G. W. Beyersbergen. 1986. Effect of density and concealment on American crow predation of simulated duck nests. J. Wildl. Manage. 50:9-14.

Sugden, L. G., and G. W. Beyersbergen. 1987. Effect of nesting cover density on American crow predation of simulated duck nests. J. Wildl. Manage. 51:481-485.

*Svedarsky, W. D., and P. E. Buckley. 1975. Some interactions of fire, prairie and aspen in northwest Minnesota. Pages 115-121 in M. K. Wali, ed. Prairie: A Multiple View.

* Svedarsky, W. D., and P. E. Buckley, and T. A. Feiro. 1986. The effect of 13 years of annual burning on an aspen-prairie ecotone in northwestern Minnesota. Pages 118-122 in G. K. Clambey, and R. H. Pemble, eds. Proc. Ninth North Am. Prairie Conf.

Svedarsky, W. D., and G. L. Van Amburg. 1996. Integrated management of the greater prairie chicken and livestock on the Sheyenne National Grassland: A literature review and background study completed for the N.D. Game and Fish Dep. in Conjunction with the U.S. For. Serv., Bismarck. 113pp.

*Svedarsky, W. D., T. J. Wolfe, M. A. Kohring, and L. B. Hanson. 1986. Fire management of prairies in the prairie-forest transition of Minnesota. Prescribed Burning in the Midwest: State-of-the-Art Symposium. Paper No. 14899 of the Sci. J. Ser., Univ. Minnesota, St. Paul.

Swengel, S. R. 1996. Management responses of three species of declining sparrows in tallgrass prairie. Bird Conserv. Int. 6:241-253.

Tester, J. R., and W. H. Marshall. 1962. Minnesota prairie management techniques and their wildlife implications. Trans. North Am. Wildl. Nat. Resour. Conf. 27:267-287.

*Towne, E. G. 1994. Influence of fire frequency and burning date on the proportion of reproductive tillers in big bluestem and indian grass. Pages 75-78 in D. C. Hartnett, ed. Proc. Fourteenth North Am. Prairie Conf.

*Towne, E. G., and C. Owensby. 1984. Long-term effects of annual burning at different dates in ungrazed Kansas tallgrass prairie. J. Range Manage. 37:392-397.

Trautman, C. G. 1960. Evaluation of pheasant nesting habitat in eastern South Dakota. Trans. North Am. Wildl. Nat. Resour. Conf. 25:202-213.

VanderWerf, E. 1992. Lack's clutch size hypothesis: an examination of the evidence using meta-analysis. Ecology 73:1699-1705.

Vandel, G. M., III, and R. L. Linder. 1981. Pheasants decline but cover-type acreage unchanged on South Dakota study area. Wildl. Soc. Bull. 9:299-302.

*Vogl, R. J. 1965. Effects of spring burning on yields of brush prairie savanna. J. Range Manage. 18:202-205.

Voorhees, L. D., and J. F. Cassel. 1980. Highway right-of-way: mowing versus succession as related to duck nesting. J. Wildl. Manage. 44:155-163.

Warburton, D. B., and W. D. Klimstra. 1984. Wildlife use of no-till and conventionally tilled corn fields. J. Soil and Water Conserv. 39:327-330.

Wark, D. B., W. R. Poole, R. G. Arnott, L. R. Moats, and L. Wetter. 1995. Revegetating with native grasses. Ducks Unlimited Canada, Stonewall, Manitoba. 133pp.

Westemeier, R. L. 1973. Prescribed burning in grassland management for prairie chickens in Illinois. Proc. Tall Timbers Fire Ecol. Conf. 12:317-338.

Westemeier, R. L., and J. E. Buhnerkempe. 1983. Responses of nesting wildlife to prairie grass management on prairie chicken sanctuaries in Illinois. Pages 39-46 in R. Brewer, ed. Proc. Eighth North Am. Prairie Conf.

Wheeler, W. E., R. C. Gatti, and G. A. Bartelt. 1984. Duck breeding ecology and harvest characteristics on Grand River Marsh Wildlife Area. U.S. Dep. Nat. Resour. Tech. Bull. 145.

*Whisenant, S. G., and D. W. Uresk. 1990. Spring burning Japanese brome in a western wheatgrass community. J. Range Manage. 43:205-208.

*White, R. S., and P. O. Currie. 1983. Prescribed burning in the northern Great Plains: yield and cover responses of 3 forage species in the mixed grass prairie. J. Range Manage. 36:179-183.

Widstrand, S. 1985. Costs compared for burning versus mowing on small prairies and old fields. Restor. and Manage. Notes 3:31.

Willms, W. D., S. Smoliak, and A. W. Bailey. 1986. Herbage production following litter removal on Alberta native grasslands. J. Range Manage. 39:536-540.

Willms, W. D., S. Smoliak, and J. F. Dormaar. 1985. Effects of stocking rate on a rough fescue grassland vegetation. J. Range Manage. 38:220-225.

Willms, W. D., S. Smoliak, and J. F. Dormaar. 1990. Vegetation response to time-controlled grazing on mixed and fescue prairie. J. Range Manage. 43:513-517.

Willms, W. D., and J. Fraser. 1992. Growth characteristics of rough fescue (*Festuca scabrella* var. campestris) after three years of repeated harvesting at scheduled frequencies and heights. Can. J. Bot. 70:2125-2129.

Willms, W. D., S. M. McGinn, and J. F. Dormaar. 1993. Influence of litter on herbage production in the mixed prairie. J. Range Manage. 46:320-324.

*Willson, G. D. 1992. Morphological characteristics of smooth brome used to determine a prescribed burn date. Pages 113-116 in D. D. Smith and C. A. Jacobs, eds. Proc. Twelfth North Am. Prairie Conf.

Wilson, S. D., and J. W. Belcher. 1989. Plant and bird communities of native prairie and introduced Eurasian vegetation in Manitoba, Canada. Conserv. Biol. 3:39-44.

Woehler, E. E., and R. B. Kahl. 1987. Establishing and managing native warm-season grasses on public wildlife lands. Wis. Dep. Nat. Resour., Bureau of Res., Wildl. Res. Sect. W-141-R-22.

Wright, H. A., and A. W. Bailey. 1980. Fire ecology and prescribed burning in the Great Plains—a research review. USDA For. Serv., Intermountain For. and Range Exp. Sta., Ogden, Utah. Gen. Tech. Rep. INT-77.

Wright, H. A., and A. W. Bailey. 1982. Fire Ecology; United States and southern Canada. John Wiley and Sons, Toronto, Canada. 501pp.

Zhang, J., and J. T. Romo. 1994. Defoliation of a northern wheatgrass community: Above- and belowground phytomass productivity. J. Range Manage. 47:279-284.

Zimmerman, J. L. 1988. Breeding season habitat selection by the Henslow's sparrow (*Ammodramus henslowii*) in Kansas. Wilson Bull. 100:17-24.

This work is dedicated to grassland conservators who strive to maintain the health and continuity of our grasslands and to teachers who educate our youth of the sociological and biological values that grasslands have to offer. Daniel Licht in his book ECOLOGY AND ECONOMICS OF THE GREAT PLAINS (1997) said it best . . .

"The subtlety and serenity of grasslands defines their character, but those same traits engender a lack of focus compared with jagged peaks and cascading waters. Grasslands require familiarity before appreciation, not the other way around. Unfortunately we never had a chance to develop that familiarity. Therefore restoring and protecting grassland ecosystems remains considerably more difficult than doing so for other natural resources."