Avian Responses During Winter to Sorghum Management in the Coastal Bend of Texas

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ABSTRACT

Post-harvest grain sorghum treatments were studied to determine those most used by birds during fall and winter 1990-92 in the Coastal Bend area of Texas. Treatment areas were allowed to grow a second seed head following harvest (July-December), then six treatments were applied in December. Bird species richness was higher in double-shredded ($\bar{x}$ = 11.5) and single-shredded ($\bar{x}$ = 10.8) than in harvested-only ($\bar{x}$ = 7.7), shred-disced ($\bar{x}$ = 8.8), shred-chisel plowed treatments ($\bar{x}$ = 6.0), or controls ($\bar{x}$ = 5.5) during post-treatment period (December-February). Post-treatment densities (birds ha^{-1}) of both ducks and geese were higher ($P < 0.10$) in double-shredded (ducks $\bar{x}$ = 39.1, geese $\bar{x}$ = 38.9) than in all other treatments (ducks $\bar{x}$ = 2.45, geese $\bar{x}$ = 3.58). Upland game bird (primarily dove and quail) densities were highest in shred-disced treatments ($\bar{x}$ = 6.04), while nongame bird (44 species) densities were highest in harvested-only ($\bar{x}$ = 18.4), double-shredded ($\bar{x}$ = 18.9), and shred-disced treatments ($\bar{x}$ = 20.69). Sorghum seeds remained available in treatments through February during the dry conditions in 1990-91. Sorghum availability declined to zero in all treatments prior to treatments in December 1991 (due to moisture-related decay), yet sorghum stubble remained an important habitat for wintering birds.

KEYWORDS: forage, nongame birds, upland game birds, waterfowl

Post-harvest cropland management affects food availability for many species of wildlife that depend on agricultural fields during winter. Cropland management strategies in the Coastal Bend of Texas have changed in recent years to promote earlier planting of crops (Refugio County farmers, pers. commun.) Fields are cultivated more intensively to prepare land for planting and are kept clean of waste grain or vegetation throughout fall and winter. Normal farming practices include repeated cultivation starting immediately after crops are harvested (July-early August) keeping fields void of all residue and vegetation throughout fall and winter if conditions allow access to fields.

Grain sorghum is the primary high-energy food grown in southern Texas. Birds such as geese rely on crop fields in this area to maintain adequate body condition

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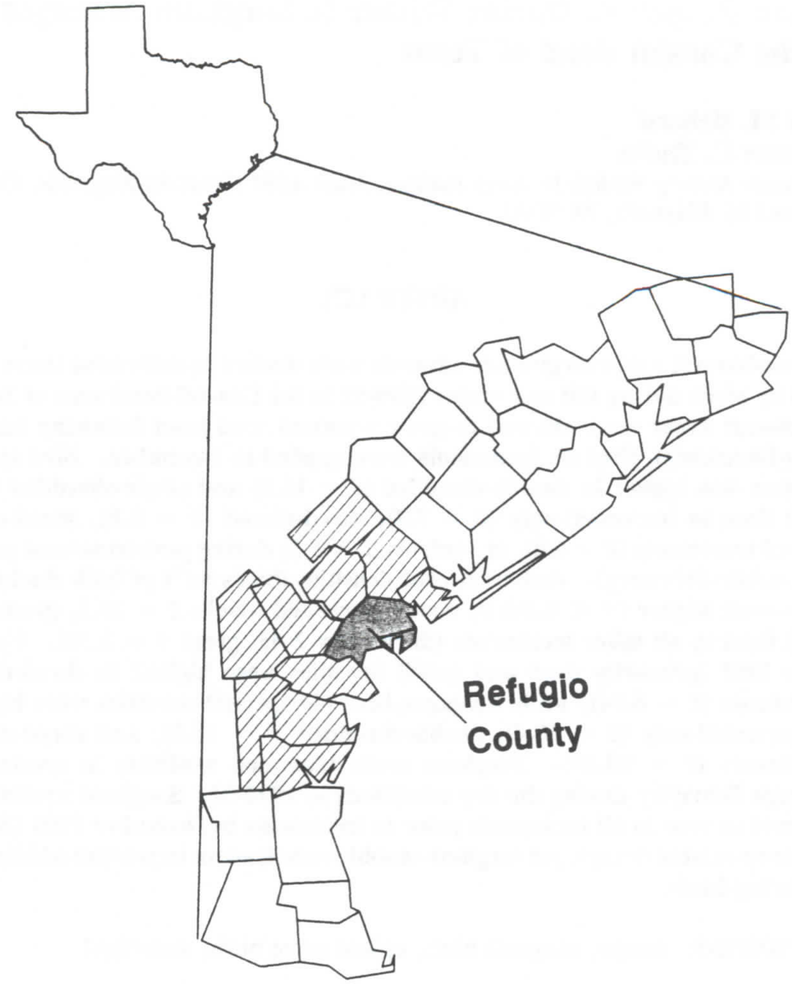

Figure 1. Location of Refugio County in the Coastal Bend (shaded area) of Texas.

throughout winter and provide adequate nutrient reserves for spring migration and nest initiation (Glazener, 1946; Reed, 1976; Ankney and MacInnes, 1978; Raveling, 1979; Bellrose, 1980). Goose use of the Coastal Bend has declined in recent years despite generally increasing populations (Tex. Parks and Wildl. Dep., unpubl. data). Clean farming may be causing this decline (C. R. Wilson, Soil Conserv. Serv., pers. commun.).

The objective of this study was to evaluate waste grain availability and avian abundance in fields under selected sorghum management practices in the Coastal Bend of Texas.

Research was conducted September 1990 to February 1991 and August 1991 to

February 1992 on sorghum set-aside fields on private lands in Refugio County, Texas (Fig. 1). The terrain is coastal prairie intermingled with streams and bays, with little variation in elevation except on the western boundary, where it is gently rolling (Guckian, 1984). Climate is subtropical with an average annual rainfall of 98.5 cm; maximum monthly precipitation typically occurs in September. Average seasonal temperatures range from 28°C in summer to 14°C in winter. The growing season averages 304 days, with the frost period generally occurring from 15 December to 14 February (Morrison, 1990). Common soil types are clayey and loamy. Approximately 78% of the land is used for livestock grazing, and 19% is in cropland. Grain sorghum and cotton are the major cash crops of the area (Guckian, 1984). Crop rotation of two years sorghum and one year cotton is typical. Sorghum harvesting generally concludes in early August.

METHODS

Study plots were comprised of grain sorghum fields in the set-aside program arranged via cooperative agreements with farmers in Refugio County. Study plots totaled 93 ha contained in six treatment areas in 1990-91, and 328 ha contained in 24 treatment areas in 1991-92. Treatment areas ranged from 6.9 to 18.2 ha in size. Each year, sorghum fields were selected based on access and size. Participating landowners received \$37-\$50 ha^{-1} depending on prescribed treatment. All study plots were managed and harvested using farming techniques typical of southern Texas (Bremer, 1976), and none of the study plots were grazed by domestic livestock.

Treatments were randomly assigned to treatment areas. Treatments in 1990-91 included (1) normal harvest with stalks left standing until the end of February (harvested-only), (2) normal harvest with stubble shredded within 10 days and left until the end of February (single-shredded), and (3) normally farmed, repeatedly disced following harvest (control treatment). Treatments in 1991-92 included those used in 1990-91 and: (4) normal harvest with stubble shredded within 10 days, and shredded again (5-10 cm high) after second-growth heads matured in October-November (double-shredded); (5) normal harvest with stubble shredded within 10 days, then lightly disced (8-12 cm depth) after the second growth heads matured (shred-disced), and (6) normal harvest with stubble shredded within 10 days, then chisel plowed (8-12 cm depth) after the second-growth heads matured (shred-chisel plowed). The second phase of treatments 3-5 were implemented between 5 and 7 December 1991.

The survey period during August to February 1991-92 was divided into two periods: pre-treatment being prior to implementation of the second phase of treatments 3-5, and post-treatment being from treatment implementation through February.

Grain and forage sampling of study plots began immediately after harvest in mid-August on a monthly schedule until the first week in October, then sampling was biweekly through February. Grain availability was estimated from two randomly located 40.4-m^2 sampling plots within each treatment area (Frederick and Klaas, 1984). The sampling plot was designed to sample a width of six rows of sorghum, the combine width used by farmers in this study. By sampling one full combine width, samples were obtained from all points across one pass of a combine. We sampled the same number of each row type (middle and edge) in case the combine left more waste grain in a certain row type (Baldassarre et al., 1983). Each treatment area was measured, and grid maps were made for each treatment area so study plots could be randomly selected.

All seed-bearing heads of sorghum within each sampling plot were counted during each sampling period. Seed heads included two types, those missed by the previous harvest and on the ground, and standing heads (those still growing on plants that were mature or maturing--turning red in color). Seed heads were designated as those that contained the main stem of the plant. The first ten standing heads and first ten heads on the ground were collected from each sampling plot to estimate grain densities from seed heads. A 1.37-m^2 quadrat within each sampling plot was sampled for loose seeds on the ground (single seeds and parts of seed heads not containing the main stem). All seeds were removed from seed heads and seed head branches and sifted with a 20-mesh sifter to remove all non-seed debris. All seed samples were oven-dried for 48 hours at 50-55°C and weighed to the nearest 0.1 gram and then extrapolated for each 40.4-m^2 sampling plot. Both sample plots in each treatment area were averaged to estimate total sorghum availability in each treatment area biweekly. Total number of seed-bearing heads on the ground in each 40.4-m^2 sampling plot were divided by the number collected in the sample, then multiplied by the dry weight of seeds from the sample heads to estimate available grain on the ground in each sampling plot. The same process was followed to estimate grain densities from standing seed heads. Total grain density was then determined by adding estimated dry weights for loose seeds, ground heads, and standing heads. The two sampling plots in each treatment area were averaged to estimate total grain densities for each treatment area biweekly.

All above-ground green biomass within four 1-m^2 quadrats (two per sampling plot; four per treatment area) was sampled by clipping (Milner and Hughes, 1968). Forage samples were dried at 40-45°C for 72 hours and weighed to the nearest 0.1 gram. Dry weights of forage from all four 1-m^2 sampling quadrats within each treatment area were averaged to estimate total forage available biweekly.

Avian surveys were conducted between one hour after sunrise and 1200 hours within each treatment area prior to grain and forage sampling during each biweekly sampling period. Treatment areas were systematically searched and all bird species were recorded. A bird was considered using a study plot if it was in the sorghum or indirectly using the plot (e.g., insectivorous species feeding on insects over the plots, or raptors hunting prey using the plots). Time of day and percentage of treatment covered with standing water were also recorded.

Differences in total grain densities between harvested-only and single-shredded treatments were compared using *t*-tests (SAS, 1985). Forage availability for all other treatments were compared using a completely randomized one-way ANOVA or two-way ANOVA. If the main effect and/or location by treatment interaction *F*-value were significant ($P < 0.05$), LSD confidence intervals were used to determine which treatments differed (Milliken and Johnson, 1984).

Birds were placed into four groups (geese, ducks, upland game, and nongame) because sample sizes of individual species were not adequate for analyses (Ballard, 1993: Table 10). All bird survey data from study plots were converted to densities (numbers ha^{-1}) to standardize for different sized treatment areas. Treatment comparisons for bird group density data were analyzed using the same procedures as for forage data. In addition, bird species richness data were analyzed using the GLM procedure of SAS, and comparisons among treatments were tested with LSD mean separation tests. Bird species diversity was compared among treatments without statistical testing.

RESULTS

Grain and Forage Availability

Due to limited acreage in the first year and wet conditions preventing farmers to complete all treatments during the second year, replication of all five treatment types at every location was not possible. Thus, inability to complete the second phase of double-shredded, shred-disced, and shred-chisel plowed treatments in several study fields were limited to one or two locations (Table 1). Wet conditions also

Table 1. Number of treatment areas and distribution of treatments among locations in Refugio County, Texas, 1990-91 and 1991-92.

Year	Location	Treatments	$n^{\dagger}$
1990-91			
	Bauer	Harvested-only	1
		Single-Shredded	1
		Control	1
	Gillespie	Single-shredded	1
	Mathis	Single-shredded	1
	Wendlend	Harvested-only	1
1991-92			
	Ermis	Single-shredded	1
		Control	1
	Franke	Single-shredded	1
		Control	1
	Teril	Harvested-only	3
		Double-shredded	2
		Shred-disced	3
		Shred-chisel plowed	2
		Control	1
	Welder	Single-shredded	5
		Double-shredded	2
		Shred-disced	1
		Control	1

†Number of treatment areas

accelerated decomposition of sorghum seeds; by the time second phase treatments were completed in December 1991, no sorghum remained in any treatment areas. For this reason, data analyses on sorghum availability is restricted to harvested-only and single-shredded treatments.

Sorghum availability (dry weight) gradually declined from October-December in 1990-91 (Fig. 2), when most seed heads had shattered, leaving seeds on the ground. Seeds and seed heads that had been on the ground from harvest had mostly decomposed or had been consumed by the end of December. Harvested-only treatments produced a second growth seed head 3-4 weeks earlier than single-shredded treatments, and therefore had more grain available earlier. Second growth seed heads in single-shredded treatments matured in mid-October in both years. The dry winter during 1990-91 in Refugio County most likely extended the longevity of seeds; since seeds were not wet as often, moisture-related decomposition was reduced. Low amounts of sorghum were available through February 1991. All available sorghum had decomposed by the end of November 1991 (Fig. 2). Above-normal rainfall accelerated decomposition of grain. Prolonged saturation of many study sites caused growing seed heads still on the stalks to mildew and rot.

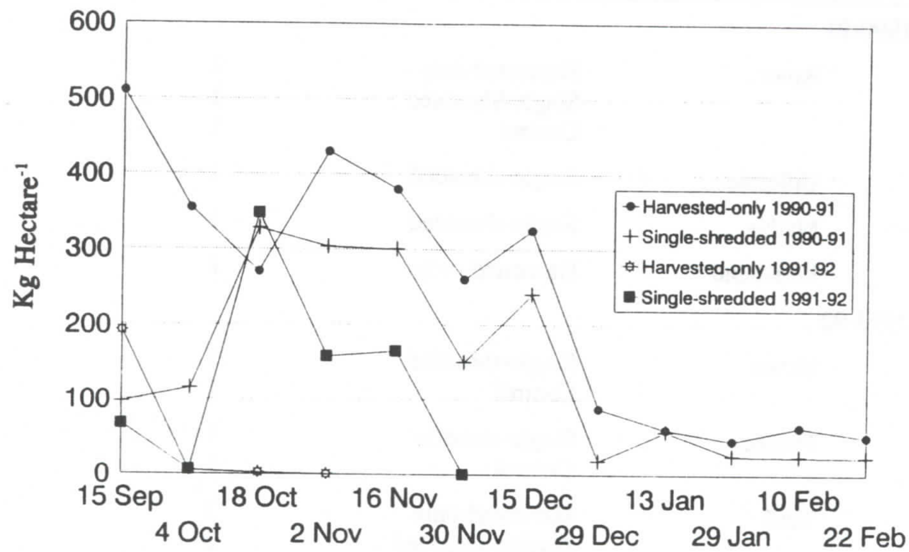

Figure 2. Post-harvest sorghum availability for harvested-only and single-shredded treatments during September to February 1990-91 and 1991-92.

Total grain availability did not differ ($P > 0.05$) between years in harvested-only or single-shredded treatments. Single-shredded treatments contained more ($F = 16.73$; 1,4 df; $P = 0.015$) grain following harvest than the controls. The location by treatment interaction was not significant ($P = 0.084$). Grain was only found in small quantities during the first sampling period in control areas during 1991-92, after which the grain had decomposed.

Forage availability (dry weight) sharply increased in mid-October 1990 due to precipitation received in several treatment areas (Fig. 3). By the end of December 1990, all green vegetation within treatments and the control had dried and died. Forage persisted longer in all treatments except harvested-only during 1991-92 (Fig. 4).

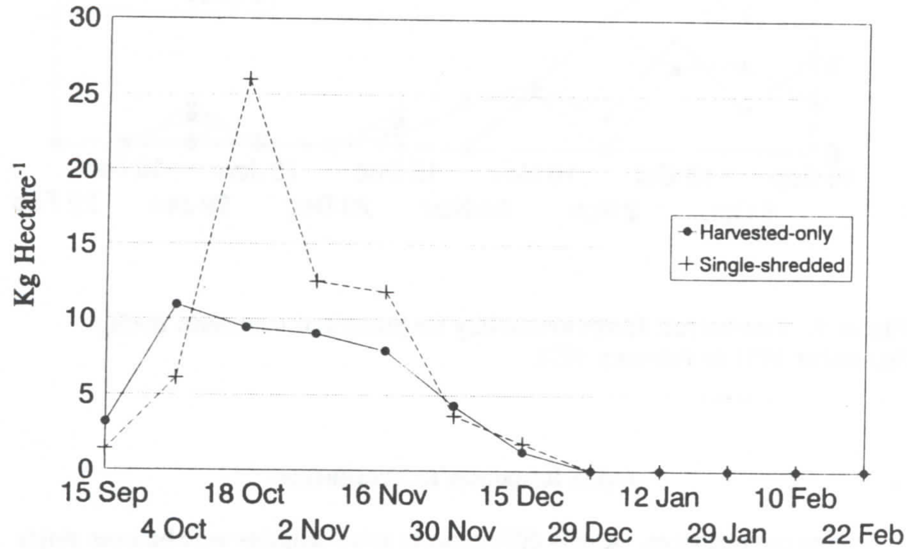

Figure 3. Post-harvest forage availability for prescribed treatments during September 1990 to February 1991.

Availability of forage did not differ between years for harvested-only treatments ($P = 0.758$) or single-shredded treatments ($P = 0.906$). Single-shredded treatments produced more forage ($n = 8$, $\bar{x} = 5.10$ kg ha^{-1}, SE = 11.84) than the controls ($n = 4$, $\bar{x} = 0.66$ kg ha^{-1}, SE = 7.28) ($F = 10.57$; 1,4 df; $P = 0.031$). The location by treatment interaction was not significant ($P = 0.140$). Saturated ground and cold conditions limited vegetation growth during post-treatment; we observed no differences ($P > 0.10$) among treatments. Forage availability in controls was higher during the wet conditions of 1991-92 than during 1990-91.

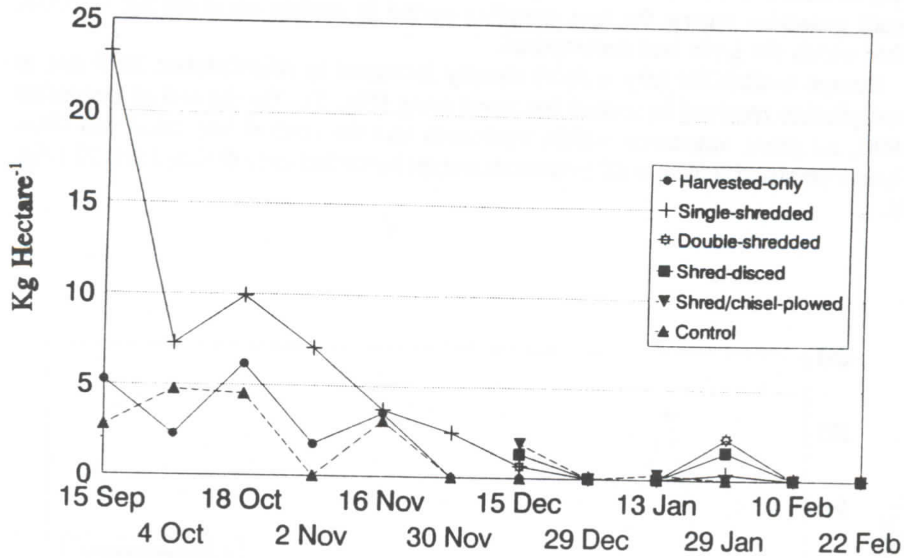

Figure 4. Post-harvest forage availability for prescribed treatments during September 1991 to February 1992.

Avian Responses to Treatments

During pre-treatment, the only differences in avian densities were between single-shredded treatments and controls. Both upland game birds (which consisted primarily of mourning doves and northern bobwhites) ($\bar{x}$ = 1.7 ha^{-1}, SE = 0.2) and nongame birds ($\bar{x}$ = 23.1 ha^{-1}, SE = 4.8) were more abundant ($P < 0.05$) in single-shredded treatments than controls (upland game birds, $\bar{x}$ = 0.6 ha^{-1}, SE = 0.4; nongame birds, $\bar{x}$ = 4.9 ha^{-1}, SE = 2.2). The location by treatment interactions were not significant for either upland game birds (P = 0.189) or nongame birds (P = 0.261). There were no differences ($P > 0.05$) among any other treatment comparisons in abundance, bird species richness, or diversity during pre-treatment.

Densities of ducks observed using the Welder study site were 5 times higher in double-shredded than single-shredded treatments (Table 3). No ducks were observed in the shred-disced treatment or control. Goose densities in double-shredded treatments were 7-8 times higher than in any other treatment and nearly 12 times higher than in the control (Table 4). Density for upland game birds in the shred-disced treatment on the Welder study site was 11 times higher than in single-shredded treatments and 7 times higher than in the control (Table 5). Upland game bird densities for double-shredded treatments averaged 6 times higher than in single-shredded treatments. Nongame bird densities in single-shredded treatments were 88 times higher than the controls (Table 6). The location by treatment interaction was not significant (P = 0.095). Nongame bird densities in single-shredded and double-

Table 2. Locations in Refugio County, Texas, involved in treatment comparisons for sorghum, forage, and bird survey analyses during September to February 1990-91 and 1991-92.

Comparison	Treatments	Years	Locations
1	Harvested-only vs Single-shredded	1990-91 1991-92	Bauer Ermis
		1991-92	Franke
		1990-91	Gillespie
		1990-91	Mathis
		1991-92	Teril
		1991-92	Welder
		1990-91	Wendlend
2	Single-shredded vs Control	1990-91 1991-92 1991-92 1991-92	Bauer Ermis Franke Welder
3	Double-shredded vs Shred-disced vs Control	1991-92 1991-92	Teril Welder
4	Harvested-only vs Double-shredded vs Shred-disced vs Shred-chisel plowed vs Control	1991-92	Teril
5	Single-shredded vs Double-shredded vs Shred-disced vs Control	1991-92	Welder

shredded treatments on the Welder study site were 3-4 times higher than in shred-disced treatments, and 63-83 times higher than in the control (Table 6).

Single-shredded treatments averaged 1.5 times more species of birds over the entire sampling period (September-February) than harvested-only treatments during both years. Single-shredded treatments averaged almost 2 times the number of species that occurred in the controls over the entire sampling period in both years. The only difference among treatments in numbers of species (richness) observed occurred on the Welder study site ($F = 8.26$; 3,5 df; $P = 0.022$) where 1.4 times more ($P < 0.05$) and 2.5 times more ($P < 0.05$) species of birds were observed in double-shredded treatments than in single-shredded treatments or the control, respectively. Bird species richness in shred-disced treatments were 1.3 times higher ($P < 0.05$) than in single-shredded treatments and 2.3 times higher ($P < 0.05$) than the control.

Table 3. Mean densities (number ha^{-1}) and standard errors (SE) for numbers of ducks on the Welder study plots during post-treatment (December-February) surveys 1991-92, in Refugio County, Texas.

Comparison†	Treatments	n	$\bar{x}$	SE
5§	Single-shredded	5	7.36b‡	4.01
	Double-shredded	2	39.10a	11.48
	Shred-disced¶	1	0.00b	
	Control¶	1	0.00b	

†Treatment comparisons not included where no ducks were observed.
‡Means having same letter are not different ($P > 0.10$) using Scheffe's procedure.
§CR 1-way ANOVA; no treatment effect ($F = 5.30$; 3,5 df; $P = 0.052$); MSE = 116.94.
¶No standard error due to sample size = 1.

Table 4. Mean densities (number ha^{-1}) and standard errors (SE) for numbers of geese in study plots during post-treatment surveys (December-February) 1990-91 and 1991-92, in Refugio County, Texas.

Comparison†	Treatments	n	$\bar{x}$	SE
2§	Single-shredded	4	3.31a‡	1.82
	Control	4	1.30a	0.99
5¶	Single-shredded	5	4.63b	2.33
	Double-shredded	2	38.89a	13.45
	Shred-disced#	1	5.41b	
	Control#	1	3.25b	

†Treatment comparisons not included were those treatments where no geese were observed.
‡Means within each comparison with same letters are not different ($P > 0.05$) using Scheffe's procedure.
§CR 2-way ANOVA with location as 2nd factor; no interaction ($F = 0.03$; 3,4 df; $P = 0.9737$), no treatment effect ($F = 0.003$; 1,4 df; $P = 0.9547$), MSE = 27.17, $R^2 = 0.2926$.
¶CR 1-way ANOVA; treatment effect ($F = 6.51$; 3,5 df; $P = 0.035$), MSE = 94.10.
#No standard error due to sample size = 1.

Table 5. Mean densities (number ha^{-1}) and standard errors (SE) for numbers of upland game birds on study plots during post-treatment surveys (December-February) in Refugio County, Texas during 1990-91 and 1991-92.

Comparison	Treatments	*n*	$\bar{x}$	SE
1‡	Harvested-only	3	0.28a†	0.12
	Single-shredded	5	0.62a	0.37
2§	Single-shredded	4	0.09a	0.07
	Control	4	0.11a	1.73
3¶	Double-shredded	4	1.26a	0.69
	Shred-disced	5	6.04a	3.16
	Control	2	3.76a	3.61
4#	Harvested-only	3	0.40a	0.22
	Double-shredded	2	1.92a	1.41
	Shred-disced	3	7.69a	3.81
	Shred-chisel plowed	2	0.47a	0.02
	Control††	1	7.37a	
5‡‡	Single-shredded	5	0.10c	0.10
	Double-shredded	2	0.60ab	0.01
	Shred-disced	1	1.08a	
	Control	1	0.15bc	

†Means within each comparison having same letter are not different ($P > 0.05$) using Scheffe's procedure.
‡CR 1-way ANOVA; no treatment effect ($T = 0.694$; df = 6; $P = 0.514$).
§CR 2-way ANOVA with locations as 2nd factor; no interaction ($F = 0.01$; 2,4 df; $P = 0.986$), no treatment effect ($F = 0.06$; 1,4 df; $P = 0.823$), MSE = 0.049.
¶CR 2-way ANOVA with locations as 2nd factor; no interaction ($F = 0.38$; 2,4 df; $P = 0.709$), no treatment effect ($F = 0.41$; 2,4 df; $P = 0.687$), MSE = 22.74.
#CR 1-way ANOVA; no treatment effect ($F = 1.96$; 4,6 df; $P = 0.220$), MSE = 15.21.
††No standard error due to sample size=1.
‡‡CR 1-way ANOVA; treatment effect ($F = 8.50$; 3,5 df; $P = 0.021$), MSE = 0.040.

Table 6. Mean densities (number ha^{-1}) and standard errors (SE) for numbers of nongame birds in study plots during post-treatment surveys in Refugio County, Texas, December to February 1990-91 and 1991-92.

Comparison	Treatments	n	$\bar{x}$	SE
1‡	Harvested-only	3	18.45a†	6.77
	Single-shredded	5	9.68a	4.03
2§	Single-shredded	4	14.09a	2.93
	Control	4	0.16b	0.07
3¶	Double-shredded	4	18.90a	4.00
	Shred-disced	5	20.69a	4.74
	Control	2	3.53a	3.24
4#	Harvested-only	3	18.31a	11.25
	Double-shredded	2	13.67a	6.45
	Shred-disced	3	25.80a	19.55
	Shred-chisel plowed	2	10.16a	6.20
	Control‡‡	1	6.77a	
5††	Single-shredded	5	18.32a	1.49
	Double-shredded	2	24.14a	0.10
	Shred-disced‡‡	1	5.38b	
	Control‡‡	1	0.29c	

†Means within each comparison having same letters are not different ($P > 0.05$) using Scheffe's procedure.
‡CR 1-way ANOVA; no treatment effect ($T = 1.201$; df = 6; $P = 0.275$).
§CR 2-way ANOVA with locations as 2nd factor; no interaction ($F = 4.49$; 2,4 df; $P = 0.095$); treatment effect ($F = 10.73$; 1,4 df; $P = 0.031$), MSE = 11.07.
¶CR 2-way ANOVA with locations as 2nd factor; no interaction ($F = 0.35$; 2,4 df; $P = 0.725$), no treatment effect ($F = 0.27$; 2,4 df; $P = 0.776$), MSE = 594.38.
#CR 1-way ANOVA; no treatment effect ($F = 0.21$; 4,6 df; $P = 0.921$) MSE = 535.61.
††CR 1-way ANOVA; treatment effect ($F = 19.52$; 3,5 df; $P = 0.003$), MSE = 8.86.
‡‡No standard error due to sample size=1.

Bird species richness and diversity were summarized across locations (Table 7) to better show patterns among treatments, although statistical tests for these pooled data were not appropriate. Mean number of species observed during post-treatment was highest for the double-shredded treatment during 1991-92. Bird species diversity averaged higher in all treatments than in controls. The five treatments had average diversity values ranging from 1.23-1.87, while the controls had an average diversity value of 0.76.

Table 7. Mean diversity and species richness, and standard errors (SE), for five treatments and control (all locations pooled) during post-treatment surveys on study plots in Refugio County, Texas, December to February 1990-91 and 1991-92.

Treatment	Diversity†		Species richness		n‡
	$\bar{x}$	SE	$\bar{x}$	SE	
Harvested-only	1.24	0.17	7.67	1.53	5
Single-shredded	1.59	0.16	10.80	1.64	10
Double-shredded	1.87	0.14	11.50	4.20	4
Shred-disced	1.42	0.16	8.75	3.86	4
Shred-chisel plowed	1.23	0.21	6.00	0.00	2
Control	0.76	0.19	5.50	0.71	5

†Shannon index was calculated for each treatment area.
‡n = number of treatment areas.

DISCUSSION

Combine efficiency, moisture content of grain, insects, and disease are factors that determine waste grain availability during harvest. Waste grain availability following harvest is affected by several other factors, the most obvious being post-harvest cultivation practices. Nearly all cropland in southern Texas is cultivated throughout fall and winter if weather permits. Fall cultivation buries available seed, and the degree of cultivation determines how much grain will remain available. Warner et al. (1985) found that even intermediate tillage systems reduced waste corn and soybean abundances by 90% and 74%, respectively.

In southern latitudes where winters are mild, precipitation following harvest can affect grain availability. Moisture can cause sprouting of sorghum seeds within 24 hours, and accelerate decomposition of grain that is on the ground. Seed heads still on the plants can also be affected by prolonged saturation of soils. Several study sites during the wet fall of 1991-92 were saturated for an extended period of time (2 weeks or more). Seed heads on the plants grew a fungus and rapidly rotted.

The two years of the study show results of dry and wet conditions. During the dry conditions of 1990-91, some grain remained available through February. However, above-normal precipitation during 1991-92 accelerated moisture-related decay of grain and all available grain had disappeared by the end of November 1991.

Forage availability after harvest is also affected by precipitation. Precipitation is not only required for vegetation growth, but also prevents farmers from cultivating fields. Disced fields throughout Refugio County were void of vegetation throughout fall and winter 1990-91, and our controls had no forage growth. Forage growth was evident in most disced fields throughout the county during 1991-92, and our controls had noticeable growth through November. Forage growth was lower in treatment areas that contained heavy harvest residues, probably because the residue prevented light penetration to the soil.

Experimental studies suggested that the double-shredded treatment was the most productive way to manage sorghum for waterfowl. Shred-disced treatments were mostly used by upland game birds, and nongame birds benefitted the most from single-shredded and double-shredded treatments. Double-shredded or shred-disced treatments provided the best cost benefit because they are intermediate steps in current post-harvest farming practices in southern Texas and are recommended for state and federal refuge croplands and set-aside lands in southern Texas.

All treatments were either harvested-only or single-shredded during pre-treatment; both treatments were similar in structure, with seed heads on standing stalks. Thus, with similar structure and no difference in grain availability, it was not surprising to find no differences in bird use. During post-treatment, there were no differences in grain or forage availability among treatments, so stubble structure appeared to be the factor affecting preference of treatments by birds. When waterfowl were found in double-shredded and shred-disced treatments and controls, they were typically found far from any cover, including standing stubble. When waterfowl occurred in treatments with standing stalks, they were in areas where the stalks had been flattened by water inundation or trampling by wild mammals.

MANAGEMENT IMPLICATIONS

Sorghum management for waterfowl and other wildlife can be beneficial, but will be practical only if valuable to farmers. Leaving stubble or any residue on fields following harvest is incompatible with current cropland management strategies of farmers in south Texas. Every farmer that planted sorghum in Refugio County was given the opportunity to leave their set-aside stubble stand after harvest for \$37-\$50 ha^{-1}. Most farmers were reluctant to change from their present practice of clean farming. According to farmers in the Coastal Bend, crop yields would be reduced about 50% (a loss of approximately \$125 ha^{-1}) the following year if fields were not kept clean of residue and green vegetation. However, several studies have shown reduced tillage practices for grain sorghum can increase crop yields over conventional tillage and improve the physical condition of the soil (Bremer, 1976; Unger et al., 1989; Matocha et al., 1990; Landivar et al., 1990). These increases in yields are brought about by increases in the storage of soil moisture due to residues left on the fields. Farmer education and research showing advantages of crop residue management through limited and/or conservation tillage practices are needed in order to change land management practices for both soil conservation and wildlife benefits.

Our experimental studies showed double-shredding to be the best treatment for both ducks and geese. However, hunting migratory birds on or near double-shredded fields may be perceived as baiting, a violation of federal game laws (T. Mason, U.S. Fish and Wildl. Serv. Spec. Agent, pers. commun.). Managers contemplating use of double-shredding as a sorghum-management tool should consider this baiting issue if nearby hunting is likely. In areas where double-shredding may not be appropriate, the shred-disced treatment was the next best treatment.

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