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TEMPORAL DISTRIBUTION OF HARVESTED MID-CONTINENT SANDHILL CRANES WITHIN THE CENTRAL FLYWAY STATES DURING THE 1997-2001 HUNTING SEASONS

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Abstract: Since 1975, annual harvest estimates for Mid-Continent sandhill cranes (*Grus canadensis*) have been collected in all states for which a hunting season has been authorized by the U.S. Fish and Wildlife Service (Service). Although these data have been used to monitor the harvest of the Mid-Continent population, analyses to promote understanding of the temporal distribution of harvested sandhill cranes by individual states throughout the Central Flyway have not been conducted. For the 1997-2001 hunting seasons, we collected harvest questionnaires from 4,408 hunters in the Central Flyway who provided information about the date, location, and number of harvested sandhill cranes on 12,639 hunt days. We calculated the number of cranes harvested on each date over the 5-year period to identify the temporal distribution of crane harvest throughout the flyway and by state. The greatest proportion of hunt days occurred in North Dakota (37%), Texas (27%), and Kansas (17%), with the remaining proportion (19%) occurring in 6 other Central Flyway states. North Dakota, Texas, and Kansas hunters also harvested the greatest number of cranes, comprising nearly 84% of the harvest and providing the richest data sets for analyses. We fit models to these data to assess the potential changes to harvest that may occur if federal framework dates were more restrictive, and possible harvest impacts that might result by reducing the number of hunt days available (i.e. season lengths) by weekly segments. Results from these analyses may provide an additional tool for harvest managers to consider in the event that changes in levels of harvest on this population are warranted in the future.

Key words: Central Flyway, *Grus canadensis*, harvest management, hunting, regulations, sandhill crane.

Throughout its range, the Mid-Continent population of sandhill cranes (MCP) has traditionally been hunted for food and recreation. In 1916, both the U.S. and Canadian governments banned the hunting of cranes because their numbers had severely declined, largely as the result of market hunting. In 1961, hunting seasons for sandhill cranes in the U.S. were authorized in portions of New Mexico and Texas in response to complaints of crop damage on wintering grounds. Three years later, Canada initiated its first hunting season in Saskatchewan, also to reduce crane depredations on small grains (Stephen 1967). Within the U.S., the MCP occupies an extensive portion of the Central Flyway (Fig. 1). Interest in hunting continued to increase within the flyway, and after New Mexico and Texas resumed hunting, portions of 7 other states were also authorized to establish seasons (Colorado: 1967; North Dakota, South Dakota, and Oklahoma: 1968; Montana and Wyoming: 1972; Kansas: 1993) (Fig. 2). This increase in state and, therefore, hunter participation, led to an increase in harvest levels (Sharp and Vogel 1992). To develop estimates of the number of cranes harvested, a permit system was implemented in 1975. Sandhill crane hunters were required to obtain a federal sandhill crane hunting permit, or in recent years, register as a crane hunter under the Harvest Information Program (HIP). After each hunting season, a sample of identified crane hunters was mailed a questionnaire asking for information about their hunt season, and estimates of harvest and daily bag success were reported for each state (Sorensen and Reeves 1976, Martin 2004). Details of the survey design and sampling methodology are provided in Office of Migratory Bird Management (1976) and Martin (2004).

During the 1975-2005 seasons, the harvest of MCP cranes generally increased (Sharp et al. 2006). This trend has been attributed to the increase in hunting opportunity and improved knowledge of crane behavior and hunting techniques (Sharp and Vogel 1992). To better understand the increasing trends in harvest levels, we analyzed data from post-season questionnaires acquired from Central Flyway hunters for the 1997-2001 hunting seasons. We fit statistical models to these data to identify temporal distributions of harvested cranes within each state and throughout the flyway. Assuming that the 1997-2001 hunting-season structures and associated harvest distributions are representative of future years, these models may be useful to managers in developing regulatory alternatives to achieve desired changes in harvest, should such changes be warranted in the future. Better information on the effects of regulations on harvest will enhance our ability to manage the MCP within desired levels of abundance.

METHODS

For the 1997-2001 hunting seasons, we acquired 4,408 harvest questionnaires from those states having a crane season in the Central Flyway (Fig. 2) from the Waterfowl Harvest Surveys Section of the Service in Laurel, Maryland. We encoded all
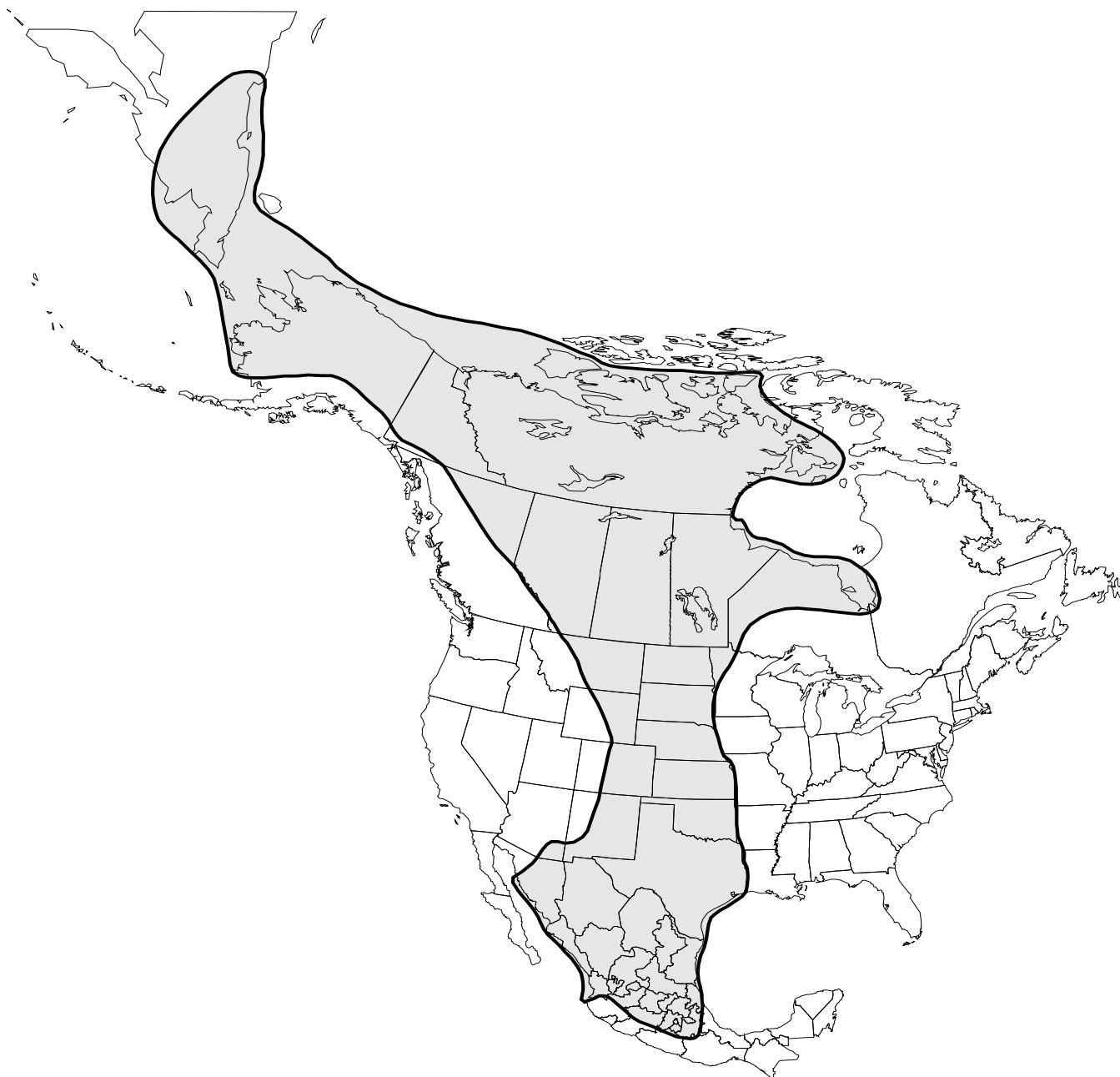
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Figure 1. Range of the Mid-Continent sandhill crane population (from Sharp et al. 2006).

information reported on the questionnaire, including the date, number, and location of harvested cranes, into an electronic database (Microsoft Access), which ultimately was comprised of 12,639 individual hunter-day records. Responses were accepted as presented, and we made no adjustments to the data for memory, exaggeration, or other possible biases. However, hunter-reported harvests in states on any date outside the legal hunting season dates for cranes were deemed as mistakenly and incorrectly documented by the hunter and excluded from the data set. We converted all calendar dates to Julian dates.

Because Julian dates of the days of the week change each year, and daily migratory bird harvests are influenced by the day of the week (M. Moore, Harvest Surveys Section, personal communication), we adjusted all Julian dates for the 12,639 recorded hunt days to correspond to the same day of the week across years. We then summed all harvests over the 5-year period to identify the temporal distribution of harvested cranes throughout the flyway and within each state.

Each year, federal regulations specify the framework dates (i.e. the earliest and latest dates on which sandhill cranes can
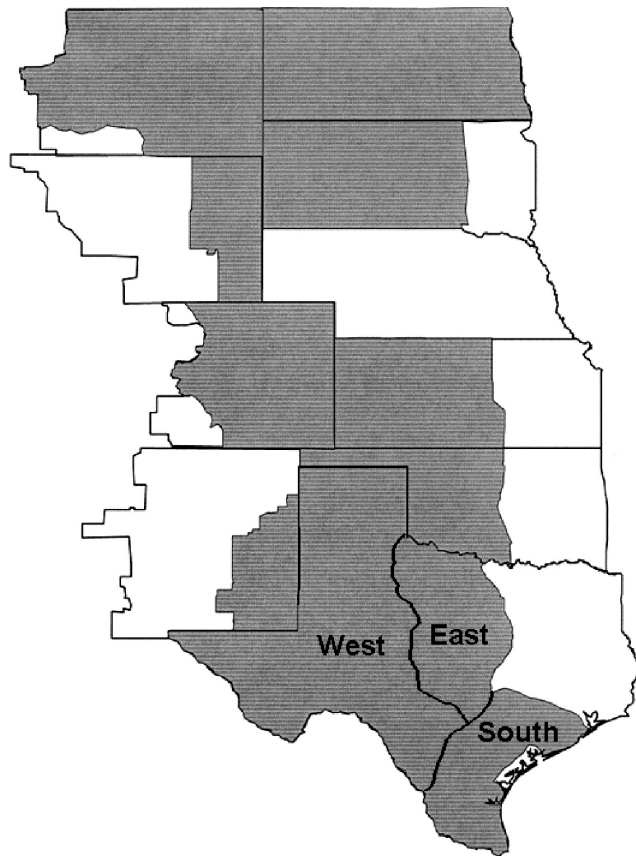
Figure 2. Areas open for hunting of Mid-Continent sandhill cranes in the Central Flyway states, 2005 (from Sharp et al. 2006).

be hunted) for crane hunting, and each state is allowed to select a season within those dates. Flyway framework dates and state-specific season selections within those frameworks were available in Sharp et al. (2006). We used SigmaPlot (SPSS Inc. 1999) to fit linear and nonlinear models to the data to describe levels and distributions of harvests over all 5 hunting seasons combined. Since 1983, generally only minor adjustments have been made to season dates, usually in an attempt to open and close seasons on a certain day of the week (Sharp and Vogel 1992). Thus, using the distributions of crane harvest and associated models, we could assess the amount of harvest encompassed by various time periods within the framework dates. Assuming that amounts of harvest within specified periods would be comparable to those which would occur if these periods were closed to hunting, we estimated the potential reduction in harvest if framework dates were more restrictive (i.e. crane hunting seasons opened later and/or closed earlier) and if season lengths within states were shorter.

RESULTS

Because states generally select their annual hunting season dates based on the migration chronology of the MCP as they migrate from their northern breeding grounds to their wintering areas in the south, the distribution of harvests within the Central Flyway tend to follow that chronology. Each year, states within the Central Flyway select their hunting seasons within the established federal framework dates of 1 September to 28 February. Plotting the information from the harvest questionnaires during the 1997-2001 hunting seasons (Fig. 3), we were able to assess the potential impacts to harvest by restricting the federal framework dates. Changing the opening framework date to 1 week later (i.e. 8 September) and moving the closing framework date to 1 week earlier (i.e. 21 February) suggested that about a 0.2% reduction in harvest might be realized. Restricting the framework dates by 2 weeks at the opening and 2 weeks at the close of the season suggested a 0.8% reduction in harvest. Changing framework dates by 3 weeks at each end of the season suggested a nearly 4% reduction in overall harvest, whereas a change of 4 weeks at each end resulted in a 9% reduction. Assuming that the temporal distribution of harvest would not differ significantly if the outside dates were more restrictive, our results suggest that a substantial restriction in the federal framework dates would be necessary to effect a modest reduction in harvest. This result occurs because states tend not to select the earliest or latest dates available (Fig. 4). As expected, harvests in states at the northernmost and southernmost portions of the flyway would be most impacted, whereas harvests in states situated in the middle of the flyway would largely be unaffected unless large changes in framework dates were enacted.

The largest proportions of hunt days occurred in North Dakota (37%), Texas (27%), and Kansas (17%) with the remaining proportion (19%) occurring in 6 other Central Flyway states. Hunters in North Dakota, Texas, and Kansas also harvested the greatest number of cranes, collectively comprising nearly 84% of the harvest. Therefore, these states provided the richest data sets for developing models (Table 1) and for estimating potential changes in harvest resulting from reducing season lengths within each state by 1 week at the beginning of the season, 1 week at the end of the season, or 1 week at both ends of the season (i.e. 2-wk reduction in season length).

We fit linear or nonlinear models to harvest-distribution data for all states in the Central Flyway. However, the fit of the models varied based on the amount of data available for each state and the temporal distribution of the harvest. Nonlinear models were fairly symmetrical and explained the data well for North Dakota ($R^2 = 0.73$, $P < 0.01$) and South Dakota ($R^2 = 0.70$, $P < 0.01$) (Figs. 5, 6). North Dakota has 2 designated hunting areas; however, the season selection
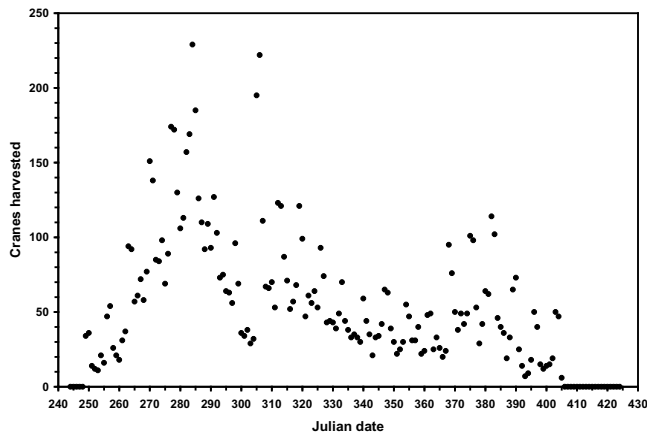
Figure 3. Temporal distribution of Mid-continent sandhill crane harvests in the Central Flyway, 1997-2001.
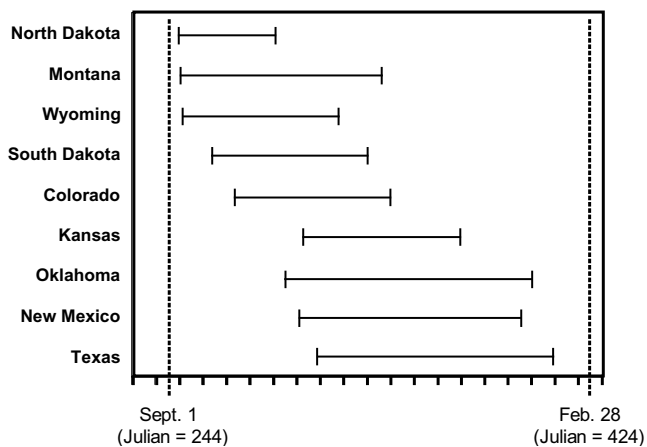

Figure 4. Earliest and latest crane hunting dates selected by Central Flyway states during 1997-2001.
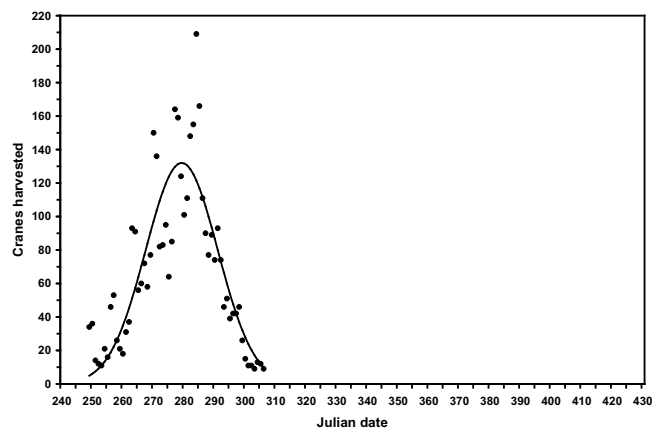

Figure 5. Model fit to sandhill crane harvest data reported by hunters in North Dakota during 1997-2001.

dates are nearly identical so data for each were consolidated. The model for Montana (Fig. 7) also suggested a symmetrical harvest distribution, but the model fit was much poorer ($R^2 = 0.36$, $P < 0.01$), likely due to far fewer data points available for that state. For Kansas, the best model ($R^2 = 0.67$, $P < 0.01$) suggested a curvilinear decline from the first part of November through the end of the calendar year (Fig. 8). This response likely is due to Kansas voluntarily delaying the start of their seasons, despite sandhill cranes being in the state, to afford additional protection to the endangered whooping crane (*Grus americana*); hunting starts around the time of peak crane populations in the state and sandhill crane abundance declines thereafter. Texas has 3 hunting areas with different season lengths and/or bag limits. Like Kansas, 2 of the areas have season-date restrictions that protect the whooping crane from being accidentally shot during times when sandhill cranes may also be present. Because the season selections within Texas were quite different, we fit models to the data in each of the 3 areas separately. In the western most zone, the best-fitting model ($R^2 = 0.13$, $P < 0.01$) suggested a fairly symmetrical harvest distribution with a peak near the middle of the season (Fig. 9). The model that best fit the distribution of the southern zone harvest indicated a linear decline during the hunting season ($R^2 = 0.27$, $P < 0.01$). The model fit for harvest in the remaining zone was poor ($R^2 = 0.02$) and was not statistically significant ($P = 0.17$). We attempted to fit several models to the data for Oklahoma, and all fit poorly. Based on coefficients of determination, a linear model fit the data as well as any nonlinear model we attempted (Fig. 10). Nonetheless, the model fit was relatively poor ($R^2 = 0.14$, $P < 0.01$). We also fit nonlinear models to harvest data for Colorado ($R^2 = 0.08$, $P = 0.05$), Wyoming $R^2 = 0.07$, $P = 0.05$), and New Mexico $R^2 = 0.21$, $P < 0.01$), but fits generally were poor (Figs. 11-13).

Because the model fits to data varied considerably across states, and because we wanted to provide information for each state in the flyway, we chose not to use model-based estimates to predict levels of harvest reductions. Instead, we assumed that reducing the season lengths on each end of the season by 1 week would result in proportional reductions in harvest equal to actual harvests encompassed by those periods observed during the 1997-2001 hunting seasons combined. Due to the differences in season structure among the 3 crane hunting zones in Texas, we estimated reductions for each zone independently and then summed the reductions to obtain overall percentage changes for the state. Results suggest that the largest percentage reductions in harvest by delaying the opening date 1 week would occur in Kansas, Montana, and Colorado (Table 2). However, few birds are harvested in Montana and Colorado, so these relatively large percentages translate into few birds. The very large reduction in Kansas is the result of their delayed opening date, so that many sandhill

cranes already are in the state at the time of their season opening date. In contrast, in most other states (except for the eastern zone in Texas), season opening dates appear to occur prior to large influxes of cranes into the hunt areas. Thus, crane abundance, and hence harvest, builds to peak levels sometime during the middle of the hunting season. In contrast to relatively large reductions by removing days from the beginning of crane hunting seasons, most states had relatively small percentage reductions in harvest if the last week of the season were removed (Table 2). The largest decreases were in Texas and Wyoming, but estimates for most states were in the 1% to 5% range. If both the first and last weeks of the season were removed (i.e. a reduction in season length of 14 days), the largest declines would be expected in Kansas and Texas. If season-length reductions were simultaneously applied in all states, potential decreases in harvest might reach 11.5%, 4.4%, and 15.9%, respectively, for restricting opening, closing, and both ends of the season by 1 week.

DISCUSSION

We note that a basic assumption of our analyses is that the temporal distribution of crane harvests for the Central Flyway and within each state would be similar if changes to

Table 2. Percent reductions in harvests estimated from reducing season lengths by 1 week at the beginning of the crane hunting season, 1 week at the end of the season, and 1 week at both ends of the season, using data on the temporal distribution of state-specific harvests observed during 1997−2001.

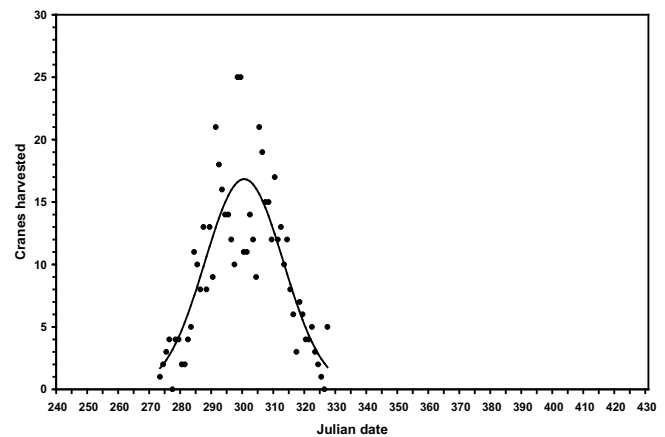| State	Restriction		
	Opening date	Closing date	Both
North Dakota	-3.9	-2.8	-6.7
South Dakota	-1.9	-3.9	-5.8
Montana	-13.5	-1.4	-14.2
Kansas	-32.9	-1.2	-34.1
Texas	-11.3	-9.4	-20.7
Oklahoma	-11.0	-3.9	-15.0
Colorado	-12.5	-4.5	-17.0
Wyoming	-3.2	-8.1	-11.3
New Mexico	-7.9	-3.0	-10.9
Total	-11.5	-4.4	-15.9

Figure 6. Model fit to sandhill crane harvest data reported by hunters in South Dakota during 1997-2001.
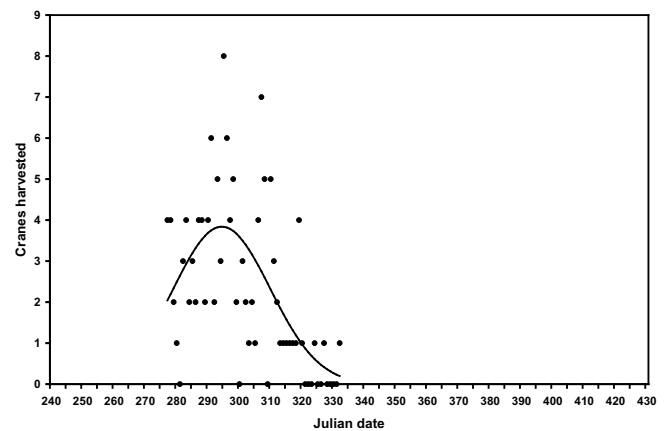

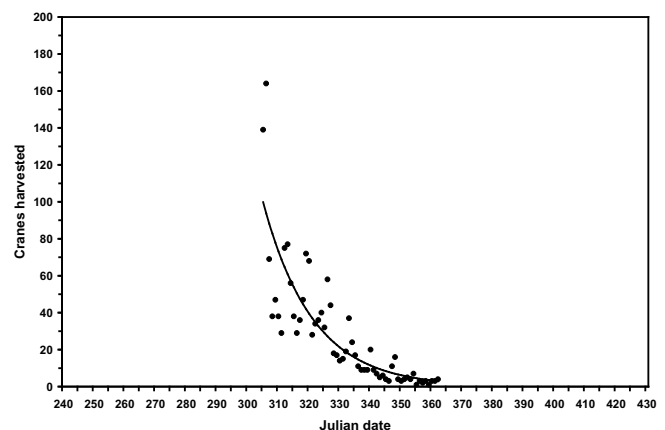Figure 7. Model fit to sandhill crane harvest data reported by hunters in Montana during 1997-2001.

Figure 8. Model fit to sandhill crane harvest data reported by hunters in Kansas during 1997-2001.

Table 1. Number of records (total *n* = 12,639) with complete information for harvests of sandhill cranes of the Mid-Continent Population in the Central Flyway, 1997–2001.

State	Total records in 5 yr	% of total	Hunting season	Annual records
Colorado	110	0.87	1997	39
			1998	5
			1999	13
			2000	0
			2001	53
Kansas	2,148	17.00	1997	417
			1998	486
			1999	338
			2000	401
			2001	506
Montana	313	2.48	1997	26
			1998	18
			1999	24
			2000	129
			2001	116
North Dakota	4,610	36.47	1997	644
			1998	900
			1999	607
			2000	1,070
			2001	1,389
New Mexico	442	3.50	1997	62
			1998	63
			1999	78
			2000	144
			2001	95
Oklahoma	797	6.31	1997	121
			1998	112
			1999	182
			2000	144
			2001	238
South Dakota	700	5.54	1997	63
			1998	144
			1999	124
			2000	207
			2001	162
Texas	3,447	27.27	1997	743
			1998	754
			1999	586
			2000	701
			2001	663
Wyoming	72	0.57	1997	4
			1998	0
			1999	1
			2000	28
			2001	39

framework dates and season lengths are enacted. The validity of our estimates will be affected by the extent to which states alter their season selections and bag limits in response to changes in framework dates and season lengths, or if hunter effort changes as a result of changes to season structures. Nonetheless, to our knowledge this paper represents the first attempt at describing temporal changes in harvest throughout MCP crane hunting seasons. Thus, we believe our results provide a useful starting point for discussions about the effects of altering crane hunting framework dates and season lengths to effect changes in harvests of MCP sandhill cranes.

Regulations, including season lengths and bag limits, assist in the conservation of the MCP sandhill cranes. Estimates of annual harvest are an important component in managing for a stable abundance, especially because over harvest may adversely influence breeding and recruitment rates (Lewis 1977, Tacha et al. 1985). Annual indices to abundance have been relatively stable since the early 1980s (Sharp et al. 2006), but recent analyses of long-term trends (1982-2004) indicate that harvests of the MCP have been increasing at a higher rate (+2.6% per year, $P < 0.01$) than population growth (+0.7% per year, $P = 0.20$). Further, consecutive record-high numbers of active hunters in the Central Flyway were estimated during the last 3 crane seasons (Sharp et al. 2006). In a related study, analyses of data from the1997-2001 harvest questionnaires indicated that successful hunters (i.e. those harvesting ≥ 1 crane per season) were unable to harvest a crane on far fewer days than in the early 1980s, and were much more successful in harvesting 2 or 3 birds per day (Dubovsky and Araya 2008).

The Management Guidelines for the MCP state that changes to the annual hunting regulations should be considered when the 3-year running average of abundance is above or below the population objective of between 349,000 and 472,000 cranes (Central Flyway Council, Pacific Flyway Council, and Mississippi Flyway Council 2006). The most recent photo-corrected estimate of MCP abundance for 2005 revealed a count of 491,900 cranes and a running 3-year average of 422,133 birds (Sharp et al. 2006). However, if diverging trends in crane harvest and abundance continue, changes in hunting regulations may be necessary to maintain numbers of cranes within the management objective.

Our results suggest that restricting opening and closing framework dates would be relatively ineffective at reducing harvests of MCP cranes because few states select seasons that either begin or end near those dates. In fact, rather large changes in framework dates (3-4 weeks at both ends of the season) would be needed to effect even modest (4% to 9%) reductions in harvest. Additionally, restricting framework dates would disproportionately affect states at the northern and southern ends of the flyway, whereas states in the middle of the flyway likely would see no reduction in harvest. A more efficacious and perhaps equitable way to reduce harvests may

be to reduce season lengths within each of the states. Just a 1-week reduction in season length might result in 4% to 15% reductions in harvests for each state. However, many combinations of restrictions are possible, all of which suggest different magnitudes of changes in harvest. Managers should work cooperatively so that changes in season structures would achieve not only desired changes in harvest, but also provide mutually agreed to opportunities to harvest cranes among states throughout the Central Flyway.

In addition to states in the Central Flyway, MCP cranes also are harvested in other parts of its range. As mentioned previously, hunting in Canada resumed in 1964 and estimates of retrieved harvests have been monitored in Saskatchewan and Manitoba since 1967. Harvest also occurs in portions of the Pacific Flyway in Alaska and in areas where the MCP co-mingles with the Rocky Mountain Population (RMP) in portions of Arizona and New Mexico. During the last decade, the retrieved harvest in these areas has averaged only about 5.5% of the total U.S harvest (data from Sharp et al. 2006). Unlike the U.S. and Canada, an annual harvest survey in Mexico does not exist. However, Mexico harvests are assumed to be 10% of harvests in the U.S. and Canada (R. Drewien, Wayan, Idaho, personal communication). Thus, except for Canada, harvest in these other survey areas is relatively small. The retrieved harvest of MCP cranes in Canada has increased in recent years (R^2 = 0.82, P < 0.01 during 1993-2005) and currently comprises about 35% to 40% of the retrieved continental sport harvest annually. This trend suggests that Canadian harvest managers may want to conduct analyses analogous to those described herein to determine how changes in their season structures may affect MCP crane harvests.

ACKNOWLEDGMENTS

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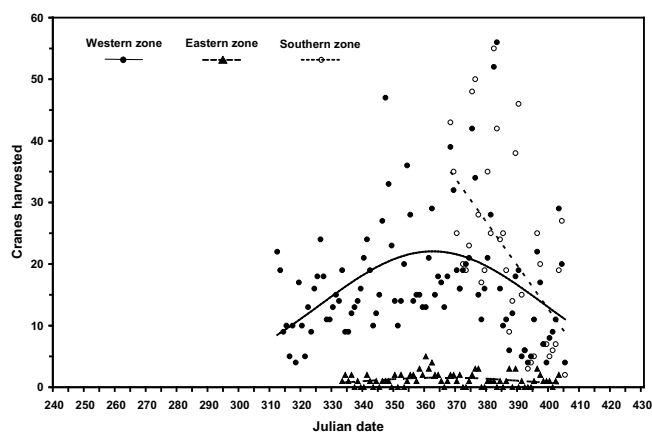
Figure 9. Model fit to sandhill crane harvest data reported by hunters in Texas during 1997-2001.
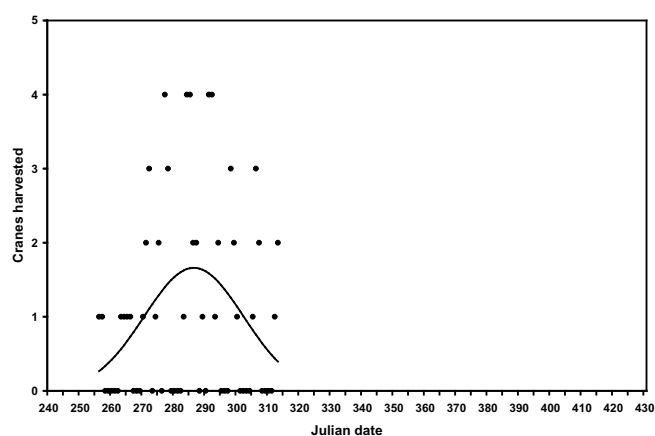

Figure 12. Model fit to sandhill crane harvest data reported by hunters in Wyoming during 1997-2001.
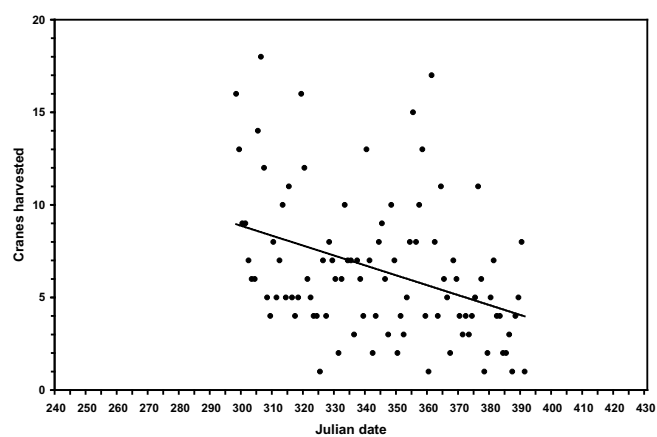

Figure 10. Model fit to sandhill crane harvest data reported by hunters in Oklahoma during 1997-2001.
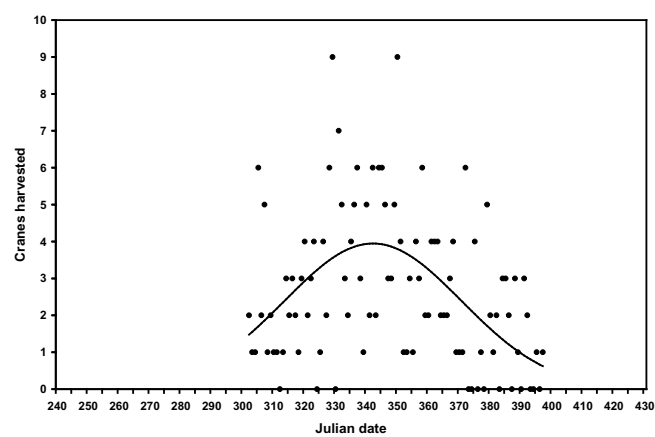

Figure 13. Model fit to sandhill crane harvest data reported by hunters in New Mexico during 1997-2001.
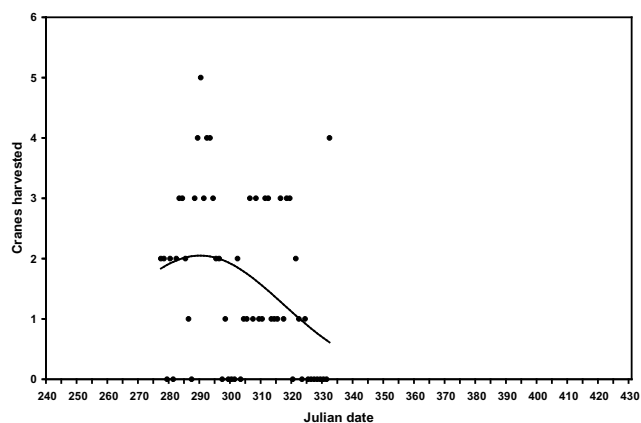

Figure 11. Model fit to sandhill crane harvest data reported by hunters in Colorado during 1997-2001.