TIME-SERIES ANALYSIS AND FORECASTING OF THE ARANSAS/WOOD BUFFALO WHOOPING CRANE POPULATION

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ABSTRACT: Several time-series statistical procedures demonstrate 10-year periodicity in relative abundance of whooping cranes (Grus americana) censused at Aransas National Wildlife Refuge, Texas (Boyce and Miller 1985). Such periodicity can only be detected after appropriate transformation (either log or square-root) and detrending of the data. Failure to perform necessary transformations accounts for the inability of Miller et al. (1974) to detect the pronounced periodicity. Forecasts based upon a periodic ARIMA model have lower variance than when not including the 10-year periodicity. Forecasts entail several critical assumptions, but may have value in assessing the effectiveness of management programs. For example, ARIMA model forecasts predict declines in growth rate at 10-year intervals which should not be attributed to failure of population/habitat management efforts. Reasons for 10-year cycles in whooping crane census are unknown. Data are not inconsistent with an explanation based upon periodic risks to predation as a consequence of 10-year periodicity in abundance of mammalian carnivores on nesting grounds. Further research to identify mechanisms behind whooping crane population periodicity may suggest management strategies to secure survival of the whooping crane.

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In a special issue of the Journal of Wildlife Management (vol. 19, no. 1) devoted to population cycles, Lamont Cole (1954) pointed out that, for a randomly-generated sequence of hypothetical population sizes, the average number between peaks converges on 3 years. Cole deduced that many of the population cycles claimed to occur in nature are not genuine cycles but rather are stochastic fluctuations in autocorrelated data. There is no justification for such a view because statistical procedures for detecting cyclic oscillations (periodicity) in a time-series are well known. In fact, one of these procedures, autocorrelation, was introduced into the field of ecology by Moran (1949), who incidentally also had a paper in the same issue of the Journal of Wildlife Management in which Cole published his misleading paper (Moran 1954). As Moran pointed out, counting the number of years between peaks in density does not constitute a satisfactory approach to studying a time-series; time-series statistical procedures use all data points to assess existence of periodicity.

It is not clear to me why so many ecologists overlooked Moran's work, but quickly embraced Cole's. Cole's paper was easier reading, and, because of the difficulty ecologists have explaining population cycles, I suspect many were relieved by the suggestion that population cycles were simply random. Nevertheless, to this day many ecologists are of the opinion that population cycles are imaginary, i.e., true population cycles do not exist, and that fluctuations in population size which appear to be repeated are actually just random, autocorrelated series.

Obviously not all populations exhibit truly cyclic fluctuations in size, and failure to employ appropriate statistical analyses has led to claims that some populations were cyclic when they were not, e.g., some microtine rodent populations (Garsd and Howard 1981). Some are cyclic, others not. However, there is solid statistical basis for the existence of cyclic fluctuations in populations of several vertebrate species (Bulmer 1974, Sauer and Boyce 1979, Finerty 1980, Garsd and Howard 1981, Roseberry and Klimstra 1984), the most pronounced and best studied being the 10-year cycle in lynx (Elton and Nicholson 1942, Schaffer 1984, 1985). In this paper I discuss aspects of 10-year periodicity for the Aransas/Wood Buffalo whooping crane population (Boyce and Miller 1985). Factors underlying this periodicity are unknown, but I emphasize the potential management significance for their discovery.

Rod Drewein convinced me to prepare this paper. I thank Jim Lewis and Tom Stehn for reviewing the manuscript and for verifying the data in Table 1 against original U. S. Fish and Wildlife Service files. Discussions with William M. Schaffer greatly improved my appreciation for nonlinear dynamics.

ANALYSIS

A time-series is simply a sequence of observations ordered through time. Analysis of a time-series is greatly facilitated if data are procured at regular intervals over a long time. Procedures have been developed for detection of trends in a time series, and for statistical detection of periodicity of "cycles". For the latter, it is essential that the time-series be "stationary", meaning free from trends. If a trend exists, tests for periodicity must be preceded by detrending via differencing or regression analysis to achieve stationarity. Such "massaging" of data does not destroy its periodic structure, but rather simply removes trends which would dominate the analysis.

An additional assumption for a valid time-series analysis is that deviations from mean population size be normally distributed (Bloomfield 1976). Most population time-series possess a positive skew due to the nature of exponential population growth (Williamson 1972). Therefore, logarithm or square root transformations of population statistics are often necessary before a valid time-series analysis can be performed.

In this paper I describe aspects of an analysis of the winter whooping crane census statistics compiled annually at Aransas National Wildlife Refuge, Texas. Miller et al. (1974) performed the first time-series analysis of the whooping crane census, reporting:

> "Inspection of the curve of population growth suggests that marked decreases in total numbers occur at approximately 10-year intervals. However, a time-series analysis of the data shows little correlation between events 10 years apart, and there is a change from only a slightly negative to a slightly positive correlation around these 10-year intervals. There is, therefore, no reason to regard these fluctuations as non-random at the present time....these decreases do not have a significant periodicity."

At the time that the Miller et al. (1974) paper appeared, I was a graduate student at Yale, taking a course in time-series analysis from John Hartigan. I attempted to repeat their analysis, but instead found a very pronounced and statistically significant 10-year periodicity. Roy Mendelssohn (third author on the Miller et al. paper) was also a graduate student at Yale at that time, and was responsible for the conclusions quoted above. Mendelssohn failed to detect the periodic pattern because he neglected to perform essential transformations before calculating an autocorrelation function for the time-series. Consequently, his autocorrelations were dominated by large values.

I was reluctant to publish the results of my analysis because the time-series only contained 35 years, or 3 1/2 cycles. Naturally, the longer the time-series the more confident one can be about a periodic pattern, and the actual length of the period. However, last year, after an additional 10 years had elapsed, I had another look to discover that the periodicity was maintained. This time we decided to publish the results (Boyce and Miller 1985).

CLEANING UP THE DATA

Before conducting further analysis of the time-series, careful scrutiny of the data seems appropriate. First, note that the data presented in Table 1 of Miller et al. (1974) and in Table 1 and Figure 3 of Binkley and Miller (1983) have many discrepancies. For this reason, in Table 1 I present the updated census data correcting several typographical errors in both Miller et al. (1974) and Binkley and Miller (1983).

The quality of the census statistics in recent years is high, usually based upon weekly aerial surveys, and we can assume that error is probably low. Nevertheless, it is still possible that some birds do not overwinter with the main flock in the vicinity of Aransas National Wildlife Refuge; it has been speculated that some birds may have migrated into Mexico (Allen 1952). Earlier counts, however, were not performed with as much effort, in part because less money was allocated to aerial surveys necessary to achieve reliable counts (Tom Stehn, pers. comm.). Although there is no way to know the actual magnitude of errors, at least one count is obviously in error, and two others appear suspect. Note that in 1945 (Table 1), only 14 adult-plumage and 3 juvenile-plumage birds were counted. Yet, in 1946, 22 adult-plumage birds were counted! Based upon the 1945 counts, the maximum possible number of adult birds is 17 assuming 100% survival of juvenile and adult birds. Obviously, at least five birds of unknown age went uncounted in 1945 if the 1946 count was correct.

Table 1. Peak numbers of whooping cranes alive in the vicinity of Aransas National Wildlife Refuge each winter, 1938-1985, updating and correcting statistics printed in Miller et al. (1974) and Binkley and Miller (1983). Statistics for 1941-42 and 1945-46 have been adjusted as described in the text; original figures in parentheses.

Winter	Adult plumage	Young	Total	% young
1938-39	14	4	18	22.2
1939-40	15	7	22	31.8
1940-41	21	5	26	19.2
1941-42	14(13)	2	16(15)	12.5
1942-43	15	4	19	21.1
1943-44	16	5	21	23.8
1944-45	15	3	18	16.7
1945-46	18(14)	4(3)	22(17)	23.5
1946-47	22	3	25	12.0
1947-48	25	6	31	19.4
1948-49	27	3	30	10.0
1949-50	30	4	34	11.8
1950-51	26	5	31	16.1
1951-52	20	5	25	20.0
1952-53	19	2	21	9.5
1953-54	21	3	24	12.5
1954-55	21	0	21	0.0
1955-56	20	8	28	28.6
1956-57	22	2	24	8.3
1957-58	22	4	26	15.4
1958-59	23	9	32	28.1
1959-60	31	2	33	6.1
1960-61	30	6	36	16.7
1961-62	34	5	39	12.8
1962-63	32[a]	0	32	0.0
1963-64	26	7	33	21.2
1964-65	32	10	42	23.8
1965-66	36	8	44	18.2
1966-67	38	5	43	11.6
1967-68	39	9	48	18.8
1968-69	44	6	50	12.0
1969-70	48	8	56	14.3
1970-71	51	6	57	10.5
1971-72	54	5	59	8.5
1972-73	46	5	51	9.8
1973-74	47	2	49	4.1
1974-75	47	2	49	4.1
1975-76	49	8	57	14.0
1976-77	57	12	69	17.4
1977-78	62	10	72	13.9
1978-79	68	7	75	9.3
1979-80	70	6	76	7.9
1980-81	72	6	78	7.7
1981-82	71	2	73	2.7
1982-83	67	6	73	8.2
1983-84	68	7	75	9.3
1984-85	71[b]	15	86	17.4

[a] Possibly two additional adults sighted near Tampico, Mexico. Not included due to questionable nature of report.
[b] Includes one subadult killed by a predator at Aransas, ca. 14 November 1984.

Errors could potentially occur in both directions, i.e., counts may have missed birds or birds may have been counted twice. The latter seems less likely, however, and in my attempt to adjust the data I will assume that birds were missed in 1945 due to insufficient survey effort. It seems logical, therefore, to increase the counts for 1945, but deciding on an appropriate magnitude for an adjustment is not easy. The simplest correction would be to add five birds to the 1945 counts thereby assuming 100% survival between 1945 and 1946. Yet it seems probable that some birds might have died. Therefore, to estimate a reasonable correction for 1945, it is necessary to evaluate patterns of mortality among years, particularly for recent years when the quality of data are uniformly high.

How does one estimate mortality? Effective recruitment can be assessed directly by the number of juvenal-plumage birds seen on the wintering grounds (Binkley and Miller 1983), yet this is obviously confounded with mortality of chicks before they reach Aransas in late autumn. If all adults and all juveniles survived, the number of adults at time t is simply

$$n_a(t) = n_j(t-1) + n_a(t-1) \qquad (1)$$

But of course some juveniles and some adults are likely to die over the period (t-1,t), thus in reality equation (1) should appear

$$n_a(t) = S(t)\cdot[n_j(t-1) + n_a(t-1)] \qquad (2)$$

where S(t) is the probability of survival for any individual (irrespective of age) over the interval (t-1,t).

The model at (2) permits us to calculate an estimator of S(t):

$$\hat{S}(t) = n_a(t)/[n_j(t-1) + n_a(t-1)] \qquad (3)$$

In Table 2 we present estimates of S(t) for each year over the period 1938-1984. Also presented is the number of individuals (age unknown) alive at time t-1 that died, M(t), during each annual interval (t-1,t), calculated

$$M(t) = [n_j(t-1) + n_a(t-1)] - n_a(t). \qquad (4)$$

Inspection of these data show two obvious outliers. First is the 1945 error, but also note the exceptionally low survivorship of 0.5 in 1941 followed by 100% survival of both juveniles and adults in 1942. Such a pattern could easily be due to missing birds in 1941 which were later counted again in 1942. Again, the problem is finding an appropriate adjustment for these statistics.

I experimented with various adjustments, but my attempts to get sophisticated in my correction procedure usually got me into even more trouble. For example, in 1945 we know there must have been at least 22 birds total, say 18 adults and 4 juveniles. Such a value implies 100% survival between 1945 and 1946 if the 1946 statistics are correct. But note that these adjustments for 1945 also suggest 100% survival over the period from 1944 to 1945. It seems improbable that 2 years with 100% survival would occur in subsequent years, although it did appear to occur in 1975 and 1976. If I assume some slightly lower probability of survival for periods 1944-45 or 1945-46, I find that adjustments are necessary for either 1944 or 1946. The easiest solution with the least arbitrary alteration is to set the 1945 census at 22 birds, 18 adults and 4 juveniles. Similarly, to minimize complications for 1941-42, I will increase the total census to 16 birds (up 1) to make the count slightly more in line with other years, but minimizing my alteration of the original time-series.

TRANSFORMATIONS AND DETRENDING

The usual transformation for a time series of population statistics is logarithmic (Williamson 1972), although Boyce and Miller (1985) found a square root transformation to yield a more stationary detrended series, as did Anderson (1977) in his study of Canadian lynx (_Lynx canadensis_) data. Detrending procedures can also vary with a choice between differencing or regression procedures (Bloomfield 1976). Although results should theoretically be similar with either procedure, the process of detrending can alter the frequency structure slightly (Trevino

Table 2. Probability of survivorship S(t), and number of mortalities M(t), among birds known to be alive at time t-1 at Aransas National Wildlife Refuge, Texas. Corrections are incorporated as detailed in Table 1.

Winter	S(t)	M(t)	Winter	S(t)	M(t)
1938-39	-	-	1962-63	0.821	7
1939-40	0.833	3	1963-64	0.813	6
1940-41	0.955	1	1964-65	0.914	3
1941-42	0.538	12	1965-66	0.857	6
1942-43	0.938(1.00)	1	1966-67	0.864	6
1943-44	0.842	3	1967-68	0.907	4
1944-45	0.714	6	1968-69	0.917	4
1945-46	0.778	4	1969-70	0.960	2
1946-47	1.000(1.294)	0	1970-71	0.911	5
1947-48	1.000	0	1971-72	0.947	3
1948-49	0.871	4	1972-73	0.780	13
1949-50	1.000	0	1973-74	0.922	4
1950-51	0.765	8	1974-75	0.959	2
1951-52	0.645	11	1975-76	1.000	0
1952-53	0.760	6	1976-77	1.000	0
1953-54	1.000	0	1977-78	0.899	7
1954-55	0.875	3	1978-79	0.944	4
1955-56	0.952	1	1979-80	0.933	5
1956-57	0.786	6	1980-81	0.947	4
1957-58	0.917	2	1981-82	0.910	7
1958-59	0.885	3	1982-83	0.918	6
1959-60	0.969	1	1983-84	0.932	5
1960-61	0.909	3	1984-85	0.947	4
1961-62	0.944	2			

1982). Unfortunately, procedures for nonstationary time-series are not yet at a stage that they can be applied in data analysis (Trevino, pers. comm.).

Boyce and Miller (1985) employed a square root transformation followed by a two-stage linear regression detrending procedure. Other transformations will reveal periodicity as well, e.g., log transforms, differencing, single linear regression, although it is essential that the series be both transformed and detrended. In Table 3, the autocorrelation function is illustrated for the first 16 lags employing three variations on the analysis of Boyce and Miller (1985). In each of these instances, the data set was "cleaned up" as described above. In the first column of Table 3 is the autocorrelation function for the raw time series with no transformation or detrending. Note that it is totally dominated by the trend in the series, and detection of periodicity is not possible.

In the second column of Table 3, the time-series has been detrended by calculating the residuals from a single linear regression of census number versus time (as in Mendelssohn's analysis). Although a vague indication of periodicity is suggested, the autocorrelation does not become negative until the 12th lag, and significant autocorrelations do not appear between the 3rd and 14th lags.

The third column of Table 3 depicts the autocorrelation function when the time-series was log-transformed and detrended with a single linear regression. The periodicity is obvious and regular, although the periodicity is not as pronounced as for the square root transformation presented by Boyce and Miller (1985). The importance of transformation for this time-series is to reduce the disproportionate influence given to large values in the series, just as one must transform variables in regression analysis to reduce the contribution from outliers.

Table 3. Autocorrelation function for the first 16 lags of original time-series, detrended series without transformation, and residuals of a linear regression of the log-transformed time-series on time (detrended, transformed).

Lag	Autocorrelation orginlnal data	Autocorrelation detrended	Autocorrelation detrended, transformed
1	0.91	0.75	0.56
2	0.83	0.53	0.27
3	0.77	0.32	0.08
4	0.70	0.20	-0.17
5	0.62	0.13	-0.26
6	0.56	0.14	-0.19
7	0.49	0.15	-0.12
8	0.43	0.17	0.00
9	0.37	0.16	0.11
10	0.33	0.11	0.20
11	0.30	0.04	0.12
12	0.26	-0.09	-0.06
13	0.22	-0.20	-0.19
14	0.15	-0.30	-0.31
15	0.09	-0.28	-0.21
16	0.03	-0.31	-0.20

DISCUSSION

Is this an esoteric exercize? No, this is not an estoeric exercise. Why does it matter that the whooping crane population exhibits population periodicity? There are at least two important ramifications from our demonstration that whooping cranes exhibit 10-year cycles.

First, better characterization of fluctuations in the time-series means that a greater proportion of the variance can be characterized, and therefore, one is able to generate forecasts with higher accuracy and precision. In Table 4, I present the forecasts based upon the nonperiodic model of Miller et al. (1974) compared with an update of Boyce and Miller's (1985) multiplicative IMA forecast model. Although the Miller et al. (1974) projections appear to reflect the mean population trajectory, there appear to be systematic deviations from their forecasts, i.e., runs of years where forecasts were either too large or too small. This occurs because they failed to recognize that every 10 years there will be a dip in growth rate. Confidence intervals around projected populations also are necessarily much higher than in the IMA model, because Miller et al. (1974) were unable to account for as much variance in the time-series.

One value of the improved forecasts is to reduce potential panic when the whooping crane population shows the occasional decrease in population size or growth rate. Rather than a failure in management, it may be more appropriate to simply recognize the periodic rhythm of boreal ecosystems as influencing the population dynamics of cranes. As a caveat, however, I emphasize that such forecasts are rather mindless projections of the current population trajectory into the future. Any change in the environment or management of the cranes over that occurring since 1957 will alter this trajectory and totally invalidate forecasts.

Second, and most important, the identification of regular periodicity suggests something about the ecology of whooping cranes which we did not previously recognize. The periodic dips in population size are subtle, and are not likely to be detected without the employment of time-series statistical procedures. But the ramifications are extremely important; i.e., the observed periodicity is a consequence of periodic decreases in both survivorship and realized fecundity (or possibly juvenile survivorship) which occur every 10 years. Is it possible to manage the environment to eliminate these periodic fluctuations?

Table 4. Forecasts for the Aransas/Wood Buffalo whooping crane population from aperiodic birth-death process model (Miller et al. 1974), and those from this study employing a multiplicative IMA model.

Winter	Observed	Miller et al. (1974) Forecast	Miller 95% C.I. Lower	Miller 95% C.I. Upper	ARIMA Model Forecast	ARIMA 95% C.I. Lower	ARIMA 95% C.I. Upper
1973-74	49	53	44	62	-	-	-
1974-75	49	55	42	68	-	-	-
1975-76	57	58	41	74	-	-	-
1976-77	69	60	41	78	-	-	-
1977-78	70	62	40	84	-	-	-
1978-79	74	65	40	90	-	-	-
1979-80	76	68	40	96	-	-	-
1980-81	78	70	39	100	-	-	-
1981-82	73	73	39	107	-	-	-
1982-83	73	76	39	113	-	-	-
1983-84	75	79	39	119	-	-	-
1984-85	86	82	39	125	-	-	-
1985-86		85	39	130	88	77	98
1986-87		89	39	138	90	79	102
1987-88		93	40	145	97	85	109
1988-89		97	41	153	100	88	113
1989-90		100	41	159	107	93	121
1990-91		104	41	167	109	96	124
1991-92		109	42	176	105	91	120
1992-93		114	43	185	100	86	115
1993-94					102	88	118
1994-95					108	93	125
1995-96					116	99	134
1996-97					119	101	138
1997-98					127	108	147
1998-99					131	111	152
1999-00					138	118	160
2000-01					141	120	164

Management implications are dependent upon our identification of the ecological mechanisms behind the periodicity. Several hypotheses may be considered: (1) demographic periodicity generated by the age-structure perturbation caused by severe reduction in numbers during the 1930's, (2) periodic predation imposed by wolves (*Canis lupus*) or other carnivores known to exhibit 10-year cycles in the vicinity of the Wood Buffalo nesting ground, (3) periodic fluctuations in water levels on the nesting grounds which require that cranes must range further to feed (Kuyt et al. 1981), (4) a periodic mortality factor on the wintering grounds, (5) a trophic-level interaction between the cranes and a food source, or between the cranes and a secondary predator, (6) a link between crane recruitment and mortality and the nodal lunar cycle (Archibald 1977, Roseberry and Klimstra 1984), and (7) periodic influences of climate, either in Texas or Canada.

None of these alternative hypotheses has been adequately evaluated, although I think (1), (4), and (5) are very unlikely. Demographic periodicity should have dampened by now, yet the periodicity is still very pronounced after 4 1/2 cycles. We have detected nothing periodic about mortality on the wintering grounds, although documentation of deaths on the wintering grounds may not be satisfactory. Our preliminary attempts to find correlations between whooping crane cycles and climate at Fort Smith, Northwest Territories, or near Aransas National Wildlife Refuge, Texas have not been rewarding.

Trophic-level interactions seem unlikely given the extremely small size of the crane population, the large area over which they range, and the overall exponential growth pattern in the crane census since 1938. Schaffer (1984, 1985) has recently found exciting promise for understanding 10-year cycles in lynx by identifying evidence for a periodic strange attractor. If the system generating the whooping crane periodicity did possess a periodic attractor, the unlimited growth pattern observed indicates that the population is probably far from its limit set. Therefore, what is seen is the transient. Ten-year oscillations in the transient do not necessarily imply the existence of a periodic attractor (W. M. Schaffer, pers. comm.).

The problem of detecting the cause for whooping crane cycles may be a difficult one. Population ecologists have toiled for decades to offer a satisfactory explanation for the classic lynx-hare cycle and for cyclic fluctuations in microtine rodents. But there is no consensus on causal mechanisms. Because of the endangered status of the whooping crane, hopefully our documentation of 10-year periodicity will stimulate interest and financial support for additional research on ultimate causes behind wildlife's 10-year cycle.

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RECENT IMPROVEMENTS TO SANDHILL CRANE SURVEYS IN NEBRASKA'S CENTRAL PLATTE VALLEY

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Abstract: Sandhill crane surveys in Nebraska's central Platte Valley during spring migration were improved to address certain survey needs specified by the Central Flyway Council's Management Plan for the mid-continent sandhill crane population. An operational vertical photographic survey was established to estimate the population every fifth year, and an improved ocular survey was developed in conjunction with coordinated surveys throughout Central Flyway states to assess trends annually. Both techniques yielded reliable estimates with low standard errors. A review of the survey assumptions and associated biases indicate relatively low bias with each technique. Future survey refinements will attempt to minimize the effects of the known and suspected biases.

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Most if not all of the mid-continent population of sandhill cranes (*Grus canadensis tabida*, *G. c. rowani*, *G. c. canadensis*) use the Platte River in Nebraska as their primary staging area during spring migration. When numbers of cranes peak in that valley during late March or early April only a small percentage of mid-continent cranes are observed elsewhere (Benning 1984). Population levels are estimated during spring staging primarily because cranes are so widely distributed during other periods of the year.

In July 1981, the Central Flyway Waterfowl Council developed a management plan that included guidelines for the cooperative management of the mid-continent sandhill cranes by state and federal agencies. One of the plan's objectives is to maintain the population at a stable level between 480,000 and 590,000 cranes. Two strategies relating to this objective are (1) "obtaining reliable estimates of the population...in 1982 and at least every fifth year thereafter...on the Platte Valley of Nebraska during late March-early April peak concentrations" and (2) "assessing trends...through annual coordinated surveys in late March in Central Flyway States" (including the central Platte Valley). Experimental surveys addressing each strategy were conducted in 1978 through 1981 within the central Platte Valley. The first successful vertical photographic survey of the entire area was conducted in 1982 to deal with the first strategy. An ocular transect survey initiated in 1978 was refined substantially in 1982 when ocular flock estimates (hereafter referred to as counts) were corrected through the use of oblique photography. This improved ocular survey was used in conjunction with the second strategy to assess trends and was conducted annually thereafter. This paper describes the modifications and improvements made in both survey designs since 1978 (Ferguson et al. 1979), documents the results and statistical analyses, and discusses the appropriateness of these survey techniques and their known and suspected biases.

Bill Lyon, Nebraska Aeronautics Division, provided technical advice and piloted the aircraft for the 1982 vertical photographic flights. Hubert Dall and Ken McHarque, Nebraska Roads Division, provided technical advice and served as photographer, respectively, for the 1982 vertical photographic flights. Jim McCord, U. S. Geological Survey, processed and custom printed the 1982 vertical photography. Al Novara and Bruce Hanson, U. S. Fish and Wildlife Service, were observer and photographer, respectively, on the 1982-84 ocular/oblique-photographer transect surveys. Judy Harr, U. S. Fish and Wildlife Service, provided photo counts on all surveys. Karen Tiedt, U. S. Fish and Wildlife Service, typed this manuscript.

METHODS

Vertical Photographic Transect Survey

Ferguson et al. (1979) developed and described the original design of the photographic survey technique. The survey area involved 2,173.8 km^2 (839.7 mi^2) within the central Platte Valley of Nebraska between Grand Island and Lexington and between North Platte and Sutherland.

The areas were divided into 10 strata. The sampled area, which totaled 177.4 km^2 (68.5 mi^2) along 54 transects was photographed with a Vinton KS69A,[1/] 70 mm camera. The camera was equipped with a 75 mm focal length Leitz lens and Wratten 12 filter. Exposures were made at 1/1000 at f-4 or f-2.8 using H & W VTE Pan black and white print film. A Cessna 180 fixed-wing aircraft was flown at 610 m (2,000 feet) above ground level providing 0.20894-km^2 (0.080707-mi^2) coverage on each frame. Coverage was discontinuous. Processed film was scanned for presence of cranes and those frames with detectable cranes were enlarged from 4X to 20X for counting.

The major change incorporated in the 1982 design was restratifying the survey area based on analysis of 11 various experimental and operational surveys during 1978-80. From a comparison of average densities on transects, correlations between transects, and a cluster analysis of transects, the survey area was divided into five new strata. Some small areas with consistently low or zero crane densities also were excluded from the survey area.

Other changes involved applying high quality, large-format photographic equipment and using a twin-engine Cessna 401 aircraft to conduct aerial photography. The camera was a Wild RC-8 with 229 X 229 mm (9 X 9 in) imagery. The camera lens had a focal length of 152 mm (6.0 in). A yellow lens filter was used to reduce the effect of haze on final imagery. Exposure was set at 1/700 second and f-8. Frame rate was controlled by an intervalometer, calibrated for 10% overlap, to provide continuous photographic coverage of each transect.

The resulting survey design (Fig. 1) covered 1,928 km^2 (744.4 mi^2). Sampling fractions in the five strata varied from 6.25% in the lowest density stratum to 50% in the highest density stratum. The sampled area totaled 295.8 km^2 (114.2 mi^2), with 104 transects totaling 735 km (456.8 mi) in length.

1/ Reference to trade names does not imply endorsement by the Federal government.

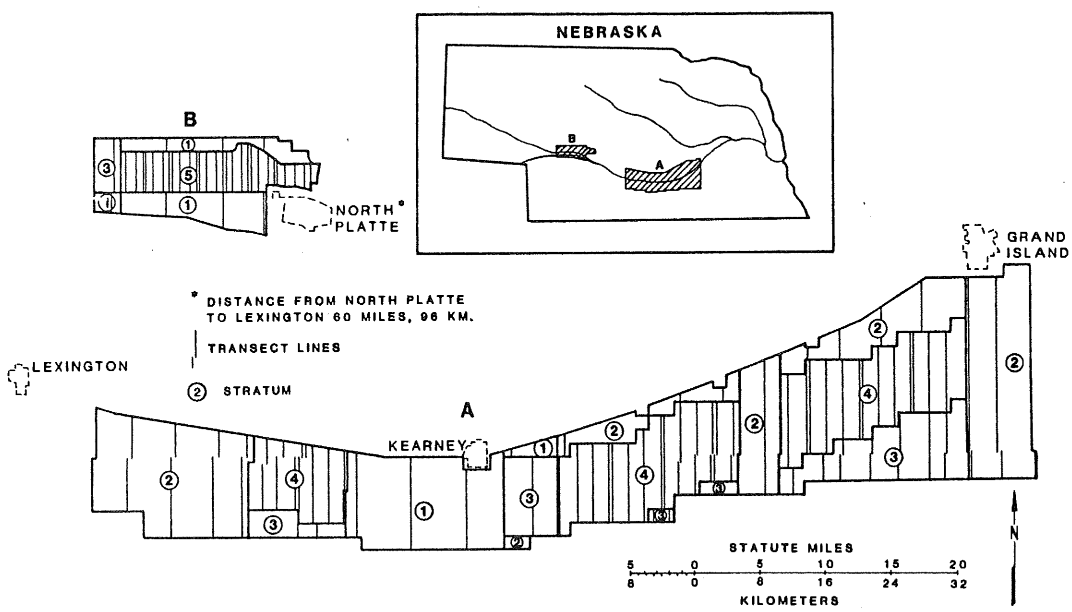

Fig. 1. Vertical photographic transect survey area for sandhill cranes in the central Platte Valley, Nebraska, 1982.

The aircraft was flown at approximately 177 km/hr (110 mi/hr) at an altitude of 268 m (880 ft). This altitude provided a scale of 1:1,760 which translates to 402-m^2 (1,320-ft^2) coverage on each frame. Complete coverage of the survey transects was anticipated to take approximately 9.5 hours flight time with an additional 3 hours for refueling, reloading film magazines, and non-transect cross-country flying.

The transect flights were scheduled between 0800 and 1600 on two consecutive days. This time period offered the greatest sunlight intensity for best photographic results. Photography was restricted to periods with less than 5% cloud cover. The dates selected for obtaining the photography were within the period 25 March through 3 April. Krapu (pers. comm.) considered this period as including the annual peak of the spring population in the Platte Valley (U. S. Fish and Wildlife Service 1981).

Film was developed for maximum contrast between the cranes and their background. Prints were cataloged by date of exposure, roll and frame number, stratum, transect, and sequence number. The overlap area on each print was depicted by drawing a black line and writing "overlap" in the appropriate area. This eliminated counting individual cranes on more than one photograph. Each print was searched for cranes with a 4X lens and high-intensity overhead illumination. An electronic pressure-activated stylus was used to enumerate and mark each individual crane identified on the photographs. All prints were scanned a second time by another individual to search for cranes not already counted, an omission evident by the absence of a stylus mark on the print. This second scanning also verified crane identification.

Ocular Transect Survey

The ocular transect survey used the same survey area and strata as the vertical photographic transect survey described by Ferguson et al. (1979) without the restratification described above. A sampling fraction of approximately 25% was established within each stratum. Line transects with a width of 0.8 km (0.50 mi) were established. Transect locations were established systematically with a minimum of 1.6 km (1.0 mi) between transects to eliminate double-counting due to roll-up of birds. As numerous options were available for choosing transects, selection for a given year was done randomly as described by Ferguson. Pilot and observer estimated the number of cranes in each flock on their respective side of the plane as the aircraft was flown down the center of each transect at an approximate altitude of 61 m (200 ft) above ground level and 177 km (110 mi) per hour. The observer recorded data by transect on forms held in a clipboard. Coverage was normally accomplished between 0900 and 1730. Survey dates were selected each year to coincide with suspected peak population buildup (the last 5 days of March). Weather criteria were not established for the survey.

Minor changes incorporated in 1982 and subsequent surveys involved: (1) conducting the survey between 0800 and 1600 to take advantage of maximum daylight for photographic purposes, (2) using the same transects each year rather than a system of different randomly selected starting points each year to eliminate variation between years associated with differing transect locations, and (3) scheduling the coordinated surveys each year on the fourth Tuesday of March to facilitate consistent scheduling between years within or just before the period of suspected peak population buildup within Nebraska's central Platte Valley.

Beginning in 1982, we made a major modification to our survey design by measuring and correcting the suspected bias associated with individual observer counts. This bias became evident when wide disparity was noted between the ocular counts and counts from vertical photographs taken simultaneously during 1978-1980. The method developed to correct this bias involved subsampling ocular flock counts with oblique photography. To obtain the subsample, a third crew member took single or multiple overlapping photographs of a representative sample of crane flocks in conjunction with each observer's counts. A Canon AE-1 35 mm single reflex camera with FD 50 mm 1:1.2 lens, ultraviolet and polarizing filters, power winder, and Kodak 135 VR 100 color film was used.

Notes were made by the observer and the photographer on each photographed flock. Exposed film was processed to maximize contrast between cranes and their background. After review of both observer and photographer notes and a comparison with the contact proof prints, selected prints were enlarged to 203 x 305 mm (8 x 12 in). Prints were examined in the same manner as the vertical photography.

For each year and observer, 32-48 crane flocks were counted ocularly and from photographs. Analysis indicated that the error (difference between ocular count and photographic count) was approximately proportional to the flock size. Accordingly we developed a ratio estimator of the visibility correction for each observer and year where:

$$V = \frac{\text{cranes counted on photographs}}{\text{cranes counted ocularly}}$$

A standard error of this ratio was obtained according to Cochran (1977:155).

For each survey date, we estimated the crane population on the left and right sides of the flight line separately. This procedure enabled us to exploit differences between pilot and observer in visibility rate. Estimates for the two sides were added together to produce a total estimate.

For each side, we took the projected count times the visibility rate (V). The standard error of this product was obtained from:

$$\mathrm{Var}\ (VX) = V^2\mathrm{Var}(X) + \mathrm{Var}(V)X^2 + \mathrm{Var}(V)\mathrm{Var}(X).$$
where X = ocular count

RESULTS

Vertical Photographic Transect Survey

Transect flights were conducted on 25 and 26 March 1982, and required 13.9 hours flight time. About 4.5 hours involved cross-country travel and duplicate transect coverage due to excessive cloud cover on the first coverage. Crane flocks were occasionally disturbed by the aircraft passing overhead. Consequently, the original flight altitude was increased to 366 m (1,200 ft), which resulted in no evident disturbance to the flocks. Subsequent photography was on a scale of 1:2,400 and each frame covered 549 m^2 (1,800 ft^2).

A total of 2,050 frames provided complete survey coverage. Another 400 frames were exposed and printed but not used due to the associated excessive cloud cover. Photographs did not require enlargement but did necessitate use of a 4X magnifier to aid in flock detection and counting of cranes. Some difficulty was encountered in distinguishing cranes from ducks, geese, crows, and even turkeys, but differences were evident upon careful examination.

A stratified ratio estimate (Cochran 1977) of crane numbers was obtained with the area of a transect serving as the denominator. The resulting estimate was 490,093 cranes, with a standard error of 47,966 (Table 1). Fig. 2 compares the 1982 data obtained using this method to other spring survey results obtained within the central Platte Valley during the period 1957 through 1984 utilizing other methods.

Table 1. Sandhill crane population estimates in the central Platte Valley of Nebraska derived from the vertical photographic survey, 1982 and ocular surveys. 1982-84.

	Survey techniques			
	Vertical	Ocular[a]		
Category	photographic	1982	1983	1984
Year	1982	1982	1983	1984
Pilot estimate		220,282	157,294	129,455
Observer estimate	490,093	196,981	186,084	132,347
Combined estimate		417,262	343,378	261,802
Standard error(±)	47,966	42,331	31,674	24,198
Coefficient of Variation (%)	9.8	10.1	9.2	9.2

[a] In 1982 and 1983, population estimates were developed using the mean of expanded counts adjusted with the appropriate observer correction factors.

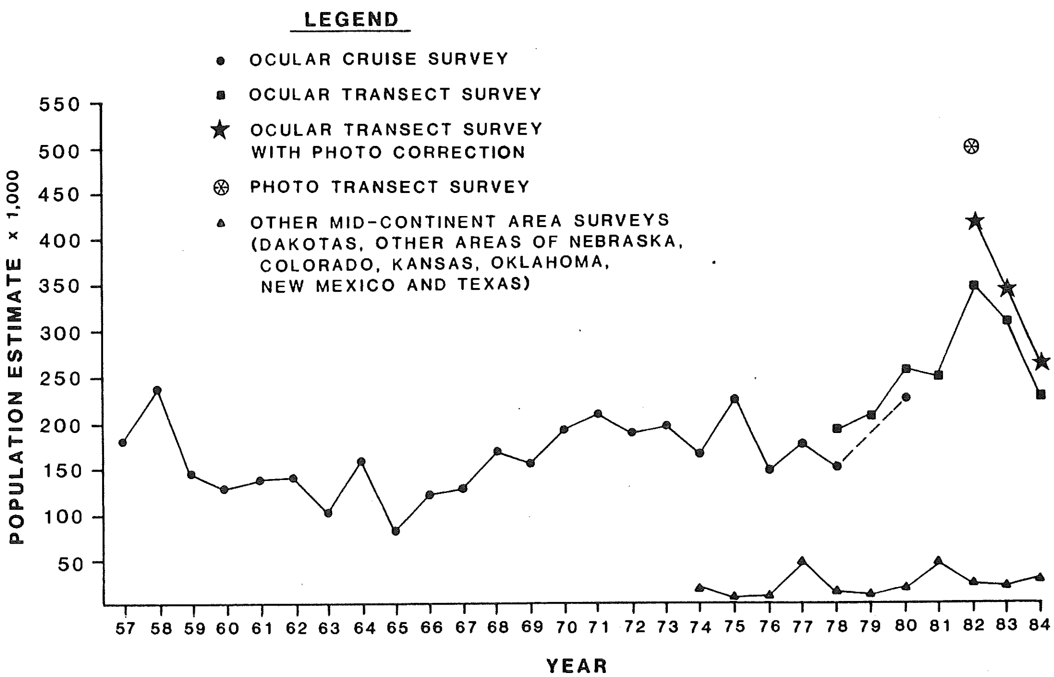

Fig. 2. Spring sandhill crane population indices in Nebraska's central Platte Valley, 1957-84.

Ocular Transect Survey

The ocular survey flights were conducted on 22 and 23 March 1982, 22 and 23 March 1983, and 27 March 1984. The flights normally required an average of 7.5 hours flight time for complete survey coverage, which included approximately 1.8 hours of cross-country flight. A mid-day refueling and lunch break usually took an additional hour. Survey coverage normally began at 0800 and ended near 1530. During 1982 and 1983 it was necessary to conduct two identical surveys within 2 consecutive days to obtain the desired number of flock photographs for each observer. In 1984 this photography was accomplished during a single survey. Nine to 14 rolls of 36-exposure film were used each year.

The 1982 and 1983 population estimates were determined from the mean of the expanded counts adjusted with the appropriate observer correction factors. The pilot's and observer's counts were corrected using 36 and 36 flocks in 1982, 48 and 46 flocks in 1983, and 36 and 32 flocks in 1984, respectively. The corresponding correction factors with the standard errors for pilot and observer, respectively, were 1.3723 (0.133183) and 1.0507 (0.064177) in 1982, 1.1204 (0.161015) and 1.1215 (0.109802) in 1983, and 1.1510 (0.11575) and 1.2005 (0.11460) in 1984. The resulting population estimates for the 1982, 1983, and 1984 (with standard error) were 417,263 (42,331), 343,378 (31,674), and 261,802 (24,198), respectively (Table 1). Fig. 2 illustrates how these data relate to crane spring survey results of 1957-84 within the central Platte Valley using this and other methods. Because the percent of mid-continent sandhill crane population surveyed within the central Platte Valley during the coordinated surveys varied between years, the indices (Fig. 2) do not necessarily indicate population changes of the magnitude depicted by the total population throughout the mid-continent region.

DISCUSSION

The vertical photographic transect survey in the central Platte Valley provided accurate estimates (low bias and low standard error) compared with earlier survey methods. The success of this technique, however, is dependent on a suitable combination of procedures in conjunction with quite restrictive weather limitations. The survey technique requires two consecutive days of nearly clear skies with flawless photography within a 10-day period. Typically, weather during this time of year in Nebraska tends to be quite variable with frequent storms. Also, the logistics of conducting an aerial photo survey of this type and magnitude require a highly coordinated team effort, professional results, and virtually no equipment malfunctions. As a consequence, the opportunity for obtaining reliable results in any given year is far less than certain.

Basic assumptions of this technique are that (1) all cranes within the transect are depicted on the photography and are detected by the person making the counts off the photography; (2) the photographic counts are 100 percent accurate; (3) there is no biasing crane movement between or on and off transects during the survey, and similarly there is no movement of cranes into or out of the survey area during the survey; and (4) the mid-continent crane population outside the central Platte Valley can be measured simultaneously. Although these assumptions have not been thoroughly tested, we do have some indications of how well our techniques satisfy these assumptions.

The first assumption was dealt with in part through an audit procedure where a second person methodically searched each photograph for cranes not enumerated by the original count. This did not preclude the possibility that both workers missed some cranes. A known bias associated with this assumption involves those cranes in flight at a substantial height above ground that are not detected on vertical photography. Cranes occasionally soar during the warmer part of the day, so that some cranes within the survey area are undetectable. As this phenomenon was of minimal magnitude during the 1982 survey, no effort was made to account for soaring cranes. If the number of cranes involved in this activity is substantial, however, this bias should be addressed.

The second assumption was treated in part through the audit process discussed above. Additionally, the electronic stylus counter was tested and found extremely reliable.

As to the third assumption, every effort was made to eliminate the effect of the survey aircraft on crane movement. Flight altitude was increased during the 1982 survey to eliminate hazing cranes off the transect. Flights of cranes between feeding and loafing areas can be expected when we conduct the survey, However, we believe that ingress and egress on and off transects within the survey area will be compensatory in its effect on survey results. Additionally, the survey is confined to two consecutive days to minimize the effect of crane movement into and out of the survey area.

The fourth assumption was dealt with through coordinated survey efforts initiated in 1974 throughout the mid-continent region. Although the techniques used in these other areas do not have associated measures of error and they quite likely do not represent every component of the population outside Nebraska's central Platte Valley, this coordinated survey activity does attempt to treat this known bias.

The ocular transect survey also provides relatively accurate estimates compared with earlier survey methods. However, this technique is more tolerant of environmental conditions and necessary logistic support to obtain reliable and complete results during this same period. Survey costs cannot be ignored; in 1982 the vertical photographic transect survey was roughly eight times the cost of the ocular transect survey.

Basic assumptions of this technique are essentially the same as the vertical photographic transect survey. However, the methods employed to ensure that these assumptions were met are somewhat different and more susceptible to criticism.

Regarding the assumption that all cranes within the transect are detected and counted by the pilot or observer, we established a low-level flight altitude and slow aircraft speed to aid the observer's ability in detecting flocks by flushing some birds in nearly all flocks. This also aided in identifying birds. We do have some indication, however, that overcast skies and the associated low light may impair both the pilot's and observer's ability to detect some crane flocks that do not flush as the aircraft passes. This relationship and associated bias must be further investigated. The photographer in the back seat of the survey aircraft documented only an occasional omission by either pilot or observer, which involved few cranes. This does not preclude the possibility that observers and photographer both missed some flocks. An important consideration in this survey technique is the ability of both observers to detect and count cranes flying at altitudes that would be missed using the vertical photographic technique. We are concerned, however, that some high-soaring cranes may go undetected even by the ocular method. Again, further investigation is suggested.

The assumption that the ocular counts are accurate was dealt with to a major extent by the addition of oblique photography to this previously untreated bias. Most observers tend to underestimate bird numbers and, perhaps more importantly, observers tend to differ in their estimating capabilities. Therefore we thought that this bias was critical to obtaining realistic results. This method of correcting observer counting error is far from perfect, but we believe the procedure has credibility and has further application to other ocular-oriented surveys.

The assumption that there are no biasing crane movements between or on and off transects during the survey was treated in two ways. The first involves the spacing of adjacent transect at a minimum of 1.6 km distance between boundaries to eliminate the effect of roll-up. This is a consideration due to the low-level flight required of the survey and the associated flight of many cranes off the transect. Roll-up was never detected using this 1.6 km spacing. The second has to do with completing the survey in one day, therefore minimizing lateral movement within the survey area and crane movement into and out of the survey area which is more likely during surveys of longer duration. As with the vertical photographic transect survey, we believe that ingress and egress on and off transects within the survey area will be compensatory in its effect on survey results.

The last assumption, that the mid-continent cranes outside the central Platte Valley can be measured simultaneously, has been treated through the annual coordinated survey efforts throughout the mid-continent region as discussed earlier.

Despite their differences, both of these survey techniques appear fairly well suited to their purpose. The relatively complex and expensive vertical-photographic survey has the potential to provide a relatively accurate estimate of the mid-continent crane population within Nebraska's central Platte Valley at infrequent intervals, whereas the relatively simple and inexpensive ocular survey within the central Platte Valley should provide a fairly reliable population trend indicator on an annual basis when used in conjunction with the coordinated surveys throughout the mid-continent region.

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Post-script: The results of the 1985 ocular survey with photo correction provided a population estimate of 514,763 with a standard error of 49,650 and coefficient of variation of 9.6.

THE WISCONSIN SANDHILL CRANE COUNT: A PUBLIC PARTICIPATION PROJECT

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Abstract: From 1975 to the present, an annual count has been made of greater sandhill cranes (*Grus canadensis tabida*) in Wisconsin. The census depends entirely on volunteer participants, some without previous experience observing cranes. In 1984, 2219 people surveyed 1284 sites in 59 of Wisconsin's 71 counties and found 5717 cranes. The crane count day occurs in the third week of April, when participants visit their assigned wetland sites for 2 early morning hours. They record all cranes seen or heard and the condition of the wetlands. These procedures became standardized in 1981, and coverage of the survey has greatly expanded since then. The project is an effective educational tool, exposing a great variety of people to cranes and conveying a sense of wonder and appreciation toward wetlands. Research value of the project depends on collection of data from many sites over several years. Results from any single year can be biased by variations in weather and number of observers. This paper summarizes count procedures and evaluates data through 1984, including a detailed analysis of two sample counties in southcentral Wisconsin. Cranes now occur throughout Wisconsin, with the greatest numbers in central counties. In the two sample counties, 59% of 58 regularly-used crane sites were in private ownership. Crane count data are now being computerized in cooperation with the Wisconsin Department of Natural Resources.

PROCEEDINGS 1985 CRANE WORKSHOP

Over the last decade, the annual sandhill crane count has become an important event for thousands of adults and children in Wisconsin. On 14 April 1984, over 2,200 people went out before sunrise and counted 5717 cranes in 59 of Wisconsin's 71 counties.

The crane count serves three purposes. First, it is a research tool. An army of volunteers checks wetlands throughout Wisconsin for the presence of greater sandhill cranes on one early morning at the beginning of the breeding season. The crane count is collecting extensive information on abundance and distribution of cranes. These data would be impossible to gather through more intensive studies by wildlife professionals -- the crane count therefore complements more traditional research efforts.

Second, and equally important, the crane count educates citizens by providing them an opportunity to participate in studying and ultimately protecting cranes and wetlands. As preparation for the count, participants learn about crane biology and behavior and the importance of wetland habitats. The count then takes the observers into the marshes at a beautiful time of morning. As people become enthusiastic about protecting cranes and their habitats, their interest can carry over into other facets of conservation.

The cranes have attracted large numbers of people as volunteers, and the count grows in popularity every year. The event is especially effective as an education tool because people learn by doing. They have a clear and practical goal for their efforts.

Third, the crane count encourages wetland conservation. Cranes serve as excellent indicators of the health of their ecosystems. Participants record not only the presence of cranes, but also the condition of their study sites and any recent habitat changes they can detect. When all these data are assembled, the extent of habitat change and its effect on crane populations can be determined. The crane data also can identify wetlands especially worthy of protection.

This paper outlines the methods used for the count, in sufficient detail that they can be adapted for similar projects in other regions. We also discuss results of the crane count.

This discussion of results will be preliminary, and is intended chiefly to demonstrate how the accumulated data can be used rather than to give an exhaustive analysis. Variations in the number and reliability of observers as well as weather have greatly influenced data from particular locations or particular years. Conclusions from crane count data must be based on many sites observed over a series of years. Due to the small size of the count in its early years, only a few counties have data bases extending back more than 3 or 4 years. We will look at two sample counties, one with 6 years and the other with 5 years of data, as an indication of what information the crane will be yielding for much of Wisconsin by 1986.

BACKGROUND

The sandhill crane is of particular interest in Wisconsin because its populations have undergone dramatic changes in the past 150 years. The status of the species has been reviewed by Hunt and Gluesing (1976). Before white settlement, sandhill cranes bred commonly in Wisconsin, especially in southern and western regions of prairies and wetlands. But hunting, settlement, and habitat alteration caused major declines that became evident by the 1880's. By 1936, only 25 pairs were estimated to remain in Wisconsin (Henika 1936). Twenty pairs survived on large marshes in Juneau, Wood, and Jackson counties, all in central Wisconsin, with a few other pairs at scattered locations.

A gradual recovery in sandhill crane numbers was detected in the 1940's. The development of large waterfowl management areas encouraged a substantial increase in cranes by the 1960's. A survey among wildlife managers and game wardens in 1967 revealed crane nests or young in 20 marshes in 16 counties (Hunt and Gluesing 1976). Most of these reports came from public wildlife areas. Then results of a follow-up survey in 1973 indicated that 250 pairs were present that summer in 32 counties. Of 40 actually located, 55% were on private land. The cranes also appeared to be using smaller wetlands for nesting, with a minimum size of 8 ha. But the increase and spread of cranes through Wisconsin made representative population surveys more difficult to accomplish.

The sandhill crane count began in 1975 on a small scale. Initial efforts were limited to Columbia County as a high school study project, but by 1978 the count had spread into five counties. For several years, the event was sponsored by the Wisconsin Wetlands Association, a non-profit conservation and education organization staffed entirely by volunteers. The International Crane Foundation (ICF) has organized the count since 1981.

Up through 1981, methods for the count varied from year to year, as organizers gained experience with counting cranes and using volunteers. In 1979, for example, observers were instructed to visit their survey sites on one or more occasions between 17 March and 24 April. From 1981 to the present, observers have counted on a single date each year throughout the state, and other procedures have been standardized so that data are easily comparable year to year. Data from the years up before 1981 require extra care and effort when they are compared to 1981-84 data.

The crane count is the result of the dedication and effort of thousands of volunteer observers, many of them returning year after year to help. The County coordinators have done a splendid job of organizing their areas, devoting literally days of work on count preparations. We wish to acknowledge individually those whose vision helped start the count in the 1970's and those who served as state coordinators for 1 or more years: Charlie Luthin, George Archibald, Al Shea, Jim Bachhuber, Steve Schmidt, Steve Landfried, Scott Freeman, Karen Voss, Karen Atkins, and Marion Hill. The Wisconsin Wetlands Association has consistently supported the count, and took responsibility for organizing the event for several years. The following organizations contributed financially to the project for 1 or more years: Citizens Natrual Resources Association, Sierra Club -- the John Muir Chapter, Madison Audubon Society, Milwaukee Audubon Society, Winnebago Audubon Society, Wisconsin Metro Audubon Society, Lakeland Audubon Society, and the Wisconsin Society for Ornithology. The Wisconsin Wetlands Inventory of the Department of Natural Resources provided extensive information on wetland locations, sizes, and vegetation types.

METHODS

Timing

Timing of the count greatly affects results. It must be standarized because Wisconsin's crane population is migratory and breeding appears synchronized, occurring directly after the birds complete their migration. Starting in 1982, the crane count has occurred during the third week in April--after most migration is over in Wisconsin, but while most pairs are highly vocal and territorial on their marshes. By early May, the cranes have eggs and have become secretive; they are then difficult to count.

Observers arrive at their assigned survey sites at 0430 hours, well before sunrise, and remain until 0630 or 0700 hours. Cranes are most conspicuous and vocal during this portion of day.

State-wide Organization

Because of the large size of Wisconsin (14.5 million ha) and the number of survey sites and participants, good organization is necessary to complete the operation. An ICF staff person serves as state coordinator, overseeing planning, site selection, and participant recruiting for the entire count. The state coordinator has the following duties.

(a) Recruit and Assist County Coordinators--The state coordinator finds people who will organize the observers in their assigned counties. This organizing is accomplished four months before the count, so that county coordinators can be trained and began to recruit observers within their counties.

(b) Develop Training Materials--We use a slide show with a narrative tape cassette with recordings of crane calls to train participants. These materials introduce observers (who often have little scientific background) to crane behavior and wetlands, and to values of wetlands for wildlife and people. Multiple copies of the slide show have been prepared and are loaned out to county coordinators.

(c) Coordinate Mapping of Survey Sites--The state coordinator maintains a permanent record of wetland sites that have been surveyed in Wisconsin. This master map is updated each year. Copies of the maps for each county, with survey sites identified, are sent to each county coordinator. In 1982, a sample of wetlands in each county were identified as "priority sites." Since then, we have instructed county coordinators to be certain each of these sites is covered annually by reliable observers.

(d) Arrange Advance Publicity--The state coordinator sends general news releases to major Wisconsin newspapers to publicize the count and recruit participants. The state coordinator also prepares public service announcements for radio and television, and special releases for youth group newsletters. These materials go out more than a month before the count day.

(e) Prepare County Coordinator Packets--These packets contain directions and background information for county coordinators and materials to be given to their participants. The maps, data sheets, and publicity posters are included.

(f) Hold a County Coordinator Meeting--This meeting occurs two months before the count day. At the meeting, the state coordinator gets to know the county coordinators and informs them of count procedures. The packets are handed out.

(g) Duties After Count Day--The state coordinator compiles the data county by county, checking the reports filed by the county coordinators for accuracy and completeness. The results are announced to the public and to participants as soon as possible, and all records are saved for permanent record.

County Coordinators

The county coordinators play a key role in organizing the Wisconsin crane count. The state is too large for the state coordinator personally to contact all participants and make sure they are sufficiently knowledgeable about cranes and count procedures. For Wisconsin's 1984 count, 54 county coordinators performed these tasks.

Coordinators volunteer from each participating county. Many have an assistant who helps them and becomes familiar with crane count procedures, so that they can replace coordinators in later years. The county coordinators have the following responsibilities.

(a) Recruit Participants--Records are kept of participants from previous years. The county coordinator sends post cards to these people a month before the count, asking them to participate again. New counters are recruited by involving youth groups, through personal contacts and news releases, and by placing posters in public areas.

(b) Identify Survey Sites--With the help of the map from the state coordinator, and through personal knowledge of the area, the county coordinator identifies all appropriate wetlands within the county and labels them on site maps.

(c) Meet With Participants--The county coordinator holds a meeting to introduce volunteer observers to cranes and wetlands and to distribute the materials they will need. At this meeting the slides and tapes supplied by the state coordinator are used. Participants also choose and sign up for their survey sites. The county meeting occurs two to three weeks before the count.

(d) Do Local Publicity--The county coordinator sends news releases supplied by the state coordinator to local radio stations and newspapers. Releases, including the date of that county's meeting for crane counters, go out two weeks before the county meeting. This helps recruit additional participants.

(e) Duties on Count Day--The county coordinator holds a morning meeting immediately after the count, for participants to hand in data sheets and share experiences. These meetings are very popular among participants, and allow them to ask questions about what they observed.

(f) After the Count--The county coordinator completes a summary sheet that includes information about the cranes and wetlands of his or her county. This summary sheet is returned to the state coordinator. The county coordinator also mails back all maps of survey sites and participants' names and addresses.

Participants

Most people who volunteer for the crane count have little prior knowledge about cranes. They learn by participating. Participants include youth groups from scouting organizations and schools, adults from birding clubs and community organizations, people who own wetlands inhabited by cranes, and many other citizens.

Observers unfamiliar with their assigned site are urged to visit the location between the training meeting and the count day. Where necessary, they obtain landowner permission. Observers are responsible for getting to and from the appropriate place at the necessary times, although sometimes the county coordinators help them to obtain transportation.

Participants for each site fill out a data sheet during their 2-hour sunrise watch on count day. They record site number, landowner, condition of the wetland, adjacent land-use, and wildlife observed. They record all crane observations, by ear or eye, together with the time. At the end of the watch, they estimate how many cranes were present and the number of breeding pairs. Breeding pairs are identified by the unison call. Participants also prepare a sketch map of the site, with the locations of the cranes. The county coordinator will review these data sheets to check observer judgement regarding total crane numbers and to make adjustments for any cranes that may have been counted twice by observers on two neighboring sites.

It is due to our varied but plentiful participants that the Wisconsin crane count can exist on the scale it does. Many crane counters later support other ICF programs and work to protect the wetlands near their homes.

RESULTS

Each year the state coordinator has tabulated results from all counties. Results for 1980-1984 are presented in Table 1. The increase in cranes counted over the decade is not evidence for an increase in numbers of cranes but rather is due to growth in the organization of the count and in the number of observers.

Data for 1981 and 1982 deserve further explanation because exactly the same number of cranes were counted in the 2 years. This result is noteworthy because twice as many counters went out in 1982 as in 1981, and they surveyed almost twice as many wetland sites. But the 1981 count occurred on 4 April, when many migrant cranes still lingered in Wisconsin, thereby inflating totals. The 17 April date for 1982 timed the count after most migration was over, when only resident birds remained. As a further complication, the weather for 1982 included wind, rain, and even snow, so that viewing conditions were terrible. Many cranes probably were missed.

Table 1. Wisconsin sandhill crane count annual totals, 1980-1984.

Year	Total cranes observed	Total counties participating	Total observers	Total survey sites
1980	977	8	about 200	178
1981	2824	32	760	490
1982	2824	43	1617	937
1983	5822	55	1802	1178
1984	5717	59	2219	1284

The results from 1981 and 1982 highlight the need for caution in interpreting crane count data. All analyses must consider the influence of weather, levels of public participation, and observer inexperience. We believe that few reported cranes were misidentified because the crane has such a striking appearance and call. But a report of no cranes at a site can only be considered tentative.

Although Table 1 cannot be used to compare crane numbers from year to year, the crane totals for 1983 and 1984 -- over 5,000 crane each year -- do provide minimum figures for Wisconsin's population. The true population must be substantially greater, because some counties received no coverage during the count and in others only a few sites were visited. Results from 1983 and 1984 clearly suggest the extent that sandhill crane populations have recovered in Wisconsin. These current figures greatly exceed estimates for Wisconsin's crane population even for 1973 and 1975 (Hunt and Gluesing 1976).

The crane count also reveals that cranes have returned to wetlands in all parts of the state. Nevertheless, cranes are concentrated in certain areas. Fig. 1 depicts the numbers of cranes counted and observers in each county in 1984. Relative crane numbers are charted by county in Fig. 2. Consistent with the situation in earlier decades, the central counties appeared to have the greater share of cranes. The counties bordering the central Wisconsin counties contained the second greatest crane densities. Cranes were sparsely represented in the southwestern counties where wetlands are scarce, and in the heavily forested northern counties. We also charted crane numbers from the 1983 count, and had an almost identical map.

In Fig. 2, crane numbers are presented without any correction for the highly variable numbers of observers or survey sites in the different counties. Some counties had no more than 2-3 observers at 1-2 sites, while others fielded over 100 people at 80-100 sites. But no easy correction can be made for such biases. Some counties may have only a couple dozen locations even marginally suitable for cranes, while others have literally hundreds of wetlands.

A county by county comparison of data in Fig. 1 reveals no clearcut correlation between numbers of cranes and numbers of observers. We have chosen not to apply statistical tests to these data which are from only 1 year. For many counties, only 2 or 3 years of data have been collected. By 1986, however, the project will have generated enough data to provide a more reliable map.

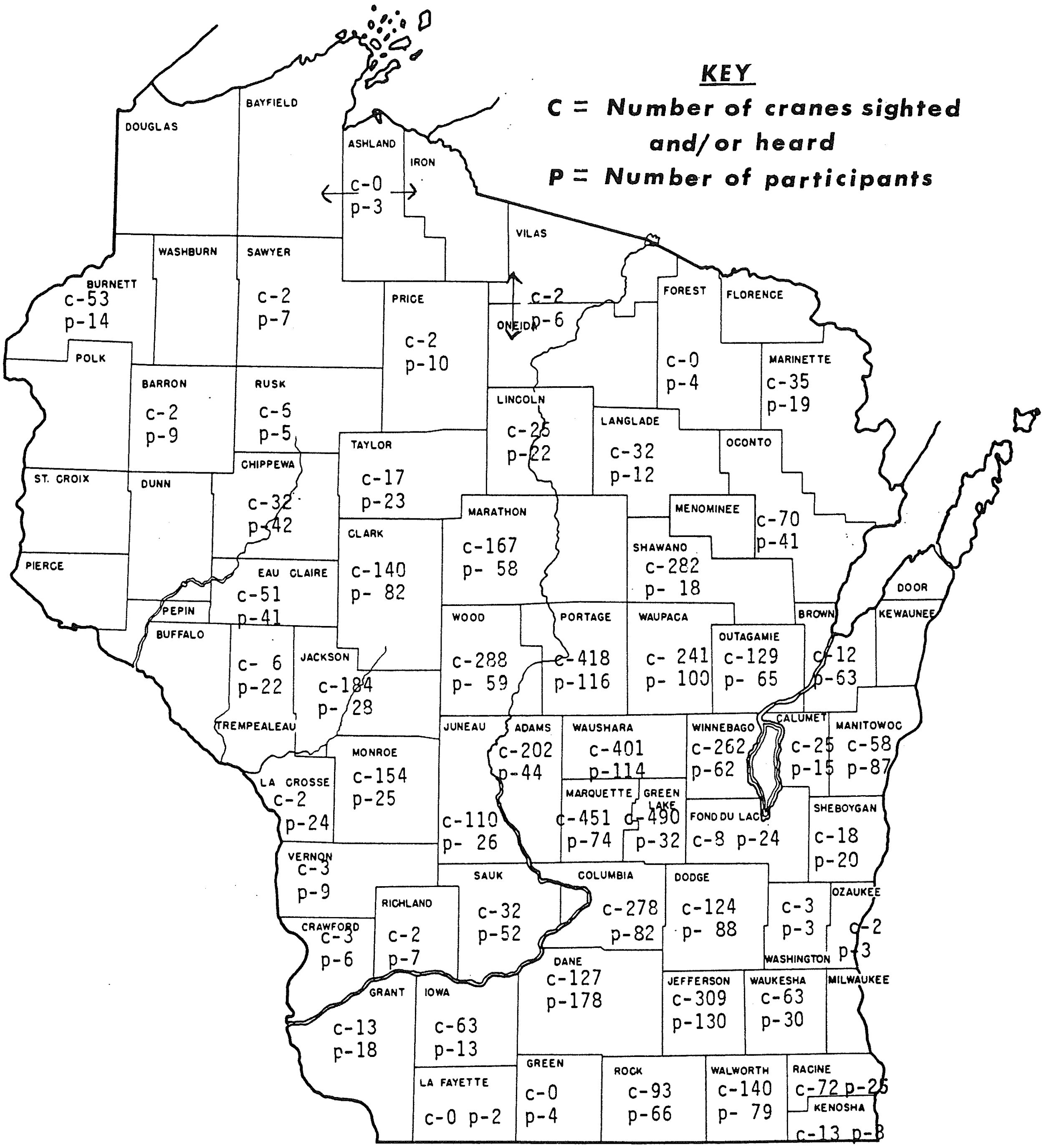
A indicated in Table 1, only a handful of counties have data extending back 5 years. We believe that a minimum of 5 years of data should be accumulated before the status of cranes in any county can be closely evaluated.

For this paper, we examined data for two counties, both located in southcentral Wisconsin (Table 2). We worked with 6 years of data from Columbia County, and 5 years of data from Jefferson County. Columbia County has an area 2,010 km^2, with a human population of 44,000; out of Wisconsin's 71 counties, it ranks 33rd in surface area and 28th in population. Jefferson County has an area of 1,461 km^2 and a human population of 67,000; it ranks 53rd in surface area among Wisconsin counties and 21st in population (Wisconsin Legislative Reference Bureau 1983). Both counties have relatively high crane populations (Figs. 1 and 2) with 278 cranes counted in Columbia County and 309 cranes counted in Jefferson County in 1984.

The crane count has significance for research because of the large number of sites surveyed. A two-county sample is too small to reveal population trends. But the two counties give us an indication of just what the project is accomplishing, and can guide data analysis for the whole state as additional years of data accumulate.

Coverage of sites in Columbia and Jefferson counties varies from year to year, so that few sites have been surveyed every year. This inconsistent coverage results mainly from the preferences of the volunteers -- because we encourage observers to visit a site near their home or a wetland they especially like. As observers change from year to year, so do the sites surveyed. But in this way, we hope to encourage people to become involved in the welfare and fate of individual wetlands, so that they are likely to try to influence governmental or private landowner decisions affecting those wetlands.

The designation of priority sites in 1982 provided for consistent coverage of many areas in each county. By this method, we are obtaining a sizable sample of wetlands surveyed every year, while still allowing considerable observer choice over survey sites.



Total Cranes = 5717 ***Breeding Pairs = 1794***

Number of Observers = 2219 ***Number of Counties :: 59***

Number of sites surveyed = 1284

Fig. 1. Crane and observer totals by county, 1984 Wisconsin sandhill crane count.

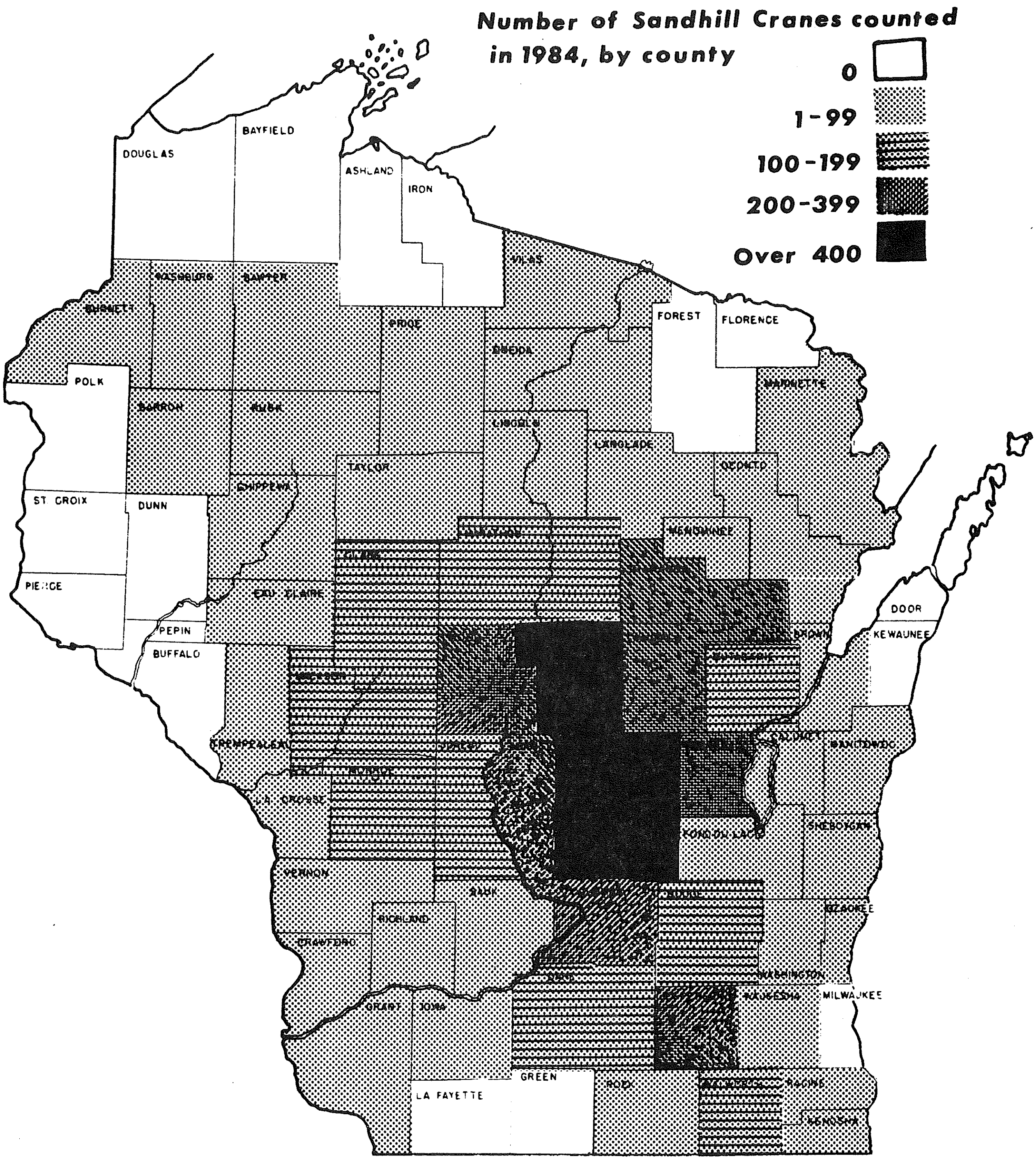


Fig. 2. Crane abundance by county, 1984 Wisconsin sandhill crane count.

For purposes of the present analysis we have divided survey sites into locations regularly used by cranes and into locations irregularly used or not used by cranes (Table 3). These locations were selected from the sites that had been surveyed 2 or more years. We classified as regular-use sites those locations where cranes were present 3 or more years. Sites reported to be without cranes for 2 or more years were catagorized as irregular-use/unused sites. Many sites did not meet either test, and three sites met both tests: these sites were placed in an intermediate category and received no further analysis.

We chose this method for classifying sites because of the variable coverage of sites from year to year. We wanted to use our limited amount of data to obtain two groupings of wetlands distinctly different in crane use. It should be noted that by our criteria, sites surveyed only 2 years were classed as irregular-use/unused sites if cranes appeared neither year; otherwise, these sites were placed in the intermediate category and not analyzed.

Table 3 reveals one bias to our data. Regular-use sites greatly outnumbered irregular-use/unused sites. The organization of the count favors coverage of sites with cranes. Both the volunteer observers and the county coordinators tended to select sites for observation with a past history of crane use -- after all, the project is designed to give volunteers experience with cranes. A site that did not have cranes for 1 or 2 years was less likely than other sites to be surveyed in subsequent years (unless it had been designated as a priority site).

The regular-use sites, 26 for Columbia County and 33 for Jefferson County, can be considered prime crane marshes. This is by no means an exhaustive list (other prime sites probably have not yet been surveyed for enough years to be considered). But the regular-use sites represent a sizable sample of marshes where cranes frequently live. We have analyzed them according to ownership and acreage.

Table 2. Numbers of surveyed wetland sites, Columbia and Jefferson counties, Wisconsin.

Number of years surveyed	Columbia County	Jefferson County	Two-county total
1	22	44	66
2	25	28	53
3	12	25	37
4	11	13	24
5	6	11	17
6	3		3
Total	79	121	200

Table 3. Frequency of crane use of survey sites, Columbia and Jefferson counties, Wisconsin.

Use category	Columbia County	Jefferson County	Two-county total
Regular-use	25	33	58
Intermediate-use	27	34	61
Irregular-use or unused	5	10	15
Total number of sites	57	77	134

We determined ownership of the regular-use sites from the 1983 platbook for Columbia County and the 1984 platbook for Jefferson County. Among the 25 regular-use sites in Columbia County, 13 were entirely or almost entirely in private ownership, 50% of the total. In Jefferson County, 21 regular-use sites were entirely or primarily in private ownership, 64% of the total. For the two counties combined, 34 out of the 58 sites (59%) were in private ownership. The remaining sites were partly or entirely owned by U. S. Fish and Wildlife Service, the Wisconsin Department of Natural Resources, or (two wetlands in Jefferson County) the University of Wisconsin. Many of these "public" lands were interspersed with private holdings.

For these two counties, the future of the crane population will be heavily influenced by how private landowners manage their wetlands. The primary dependence of cranes on state and federal wildlife areas, noted through the 1950's and 1960's, no longer appears to characterize Wisconsin's crane population. Private ownership of crane marshes in Columbia and Jefferson counties for 1983-84 is similar to the 55% reported for Wisconsin as a whole in 1973 (Hunt and Gluesing 1976).

Cranes do not appear to co-exist with people in Wisconsin's cities and villages, perhaps because remnant wetlands in urban areas are too small and too highly disturbed for cranes. None of the 58 regular-use sites from the two counties were located in incorporated areas.

We have also examined acreages for wetlands at regular-use survey sites. The Wisconsin Wetlands Inventory of the Department of Natural Resources (DNR) provided acreages for these two counties, based on computer analysis of the wetland maps recently completed for the state (see Wisconsin Department of Natural Resources, 1982, for a description of the Wisconsin Wetland Inventory). Several larger wetlands in each county contained more than one regular-use site. We analyzed sizes for 42 wetlands regularly used by cranes.

The DNR maps depict all wetland types, including heavily forested swamps, wet areas covered with shrubs, and open waters to a depth of 2 m. In calculating sizes of crane marshes, we only included wetland areas where at least 30% of the surface was covered by emergent vegetation. Wooded swamps and other areas unsuitable for cranes were thus not included in our size determinations.

Of the 42 cranes marshes, 7 (or 17%) were less than 41 ha; 8 (or 19%) were between 41 and 81 ha; 3 (or 7%) were between 81 and 122 ha; 4 (or 10%) were between 122 and 162 ha; 5 (or 12%) were between 162 and 203 ha; 4 (or 10%) were between 203 and 405 ha; and 11 wetlands were larger than 405 ha. Sizes of the wetlands regularly used by cranes ranged from 23 to 1,251 ha.

These figures are roughly comparable to the sizes for 139 crane marshes reported for Wisconsin by Hunt and Gluesing (1976), although our sample contains a greater proportion of large wetlands. This difference could simply reflect the sizes of wetlands present in Jefferson and Columbia counties, and thus available to the cranes.

Along with revealing the characteristics of marshes frequently used by cranes, the crane count data should also provide information on the differences between sites preferred and sites not preferred by cranes. Such between-group comparisons are best made with a large sample size, such as will be available after 1 or 2 additional years of data are collected for the projects' randomly selected priority sites. But we have used our two-county sample for an initial comparison of sizes of regular-use sites and irregular-use/unused sites.

The 42 regular-use marshes averaged 262 ha, while the 15 irregular-use/unused marshes averaged 76 ha in size. The difference appears substantial, although we do not consider this present sample to have been randomly selected and therefore did not analyze the data statistically.

DISCUSSION

Based on our experience with data from the two sample counties, we are now working with the Wisconsin DNR to develop a computer data bank for Wisconsin crane count results. Information stored will include site number and location along with an expandable array of variables about each site -- ownership, acreage, other wildlife use, etc. We will enter the total number of cranes present and the number of crane pairs for each site for each year of the count.

The data bank will serve two main purposes. The DNR will have the crane count results available for use in its water regulatory and environmental impact programs. And ICF will have the data readily accessible for research and analysis.

Our work with the data from our two sample counties has suggested the breadth of information about cranes that can be derived from the count results. By 1986, hundreds of sites across much of the state will have each been counted three to eight times. The limitations encountered in our small two-county sample -- limitations inherent in the type of data the crane count generates -- can partially be overcome as the sample size grows. We will then be able to analyze numbers of cranes reported at sites and evaluate habitat. In this manner, for example, we can assess characteristics of wetlands that support more than one pair of cranes.

The count as a whole does not directly measure population size or change for sandhill cranes, due to variations in the coverage of sites. But the priority sites, surveyed every year, will allow close comparison of crane numbers for a large sample of Wisconsin wetlands. These data will serve as our measure of population change.

There is a special advantage to computerizing the data in cooperation with the DNR. The DNR, particularly through its Wetlands Inventory and Endangered Resources programs, has assembled extensive information about wetlands, information that may assist in analyzing crane count data. The Wetlands Maps, for example, can be used to obtain acreage and habitat type figures by county, township, or individual wetland across the state. The Endangered Resources Program has been conducting surveys of black terns (Chlidonias niger) and other wildlife on many of the same wetlands surveyed in the crane count. By storing crane count data with the DNR, there is further opportunity for analysis using two or more of the data banks.

There are, however, definite limits to the accessibility and usefulness of the Wetlands Inventory data. Wetland acreage figures were provided at our request for the two counties, but budget constraints may prevent generation of similar data for most other counties. And the habitat types used for the Wetland Maps may not follow the criteria most useful for classifying crane habitats. Crane habitat analysis may need to depend on other wetland inventories or on field checks of selected crane marshes.

We plan to continue indefinitely conducting the annual crane count. The more data we have from particular sites, the more useful it becomes. But also, the network of volunteer county coordinators and participants that we have developed over the years probably would not remain involved if the count occurred only once every 2 to 3 years.

Although this paper has not emphasized the project's education and wetland conservation goals, much of the value of the crane count derives from its multiple impacts. When one considers the substantial percentage of crane marshes in private hands, active involvement of thousands of citizens, including many wetland owners, in the cause of crane conservation may prove to be the most important result of our efforts.

We highly recommend crane counts as research-education projects for other areas within the United States and abroad. The essential need is for an institution able to make a long-term commitment to organizing a count and carefully keeping the data. ICF has developed an instructional packet about the census in Wisconsin, including samples of forms and guidelines for coordinators and participants. These materials can be adapted for other areas. For a copy of the packet, contact the Education Coordinator, International Crane Foundation, Route 1, Box 230C, Baraboo, Wisconsin 53913.

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THE GREATER SANDHILL CRANE IN YELLOWSTONE NATIONAL PARK: A PRELIMINARY SURVEY

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Abstract: A preliminary study of status, distribution, and seasonal movements of greater sandhill cranes (Grus canadensis tabida) summering in Yellowstone National Park was conducted from July 1984-March 1985. Historical records indicate that although cranes were abundant when the Park was established in 1872, numbers declined rapidly with human settlement of surrounding areas and increased only slowly after the 1930's. In 1984, we surveyed 53 areas of potential crane habitat by fixed-wing aircraft. Eighteen of these areas were resurveyed by helicopter and 15 from the ground. Counts from fixed-wing aircraft underestimated adult crane numbers by 60-70.6% due to visibility bias. A regression estimation method was used to correct for this bias. The predicted mean number of adult cranes inhabiting 53 areas was 188 (107-269, 90% C.I.) based on ground survey and 203 (135-271, 90% C.I.) from helicopter survey. By combining all survey counts and supplemental observations provided by the Park Service, and eliminating duplications, we accounted for 209 cranes at 47 locations. Suitable crane habitat is widely interspersed throughout vast forested areas in the Park, consequently, we suspect the total crane population may substantially exceed our estimates for 53 primary areas. Helicopter surveys appear to provide the best method for estimating crane numbers in the Park. Seasonal movements of marked cranes confirm that they are affiliated with the Rocky Mountain population. The major fall premigration staging area for cranes from western portions of the Park is Teton Basin, Idaho. Park cranes stop in the San Luis Valley, Colorado, during spring and fall migrations and winter principally in the Rio Grande Valley, in Valencia and Socorro Counties, New Mexico.

PROCEEDINGS 1985 CRANE WORKSHOP

The historical breeding distribution of greater sandhill cranes in the Rocky Mountains includes Yellowstone National Park (Park) (Merriam 1873, Grinnell 1876, Skinner 1925, Wright et al. 1933, Brown 1942, Walkinshaw 1949, Drewien and Bizeau 1974, and others). Recent studies have delineated status, distribution, and seasonal movements of the Rocky Mountain crane population in areas adjacent to the Park in western Wyoming, eastern Idaho, and southwestern Montana (Drewien and Bizeau 1974, Lewis 1977). This population has increased in recent decades and is currently estimated at 17,000-20,000 cranes (Unpubl. data, Id. Coop. Wildl. Res. Unit). Due to increasing numbers and crop depredations at certain locations, limited hunting of this subspecies has been allowed since 1981 in Arizona, and in New Mexico and Wyoming since 1982. We have no knowledge whether these hunts impact cranes from the Park.

Prior to this study, little was known about the status of sandhill cranes in the Park and nothing was known of their seasonal distribution and movements outside the Park. This lack of information was noted recently by the Pacific Flyway Technical Committee and identified as a research need to provide better management guidelines for the population (Wrakestraw and Serdiuk 1982).

Whooping cranes (G. americana) have also been recorded in the Park during the first half of the 20th century (Kemsies 1930, Allen 1952:64). With recent efforts to reestablish whooping cranes in the Rocky Mountain area (Drewien and Bizeau 1978), it is possible that some may settle in the Park in the near future. Whoopers from the reintroduction project have summered in adjacent areas and we have unconfirmed reports from within the Park.

Objectives of this study were to determine the status and distribution of sandhill cranes summering in Yellowstone National Park, identify major areas of crane habitat, and delineate seasonal movements of these cranes. This paper summarizes our findings from July 1984-March 1985.

We thank R. Barbee, Superintendent, Yellowstone National Park, for approving the study and generously providing assistance and aircraft time for aerial surveys and banding operations. R. Knight and B. Blanchard, Interagency Grizzly Bear Study Team, kindly shared their knowledge of crane distribution in the Park. The experience and knowledge of D. Stradley, Gallatin Flying Service, contributed greatly to the aerial survey effort. We gratefully acknowledge the cooperation, support, and information provided by Park Service personnel including K. Czarnowski, J. Gulvin, M. Meagher, and all others who provided observations of cranes. K. Clegg, University of Idaho, provided valuable assistance with ground surveys. Special thanks are due M. Samuel, University of Idaho, for providing statistical advice and for analyzing survey data. We appreciate the assistance of E. Bizeau in implementing the study. helpful reviews of the manuscript were provided by E. Bizeau, S. Derrickson, and M. Samuel. HD. Stahlecker provided radio locations of migrating cranes. E. Myers typed the manuscript. The study was supported by the National Park Service, the University of Idaho, and the U. S. Fish and Wildlife Service.

METHODS

Historical distribution and status of cranes in the Park was ascertained from the literature and unpublished records maintained in the Park's Research Office. Information about cranes summering in the Park in 1984 was obtained from fixed-wing aircraft, helicopter, and ground surveys. Supplemental observations were provided by the Park Service. Cranes were recorded on all surveys as follows: (1) single bird, (2) pair, (3) pair/single at nest or with one or two young, and (4) groups of three or more adults. To avoid spring and fall migrants, only May through September observations were used to plot summer distribution. For brevity, fixed-wing aircraft surveys are hereafter referred to as air surveys.

After preliminary investigation to delineate potential crane habitat, 53 primary areas were surveyed by air (Piper supercub) on 13-14 July. The aerial survey was conducted by a pilot and one observer from sunrise to 1030 hours, MDT, a period when cranes normally forage in open areas. Major meadow, marsh, lake, and riparian habitats were surveyed within the Park.

We obtained two measures of visibility bias in order to refine air survey population estimates. Of 53 areas surveyed by air, we resurveyed 15 areas from the ground and 18 from a helicopter to assess the proportion of cranes observed by air. Assumptions in this visibility bias correction method are: (1) in ground and helicopter surveys all cranes inhabiting a location are observed, (2) the estimated corrections are representative of all other areas surveyed by air, and (3) no movement of adult cranes occurred between surveys.

Ground surveys were conducted on foot or horseback during early morning or late afternoon hours. An effort was made to locate cranes hidden in emergent vegetation or in timber by using binoculars and spotting scopes. During helicopter surveys, densely vegetated areas adjacent to meadows and wetlands were flown in an attempt to flush hidden birds.

Population estimates of adult cranes on the 53 areas surveyed by air were obtained by using a double sample regression estimation method (Scheaffer et al. 1979, Seber 1982:456). A similar ratio estimation is discussed by Jolly (1969) and Eberhardt et al. (1979:21-22). The linear relationship between helicopter-air counts was estimated from 18 sample areas and ground-air counts from 15 sample areas. Two estimates of the adult population and variance were then obtained by multiplying the total number of areas (53) by the linear regression estimates of the mean and variance for helicopter and for ground counts (Scheaffer et al. 1979:123).

Observations of cranes throughout the Park were solicited from Park personnel by the Research Office. These sightings supplemented survey and distribution data but were not employed in population estimates.

To assess seasonal movements, seven cranes were captured and color-marked with 7.6 cm high colored plastic leg bands, and five of these were radio-tagged (Drewien and Bizeau 1981, Melvin et al. 1983). Capture methods entailed locating flightless cranes from the ground or with the aid of a helicopter and running them down (Drewien and Bizeau 1974, 1978). Observations of marked cranes along their migration route and on winter areas were made in conjunction with our ongoing studies of sandhill cranes and introduced whooping cranes in the Rocky Mountain region.

RESULTS

Historical Status and Distribution in the Park

Limited evidence indicates that cranes were relatively abundant in the Yellowstone region when the Park was established in 1872. Merriam (1873:702) lists cranes as being numerous along nearby Henry's Fork, Idaho, and in northwestern Wyoming in 1872. Grinnell (1876:653) reported cranes were "very abundant all through the Yellowstone Park" in 1875. Little information is available for the period 1876-1925 but it is apparent that cranes in sites bordering Yellowstone Park declined rapidly with settlement (Drewien and Bizeau 1974). By the early 1900's cranes were considered very rare in Wyoming (Knight 1902, Graves and Walker 1913).

Published (Skinner 1925, Kemsies 1930, Wright et al. 1933, Wright 1934, Brown 1942) and unpublished records reveal that cranes were rare in Yellowstone during the 1920's and early 1930's. Phillips (1926:5) observed a pair in 1926 near Norris Junction and reported "The sandhill crane, however, is so rare that one can usually count on his finger-tips all he has even seen alive." Wright et al. (1933) reported a minimum of five pairs in the Park in 1932. Observations from 1925-1934 showed cranes were confined to 10 locations, primarily in Bechler Meadows and the Madison River drainage including major tributaries, the Firehole and Gibbon rivers (Fig. 1A).

Observations in Park files suggest that after the mid-1930's cranes were slowly increasing in numbers and dispersing within the Park. W. L. Evans observed a pair in August 1935 in the Gallatin River meadows and commented, "These were the first I have ever seen in this section." In July 1938, W. S. Chapman observed four cranes in Cougar Creek and commented "This is the first time I have seen any sandhill cranes in the vicinity." From 1935-1944, cranes were reported at 26 locations with most sightings again in Bechler Meadows and the Madison River drainage; however, they were also noted in the Gallatin, Gardiner, and Yellowstone drainages (Fig. 1B).

By 1937, McCreary (1937:34) listed them as uncommon residents and migrants in Wyoming. In 1942, Brown (1942:8) considered sandhills rare in Wyoming but believed "numbers were increasing slightly, particularly in the northwestern part of Wyoming and Yellowstone Park." Walkinshaw (1949:134) estimated 10-15 breeding pairs in Wyoming in 1944. He also believed that numbers were increasing during the 1940's.

Observations from the Research Office files for the period 1925-1944 definitely indicate that cranes were increasing in distribution and numbers within the Park (Fig. 1). Although records since the 1950's are incomplete, available evidence suggests numbers continued to increase in the Park and in the surrounding region. (Caslick 1955, Drewien 1973a, Drewien and Bizeau 1974, Lewis 1977).

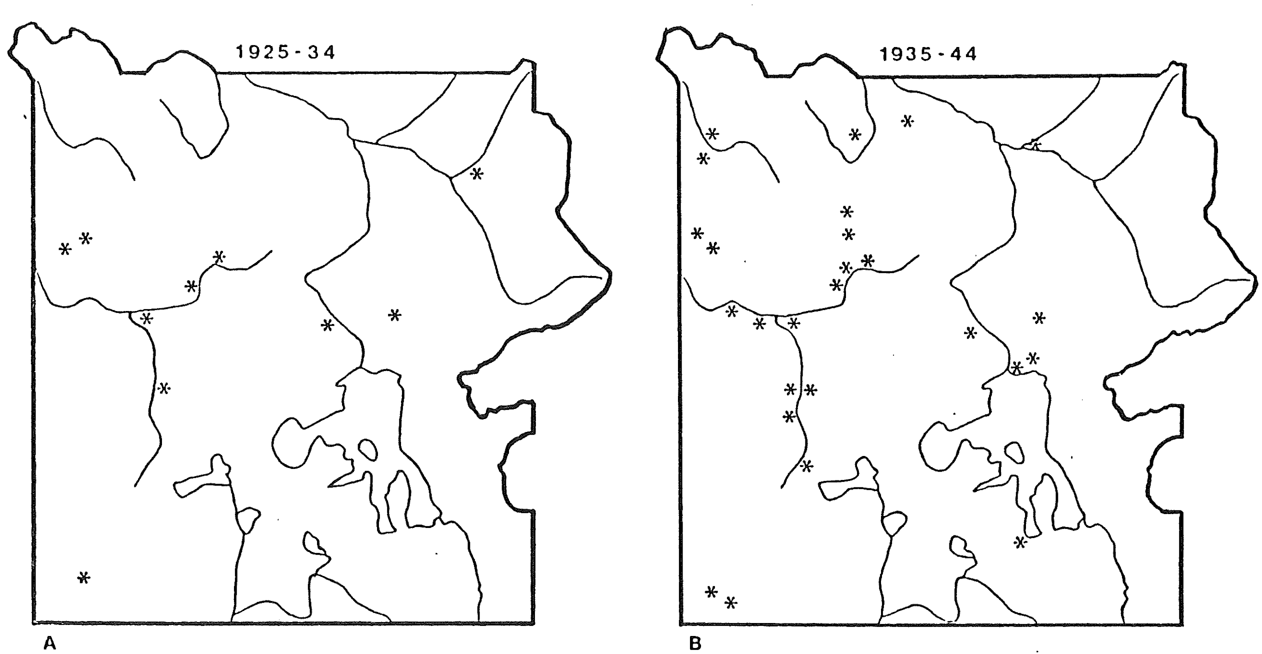

Fig. 1. May-September observations of sandhill cranes in Yellowstone National Park during the decades (A) 1925-1934, and (B) 1935-1944.

1984 Crane Surveys

In mid-July, 53 areas were surveyed by air (Fig. 2) and 61 adults and 7 young were recorded at 17 locations. Number of adults ranged from 1-13 on these areas (Tables 1 and 2). Two of seven young observed had recently hatched and were still on nests.

Corrections for visibility bias in air surveys showed that we missed 60.0 and 70.6% of the adult cranes recorded during helicopter and ground surveys, respectively (Table 2, Fig. 3). The regression estimation derived from air-helicopter comparison predicted a mean of 203 adults (135-271, 90% C.I.), whereas, the air-ground estimation predicted a mean of 188 adults (107-269, 90% C.I.) for the 53 areas.

Observations during ground and helicopter surveys revealed that cranes spent much time close to or inside edges of conifers, mainly lodgepole pine (<u>Pinus contorta</u>), or willows adjacent to meadow and wetland habitats. Many higher elevation meadows (>1,900 m) and wetlands lack tall, emergent vegetation, such as cattail (<u>Typhus</u> sp.) and bulrush (<u>Scirpus</u> sp.). The predominant vegetation on these areas is grasses, forbs, sedges, and rushes <1 m tall which do not provide adequate escape or resting cover. Because cranes frequent the taller conifers and willows for these habitat requirements, their visibility during air surveys is greatly reduced.

We accounted for 209 cranes including 11 young at 47 of 61 locations by tallying results of our surveys and Park Service observations, and eliminating cranes reported more than once from the same location (Table 1, Fig. 2). Total adjusted sightings obtained for the 53 areas initially surveyed by air revealed a population of 194 cranes (185 adults, 9 young) at 39 locations. This total approximates the mean number of cranes predicted by both regression estimations (Table 2).

Cranes were recorded by group size and age (Table 3). In a sample of 160 birds, pairs without young comprised 69.8% of the adult population, pairs with young 12.1%, single birds 2.7%, and grouped birds 15.4%. Single birds are probably members of pairs where the other member was not observed. Birds in groups represent subadults, mainly 1-2 years old, that have not reached breeding age. All pairs are not necessarily breeders; many 2-4 year-olds and a few older cranes are paired but do not attempt to nest (Drewien 1973b, unpubl. data, Id. Coop. Wild. Res. Unit).

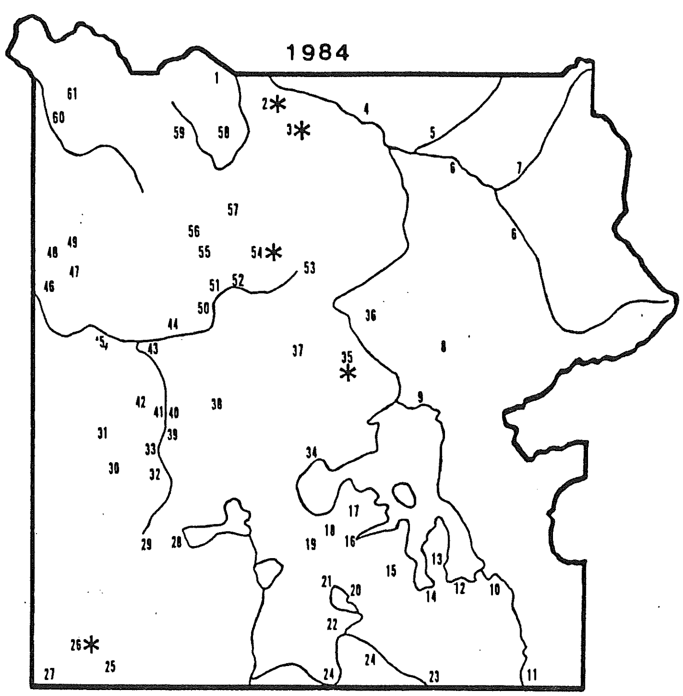

Fig. 2. Survey areas and banding sites for sandhill cranes in Yellowstone National Park, 1984. See Table 1 for location names.

Table 1. Numbers of sandhill cranes observed in summer 1984 in Yellowstone National Park during air, helicopter, and ground surveys with supplemental observations provided by Park Service. The map reference numbers correspond to the numbered locations labelled in Fig. 2.

Location	Map reference no.	No. Cranes (ad/yg)			Other crane obs.[a]	Total cranes[b] (ad/yg)
		Air	Helicopter	Ground		
Rainbow Lake/Gardiner Flat	1	0				0
Mt Evert	2	N.S.[c]	2/2[d]			2/2
Blacktail Deer Plateau	3	0	15/0			15/0
Hellroaring Creek/Yellowstone River	4	0				0
Slough Creek	5	0			4/0	4/0
Lamar River	6	0		0/0		0
Soda Butte Creek	7	0			3/0	3/0
Fern Lake/Broad Creek Area	8	0			1/0	1/0
Pelican Valley	9	2/0		14/0		14/0
Yellowstone River-southeast arm	10	0			2/0	2/0
Thorofare Creek	11	2/0			2/0	4/0
Chipmunk Creek	12	4/2				4/2
The Promontory	13	2/0				2/0
South Arm Meadows	14	0				0
Surprise Creek	15	0				0
Flat Mt. Arm Meadows	16	0				0
Delusion Lake	17	0				0
Solution Creek	18	2/0				2/0
Riddle Creek	19	0				0
Beaver Creek	20	0		4/0		4/0
Witch Creek	21	0		2/0		2/0
Basin Creek-Heart River	22	6/0				6/0
Fox Park	23	N.S.			occur[e]	occur
Snake River	24	2/0				2/0
Upper Falls River Meadows	25	2/0				2/0
Bechler Meadows	26	13/4	19/3			19/3
Bechler Ranger Station Area	27	N.S.			2/0	2/0
Shoshone Lake	28	0				0
Upper Firehole Meadows	29	0				0
Little Firehole Meadows	30	0	4/0			4/0
Buffalo Meadows	31	0	6/1			6/1
Fern Cascades	32	N.S.			2/0	2/0
Upper Geyser Basin	33	N.S.			1/0	1/0
Arnica Creek	34	N.S.			2/0	2/0
Hayden Valley	35	0		9/1	2/0	11/1
Sour Creek	36	0	0/0			0
Cygnet Lakes	37	0	2/0			2/0
Nez Perce Creek	38	3/0	5/0			5/0
Midway Geyser Basin	39	0		0/0		0
Lower Geyser Basin	40	4/0		6/0		6/0
Fairy Creek	41	4/0	4/0	4/0		4/0
Sentinal Creek	42	2/0	4/0	6/0		6/0
Madison Jct/Terrace Spring	43	0		2/1		2/1
Secret Valley	44	0	2/0			2/0
Madison River	45	0			2/0	2/0
Madison Valley	46	N.S.			2/0	2/0
Cougar Creek	47	0				0
Richards Pond	48	0	0/0			0
Duck & Gneiss Creeks	49	0	6/0		8/0	14/0

(continued next page)

Table 1 (cont.). Numbers of sandhill cranes observed in summer 1984 in Yellowstone National Park during air, helicopter, and ground surveys with supplemental observations provided by Park Service. The map reference numbers correspond to the numbered locations labelled in Fig. 2.

Location	Map reference no.	No. Cranes (ad/yg) Air	Helicopter	Ground	Other crane obs.[a]	Total cranes[b] (ad/yg)
Gibbon Meadows	50	2/0	2/0	0/0		2/0
Elk Park & adjacent meadows	51	0		0/0	2/0	2/0
Norris Geyser Basin-Twin Lakes	52	4/0				4/0
Grebe, Cascade, Wolf Lakes	53	0	2/0			2/0
Solfatara Creek	54	6/1	6/1			6/1
Grizzly Lake/Straight Creek	55	0	2/0			2/0
Winter Creek	56	N.S.			2/0	2/0
Willow Park/Obsidian Creek	57	0		0/0	2/0	2/0
Swan Lake Flats	58	1/0	1/0	0/0	4/0	5/0
Gardiner Hole	59	0		4/0		4/0
Gallatin River	60	0	0/0		2/0	2/0
Fan Creek	61	0			4/0	4/0
Total cranes		61/7	82/7(80/5)[f]	51/2	40/0	198/11
No. areas surveyed		53	19 (18)[f]	15	20	61

[a] Observations provided by NPS personnel and adjusted for duplication with sightings from fixed-wing, helicopter, and ground surveys.
[b] Total cranes observed by location adjusted for duplication.
[c] N.S. = not surveyed by air.
[d] Data not included in population estimate obtained by comparing air-helicopter surveys.
[e] Cranes were heard calling in area but not observed.
[f] Data used for population estimate obtained from air-helicopter comparison.

Table 2. Comparison of air surveys with helicopter and ground surveys employed to correct visibility bias, and parameters used in the regression estimation to predict numbers of adult cranes on 53 areas in Yellowstone National Park, 1984.

Characteristic/parameter	Air survey	Air-helicopter comparison Air	Hel	Air-ground comparison Air	Ground
No. areas surveyed	53	18	18	15	15
No. (%) areas in survey cranes obs.	17(32.1)	15(83.3)	15(83.3)	6(40.0)	9(60.0)
No. cranes obs. - ad./yg.	61/7	32/5	80/5	15/0	51/2
Sample areas					
$\bar{x}\pm$SE No. cranes sample area		1.8±0.48	4.4±1.19	1.0±0.20	3.4±1.05
Linear regression estimator					
$\bar{x}$(90%) CI) No. cranes/sample area			3.83(2.55-5.12)		3.55(2.02-5.07)
Total (90% CI) No. cranes on 53 areas			203(135-271)		188(107-269)
Correlation coefficient			0.68		0.35

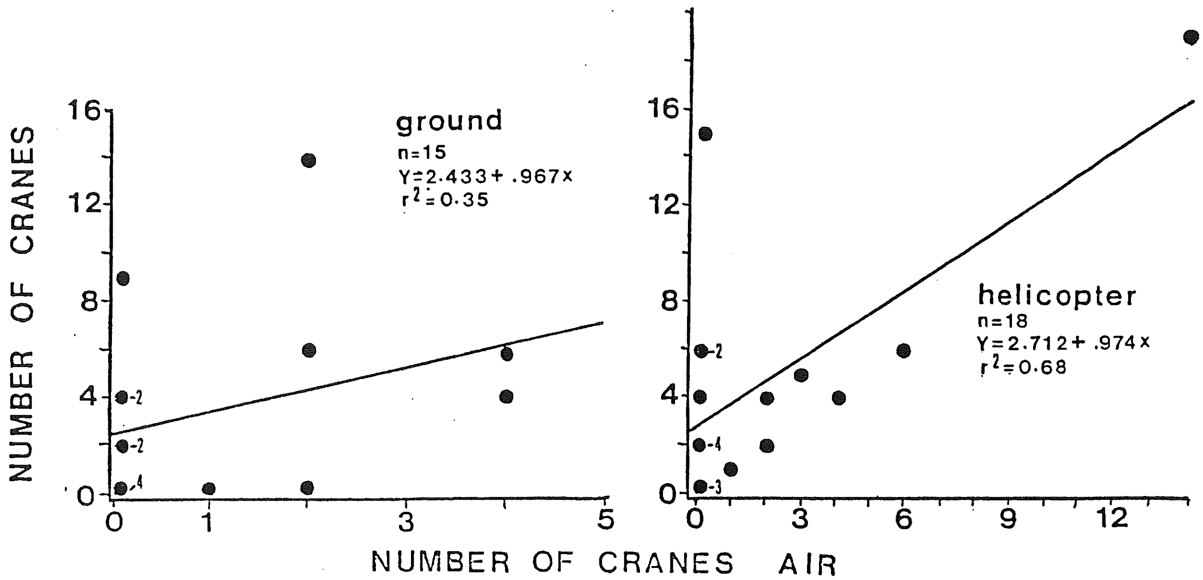

Fig. 3. Relationship between numbers of adult sandhill cranes observed at specific sites during air surveys compared to numbers of adult cranes observed during ground and helicopter counts at the same locations, Yellowstone National Park, summer 1984.

Table 3. Group and age compositions of sandhill cranes observed during air, helicopter, and ground surveys, Yellowstone National Park, summer 1984.

Data source	No. locations	Crane group and age composition						
		Single	Pair	Pair + 1 yg.	Pair + 2 yg.	Group[a]	Total (ad/yg)	%yg.
Survey method								
Air	53	3	24	5	1	0	61/7	10.3
Helicopter	19	2	27	5	1	14	82/7	7.9
Ground	15	2	18	2	0	9	51/2	3.8
Total (adjusted for duplication)[b]	54	4	52	7	2	23	149/11	6.9

[a] Group = 3 or more adult cranes
[b] All cranes counted more than once at the same specific locations were eliminated from totals.

Table 4. Movements during fall and winter 1984-85 of seven sandhill cranes banded in Yellowstone National Park, August 1984.

Locations	Crane identification no. 1	2	3	4	5 (adult)	6-7 Broodmates
Banding Location[a] and Markings	Bechler Meadows(26) Radio	Bechler Meadows(26) Radio	Hayden Valley(35) Radio	Solfatara Cr. (54) Colored leg band	Blacktail Deer Plateau (3) Radio	Mt. Everts (2) 6-radio 7-colored leg bands
Fall Premigration Staging area (1984)						
Teton Basin, near Driggs, Idaho	10/5	9/29-10/5	9/20	Not obs.	9/20	10/5
Fall Migration (1984)[b]						
San Luis Valley, Colo.				Not obs.	Not obs.	
1. Monte Vista NWR, Rio Grande Co.		10/20-11/10				
2. Rio Grande River, Alamosa Co.			10/22-28			10/20-11/9
3. W of Rio Grande River, Conejos Co.	10/26					
Bandelier Nat'l Mon., near White Rock, Los Alamos Co., N.M.				11/1[c]		
Winter Grounds (1984-85)[b]				Not obs.		
Rio Grande Valley, N.M.						
1. Bosque del Apache NWR, Socorro Co.			11/13-3/5(am)		11/13-2/17	11/13-14
2. Bernardo State Refuge, Socorro Co.	11/18-12/19					
3. Veguita, Socorro Co.	1/3					
4. Los Lunas, Valencia Co.			11/13,11/27			
5. Belen-Casa Colorado State refuges, Valencia Co.	1/8-2/22		11/15-20,12/7-2/19		2/19	
Spring Migration (1985)[b]				Not obs.		
near White Rock, Los Alamos Co., N. M.					2/20[c]	2/21[c]
near Espanola, Rio Arriba Co., N.M.		3/5(pm)[c]				
San Luis Valley, Colo, (1985)				Not obs.		
1. Monte Vista NWR, Rio Grande Co.		3/10				3/11
2. Rio Grande River, Alamosa Co.			3/13			
3. W of Rio Grande River, Conejos Co.	3/11				3/11	

[a] See Fig. 2 for map reference number of banding locations in Yellowstone Park.
[b] See Fig. 4 for migration and winter area locations
[c] Radio signal from flock of migrating cranes (D. Stahlecker, pers. commun.)

Age ratios from a sample of 160 cranes, showed 6.9% (11) young (Table 3). Chi-square analysis revealed that the percent young in the Park did not differ significantly (X^2=0.32, 1 d.f., p>0.05) from estimates we collected for the entire Rocky Mountain population (8.1%) during October 1984 in the San Luis Valley, Colorado. However, the age ratio obtained in the Park is maximal because some young had not yet fledged and additional mortality may have occurred before Park cranes arrived in Colorado.

Capturing and Marking Cranes

In August, seven cranes (six flightless young and one adult) were captured and marked in the western and central portions of the Park (Table 4, Fig. 2). Captured cranes included four broods containing single young, one brood of two young, and one molting adult from a family containing one young which eluded capture.

Exact fall departure dates from the Park were not determined. Two young from Bechler Meadows were still on their natal marshes on 20 September, whereas, two other marked cranes had arrived in eastern Idaho by this date. Six marked cranes had left the Park before 4 October (Table 4).

Movements and Distribution After Leaving the Park

Migratory movements of sandhill cranes in the Rocky Mountain population have been described by Drewien and Bizeau (1974) and are briefly summarized here. After mid-August, cranes depart their respective summer sites and gather at nearby premigration staging areas, primarily located in eastern Idaho and western Wyoming. The major attraction is the availability of grain, mainly barley, located near wetland roost sites. Cranes normally migrate from staging areas by mid-October and stop for up to 6 weeks in the San Luis Valley, Colorado. Most leave Colorado by mid-November for winter areas in western New Mexico, southeastern Arizona, and northern Mexico. During spring migration, cranes return to the San Luis Valley between mid-February and early March and arrive on summer areas in April and May. Park records show that the first cranes normally arrive in mid-April.

We surveyed premigration staging areas and located six of seven marked cranes in Teton Basin near Driggs, Idaho, between 20 September-5 October (Table 4, Fig. 4). Teton Basin is a major fall premigration staging area in the Rocky Mountain region (Drewien and Bizeau 1974). Distances from banding sites in the Park to Teton Basin range from 40-140 km. Only one marked crane, a junevile from Solfatara Creek, was not observed in Teton Basin or anywhere along the migration route (Table 4). Although this bird may have died, it was not radio-tagged and was possibly overlooked in our surveys.

During the fall migration, we located five marked cranes in the San Luis Valley, Colorado, between 20 Oct.-10 Nov. (Table 4). This Valley is about 875 km southeast of Yellowstone Park. Each marked crane was observed in a separate flock. Two families that originated from breeding territories 0.5-1 km apart in Bechler Meadows utilized areas over 15 km apart in the Valley.

One crane, migrating on 1 November from Colorado to the winter grounds, was detected by radio signal as it passed over Bandelier National Monument near White Rock in northern New Mexico (Table 4, Fig. 4) (D. Stahlecker, pers. comm.). Six cranes were located in November on winter areas in the middle Rio Grande Valley in west-central New Mexico; four remained during the winter (Table 4). One family with two marked young stopped at the Bosque del Apache National Wildlife Refuge (Bosque Refuge) (Fig. 4) on 13-14 Nov., but apparently continued south for the winter. We surveyed other winter areas in southwestern New Mexico, southeastern Arizona, and Mexico but failed to relocate this family. We suspect that they wintered in northern Mexico.

Locations and movements of four marked cranes wintering in the Rio Grande Valley varied (Table 4). Cranes Nos. 2 and 5 remained at the Bosque Refuge until 17 February and 4 March. Two others wintered between Los Lunas and Bernardo (Fig. 4). Crane No. 1 spent a month at Bernardo State Refuge before moving 20 km north to the Belen-Casa Colorado State refuges where it remained through 22 February. Crane No. 3 moved between Los Lunas and the Belen Refuge, some 25 km apart, before settling for the winter in the Belen Refuge area.

All four cranes in the Rio Grande Valley migrated from the wintergrounds between 19 February-5 March. Crane No. 6 returned from an unknown winter site and its radio signal was detected as it migrated over White Rock, New Mexico on 21 February. Cranes Nos. 2 and 5 were also detected by radio signal in northern New Mexico during spring migration. Crane No. 2 departed Bosque Refuge during mid-morning, 5 March, and was detected at 1530 hours, some 260 km north, near Espanola, New Mexico (Table 4, Fig. 4).

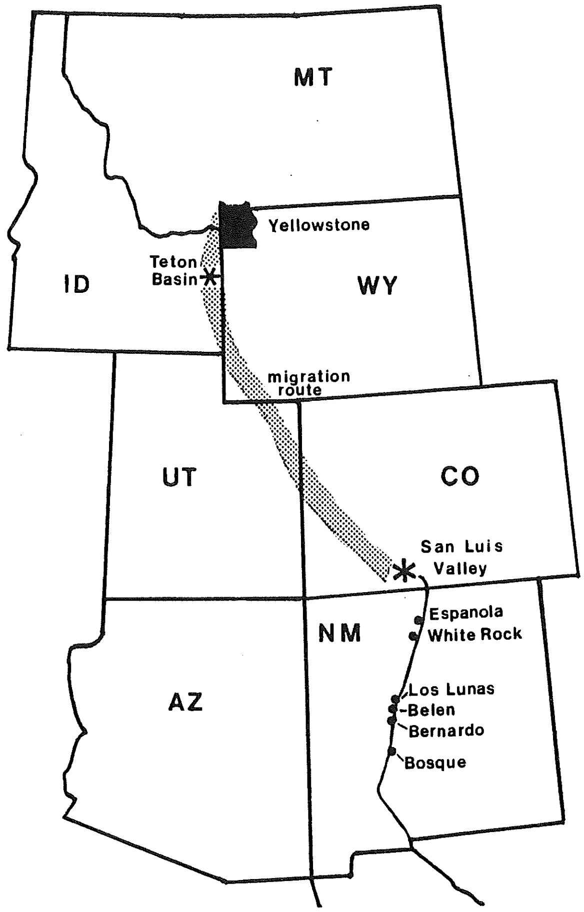

Fig. 4. Distribution during fall, winter, and spring, 1984-85, of sandhill cranes banded in Yellowstone National Park, August 1984. Migration route is adapted from Drewien and Bizeau (1974, 1981).

Six cranes were relocated in March 1985 in the San Luis Valley, Colorado. Five had returned to the same locations in the Valley where they had been observed during the previous fall. Crane No. 5 was not observed in the Valley during fall migration but was found in March along the Rio Grande River near Alamosa National Wildlife Refuge (Table 4).

DISCUSSION

The history and population trends of sandhill cranes in the Park are similar to that of other population segments in the Rocky Mountains. Apparently abundant before the 1880's, numbers declined rapidly following settlement of the region and cranes were considered rare by the early 1900's. Subsequent protection of the subspecies and favorable habitat changes allowed cranes to slowly increase and expand their range (Drewien and Bizeau 1974). When our survey results are compared with Park records it becomes apparent that cranes have increased substantially in numbers and distribution in the Park over the past 60 years (Fig. 1 and 2).

Certain Park locations have a long history of crane use, but other sites have only recently been colonized as the population increased. Park records show that areas such as Bechler meadows, Lower Geyser Basin, and meadows and wetlands along the Firehole and Gibbon rivers (Fig. 1 and 2) were occupied even when cranes were considered rare in the Park. Bechler Meadows represents some of the best sandhill habitat within the Park; whooping cranes also have been reported from this area (Kemsies 1930, Allen 1952).

We agree with Caughley (1974:921) who stated "Aerial survey is, at best, a rough method of estimating the size of a population." Our air surveys provided highly inaccurate counts because many cranes frequented woody cover types where they could not easily be observed. We attempt to measure visibility bias and to correct our population estimates accordingly.

We have not yet surveyed numerous but widely-distributed small areas of suitable crane habitat within the Park. Consequently, we suspect that the total crane population may substantially exceed the mean population estimates of 188-203 adults for the 53 primary areas surveyed.

Conducting surveys for cranes is difficult in this 9,000 km^2 mountainous Park. About 80% of the Park is forested and elevations vary from 1,600-3,000 m (Despain 1983). Crane habitat is confined primarily to river valleys, wetlands, and meadows widely interspersed throughout forested areas. Access to much of the crane habitat is limited to travel on foot, by horse, or by aircraft.

Our data indicate that the best estimate of crane numbers would probably be obtained by helicopter survey. The correlation coefficient for air-helicopter comparisons was nearly twice as high as for air-ground comparisons (Table 2, Fig. 3) indicating a greater consistency between air and helicopter counts. This consistency is also reflected by the smaller confidence interval for the population predictions from the helicopter survey. However, cost of helicopter surveys may be prohibitive.

Fall, winter, and spring observations of marked cranes originating from the Park confirmed their affiliation with the Rocky Mountain population. Cranes from western portions of the Park share a premigration staging area at Teton Basin, Idaho, with cranes summmering in eastern Idaho and southwestern Montana (Drewien and Bizeau 1974). Park cranes also stage in fall and spring in the San Luis Valley, Colorado, and utilize the population's principal winter grounds in the middle Rio Grande Valley in west-central New Mexico. The distance traveled by cranes migrating from northern areas of the Park via Teton Basin, the San Luis Valley, and on to winter sites near the Bosque Refuge, New Mexico, is about 1,450 km.

FUTURE STUDIES

We plan to continue our surveys to refine population estimates and better define crane distribution within the Park. Efforts will be directed towards surveying numerous, small areas of crane habitat that were not included in our initial surveys. Additional banding and marking efforts will be confined to cranes inhabiting eastern and south-central areas so we can document and compare their movements to birds already banded in western areas of the Park. Whether birds inhabiting these areas stage for migration in Teton Basin remains unknown at this time.

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HUNTING IN THE MANAGEMENT OF MID-CONTINENT SANDHILL CRANES

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Abstract: Mid-continent sandhill cranes were protected from 1916 until 1959 when a season was re-opened in Canada. In the Central Flyway, seasons were re-opened in 1961 in New Mexico and, by 1972, in seven other states. The concern over the expansion of seasons prompted efforts to obtain better estimates of harvests. Since 1975, all hunters have been required to possess special Federal permits. Post-season questionnaires were mailed to permittees to determine their activity and success. During 1975-83 seasons, averages of 13,400 permits were issued, 6,800 permittees hunted one or more times, and 2,900 hunters bagged one or more cranes. Estimated harvests during those nine seasons averaged 10,100. Those harvests were considered to be within management guidelines.

PROCEEDINGS 1985 CRANE WORKSHOP

An objective of management of mid-continent sandhill cranes is a stable population not substantially different from that of 1980 (Central Flyway Council 1981). Sport hunting is recognized as a primary tool for accomplishing that objective. The long-standing interest in sport hunting of cranes is illustrated in the 16 August 1916 Convention For The Protection Of Migratory Birds wherein representatives of the United States and Great Britain (for Canada) agreed that, for the following 10-year period, there would be a ". . . continuous close (sic) season on. . . little brown, sandhill and whooping cranes,. . . ." That "close season" exceeded expectations and sport hunting of sandhill cranes was not resumed until 1959, 43 years later, in Canada and even later, in January 1961, in the United States. This resumption, after so long a "close season," naturally attracted even greater interest in sport hunting.

Hunting seasons in the Central Flyway soon were expanded, from only a portion of New Mexico in 1961, to include a portion of Texas in 1962, portions of four more states in 1968, and portions of two more in 1972. Those expansions undoubtedly contributed to sport hunting of cranes becoming a subject of considerable controversy. Fortunately that controversy, probably more than anything else, fostered initiation of substantive efforts to learn more about sandhill cranes. The results of the efforts, well known to the participants in these workshops, have made sandhill cranes among the better known migratory birds.

Among the increased efforts were those to obtain better estimates of hunting activity and harvests of cranes. The purpose of this paper is to report a preliminary assessment of some of the results and their relationships to hunting regulations and harvest guidelines.

I am particularly indebted to M. F. Sorensen who conducted the special sandhill crane harvest surveys and reported the results so essential to this effort. My special thanks to K. L. Tiedt for assistance in preparing Tables and Figures and for typing the manuscript. I thank my colleagues in the Central Flyway States who coordinated the distribution of the Federal permits and provided the encouragement to conduct the special studies.

METHODS

All persons who hunted cranes during regular seasons have been required, in 1975 and since, to possess valid Federal sandhill crane hunting permits in addition to any licenses required by individual states. The permits (Fig. 1) were provided by the U.S. Fish and Wildlife Service (FWS) and were issued, free and unlimited, by the respective state wildlife conservation agencies. The permit required only recording the hunter's name and address and became valid when signed by that individual. It included a "crane hunting diary," for recording daily hunting activity and success, along with a message that a sample of permittees would be contacted following the season. Carbon copies of the permits were forwarded to the FWS Section of Waterfowl Harvest Surveys, Laurel, Maryland, and made up the universe of potential crane hunters.

Post-card questionnaires (Fig. 2), pre-addressed and no postage necessary, were mailed to hunters in the samples shortly after the seasons closed in each state. The sampling rate was 100% in all states except in North Dakota, where it was reduced to 77% in the 1982-83 survey and 50% in the 1983-84 survey, and in Texas where it was reduced to 71% in 1982-83 and 50% in 1983-84. Follow-up questionnaires were sent to those who did not respond to initial contacts

1983
SANDHILL CRANE
HUNTING PERMIT
(Void after June 30, 1984))

U.S. FISH & WILDLIFE SERVICE

No. 16735

This permit authorizes the person whose name and address appears on the reverse side, and whose signature appears below, to participate in the Sandhill (Little Brown) Crane hunting season in accordance with the provisions of both Federal and State regulations governing the season. Following the close of the season, a sample of permittees will be contacted by mail and asked to report by separate daily hunts the information indicated on diary portion at right. If contacted, report only information on your personal bags (for party hunting report only your personal take-home share of party bags).
Your assistance is appreciated.

U.S. FISH AND WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

SIGNATURE OF HUNTER:

Harvey W. Miller
(Not valid unless signed)

CRANE HUNTING DIARY

Please use the below diary to record your personal hunting activity, for possible later transfer to a questionnaire you may be mailed. Include hunts on which you bagged nothing.

DATE OF HUNT	NUMBER I KILLED and RETRIEVED	NUMBER I DOWNED BUT LOST	COUNTY OF HUNT
SEASON TOTALS			

DEPARTMENT OF THE INTERIOR
U. S. FISH AND WILDLIFE SERVICE
OFFICE OF MIGRATORY BIRD MANAGEMENT
LAUREL, MD. 20708

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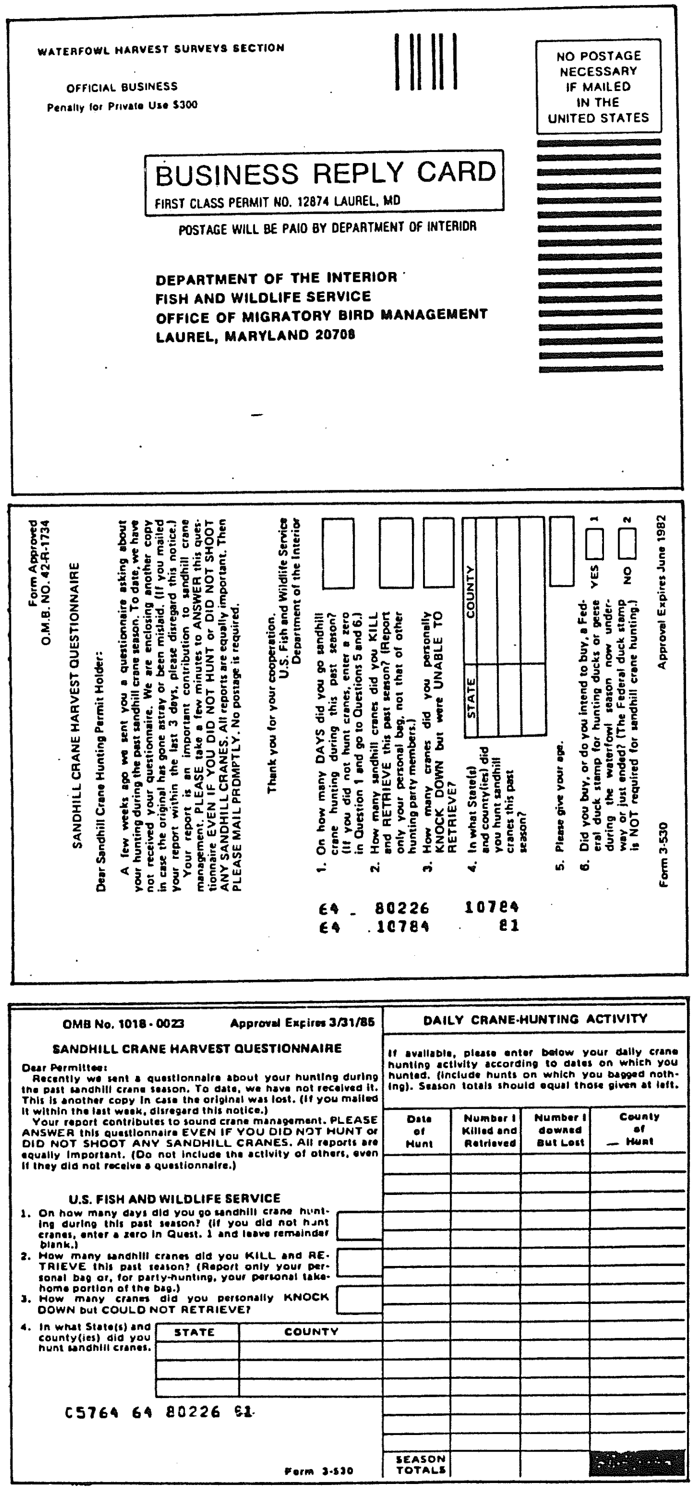
Golden Colorado
City or Town State

80401
Zip Code

County of Residence: Unk

Fig. 1. Federal sandhill crane hunting permit.



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Form Approved
O.M.B. NO. 42-R-1734

SANDHILL CRANE HARVEST QUESTIONNAIRE

Dear Sandhill Crane Hunting Permit Holder:

A few weeks ago we sent you a questionnaire asking about your hunting during the past sandhill crane season. To date, we have not received your questionnaire. We are enclosing another copy in case the original has gone astray or been mislaid. (If you mailed your report within the last 3 days, please disregard this notice.)
Your report is an important contribution to sandhill crane management. PLEASE take a few minutes to ANSWER this questionnaire EVEN IF YOU DID NOT HUNT or DID NOT SHOOT ANY SANDHILL CRANES. All reports are equally important. Then PLEASE MAIL PROMPTLY. No postage is required.

Thank you for your cooperation.
U.S. Fish and Wildlife Service
Department of the Interior

1. On how many DAYS did you go sandhill crane hunting during this past season? (If you did not hunt cranes, enter a zero in Question 1 and go to Questions 5 and 6.)
2. How many sandhill cranes did you KILL and RETRIEVE this past season? (Report only your personal bag, not that of other hunting party members.)
3. How many cranes did you personally KNOCK DOWN but were UNABLE TO RETRIEVE?
4. In what State(s) and county(ies) did you hunt sandhill cranes this past season?

STATE	COUNTY

5. Please give your age.
6. Did you buy, or do you intend to buy, a Federal duck stamp for hunting ducks or geese during the waterfowl season now underway or just ended? (The Federal duck stamp is NOT required for sandhill crane hunting.) YES 1 NO 2

Form 3-530 Approval Expires June 1982

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64 . 10784 81

OMB No. 1018 - 0023 Approval Expires 3/31/85

SANDHILL CRANE HARVEST QUESTIONNAIRE

Dear Permittee:
Recently we sent a questionnaire about your hunting during the past sandhill crane season. To date, we have not received it. This is another copy in case the original was lost. (If you mailed it within the last week, disregard this notice.)
Your report contributes to sound crane management. PLEASE ANSWER this questionnaire EVEN IF YOU DID NOT HUNT or DID NOT SHOOT ANY SANDHILL CRANES. All reports are equally important. (Do not include the activity of others, even if they did not receive a questionnaire.)

U.S. FISH AND WILDLIFE SERVICE
1. On how many days did you go sandhill crane hunting during this past season? (If you did not hunt cranes, enter a zero in Quest. 1 and leave remainder blank.)
2. How many sandhill cranes did you KILL and RETRIEVE this past season? (Report only your personal bag or, for party-hunting, your personal take-home portion of the bag.)
3. How many cranes did you personally KNOCK DOWN but COULD NOT RETRIEVE?
4. In what State(s) and county(ies) did you hunt sandhill cranes.

STATE	COUNTY

C5764 64 80226 81

Form 3-530

DAILY CRANE-HUNTING ACTIVITY

If available, please enter below your daily crane hunting activity according to dates on which you hunted. (Include hunts on which you bagged nothing). Season totals should equal those given at left.

Date of Hunt	Number I Killed and Retrieved	Number I downed But Lost	County of Hunt
SEASON TOTALS			

Fig. 2. Questionnaire mailed post-season to crane permittees. Lower view shows modification initiated in 1982.

within approximately 3 weeks and the survey was terminated approximately 3 weeks thereafter.

Responses to the surveys have been accepted as presented, that is, there have been no adjustments for memory, prestige, or other possible biases. The respondents were considered representative of all permittees, e.g., the fraction of respondents who reported hunting one or more times, multiplied by the number of permits issued, became the estimated number of active hunters. An identification code for each permittee contacted enabled elimination of duplicate responses in instances where follow-up questionnaires were mailed before responses to initial contacts have been received in Laurel, Maryland.

RESULTS

There were several changes in the regular Central Flyway seasons (Table 1) for which sandhill crane hunting permits have been required. Those changes were designed to permit hunting when and where cranes usually occur, under reasonable regulations, and in consideration of the usual migration of whooping cranes. The 1984-85 seasons (Table 1) and areas open (Fig. 3) in those eight states are considered "operational," i.e., no additional substantive changes are contemplated.

The sandhill crane hunting permits issued (Table 2) during the first eight regular seasons, 1975-76 through 1982-83, ranged from about 11,350 to 13,800 and averaged nearly 12,800. The number issued for the 1983-84 season jumped to just over 18,300. Within individual states, the number issued varied from year to year without pattern and apparently independently of the numbers issued in other states.

In total, following the 1975-76 through 1983-84 seasons, just over 110,500 permittees were contacted. Just over 80,000 (72%) responded to either the initial or follow-up contacts. Of all respondents, 51% reported hunting sandhill cranes. Those who hunted averaged 3.14 recreational hunting days and 42% were successful in bagging one or more cranes during an average season.

The proportion of active hunters among the permittees, i.e., those who hunted one or more times during the nine regular seasons (Table 2), ranged from 39% in 1983-84 to 59% in 1975-76. Estimated numbers of active hunters ranged from nearly 5,100 in 1976 to just over 8,000 in 1977 and averaged just over 6,800.

The reported harvests of cranes per active hunter ranged from an average of 1.32 in 1978 to 1.81 in 1983 and averaged 1.48 cranes during the nine regular seasons. The estimated harvests (Table 3) ranged from nearly 7,400 in 1976 to nearly 13,000 in 1983 and averaged approximately 10,100.

The modified questionnaire (Fig. 2), initiated in 1982, permitted respondents to report their activity and success by day. Those who completed that portion of the questionnaire following the 1983-84 seasons, considered "operational," and were unsuccessful (season bag - 0) reported hunting an average of 2.6 days. Respondents who were successful reported hunting an average of 3.4 days. The successful respondents bagged nothing on 44% of the days they hunted, one crane on 28% of the days, two cranes on 15% of the days, and three cranes (the daily limit) on 13% of the days they hunted.

DISCUSSION

Federal sandhill crane hunting permits apparently served the purpose of identifying potential crane hunters. Personal contacts in the field indicated compliance with the requirement that all hunters possess the free permit. There were no reports of specific violations of the requirement. Harvests reported by permittees were assumed to be representative of cranes taken during regular hunting seasons in the Central Flyway.

The numbers of permits issued in some states appeared to reflect the influence of changes in hunting seasons. For example, in North Dakota, the substantial increase in permits issued in 1977 probably reflected the perceived greater likelihood of cranes being present in September and the increase in 1983 probably reflected perceived opportunities to hunt cranes during seasons on other game birds. The opening of a new hunting area (Zone C, Fig. 3) in Texas in 1983 obviously influenced more persons to obtain permits. However, there also were variations in numbers of permits issued in New Mexico where there were no changes in hunting seasons.

The proportion of active crane hunters (average 51%) among permittees was lower than usual among those who obtained Federal permits, e.g. 83% of those who obtained "duck stamps" hunted one or more times during 1983-84 seasons (Carney et al. 1984). Such low participation probably reflected the free permits, i.e., there was no fee to dissuade anyone from obtaining a permit "just in case" an opportunity arose. Participation was not well associated with the number of permits issued in the nine regular seasons; however, potential associations may have been masked by changes in hunting seasons that influenced the demand for free permits. The estimated numbers of active hunters appeared to be relatively stable; certainly there were no indications of an increasing trend.

The 1975-83 sandhill crane harvest surveys were exemplary because all hunters were required to have permits, permits included diaries for recording daily activity and success, post-season questionnaires went to all (7 years) or most (2 years) of the permittees, and the response rate (72%) was exceptional. Accordingly the responses, and their projections, were considered reliable. If anything, estimates of harvests may have been somewhat inflated by a recognized tendency for unsuccessful hunters to not respond and by duplicate reporting, i.e., there were strong suggestions that the same crane(s) were reported by more than one member of a family or party. The latter would be a disadvantage of 100% or other high rates of post-season contacts.

Mid-continent sandhill cranes also are harvested in other areas. Harvests in Alaska, estimated from surveys of those buying duck stamps, ranged from 280 to 1,080 and averaged just over 700 during 1975-83 seasons. Harvests in Canada (Canadian Wildlife Service 1979, 1984) ranged from 1,640 to 6,165 and averaged just over 3,800 during 1975-76 and 1979-82 (seasons in Saskatchewan were closed in 1977 and 1978). Harvests in Mexico reportedly are less than 1,000 per year (J. Trevino, pers. comm.). The total harvests in all areas, including the Central Flyway, ranged from 11,100 (in 1976) to 17,800 (in 1980) and averaged just under 15,000 in years when all seasons were open.

The management guideline (Central Flyway Council 1981) is that the total kill not exceed 5% of the population. This guideline was designed to achieve the objective of a stable population

Table 1. Regular seasons for hunting sandhill cranes in the Central Flyway (Fig. 3).[a]

	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85
CO	O4-N8[b]	O2-N6	O1-N6	S30-N5	O13-N18	O11-N16	O10-N15	O2-N28	O1-N27	S29-N25
MT	O4-N9	O2-N7	O1-N6	S30-N5	S29-N4	O4-N9	O3-N8	O2-N28	O1-N27	S29-N25
Sheridan Zone									N1-N27	N1-N25
NM	O25-J25	O30-J30	O29-J29	O28-J28	O27-J27	O30-J31	O31-J31	O31-J31	O29-J28	O27-J27
ND	N8-D8	N6-D5	S7-S11	S7-S11	S7-S11					
Zone 1						S6-S14	S5-S20	S4-S19	S10-N6	S8-N4
Zone 2						S6-S10	S5-S13	S4-S12	S10-S30	S8-S28
OK	N29-J25	N27-J23	N26-J22	N25-J21	N24-J20	N22-J18	N22-J18	O23-J23	O22-J22	O13-J13
SD	N8-D7	N6-D5	S7-S11	S7-S11	S7-S11	S20-S28	S20-S28	O2-N11	O1-N6	S29-N4
TX										
Zone A	O25-J25	O30-J30	N1-J31	O31-J31	O30-J30	O31-J31	O31-J31	O30-J30	N12-F12	N10-F10
Zone B	N29-J25	D4-J30	D5-J31	D5-J31	D4-J30	D5-J31	D5-J31	D4-J30	D3-F12	D1-F0
Zone C									J14-F12	J12-F10
WY	O11-N9	O9-N7	O8-N6	O7-N5	O13-N8	O11-N16	O3-N8	S25-N21	S24-N20	S22-N18

[a] The "regular" seasons do not include "experimental or special" seasons such as those held in New Mexico 1982-1984.

[b] S=September, O=October, N-November, D=December, J=January, and F=February.

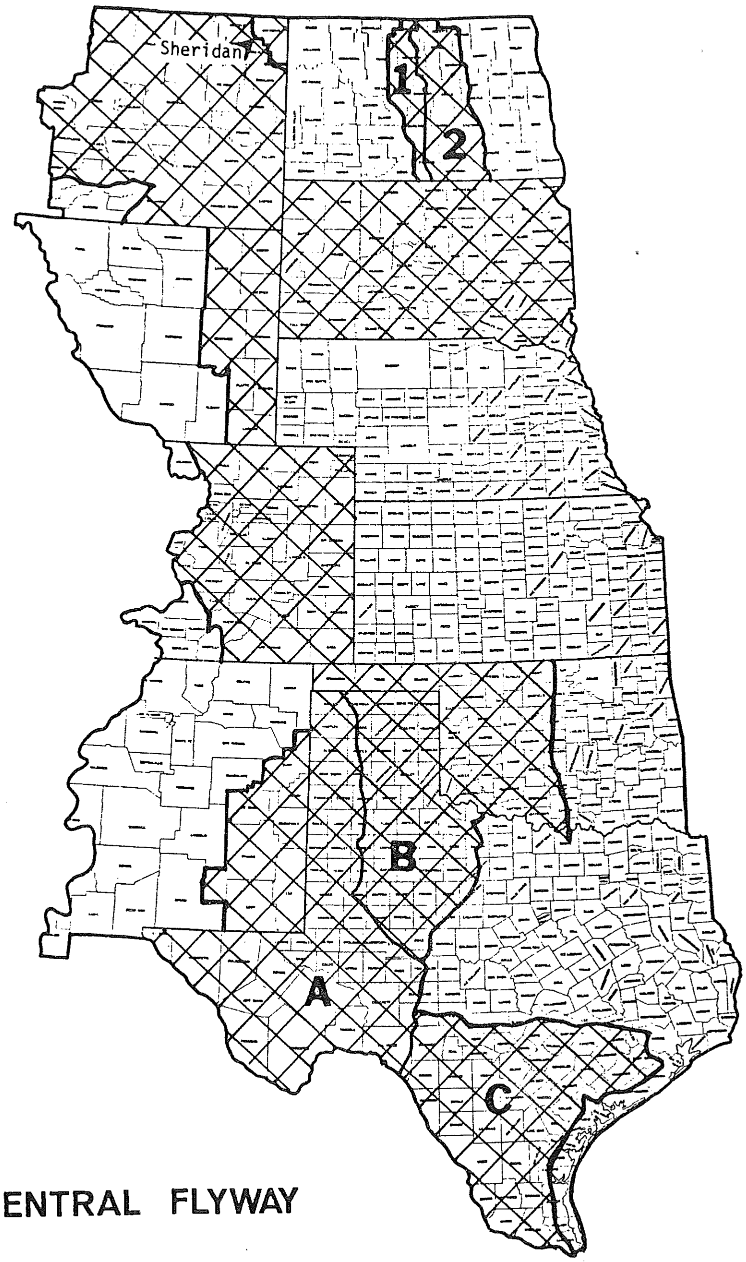

Fig. 3. Areas open (crosshatched) to crane hunting in 1983-84 regular seasons. Zones in Montana, North Dakota, and Texas referred to in Table 1.

and was based upon (1) information that the fall population would be expected to average 11% young-of-the-year (Buller 1979) and that annual mortality would average 6% (R. Driewien pers. comm.) and (2) assumptions that one-third of annual mortality would occur between 20 March and 1 September and that hunting kill would not be compensated by reductions in other mortality. Allowance for unretrieved kill, equal to 20% of the harvest, indicates that the total kill in 1980 could have been nearly 21,500. That kill would have been less than 4% of the fall flight, estimated to be at least 550,000 in recent years. If harvests equal to the maximums reported in recent years, including 1983 in the U.S., occurred in a single year, and the unretrieved kill was equal to 20% of the harvest, that total kill still would be less than 5% of the fall flight.

Table 2. Sandhill crane permits issued and estimated active crane hunters[a] in the Central Flyway.

State	Number of	1975	1976	1977	1978	1979	1980	1981	1982	1983
CO -	Permits	401	341	374	343	528	437	397	528	575
	Hunters	226	203	189	190	275	216	216	138	211
MT -	Permits	158	117	82	209	159	118	53	147	175
	Hunters	69	68	40	86	61	50	23	56	64
NM -	Permits	1,225	1,195	1,452	956	1,288	1,082	1,022	962	706
	Hunters	806	752	921	836	745	625	598	386	253
ND -	Permits	4,172	4,137	6,294	5,798	4,949	5,754	5,796	4,714	8,033
	Hunters	2,896	1,328	4,126	3,776	3,225	3,387	3,315	2,429	3,551
OK -	Permits	171	265	519	620	470	510	466	750	909
	Hunters	80	148	339	334	307	275	269	342	384
SD -	Permits	198	200	134	98	63	240	197	579	528
	Hunters	117	80	77	50	29	160	103	260	225
TX -	Permits	5,482	5,060	4,897	5,198	5,098	5,239	5,297	4,650	7,317
	Hunters	2,733	2,497	2,329	2,390	2,356	2,439	2,543	1,553	2,435
WY -	Permits	56	37	48	52	43	33	30	40	63
	Hunters	22	16	27	21	13	12	14	8	20
All-	Permits	11,863	11,352	13,800	13,650	12,598	13,413	13,258	12,370	18,306
	Hunters	6,949	5,092	8,008	7,683	7,011	7,164	7,081	5,172	7,143

[a] Those permittees who reported hunting cranes one or more times.

Table 3. Estimated harvests of sandhill cranes during regular seasons in the Central Flyway.

State	1975	1976	1977	1978	1979	1980	1981	1982	1983
CO	91	106	39	106	129	68	92	49	70
MT	16	29	18	36	14	16	11	21	28
NM	911	858	1,456	1,089	1,170	1,019	907	335	354
ND	2,122	52	4,078	2,777	2,733	2,245	2,395	2,469	6,471
OK	142	200	410	389	397	363	397	535	373
SD	86	12	47	19	19	130	78	212	177
TX	6,123	6,122	6,094	5,720	5,917	6,305	6,245	4,295	5,471
WY	6	14	9	10	0	6	9	0	15
All	9,497	7,393	12,151	10,146	10,379	10,152	10,134	7,916	12,959

Information on the daily activity and success during 1983-84 seasons (Table 4) indicates the probable effect of reductions in the daily bag limits should harvests have to be restricted. To illustrate, a reduction of the daily bag limit from three to two would have been expected to reduce the harvest by approximately 14%, i.e., hunters would have taken two cranes instead of three on 526 days and reduced the "total cranes reported" by 526.

Table 4. Summary of responses to daily activity portion of harvest survey questionnaire, 1983-84 sandhill crane seasons.

	Unsuccessful hunters		Successful hunters							
				days on which bag was reported as					Total
State	Number of respondents	Days hunted	Number of respondents	0	1	2	3	3+[a]	cranes reported
CO	130	443	26	53	31	6	1	0	46
MT	48	147	9	8	5	4	1	0	16
NM	112	337	38	157	23	21	34	4	167
ND	504	1,121	565	735	540	287	221	5	1,777
OK	200	522	71	146	63	36	27	0	216
SD	132	336	60	60	52	16	20	0	144
TX	373	905	377	547	366	235	222	0	1,502
WY	10	34	7	6	6	3	0	0	12
Total	1,509	3,874	1,153	1,712	1,086	608	526	0	3,880

[a]Assumed to be party bags, not included in totals.

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AN EXPERIMENTAL GREATER SANDHILL CRANE AND CANADA GOOSE HUNT IN WYOMING

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Abstract: An experimental, September hunting season was conducted on resident greater sandhill cranes (*Grus canadensis tabida*) and Canada geese (*Branta canadensis moffitti*) in 1982-84 in the Bear River and Salt River valleys of Lincoln County, Wyoming. Objectives were to reduce local crane and goose numbers and decrease depredations to small grain crops. Hunts were designed to protect and safeguard the endangered whooping crane (*G. americana*). Data were collected on hunter effort, harvest, hunting techniques, crippling loss, and illegal kill. Harvested cranes were measured and their gizzards collected for food habits analysis. Crane and goose numbers and distribution were monitored through each hunt period on each area. Impacts of hunting on local crane production were monitored by counts of young/adult and census of fall premigration staging areas. Impacts on goose production were measured by changes in breeding pair densities. Of 125 permits allotted annually to both areas, the mean annual harvest was 70 cranes and 22 geese in the Bear River Unit and 62 cranes and 119 geese in Salt River Unit. A portion of the hunt area was closed in Bear River in 1982 and Salt River in 1984 due to the presence of a whooping crane. Closure areas occupied by a whooper provided refuges for cranes and geese from surrounding open hunt areas. Over the 3 years, 54 to 82% of the prehunt goose flock had left the drainages entirely by the last day of the hunt, but the crane population increased through the hunt period. Local breeding-age cranes were most vulnerable to over-harvest in the early part of the season when families were still dispersed on territories. The annual average removal rate (harvest + cripple loss + illegal take) of 13.7 to 16.6% of the prehunt crane population was approximately twice the average recruitment rate. Increased crane numbers during 1982-84 were attributed to ingress from other population segments. The special hunt was effective in minimizing local depredations to small grain crops. Results showed that sandhills can be hunted in Wyoming with minimal risk to whooping cranes provided that proper precautions were taken. Analysis of 54 crane gizzards collected in 1982 indicated 60.4 to 70.7% of the food volume was barley and wheat with other plant foods comprising most of the remainder.

PROCEEDINGS 1985 CRANE WORKSHOP

Local populations of greater sandhill cranes and Canada geese have increased in western Wyoming in recent years (Drewien 1973, Drewien and Bizeau 1974, Krohn 1980). Depredations of barley and wheat in late August and September, before harvest, have become more severe as bird numbers increased. Before 1982, the Wyoming Game and Fish Department (WGFD) responded to crane and goose depredations by (1) standard harrassment techniques, (2) planting lure crops in cooperation with the U. S. Fish and Wildlife Service (FWS), and (3) payments for crop damage to landowners as provided by state law. Cost, in both funds and manpower, became excessive and the problem of increasing bird numbers was not addressed. The Bear and Salt River valleys in Lincoln County are primary problem areas.

To minimize fall depredations in Lincoln County, a proposal for a September hunt of resident cranes and geese was submitted by WGFD to the waterfowl councils of the Pacific and Central flyways in March 1982, and approved by FWS in August. The "experimental" season was the first early September Canada goose hunt in the Pacific Flyway. It was also the first greater sandhill crane hunt within their breeding range since implementation of migratory bird hunting regulations in this century.

Objectives of the special early September hunt were: (1) to decrease depredations to small grain crops before harvest in September, and (2) to reduce local crane and goose numbers to levels more compatible with agricultural land use. Desired fall premigration numbers of cranes were set at 400 and 600, and of geese at 200 and 950 breeding pairs in the Salt and Bear River valleys, respectively. The number of cranes and geese to be maintained in these valleys is commensurate with the objectives of the Rocky Mountain greater sandhill crane and Canada goose population objectives and management strategies (Pacific Flyway Technical Committee 1982, 1983). Hunts were also designed to safeguard the endangered whooping crane, which is occasionally found in these areas.

We thank those individuals who assisted in operating the hunt: L. Schroeder, and J. Klett (FWS); and R. Ferguson, D. Hyde, F. Herbal, K. Jones, J. Smith, D. Kerr, E. Wampler, P. Riddle, Tom Toman, B. Taylor, D. Sparks, E. Dayton, B. MacPherron, H. Wixom, E. Hyde, B. Wakeman, C. Murray, Keith Tindall, and D. Flukiger (WGFD). R. Oakleaf, S. Fitton, S. Findholt, F. Hammond, and K. Clegg assisted in whooping crane monitoring; D. Walker helped in food habits analysis; W. Brown reviewed the manuscript; and W. Gasson helped with economic analysis. R. Geesaman assisted with agricultural crop data compilation. A special thanks to the many private landowners who cooperated fully in opening their lands to hunters and to A. Anderson, G. Barrus, L. D. Nield, D. Nield, D. Taylor, R. Johns, and others who hosted a whooping crane during some hunts. Helicopter time was donated by Kjerstad Helicopters, Atlantic Richfield Company, and Mile-Hi Exploration Company.

METHODS

Hunt Regulations and Data Collection

After approval of the experimental hunt by FWS, the WGFD authorized closure of portions of hunting areas on an emergency basis if a whooping crane appeared. Provisions of the special hunt, divided into two units--(1) Bear River, and (2) Salt River--are described in Table 1. All free permits were allocated by annual drawings.

Hunters were required to check in and out daily. Check stations were equipped with maps of emergency closure areas, displays on crane identification, regulations, and reminders on maintaining good landowner relations. Check stations were manned daily from 0530 to 2100 hours MDT. Attendants recorded the birds' age, sex and hunting success data, and took morphological measurements (weight, tarsus, mid-toe, culmen, wing chord). All cranes were aged; however, morphological measurements were only collected from adults when sex was determined.

In 1982, gizzards were collected from cranes to obtain food habits information. Volumetric percentages of food items were determined by D. Walker, New Mexico State University, using the aggregate volume method described by Martin et al. (1946).

Numbers and distribution of cranes and geese within and adjacent to hunt areas were obtained annually by aerial (Piper super cub and Maule M5-235 aircraft) surveys conducted before the hunt (29-31 August), mid-season (7-8 September), and immediately following hunts (15-17 September). Total area counts were obtained by counting from one side of the aircraft along transect lines 0.4 to 0.8 km wide. Each area was stratified and count data were tabulated by strata.

Age ratios of cranes were collected before and immediately after each hunt. Young cranes were differentiated from adults by presence of feathered crowns (Lewis 1979). Surveys were conducted on roosting, loafing, and feeding sites. Age ratios collected at the peak of premigration staging were used to assess annual production within each area.

Table 1. Provisions of special sandhill crane and Canada goose hunting season, Lincoln County, Wyoming, 1982-84.

	Season dates		Bag Limits	
Hunt areas	Opens	Closes	Daily possession	Limitations
Bear River Salt River	1 Sept.	14 Sept.	Season limit: 2 sandhill cranes and 3 Canada geese	Limited quota; 125 special permits each hunt area, any sandhill crane or Canada goose. All special permit holders must check in and out of station daily when hunting. Shooting hours are sunrise to sunset daily.

Young flightless cranes were captured with the aid of a helicopter and color-marked with plastic leg bands and neck collars in July 1982. Subsequent sightings of marked cranes were obtained during surveys of hunt areas.

Public and Landowner Education

Major landholders in hunt areas were contacted, and sportsmen, conservation, and civic groups were informed about the special season. News releases further informed the public of the season, special provisions, and precautions.

Before each season, successful applicants were sent packets containing: (1) a permit, (2) hunting regulations, (3) information illustrating sandhill and whooping crane identification characteristics, and (4) a detailed area map that showed the check station location.

Protective Measures for Whooping Cranes

Provisions to protect whooping cranes included: (1) a 14 September closing date to minimize the possibility of migrating whoopers arriving from Grays Lake, Idaho; (2) permit hunting only, thus regulating hunter density and distribution; (3) mandatory daily check-in and check-out to inform hunters of any emergency closures; (4) emergency closure authorization for any portion of a hunt area; (5) literature on crane identification provided to hunters and posters placed in conspicuous locations in hunt areas; (6) state and federal law enforcement patrol; (7) coordinated monitoring of whooping cranes in Wyoming and Idaho; (8) hunters and landowners were asked to report whooping crane sightings to WGFD personnel; and (9) daily monitoring of whooping cranes located in a hunt area.

Crop Depredation

A cost:benefit analysis was conducted to evaluate and compare the special hunting season to other cropland depredation prevention methods (i.e., lure crops and conventional control). The evaluation compared depredation prevention methods employed in Lincoln County since 1976, including payments to landowners, lure crops, and standard harrassment procedures. Costs and benefits were based on 1980 monetary values. All costs encumbered by the WGFD were assessed. Benefits to the Department and State/local economies generated by consumptive user recreation of cranes and geese were assessed. Goose and crane hunter recreation days accrued during each year's hunt were considered benefits (Phillips 1981, WGFD harvest surveys 1976-84).

RESULTS AND DISCUSSION

Hunter Participation and Effort

Mean number of applicants for the 125 Bear River and 125 Salt River permits were 164 and 212, making applicant drawing success 76% and 59%, respectively. Mean number of permit holders that participated annually was 95 (76%) in both hunt areas.

Locals and nonresidents comprised 15% and 16%, respectively, of the annual mean number of Bear River hunters; non-local hunters (Wyoming residents outside hunt area) represented 69%. In Salt River, nonresidents comprised 7%, locals 51%, and nonlocals 42% of the mean annual hunters. The larger number of non-local hunters in Bear River was attributed to the lower population of local hunters. In both hunt areas, most non-local hunters came from population centers within 200 km. In three seasons, 76 to 94% of the nonresidents were from northern Utah.

The greatest hunting pressure and harvest was on opening day. More than 52% of the hunting effort occurred on opening day and Labor Day weekend. After Labor Day weekend an average of 6.3 and 3.0 hunters were afield each weekday in Salt River and Bear River, respectively. Hunters traveling longer distances tended to spend more weekends or contiguous days hunting; whereas, local hunters tended to hunt weekdays before or after work.

Hunter Harvest and Success

In Bear River, 211 cranes and 67 geese were harvested in the 3-year period; annual $\bar{x}$ = 70 cranes and 22 geese. Non-local and nonresident hunters sustained the highest success on cranes, and local hunters had higher success on geese, annually, except in 1983. Low local hunter success on geese in 1983 and cranes in 1984 was attributed to lower effort.

In Salt River, 187 cranes and 358 geese were harvested; annual x = 62 cranes and 119 geese. Lower harvest of cranes and geese in 1984 was attributed to decreased bird numbers using open hunt areas.

Bear River hunters had a slightly higher success rate for cranes (0.74) than Salt River hunters (0.65). However, Salt River hunters had a higher success rate for geese (1.43) than Bear River hunters (0.24). During all hunts, 76% and 69% of cranes in Bear River and Salt River, respectively, were harvested in 4 days, including opening day and Labor Day weekend. Seventy-eight percent of Bear River and 75% of Salt River goose harvest occurred in this same period. About 24% (67) of 285 Bear River hunters and 16% (46) of 286 Salt River hunters bagged limits of cranes. About 10% of the Salt River and none of the Bear River hunters bagged limits of both cranes and geese.

Pass-shooting accounted for 61% and 40% of the crane and goose harvest, respectively. Decoy hunting was employed by 24% of successful crane hunters and 50% of successful goose hunters. Stalking provided less than 12% of the cranes and geese taken.

Based upon hunter's reports of crippled cranes, estimated crippling loss, and illegal harvest was 45% of the legal reported harvest in 1982 (Lockman et al. 1983), 29% in 1983 (Lockman et al. 1984), and 20% in 1984.

Whooping Crane Occurrence and Protection

On 26 August 1982 a 2-year-old whooping crane arrived in the Bear River hunt area, and 6 km^2 were closed to hunting. The closed area provided a refuge for sandhill cranes which increased in numbers from 21 to 249 by 17 September.

Between 20-25 August 1984, a yearling whooper, which summered nearby, moved into the highest density crane and goose use area of the Salt River hunt. The whoopers daily movements and activity were monitored. To protect the whooper, about 24 km^2 were closed to hunting. Area landholders were informed of the closure. Bird movements within the closed area were influenced mainly by farming activity, requiring a relatively large closure to accommodate the whooper's movements. About 12 km^2 were re-opened to hunting on 5 September after the bird's movements were better defined. Before the hunt, the closed area supported 349 (73%) of the hunt area's cranes and by post-hunt, 859 cranes (92%). A similar influx of Canada geese was noted into the closed area.

Impact of Hunting of Cranes and Geese

On opening day, crane numbers were similar between areas and years (Fig. 1). Numbers in hunt areas decreased markedly by mid-hunt between years and areas. Between mid-hunt and post-hunt periods, crane numbers increased. Bear River had 35 to 50% more cranes than Salt River each year by post-hunt; however, more than 30% of the Bear River cranes remained in closed areas of adjacent Idaho and Utah. The emergency-closed areas on Bear River in 1982 and Salt River in 1984 served as refuges and attracted cranes and geese from hunted areas. The 1982 closure did not result in concentrating cranes and geese as much as the 1984 closure (Figs. 1 and 2). This difference was attributed to the high density and wide interspersion of grain fields and wetland roosting sites in the 1984 closed area.

Crane numbers and harvest in both hunt areas remained similar through 1982-84 except in Salt River in 1984 when crane and goose availability and harvest decreased 60% as a result of the closure. Before the 1984 closure, Salt River goose harvest was about 6 times that of Bear River while geese were 9 to 11 times more abundant in Salt River on opening day each year (Fig. 2). The greater number of geese in Salt River was believed responsible for the larger number of applicants and the greater effort expended hunting both species.

Cranes moved as a result of hunting pressure; however, their movements were not as dramatic as geese. Over the 3 years, 54 to 82% of the pre-hunt goose flock had left the drainages by the last day of the hunt. In the 1984 hunt most Salt River geese remained within the closed area.

Crane numbers increased after the mid-hunting period in each area due to a movement from higher elevation summer sites into lower elevation cropland staging areas. This movement was triggered by frosts in early September which reduced natural food availability. Pre-hunt crane counts were indicative of the number of cranes summering in hunt areas. Peak numbers at fall

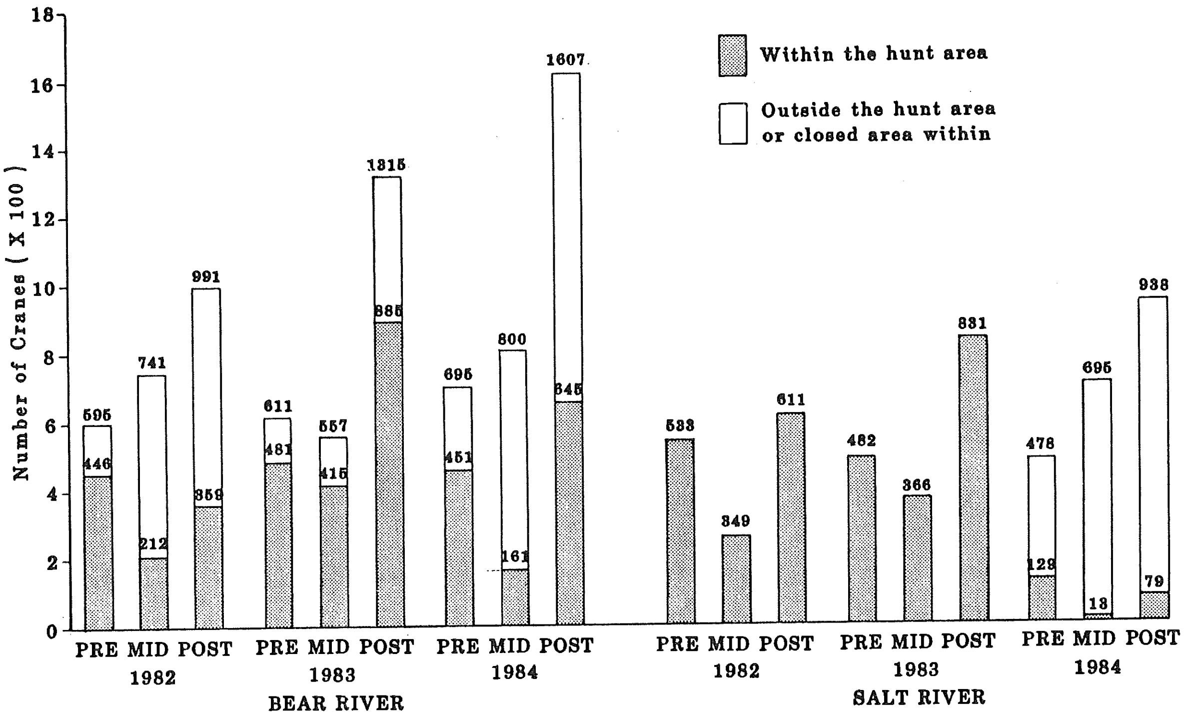

Fig. 1. Greater sandhill crane numbers and distribution by hunt period - aerial survey, 1982-84.

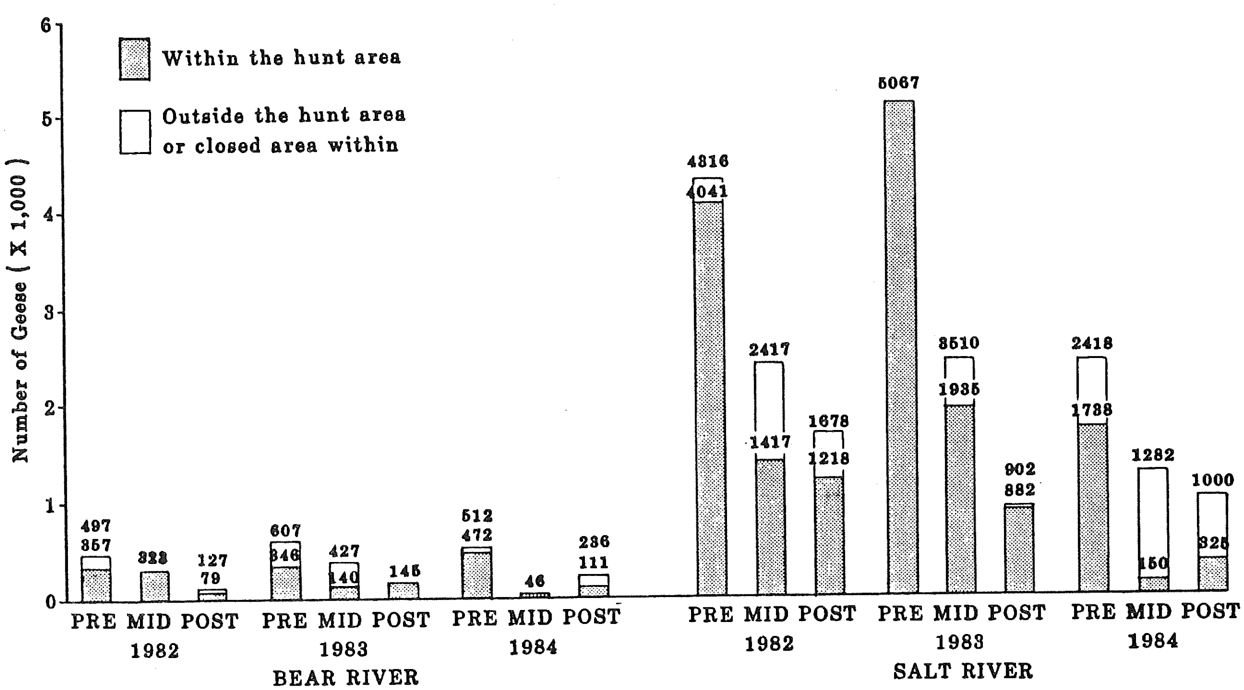

Fig. 2. Canada goose numbers and distribution by hunt period - aerial survey, 1982-84.

pre-migration staging sites occurred from 15-20 September (Fig. 1). The staging area peak counts coincided with those dates observed in years previous to the hunt (Unpubl. data, Id. Coop. Wildl. Res. Unit).

During the previous 12 years, juvenile cranes in the Salt River and Bear River comprised from 6 to 14% of flocks (Unpubl. data, Id. Coop. Wildl. Res. Unit). Sandhill crane age composition in flocks and in the harvest appeared to be similar except in Bear River in 1984 (Table 2) when the number of juveniles in the harvest was significantly higher ($P < 0.05$) than their occurrence in the population. In 1984 the larger percentage of harvested young resulted from a larger number of late-hatched chicks that remained in family groups on breeding territories, which apparently increased their vulnerability. The low percentage of young in Bear River in 1983 and 1984 was attributed to nest failure from spring flooding. Harvest of some local adult breeders in 1982 and 1983 may have also contributed to lowered production in 1984. Composition of young in the harvest in Salt River remained similar between years. The annual mean number of crane groups consisting of four or fewer individuals (non-breeders, failed breeders, and pairs with chicks) decreased from 59.8 pre-hunt to 28.8 post-hunt. These data suggest that local breeding-age cranes and their young were most vulnerable to over-harvest in the early part of the hunt season while they were still dispersed on nesting territories.

Analysis of the 3-year hunt data on the resident crane population indicated that harvest exceeded recruitment of young. Percent juveniles in the fall population ranged from 7.6 to 8.1 ($\bar{x} = 7.8$) in Salt River and 4.2 to 8.9 ($\bar{x} = 6.5$) in Bear River (Table 2). The mean pre-hunt crane populations were 511 and 639 for Salt and Bear rivers, respectively; mean harvests of the pre-hunt populations were 62 (12.1%) and 70 (11.0%), respectively. Most of the harvest occurred early in the hunt before cranes from surrounding tributaries arrived in hunt areas, therefore, we assume that resident cranes sustained most of the kill. Adjustment for crippling losses (20 to 45% of harvest) resulted in an average removal rate of 13.7 to 16.6% of the pre-hunt population or about double the average recruitment rate. Continuation of long-term banding would provide insight into breeding pair recruitment rates, as well as ingress into local breeding flocks. Increased peak staging numbers (post-hunt) over the 3 years were attributed to increases in adjacent areas and ingress into local population segments (Fig. 1). If hunts continue, breeding pair numbers and recruitment of young should be monitored closely to assess local population trends.

Food Habits

During the 1982 hunt, 54 crane gizzards (29 - Salt River, 25 - Bear River) were analyzed for food contents (Table 3). Some foods were too finely ground to identify. Soft foods such as many invertebrates may not be well represented due to differential digestion rates (Swanson and Bartonek 1970, Walker 1983).

Barley and wheat accounted for 60.4 to 70.7% of the food volume; unidentified vegetation was 24.0 to 29.0%. These two food categories accounted for 89.4 to 94.7% of the total food volume in crane gizzards in Bear and Salt River areas, respectively (Table 3). Much unidentified vegetation probably was barley and wheat.

Animal foods, primarily grasshoppers, were 1.4 to 2.7% of the food volume. Beetles, caterpillars, and snails appeared infrequently and in small volume (Table 3). Grit averaged 40.2 and 58.7% of the total volume of material in gizzards from the Salt and Bear river areas, respectively.

Morphological Characters

Weights and four morphological measurements (tarus, mid-toe, wing-chord, culmen) were obtained from 101 to 109 adult males and 89 to 91 adult females between 1982-84 (Table 4). The means for all measurements were larger for males than for females, but t-tests revealed no significant differences between the means of morphological characters except for weights ($P < 0.05$) and culmen length ($P = < 0.05$). However, the overlap of these characteristics precluded accurate separation of sexes except for larger males.

Ninety-five percent of all females weighed < 5450 g and had culmens < 108 mm. All males had culmens > 110 mm and weighed > 5674 g. Morphological data gathered in this study are similar to those reported by Walkinshaw (1965) and Aldrich (1979) but showed more variation due to our much larger sample size (Table 4).

Table 2. Greater sandhill crane flock age composition and harvest age composition in the Bear River and Salt River drainages of Lincoln County, Wyoming.

Year	Area	Survey	Sample size	No. young	No. adults	% young
1982	Bear River	Flock	698	62	636	8.9
		Harvest	68	6	62	8.8
	Salt River	Flock	569	44	525	7.7
		Harvest	68	7	61	10.3
1983	Bear River	Flock	508	32	476	6.3
		Harvest	65	5	60	7.7
	Salt River	Flock	322	26	296	8.1
		Harvest	89	8	81	8.9
1984	Bear River	Flock	814	34	780	4.2
		Harvest	74	12	62	16.2
	Salt River	Flock	471	36	435	7.6
		Harvest	27	2	25	7.4

Table 3. Summary of food items from 54 gizzards of greater sandhill cranes from Lincoln County, Wyoming, 1-14 September 1982.

	Bear River (n = 25)		Salt River (n = 29)	
Food item	Percent occurrence[a]	Percent volume	Percent occurrence	Percent volume
Plant food				
Barley & wheat	68.0	60.4	58.6	70.7
Unidentified vegetation	72.0	29.0	65.5	24.0
Timothy corms (Phleum)	12.0	9.2	3.4	Tr.
Unidentified tubers			24.1	2.6
Unidentified seeds			6.8	Tr.
Total vegetation	100.0	98.6	100.0	97.3
Animal food				
Grasshoppers	32.0	1.3	24.1	1.1
Bone fragments	4.0	0.1	10.3	0.2
Caterpillars			10.3	0.6
Beetles (Carabidae)			3.4	0.2
Beetles (Tenebrionidae)			3.4	Tr.
Small snails	4.0	Tr.	6.9	0.3
Large snails			3.4	0.3
Unid. invertebrates	4.0	Tr.		
Total invertebrates	36.0	1.4	51.7	2.7

[a] % occurrence refers to the percent of gizzards containing the food item. Grit is excluded from occurrence and volume calculations. Tr. = < 0.1%.

Table 4. Weights (g) and measurements (mm) of adult greater sandhill cranes from Lincoln County, Wyoming, 1982-84, and comparisons with measurements reported in other studies.[a]

Sex	Weight	Culmen	Tarsus	Midtoe	Wing chord
Male					
Mean	5,430	105	239	94	545
Std. Deviation	432	6.9	13.0	4.9	20.9
Lowest	4,425	88	210	80	495
Highest	6,600	120	280	110	600
Sample size	101	109	109	108	105
Female					
Mean	4,845	99	231	91	524
Std. deviation	338	4.8	15.1	4.2	20.1
Lowest	3,975	86	200	82	485
Highest	5,675	110	272	102	575
Sample size	88	89	90	91	90
Other studies					
Walkinshaw (1965)					
Male					
$\bar{x}$ (n)		107.2(8)	244.5(8)		561.5(8)
range		101-116	226-264		526-598
Female					
$\bar{x}$ (n)		97(1)	230.5(9)		546.0(9)
range			222-239		510-575
Aldrich (1979)					
Male					
$\bar{x}$ (n)		107.11(9)	243.47(17)	84(4)	547(17)
range		100-120	226-264	80-88	502-598
Female					
$\bar{x}$ (n)		100.13(8)	227.21(14)	79.43(7)	523.38(13)
range		97-103	217-238	75-85	490-575

[a] Culmen from posterior edge of nostrils. Midtoe length not including toenail.

Crane and Goose Depredations on Grain Crops

The special hunt minimized depredations on grain crops in all 3 years in Bear River, and no damage claims were filed by farmers. In Salt River, damage claims were minimal in 1982 and 1983 ($300/year). In 1984, however, $1,685 of damage claims were filed by three landowners, two within the emergency-closed area and one outside. Claims within the closed area were due to increased goose and crane numbers during the hunt (Fig. 1). Another factor that contributed to increased depredation in 1984 was the late grain harvest in Salt River Valley due to wet weather. Total 1984 damage claims were still much lower than when conventional control methods were used (Table 5).

Manpower expenditures increased by 24 to 31% for hunt administration when whoopers utilized hunt areas ($2,692.05 in 1982 and $3,893.87 in 1984). When total costs were adjusted to 1980 dollars, capital outlay was greatest for the lure crop program. Costs were similar for conventional damage control and the experimental hunt. Landowners tended to favor the lure crop program, but also believed it is important to regulate local crane and goose numbers through hunting. The hunt placated most farmers and decreased damages by moving geese out of the valleys and preventing prolonged concentrations of cranes on one area. Very likely there are feasible methods for alleviating spring and summer crop depredations by waterfowl in either valley, however, hunting to curtail local population increases should reduce spring and summer depredations.

The hunt provided an additional 391 hunter recreation days annually and generated an additional $11,928.58 revenue to the local economy (Table 5). Non-consumptive user benefits were not determined; however, they were believed to exceed the consumptive (hunting) user values. When a whooping crane was present, considerable local interest was generated and 10 to 20 people daily came out to observe the bird. Overall, the hunt was the most effective method for minimizing depredations to early maturing grain crops and reducing increases in local crane and goose numbers. Also, more economic benefits were generated for more sectors of the local economy and sportsmen were provided increased recreation days of quality hunting opportunity.

Table 5. Cost/Benefit analysis of fall crane and goose depredation prevention methods employed in the Bear River and Salt River areas, 1976-84.

	Costs ($\bar{x}$/yr)		
Cost item	Conventional methods[a] 1976, 1977, 1981	Lure crop program 1978-1980	Experimental hunt 1982-1984
Salaries	$ 4,439.50	$ 3,722.35	$10,803.24
Vehicles	1,600.00	2,195.30	1,649.00
Per diem		129.12	542.67
Supplies	300.00	150.42	206.00
Subtotal	$ 6,339.50	$ 6,197.19	$13,200.91
Aircraft rental		33.33	1,281.29
Hunt season operations			166.67
Lure crop purch.		7,340.31	
Damage claim payments	4,308.18	200.00	762.00[b]
Subtotal	$ 4,308.18	$ 7,573.64	$ 2,209.96
Total costs	$10,647.68	$13,770.83	$15,410.87
Adjusted total[c]	$12,247.50	$13,770.83	$12,595.10
Consumptive user benefit		Benefits[d]	
Experimental hunt			$11,928.58
Regular season (goose only)	$35,453.00	$71,087.50	81,745.58
Total benefits	$35,453.00	$71,087.50	$93,674.16
Cost/Benefit	1.22/3.54 = .345	1.38/7.11 = .194	1.26/9.37 = .134
Cost/Benefit adjusted[e]	1.22/8.17 = .145	1.38/8.17 = .169	1.26/9.37 = .134

[a] Conventional methods include landowner contact, daily hazing, pyrotechnics, etc.

[b] Includes damage claim payments of $300, in 1982 and 1983 and an expected payment of $2,685 for 1984.

[c] Mid-point of each period adjusted to 1980 dollar values.

[d] Benefits calculated as economic benefits to local and state economy for each waterfowl hunter recreation day, valued at $30.50/recreation day (Phillips 1981).

[e] Cost/Benefit adjusted - benefits were adjusted to reflect a constant regular season recreation day value at 1982-84 regular goose season levels.

Public, Hunter, and Landowner Attitudes

Most people were satisfied with safeguards implemented for whoopers. Landowners in 1982 were very accommodating to our requests to protect the whooper on their property. Most landowners in 1984 were also accommodating, but several expressed dissatisfaction with increased bird numbers in the closed area. Personnel monitoring whoopers received many visitors who inquired about the bird and wished to view it. In 1984, a local sportsman's club offered to assist with the hunt and protect the whooper. Cooperation of landowners and others and the migration of whoopers from hunt areas indicated to us that sandhills can be hunted in Wyoming with minimal risk to whoopers.

Landowners expressed positive feelings about the success of hunts, hunter conduct, and efforts to minimize depredations. Many landowners and sportsmen offered suggestions for future seasons. Landowners and hunters alike expressed ideas that local hunters should be allowed a greater portion of the permits.

Most hunters regarded the hunt as a quality experience. The annual increase in applicants, especially nonresidents, affirmed the hunt's popularity. The success of the landowner/hunter and WGFD/public relations was attributed to local and statewide information effort, hunter education, daily contact with hunters at check stations, local enforcement efforts, and communications with landowners.

Five game violations were recorded; one was an overbag of cranes and four involved shooting great blue herons (Ardea herodias). Mistaking herons for cranes was a problem in all years, indicating a need to educate hunters on field identification of game and nongame species.

CONCLUSIONS AND RECOMMENDATIONS

The 1-14 September hunts were successful in reducing crane and goose depredation on maturing grain crops by dispersing bird concentrations. Hunting apparently had a greater influence on geese because many left open hunt areas for longer periods.

Early hunts of local breeding birds could detrimentally affect maintenance of desired flock levels. By regulating harvest through permits, impacts on future production can be monitored and seasons adjusted accordingly. Our findings show that we could expect about 76% of the permit holders to hunt. Increased hunter recreation and consumptive user benefits to local economies could be significant because 75% of the hunters would be non-local.

Most hunting effort (52%) occurred the first weekend and only minimal hunting effort occurred during weekdays. Substantial decreases in annual administration costs ($6,000) could be realized with permit hunting on several successive weekends with a limited number of permits per weekend. Such hunts should be as effective in minimizing depredations and intensity of harvest of local breeding cranes could be better regulated by permit numbers.

Early season hunting was the most cost effective method of minimizing fall depredation on grain. It also provided increased hunter recreational opportunity and helped regulate local crane and goose populations. Based upon the results of the 3-year experiment, we recommend the following:

1. Early September hunting of sandhill cranes and Canada geese in the Salt River and Bear River drainages of Lincoln County, Wyoming, should be continued annually.
2. Annual goose harvest should be manipulated to ensure that numbers do not decline below 950 and 200 breeding pairs in the Bear River and Salt River areas, respectively, for more than 3 consecutive years.
3. Sandhill crane flock objectives for these management areas should be established to reflect numbers at the peak of the fall pre-migration staging period (15-25 September). These objectives should be 1,200 for lower Bear River and 700 for Salt River.
4. Annual crane harvests should be manipulated to ensure that peak fall pre-migration staging numbers and chick recruitment rates are sustained at desired levels.
5. Crane harvest rates of local breeding pairs and young should be monitored annually.
6. Whooping crane protection measures should be continued as designed in the experimental hunt.
7. WGFD should continue to monitor hunts and collect information as occurred in this experimental hunt.
8. Legislation authorizing the Department to charge a fee for a special crane and/or goose hunt permit (i.e., special migratory bird hunting permit) would be beneficial and aid in defraying hunt costs.

9. We recommend future hunt season's quotas be as follows but adjusted when necessary to reflect crane and goose population changes: Bear River Area. 1-2 Sept.: 35 permits, 2 crane & 3 goose limit; 7-8 Sept.: 40 permits, 2 crane & 3 goose limit; and 14-15 Sept.: 50 permits, 2 crane and 3 goose limit. The Salt River area should have similar dates, permits, and limits.

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MINIMIZING CONFLICTS BETWEEN MIGRATORY GAME BIRD HUNTERS AND WHOOPING CRANES IN TEXAS

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Abstract: Sandhill crane (*Grus canadensis*) hunting seasons established in three Texas zones from 1961 through 1984 provided temporal and spatial separation between sandhill crane hunters and endangered whooping cranes (*G. americana*) migrating or wintering in Texas. Hunter information programs and contingency plans further minimized potential conflicts between migratory game bird hunters and whooping cranes. Aerial surveys of weekend coastal waterfowl hunting activities from 1976 through 1984 in the vicinity of whooping crane wintering grounds at Aransas National Wildlife Refuge indicated some temporary changes in whooping crane use which could be attributed to hunter presence or airboat activity, but gross changes in distribution were not evident. The management plan and operating procedures developed under a 1983 federal/state agreement regarding management of publicly-owned portions of Matagorda Island provided for buffer zones between hunters and normal whooping crane use areas.

PROCEEDINGS 1985 CRANE WORKSHOP

The U. S. Fish and Wildlife Service (USFWS), the Canadian Wildlife Service, various state wildlife agencies, the National Audubon Society, and other public and private organizations have been involved for many years in efforts to protect the endangered whooping crane. This magnificent species, which reached a low of only 16 surviving individuals in the Texas Coast population in 1940 -1941, has become a symbol of international efforts to save endangered wildlife throughout the world (Whooping Crane Recovery Team 1986).

Since loss of even a single individual may be detrimental to the survival of an endangered species, protection of whooping cranes from mortality and injuries resulting from all factors including hunting is an obvious necessity. Potential conflicts between hunters and whooping cranes were reduced by a general closed season on all cranes in the United States in 1916, and efforts to further minimize conflicts slowly evolved to include improved law enforcement, establishment of refuges, public awareness efforts, and modification of hunting regulations for game species. Available evidence indicates these steps have eliminated most direct hunter-related mortality of whooping cranes. However, the sympatric distribution, similarity of appearance, and mutual habitat preference of the whooping crane and certain other species of migratory fowl, particularly the closely-related sandhill crane, render migratory game bird hunting a continued concern for those responsible for the safety of whooping cranes.

State and federal wildlife administrators have been extremely cautious in modifying migratory bird hunting regulations because of potential whooping crane conflicts. Recent changes in migratory bird hunting regulations in Texas have been accompanied by hunter education efforts, contingency planning, and evaluation of the effects of waterfowl hunting and other human activities on whooping cranes. The purpose of this paper is to describe steps that have been taken in Texas to assess and minimize the impact of migratory game bird hunting on the endangered whooping crane.

Whooping crane surveys were conducted within Texas Federal Aid Project W-103-R and this report is a contribution of Texas Federal Aid Projects W-103-R and W-115-R. J. C. Smith, D. W. Mabie, and W. C. Brownlee assisted in the collection and compilation of aerial survey data throughout the study. D. Armentrout, D. R. Blankinship, W. C. Brownlee, R. C. Drewien, D. W. Mabie, H. W. Miller, and T. V. Stehn reviewed the manuscript and provided valuable editorial assistance.

SANDHILL CRANE HUNTING

Season Timing and Zone Boundaries

The need to reduce sandhill crane crop depredation problems for farmers led to the authorization of a 30-day season on sandhill cranes in parts of New Mexico and Texas during the early 1960's (Buller 1979, Central Flyway Representative 1981). From the beginning, an effort was made by the USFWS and the Texas Parks and Wildlife Department (TPWD) to provide temporal and spatial separation for whooping cranes and sandhill crane hunters in Texas. The first of three sandhill crane hunting zones was established in Texas in 1961. This area, later designated as Zone A (Fig. 1) permitted sandhill crane hunting in the Trans-Pecos and Western Panhandle Regions, well to the west of known whooping crane migration routes. After a lengthy evaluation period, Zone B was opened in the Eastern Panhandle in 1968. Zone B overlapped suspected whooping crane migration routes, consequently the opening date for the sandhill crane hunting season in Zone B was delayed until around 1 December each year (Table 1) to allow completion of the mid-October to mid-November whooping crane migration. Considerable numbers of sandhill cranes were also known to winter in South Texas, but concern about conflicts with whooping cranes wintering along the Texas Coast as well as questions about sandhill crane racial composition and population status in this area (Lewis 1977) precluded immediate establishment of a South Texas crane hunting season.

In 1983, a 30-day, mid winter sandhill crane hunting season for South Texas, exclusive of the coastal areas used by wintering whooping cranes, was proposed by the TPWD and approved by the Central Flyway Council and the USFWS. This area, designated as Zone C (Fig. 1), was designed to open after all whooping cranes had reached the Texas Coast in the fall and terminate before the whoopers began their return migration in the spring.

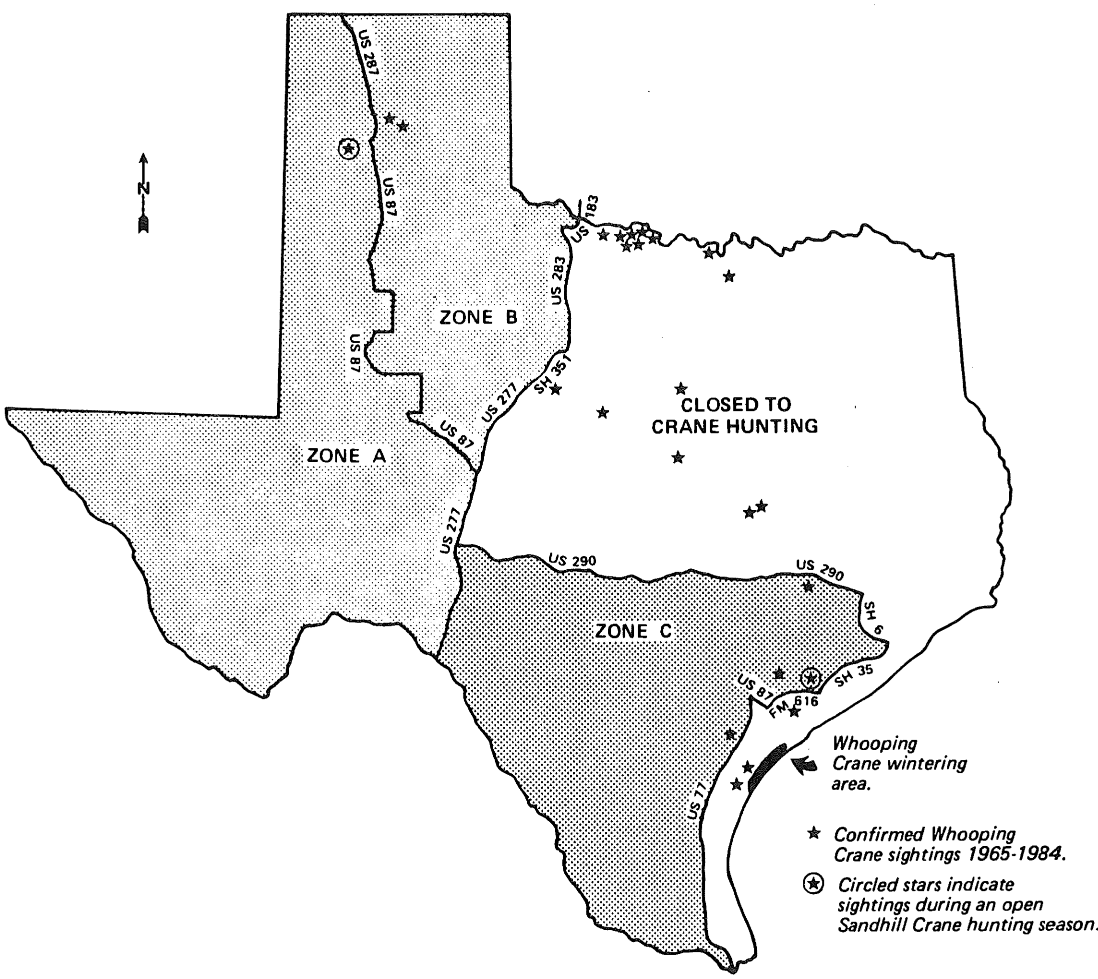

Fig. 1. Location of Texas sandhill crane hunting zones, confirmed whooping crane sightings 1965-1984, and primary wintering area of the Wood Buffalo-Aransas whooping crane population.

Table 1. Sandhill crane hunting season dates and daily bag limits in Texas, 1961-84.[a]

Year	Zone A	Zone B	Zone C
1984-85	10 Nov. - 10 Feb.	1 Dec. - 10 Feb.	12 Jan. - 10 Feb.
1983-84	12 Nov. - 12 Feb.	3 Dec. - 12 Feb.	14 Jan. - 12 Feb.
1982-83	30 Oct. - 30 Jan.	4 Dec. - 30 Jan.	
1981-82	31 Oct. - 31 Jan.	5 Dec. - 31 Jan.	
1980-81	31 Oct. - 31 Jan.	5 Dec. - 31 Jan.	
1979-80	30 Oct. - 30 Jan.	4 Dec. - 30 Jan.	
1978-79	31 Oct. - 31 Jan.	5 Dec. - 31 Jan.	
1977-78	1 Nov. - 31 Jan.	5 Dec. - 31 Jan.	
1976-77	30 Oct. - 30 Jan.	4 Dec. - 30 Jan.	
1975-76	25 Oct. - 25 Jan.	29 Nov. - 25 Jan.	
1974-75	26 Oct. - 26 Jan.	30 Nov. - 26 Jan.	
1973-74	27 Oct. - 27 Jan.	1 Dec. - 27 Jan.	
1972-73	28 Oct. - 28 Jan.	2 Dec. - 28 Jan.	
1971-72	30 Oct. - 30 Jan.	4 Dec. - 30 Jan.	
1970-71	31 Oct. - 10 Jan.	5 Dec. - 10 Jan.	
1969-70	1 Nov. - 28 Dec.	13 Dec. - 11 Jan.	
1968-69	2 Nov. - 28 Dec.	14 Dec. - 12 Jan.	
1967-68	4 Nov. - 2 Jan.		
1966-67	29 Oct. - 27 Nov.		
1965-66	30 Oct. - 28 Nov.		
1964-65	31 Oct. - 29 Nov.		
1963-64	2 Nov. - 1 Dec.		
1962-63	3 Nov. - 2 Dec.		
1961-62	4 Nov. - 3 Dec.		

[a] Daily bag limit was 2 cranes 1961-62 through 1968-69 and 3 cranes from 1969-70 through 1984-85.

Hunter Information Program

Newspaper, radio, and television coverage about endangered species as well as the need for positive hunter identification of game species has been a joint effort of many organizations in Texas. USFWS informational materials as well as an excellent National Audubon Society pamphlet entitled "Is It A Whooping Crane?" have been available for several years. A TPWD pamphlet entitled "Sandhill Crane Identification" that illustrated and described sandhills, whoopers, and other large wading birds was prepared and distributed to all persons who requested federal sandhill crane hunting permits for Zone C in 1983. This leaflet was distributed to all crane hunters statewide in 1984.

Contingency Planning

Procedures to be followed in the event a whooping crane was reported in a sandhill crane hunting zone during the open season were outlined in annual preseason memoranda to all TPWD field personnel. In brief, field personnel were instructed to immediately investigate whooping crane sighting reports, verify identifications, notify TPWD headquarters, and leave qualified personnel in visual contact with the whoopers to monitor movements and ensure protection of the birds until they departed the hunting zone.

TPWD officials were responsible for contacting USFWS representatives and coordinating any additional protective measures. If deemed necessary, the USFWS could temporarily suspend hunting under federal regulations (50 CFR, Sec. 20.26) in an area encompassing at least the daily range of the subject whooping cranes (Central Flyway Representative 1981).

Effectiveness

To date, there have been no known encounters between sandhill crane hunters and whooping cranes in Texas. However, a whooping crane sighting was confirmed by qualified observers on the Buffalo Lake National Wildlife Refuge in the Texas Panhandle on 6 November 1973 (Whooping Crane Recovery Team 1985). Prior to 1985, this sighting on a non-hunted refuge located within Zone A (Fig. 1) was the only whooper sighting ever confirmed within a sandhill crane hunting zone in Texas at the time the hunting season was in progress. On 22 December 1984, the first of several reports was received concerning the sighting of a juvenile whooping crane near Edna and later, Midfield, Texas. TPWD and USFWS personnel on 2 January 1985 confirmed the presence of a juvenile whooper that had been color-banded (blue-left leg, white-right leg) at Wood Buffalo National Park, Canada during the summer of 1984.

This whooper apparently became separated from its parents during fall migration and its parents continued to the Texas coast and occupied their normal winter territory (T. Stehn, pers. comm.). As the Zone C sandhill crane hunting season opening on 12 January 1985 approached, the whooper maintained close association with sandhill cranes and confined its movements to about a 20 km^2 area 3 to 6 km northwest of Midfield, Texas (approximately 13 km inside the Zone C boundary). Subsequent to detailed discussions and on-site examination, TPWD and USFWS officials agreed that daylight surveillance of the whooper throughout the 30-day Zone C sandhill crane season and a vigorous public information program offered sufficient means of protecting the whooper. This decision was endorsed by representatives of the Canadian Wildlife Service.

A sandhill crane season closure in the vicinity of this whooper was carefully considered but not implemented because the whooper confined its movements to closely-controlled private land with limited access and low hunting pressure. Local landowners (some of which initially photographed and reported the whooper) were extremely cooperative in establishing local hunting restrictions or closures to ensure the whooper's well-being. Cooperative state-federal monitoring began on 12 January 1985 and ended on 10 February 1985. Throughout this period, the whooper remained relatively sedentary within the identified use area and was largely insulated from hunting activity. Administrative actions and field activities associated with this monitoring effort were summarized by Thompson (1985).

Whooping cranes reportedly traveling with sandhill cranes in the Texas Panhandle (Zone A) in both 1984 and 1985 were later identified as partial albino sandhills exhibiting all white body plumage but normal, gray-colored primary and secondary wing feathers. Additional reports of one to three whoopers at other locations in Zone A during the 1984-85 sandhill crane season were never verified by qualified observers.

COASTAL WATERFOWL HUNTING

Waterfowl hunting, unlike sandhill crane hunting, was not subject to federal closure during the period from 1916 to 1960 and has traditionally been permitted within the winter range of the whooping crane in Texas throughout this century. Duck and goose hunting seasons generally opened in November when whooping cranes were still in migration and continued into January, about one-half way through the winter use period. Substantial whooping crane use is concentrated on Aransas National Wildlife Refuge (ANWR), an area closed to hunting. However, many of the cranes use public and private lands and waters that are outside the refuge and are normally hunted during open seasons. Only one instance of accidental crane mortality related to hunting is known in Texas despite the temporal and spatial overlap of waterfowl hunting with crane use areas (Whooping Crane Recovery Team 1986). This incident in January 1968 involved a goose hunter who killed a whooper thinking it was a snow goose. The hunter voluntarily surrendered to authorities when he realized his error.

Nonetheless, uncertainty existed regarding the effect that hunting activities had on whooping cranes. Concerns existed not only for effects on day-to-day and annual use, but also for the effect on potential expansion of habitat use as the whooper population continued to increase. Annual monitoring of whooping cranes from the time of the acquisition of ANWR in 1937, through the mid-1970's was generally limited to weekly (mostly midweek) counts conducted by the USFWS. Use patterns and responses of cranes had not been investigated on weekends when hunter activity was presumably highest.

Survey Methods

During the winter of 1976-77 (late December-mid April), the TPWD initiated a weekend aerial survey to document whooping crane occurrence in proximity to waterfowl hunting activity and detect any shifts in habitat use associated with hunter presence. This survey was not funded in 1977-78, but flights were reinstituted in 1978-79 and continued through the winter of 1983-84.

The weekend aerial survey consisted of 19 to 27 fixed-wing flights annually, generally from late October to early March each winter. Flights were scheduled each Saturday and Sunday, weather permitting, for approximately 2 hours starting at about 0700 CST during hunting seasons. Prior to and after hunting seasons, flights were scheduled during the same daily time period on 1 day each weekend. All known crane-use areas outside ANWR were examined on each flight and numbers and locations of whoopers, active blinareas ds, hunters, outboard-powered boats, and airboats were recorded and plotted on maps.

Excluding ANWR, the cranes predictably used four general areas: Isla San Jose, Matagorda Island, Welder Point, and Lamar Peninsula (Fig. 2). Data were summarized independently for these areas. Matagorda Island was divided into four segments for data collection because of its size and variation in use by hunters and cranes, but data for all segments were grouped for presentation in this report. Survey personnel recognized that all hunters and boats were not detected during each flight, but this factor was considered to be constant over the years of the survey and a correction factor was not used. Comparisons of crane locations before, during, and after hunting seasons were used to assess use patterns related to hunter activities. Maximum numbers of cranes, active blinds, hunters, and boats within the major use areas were used to index trends in use of the major areas over the duration of the study. Additional details on methods and individual survey counts were reported previously by Brownlee (1977) and Smith (1980, 1981, 1982).

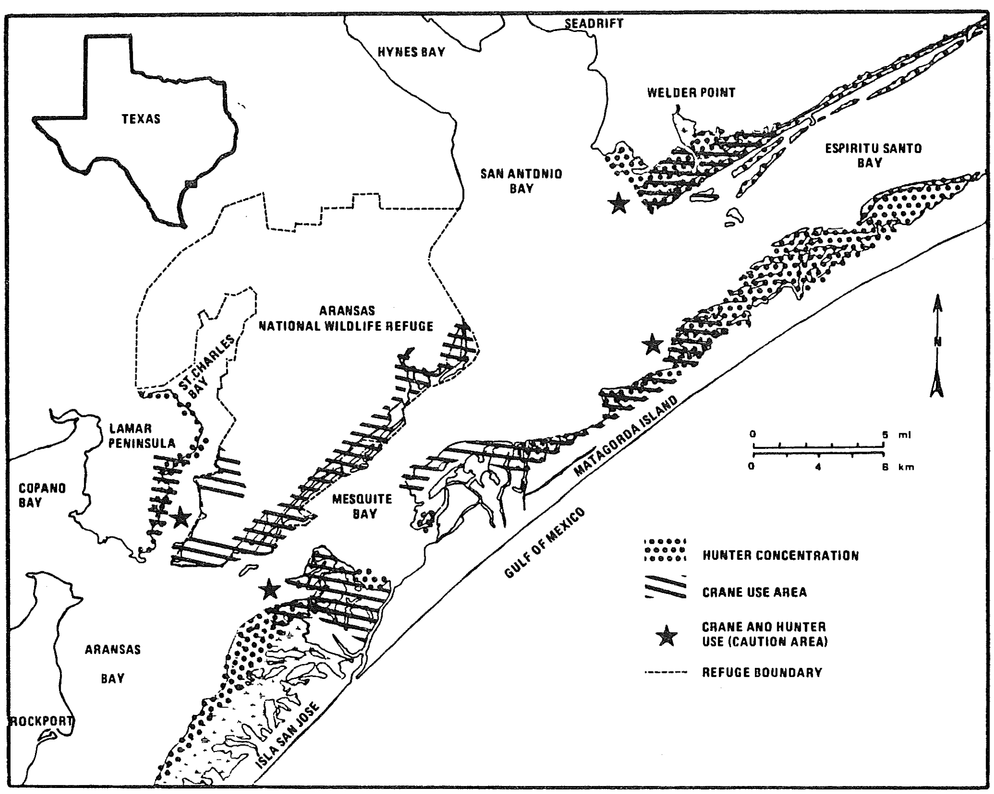

Fig. 2. Proximity of areas used by waterfowl hunters and whooping cranes on the Texas Gulf Coast as identified through aerial survey during the wintering periods of 1976-1977 through 1983-84.

Hunter and Crane Use Patterns

Generally, the areas heavily used by whooping cranes were not heavily used by hunters (Fig. 2). Cranes seemed to prefer closed marsh with small water bodies, whereas waterfowl and associated hunters frequented more open marsh with scattered, larger lakes. However, four locations were identified that deserve particular caution because of concurrent crane and hunter use. These areas were Welder Point, Panther Point to Twin Lakes on Matagorda Island, Lamar Peninsula across from Egg Point, and the Spalding Cove area of Isla San Jose (Fig. 2).

Although some variation was evident, the maximum occurrence of whooping cranes in the general use areas remained relatively stable during the 7 years of the survey (Table 2). The amplitude of variation in maximum numbers of cranes was as great for the non-hunted ANWR as it was for Matagorda Island and Isla San Jose (Table 2). Some variation resulted from differing numbers of young and breeding success of specific pairs over the years along with the net population change of 6 additional cranes from 69 in 1976 to 75 in 1983.

Table 2. Maximum number of whooping cranes observed during weekend aerial surveys in five general use areas on the Texas Gulf Coast, 1976-84.

	Maximum number of cranes observed during weekend surveys[a]						
Location	76-77	78-79	79-80	80-81	81-82	82-83	83-84
Lamar Peninsula	4	2	2	2	2	2	3
Aransas NWR	43	52	54	59	43	48	47
Isla San Jose	7	8	13	6	10	8	7
Matagorda Island	22	15	17	18	21	16	19
Welder Point	3	5	5	6	4	5	5

[a] Includes adult-plumaged cranes and juveniles. No survey in 1977-78. Aransas NWR 1983-84 count provided by T. Stehn.

Crane use in some portions of the wintering area appeared to shift somewhat during the hunting season in response to hunter presence or airboat activity as exemplified by Welder Point and Twin Lakes on Matagorda Island during 1978-79 (Figs. 3 and 4), but gross changes in distribution were not evident over the wintering period as a whole. The general stability of whooping crane use in these limited areas along the Texas Coast further substantiates the suitability of the southeastern boundary selected for Zone C of the sandhill crane hunting area (Fig. 1).

Maximum hunter numbers and presence of associated boats was substantial in the survey areas during all years but tended to be stable or declining over the course of the survey (Table 3). With few exceptions, maximum numbers of hunters and boats were recorded during the opening weekend of the hunting season in early November. Only 75% of the whooping cranes typically have arrived at the wintering area by this time (Tom Stehn, pers. comm. - USFWS unpubl. rept.). The greatest hunter use was associated with Matagorda Island, but much of this use was concentrated near Pringle Lake, an area not used by whooping cranes during this study. Overall, hunter presence near whooping cranes was routine but declined over time within each season.

Whooping crane occurrences within 400 m of active hunters were recorded 27 times in all parts of the area open to hunting but were detected most frequently at Lamar Peninsula (Table 4).

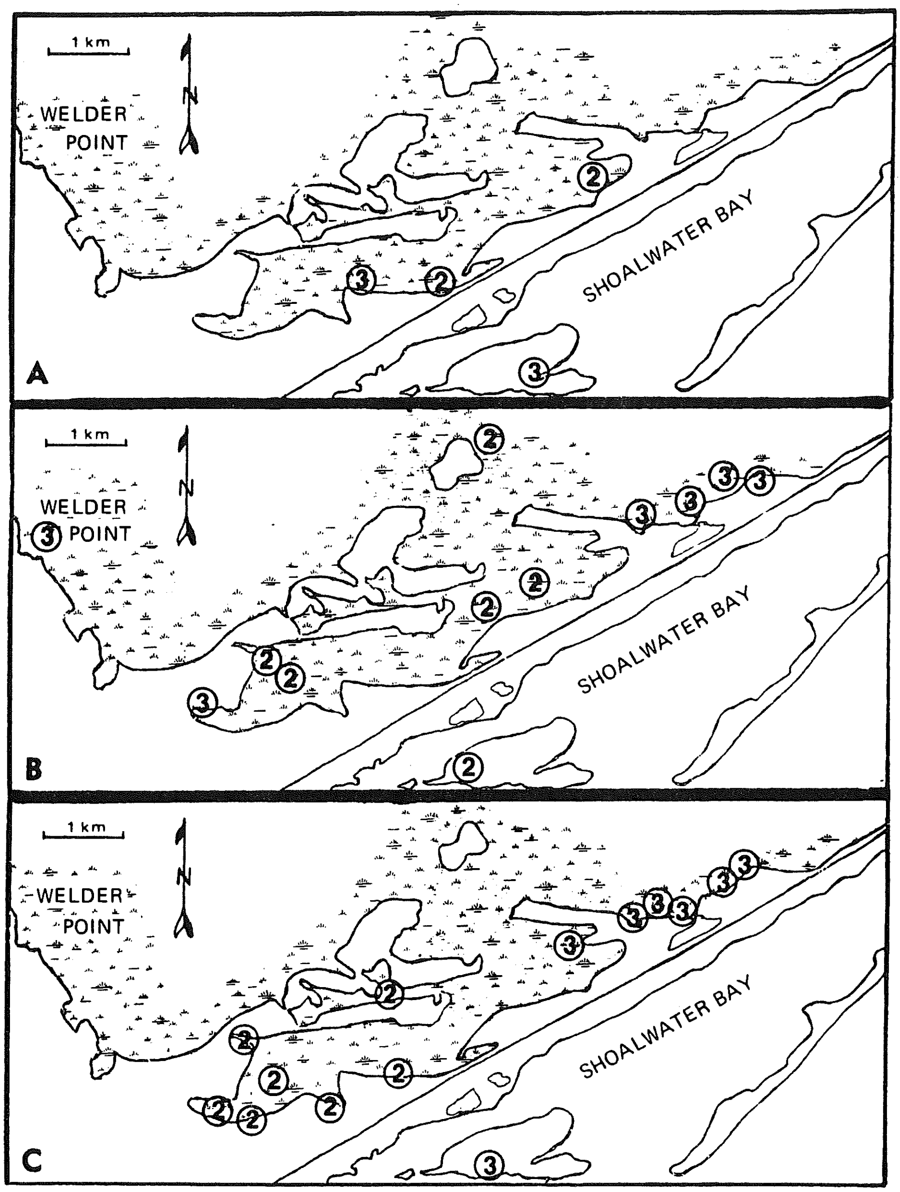

Fig. 3. Locations of whooping cranes observed in the Welder Point area of the Texas Gulf Coast during weekend aerial surveys during (A, 4-26 Nov; B, 17 Dec-21 Jan) and after (C, 27 Jan-17 Mar) the waterfowl hunting season, winter 1978-79. Circled numbers on the maps represent the numbers and locations of cranes observed during seven flights within each survey period.

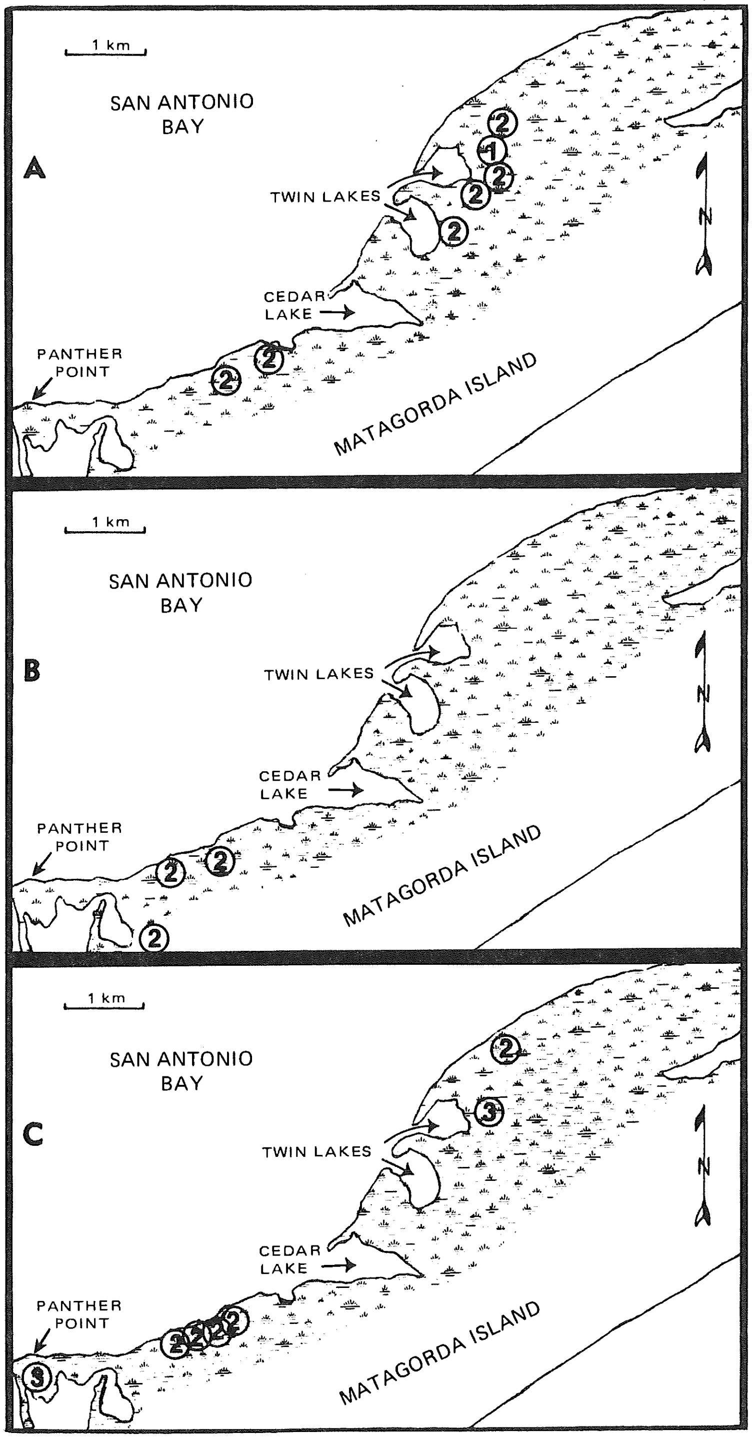

Fig. 4. Locations of whooping cranes observed on a portion of Matagorda Island, Texas during weekend aerial surveys during (A, 4-26 Nov; B, 17 Dec-21 Jan) and after (C, 27 Jan-17 Mar) the waterfowl hunting season, winter 1978-79. Circled numbers on the maps represent numbers and locations of cranes observed during seven flights within each survey period.

Table 3. Maximum number of boats, active hunting blinds, and hunters observed during weekend aerial surveys in whooping crane winter use areas 1976-84.

Location and disturbance factors	Maximum number observed[a]						
	76-77	78-79	79-80	80-81	81-82	82-83	83-84
Lamar Peninsula							
Airboat	-	1	0	7	1	2	1
Outboard	-	3	8	7	3	12	5
Active blind	18	5	14	10	10	12	7
Hunter	46	11	37	26	26	31	16
Isla San Jose							
Airboat	-	5	5	17	7	5	4
Outboard	-	14	16	21	20	7	11
Active blind	17	18	25	31	35	17	15
Hunter	40	43	50	69	91	40	34
Matagorda Island							
Airboat	-	21	21	34	21	25	15
Outboard	-	12	12	19	16	16	25
Active blind	30	37	40	49	51	40	24
Hunter	58	83	83	110	122	102	43
Welder Point							
Airboat	-	9	14	11	8	4	3
Outboard	-	4	10	7	5	3	4
Active blind	10	20	41	15	15	8	7
Hunter	17	43	69	33	38	17	14

[a] Counts are not listed for Aransas National Wildlife Refuge where hunting is not allowed. No survey in 1977-78.

Proportionally, the most whooper occurrences within 200 m of hunters also were observed on Lamar Peninsula, the area used by the fewest cranes. This distinction may indicate individual or pair-by-pair differences in tolerance to disturbance which has been observed under other circumstances (D. R. Blankinship, pers. comm.). However, significantly more (59.3%, X^2=16.99, df=3, p<0.01) of the 27 recorded occurrences of whoopers in close proximity to hunters were 301-400 m distant (Table 4), thus indicating some tendency for the whoopers to maintain a substantial separation. Considering that these observations represent very brief segments in the overall exposure of cranes to hunters, it is possible that whoopers may frequently be in close proximity to hunters without negative effects.

Management Actions

In the absence of major conflicts between whooping cranes and hunting activities, recommendations have not been made for regulatory changes with respect to waterfowl hunting in whooping crane use areas. However, the substantial use of Matagorda Island by cranes and hunters, documented during the survey, indicated the need for reasonable precautions. In Sept. 1983, a memorandum of agreement between the U.S. Department of Interior and the State of Texas transferred management responsibilities for about 43,000 acres of publicly-owned land and waters on Matagorda Island to the TPWD. The management plan for the island has as a primary objective the protection of state and federal endangered/threatened species, including the whooping crane, and hunting programs provided only when consistent with the primary objective.

Table 4. Numbers of occasions where whooping cranes were observed within 400 m of active hunters at four general areas within the winter range, 1978-1984.

Distance (m)	Lamar Peninsula	Isla San Jose	Matagorda Island	Welder Point	Total
≤ 100	4	0	0	0	4
101 - 200	2	1	1	0	4
201 - 300	0	1	1	1	3
301 - 400	4	1	4	7	16
Total	10	3	6	8	27

Hunting activities on the island, particularly waterfowl hunting, during the two seasons since assumption of management authority, have been structured to provide buffers between hunters and normal crane use areas. Hunters on the island proper are briefed on identification of endangered species, provided a pamphlet on species easily confused with whooping cranes, and familiarized with a map of species locations relative to hunting areas. Hunters are further cautioned about shooting in the vicinity of endangered species and instructed on how to report species of special interest to the Department. Although waterfowl hunters in the bayside marshes on the island are not under direct supervision of Department personnel, specific surveillance activities are scheduled to monitor possible conflicts between hunters and whooping cranes and to evaluate the effects of airboat use or other watercraft on whooping cranes. This information, combined with past survey data presented in this report and other ongoing whooping crane investigations, form the basis for annual management and regulatory recommendations. Under circumstances where a whooping crane enters a hunting area on the island, procedures are established to cease hunting immediately.

DISCUSSION

Temporal and spatial considerations made within the regulatory planning process generally provide sandhill crane hunting zones and seasons that effectively separate sandhill crane hunters in Texas from likely contact with whooping cranes in the Wood Buffalo-Aransas population. However, errant migrants from the Wood Buffalo-Aransas population are possible, and the expanding Grays Lake-Bosque del Apache population of whooping cranes presents limited potential for whoopers wandering from New Mexico into Texas during the sandhill season (R. C. Drewien, pers. comm.). Thus, hunter awareness programs and contingency planning for unexpected whooping crane occurrences in all crane hunting zones are appropriately continued on an annual basis. A satisfactory information transfer program and network to deal with unexpected whooping crane occurrences has been developed and tested within TPWD, but its success depends on routine commitment of program staff to provide timely reminders to field staff well in advance of hunting seasons.

Monitoring of whooping cranes within waterfowl hunting zones has revealed no gross effects on distribution or habitat use related to hunting activities. The observed stability in maximum number of cranes using specific areas agreed closely with "typical" distribution through the winter for the same periods (Stehn and Johnson this proceedings). However, hunting or associated boating disturbance of whooping cranes may have subtle effects on the activity (= energy) budget of certain groups or age classes of cranes (Blankinship 1976, Bishop 1984), thus being an important factor in long-term recovery of the species. Data from past surveys are insufficient to address that issue, and further investigation is necessary to measure whooping crane responses to specific disturbance factors and estimate if associated energy costs or restrictions in habitat use are detrimental to recovery efforts. Airboats have been suggested as a possible source of disturbance and investigation of the effects of their use within the whooping crane winter range is an important component of future research.

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