



Conservation Priorities and Best Management Practices for Wintering Sandhill Cranes in the Central Valley of California



International Crane Foundation
www.savingcranes.org

Prepared for The Nature Conservancy, California
December 2014

Gary L. Ivey, Caroline P. Herziger, and David A. Hardt

Conservation Priorities and Best Management Practices for Wintering Sandhill Cranes in the Central Valley of California

Gary L. Ivey, Caroline P. Herziger, and David A. Hardt



International Crane Foundation
PO Box 447
Baraboo, WI 53913 USA
www.savingcranes.org

December 2014
Version 1.0

Prepared for The Nature Conservancy of California
190 Cohasset Road, Suite 177 Chico, CA 95926

Suggested citation: Ivey, G. L., C. P. Herziger, and D. A. Hardt. 2014. Conservation priorities and best management practices for wintering Sandhill Cranes in the Central Valley of California. Prepared for The Nature Conservancy of California. International Crane Foundation. Baraboo, WI, USA.

EXECUTIVE SUMMARY

The purpose of this project is to identify important private lands to focus conservation strategies for Sandhill Cranes (*Grus canadensis*) wintering in the Central Valley of California and provide recommendations for crane-friendly management of foraging and roosting habitats. This project includes the following goals: 1) identifying current and historical crane roosting and foraging sites throughout their Central Valley, California wintering range, 2) providing recommendations for prioritizing among these sites, and 3) recommending strategies for conservation and crane-friendly management. This project was initiated by The Nature Conservancy to advance habitat conservation and enhancement for cranes in the Central Valley.

We mapped 1,858 Sandhill Crane flock locations between 9 December 2012 and 3 March 2013. Flocks were observed between southern Tehama County in the north and northwest Kern County in the south. Due to the vastness of the valley, and time limitations for data collection, it was not possible to do a comprehensive survey. As expected, flocks were concentrated in the historically most used areas: the northern Sacramento Valley, the Sacramento-San Joaquin Delta (Delta), the northern San Joaquin Valley south of Tracy to Mendota (including the lower Stanislaus and Tuolumne River floodplains and the Grasslands Region), and the southern San Joaquin Valley in the vicinity of Pixley in Tulare County. We also mapped 121 roost sites that have been used by Sandhill Cranes in recent years.

During our flock surveys, 73% of the Sandhill Cranes we classified were the Lesser subspecies, 23% were the Greater subspecies, and 2% were the Canadian subspecies. We assessed trends in crane populations from Mid-winter Waterfowl Survey and Christmas bird count data. Because neither survey is designed specifically to estimate crane population abundance, there are major limitations to what can be concluded from the data. Even so, the Mid-winter data indicated an increasing trend (+4%/year). Based on recent surveys, we provide a current estimate of approximately 50,000 Sandhill Cranes in the Central Valley. We used our subspecies ratios from flock surveys to provide estimates of each subspecies: Lessers - 36,500, Greaters - 9,000, and Canadians 3,000.

We reviewed historic occurrences of cranes wintering in California. Although they formerly wintered in the Los Angeles Basin and the San Francisco Bay Region, these areas are currently too populated to support cranes. Within their current Central Valley winter range, their use areas have generally expanded, except perhaps in the Southern San Joaquin Valley. Two formerly used wintering areas apparently have been abandoned or used very sparsely by Sandhill Cranes in recent years; the Red Bluff area (along the Sacramento River between Red Bluff and Anderson, Tehama County), and the Carrizo Plain (San Luis Obispo County). Cranes stopped using the Carrizo Plain when the type of agriculture in the area became incompatible.

We suggest an assessment of priorities for conservation of Sandhill Crane habitat should first consider whether roost site distribution is adequate within a given region, and secondly whether the associated foraging landscape around the roosts is adequate to support Sandhill Cranes using a given roost. The area surrounding roost sites that should be considered for conservation differs by subspecies due to differences in their foraging distances. Greater Cranes have very restricted foraging range, and primarily utilize lands within 3 miles of their roost sites, while Lesser Cranes, however, are likely to travel twice as far.

We recommend the following crane conservation strategies (listed in order of priority) be implemented for each major crane wintering region: 1) protect existing, unprotected roost sites by fee-title acquisition or conservation easements (and prioritize among sites according to their importance to Greater Cranes); 2) protect foraging landscapes around existing roosts, primarily through easements restricting incompatible crop types and development; 3) enhance food availability within those landscapes by improving conditions on conservation lands and providing annual incentives for improvements on private lands; 4) develop additional protected roost sites towards the edge of their existing range to allow them to access additional foraging areas.

We propose that five Central Valley wintering regions be considered for conservation focus: 1) the Delta, 2) the Sacramento Valley, 3) the Grasslands, 4) the Pixley NWR area, and 5) the San Joaquin River area. We recommend that they be prioritized in the order listed; however, it would be good to work simultaneously in all of these regions to take advantage of conservation opportunities as they become available. Within this report, we provide more specific conservation recommendations for sites within each of these wintering regions.

We reviewed and synthesized Sandhill Crane habitat management recommendations. For management of roost sites, the timing of flooding should begin in early September and be maintained through mid-March. Flooding and draining of roost sites should be conducted over approximately a 2-week period to allow Sandhill Cranes to take advantage of the foraging opportunities these events create. Where there are multiple roost sites within a particular Sandhill Crane landscape, we recommend staggering their flood-up and drawdowns to extend Sandhill Crane feeding opportunities throughout the winter period. Management of shallow water depths is critical for Sandhill Crane roosting use. Roost sites should be managed to maximize the area that provides ideal roosting depths of 4 – 6 inches. When designing new roost sites, consideration should be given to whether a seasonal wetland or a flooded cropland roost would best fit in a given landscape. Roost site complexes should be large (~250 – 2,500 acres). Individual sites within a managed roost complex should be >12 acres, of mostly level topography, dominated by shallow water, and should not be dominated by tall emergents.

Past studies provided summaries of habitat types used by cranes in the Delta region and identified corn as the most important crop, followed by rice, wheat, alfalfa, pasture, oak savannah, fallow fields, wetlands, levees, and Sudan grass. Habitats used in the Sacramento Valley included rice as the most important crop, followed by wheat, corn, grassland, alfalfa,

fallow fields, and oak savannah. Habitats that we documented cranes using during our foraging flock surveys appeared roughly proportional to what was available in the regional landscapes we monitored. For the Sacramento Valley, rice was used by 89% of the flocks; in the Delta 43% and 19% of flocks were recorded in corn and alfalfa, respectively; in the northern San Joaquin Valley, 30%, 23% and 16 % of flocks used new-planted wheat, alfalfa, and corn, respectively; and, in the southern San Joaquin Valley 58% of flocks used alfalfa and 30% used new-planted wheat.

Since grain crops are of primary importance to Sandhill Cranes, we recommend that farmers be encouraged thorough easements and incentives to continue farming grains in landscapes being managed for cranes. Greaterers rarely used alfalfa in the Delta, in contrast to Lessers, which often favored alfalfa. Therefore, alfalfa should not be considered a major food source for Greaterers in a conservation planning context. However, alfalfa should be encouraged in Sandhill Crane landscapes in the San Joaquin Valley, where Lessers dominate the Sandhill Crane flocks.

Management of crop conditions can greatly influence Sandhill Crane food availability. We recommend using mulching to manage corn stubble as this condition was often favored by Sandhill Cranes. However, mulching of rice stubble did not appear to be as attractive to Sandhill Cranes, so we recommend providing large areas of unmanipulated rice stubble for Sandhill Crane foraging. Tillage tends to reduce grain availability and should be discouraged or delayed until late winter to allow Sandhill Cranes sufficient time to consume the available waste grains.

Flooding and irrigation can be managed to enhance food availability to Sandhill Cranes, as they are particularly attracted to newly flooded habitats; however, because deep flooding can reduce Sandhill Crane food availability, we recommend using shallow flooding and sub-irrigation to enhance feeding conditions. For grain fields, flooding should be delayed until after Sandhill Cranes consume most of the available waste grains. If large areas need to be flooded within a Sandhill Crane landscape (such as in rice fields to decompose stubble), we recommend that very shallow flooding of individual fields and wetlands be staggered over winter, rather than done all at once, to spread out the feeding opportunities that flood-up provides. With the exception of grain fields flooded to provide night roost sites, it would be best to delay flooding as late as possible (perhaps beginning in January) to allow Sandhill Cranes and other wildlife access to waste grains. Because burning was found to reduce waste grain for Sandhill Cranes, we recommend providing incentives for farmers to avoid or delay burning of fields until late winter, after Sandhill Cranes have consumed most of the waste grain. Food plots (e.g., corn or barley) can be used to increase crane food availability and in times of food shortage, may be needed to maintain Sandhill Crane carrying capacity in a given crane landscape.

Minimizing disturbance is an important Sandhill Crane conservation strategy. Cranes are particularly sensitive to disturbance from hunting, low-flying aircraft, ultralight aircraft, all-terrain vehicles, motorcycles and bicycles. Sandhill Crane roost sites and waterfowl hunting should not be considered readily compatible, therefore, managers should consider hunting disturbance in planning Sandhill Crane conservation and management in a given crane

landscape. Larger parcels with no or minimal disturbance issues should be considered as a higher priority for selection of Sandhill Crane conservation sites.

We recommend that TNC work with other conservation organizations and natural resource management agencies to implement our recommendations. Since Central Valley NWRs are core to Sandhill Crane conservation we suggest that TNC approach the USFWS and the National Wildlife Refuge Association to investigate if their Beyond the Boundaries program could be implemented for Central Valley Refuges. Funding for incentive programs for crane-friendly management on private lands is primarily the realm of NRCS, but perhaps TNC and Audubon California could also support these efforts. Detailed, on-the-ground planning of easement locations and actual cropland and roost site management is needed to develop a successful crane conservation program, and monitoring is also important to ensure success and enable adaptive management.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	i
STUDY AREA	2
METHODS.....	4
Identification of current roosting and foraging sites and relative abundance of Sandhill Cranes	4
Sandhill Crane Surveys	4
Subspecies composition among flocks	4
Estimates of Sandhill Crane population trend.....	4
Estimates of Sandhill Crane abundance	5
Historic Sandhill Crane habitat use patterns	5
Development of conservation recommendations	5
CURRENT SANDHILL CRANE DISTRIBUTION IN THE CENTRAL VALLEY	6
SANDHILL CRANE POPULATION TRENDS AND ABUNDANCE	9
Sandhill Crane population trends	9
Mid-winter Waterfowl Surveys	9
Christmas Bird Counts	12
Estimates of Sandhill Crane abundance from the literature	12
A current estimate of Sandhill Crane population abundance	13
Estimates of Sandhill Crane populations by subspecies—	15
HISTORIC SANDHILL CRANE USE PATTERNS IN THE CENTRAL VALLEY	15
Changes in Sandhill Crane use patterns in the Delta region	20
Changes in Sandhill Crane use patterns in the Grasslands region.....	23
Changes in Sandhill Crane use patterns in the southern San Joaquin Valley region	23
Areas of former importance for Sandhill Cranes	25
Carrizo Plain	25

Red Bluff	25
SANDHILL CRANE CONSERVATION RECOMMENDATIONS	26
PRIORITIZING AMONG WINTERING SITES.....	27
RECOMMENDATIONS FOR CONSERVATION ACTIVITIES BY WINTERING REGION....	28
Highest priority sites in the Delta.....	29
Brack Tract	29
Canal Ranch Tract.....	30
South New Hope Tract	31
Tyler Island	31
Bouldin Island.....	31
Terminus Tract.....	31
Grand Island	31
Secondary priority sites in the Delta	32
Dry Creek Area.....	32
Valensin Ranch Area.....	33
West Galt area.....	33
Elk Grove area.....	33
Thornton area	33
Pearson Tract	33
Clarksburg area.....	33
Other Delta areas.....	33
Conservation priorities and strategies for the Sacramento Valley.....	34
Conservation priorities and strategies for the San Joaquin Valley.....	35
BEST MANAGEMENT PRACTICES	38
Roost site management.....	38
Timing	38

Flooding and draining	39
Water depths.....	40
Roost site design	40
Foraging habitats Sandhill Cranes use.....	40
Grains.....	41
Other crops and habitats	41
Sandhill Crane response to management conditions	44
Unaltered grain stubble	44
Tillage.....	44
Mulching	44
Flooding and irrigation.....	45
Burning.....	46
Food plots.....	46
Managing disturbance	47
POTENTIAL PARTNERSHIPS AND OPPORTUNITIES	48
ACKNOWLEDGMENTS	48
LITERATURE CITED	49

LIST OF TABLES

Table 1. Proportions of Greater Sandhill Cranes (Greater), Lesser Sandhill Cranes (Lesser) and Canadian Sandhill Cranes (Canadian) recorded in foraging flocks in the wintering regions of the Central Valley of California in 2012 and 2013.....	9
Table 2. Summary of Sandhill Crane data from aerial Mid-winter Waterfowl Surveys of the Central Valley of California, 1990-2014. ^a	11
Table 3. Numbers of Sandhill Cranes counted during the 2007-2008 winter at important roost sites in the Sacramento-San Joaquin Delta and San Joaquin Valley Sandhill Crane wintering regions of California, representing the most complete area coverage to date.....	14

Table 4. Peak numbers of Greater Sandhill Cranes (Greater) and all Sandhill Cranes counted during surveys of the wintering regions of the Central Valley of California, 1970 – 2014..... 28

Table 5. Proportions of Sandhill Crane flocks found, by habitat type and management conditions during surveys conducted in December 2012-March 2013 in the Central Valley of California. 43

LIST OF FIGURES

Figure 1. Central Valley California Study Area with approximate locations of the Central Valley (red line) and major wintering areas of Sandhill Cranes. 3

Figure 2. Distribution of Sandhill Crane foraging flocks mapped in December 2012 and January and February 2013 in the Central Valley of California..... 7

Figure 3. Sandhill Crane roost site locations mapped in the Central Valley of California, 2002-2013. 8

Figure 4. Mid-Winter Waterfowl Survey totals for Sandhill Cranes counted in the Central Valley of California, 1990-2014. 10

Figure 5. Christmas Bird Count totals for Sandhill Cranes counted in the Central Valley of California, 1990-2014..... 12

Figure 6. Distribution of historic geo-referenced Sandhill Crane flocks in the Central Valley of California..... 18

Figure 7. General distribution of wintering Sandhill Cranes in the Sacramento Valley of California over time. 19

Figure 8. General distribution of wintering Sandhill Cranes in the Sacramento-San Joaquin Delta region of California 21

Figure 9. General distribution of wintering Sandhill Cranes in the San Joaquin River National Wildlife Refuge area of California..... 22

Figure 10. General distribution of wintering Sandhill Cranes in the Grasslands Region in 2013, Merced County, California. 23

Figure 11. General distribution of wintering Sandhill Cranes in the Pixley National Wildlife Refuge Region in 2013, Tulare County, California. 24

Figure 12. Numbers of Sandhill Cranes recorded on the Carrizo Plain Christmas Bird Count, 1970-2012. 25

Figure 13. Numbers of Sandhill Cranes recorded on the Red Bluff Christmas Bird Count, 1975-2012. 26

Figure 14. First priority Sandhill Crane conservation sites in the Delta region. 30

Figure 15. Secondary priority Sandhill Crane conservation sites in the Delta region. 32

Figure 16. General bounds of Sandhill Crane landscape areas in the northern Sacramento Valley of California with recent roost sites and suggestions of general locations where new roost sites might be placed. 35

Figure 17. General bounds of the Grasslands Sandhill Crane wintering region in the northern San Joaquin Valley, California. 36

Figure 18. General bounds of the Pixley National Wildlife Refuge Sandhill Crane wintering region in the southern San Joaquin Valley, California. 37

Figure 19. General bounds of the San Joaquin River National Wildlife Refuge Sandhill Crane wintering region in the northern San Joaquin Valley, California. 38

INTRODUCTION

The purpose of this project is to identify important private lands to focus conservation strategies for Sandhill Cranes (*Grus canadensis*) wintering in the Central Valley of California and provide recommendations for crane-friendly management of foraging and roosting habitats. This project includes the following objectives: 1) identification of current and historical Sandhill Crane roosting and foraging sites throughout their Central Valley, California wintering range, 2) providing recommendations for prioritizing among these sites, and 3) recommending strategies for conservation and crane-friendly management. This project was initiated by The Nature Conservancy (TNC) to advance habitat conservation and enhancement for Sandhill Cranes in the Central Valley. Information presented in this report will be used to guide development and implementation of collaborative projects with agencies, other conservation groups, and private landowners to protect existing Sandhill Crane habitats from development and conversion to incompatible crops, and to promote crane-friendly management in agricultural landscapes.

The Central Valley Population (CVP) of Greater Sandhill Cranes (*G. c. tabida*; hereafter, Greater) and the Pacific Flyway Population (PFP) of Lesser Sandhill Cranes (*G. c. canadensis*; hereafter, Lessers) are the two populations recognized by the Pacific Flyway Council that winter in the Central Valley. The breeding range for Greater includes central and eastern Oregon, northeast California, northwest Nevada, and south-central Washington (Pacific Flyway Council 1997). The “southern half” of interior British Columbia, Canada, has also been considered a breeding region for Greater (Pacific Flyway Council 1997), but the subspecies occurring there has not been confirmed. The PFP of Lessers is known to breed in southwest Alaska (Pacific Flyway Council 1983, Mickelson 1987, Petrula and Rothe 2005), but they also possibly breed north of the Alaska Range and in Siberia. In addition to Greater and Lessers, the Canadian subspecies (*G. c. rowani*) is also present in the Central Valley during winter (Ivey et al. 2005), and is difficult to distinguish from the other subspecies. It can best be distinguished by measurements of captured birds (Johnson and Stewart 1973, Johnson et al. 2005), or by very experienced observers in very good viewing conditions (being close with good lighting). Therefore, past studies have typically combined Greater and Canadians into a “large crane” category and Canadians have been included in the total population estimates for the CVP (e.g., Pogson and Lindstedt 1991, Hoffman 2000).

Some studies suggest that the Greater and Canadian subspecies may not be genetically distinct (Tacha et al. 1985, Rhymer et al. 2000, Glenn et al. 2002, Petersen et al. 2003, Jones et al. 2005). However, the Canadians in the Pacific Flyway may be distinct from the other two populations, since cranes measured as Canadians along the Lower Columbia River at Ridgefield National Wildlife Refuge (NWR), Washington and at Sauvie Island Wildlife Management Area, Oregon were tracked with satellite telemetry to wintering grounds in the Central Valley, and to breeding grounds along the coast of southwest Alaska and British Columbia (Ivey et al. 2005);

these data suggest that their breeding ranges do not overlap with other populations. Consequently, it has been recommended that they be considered the Pacific Coast Population of Canadian Sandhill Cranes (Ivey et al. 2005). In California, Greaterers are listed as a Threatened species (California Department of Fish and Wildlife [CDFW] 2013), and Lessers as a Bird Species of Special Concern (Littlefield 2008).

Sandhill Cranes only use a small proportion of the available habitat within the Central Valley, because they focus their habitat use around traditional night roost sites and show strong inter-annual fidelity to these sites and their associated foraging landscapes. Traditional roosts occur in several wintering regions in the Central Valley, most often on National Wildlife Refuges (NWRs) or other conservation lands (e.g., Staten Island in San Joaquin County), and more rarely on private lands. Because of their strong tradition of using specific roosting areas, conservation and management of Sandhill Crane wintering habitat should focus on lands in proximity to these traditional roosting areas. Before this study, there has not been a comprehensive effort to map Sandhill Crane winter range or an assessment of roost site distribution throughout the Central Valley. Also, previous reports have not addressed how use of landscapes by Sandhill Cranes has changed over time.

Previous estimates of the populations of each subspecies have been problematic, as in some cases, they have combined subspecies (Greaterers and Canadians) and in other cases only address populations in certain regions. More recently, coordinated roost site surveys in certain regions have provided a better estimate of Sandhill Crane abundance in the Central Valley. Identification of important areas of Sandhill Crane habitat use can help inform population monitoring, and in the absence of good survey numbers, identifying trends in habitat availability and use can help characterize the status of the Sandhill Crane populations.

STUDY AREA

Our study area included the Central Valley and the Carrizo Plain in San Luis Obispo County. The Central Valley extends from Red Bluff in the north to Bakersfield in the south, approximately 450 miles in length and is as wide as 60 miles, between the Sierra Nevada range to the east and the Coast Range to the west. The primary Sandhill Crane wintering areas in this study area include: the Sacramento Valley rice-growing region from Chico south to Williams and Marysville; the Sacramento-San Joaquin Delta (hereafter, Delta; including the Cosumnes River Floodplain and the Delta region from Freeport south to Highway 4 west of Stockton; the North San Joaquin Valley south of Tracy to Mendota, including the lower Stanislaus and Tuolumne River floodplains, San Joaquin River NWR and the Grasslands (Merced County); and the South San Joaquin Valley south of Visalia to Bakersfield, especially on Pixley NWR (Fig. 1). Additionally, Sandhill Cranes occasionally use areas along the Sacramento River floodplain

between Red Bluff and Anderson in Tehama County, the Mendota area in Fresno County, the eastern foothills of Merced and Stanislaus counties, and the Goose Lake area in Kern County.



Figure 1. Central Valley California Study Area with approximate locations of the Central Valley (red line) and major wintering areas of Sandhill Cranes.

METHODS

Identification of current roosting and foraging sites and relative abundance of Sandhill Cranes

Sandhill Crane Surveys—Sandhill Crane winter foraging flock surveys were conducted in December 2012 through February 2013 on private lands in the Central Valley to help identify important areas to prioritize conservation of Sandhill Cranes. When possible, we classified habitat types by crop or natural land cover type (e.g., grassland) and by management condition (e.g., flooded, disced, etc.). When cranes were too distant to record habitat data, we recorded the habitat as unknown. These data, along with flock size and location, were consolidated into a spatial database. Because our focus was counting flocks on private lands from public roads, we did not attempt to measure specific attributes such as stubble height or water depths, since it would have been problematic to obtain permission for access and would have required more time than available while attempting to complete landscape-scale surveys for Sandhill Cranes. Flock surveys were primarily conducted by the authors, but volunteers also assisted. In addition, we included relevant 2013 flock reports from eBird (Sullivan et al. 2009) in our dataset. Field work focused on identifying foraging sites, but also, when observed, new roost sites were mapped. We logged 741 hours of survey time (including 119 hours of volunteers' time), and drove 17,098 survey miles. We focused our survey efforts on five Central Valley wintering regions to define the bounds of the Sandhill Crane winter ranges in these areas (Fig. 1): 1) the Sacramento Valley between Marysville and Chico; 2) Sacramento-San Joaquin Delta; 3) lower Stanislaus-Tuolumne-San Joaquin rivers floodplains (San Joaquin River NWR area); 4) Grasslands Region; and 5) southern San Joaquin Valley (Pixley NWR area). We spent less survey effort in the Delta than in other regions, because a recent study defined the Sandhill Crane winter range there (Ivey et al. 2014b). Flock and roost site locations were entered into databases and plotted using ArcGIS version 10.1 (Environmental Systems Resource Institute, Redlands, California). For the roost site map, in addition to sites mapped in 2012-2013, we also included roost sites identified during recent studies (Ivey and Herziger 2003, Shaskey 2012 and Ivey et al. 2014b).

Subspecies composition among flocks—We classified subspecies in flocks that were close enough to allow identification and estimate the relative abundance of each subspecies. We also analyzed current and recent data (collected since 2000) to estimate Sandhill Crane subspecies abundance at individual sites and to provide an overall estimate of Sandhill Crane subspecies populations wintering in the Valley.

Estimates of Sandhill Crane population trend

We evaluated two long-term data sets to evaluate wintering population trends since 1990, using simple linear regression in Excel: the Mid-Winter Waterfowl Survey (USFWS 2014) and Christmas Bird Count data (National Audubon Society 2014).

Estimates of Sandhill Crane abundance

To estimate the total number of Sandhill Cranes wintering in the Central Valley, we used two different data sources. We used roost data from the 2007-2008 to estimate crane abundance in the Delta and San Joaquin Valley. That winter, roost counts were conducted in the major roost sites in the Delta Region (Ivey et al. 2014a), and also at NWRs in the San Joaquin Valley. Unfortunately, there are no roost counts available for the Sacramento Valley during that period, so we estimated abundance in the Sacramento Valley using Mid-winter Waterfowl Survey data for 2007-2008 and more recent years, plus our total flock estimates from this study. Given that flocks in the Sacramento Valley are dominated by Greater, which tend to be very loyal to their wintering sites, we expect that numbers of Sandhill Cranes in the Sacramento Valley to be generally stable between years. We used our estimates of subspecies ratios from our flock surveys (from the ground) to estimate numbers of each subspecies by region.

Historic Sandhill Crane habitat use patterns

We estimated changes in use of historic roost and foraging locations, as well as patterns of abundance at roost and foraging locations by summarizing available reports, publications, and data from Sandhill Crane roost site surveys, ground surveys of foraging flocks, and aerial surveys from published literature, agency files and other resources. Aerial surveys sources that recorded Sandhill Crane abundance included: 1) Mid-winter Waterfowl Surveys flown in January by CDFW and the U.S. Fish and Wildlife Service (USFWS; 1980-2014); 2) Periodic Aerial Waterfowl Surveys, conducted by CDFW to determine regional waterfowl numbers (1958-2008); 3) flights conducted specifically for Sandhill Cranes in the Delta by CDFW (periodically, 1983-2003); and, 4) flights of the Delta, conducted by Ducks Unlimited, Inc. (DU) to count waterfowl and Sandhill Cranes (1990-1993). We also compiled data from the Christmas Bird Count and eBird. We created databases and summaries of available historic abundance and distribution from all these sources and created a spatial database of historic roost sites and wintering areas using ArcGIS version 10.1. We then compared recent Sandhill Crane distribution to historic information to qualitatively assess changes in Sandhill Crane use patterns.

Development of conservation recommendations

We reviewed existing reports and published literature to synthesize relevant conservation recommendations and considered them in conjunction with the findings of this study. We estimated abundance of each subspecies at important sites and make recommendations for prioritizing sites for conservation. We prioritized conservation among sites based on: the number of threatened Greater present, relative risk of habitat loss (based on apparent recent trends), and the relative number of all Sandhill Cranes present.

CURRENT SANDHILL CRANE DISTRIBUTION IN THE CENTRAL VALLEY

We mapped 1,858 diurnal Sandhill Crane flock locations between 9 December 2012 and 3 March 2013. These locations and associated flock sizes and land use attributes were used to create a GIS layer. Observed flocks ranged between southern Tehama County in the north and northwest Kern County in the south. As expected, flocks were concentrated in the historically most used areas: the northern Sacramento Valley, the Delta, the northern San Joaquin Valley south of Tracy to Mendota (including the lower Stanislaus and Tuolumne River floodplains, San Joaquin River NWR and the Grasslands Region), and the southern San Joaquin Valley south of Visalia to Bakersfield (primarily Pixley NWR) (Fig. 2). We spent less effort in surveys near Red Bluff and the Mendota area (2 mornings each), as we did not locate any Sandhill Crane flocks when we were there, and available data suggests Sandhill Crane use is sporadic at those two sites. We did not visit Carrizo Plain, as recent data suggests that Sandhill Crane use is very limited in recent years, and because of loss of grain fields there, we doubt that it will become an important Sandhill Crane area in the future.

The geographic sizes of the Sandhill Crane winter range in the wintering regions are likely most influenced by the number and distribution of roost sites. The Sacramento Valley and Delta wintering regions are larger because they host more roost sites and the roost sites are more dispersed (primarily due to cropland flooding) which gives Sandhill Cranes access to broader landscapes. In the southern San Joaquin Valley, the only major roost site is Pixley NWR. Therefore, one method of improving habitat availability to Sandhill Cranes is to increase the number of suitable roost sites.

We mapped 121 roost sites that have been recorded in recent years (since 2006) and classified them as either wetland (typically permanently available during winter on the landscape) or cropland (often only temporarily available) (Fig. 3). These records are far from complete, especially in the Sacramento Valley, where there are numerous roost sites that are temporarily used when rice fields are flooded. Our surveys only spanned 10 weeks in late winter and it is likely we missed many temporarily-used roost sites. There are also roost sites on Delevan and Colusa NWRs which are used, apparently sporadically (M. Wolder, personal communication). In the future, a season-long, valley-wide survey, focused on locating roost sites would provide better information about current roost site locations.



Figure 2. Distribution of Sandhill Crane foraging flocks mapped in December 2012 and January and February 2013 in the Central Valley of California.

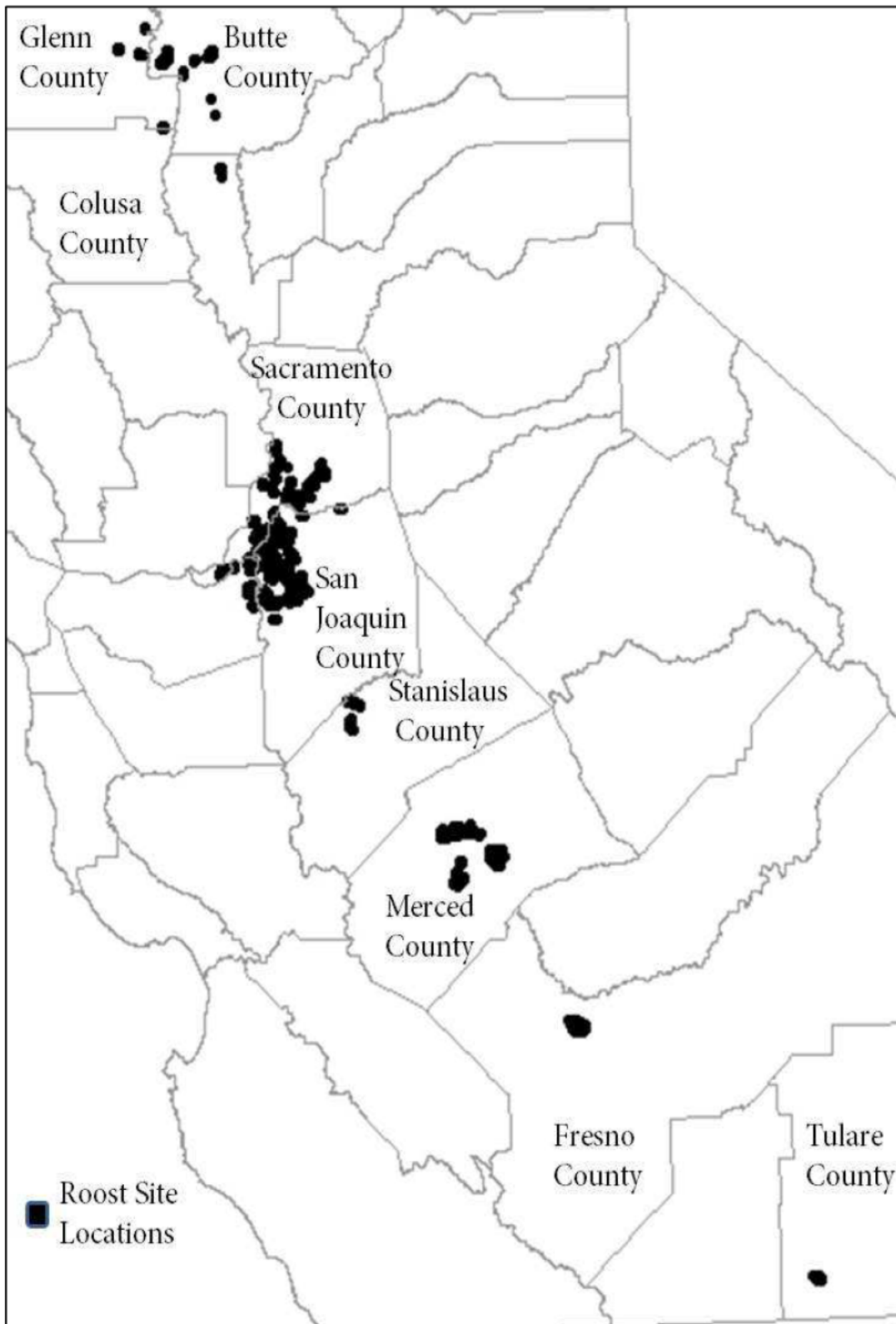


Figure 3. Sandhill Crane roost site locations mapped in the Central Valley of California, 2002-2013.

SUBSPECIES COMPOSITION IN THE CENTRAL VALLEY

Across the Central Valley, 73% of the birds we classified were Lesser Sandhill Cranes, 25% were Greater and 2% were the Canadian subspecies (Table 1). Greater were dominant (88%) in the Sacramento Valley, while Lessers dominated in the other regions.

Table 1. Proportions of Greater Sandhill Cranes (Greater), Lesser Sandhill Cranes (Lesser) and Canadian Sandhill Cranes (Canadian) recorded in foraging flocks in the wintering regions of the Central Valley of California in 2012 and 2013.

Region/Sub-region	Sample size	% Greater	% Lesser	% Canadian
<i>Sacramento Valley</i>	7,090	88.3	5.5	6.2
NE Sacramento Valley	3,378	93.4	2.8	3.8
NW Sacramento Valley	1,727	67.5	15.7	16.9
SE Sacramento Valley	1,596	98.2	1.1	0.8
SW Sacramento Valley	389	96.4	1.3	2.3
<i>Delta Region</i>	10,363	11.5	88.2	0.3
Cosumnes-Stone Lakes area	1,864	32.8	66.8	0.4
Delta Tracts and Islands	8,499	6.8	92.9	0.3
<i>Northern San Joaquin Valley</i>	10,905	0.5	99.4	0.1
San Joaquin NWR area	6,549	0.5	99.5	0
Grasslands	4,356	0.6	99.2	0.2
<i>Southern San Joaquin Valley</i>	1,371	0.5	97.4	2.0
Entire Central Valley	29,729	25.3	73.0	1.7

SANDHILL CRANE POPULATION TRENDS AND ABUNDANCE

Sandhill Crane population trends

A previous ranking of population trends (Ivey 2014a, b) indicated that Greater evidenced an apparent population increase, while Lessers were ranked as an apparently stable population (Ivey et al. 2014a, b). Canadians weren't ranked; however, survey data from their staging area along the Lower Columbia River in Oregon and Washington suggests that their population is also increasing (Ridgefield NWR data).

Mid-winter Waterfowl Surveys—These aerial surveys are conducted from fixed-winged aircraft, with the intention of estimating waterfowl and Sandhill Crane populations and tracking their trends. These aerial surveys generally cover a greater extent of Sandhill Crane wintering regions than other available surveys. Aerial surveys are somewhat problematic for population

estimates because Sandhill Cranes are difficult to see from the air (detectability issues) and also, surveys that are designed for counting waterfowl focus on wetlands and flooded areas, with partial coverage of upland areas that Sandhill Cranes may use for foraging. Although these counts are conducted annually, some regions weren't surveyed every year. Our evaluation of the data from 1990-2014 shows an average of 13,132 Sandhill Cranes counted, a peak of 23,818 counted in 2001, and an increasing trend (+4%/year) in the wintering population ($R^2 = 0.29$, $P < 0.01$; Fig. 4; Table 2).

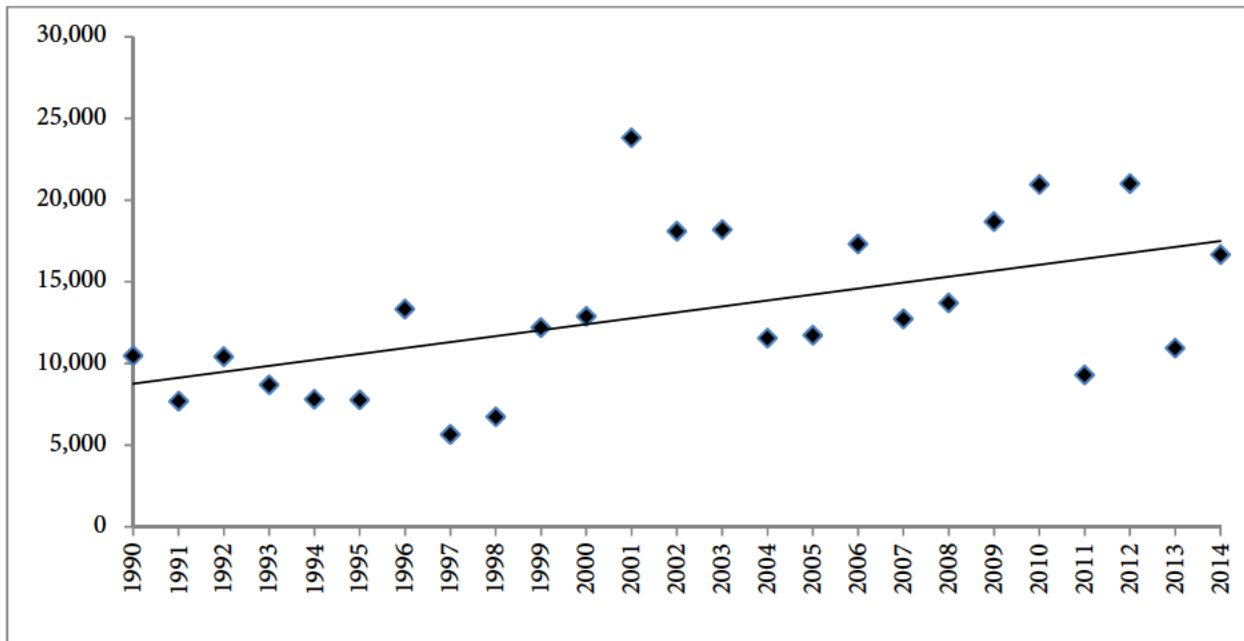


Figure 4. Mid-Winter Waterfowl Survey totals for Sandhill Cranes counted in the Central Valley of California, 1990-2014 (trend line $y = 364.01x - 715623$).

Table 2. Summary of Sandhill Crane data from aerial Mid-winter Waterfowl Surveys of the Central Valley of California, 1990-2014.^a

DATE	SACRAMENTO VALLEY				DELTA TOTAL	N. SAN JOAQUIN VALLEY				S. SAN JOAQUIN VALLEY				TOTAL
	Butte Sink	Upper Butte Basin	West Sac	TOTAL		Merced Grasslands	Mendota	Sierra Foothills	TOTAL	Goose Lake	Pixley-Alpaugh	Tulare Basin	TOTAL	
Jan 1990	371	437	0	808	7,265	1,098	408	0	1,506	900	0	900	10,479	
Jan 1991	780	2,640	0	3,420	4,173	10	15	0	25	75	0	75	7,693	
Jan 1992	11	480	0	491	7,825	1,690	0	0	1,690	0	400	400	10,406	
Jan 1993	72	2,740	0	2,812	2,467	2,939	3	0	2,942	0	470	470	8,691	
Jan 1994	970	889	69	1,928	4,132	1,211	0	0	1,211	360	180	540	7,811	
Jan 1995	0	1,704	20	1,724	1,938	3,443	0	0	3,443	0	663	663	7,768	
Jan 1996	0	2,933	205	3,138	8,033	0	0	0	NC	96	2,070	2,166	13,337	
Jan 1997	0	367	171	538	1,791	778	15	0	793	4	2,534	2,538	5,660	
Jan 1998	0	2,247	114	2,361	3,267	1,085	0	0	1,085	0	17	17	6,730	
Jan 1999	45	4,026	235	4,306	7,855	0	0	0	NC	0	36	36	12,197	
Jan 2000	0	7,654	147	7,801	4,764	89	0	5	94	155	70	225	12,884	
Jan 2001	502	7,967	740	9,209	13,069	1,190	0	0	1,190	340	10	350	23,818	
Jan 2002	47	5,508	2,008	7,563	7,714	2,805	0	0	2,805	0	0	NC	18,082	
Jan 2003	0	5,446	1,667	7,113	7,591	3,075	0	0	3,075	0	405	405	18,184	
Jan 2004	0	5,077	1,492	6,569	4,734	135	0	0	135	0	105	105	11,543	
Jan 2005	0	6,499	1,287	7,786	2,611	1,335	0	0	1,335	0	0	NC	11,732	
Jan 2006	347	4,743	1,193	6,283	5,423	5,505	0	0	5,505	0	105	105	17,316	
Jan 2007	85	5,398	994	6,477	3,552	2,231	0	0	2,231	0	460	460	12,720	
Jan 2008	0	4,014	834	4,848	7,821	815	0	15	830	0	207	207	13,706	
Jan 2009	0	4,339	557	4,896	11,878	1,865	0	0	1,865	0	40	40	18,679	
Jan 2010	2	3,178	675	3,855	NC	16,815	0	215	17,030	0	73	73	20,958	
Jan 2011	253	3,318	673	4,244	NC	3,687	0	0	3,687	0	1,370	1,370	9,301	
Jan 2012	5	6,391	1,744	8,140	10,650	1,992	0	0	1,992	0	217	7	224	21,006
Jan 2013	0	4,643	1,940	6,583	4,362	0	0	0	0	0	0	0	0	10,945
Jan 2014	0	7,984	2,259	10,243	4,911	1,513	0	0	1,513	0	237	0	237	16,904

^aU.S. Fish and Wildlife Service and California Department of Fish and Wildlife, unpublished data.

Christmas Bird Counts—Christmas Bird Count data are also available for our study area from 1915-2012. Although these counts are ground counts (which have better detection probabilities), they are likely biased by double-counting flocks, the area covered (the Christmas Bird Count circles only cover portions of Sandhill Crane range) and incomplete data (not all circles are counted each year). Our evaluation of the data from 1990-2012 shows an average count of 17,938, a peak of 27,530 counted in 1992, and an insignificant increasing trend (suggesting Mid-winter data is better for assessing trend; Fig. 5). The average and peak numbers were higher than the Mid-Winter Waterfowl survey numbers.

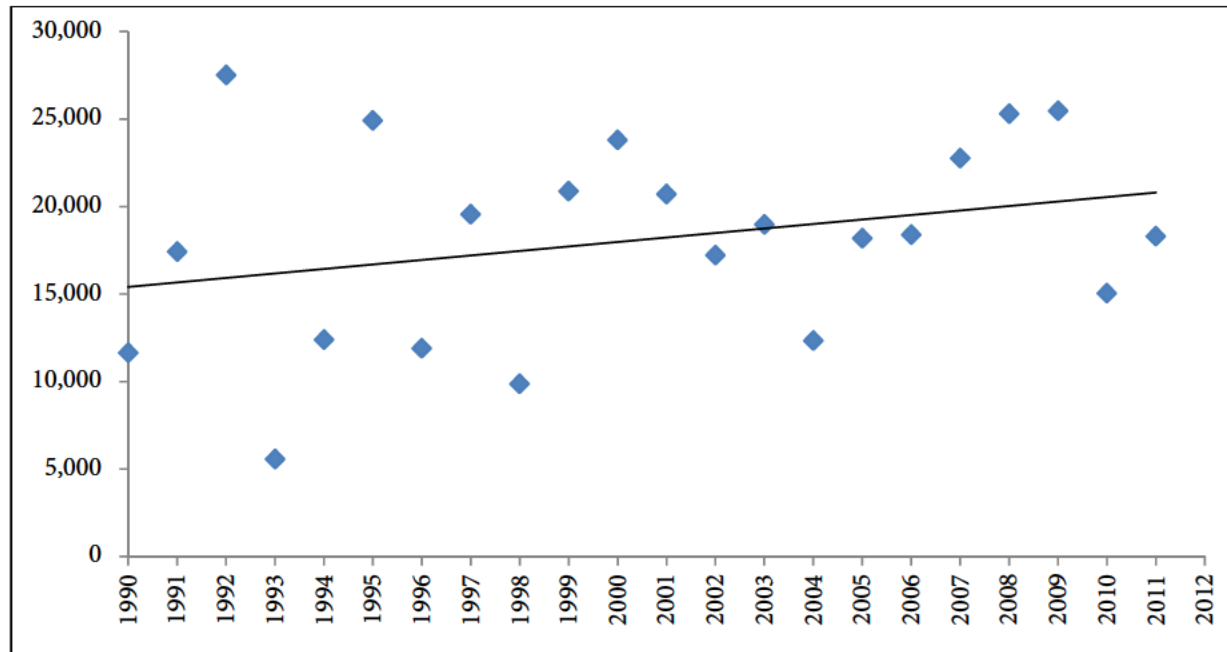


Figure 5. Christmas Bird Count totals for Sandhill Cranes counted in the Central Valley of California, 1990-2014 (trend line: $y = 257.34x - 496709$).

Estimates of Sandhill Crane abundance from the literature

Existing Central Valley population estimates for Sandhill Cranes vary considerably and likely suffer from varying forms of bias. In the early 1980s, the Pacific Flyway Council (1983) estimated that there were 20,000 - 25,000 Lessers in the Pacific Flyway Population, an estimate derived from Herter (1982) based on records of Sandhill Cranes passing through the Copper River Delta region of coastal south-central Alaska. Pogson and Lindstedt (1991) estimated the CVP of Greater to be 6,000 to 6,800, based on their surveys throughout the Central Valley from 1981-1985; however, this was an estimate of “large cranes” which did not distinguish between Greater and Canadian. More recently, Littlefield (2002) estimated that 6,000 Greater winter in the Sacramento Valley region, but did not mention the other subspecies that winter there so it is unknown if he considered the Canadian in his estimate (see Table 1). Hoffman (2000) estimated

the CVP at 14,000 (combining Greater and Canadian), using methodology that may have been flawed, leading to an overestimate. Biases were likely introduced in his estimate as the observers collected subspecies ratios near roosts which were then applied to roost site numbers. This method leads to bias in overall ratios of subspecies because Greater tend to forage closer to roost sites and Lesser tend to forage much further away (Ivey 2015). For example, Hoffman (2000) surveys resulted in estimating that 14% of the Sandhill Cranes at Staten Island and Brack Tract, and zero at Cosumnes River Preserve were Lesser, while in contrast, Ivey et al. (2014b) documented that Lesser dominated the composition of Sandhill Crane flocks roosting at those locations (averaged 74%, 73%, and 55%, respectively, in 2007-2008). Therefore, in addition to being outdated, past population estimates are generally incomplete, based on flawed assumptions, and likely inaccurate at the population scale. Unfortunately, there has been no formal effort to estimate the numbers of the three populations that winter in the Central Valley or at the Pacific Flyway scale, so the available information provides an incomplete picture of population numbers.

A current estimate of Sandhill Crane population abundance

Because survey data are incomplete (i.e., not all areas are covered) the peaks in the available data from Mid-Winter and Christmas Bird Count surveys suggest a minimum wintering population size for the Central Valley (e.g., at least 27,530). We believe that this is a substantial underestimate of the entire wintering population. For example, a total roost count in the Delta region in February 2008 estimated 27,213 (Ivey et al. 2014a), and that survey did not count every roost site in the Delta, (roost sites in the south half of the Delta were not surveyed because that area typically has few Sandhill Cranes and access to roost sites was difficult). Given the existing information, we believe that the roost counts conducted during the 2007-2008 winter season in the Delta and San Joaquin Valley regions provide the best information for estimating total numbers. Table 3 summarizes counts during periods when those regions were well covered (although there were likely additional roost sites in those areas that were not counted). Assuming the peak number for these counts during that season most closely represents the total number of Sandhill Cranes in those regions (Table 3); then there were at least 40,138 Sandhill Cranes in the valley. Unfortunately, no comprehensive roost site counts were conducted in the Sacramento Valley during the 2007-08 winter season.

Table 3. Numbers of Sandhill Cranes counted during the 2007-2008 winter at important roost sites in the Sacramento-San Joaquin Delta and San Joaquin Valley Sandhill Crane wintering regions of California, representing the most complete area coverage to date.

Count Period	Delta Region^a	North San Joaquin Valley Region^b	South San Joaquin Valley Region^c	Total
Early Oct	10,164	22,740	2,610	35,514
Early Nov	6,421	11,102	3,953	21,476
Early Jan	15,264	4,970	6,232	26,466
Late Jan	14,907	4,970	7,860	27,737
Mid Feb	27,213	5,479	7,446	40,138

^aIvey et al. 2014a. ^bSan Luis National Wildlife Refuge files. ^cPixley NWR files.

We would not expect much movement of Greater Sandhill Cranes in the Sacramento Valley to other regions, as Greater Sandhill Cranes tend to be sedentary (only 4% used more than one wintering region; Ivey 2015). Estimates of winter fidelity by Greater Sandhill Cranes vary among studies, likely reflecting differences in habitat predictability among study areas (Drewien et al. 1999). A study of wintering Greater Sandhill Cranes in Georgia reported a relatively low return rate (34%), which the authors speculated was caused by variable roost site conditions (Bennett and Bennett 1989). Similarly, Greater Sandhill Cranes in Florida moved between wintering areas in response to changes in roost water levels and loss of foraging habitats (Wenner and Nesbitt 1987). A previous study of Greater Sandhill Cranes in the Central Valley of California reported much lower winter region fidelity documenting that 22% of marked birds used 2 wintering regions, the Sacramento Valley and the Delta (Pogson and Lindstedt 1991). Perhaps ideal roost site conditions in the Sacramento Valley during the 1980s were less reliable, as most roost sites were on private lands which were not managed to provide ideal conditions for Sandhill Cranes. These patterns suggest that Greater Sandhill Cranes likely prefer to return to the same areas each winter and that site fidelity could provide an indication of habitat quality or management success, but they are capable of being opportunistic and shifting wintering regions when habitat becomes unsuitable. Therefore, estimates of numbers of Greater Sandhill Cranes in the Sacramento Valley should not be contributing much to seasonal changes in numbers elsewhere and using the best available Sacramento Valley estimates seems appropriate.

The Mid-Winter Waterfowl Survey reported 4,849 Sandhill Cranes in the Sacramento Valley in January 2008 and if that number is added to the previous total, there are at least 44,987 Sandhill Cranes in the Central Valley. However, the 2014 Mid-Winter Survey recorded 10,243 Sandhill Cranes (all subspecies) and if we use that number, the total population estimate is 50,381. Lastly, our foraging flock surveys suggest a total of at least 8,253 Sandhill Cranes in the Sacramento Valley region. If we assume this number represents the Sacramento Valley, then the population estimate increases to 48,391. Given that all these survey methods have issues with

incomplete habitat coverage and detectability, and that they generally underestimate numbers, we believe that there are easily at least 50,000 Sandhill Cranes wintering in the Central Valley, and likely a larger number.

Estimates of Sandhill Crane populations by subspecies—Assuming a total population of 50,000 Sandhill Cranes wintering in the Central Valley and applying our ratios of subspecies composition of the foraging flocks (Table 1) we estimate that there are approximately 36,500 Lessers, 12,650 Greater, and 850 Canadians wintering in the valley (additionally, approximately 1,500 Canadians winter near Portland, Oregon). However, we believe that Canadians were underestimated with our method, sometimes being classified as Greater. The entire population of Canadians is believed to stage along the lower Columbia River in Oregon and Washington (Ivey et al. 2005), and coordinated roost counts during fall migration have peaked at just over 5,000 (Ridgefield NWR data); we believe that this number is the best estimate of the Canadian population in the Pacific Flyway. Therefore, we assume the total for Canadians is approximately 5,000 and adjust our estimate for Greater to 8,500.

We also evaluated other available data to estimate the CVP of Greater. In 1999 and 2000, comprehensive surveys were conducted of summering Greater in Oregon and California, reporting 2,854 in Oregon (Ivey and Herziger 2000), 1,281 in California and 22 in Nevada (Ivey and Herziger 2001). Additionally, a recent estimate for the summering population of 84 in south-central Washington (McFall 2013), and an estimated 4,398 in the interior of British Columbia, Canada (Breault et al. 2007) for a total of 8,639, which suggests that an estimate of 8,500 Greater is reasonable. We strongly recommend that the Pacific Flyway Council, agencies and conservation groups work together to develop a more accurate measure of the abundance of these populations.

HISTORIC SANDHILL CRANE USE PATTERNS IN THE CENTRAL VALLEY

Fossil remains of Sandhill Cranes in California suggest a wide historic distribution, beyond the bounds of the Central Valley; however, their historic distribution was likely most affected both by over-hunting and habitat loss (Littlefield and Thompson 1979, Littlefield and Ivey 2000), which significantly reduced early 20th century populations. For Greater, historic records outside the Central Valley include observations from the southern end of the Salton Sea, Imperial County (Abbott 1940), and from a bird collected along the Colorado River in 1857 or 1858 (Grinnell et al. 1918); Greater which still occur in these latter two areas are members of the Lower Colorado River Population (Pacific Flyway Council 1995). Greater were formerly reported to be common in southern California during migrations and occasionally in winter, as they were occasionally seen in Ventura County, and in Los Angeles County (near Los Angeles and Pasadena); however, there is some uncertainty about these records (no specimens were collected; Willett 1933).

Within the Central Valley, Sandhill Crane flocks (both subspecies were present) were reported in the “Fresno District” defined as the valley floor, between Firebaugh and Wheatland on the west, and between Friant and Reedley on the east, in Fresno County (Tyler 1913). Also, museum specimens of Greaterers were collected near Gridley, Butte County in 1924, from the Butte Creek Basin, near Colusa, Colusa County in 1923 and 1924, from 6 miles west of Pennington, Sutter County in 1936 (Grinnell and Miller 1944), from Los Baños, Merced County in 1898 and 1909 (Mailliard 1921), and from Corcoran, Kings County, 1918 (Swarth 1919).

Fossils of Lessers were reported from Rancho La Brae in Los Angeles County (Miller 1912), and McKittrick in Kern County (Miller 1925). Also, 1,000 – 5,000 year old Sandhill Crane bones were found in Indian middens near Emeryville, Alameda County (Howard 1929). Historic records report that Lessers ranged as far south as San Diego (Grinnell et al. 1918), along the southern California Coast and near Pasadena in Orange County (Willet 1912). In the 1840’s, museum specimens were collected from Mission San Rafael, Marin County and Yerba Buena (now San Francisco), San Francisco County (Buturlin 1907) and in the San Francisco Bay area (Grinnell and Wythe 1927). In Riverside County, a specimen was shot near Riverside in 1893 (Willett 1912), and another near Corona in 1917. A specimen was shot near Newport, Orange County about 1897 (Grinnell 1909). In Los Angeles County, two specimens were collected in 1904 near Los Angeles (Grinnell 1909); another shot there in 1918 (Wyman 1919); one was shot near Long Beach in 1912 (Willett 1912); and also one was shot near Culver City in 1929 (Willett 1933). Lessers were also reported as fairly common near Salton Sea, in the Imperial Valley (Abbott 1940, Grinnell and Miller 1944), and also the Colorado River Valley (Grinnell and Miller 1944). These San Francisco Bay and Los Angeles Basin regions are too populated to support wintering Sandhill Cranes in present time.

Historic records of Lessers within the Central Valley include museum specimens from Los Baños, Merced County (two without collection dates; Mailliard 1911), two from 1897, and an additional six from Merced County (Mailliard 1921), one from Corcoran, Kings County, 1918 (Swarth 1919). Flocks of Lessers were reported near Los Baños in 1918, near Lathrop in San Joaquin County in 1914, near Stockton in 1880-1881, and near Marysville, Yuba County, and Gridley and Chico, Butte County, in 1884 (Grinnell et al. 1918); also, flocks were reported near Firebaugh and Mendota, Fresno County, in 1929 (McLean 1930).

There have only been a few studies that provide more specific information on historic Sandhill Crane distribution in the various wintering regions. Distribution of Sandhill Cranes in the Delta region was described in a report by Zeiner (1965). Distribution of Lessers in the Central Valley was studied by Pogson and Kincheloe (1981) and Littlefield and Thompson (1982). Studies of Greaterers were conducted throughout the Central Valley in the mid-1980s (Pogson and Lindstedt 1991) and in the early 1990s (Littlefield 1992). Additionally, we found a map in Sacramento NWR files that indicated Sandhill Crane distribution in the Sacramento Valley in 2005. An extensive study was conducted of Sandhill Crane distribution in the Delta region (Ivey et al. 2014b).

We have synthesized available geo-referenced historic flock location data in Figure 6. We did not locate any specific geo-referenced flock location data for the southern San Joaquin Valley.

Changes in Sandhill Crane use patterns in the Sacramento Valley region

Since the 1980s study by Pogson and Lindstedt (1991), Sandhill Crane winter distribution has greatly expanded (Fig. 7). The winter ranges depicted in Figure 7 should not be considered exact bounds of Sandhill Crane winter ranges, but rather generalized outside bounds of Sandhill Crane distribution, subject to the judgment of the individuals who drew them. In the early 1980s, undisturbed, secure night roost habitat was the significant limiting factor for Sandhill Cranes in this region (J. Snowden, personal communication), and we believe that this limitation contributed to the smaller winter Sandhill Crane landscape during that time (Fig. 7A). Legislation in 1991 (Connelly-Areias-Chandler Rice Straw Burning Reduction Act: AB 1378, Ch. 787, 1991) limited burning of rice stubble and resulted in greatly increasing the practice of flooding to decompose stubble (Miller et al. 2010). We believe this change has allowed Sandhill Cranes to extend their winter range considerably in the Sacramento Valley since 1991.

Occasional Sandhill Crane surveys in this region during the winter of 1981-1982 revealed that most cranes were using areas surrounding Gray Lodge and only one flock was ever found west of the Sacramento River during that winter (G. Ivey, personal observation). The wintering region described by Pogson and Lindstedt (1988) from their mid-1980s study showed Sandhill Cranes focused in two major areas, the Upper Butte Basin and the Butte Sink (Fig. 7A). West of the Sacramento River, they reported only "isolated records" of Sandhill Cranes. Sandhill Cranes had expanded their range, towards Biggs and Riceton by 1993 (Littlefield 1993; Fig. 7B). In 1994, the mid-winter survey recorded 69 Sandhill Cranes west of the Sacramento River, and since, Sandhill Cranes have been regularly recorded there on those surveys; increasing to a peak of 2,259 in 2014 (USFWS 2014). By 2005, the winter range of Sandhill Cranes had expanded west of the Sacramento River, using areas west of Interstate 5 between Williams and Maxwell and around Delevan NWR (Sacramento Refuge files, map dated 2005; Fig. 7C). During our study, we found Sandhill Cranes had further expanded their use areas towards Live Oak and Sutter, around Colusa NWR, and towards Willows and Hamilton City (Fig. 7D). Our foraging flock surveys documented largest concentrations of Sandhill Cranes in the Willows-Bayliss-Hamilton City and the Rancho Llano Seco-Rancho Esquon areas.

East of the Sacramento River, some sites have experienced reduced use by Sandhill Cranes, apparently due to the establishment of Upper Butte Basin Wildlife Area and Sacramento River NWR, as some former pastures and rice fields that had been used by foraging Sandhill Cranes were converted to wetlands, which generally have lower foraging value (and therefore support fewer Sandhill Cranes), and associated waterfowl hunting programs that were established displaced Sandhill Cranes. Additionally, duck clubs were established surrounding these new areas which lead to increased disturbance (J. Snowden, personal communication). Those cranes apparently have shifted to other use areas.

Sandhill Crane populations appear to have increased in the Sacramento Valley, as evidenced by increasing trend of mid-winter survey Sandhill Crane numbers (Fig. 4), which likely has contributed to their range expansion. However, even though there are extensive areas of flooded rice for Sandhill Cranes to choose from, most flooded rice fields are subject to disturbance from waterfowl hunting (Fleskes et al. 2005) and the majority are managed at levels too deep to provide ideal roost site conditions (Shaskey 2012). It is likely that areas of private lands where we found concentrations during this study have lower hunting pressure (less disturbance) and if that is the case, they should provide more successful conservation areas.

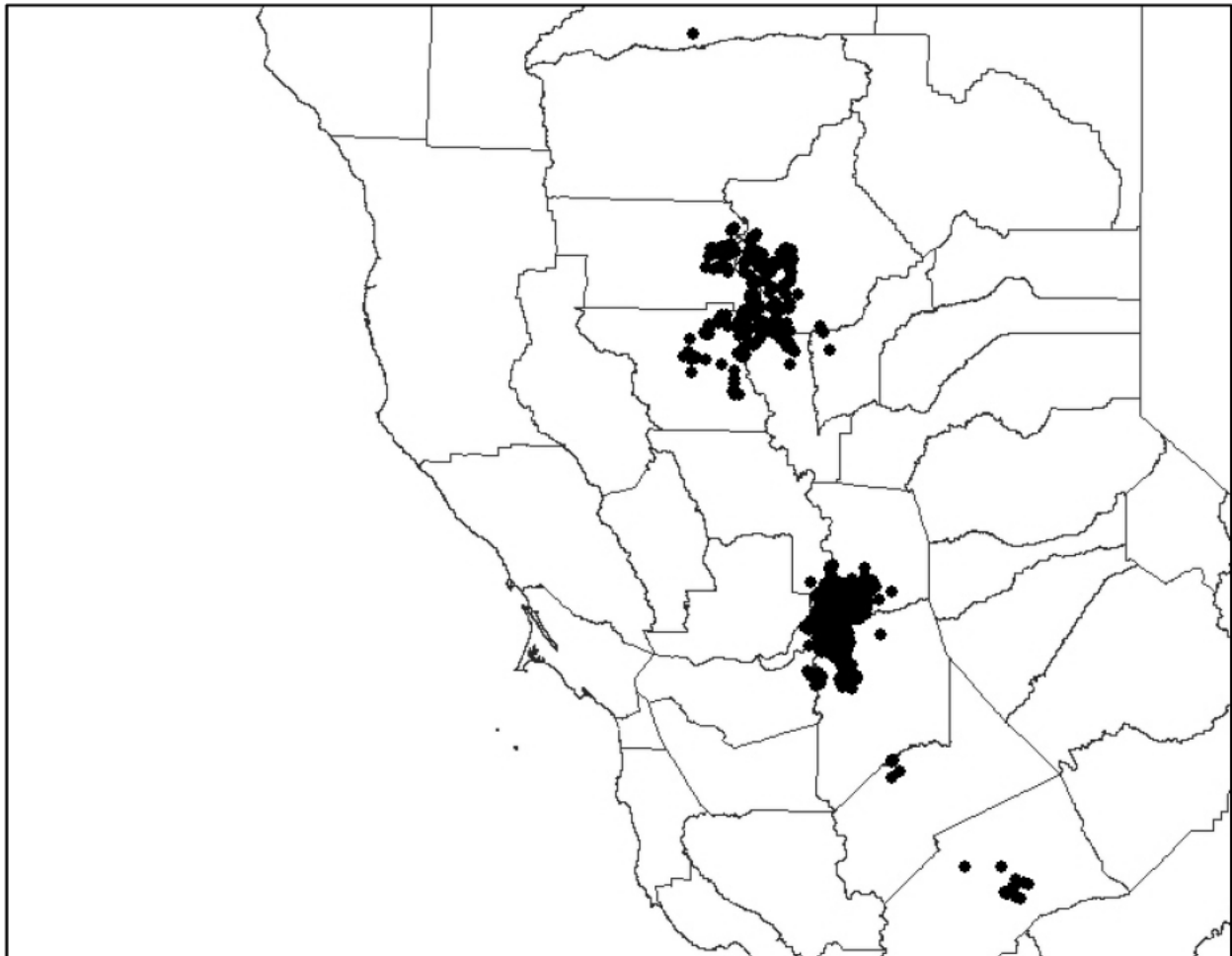


Figure 6. Distribution of historic geo-referenced Sandhill Crane flocks in the Central Valley of California.

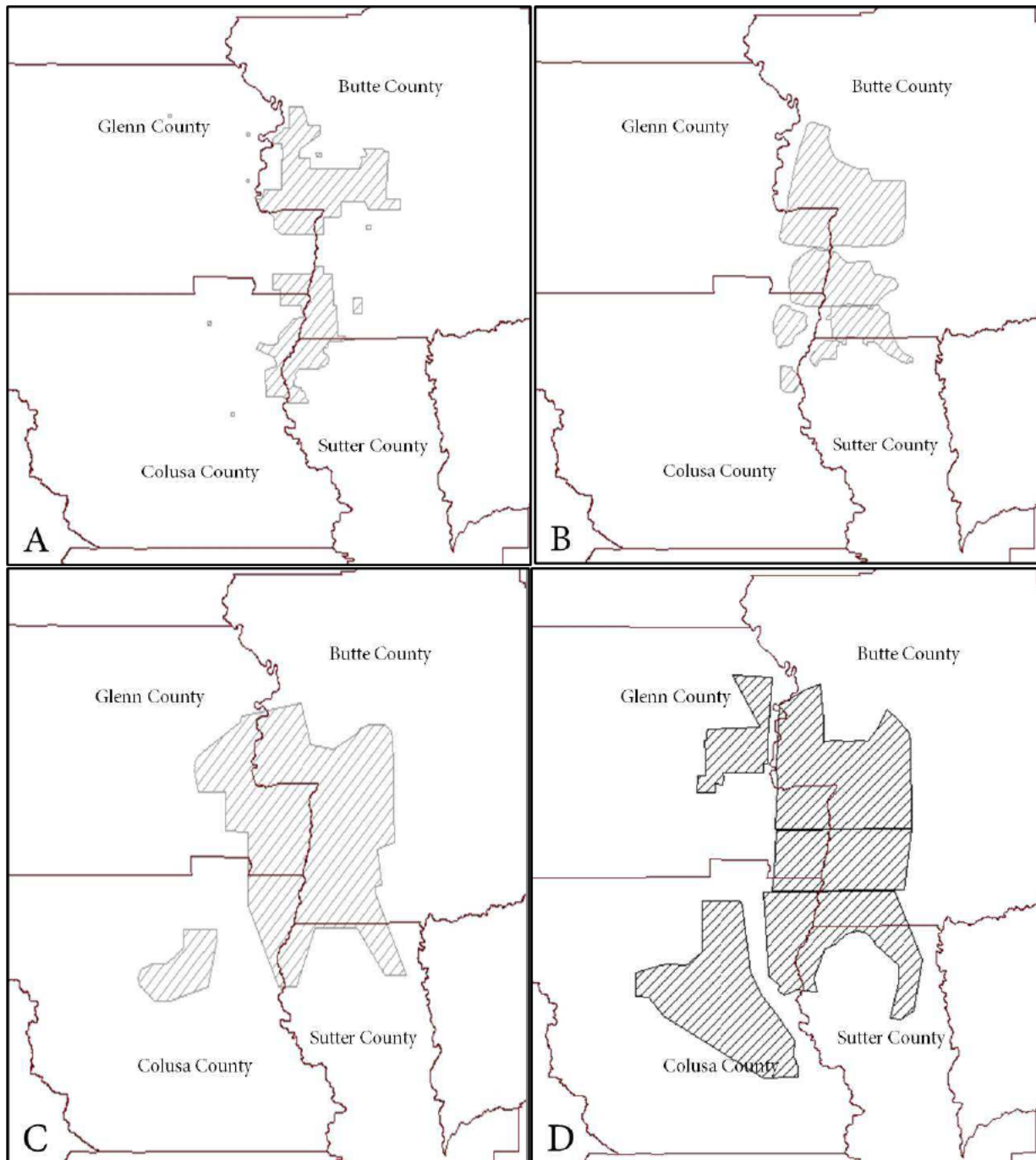


Figure 7. General distribution of wintering Sandhill Cranes in the Sacramento Valley of California over time; A = 1983-1984 (Pogson and Lindstedt 1988), B = 1991-1993 (Littlefield 1993), C = 2005 (Sacramento Refuge files), and D = 2012-2013 (this study).

Changes in Sandhill Crane use patterns in the Delta region

Several key conservation areas that now provide important Sandhill Crane roost sites were established in this region since the mid-1980s study of Greater by Pogson and Lindstedt (1991). The El Dorado and Robin Bell gun clubs on Brack Tract were purchased in 1985 by CDFW to provide secure Greater Sandhill Crane roosts on Brack Tract. Originally designated as Woodbridge Ecological Reserve, these two sites are now the Isenberg Sandhill Crane Reserve. Cosumnes River Preserve was established in 1987 and has grown to over 50,000 acres, including the 9,200-acre Staten Island which was added in 2002. This preserve is managed under a broad partnership with TNC, Bureau of Land Management (BLM), CDFW, Sacramento County, California Department of Water Resources, Ducks Unlimited, and the California State Lands Commission. In 1994, the Stone Lakes NWR was established by USFWS.

In a 1965 report (Zeiner 1965) the winter range of cranes in the Delta region was relatively small, and spanned most of the area between the West Fork of the Mokelumne River at Staten Island and Interstate 5, to the south, including most of Terminous Tract, and all of Brack, Canal Ranch and New Hope Tracts, plus, west of Interstate 5, south of the Cosumnes River channel to about 2 miles west of Galt, and south to the Mokelumne River channel, including the fields about 1 mile south of Thornton (Fig. 8A). Zeiner also indicated the greatest concentration of cranes was centered on what is now the North Isenberg Sandhill Crane Reserve. Pogson and Lindstedt (1988) mapped Sandhill Crane winter range which included Tyler and Grand Islands, and a few isolated locations south of Highway 12 (Fig. 8B). They noted a couple of large roost sites on the Cosumnes River Floodplain, which are now part of the Cosumnes River Preserve, and four roost sites on Brack Tract, one on Canal Ranch, three on Staten Island, three on Tyler Island and one on Grand Island. These additional roost sites likely allowed Sandhill Cranes to expand their wintering range.

An extensive study of the Delta region from 2006-2009 (Ivey et al. 2014b) documented a much broader winter range (Fig. 8C [we included data from our 2012-13 surveys in this range map]), indicating that Sandhill Cranes have expanded their range north to Stone Lakes NWR and vicinity, east of Highway 99 on the Cosumnes River and Dry Creek floodplains, and further west and south in the Delta. This was likely due to an expanded number and distribution of roost sites, as they documented 69 roost sites; about half of which were flooded croplands. The establishment of protected areas providing roost sites since the 1980s study, plus an apparent increase in farming practices using winter flooding as a management tool to reduce soil salts and weeds (see Ivey et al. 2003) has apparently contributed to this broader distribution of Sandhill Cranes in the Delta. However, since the 1980s study, approximately one-third of the winter range mapped in Fig. 8C has been lost following conversion to orchards, vineyards, and in some cases, turf farms, blueberries, and more recently, small solar farms.

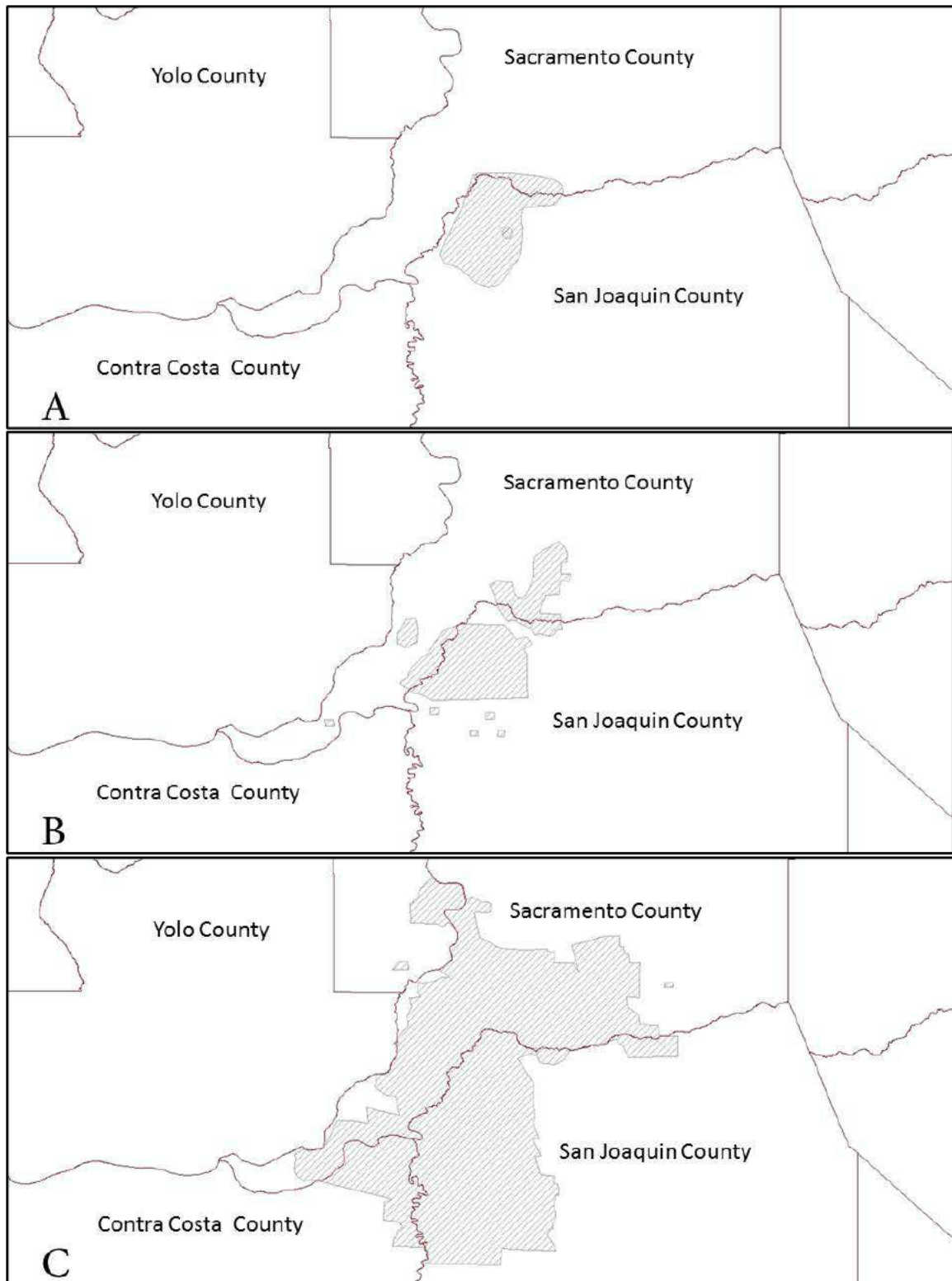


Figure 8. General distribution of wintering Sandhill Cranes in the Sacramento-San Joaquin Delta region of California; A = 1963-1965, B = 1983-1984, and C = 2006-2013.

Changes in the San Joaquin River NWR region—The Sandhill Crane winter range in this region during the mid-1980s was mapped by Pogson and Lindstedt (1988; Fig. 9A). They also mapped four roost sites in this region. Since their study, San Joaquin River NWR was established in 1997 and the USFWS subsequently acquired easements on several important properties, including large portions of the Faith and Mapes ranches. Consequently, Sandhill Crane winter range has expanded (Fig. 9B); likely because of increased security at roost sites and also, the provisioning of a large roost site on the refuge, south of Highway 132 (White Lake). However, many of the croplands in this region have been converted to orchards, and urban expansion from Salida and Modesto has reduced available habitat on the eastern side of this wintering area (G. Ivey, personal observation).

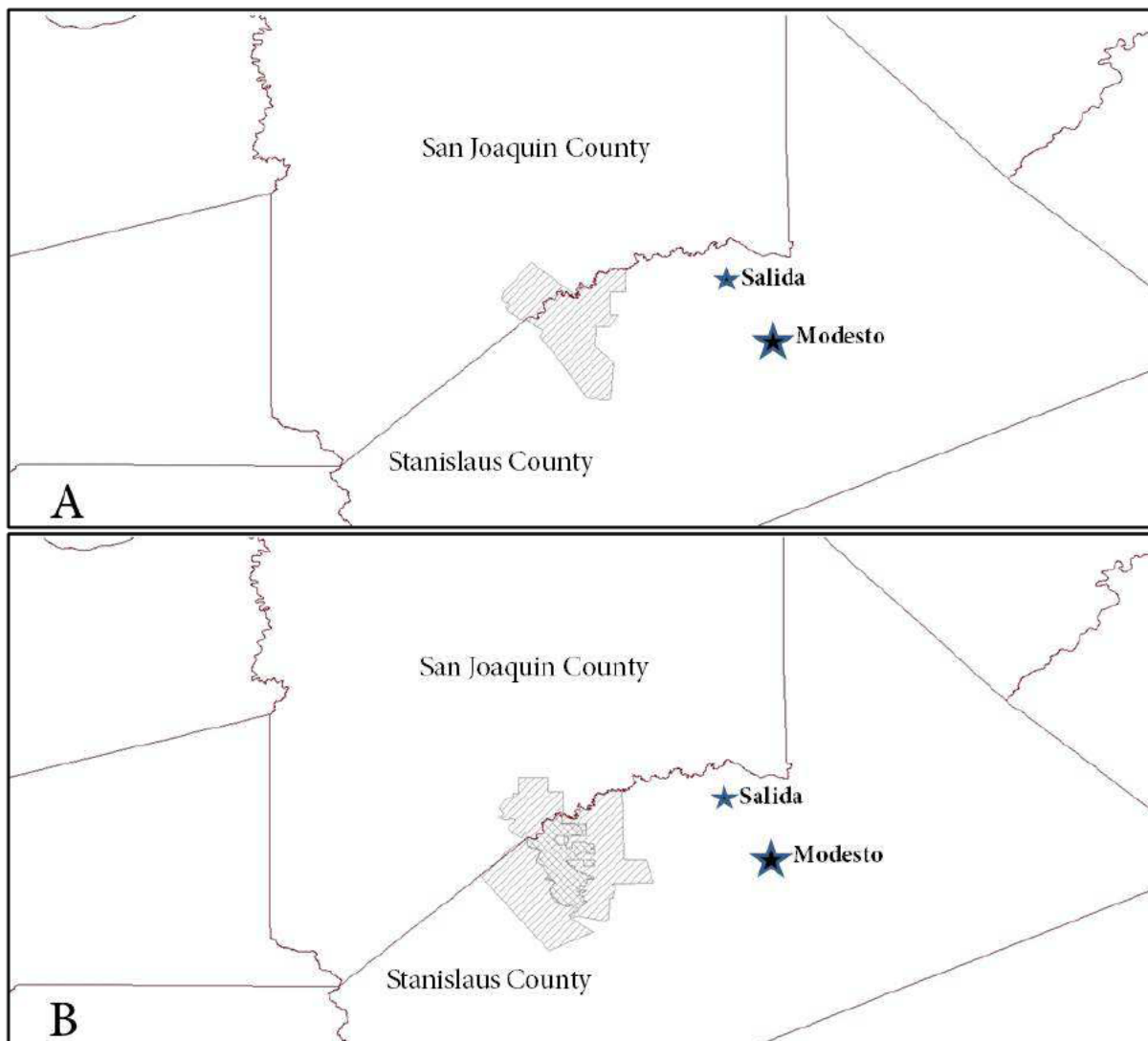


Figure 9. General distribution of wintering Sandhill Cranes in the San Joaquin River National Wildlife Refuge area of California, A = 1983-1984 (Pogson and Lindstedt 1988), and B = 2006-2013 (Ivey 2015, this study).

Changes in Sandhill Crane use patterns in the Grasslands region

Historic maps of Sandhill Crane winter range for this region were not available; however, since the mid-1980s, there has been significant expansion of conservation properties in the vicinity of the refuges here. The Grasslands Wildlife Management Area (GWMA) is a USFWS block of conservation easements on private lands that was initiated in 1979, which currently encompasses over 80,000 acres. However, because much of the GWMA is comprised of duck hunting clubs, it is rarely used by Sandhill Cranes. Areas within the GWMA that are east of Highway 165 are within the current Sandhill Crane winter range. Also, the Arena Plains Unit of the Merced NWR was established in 1992. Expansion of these conservation areas has provided additional secure Sandhill Crane roost sites. However, orchards appear are encroaching into this range around Stevinson, Merced, and El Nido. Fig. 10 illustrates the current Sandhill Crane winter range in the Grasslands region, interpreted from our flock surveys and other recent data.

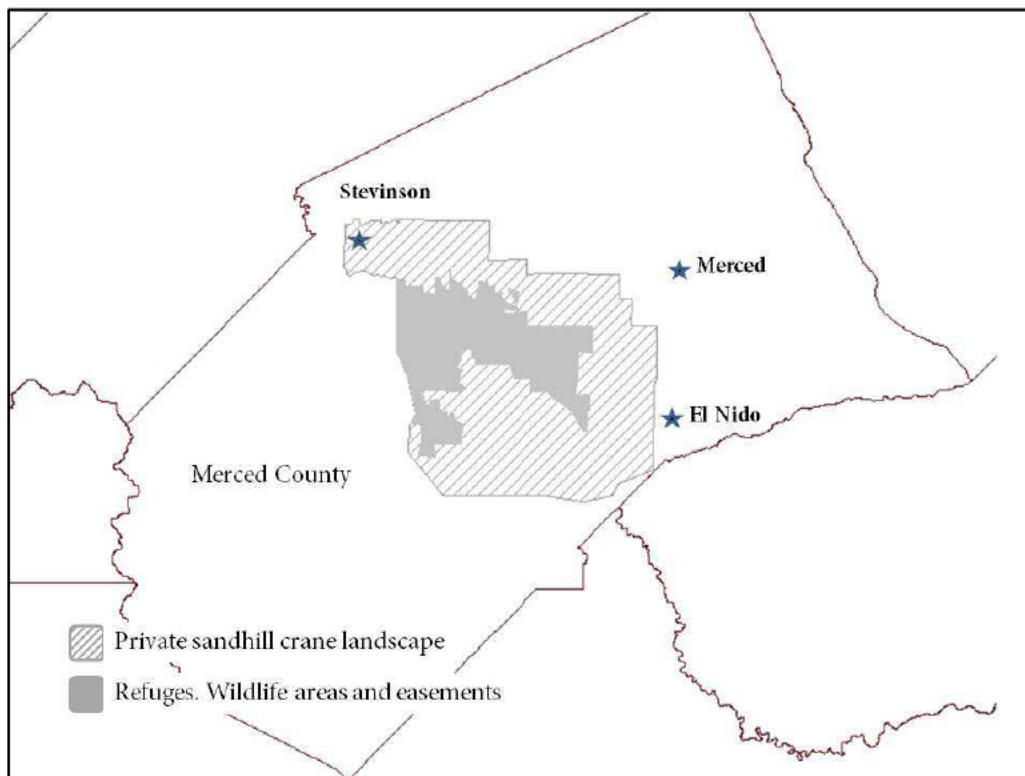


Figure 10. General distribution of wintering Sandhill Cranes in the Grasslands Region in 2013, Merced County, California.

Changes in Sandhill Crane use patterns in the southern San Joaquin Valley region

Historic maps of Sandhill Crane winter range for this region were not available; therefore, our 2013 flock surveys represent the first intensive surveys of the Sandhill Crane winter range in this region. A review of the distribution of Lessers (Littlefield and Thompson 1982) reported only

8 Lessers in 1969 at Pixley NWR (established in 1959) and a peak of 628 Lessers in 1970 at Goose Lake in Kern County (Littlefield and Thompson 1982). A 1979 aerial survey recorded 2,050 Sandhill Cranes at Goose Lake, while Pogson and Kincheloe (1981) found 1,500 Lessers there in 1981. Since those early investigations Sandhill Crane numbers have apparently greatly increased at Pixley NWR and decreased in the Goose Lake area. Since 2000, numbers have reached peaks of over 9,400 roosting at Pixley NWR (Kern NWR files) , and for the available data from Periodic Aerial Waterfowl surveys (which ended in 2007), the peak numbers reported from Goose Lake was 405 in 2000. We found no Sandhill Cranes during our flock surveys in the Goose Lake area during January or February, 2013, however, a flock of 78 was observed there in October 2013 (D. Hardt, personal observation). Our map of the current Sandhill Crane winter range is displayed in Fig. 11. We note that orchards are also encroaching, primarily into the east side of this range, near the town of Pixley.

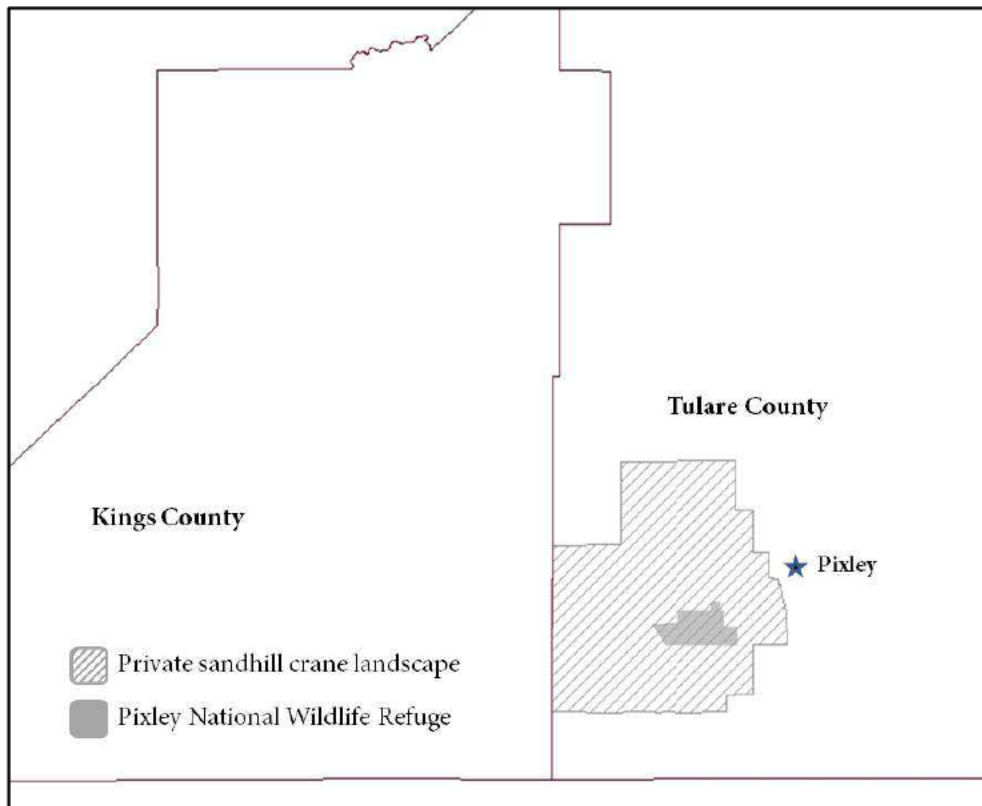


Figure 11. General distribution of wintering Sandhill Cranes in the Pixley National Wildlife Refuge Region in 2013, Tulare County, California.

Areas of former importance for Sandhill Cranes

Carrizo Plain—This site was formerly important, primarily to Lessers, as 3,200 were reported there in 1947 (Walkinshaw 1973) and an estimated 10,000-14,000 Sandhill Cranes were observed there in the 1960s (McCaskie 1967). More recently, this site has received little use by Sandhill Cranes, particularly since acquisition of Soda Lake by TNC and the BLM which began in 1988 and which led to the designation of Carrizo Plain as a National Monument in 2001. The CBC count data provides an assessment of the change in numbers (Fig. 12). According to BLM, the decline is probably due to the elimination of 40,000 acres of grain crops that were cultivated within the Monument prior to acquisitions and the overall decline of cultivated grain fields in the valley and the foothills adjacent to the Monument (BLM 2010). It is not likely that this area will recover its former importance given the status of the Monument and the paucity of grain-farming there now. While this change in land management appears to have negatively affected Sandhill Cranes, it has likely benefited a suite of arid upland species.

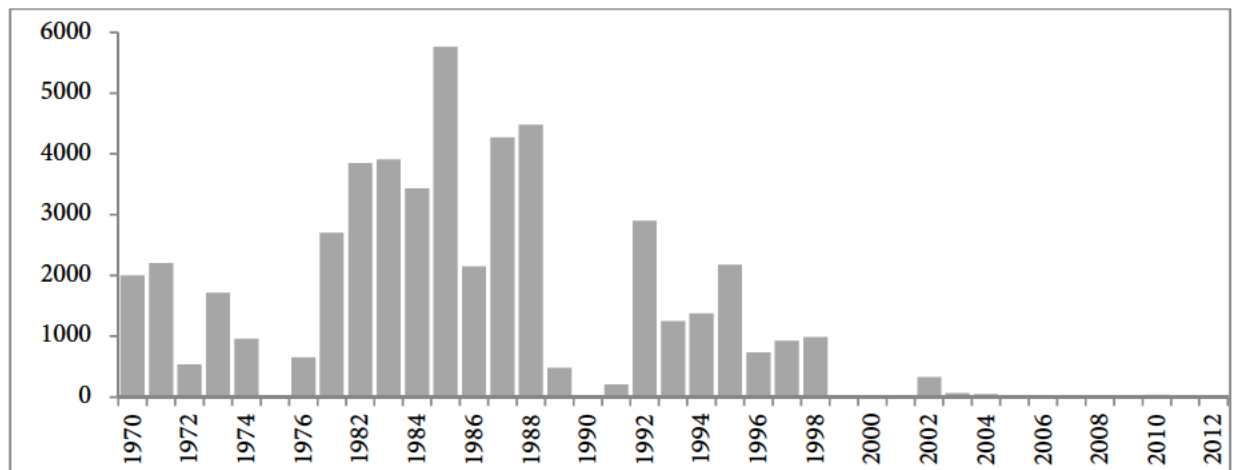


Figure 12. Numbers of Sandhill Cranes recorded on the Carrizo Plain Christmas Bird Count, 1970-2012.

Red Bluff— This site is in the vicinity of Jellys Ferry, between Anderson and Red Bluff, along the Sacramento River. In 1970, 1,400 Lessers were reported here (Littlefield and Thompson 1982). Another report states that up to 500 Sandhill Cranes were observed in this location in the 1970s and 1980s (Pogson and Kincheloe 1981), with birds roosting in the Table Mountain area and foraging north to the Anderson Bottoms and south to the Antelope Creek and Cond Ranch area (Littlefield 2008). However, Sandhill Crane use here has apparently diminished since the early 1990s, as evidenced by CBC count data which last recorded Sandhill Cranes in 1991 (Fig. 13). Yet Sandhill Cranes are still occasionally reported here in recent years (B. Deuel, personal communication; eBird data). Most recent sightings are relatively small flocks observed in late February or early March, during the period when Sandhill Cranes begin moving north, so the area is apparently serving as a staging area for spring migrants.

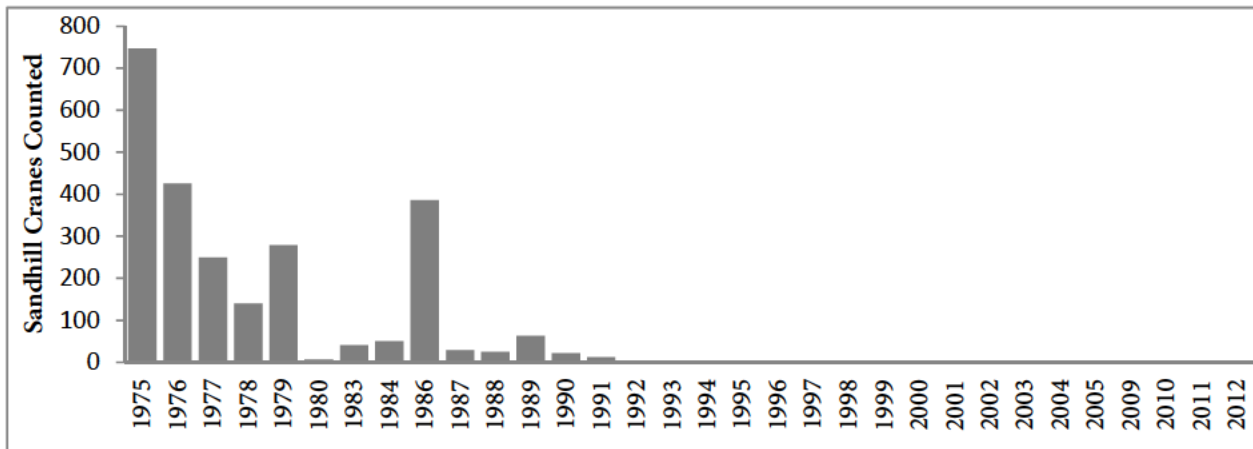


Figure 13. Numbers of Sandhill Cranes recorded on the Red Bluff Christmas Bird Count, 1975-2012.

SANDHILL CRANE CONSERVATION RECOMMENDATIONS

Two necessary components of Sandhill Crane winter range include: 1) suitable, undisturbed roost sites, and 2) an associated foraging landscape with enough carrying-capacity to support populations using those roost sites. Conservation of Sandhill Crane roost sites and the surrounding foraging landscape is consistent with recommendations in the 2006 Central Valley Joint Venture [CVJV] Implementation Plan (CVJV 2006). The roost site is critical to Sandhill Crane habitat needs, for without the roost site, they have no access to the available foraging habitats and will abandon those landscapes. Additionally, Greater Sandhill Cranes are very loyal to their wintering site which makes them less adaptable to change compared to Lesser Sandhill Cranes (Ivey 2015); therefore, conservation of their roost sites should be a priority. Because of energetic limitations, cranes can only fly a certain distance from roost to forage, so foraging sites close to roost sites are more important to cranes than sites more distant. A suitable roost site and the associated foraging areas radiating out to a certain distance from the roost form a conceptual framework for thinking about “landscape units” as a basis for Sandhill Crane conservation (Ivey 2015). The scale of effective conservation planning differs by subspecies. For Greater Sandhill Cranes, focusing on a conservation radius within 3 miles of a known roost is recommended (Ivey 2015). This radius encompassed 90% and 64% of the commuting flights made by Greater and Lesser Sandhill Cranes, respectively. For Lesser Sandhill Cranes, a conservation radius of 6 miles was recommended, which encompassed 90% of the commuting flights. Management, mitigation, acquisition, easement, planning, and farm subsidy programs intended to benefit Sandhill Cranes will be most effective when applied at these scales. Conservation and management of wintering habitats should include creating both new roost and feeding areas within these radii to ensure high chances of successful use. Developing new roost

sites towards the edge of these crane landscape units will allow Sandhill Cranes access to additional agricultural fields and increase their winter range carrying capacity.

In the Delta and San Joaquin Valley regions, most of the important roost sites are protected, as they occur on NWRs, other wildlife areas, and natural area preserves and conservation easement lands. In contrast, in the Sacramento Valley region, most existing roost sites currently occur on private lands, where they are susceptible to conversion to unsuitable crops, incompatible farming practices (i.e. deep flooding), increased disturbance, and loss of irrigation water that prevents crop production and/or post-harvest flooding (i.e. due to drought). In addition, in all Sandhill Crane wintering regions, their foraging areas are primarily on private lands (Littlefield 2002, Ivey and Herziger 2003, Shaskey 2012). These private lands are subject to loss from urbanization and conversion to incompatible crops, and also are not typically managed to optimize food availability to Sandhill Cranes. Habitat changes that occur on privately owned fields within the daily flight radius of a Sandhill Crane may change crane abundance at a roost, regardless of management actions at the roost site itself. The carrying capacities of existing wintering sites are threatened by habitat loss, which is occurring throughout the Central Valley. Habitat losses are primarily due to conversion of private lands to incompatible crop types (e.g., vineyards and orchards) as well as expanding urbanization (Littlefield and Ivey 2000, Littlefield 2002). In the Delta, sea level rise will likely destroy significant areas of Sandhill Crane wintering habitat in the future, and generally the effects of climate change may limit future water supplies to critical Sandhill Crane roost sites throughout the valley. Other threats to Sandhill Crane habitat include development projects such as new water delivery systems, and solar farms and the associated powerlines that serve them. Excessive disturbance (primarily from waterfowl hunting) can also reduce habitat availability to Sandhill Cranes. Additionally, some Sandhill Crane foraging habitat loss has occurred due to riparian forest and shrub plantings.

We recommend the following principal conservation measures, in priority order, that should be considered in development of conservation strategies for each major Sandhill Crane wintering region: 1) protect existing, unprotected roost sites by fee-title acquisition or conservation easements (and prioritize by their importance to Greater); 2) protect foraging landscapes around existing roosts, primarily through easements restricting incompatible crop types and development; 3) enhance food availability within those landscapes by improving conditions on conservation lands and providing annual incentives for improvements on private lands; 4) develop additional protected roost sites towards the edge of ecosystem units to allow Sandhill Cranes to access additional foraging areas.

PRIORITIZING AMONG WINTERING SITES

We recommend prioritizing conservation among winter regions based on: the relative number of threatened Greater present, the relative number of all Sandhill Cranes present, and the relative risk of habitat loss. On the first consideration, the highest numbers of Greater occur

in the Sacramento Valley Region, followed by the Delta Region (Table 4). The Delta Region has supported highest total numbers of Sandhill Cranes, followed by the Grasslands, Southern San Joaquin Valley, Sacramento Valley, and the San Joaquin River NWR regions (Table 4).

Table 4. Peak numbers of Greater Sandhill Cranes (Greater) and all Sandhill Cranes counted during surveys of the wintering regions of the Central Valley of California, 1970 – 2014.

Sandhill Crane Wintering Region	Highest estimate of Greater (Period)	Highest estimate of all Sandhill Cranes (Period)
Sacramento Valley	6,000 (1991-93)	7,984 (2014)
Sacramento-San Joaquin Delta	5,219 ^a (1983-85)	24,487 (2008)
San Joaquin River NWR	298 (1971)	4,383 (2012)
Grasslands	110 (1971)	15,275 (2010)
Southern San Joaquin Valley	68 (1970)	9,403 (2009)

^aIvey et al. (2014b) reported a peak estimate of 6,867; however, they indicated that particular estimate was biased high and had more confidence in an estimate of 2,658 Greater using the region.

Sandhill Crane habitat loss is occurring throughout the Central Valley, primarily due to conversion to incompatible crop types (e.g., vineyards and orchards) as well as expanding urbanization, which could pose a threat to these populations (Littlefield and Ivey 2000, Littlefield 2002); thus conservation and management of wetlands and agricultural areas within Central Valley Sandhill Crane wintering regions is important.

Although we are not aware of any detailed analyses of habitat loss for Sandhill Cranes, we believe that habitat loss is advancing fastest in the Delta Region. This Delta is certainly under the greatest threat due to pressures from expanding urban areas and is losing habitat to incompatible permanent crops faster than other regions (CVJV 2006: 230). Also, this region has the threat of sea level rise (which will likely eliminate many of the Delta Islands). Therefore, we propose that the major wintering regions be considered in this priority for conservation focus: 1) the Delta, 2) the Sacramento Valley, 3) the Grasslands, 4) the Pixley NWR area, and 4) the San Joaquin River area. However, it would be good to work simultaneously in all five of these regions and take advantage of conservation opportunities as they become available.

RECOMMENDATIONS FOR CONSERVATION ACTIVITIES BY WINTERING REGION

Highest priority sites in the Delta

The largest concentrations of Greater in this region occur at Staten Island (approximately 1500) and Brack Tract (approximately 500; G. Ivey, unpublished data). These two sites support the majority of the Greater in the Delta region. Greater are particularly loyal to their wintering sites, have very small winter home ranges, and their average flights from roost sites to foraging areas were less than 1 mile (Ivey 2015). Therefore, we suggest focusing on sites within approximately 2 miles of Staten Island and Brack Tract roost sites as initial priorities for conservation. These include: Brack Tract, Canal Ranch, New Hope Tract, Tyler Island, Bouldin Island, Terminous Tract, and Grand Island (Fig. 14). Specific recommendations for these sites follow.

Brack Tract—Brack Tract is one of the most important sites for Sandhill Crane use in the Delta, particularly for Greater. CDFW owns two parcels on the Tract that collectively form the Isenberg Crane Reserve (dark polygons in Polygons 2 and 3). These are important historic roost sites which were purchased specifically to manage to provide roost sites for Greater. However, approximately 25% of Brack Tract is no longer suitable for Sandhill Crane foraging, and there are ways that current management of the private croplands could be improved. Most of the Greater on Brack Tract use the Polygon 1 area (Fig 14). Here, the farmers tend to till the corn stubble too early, which buries much of the waste corn. They also usually temporarily flood fields. The parcel on the northwest part of this polygon is usually flooded by November and appears to be a waterfowl hunting club. Polygon 2 represents rice fields which also get used extensively by Greater; however, they tend to be tilled and flooded much too early in the season, and the flooding proceeds too rapidly for the maximum benefit to Sandhill Cranes, so foraging use drops significantly after early November. Polygon 3 is usually planted in corn, wheat and alfalfa. Greater primarily use the corn and wheat fields and avoid alfalfa, while Lesser Sandhill Cranes use the alfalfa extensively. The fields just east of South Isenberg Reserve get the most use by Greater. We recommend easements on these polygons, where possible, that would protect these fields from development and incompatible crops, to restrict crops primarily to grains. Management practices that should be encouraged (perhaps through incentive programs) include: avoiding or delaying tillage of grain fields until late winter, mulching corn stubble, and delaying initiation of rice flooding until mid-December, and then staggering the flooding of rice checks through January.

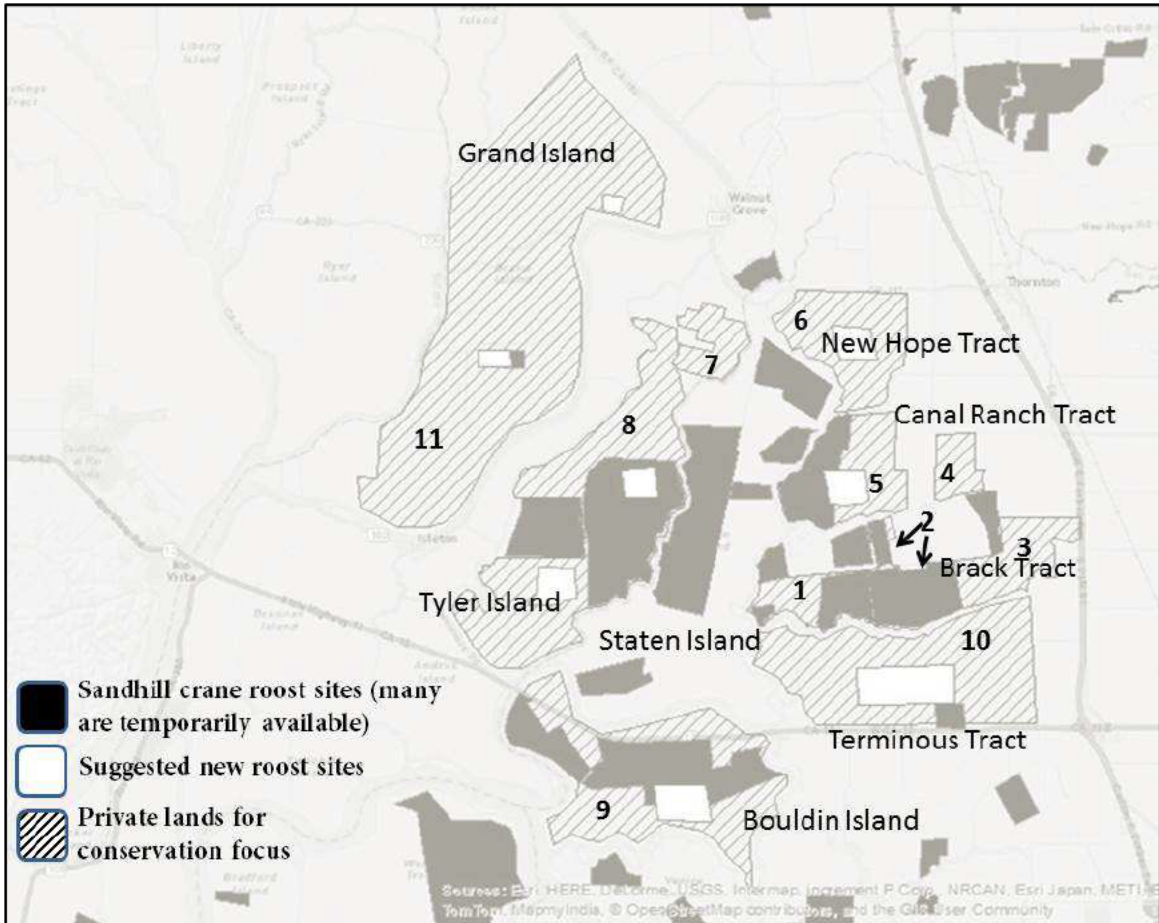


Figure 14. First priority Sandhill Crane conservation sites in the Delta region. We include suggested general locations where new roost sites should be encouraged through easements and incentives. Polygon numbers are referenced in the text.

Canal Ranch Tract—The fields of Polygon 4 get heavy use by the Greater Sandhill Cranes which roost on North Isenberg Reserve. These parcels were recently sold, and rumor has it that they will be soon converted to vineyards, so conservation of this area is urgent. This site would be our highest priority, because of the eminent threat of loss. Polygon 5 is an area on Canal Ranch that is important to Sandhill Cranes roosting on the northeast end of Staten Island. Farmers occasionally flood some of the fields here which then provide roost sites, but not on a regular basis. Again, we recommend easements on these polygons, where possible, to protect these sites from development and incompatible crops, and incentives to primarily grow grains, to avoid or delay tillage of grain fields until late winter, and to mulch corn stubble. Also, we suggest offering incentives for creation and management a flooded cropland roost (about 50 acres) towards the center of Polygon 5, flooded from mid-September through mid-March.

South New Hope Tract— Polygon 6 has extensive use by Sandhill Cranes roosting on northeast Staten Island. There is an existing TNC easement on the east side of this parcel. Much of the area is in alfalfa, which is avoided by Greater and used heavily by Lesser. We recommend providing easements to protect these fields from incompatible crops and incentives to keep fields primarily in grains, and to avoid or delay tillage and to mulch corn stubble.

Tyler Island—Polygon 7 was primarily alfalfa and has been heavily used by Lesser roosting on Staten Island. Polygon 8 was mostly corn and received extensive use by Greater which roost on the west side of Staten Island. Corn fields there are typically flooded which have provided roost sites for Sandhill Cranes. We recommend providing easements to protect these fields from incompatible crops and incentives to keep fields primarily in grains, and to avoid or delay tillage, and to mulch corn stubble. Typically, there has been more flooded area than ideal for Sandhill Crane foraging (and usually the depths are too deep for ideal roosting), so it would be good to provide incentives to reduce field flooding to a couple of 40-80-acre parcels to provide roost sites and delay any other field flooding until after November.

Bouldin Island—Bouldin Island (Polygon 9) has been primarily corn. Some of the Greater from Staten Island use the north portion of the island. We recommend providing easements to protect these fields from incompatible crops and incentives to keep fields primarily in grains, and to avoid or delay tillage, and mulch corn stubble. We also recommend providing incentives to manage a couple of 40-80-acre parcels to provide roost sites and delay any other field flooding until after November.

Terminous Tract—The north end of this tract (Polygon 10) gets the highest use by Greater from roosts on Brack Tract and Staten Island. There are some vineyards in portions of this polygon, but also a mix of grain and row crops. We recommend providing easements to protect these row crop fields from more incompatible crops and incentives to keep fields primarily in grains, and to avoid or delay tillage and to mulch corn stubble. We also recommend providing incentives to manage a couple of 40-80-acre parcels to provide roost sites (towards the east end of this polygon) and to delay and stagger any other field flooding until after November.

Grand Island—Sandhill Cranes regularly use the area of Polygon 11 on Grand Island, which contains a mix of grain and row crops; however, use by Greater is limited because of the distance from roost sites. A few Greater have been seen there occasionally, when fields have been flooded, which then that provide temporary roost sites. In recent years, a mix of crop types has been grown there, and although there are some vineyards and orchards, much of the habitat remains suitable for Sandhill Cranes. We recommend providing incentives to manage a couple of 40-80-acre parcels to provide roost sites there to encourage more Sandhill Crane use (see Fig. 14 for general locations to consider for roost sites). A roost site towards the north end of Polygon 11 would provide a linkage to allow Sandhill Cranes to move between Grand Island and Pearson Tract. We also recommend providing easements to protect these fields from incompatible crops and to keep fields primarily in grains. Appropriate management practices should also be

encouraged or incentivized. This includes mulching corn stubble, avoiding or delaying tillage, and delaying and staggering flooding of additional croplands until after December.

Secondary priority sites in the Delta

Concentrations of Greater occur near roost sites on the Cosumnes River Preserve in the wetlands and rice fields near the Preserve headquarters, and in the wetlands on Stone Lakes NWR. Smaller numbers of Greater roost on the Cosumnes Floodplain, upstream from Twin Cities Road and on the Valensin Ranch property. In 2013, we also discovered a roost site near Dry Creek, about 4 miles east of Galt (Fig. 15). Specific recommendations for these areas follow.

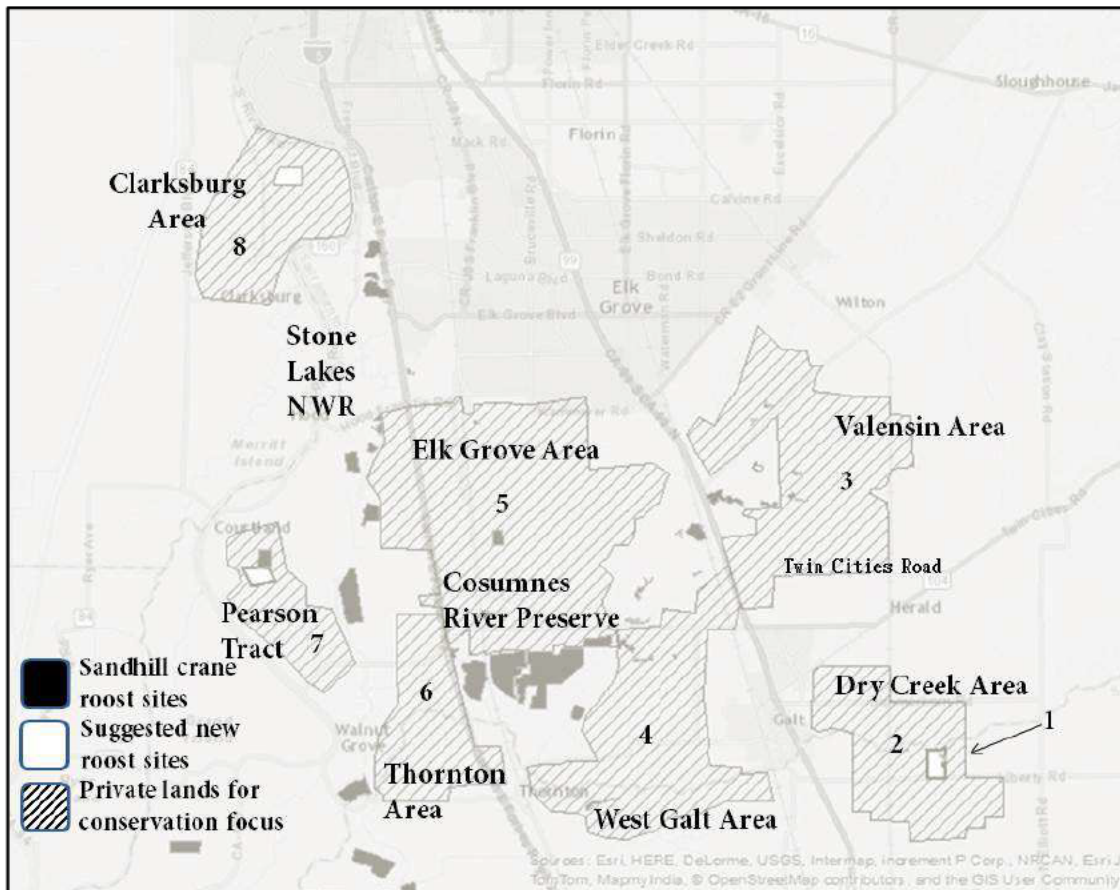


Figure 15. Secondary priority Sandhill Crane conservation sites in the Delta region. We include suggested general locations where new roost sites should be encouraged through easements and incentives. Polygon numbers are referenced in the text.

Dry Creek Area—We discovered this Sandhill Crane use area during our flock surveys and counted a peak of 252 Sandhill Cranes using a roost site near Dry Creek (in Polygon1; flock surveys showed about 25% Greater). The roost site was in a slough in Polygon 1 (Fig. 15). Since this roost site and the surrounding foraging landscape are unprotected, the property in Polygon 1 should be a high priority for a conservation easement with a management agreement to maintain

water in this roost site. A water supply for the roost might need to be developed to ensure it is available during dry years. Polygon 2 shows the general foraging distribution of the Sandhill Cranes around that roost site. Much of this foraging habitat occurs on a couple of large dairies (which grow grain crops and alfalfa to feed their cows) which potentially could be protected with conservation easements. Urban sprawl is reducing the available Sandhill Crane habitat on the west side of Polygon 2.

Valensin Ranch Area—The Sandhill Cranes using this region roost in Horseshoe Lake and also Badger Creek, just north of the Mustang airstrip. They primarily use winter wheat and corn crops in Polygon 3, associated with a couple of dairies (one of which is already under a TNC easement). Urban sprawl is reducing Sandhill Crane habitat on the east side of Polygon 3.

West Galt area—Sandhill Cranes roosting along the Cosumnes River near Twin Cities Road and in the flooded rice on Cosumnes River Preserve use grain fields and pastures Polygon 4. Urban sprawl is reducing Sandhill Crane habitat on the east side of Polygon 4.

Elk Grove area—Sandhill Cranes using Polygon 5 roost on Cosumnes River Preserve and Stone Lakes NWR. Urban sprawl is threatening Sandhill Crane habitat on the north side of Polygon 5. Much of the foraging habitat is winter wheat fields, corn fields and large pastures which support a few local dairies and cattle grazing operations.

Thornton area—Sandhill Cranes using Polygon 6 primarily roost in the wetlands on Cosumnes River Preserve. Habitat in this polygon is rapidly being converted to vineyards. Parcels closer to the Preserve should be a priority for protection through conservation easements.

Pearson Tract—Sandhill Cranes foraging in this area typically roost on the Sunriver Unit of Stone Lakes NWR, but Lesser Sandhill Cranes from Cosumnes River Preserve roost sites have also been observed here (Ivey, unpublished data). More Sandhill Cranes seem to use Polygon 7 when a temporary roost site at Zacharias Island (within the approved boundary of Stone Lakes NWR) is available. We recommend provision of a dependable roost site, in the general area of the white polygon. About half of this area is planted to alfalfa and the remainder has primarily been corn. Because Greater favor corn and avoid alfalfa (Ivey 2015), corn growing properties should be prioritized for conservation in this area.

Clarksburg area— Sandhill Cranes foraging in Polygon 8 fly in from roosts on the north end of Stone Lakes NWR. Fairly large numbers of Greater were recorded foraging here (~170 during our flock surveys). Because of the surrounding urban areas at the north end of Stone Lakes NWR, we believe the habitats in this polygon are important to maintaining the Sandhill Crane carrying capacity for Stone Lakes NWR; therefore conservation easements here should be a priority. Also, we recommend provision of a dependable roost site in the general area of the white polygons (Fig. 15).

Other Delta areas

Because Sandhill Crane densities are typically lower than in the areas mentioned previously, and flocks there are dominated by Lessers, we consider areas in the south Delta (south of Highway 12) a lower conservation priority. Additionally, access is difficult to the interior islands in this region, so our data on this region is limited. Aerial survey data also suggest lower numbers here (hundreds, as opposed to thousands north of Highway 12). Therefore, we recommend additional study of this area before undertaking major conservation work there. The

roost sites in this area are primarily temporary, so provision of dependable roost sites, preferably at higher elevations in this zone (less at risk from sea level rise) would help maintain and likely lead to increased Sandhill Crane use there.

Conservation priorities and strategies for the Sacramento Valley

For discussion purposes, we divided the Sacramento Valley into the general areas reported by Littlefield (1993), with the exception that we combined the Butte Sink and Gray Lodge areas that he had mapped separately. Flocks in this wintering region are dominated by Greater. The largest concentrations of Sandhill Cranes, based on our foraging flock surveys, included the Willows-Bayliss-Hamilton City area (Fig. 16; ~2,300), followed by the Rancho Llano Seco-Rancho Esquon area (~2,150); the Afton-Biggs area, including Little Dry Creek and Howard Slough units of Upper Butte Basin Wildlife (~1,770); the Willows-Maxwell-Colusa area (~1,045), and the Gray Lodge-Butte Sink area (~660). Generally, in this region, potential Sandhill Crane roost sites are abundant because of extensive flooding for rice straw decomposition which began in the early 1990s; however, their choices are limited by extensive waterfowl hunting in flooded fields and generally because water depths in most fields are too deep (Shaskey 2012). Also, because of water issues in California, there is no guarantee that such extensive areas will be flooded in this region in the future.

For private lands in this region, we suggest finding landowners willing to accept a conservation easement to protect their property from conversion to incompatible crops and enlist their property (of a minimum, 1 square mile blocks) in a Sandhill Crane management program to provide ideal roost site conditions (ideal water depths, flooded from mid-September – mid March, a half-mile no hunting buffer) on approximately 60-80-acre blocks of flooded rice fields, with the remaining fields managed to provide unaltered rice stubble, until at least early January, after most of the waste grains are consumed. For each enlisted property, a detailed, site-specific management strategy should be developed to define flood-up timing by individual management unit, water depths, and a schedule for managing rice stubble practices that would maximize Sandhill Crane foraging opportunities later in winter, after most of the waste grain is consumed in unaltered fields (e.g., late winter flooding, burning, discing). Additionally, the management strategies should consider staging the flooding of fields and de-watering of fields, and other management practices to extend new Sandhill Crane foraging opportunities throughout the winter season (e.g., perhaps not flooding some fields until February). We also recommend that Sandhill Crane roost site and foraging use be monitored on these properties to ensure management is working and provide a means to adjust specific management to improve success. Such Sandhill Crane management properties should be distributed in the rice-growing Sandhill Crane landscape (Fig. 16) so that roosts are distributed about 5 miles apart. We have suggested some general locations of such sites in Fig. 15, by displaying potential locations of new roost sites. Existing secured roost sites on refuges and conservation areas should be considered in selecting the placement of these new roost areas. The largest blocks of private lands that do not

have secure roost sites include the Willows-Bayliss-Hamilton City area, and the area west of Interstate 5, between Williams and Maxwell. We therefore suggest that these areas be considered a priority. Additionally, we suggest placing Sandhill Crane management properties on areas south of Colusa NWR, and in the vicinity of Hamilton City, Sutter, Live Oak, Gridley, Riceton, Afton, and Nelson, if possible (listed in priority based on numbers of Sandhill Cranes we found during flock surveys).

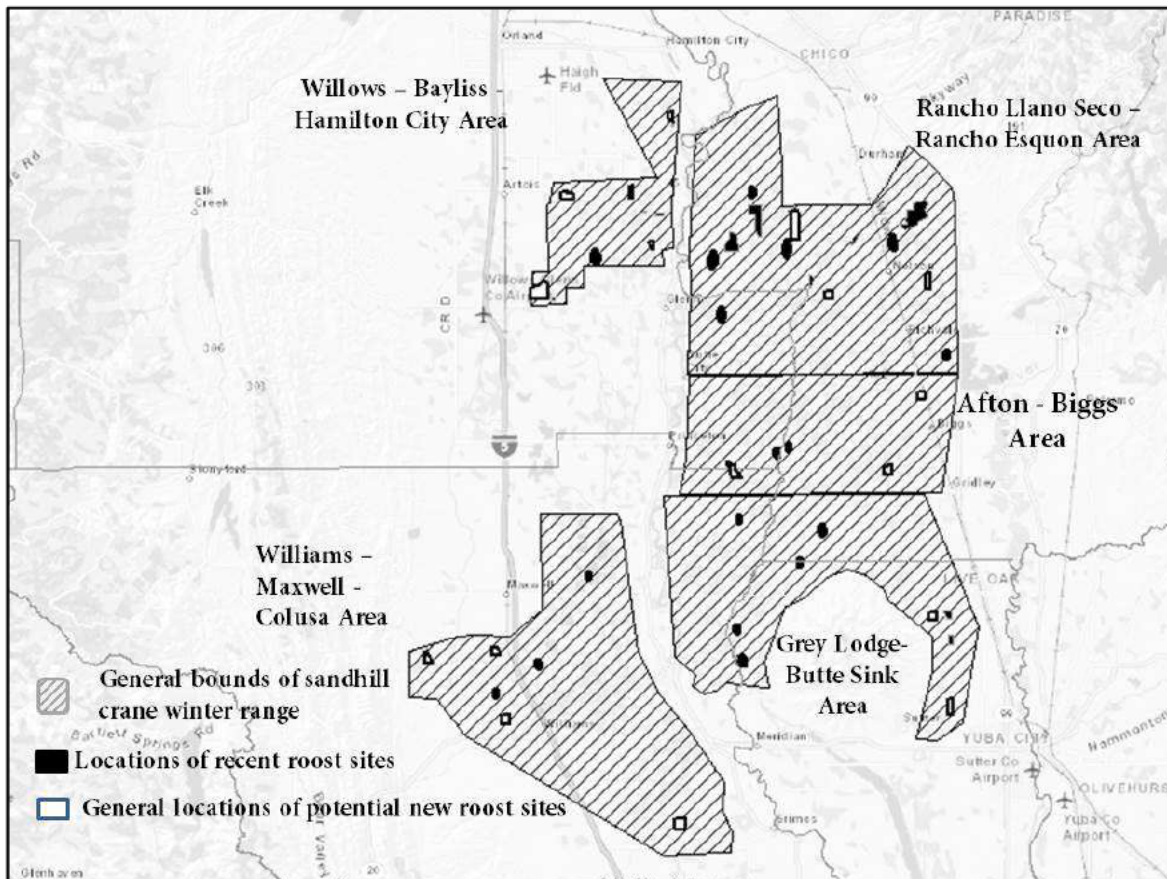


Figure 16. General bounds of Sandhill Crane landscape areas in the northern Sacramento Valley of California with recent roost sites and suggestions of general locations where new roost sites might be placed.

Conservation priorities and strategies for the San Joaquin Valley

Although Greater Sandhill Cranes are only a small proportion of Sandhill Cranes in the wintering regions of the San Joaquin Valley, these areas are also important crane conservation sites, as they support very large numbers of Lesser Sandhill Cranes. A majority of roost sites in these regions are secured, on NWRs, Wildlife Areas, or other conservation properties, so conservation efforts should focus on private croplands where the birds go to forage. These croplands are suffering ongoing losses from

expanding orchard and vineyards, and such continued loss could reduce the Sandhill Crane carrying-capacity of these regions, as occurred at Carrizo Plain. These croplands support bird populations using NWRs, as well as a wide variety of waterfowl, waterbirds, and shorebirds which use refuges as roost sites, and forage in adjoining private landscapes which are part of the functional landscapes for refuges. Therefore we recommend the development of strategies to conserve these functional landscapes beyond NWR boundaries. A high proportion of the crane-friendly croplands in each of these regions are owned, or managed to serve local dairies, so we recommend a focus on engaging these dairies and finding means to help them remain in business. Also, pastures used for livestock grazing are important to Sandhill Cranes in these regions.

In the Grasslands region (Fig. 17), we found concentrations of foraging Sandhill Cranes in three general areas: the area between Merced NWR and Highway 152 (1, in Fig. 17), the areas between Merced NWR and El Nido (2), and the area around Stevinson, between Highway 140 and the Merced River (3); therefore conservation efforts should focus on those general areas.

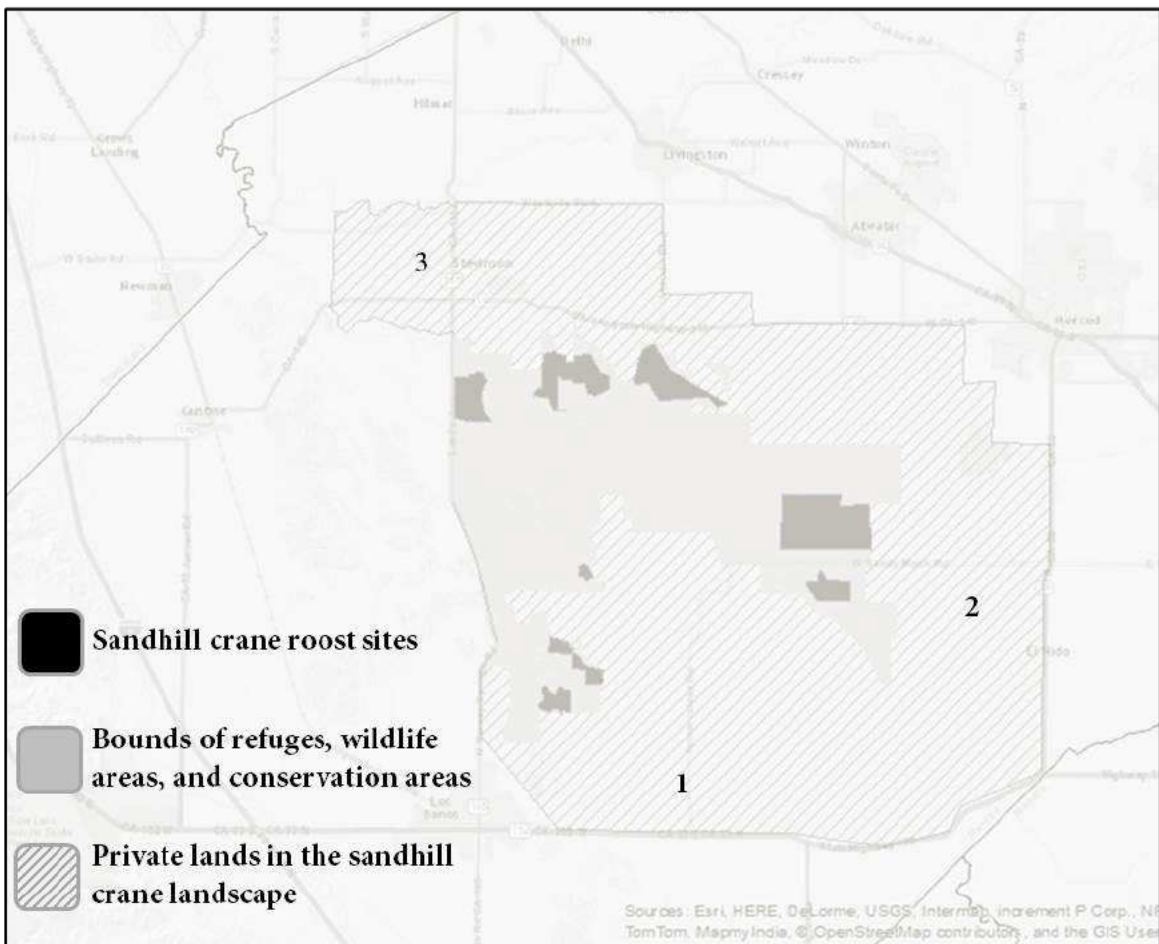


Figure 17. General bounds of the Grasslands Sandhill Crane wintering region in the northern San Joaquin Valley, California.

In the Pixley NWR region (Fig. 18) the greatest concentrations of foraging Sandhill Cranes were in the area just south of the refuge (out to 3 miles) and east of Highway 43 (1 in Fig. 18), east of the east refuge boundary (out to 3 miles; 2), and north of the refuge, between Highway 43 and Highway 99, out to 8 miles (3). In our map of the Sandhill Crane landscape (Fig. 18) we included an area west of Highway 43, around Alpaugh (4), where we did not find many Sandhill Cranes during our surveys, because that area appeared to have crane-compatible crops and was in close proximity to the refuge. We would expect Sandhill Cranes to use those croplands also, but because we found few flocks there, it should be a lower conservation priority.

Since there is only one major roost site in this region (Pixley NWR), it would be good to provide additional options for secure roost sites in the landscape around the refuge to improve Sandhill Crane access to agricultural areas. Also, the Goose Lake roost site(s) should be further investigated to determine whether easements or management incentives would improve Sandhill Crane use of that area, since historically it was more important.

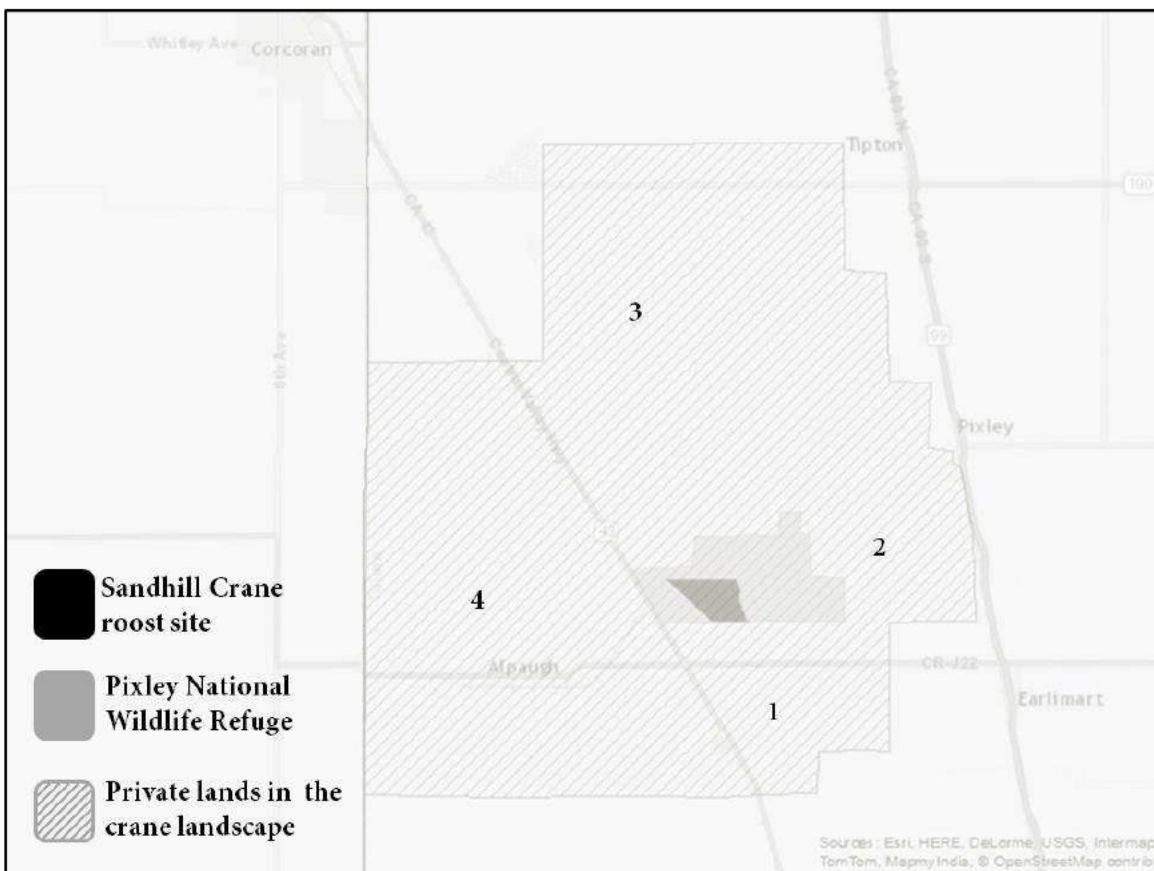


Figure 18. General bounds of the Pixley National Wildlife Refuge Sandhill Crane wintering region in the southern San Joaquin Valley, California.

Our surveys in the San Joaquin River NWR region (Fig. 19) revealed the greatest concentrations of foraging Sandhill Cranes north of the Stanislaus River (1 in Fig. 19), followed by the area east of the refuge and conservation areas (2). The area west of the refuge (3), supported much fewer flocks during our surveys, so it should be a lower priority for conservation.

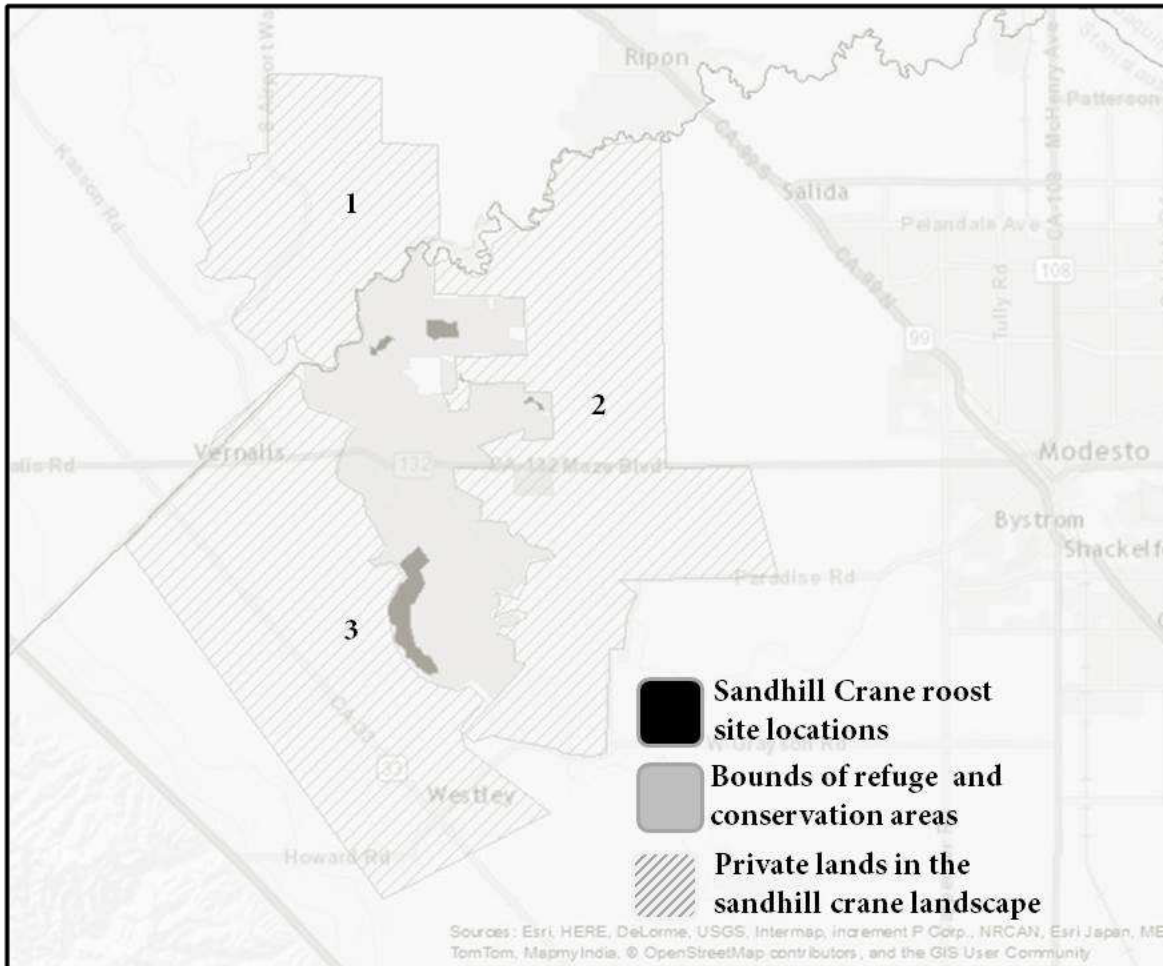


Figure 19. General bounds of the San Joaquin River National Wildlife Refuge Sandhill Crane wintering region in the northern San Joaquin Valley, California.

BEST MANAGEMENT PRACTICES

Roost site management

Timing— Timing and duration of roost site flooding are important consideration for management of Sandhill Crane roost sites. In recent years, the earliest migrant Sandhill Cranes arrive in early September (Ivey et al. 2014b); however, they were reported in the Delta on 25 August 2012 (E. Milnes, personal communication), and 11 August 2013 (S. Shanks, personal

communication). During August and September, the numbers of Sandhill Cranes in the Central Valley is very low, so these early arrivals can get by on very small roost sites. In a radio telemetry study, radio-tagged Lessers and Greateres first arrived on 3 and 4 October 2008, respectively, while their average arrival dates were 17 and 13 October, respectively (Ivey et al. 2014b). Their average departure dates were 22 February 2009 for Lessers and 25 February for Greateres; latest departure dates were 7 March and 13 March respectively. However, small numbers of Sandhill Cranes have occasionally been reported in areas through early April. Based on arrival dates, flooding of some sites managed for Sandhill Crane roosting should begin slowly in early September (and perhaps mid-August if such early arrivals continue). Generally, flooded areas of 5 -20 acres within Sandhill Crane landscapes should meet the needs of these small early flocks. Managers should begin flooding larger areas for roosting Sandhill Cranes in mid-September. It is important to maintain roost sites within each crane landscape throughout the wintering period. In the mid-1980s, Pogson and Lindstedt (1991) noted that marked Greateres were observed moving from the Delta to the Cosumnes River Floodplain after roost sites they were using were drained at the end of waterfowl hunting season (mid-January). In 2008, roost sites on Staten Island were drained in mid-January, causing radio-tagged Greateres that used the island all winter to move to Bouldin Island and Brack Tract. We recommend maintenance of flooded roosts until mid-March, when most birds leave the valley for spring migration, which would provide roosting habitat throughout their core wintering period. A few small areas (5 – 20 acres) should be maintained through late March, and perhaps a bit longer, if Sandhill Cranes remain and continue using them into April.

Flooding and draining—Generally, Sandhill Crane roost sites also serve as foraging sites. Flooding and draining of roost sites provides enhanced food availability and Sandhill Cranes are regularly attracted to these events. Spreading water concentrates insects and other invertebrates, as well as bringing earthworms to the surface, making them available; and drawdowns concentrate aquatic prey such as fish, aquatic invertebrates, and crayfish. Generally, newly flooded sites, regardless of the habitat type, were highly preferred foraging areas in the Delta (Ivey 2015). In 2002, a small newly-flooded wetland on Staten Island had the highest selection index for Sandhill Cranes on the entire island (Ivey and Herziger 2003). However, we have observed that water managers tend to flood and drain sites rapidly, limiting the foraging value to Sandhill Cranes and other waterbirds. We recommend that flood-up and drawdown of individual roost site should proceed over an approximate 2 week period to maximize this feeding opportunity. Where there are multiple individual roost sites within a particular crane landscape (e.g., Cosumnes River Preserve, Stone Lakes NWR, Staten Island), we recommend staggering their flood-up and drawdowns to extend Sandhill Crane feeding opportunities throughout the winter period. Where flooding is used to reduce salts for farm field management, we suggest a mid-winter drawdown (presuming other roost sites are present close by) followed by reflooding to flush salts and improve water quality for wildlife. It is likely that Sandhill Cranes will be attracted to the drawdown conditions.

Water depths—Sandhill Cranes prefer to roost in very shallow water. A study in the Sacramento Valley documented Sandhill Cranes selecting an average roost water depth of 15.5 cm (6.1 inches; Shaskey 2012) while a Delta study documented 10 cm (3.9 inches; Ivey et al. 2014a). Therefore, we suggest ideal water depths for Sandhill Crane roosting are 4-6 inches and managers should strive to manage water-levels in roost sites to maximize the area that provides this range of depths. If Sandhill Cranes are commonly seen roosting where water depths are greater than 20 cm (8 inches), it is an indication that ideal roost sites are limited (Shaskey 2012, Ivey et al. 2014a).

Roost site design

Sandhill Cranes readily use wetlands and seasonally-flooded croplands for night roosting (Shaskey 2012, Ivey et al. 2014a), so this choice gives managers some flexibility in designing a roost-site program. Seasonal wetlands generally provide more values to Sandhill Cranes than flooded croplands (as they provide a variety of invertebrate prey, fish and plant tubers), while flooded croplands may be a better option for building crane habitat into a working farm. Flooding croplands to provide temporary roost sites might be of value to expand roosting habitat options and to attract cranes to additional foraging landscapes.

Considerations for design and management of wetlands and flooded croplands include providing large roost site complexes (~250-2500 acres, depending on the objective for number of Sandhill Cranes to support; Ivey et al. 2014a). Larger sites likely give Sandhill Cranes more security from predators. Individual sites within a managed roost complex should be >12 acres, of mostly level topography, and dominated by shallow water (Ivey et al. 2014a). Additionally, they should not be dominated by tall emergents (Shaskey 2012). To plan design of roost sites for a given population objective for Sandhill Cranes, Ivey et al (2014a) suggested using a ratio of ~60 cranes/100 acres as a minimum roost site area goal.

Foraging habitats Sandhill Cranes use

It is likely that Sandhill Cranes historically depended on the vast floodplain wetlands and oak savannahs of the Central Valley, but wetlands were reduced by > 90% since European settlement (Frayser et al. 1989), and oak savannahs were similarly reduced. However, similar to some waterfowl species (e.g., Foster et al. 2010), Sandhill Cranes have adapted to increases in agriculture and feed commonly in grain fields and some row crops (Lovvorn and Kirkpatrick 1982; Krapu et al. 1984; Iverson et al. 1985; Reinecke and Krapu 1986; Iverson et al. 1987; Sparling and Krapu 1994; Ballard and Thompson 2000; Littlefield 2002; Davis 2003).

A recent Delta study (Ivey 2015) documented that the highest use by Greater was in corn, followed by rice, pasture, oak savannah, fallow fields, wetlands, wheat, Sudan grass, and other habitats; and for Lessers, the highest use was also in corn, followed by alfalfa, pasture, rice, wheat, oak savannah, wetlands, fallow fields, levees, and other habitats. However, those data are biased by what is present in the Delta landscape. Studies in the Sacramento Valley documented

rice as the most used crop, followed by wheat, corn, grassland, alfalfa, fallow, other crops and oak savannah (Littlefield 2002).

We summarized Sandhill Crane foraging habitat use data from our flock surveys in Table 5. Sandhill Crane use was greatly influenced by the availability of crops and their management conditions within these wintering regions during these late winter surveys. In the Sacramento Valley, the highest proportion of Sandhill Crane flocks used rice (89%), which is the dominant habitat type in that landscape. Within rice, 33% of Sandhill Cranes used flooded fields, 26% used unaltered stubble, 20% used tilled rice, while only small proportions. Proportions of flocks using other habitat types were low; 3% in fallow fields, 2% on rice levees, and less than 1% for all other habitat types. For the Delta region, the highest proportion of Sandhill Crane flocks was recorded in corn (43%), followed by alfalfa (19%), newly planted wheat and unidentified crops (9%, each), while very low proportions of flocks used other habitat types there. In the northern San Joaquin Valley, 30% of Sandhill Crane flocks used new-planted wheat, 23% used alfalfa, 16% used corn and unidentified crops. In the southern San Joaquin Valley, the highest proportions of Sandhill Cranes were found in alfalfa (58%) and new-planted wheat (30%); 4% of flocks were recorded in corn, while use of other habitat types was very low. We want to emphasize that these data do not indicate Sandhill Crane preference for a particular habitat or management condition, as they generally reflect the habitat availability in those landscapes during our late winter survey period.

Grains—Grain crops, particularly corn and rice, are important to wintering Sandhill Cranes and farmers should be encouraged thorough easements and incentives to continue farming grains in landscapes being managed for them. Although wheat was also important in the Sacramento Valley and Delta studies (Littlefield 2002, Ivey 2015) its use was of limited duration in those regions, so corn and rice should be emphasized over wheat for value to Sandhill Cranes. In the Delta study (Ivey 2015), Sandhill Crane use of fall-planted wheat varied. The general pattern was that Sandhill Cranes favored new wheat early during its availability and used it less as the season progressed. Employing a successional pattern of planting wheat in fall can extend Sandhill Crane feeding opportunities in wheat. Sandhill Cranes can cause damage to new wheat plantings; however, this can usually be compensated for by planting an extra 25 pounds of seed/acre (Ivey et al. 2003). Because wheat fields can be harvested in late summer, they may be flooded to provide roosts for early-arriving Sandhill Cranes.

Other crops and habitats—Crops that are used by Sandhill Cranes include alfalfa (particularly for Lessers), irrigated pasture, seasonal wetlands, native grasslands and oak savannahs. Therefore, these should be maintained or included in crane landscape conservation planning where possible. Sandhill Cranes did not use orchards, vineyards, blueberries, turf farms, or nursery areas (Ivey 2015), so conversion of grains and row crops to these habitat types should be avoided within crane landscapes.

Greaterers rarely used alfalfa in the Delta, in contrast to Lessers, which often favored alfalfa through the winter season (Ivey 2015). Similarly, Greaterers avoided alfalfa in the Sacramento

Valley studies (Littlefield 2002, Shaskey 2012). Although alfalfa appears important to Lessers, this crop should not be considered a major food source for Greater in a conservation planning context. However, alfalfa should be encouraged in crane landscapes in the San Joaquin Valley, where Lessers dominate the crane flocks.

Wintering Greater Sandhill Cranes generally obtain protein-rich foods by foraging in irrigated pastures and grasslands, but birds usually avoid these lands when vegetation exceeds 25 cm (10 inches; Littlefield and Ivey 2000). At Staten Island, newly-planted pasture was regularly favored by Greater in two seasons of study, and by Lessers in the second season only (Ivey 2015). Conversely, established pasture was unused and avoided at Brack Tract and rarely selected on Staten Island. Sandhill Cranes are typically attracted to pastures and grasslands after heavy winter rains as earthworms and other prey come to the soil surface. Established irrigated pastures were used by Sandhill Cranes primarily when they were being irrigated, and after heavy rains, otherwise, they were generally avoided (G. Ivey, personal observation). In grazed areas, Sandhill Cranes frequently overturn cattle dung pads, feeding on the associated invertebrates beneath. More foraging Sandhill Cranes were found in grazed pastures than ungrazed pastures in a study at Los Banos Wildlife Area (Carrol 1999). Therefore, we recommend allowing livestock grazing in these habitats, and, where feasible, provide incentives to do periodic irrigations to attract Sandhill Cranes to pastures and grasslands.

Table 5. Proportions of Sandhill Crane flocks found, by habitat type and management conditions during surveys conducted in December 2012-March 2013 in the Central Valley of California.

Habitat - Crop	Management Condition	Locations (sample size)				Total (n =1519)
		Sacramento Valley (n = 555)	Delta (n=416)	North San Joaquin Valley (n=247)	South San Joaquin Valley (n = 301)	
alfalfa	all	0.014	0.185	0.231	0.575	0.207
alfalfa	established	0.014	0.185	0.223	0.571	0.205
alfalfa	grazed			0.004		0.001
alfalfa	new				0.003	0.001
alfalfa	tilled			0.004		0.001
asparagus	stubble		0.010			0.003
corn	all	0.016	0.428	0.162	0.043	0.158
corn	flooded		0.084			0.023
corn	mulched		0.019			0.005
corn	stubble	0.002	0.168	0.049	0.037	0.062
corn	tilled	0.014	0.149	0.113	0.007	0.066
corn	tilled flooded		0.002			0.001
corn	unknown		0.005			0.001
cotton	tilled			0.004		0.001
fallow	all	0.031	0.034	0.020	0.040	0.032
fallow	flooded	0.002	0.002		0.037	0.009
fallow	tilled	0.014	0.010	0.020		0.011
fallow	tilled flooded	0.002				0.001
fallow	idle	0.013	0.022	0.004	0.003	0.012
grassland	all	0.007	0.005	0.020	0.007	0.009
grassland	grazed	0.002	0.005	0.020	0.003	0.006
grassland	idle	0.005			0.003	0.003
levee	all	0.018	0.022			0.013
orchard	tilled	0.002			0.027	0.006
pasture	all	0.005	0.077	0.097	0.010	0.041
pasture	grazed	0.005	0.075	0.097	0.010	0.040
pasture	flooded		0.002			0.001
potatoes	tilled		0.005			0.001
rice	all	0.888	0.012			0.328
rice	burned	0.016				0.006
rice	flooded	0.337	0.012			0.126
rice	mulched	0.009				0.003
rice	stubble	0.263				0.096
rice	tilled	0.204				0.074
rice	tilled flooded	0.041				0.015
rice	unharvested	0.007				0.003
rice	unknown	0.011				0.004
squash	tilled			0.004		0.001
Sudan grass	stubble		0.017			0.005
sunflower	all	0.002				0.001
unknown	all	0.007	0.094	0.158		0.054
unknown	tilled	0.000	0.019	0.089		0.020
wetland	all	0.007	0.019			0.008
wheat	all	0.002	0.094	0.304	0.299	0.135
wheat	new	0.002	0.094	0.300	0.296	0.134
wheat	stubble	0.014			0.003	0.001
wheat	tilled	0.014		0.004		0.001

Sandhill Crane response to management conditions

Unaltered grain stubble—In a Delta study (Ivey 2015), dry unaltered corn stubble was generally unused or avoided by Sandhill Cranes at both Brack Tract and Staten Island. This is similar to results in a Nebraska study which reported that Sandhill Cranes were least likely to use unaltered corn stubble in comparisons to their other foraging habitat choices (Anteau et al. 2011). In contrast, unaltered dry rice and wild rice stubble at Brack Tract and Cosumnes River Preserve was generally favored early during its availability. In the Sacramento Valley studies, unaltered rice stubble was the most preferred foraging habitat type (Shaskey 2012, Littlefield 2002). Unaltered rice stubble was found to retain the most seeds among rice stubble treatment types in the Sacramento Valley (Miller et al. 1989). Therefore, rice farmers should be encouraged to maintain unaltered rice stubble in fields, at least until late winter, by which time most of the waste grains have been consumed.

Tillage—Sandhill Cranes usually avoid tilled grain fields, as tillage is known to reduce the availability of waste grains (Baldassarre et al. 1983, Iverson et al. 1985, Miller et al. 1989, Sherfy et al. 2011). In the Delta study (Ivey 2015) all tilled crop types were generally avoided, and only occasionally selected. In the Sacramento Valley, Littlefield (2002) reported Sandhill Cranes avoided tilled rice stubble and reported that Sandhill Cranes generally abandoned rice fields shortly after tilling, while Shaskey (2012) reported that Sandhill Cranes neither selected nor avoided tilled rice. Also, a Nebraska study reported that Sandhill Cranes were unlikely to use tilled corn fields (Anteau et al. 2011). However, Littlefield (2002) found that Sandhill Cranes selected tilled corn fields on several surveys. A general pattern is that Sandhill Crane use occurred in tilled fields early during their availability, likely to take advantage of exposed invertebrates. Therefore, we recommend avoiding tillage of grain fields or otherwise, delaying tillage until late in the winter to allow Sandhill Cranes sufficient time to consume the available the waste grains.

Mulching— Mulching (otherwise known as chopping, mowing, or chopping and rolling) is a growing practice in corn stubble management as allowing the crop residue to decompose on the soil surface through the winter, has advantages to farmers such as reducing the need for tillage, helping retain soil moisture, reducing erosion, limiting weed growth, and reducing labor and costs (Ivey et al. 2003). It also likely keeps earthworms and other invertebrates at the soil surface (because of improved soil moisture and the decomposing litter) which should enhance Sandhill Crane foraging.

In the Delta study (Ivey 2015), mulched corn tended to be favored more often than any other post-harvest condition, particularly after mid-winter. A more recent study at Staten Island was less convincing, as they documented similar Sandhill Crane densities in mulched and unmanipulated corn stubble (Shuford et al. 2013); however, they did not restrict their surveys to early morning or late afternoon foraging periods, which may have clouded their results. A Nebraska study also documented a strong preference of Sandhill Cranes in spring for mulched corn stubble (Anteau et al. 2011), while conflicting results were reported in an earlier Nebraska

study, where mulched corn stubble was not selected over other habitats (Davis 2003). Therefore, we recommend that mulching of corn stubble be implemented as a crane-friendly practice, and that it be encouraged through land owner incentives.

Results of Sandhill Crane foraging selection of mulched rice fields differed between the Delta and Sacramento Valley studies, where it was generally favored in patterns similar to unaltered stubble in the Delta (Ivey 2015) and conversely, avoided compared to unaltered stubble in the Sacramento Valley (Shaskey 2012).

Flooding and irrigation—In the Delta study (Ivey 2015) Sandhill Cranes often showed high selection of cropland habitats when they were initially flooded. This same pattern occurred in the seasonal wetlands at Cosumnes River Preserve, when they were flooded through the fall seasons (G. Ivey, personal observation). After the initial response to flooding, Sandhill Crane use varied by stubble treatment. Sandhill Cranes generally avoided foraging in flooded corn stubble at Staten Island and Brack Tract, while use of flooded tilled corn stubble was mixed. Flooded rice and wild rice stubble, and mulched rice stubble were also favored by Sandhill Cranes when the habitats were initially flooded, and at Cosumnes River Preserve, where organic rice is grown, all flooded rice types were often favored through most of the winter. This was primarily because of the staggered flooding of individual fields through the winter season which kept Sandhill Cranes interested in this habitat type. Also, their higher attraction to the flooded organic rice appeared to be due, in part, to an abundance of yellow nut sedge (*Cyperus esculentus*) which sprouted shortly after flooding. This plant has been shown to be an important food of Sandhill Cranes in other areas (e.g., Taylor and Smith 2005). We suspect that nut sedge occurred more in the organic rice fields, where herbicides were not used for weed control. Tilled wheat, rice and safflower were also favored when initially flooded, but were generally avoided after that (Ivey 2015).

In one Sacramento Valley study (Littlefield 2002), Sandhill Cranes selected flooded rice stubble soon after it was available, but it received very little use after late December (Littlefield 2002). A similar pattern was reported by Shaskey (2012); however, she distinguished levels of flooding (full flooding vs. partial flooding) and found that Sandhill Cranes regularly preferred the very shallow partially flooded fields throughout the winter period. Fully flooded rice fields were only used early in the season and then avoided the remainder of the season (Shaskey 2012).

Flooding and irrigation are common practices for crop management and they can be used to provide forage benefits to Sandhill Cranes. For example, Ivey (2015) observed that Sandhill Cranes were very attracted to pastures when they were being irrigated and after heavy rains, and also to late-season mulched corn stubble when it was being pre-irrigated to provide soil moisture before spring planting. Even though the pre-irrigated area was large, this habitat was selected by both Greater and Lesser subspecies as they responded to the irrigation. Sandhill Cranes were attracted to newly-flooded wetlands, corn, rice, and even safflower fields (which received little use otherwise), regardless of crop treatment type. As fields flooded, they observed Sandhill Cranes feeding on invertebrates (e.g., earthworms and arthropods [including crayfish; *Procambarus clarkia*]) and small rodents that were exposed as they moved to escape rising water.

Rice fields typically support populations of crayfish which burrow into the soil when fields are dry and become available when they are re-flooded (G. Ivey, personal observation).

During the Delta study, Cosumnes River Preserve staff partnered with the researchers to develop a plan to stagger the flooding of rice fields during the winter of 2007-2008 to facilitate Sandhill Crane trapping opportunities. This practice proved to maintain high use of Sandhill Cranes in rice fields throughout the winter (Ivey 2015). However, no staggered flooding was planned for 2008-2009 and Sandhill Crane use declined by 66% that season, compared to 2007-2008. Therefore, if large areas need to be flooded within a Sandhill Crane landscape, we recommend very shallow flooding of individual fields and wetlands be staggered over winter, rather than done all at once, to spread out the feeding opportunities that flood-up provides. For pastures, irrigations during the early dry period of fall would be beneficial to attract Sandhill Crane use, but for croplands, we recommend that irrigations be provided later in winter (January-March), when possible, to facilitate use by Sandhill Cranes. For fields that have been disked or plowed, we recommend slow flooding, where possible, to begin about a month after the tillage occurred, to allow Sandhill Cranes to forage first on invertebrates in the fresh dirt.

While flooding of grainfields provides night roost sites and foraging opportunities for Sandhill Cranes, it likely also reduces season long grain availability at those sites, so the balance between better grainfield foraging areas and roost site needs should be considered. With the exception of grain fields flooded to provide night roost sites, it would be best to delay flooding as late as possible (perhaps beginning in January) to allow Sandhill Cranes and other wildlife access to waste grains.

Burning—Sacramento Valley studies (Littlefield 2002, Shaskey 2012) reported that Greater selected burned fields in the fall, but not late winter, and that burned rice fields contained 30% less waste grain than unaltered rice stubble (Miller et al. 1989). Littlefield (2002) reported that burning of rice stubble usually resulted in intensive short-term use, because burned fields regularly attracted large numbers of geese, ducks, and blackbirds that rapidly depleted the food. Therefore, we recommend providing incentives for farmers to avoid or delay burning of fields until late winter, after Sandhill Cranes have consumed most of the waste grain.

Food plots—One consideration for maintaining Sandhill Crane carrying capacity within a crane landscape is to provide plots of unharvested grain fields for crane use. Approximately 60 ha (150 acres) of experimental unharvested corn plots received extensive Sandhill Crane use on the Little Dry Creek Unit of the Upper Butte Basin WA; over 3400 Greater were feeding in these plots in January 1993, and a nearby flooded unharvested plot also accrued high use in January 1992 (Littlefield 1993). A similar management strategy has been successful at Merced and Bosque del Apache NWRs (J. P. Taylor [now deceased], personal communication). At Bosque del Apache NWR, individual Sandhill Cranes generally consume about 0.75 lbs. of corn, geese 0.50 lbs., and ducks 0.25 lbs. daily (reported as a personal communication from J. Taylor in Littlefield and Ivey 2000). Based on these estimates, the amount of corn to be planted annually could be calculated based on predicted yields and the projected number of Sandhill Cranes, geese and

ducks which are to be supported for 6 months. Also at Bosque del Apache NWR, standing corn is mowed or dragged down to encourage use by Sandhill Cranes and waterfowl. Such a strategy could be employed on additional refuges, wildlife areas and preserves, and could also be encouraged through incentives on private farms.

Managing disturbance

Excessive human disturbance can limit Sandhill Crane use of roost sites and foraging areas and should be minimized where possible. Sandhill Cranes are particularly sensitive to disturbance from low-level aircraft (e.g., crop dusters, mosquito abatement), ultralight aircraft, use of all-terrain vehicles, motorcycles and bicycles (Ivey and Herziger 2003, G. Ivey, personal observation). Waterfowl and pheasant hunting have also been reported to displace Sandhill Cranes (Lovvorn and Kirkpatrick 1981, Ivey and Herziger 2003, Shaskey 2012, Ivey et al. 2014a). At Gray Lodge Wildlife Area, Sandhill Cranes which had shifted to the closed zone at the start of hunting season completely abandoned the site when it was open to pheasant hunting (Pogson and Lindstedt 1991). In the Sacramento Valley, roost sites at Delevan and Colusa NWRs are generally only used early in the season (M. Wolder, personal communication) and Sandhill Cranes tend to disperse away from these refuges as the season progresses which may be due to waterfowl hunting disturbance or because wetland roost sites become too deep over time (L. Shaskey, personal communication). Nearly all the flooded rice fields in the Sacramento Valley are used for waterfowl hunting (Fleskes et al. 2005), which limits options there for managing Sandhill Crane roost sites. However, the effects of hunting disturbance on Sandhill Cranes depend on the frequency of hunting and whether they are hunted all day or just part of the day. Sandhill Cranes likely select areas with no hunting or low levels of hunting disturbance, and since most areas are only hunted 3 days per week; Sandhill Cranes may shift their use areas on non-hunt days. Roost sites and waterfowl hunting should not be considered readily compatible (Ivey et al. 2014a), as active waterfowl hunting and Sandhill Crane use are mutually exclusive (Shaskey 2012), and managers should consider hunting disturbance in planning crane conservation and management in a given crane landscape. We suggest a one-half mile buffer between crane conservation areas and hunting disturbance, when possible. If the management objective of an area includes waterfowl hunting, limiting hunting to low blind densities and restricting hunting to early morning may be viable. Parcels with no or minimal disturbance issues should be considered as higher priority for Sandhill Crane conservation. Larger parcels are better than smaller ones, as they will buffer disturbance from neighboring activities.

POTENTIAL PARTNERSHIPS AND OPPORTUNITIES

We recommend that TNC join with agency and other conservation organizations to implement our recommendations. The CVJV Implementation Plan (CVJV 2006) also provides recommendations for easement programs for Sandhill Cranes in the valley. Potential agency and conservation partners who might assist TNC with conservation easements include Audubon California, Natural Resource Conservation Service (NRCS), USFWS, California Wildlife Conservation Board, California Department of Conservation, and California Department of Water Resources.

Since Central Valley NWRs are core to Sandhill Crane conservation, we suggest that TNC approach the USFWS and the National Wildlife Refuge Association (NWRA) to investigate if NWRA's Beyond the Boundaries program (see: <http://refugeassociation.org/where-we-work/beyond-the-boundaries/>) could be applied to valley refuges to help conserve private lands that support refuge values. Also, USFWS has a new planning policy that encourages a landscape approach to refuge planning and working beyond refuge boundaries (USFWS 2013). Refuges have easement staff stationed at Sacramento and San Luis NWR complexes that have focused on wetlands easements in landscapes in the San Joaquin and Sacramento Valleys. Perhaps the USFWS could be persuaded to expand their easement program to include important croplands that help support migratory birds that use refuges.

Funding for incentive programs for crane-friendly management on private lands is primarily the realm of NRCS, but perhaps TNC and Audubon California could also help fund such activities and seek grants to help accomplish this program. Detailed, on-the-ground planning of easement locations and actual cropland and roost site management is needed to develop a successful Sandhill Crane conservation program, and monitoring is also important to ensure success and adaptive management. The groups and agencies mentioned above, plus the following agencies may assist with funding for regional conservation planning: CVJV, CDFW, Bureau of Reclamation, and BLM. Monitoring of the response of Sandhill Cranes to such management is also important and perhaps the International Crane Foundation and Point Blue Conservation Science other conservation science groups could assist with design and implementation of monitoring.

ACKNOWLEDGMENTS

The Nature Conservancy of California funded this project. We thank flock survey volunteers M. and L. Boyd, H. Brink, J. Delu, M. Eaton, G. Gray, L. Guevara, B. McDermott, J. Medina, J. Miller, D. Pleau, A. Redmon, M. Savino, S. Shanks, R. and L. Tobeck, and E. Whisler. We were allowed access to historic files by staff at Sacramento NWR (M. Wolder), CRP (M. Garr), San Luis NWR Complex (D. Woolington and K. Guereña), Pixley NWR (S. Ludwig and N. Stanley), and the CDFW office in Sacramento (E. Burkett). W. Cook Jr. provided roost site locations for Los Banos Wildlife Area. Additional historic information was provided by B. Deuel,

T. Keldsen, S. Shanks, J. Snowden, and M. Weaver. We thank the late W. Holt for providing information about Sandhill Crane distribution in the South Delta. Housing was graciously provided by D. McCullough, E. Deel, and San Luis and Stone Lakes NWRs. We also thank G. Golet, R. Kelsey, J. Langenberg, and L. Shaskey for improving this report with their editorial comments

LITERATURE CITED

- Abbott, C. G. 1940. Notes from the Salton Sea, California. *Condor* 42:264-265.
- Anteau, M. J., M. H. Sherfy, and A. A. Bishop. 2011. Location and agricultural practices influence spring use of harvested cornfields by cranes and geese in Nebraska. *Journal of Wildlife Management* 75:1-8.
- Baldassarre, G. A., R. J. Whyte, E. E. Quinlan, and E. G. Bolen. 1983. Dynamics and quality of waste corn available to postbreeding waterfowl in Texas. *Wildlife Society Bulletin* 11:25-31.
- Ballard, B. M., and J. E. Thompson. 2000. Winter diets of Sandhill Cranes from central and coastal Texas. *112:263-268.*
- Bennett, A. J., and L. A. Bennett. 1989. Wintering population of Greater Sandhill Cranes in the Okefenokee Swamp, Georgia. *Wilson Bulletin* 101:87-93.
- Breault A., B. Harrison, and M. Drever. 2007. Population Estimates for Sandhill Cranes in BC Interior. Unpublished report. Canadian Wildlife Service, Delta, British Columbia, and Ducks Unlimited Canada. Kamloops, British Columbia, Canada.
- Bureau of Land Management. 2010. Carrizo Plain National Monument Approved Resource Management Plan and Record of Decision. Bakersfield Field Office, CA, USA.
- Buturlin, S. A. 1907. Letters, notes and extracts. *Ibis* 49:364-365.
- California Department of Fish and Wildlife. 2013. State and federally listed endangered and threatened animals of California. Sacramento, CA, USA.
- Carrol, L. 1999. Use of grazed and non-grazed fields by wintering Sandhill Cranes and nesting dabbling ducks. M.S Thesis, Humboldt State University, Arcata, California.

- Central Valley Joint Venture, 2006. Central Valley Joint Venture Implementation Plan – Conserving Bird Habitat. U.S. Fish and Wildlife Service, Sacramento, CA, USA.
- Davis, C. A. 2003. Habitat use and migration patterns of Sandhill Cranes along the Platte River, 1998-2001. *Great Plains Research* 13:199-216.
- Drewien, R. C., W. M. Brown, J. D. Varley, and D. C. Lockman. 1999. Seasonal movements of Sandhill Cranes radiomarked in Yellowstone National Park and Jackson Hole, Wyoming. *Journal of Wildlife Management* 63:126-136.
- Fleskes, J. P., W. M. Perry, K. L. Petrik, R. Pell and F. Reid. 2005. Change in area of winter-flooded and dry rice in the northern Central Valley of California determined by satellite imagery. *California Fish and Game* 91:207-215.
- Foster, M. A., M. J. Gray, and R. M. Kaminski. 2010. Agricultural seed biomass for migrating and wintering waterfowl in the Southeastern United States. *Journal of Wildlife Management* 74:489-495.
- Framer, W. E, D. E. Peters, and H. R. Pywell. 1989. Wetlands of the California Central Valley: status and trends – 1939 to mid-1980s. U.S. Fish and Wildlife Service, Portland, OR. <http://www.fws.gov/wetlands/Documents/Wetlands-of-the-California-Central-Valley-Status-and-Trends-1939-to-mid-1980s.pdf>
- Glenn, T. C., J. E. Thompson, B. M. Ballard, J. A. Roberson, and J. O. French. 2002. Mitochondrial DNA variation among wintering Midcontinent Gulf Coast Sandhill Cranes. *Journal of Wildlife Management* 66:339-348.
- Grinnell, J. 1909. The Little Brown Crane in California. *Condor* 11:128-129.
- Grinnell, J., H. C., Bryant, and T. I. Storer. 1918. The game birds of California. University of California Press, Berkeley.
- Grinnell, J., and A. H. Miller. 1944. The Distribution of the Birds of California. *Pacific Coast Avifauna*. No. 27.
- Grinnell, J., and M. W. Wythe. 1927. Directory of the bird-life of the San Francisco Bay Region. *Pacific Coast Avifauna* 18.

- Herter, D. R. 1982. Habitat use and harassment of Sandhill Cranes staging on the eastern Copper River Delta, Alaska. M.S. Thesis, University of Alaska, Fairbanks.
- Hoffman, P. S. 2000. Greater Sandhill Crane Central Valley Population survey results, Fall 2000. Unpublished report. California Department of Fish and Wildlife, Sacramento, CA.
- Howard, H. 1929. The Avifauna of Emeryville Shellmound. University of California Publications in Zoology 32:378-383. Berkeley, CA, USA.
- Iverson, G. C., P. A. Vohs and T. C. Tacha. 1985. Habitat use by Sandhill Cranes wintering in western Texas. *Journal of Wildlife Management* 49:1074–1083.
- Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1987. Habitat use by midcontinent Sandhill Cranes during spring migration. *Journal of Wildlife Management* 51:448–458.
- Ivey, G. L. 2014a. Greater Sandhill Crane. Pages 96-97 in Shuford, W.D., editor. Coastal California (BCR 32) Waterbird Conservation Plan: Encompassing the Coastal Slope and Coast Ranges of Central and Southern California and the Central Valley. U.S. Fish and Wildlife Service, Pacific Southwest Region, Sacramento, CA, USA.
- Ivey, G. L. 2014b. Lesser Sandhill Crane. Pages 96-97 in Shuford, W.D., editor. Coastal California (BCR 32) Waterbird Conservation Plan: Encompassing the Coastal Slope and Coast Ranges of Central and Southern California and the Central Valley. U.S. Fish and Wildlife Service, Pacific Southwest Region, Sacramento, CA, USA.
- Ivey, G. L. 2015. Comparative Wintering Ecology of Two Subspecies of Sandhill Crane: Informing Conservation Planning in the Sacramento-San Joaquin River Delta Region of California. Ph.D. dissertation, Oregon State University, Corvallis, Oregon, USA.
- Ivey, G. L., B. E. Dugger, C. P. Herziger, M. L. Casazza, and J. P. Fleskes. 2014a. Characteristics of Sandhill Crane roosts in the Sacramento-San Joaquin Delta of California. *Proceedings of the North American Crane Workshop* 20: 12-19.
- Ivey, G. L., B. E. Dugger, C. P. Herziger, M. L. Casazza, and J. P. Fleskes. 2014b. Distribution, abundance, and migration timing of Greater and Lesser Sandhill Cranes wintering in the Sacramento-San Joaquin River Delta region of California. *Proceedings of the North American Crane Workshop* 20: 1-11.

- Ivey, G. L., and C. P. Herziger. 2000. Distribution of Greater Sandhill Crane pairs in Oregon, 1999/00. Oregon Department of Fish and Wildlife, Wildlife Diversity Program Technical Report #03-01-00, Portland, OR, USA.
- Ivey, G. L., and C. P. Herziger. 2001. Distribution of Greater Sandhill Crane pairs in California, 2000. California Department of Fish and Game, Sacramento, CA, USA.
- Ivey, G. L., and C. P. Herziger. 2003. Sandhill Crane monitoring at Staten Island, San Joaquin County, California, 2002-03. Unpublished report. The Nature Conservancy, Sacramento, CA, USA.
- Ivey, G. L., C. P. Herziger, and M. Gause. 2003. Farming for Wildlife: An Overview of Agricultural Operations at Staten Island, San Joaquin California. Unpublished report. The Nature Conservancy, Sacramento, CA, USA.
- Ivey, G. L., C. P. Herziger, and T. J. Hoffmann. 2005. Annual movements of Pacific Coast Sandhill Cranes. Proceedings North American Crane Workshop 9:25-35.
- Johnson, D. H., and R. E. Stewart. 1973. Racial composition of migrant populations of Sandhill Cranes in the northern plain states. *Wilson Bulletin* 85:148-162.
- Johnson, D. H., J. E. Austin, and J. A. Schaffer. 2005. A fresh look at the taxonomy of Midcontinental Sandhill Cranes. Proceedings North Crane Workshop 9:37-52.
- Jones, K. L., G. L. Krapu, D. A. Brandt, and M. V. Ashley. 2005. Population genetic structure in migratory Sandhill Cranes and the role of Pleistocene glaciations. *Molecular Ecology* 14:2645-2657.
- Krapu, G. L., D. E. Facey, E. K. Fritzell and D. H. Johnson. 1984. Habitat use by migrant Sandhill Cranes in Nebraska. *Journal of Wildlife Management* 48: 407-417.
- Littlefield, C. D. 1992. Annual assessment and monitoring report for Greater Sandhill Cranes and other threatened and endangered species on the Little Dry Creek Unit, California (October 1991 through June 1992). Unpublished report. California Department of Fish and Game, Sacramento, CA.
- Littlefield, C. D. 1993. Greater Sandhill Crane assessment in the Upper Butte Basin, California 1991-1993. California Department of Fish and Game, Rancho Cordova, CA.

- Littlefield, C. D. 2002. Winter foraging habitat of Greater Sandhill Cranes in northern California. *Western Birds* 33:51-60.
- Littlefield, C. D. 2008. Lesser Sandhill Crane. Pages 167-172 *in* California Bird Species of Special Concern: A ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. W. D. Shuford and T. Gardali, editors. Studies of Western Birds 1. Western Field Ornithologists, Camarillo, CA, and California Department of Fish and Wildlife, Sacramento, CA, USA.
- Littlefield, C. D., and G. L. Ivey. 2000. Conservation Assessment for Greater Sandhill Cranes wintering on the Cosumnes River Floodplain and Delta regions of California. Unpublished report. The Nature Conservancy, Galt, California.
- Littlefield, C. D., and S. P. Thompson. 1979. Distribution and status of the Central Valley Population of Greater Sandhill Cranes. Pages 113-120 *in* Proceedings 1978 Crane Workshop. J. C. Lewis, editor. Colorado State University Print Services, Fort Collins, CO, USA.
- Littlefield, C. D., and S. P. Thompson. 1982. The Pacific Coast Population of Lesser Sandhill Cranes in the contiguous United States. Pages 288-294 *in* Proceedings 1981 Crane Workshop. J. C. Lewis, editor. National Audubon Society, Tavenier, FL, USA.
- Lovvorn, J. R., and C. M. Kirkpatrick. 1981. Roosting behavior and habitat of migrant greater Sandhill Cranes. *Journal of Wildlife Management* 45:842-857.
- Lovvorn, J. R. and C. M. Kirkpatrick. 1982. Field use by staging eastern Greater Sandhill Cranes. *Journal of Wildlife Management* 46: 99-108.
- Mailliard, J. 1911. Odds and ends. *Condor* 13: 49-51.
- Mailliard, J. 1921. Notes on some specimens in the ornithological collection of the California Academy of Sciences. *Condor* 23: 28-32.
- McCaskie, G. 1967. *Audubon Field Notes* 21: 456-460.
- McFall, S. 2013. Greater Sandhill Crane Breeding Season at Conboy Lake NWR, Klickitat County, Washington. Unpublished report. Mid-Columbia National Wildlife Refuge Complex, Washington.

- McLean, D. D. 1930. Spring observations on cranes in Fresno County, California. *Condor* 32:3-8.
- Miller, L. H. 1925. The birds of Rancho La Brea. *Carnegie Institution of Washington* 349:63-106.
- Mickelson, P. G. 1987. Management of Lesser Sandhill Cranes staging in Alaska. Proceedings—1985 International Crane Workshop (J. C. Lewis, Editor). Platte River Trust, Grand Island, NE, USA. pp. 264-275.
- Miller, M. R., D. E. Sharp, D. S. Gilmer, and W. R. Mulvaney. 1989. Rice available to waterfowl in harvested fields in the Sacramento Valley, California. *California Fish and Game* 75:113-123.
- Miller, M. R., J. D. Garr, and P. S. Coates. 2010. Changes in the status of harvested rice fields in the Sacramento Valley, California: Implications for wintering waterfowl. *Wetlands* 30:939-947.
- National Audubon Society. 2014. The Christmas Bird Count Historical Results [Online]. <http://www.christmasbirdcount.org>. Accessed 6/1/2014.
- Pacific Flyway Council. 1983. Pacific Flyway Management Plan: Pacific Flyway Population of Lesser Sandhill Cranes. Pacific Flyway Study Committee (c/o Pacific Flyway Representative USFWS), Portland, OR, USA.
- Pacific Flyway Council. 1995. Pacific Flyway management plan for the Greater Sandhill Crane population wintering along the lower Colorado River Valley. Pacific Flyway Study Committee (c/o Pacific Flyway Representative USFWS), Portland, OR, USA.
- Pacific Flyway Council. 1997. Pacific Flyway management plan for the Central Valley Population of Greater Sandhill Cranes. Pacific Flyway Study Committee (c/o Pacific Flyway Representative USFWS), Portland, OR, USA.
- Petersen, J. L., R. Bischof, G. L. Krapu, and A. L. Szalanski. 2003. Genetic variation in the midcontinental population of Sandhill Cranes, *Grus canadensis*. *Biochemical Genetics* 41:1-12.
- Petrula, M. J., and T. C. Rothe. 2005. Migration chronology, routes, and winter and summer range of Pacific Flyway Population of Lesser Sandhill Cranes. Proceedings North American Crane Workshop 9:53-68.

- Pogson, T. H., and K. Kincheloe. 1981. Winter survey of the Pacific Flyway Population of Lesser Sandhill Cranes in California. Unpublished report.
- Pogson, T. H., and S. M. Lindstedt. 1988. Abundance, distribution and habitat of Central Valley Population greater Sandhill Cranes during winter. Unpublished report. University of Alaska, Fairbanks.
- Pogson, T. H., and S. M. Lindstedt. 1991. Distribution and abundance of large Sandhill Cranes (*Grus canadensis tabida*) wintering in California's Central Valley. *Condor* 93:266-278.
- Reinecke, K. J., and G. L. Krapu. 1986. Feeding ecology of Sandhill Cranes during migration in Nebraska. *Journal of Wildlife Management* 50:71-79.
- Rhymer, J. M., M. G. Fain, J. E. Austin, D. H. Johnson, and C. Krajewski. 2000. Mitochondrial phylogeography, subspecific taxonomy, and conservation genetics of Sandhill Cranes (*Grus canadensis*; Aves: Gruidae). *Conservation Genetics* 2:203-218.
- Shaskey, L. E. 2012. Local and landscape influences on Sandhill Crane habitat suitability in the northern Sacramento Valley, CA. M.S Thesis, Sonoma State University, Rohnert Park, California.
- Sherfy, M. H., M. J. Anteau, and A. A. Bishop. 2011. Agricultural practices and residual corn during spring crane and waterfowl migration in Nebraska. *Journal of Wildlife Management* 75:995-1003.
- Shuford, W. D., M. E. Reiter, K. M. Strum, C. J. Gregory, M. M. Gilbert, and C. M. Hickey. 2013. The effects of crop treatments on migrating and wintering waterbirds at Staten Island, 2010–2012. PRBO Conservation Science. Unpublished report. Then Nature Conservancy, Chico, CA USA.
- Sparling, D. W., and G. L. Krapu. 1994. Communal roosting and foraging behavior of staging Sandhill Cranes. *Wilson Bulletin* 106:62-77.
- Sullivan, B. L., C. L. Wood, M. J. Iliff, R. E. Bonney, D. Fink, and S. Kelling. 2009. eBird: a citizen-based bird observation network in the biological sciences. *Biological Conservation* 142: 2282-2292.
- Swarth, H. S. 1919. A California specimen of the Sandhill Crane. *Condor* 21:212-213.

- Tacha, T. C., P. A. Vohs, and W. D. Warde. 1985. Morphometric variation of Sandhill Cranes from mid-continent North America. *Journal of Wildlife Management* 49:246-250.
- Taylor, J. P., and L. M. Smith. 2005. Migratory bird use of belowground foods in moist-soil managed wetlands in the Middle Rio Grande Valley, New Mexico. *Wildlife Society Bulletin* 33:574–582.
- Tyler, J. G. 1913. Some birds of the Fresno District, California. *Pacific Coast Avifauna* 9.
- U.S. Fish and Wildlife Service. 2013. A landscape-scale approach to Refuge System planning. (<http://www.fws.gov/refuges/vision/pdfs/PlanningGuideRev10.pdf>). Washington, DC, USA.
- U.S. Fish and Wildlife Service. 2014. Mid-Winter Waterfowl Survey data. Pacific Flyway Study Committee (c/o Pacific Flyway Representative USFWS), Portland, OR, USA.
- Walkinshaw, L. H. 1973. *Cranes of the World*. Winchester Press, New York, NY, USA.
- Wenner, A. S. and S. A. Nesbitt. 1987. Wintering of Greater Sandhill Cranes in Florida. In *Proceedings—1985 International Crane Workshop* (J. C. Lewis, Editor). Platte River Trust, Grand Island, NE, USA. pp. 196-200.
- Willett, G. 1912. Birds of the Pacific slope of southern California. *Pacific Coast Avifauna* 7.
- Willett, G. 1933. A revised list of the birds of southwestern California. *Pacific Coast Avifauna* 21.
- Wyman, L. E. 1919. Notes from southern California. *Condor* 21:172-173.
- Zeiner, D. 1965. Effects of the peripheral canal on Sandhill Cranes. In: *Delta Fish and Wildlife Study, Report No. 4 – June 30, 1965*. California Department of Fish and Game and Department of Water Resources. Stockton, CA.