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***Abstract***: The U.S. Fish and Wildlife Service (USFWS) recognizes 6 migratory populations of sandhill cranes (*Grus canadensis*) in the United States, 4 of which occur in or west of the Rocky Mountains. Traditionally the Lower Colorado River Valley Population (LCRVP; greater sandhill crane [*G. c. tabida*]) was thought to be distributed across the Imperial (California) and Lower Colorado River (Arizona) Valleys, southward into Mexico via the Colorado River delta in winter and northeastern Nevada (Elko and White Pine Counties) during summer. Conservation and management concern exists over known distribution based on winter and summer surveys because discrepancies exist between the number of individuals counted on winter and summer termini. In 2014 the USFWS initiated a mark-recapture program on the LCRVP to aid in the development of long-term management of this least abundant greater sandhill crane population. The objective of this paper is to update the known distribution of the LCRVP from greater sandhill cranes by using platform transmitter terminals (PTTs). We captured 44 individual greater sandhill cranes and equipped 22 with PTTs on the wintering and summering grounds in the Imperial and Lower Colorado River Valleys and west-central Idaho, 2014-2015. Our updated distribution map from 18 of 22 PTT-tagged individuals identified several new summer locations extending north and west into west-central Idaho and numerous new migratory locations extending east into Utah. We also confirmed winter locations on the Gila River southwest of Phoenix, Arizona. The extent of the distribution of the LCRVP extends farther north and east than previously expected and, most importantly, overlaps with areas commonly affiliated with the Central Valley and Rocky Mountain Populations in the Intermountain West.

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**Key words**: distribution map, greater sandhill crane, *Grus canadensis tabida*, Lower Colorado River Valley Population, platform transmitter terminals.

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The U.S. Fish and Wildlife Service (USFWS) recognizes 6 migratory populations of sandhill cranes (*Grus canadensis*) in the United States (Fig. 1). Four of the 6 populations, the Pacific Coast (PC), Central Valley (CVP), Lower Colorado River Valley (LCRVP), and Rocky Mountain (RMP), are distributed in or west of the Rocky Mountains. The RMP primarily winters along the Middle Rio Grande River Valley in central New Mexico, Willcox Playa in southeast Arizona, and the Interior Highlands in Chihuahua, Mexico, and is the only population of the 4 not wintering in southern California. The other 3 populations (PC, CVP, LCRVP) have adjacent wintering grounds in river valleys associated with desert or mountain ecosystems in central and south California (Fig. 1). Specifically, the LCRVP winter termini consists of the Imperial Valley in southern California and Lower Colorado River Valley in Arizona, with some evidence of additional winter locations on the Gila Bend along the lower Gila River southwest of Phoenix, Arizona (Pacific Flyway Council and USFWS 1995, Pacific Flyway Council 2017).

The LCRVP is the least abundant of the migratory greater sandhill crane (*G. c. tabida*) populations in the Intermountain West with an estimated 2,716 individuals (Dubovsky 2017) based on winter counts. The

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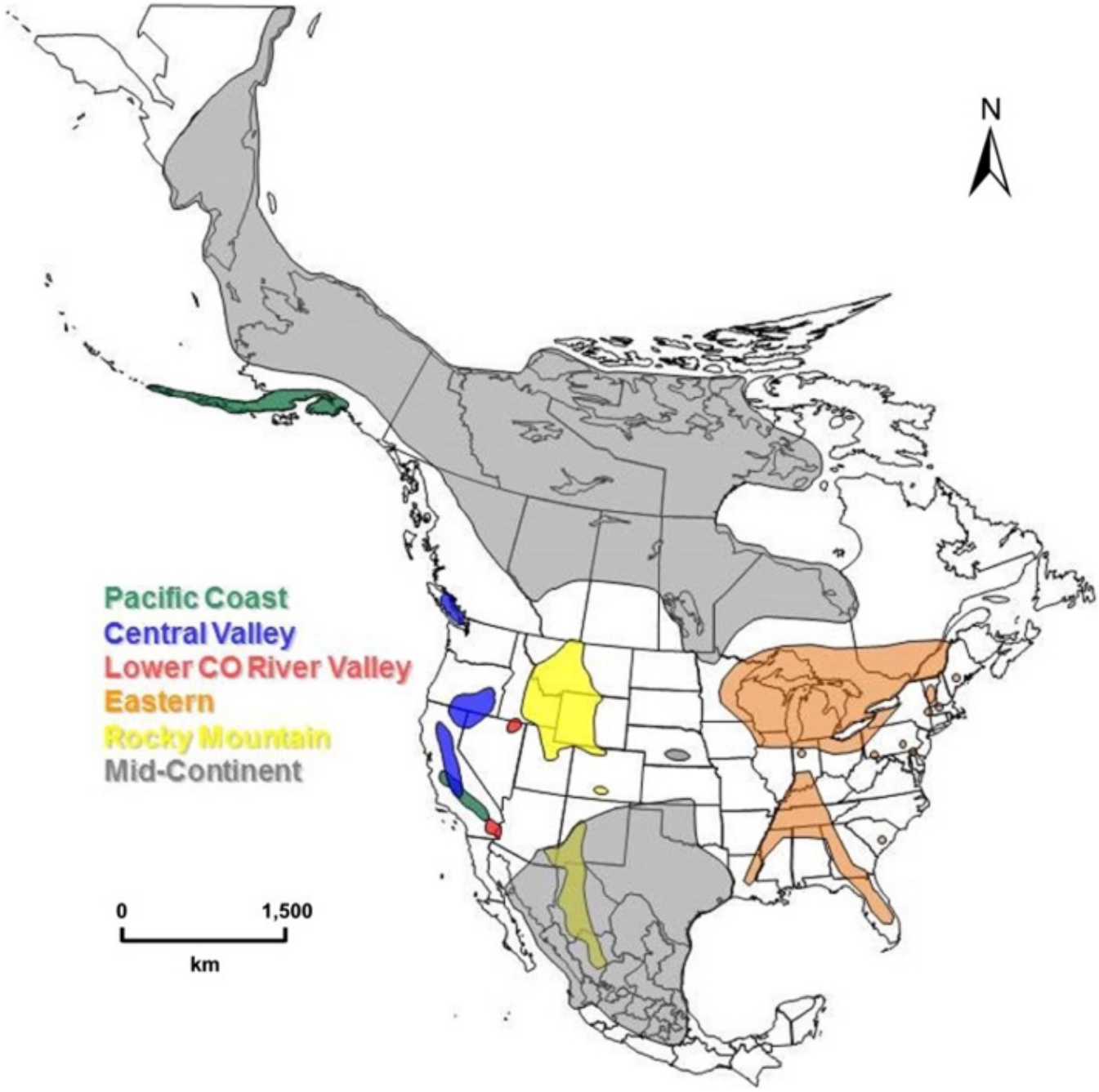


**Figure 1. Approximate nesting, winter, and primary migration staging areas of the 6 migratory sandhill crane populations (from Collins et al. 2016). Areas depicted in this figure are generalizations and show relative position of migratory ranges; the ranges of each migratory population are still being determined in North America.**

conventional wisdom was that the LCRVP summered exclusively in northeastern Nevada and migrated south in a very linear fashion to winter along the Lower Colorado River Valley, Imperial Valley of California, and in Mexico on the Colorado River delta region (Pacific Flyway Council and USFWS 1995). Survey data in northeastern Nevada, however, only account for ~30% of those counted on the winter termini (Conring 2016, Pacific Flyway Council 2017). These data suggest that the LCRVP does not exclusively summer

in northeastern Nevada, and other cranes wintering along the LCRV and Imperial Valley may be from different migratory populations. Nevertheless, efforts to expand and conduct surveys (aerial and ground surveys, mark-recapture) on the breeding grounds to locate new areas within the large geographic distribution of the Intermountain West is time consuming and difficult. As such, the delineation of greater sandhill crane populations in the western United States potentially excludes numerous migratory, summer, and winter locations of 3 of the 6 migratory populations. Meticulous delineation of the migratory populations in the West is important for long-term conservation of greater sandhill cranes due to various harvest guidelines as well as varying state-level conservation status for greater sandhill cranes in Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. For example, greater sandhill cranes are a state-level threatened species in California and Washington, but are harvested in other western states (e.g., Arizona and New Mexico).

In 2014, USFWS Southwest Region initiated a mark-recapture program on the LCRVP winter grounds to provide additional data for long-term management. Specific goals of the mark-recapture program were to quantify habitat selection, assess migratory routes and summer distribution, and assess overwinter spatial ecology of the LCRVP by using platform transmitter terminals (PTTs) (Collins et al. 2016, Conring 2016, Kruse et al. 2017). Also, intermixing on the summer and migratory areas has been previously identified from preliminary samples used herein (Collins et al. 2016). Our objectives were to create an updated distribution map of the LCRVP that identifies 1) migratory pathways, 2) summer distribution, and 3) winter distribution using location data from PTT-tagged greater sandhill cranes (hereafter cranes) captured in the known winter range of the LCRVP and in Long Valley, Idaho (an area that was suspected to be a summer area for LCRVP; Collins et al. 2016). Improved population delineation will assist state and federal-level management of the LCRVP across their geographic distribution.

## METHODS

### Capture Sites

We captured 25 cranes on Cibola National Wildlife Refuge (NWR) (33.318°N, 114.698°W), which encompasses 6,988 ha of land in La Paz County, Arizona, and Imperial County, California. Cibola NWR is located on the main branch of the lower Colorado River. We also captured 12 and 2 cranes on 13,259 ha near Brawley (32.588°N, 115.318°W) and Sonny Bono Salton Sea NWR (33.158°N, 115.738°W), respectively, in the Imperial Valley of California. The entire Imperial Valley, including Sonny Bono Salton Sea NWR, is surrounded by Sonoran Desert uplands. All cranes captured in Arizona and California were in adult plumage but a more specific age class (subadult or adult, i.e., $<$ or $\geq$ 3 years old, respectively) was not determined.

We opportunistically captured 5 cranes as flightless colts on their natal territories in Idaho (44.528°N, 116.058°W) in collaboration with the Idaho Department of Fish and Game. We scouted for breeding pairs of cranes to locate colts starting near Boise, Idaho, and then moved north to the Long Valley, and then east to the Bear Valley and southeast to the Camas Prairie Wildlife Area near the town of Fairfield (43°20′N, 114°47′W).

We used rocket nets and noose snares in upland areas away from roost sites to capture wintering cranes at Cibola NWR and Sonny Bono Salton Sea NWR during January and February 2014 and January 2015 (Wheeler and Lewis 1972, Urbanek et al. 1991, Hereford et al. 2001). We captured colts on the summering grounds in Idaho by hand with dip nets (68 × 78 cm; 121 cm deep with 121-cm handle) in July 2014 and 2015. We used plumage characteristics to distinguish adult cranes from hatch-year cranes in instances where we were targeting adults on the wintering grounds (Lewis 1979, Krapu et al. 2011). A 22-g solar-powered PTT was mounted on a 2-piece leg band with one-half engraved with a unique alpha-numeric code. We attached the leg bands mounted with the PTTs to individual cranes (Microwave Telemetry, Inc., Columbia, MD, USA; Ivey et al. 2005, Krapu et al. 2011). Additionally, we attached a U.S. Geological Survey Bird Banding Laboratory band (no. 9 butt-end aluminum) on the right tibia above the tibio-tarsus on all captured cranes (Krapu et al. 2011). Platform transmitter terminals are useful for identifying extent and distribution of LCRVP (and other crane) populations due to the large spatial extent and remote locations of the Intermountain West, and PTTs can remotely send data via satellite in these situations. Population designations of cranes are a

management construct which, in the past, has relied on spatial affiliations between annual cycle events and were previously based on general ground or aerial surveys, which lacked the ability to cover large geographic or remote locations.

Each PTT was programmed by the manufacturer to record 4 GPS locations per 24-hour cycle (Microwave Telemetry, Inc., Columbia, MD, USA; for a complete description of the ARGOS system, see Fancy et al. 1988; Harris et al. 1990). All capture and handling methods were approved by the Texas Tech University Institutional Animal Care and Use Protocol #13108-12.

Kruse et al. (2017) developed a timing of movement graph by classifying a location as a "summering", "wintering", "fall migration" or "spring migration" location for each PTT-marked crane (see Fig. 1, Kruse et al. 2017). The criteria for the different categories were as follows: "spring migration" status when the birds departed the wintering area, "fall migration" status when cranes made a significant move away from the summer area, "summering" when a crane stayed in a northern summer area for more than a week, and "wintering" when it reached the southern wintering areas. We implemented this procedure for the PTT-marked cranes that were included in the analysis for this manuscript. We then combined fall and spring migration into 1 category for the analysis. We created 99% Kernel Density Estimator (KDE) isopleths using the KDE and Isopleths tools in the Geospatial Modeling Environment (GME) program (Beyer 2015) for each time period using the data from all PTT-tagged cranes and exported the data as shapefiles. We created the revised distribution map by displaying the 99% KDEs in ArcGIS 10.3 (hereafter GIS, ESRI 2014) to demonstrate the geographic distribution of the LCRVP across the 3 time periods of our assessment.

## RESULTS

### Capture and PTT Analysis

We captured 44 cranes (39 after-second-year birds and 5 colts). We deployed 17 PTTs on after-second-year cranes on the wintering grounds (January 2014: $n$ = 10 Cibola NWR, $n$ = 1 Sonny Bono Salton Sea NWR, $n$ = 5 Imperial Valley; January 2015: $n$ = 1 Sonny Bono Salton Sea NWR). In July of 2014 and 2015, we captured and deployed PTTs on 5 flightless colts. The updated distribution map was generated using 40,530 locations (3,755 migration; 20,715 summer; 16,060 winter) from 18 PTT-tagged cranes from 10 January 2014 to 27 August 2017 (Table 1). We did not include any locations that indicated the PTT-tagged crane was in flight (speeds >10 knots [18.5 km/hr]), locations that were likely incorrect due to drained batteries, 2-dimensional fixes, or no fix, or locations from cranes that died before they migrated from the capture location.

### Migration

The updated distribution map (Fig. 2) includes a previously identified migratory pathway through central Nevada from the winter termini in southern Arizona and California to summering areas in northeastern Nevada. With the new information gathered from the PTT-marked cranes, the revised migration corridor includes 4 new geographic areas not previously associated with the LCRVP: 1) southwest Idaho near the Duck Valley Indian Reservation north into the Payette River Valley, extending northwest into northeastern Oregon; 2) the Cache Valley of Idaho and Utah; 3) the Duchesne River Valley south of the

**Table 1. Capture site location and age of 18 PTT-tagged greater sandhill cranes used to develop an updated distribution map for the Lower Colorado River Valley Population, 2014-2016.**

| IDs | Time of capture | Capture site[a] |
|---|---|---|
| ID001 | Jul 2014 | Long Valley, Id. |
| ID005 | Jul 2015 | Bear Valley, Id. |
| SBS001, SBS003-SBS005 | Jan 2014 | Imperial Valley, Calif. |
| SBS006 | Jan 2014 | Sonny Bono Salton Sea NWR, Calif. |
| SBSS007 | Jan 2015 | Sonny Bono Salton Sea NWR, Calif. |
| CIB001-CIB010 | Jan 2014 | Cibola NWR, Ariz. |

[a] See Collins et al. (2016) and Conring (2016) and for information pertaining to winter and summer termini and winter site fidelity of PTT-tagged individuals. NWR = National Wildlife Refuge.

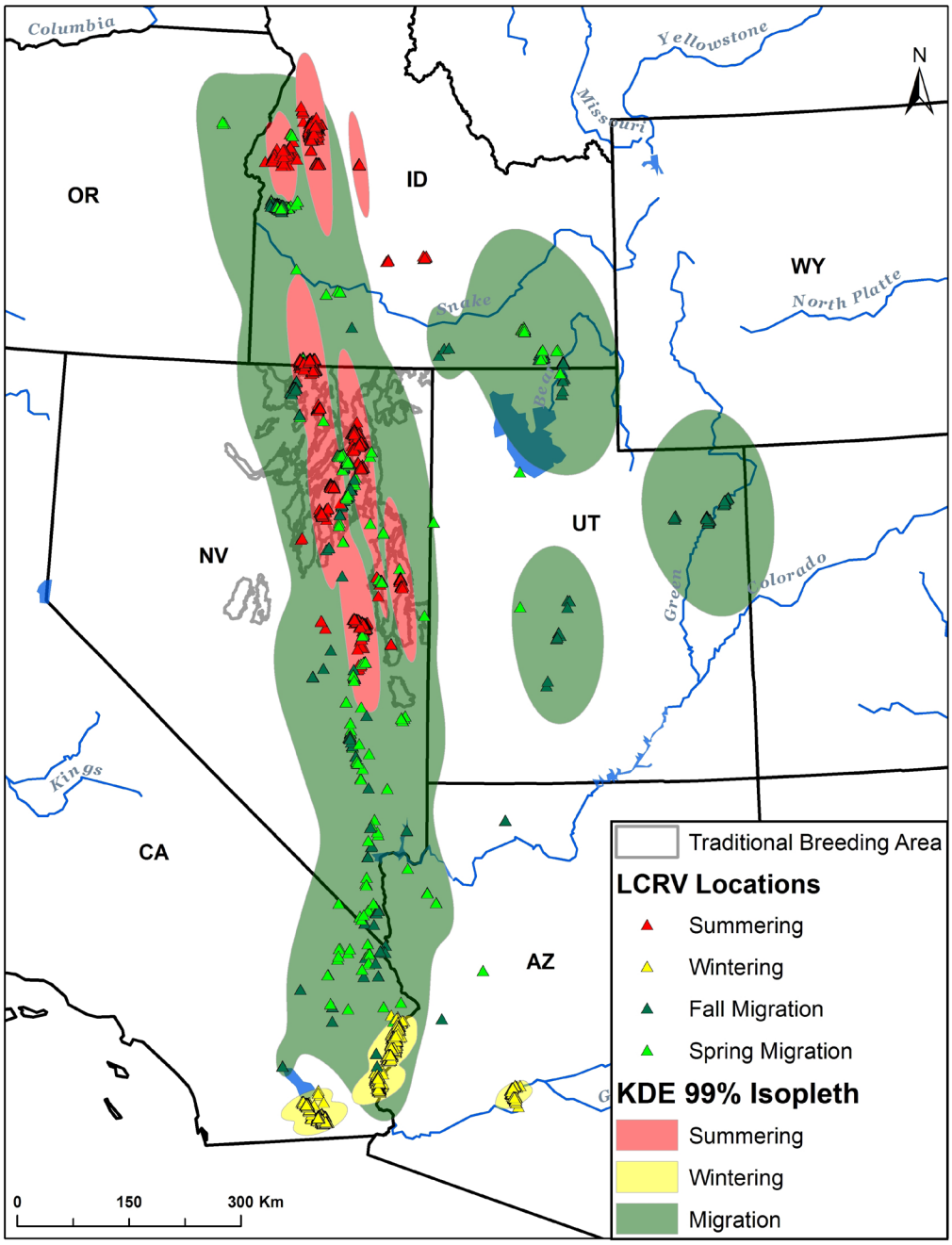


**Figure 2. An updated distribution map of the Lower Colorado River Valley Population of greater sandhill cranes based on data from 18 individuals equipped with platform transmitter terminals, 2014-2017.**

Uinta mountains in Utah; and 4) Sevier River Valley in central Utah. The newly identified area in northeast Oregon geographically overlapped with the Central Valley Population, whereas the 3 areas in southeast Idaho and northeast Utah overlap with the Rocky Mountain Population (Fig. 3).

## Summer

The updated distribution map (Fig. 2) includes previously identified summer areas in northeastern Nevada but now includes 3 new summer areas previously not identified for the LCRVP in Idaho: 1)

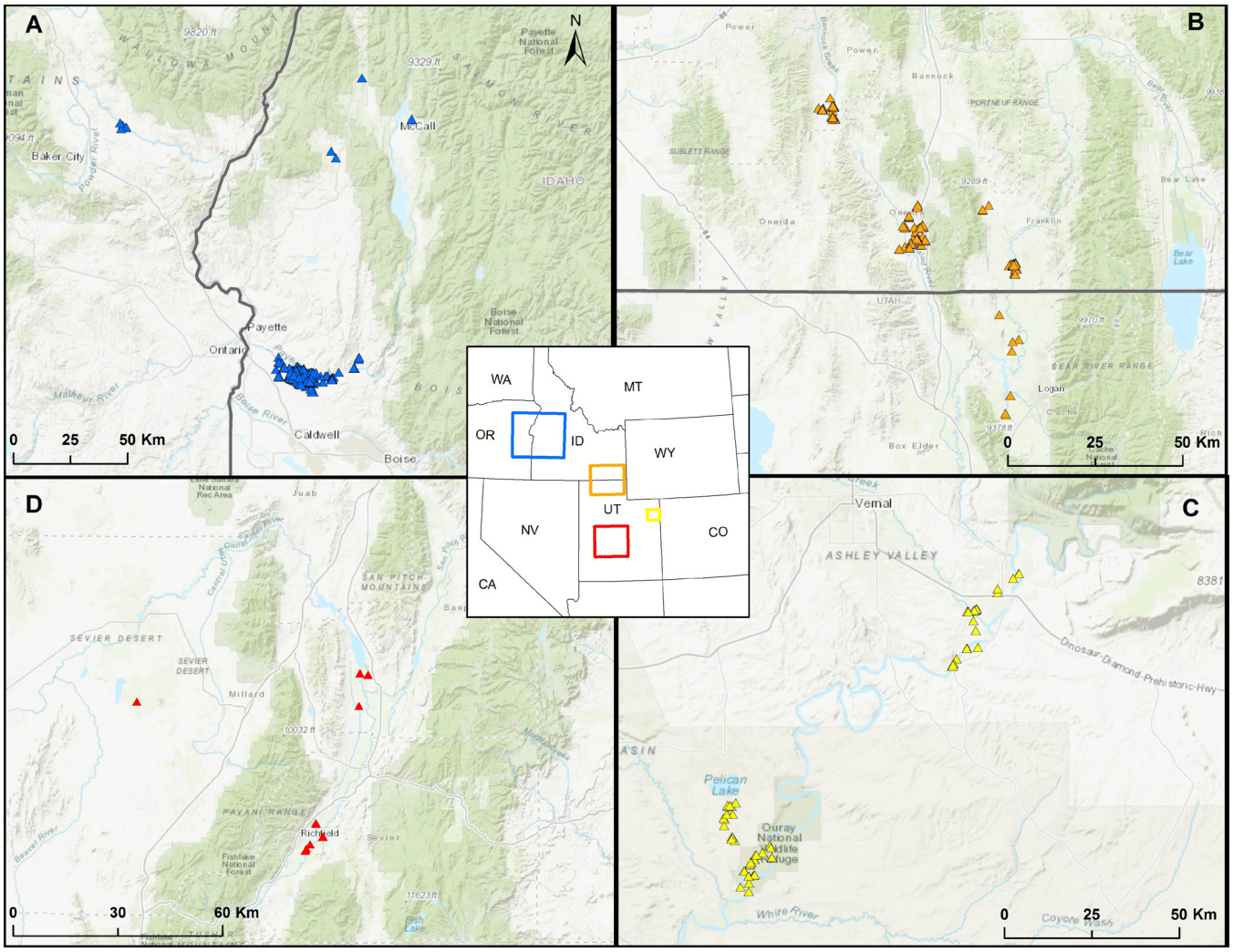


**Figure 3. Newly identified migration areas of the Lower Colorado River Valley Population based on data from 18 greater sandhill cranes equipped with platform transmitter terminals, 2014-2017, in (A) southwest Idaho near the Duck Valley Indian Reservation north into the Payette River Valley, extending northwest into northeastern Oregon, (B) Cache Valley of Idaho and Utah, (C) Duchesne River Valley south of the Uinta Mountains in Utah, and (D) Sevier River Valley in central Utah.**

Long Valley, 2) Midvale-Indian Valley, and 3) Duck Valley Indian Reservation, which is an extension of traditional areas in Nevada (Fig. 4).

### Winter

The updated distribution map includes previously identified winter areas on Cibola and Sonny Bono Salton Sea NWRs, Colorado River Indian Tribes land, and in close proximity of Brawley, California (Collins et al. 2016, Conring 2016). Also, we corroborated information from previous Flyway management plans and confirmed 1 winter area for the LCRVP, the Gila River Valley in southern Arizona (Fig. 5), via a PTT-tagged crane.

## DISCUSSION

The goal of our study was to provide an updated distribution map for LCRVP cranes by using PTTs. The updated map included numerous new migratory, summer, and winter locations not previously identified via surveys conducted by state agencies or the USFWS. Our results highlight the limitations of ground or aerial surveys over large geographic regions and stress the importance of combining on-the-ground and aerial surveys with PTT data. For example, survey efforts in the summer are concentrated in the Ruby Valley, Nevada, and traditionally not conducted in Idaho. The extent of the distribution of the LCRVP extends farther north and

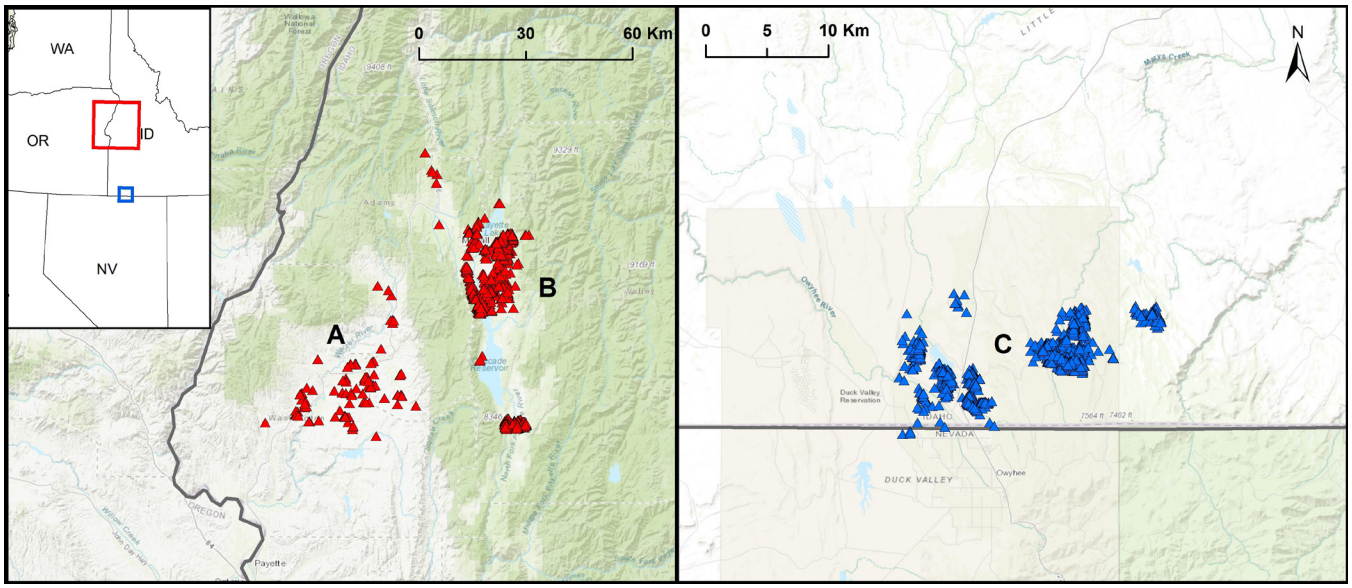


**Figure 4. Newly identified summering areas of the Lower Colorado River Valley Population based on data from 18 greater sandhill cranes equipped with platform transmitter terminals, 2014-2017, in (A) Midvale-Indian Valley, Idaho, (B) Long Valley, Idaho, and (C) Duck Valley Indian Reservation.**

east than previously expected, and most importantly, overlaps with areas commonly affiliated with the Central Valley and Rocky Mountain Populations. Our results highlight the importance of completing a thorough evaluation of the distribution of the 3 greater sandhill crane populations in the Intermountain West due to population delineations that were built upon incomplete data sets, using technologies that were previously unavailable.

We caution that the updated map may not incorporate the entirety of the LCRVP distribution due to the small sample size of PTT-tagged cranes. Kruse et al. (2017) found that LCRVP birds selected wetland habitats during summer in Idaho and Nevada, and wetlands are typically interspersed in the mountain valleys throughout the geographic extent of the American West. Given the large geographic extent of the Intermountain West, and subsequent location and juxtaposition of wetlands in this region, conservation and management of western crane populations would benefit from habitat suitability analyses to develop predictive models of potential occupancy from PTT locations to identify areas for expanded or focused survey efforts.

The migratory areas used in northeast and central Utah were from 3 of our 18 PTT-tagged cranes and are likely the result of exploratory movements by non-breeding cranes. We deployed PTTs on the wintering grounds based on plumage characteristics, and this method does not differentiate specific age classes (2-3 years post hatch, >5 years post hatch, etc.), so our sample likely included subadults that, at the time of PTT deployment, did not have established breeding territories. Therefore, our updated map may underestimate the extent of the LCRVP in the summer and yet may simultaneously over-represent the distribution of the LCRVP during migration. Exploratory movement is a common phenomenon among subadult cranes after the adults evict them in efforts to raise a new colt. The unexpected movements into Utah were during migration, when non-breeding cranes either form a pair-bond for mating or join a bachelor group with other cranes. As such, the new areas identified in Utah (and other areas) were a function of 1) capture location, 2) site fidelity, 3) age at capture and 4) longevity of crane and PTT. Therefore, we suggest research and management agencies use professional discretion when affiliating geographic regions in the Intermountain West with existing management populations of greater sandhill cranes due to the variation in the 4 factors listed above. Regardless of proximate mechanisms that drive migration and subsequent winter and summer termini, the new areas identified in our updated map are important for greater sandhill crane conservation and management in the western United States because of the extent of the previously unidentified population overlap.

Our data emphasize the current lack of knowledge

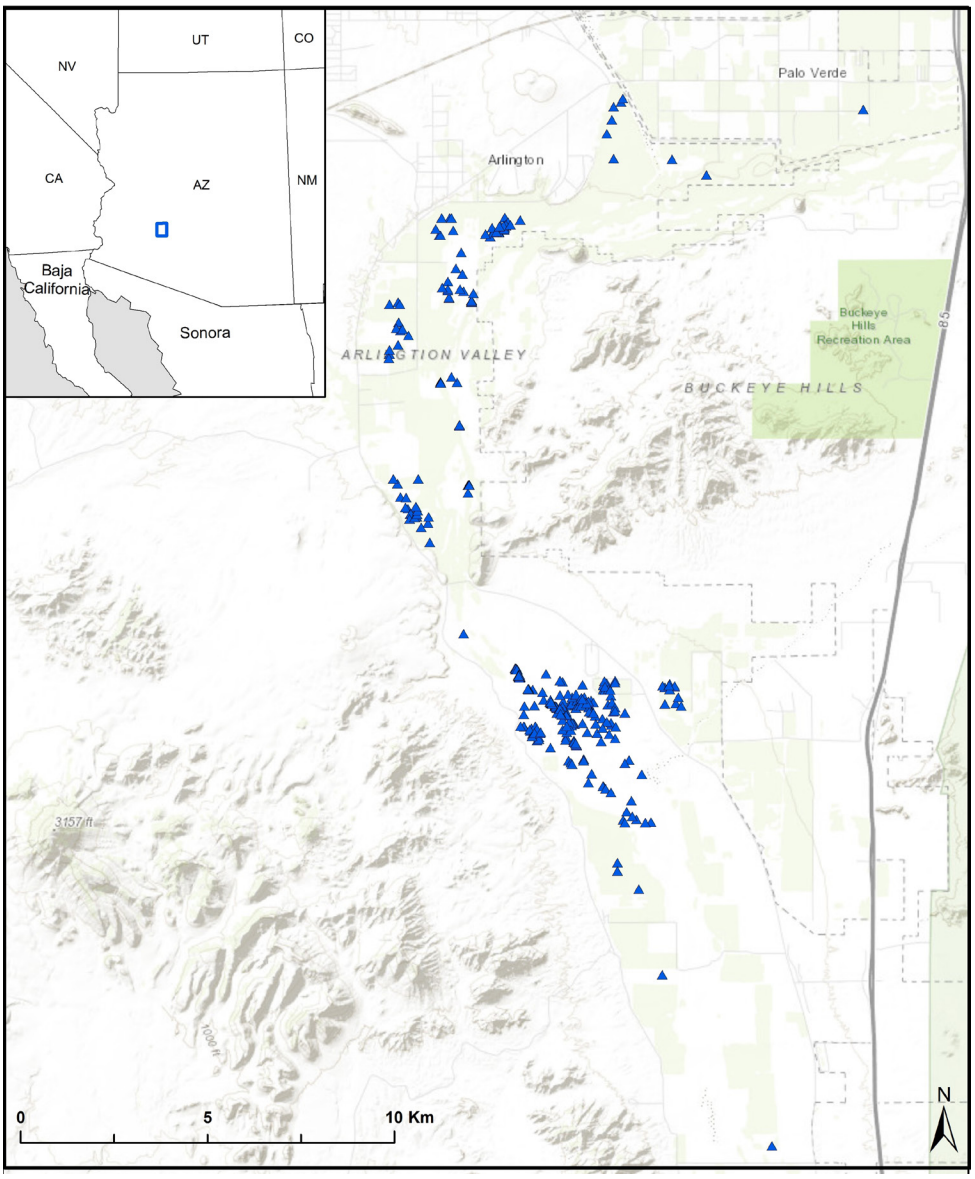


**Figure 5. Confirmed wintering area of the Lower Colorado River Valley Population of 18 greater sandhill cranes equipped with platform transmitter terminals, 2014-2017, in the Gila Bend on the lower Gila River southwest of Phoenix, Arizona.**

on the extent of the distribution of the CVP, LCRVP, and RMP, which may have long-term important management implications due to various state-level harvest and management guidelines affiliated with each respective population. We suggest combining long-term monitoring efforts via additional PTT-tags, color bands, and on-the-ground and aerial surveys throughout the west to aid in the development of new distribution maps for the CVP, LCRVP, and RMP. Finally, we suggest management agencies and researchers collaborate and revisit the objectives and need for discrete population affiliations to maximize crane conservation efforts in the Intermountain West.

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