2016 MIGRATORY WATERBIRD AND SHOREBIRD SURVEYS TO INFORM SOLAR ENERGY ZONE PLANNING, AVIAN IMPACT MINIMIZATION, AND SPECIES CONSERVATION IN THE SAN LUIS VALLEY, COLORADO

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INTRODUCTION

In 2012, the U.S. Department of the Interior (DOI) and U.S. Department of Energy (DOE) designated approximately 6600 ha (16,308 ac) of Bureau of Land Management (BLM) lands in the San Luis Valley (SLV) as Solar Energy Zones (SEZs) through the *Approved Resources Management Plan/Record of Decision (ROD) for Solar Energy Development in Six Southwestern States* (BLM 2012a). SEZs are solar energy development focus areas with high intensity solar radiation (>6.0 kw/m^2/day) and where land use priority includes generation of renewable energy to meet national energy diversification and climate change goals. The four SEZs in the SLV include: 1) De Tilla Gulch, approximately 4.3 km^2 (1,064 ac), located in Saguache County; 2) Los Mogotes East, approximately 10.7 km^2 (2,650 ac), located in Conejos County; 3) Antonito Southeast, approximately 39.4 km^2 (9,712 ac), also located in Conejos County; and 4) Fourmile East, approximately 11.7 km^2 (2,882 ac), located in Alamosa County (Fig. 1).

The SLV, with the Rio Grande and Conejos rivers and a wide array of wetland complexes, is a major migratory flyway for wetland birds protected under the Migratory Bird Treaty Act (16 U.S.C. 703–712). The *Draft/Final Programmatic Environmental Impact Statement (PEIS) for Solar Energy Development in Six Southwestern States* (BLM 2010, 2012b) identified direct and indirect effects of solar energy development on wildlife, primarily habitat loss/alteration, disturbance from human presence, temporary and chronic noise disturbance, and injuries and mortalities. Of particular concern to migratory birds is the potential for behavioral attraction to solar energy facilities that reflect the sun, which may result in injury or death via collisions with infrastructure, exposure to fire, and burning at standby points (McCrary et al. 1986). In 2014, the National Fish and Wildlife Forensics Laboratory released the findings of a study on bird mortality at three solar energy facilities using different solar technologies—photovoltaic, trough system with parabolic mirrors, and power tower—in southern California (Kagan et al. 2014). They reported injury and mortality at all three solar facilities from impact trauma (from collisions with solar panels), solar flux (resulting in burning), and predation. They documented mortality for 233 individual birds of 71 species, from a variety of taxa including waterbirds (e.g., grebes, coots, pelicans, cormorants, gulls) and shorebirds (e.g., avocets, herons, sandpipers).

To protect the diverse bird life in the SLV from impacts of solar energy facilities, the BLM contracted Animas Biological Studies (ABS) to conduct migratory waterbird and shorebird surveys across the SLV prior to the development of the four SEZs. The results of these surveys will inform the BLM on the diversity and abundance of migratory waterbirds and shorebirds using the SLV as well as to guide the development of mitigations and management recommendations for avian protection during construction and operation of proposed solar energy facilities. ABS initiated spring and fall migratory waterbird and shorebird surveys in 2015 and reported the results of those surveys to the BLM (Animas Biological Studies 2016). ABS initiated a second year of surveys in 2016. This report summarizes those survey results and compares them with the results from 2015.

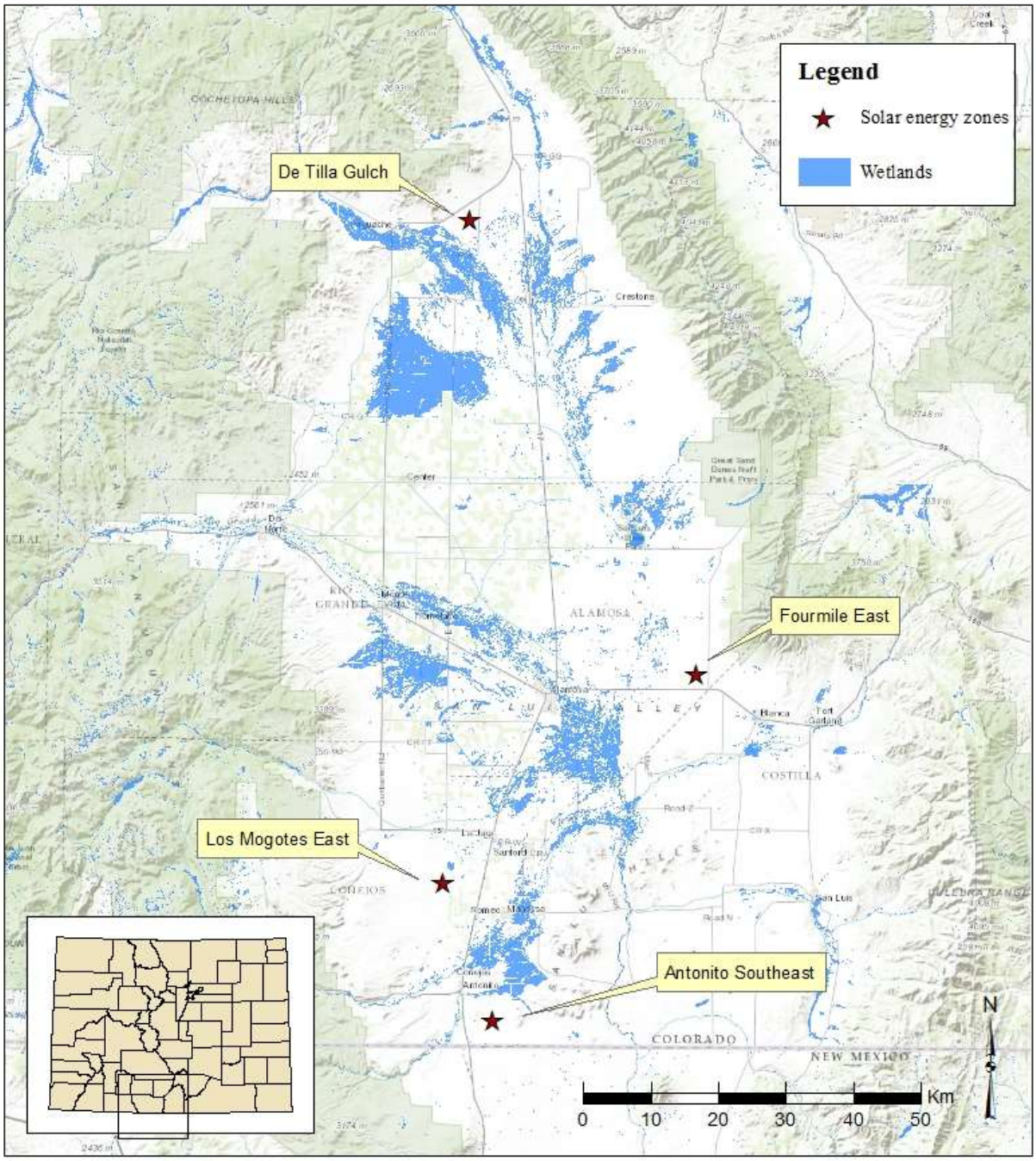

FIGURE 1.

Location of solar energy zones in the San Luis Valley.

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STUDY AREA

The SLV is a large, high desert, intermountain valley extending approximately 170 km long by 75 km wide, from south-central Colorado into north-central New Mexico (Fig. 1). In Colorado, the valley is bound to the east by the Sangre de Cristo Mountains and to the west by the San Juan Mountains. The valley floor averages about 2345 m (~7,700 ft) and is nearly flat, with the exception of the San Luis Hills and the Great Sand Dunes. Land cover in the SLV, as described and mapped by the Southwest Regional GAP Analysis Project (Lowry et al. 2005), is dominated by semi-desert shrub-steppe, with greater than 25% perennial grasses and an open shrub and/or dwarf shrub component; greasewood (*Sarcobatus vermiculatus*) flats, dominated by greasewood and generally occurring in areas with saline soils, a shallow water table, and intermittent flooding; and agriculture, where pasture or crops account for more than 20% of vegetative cover. Additionally, a variety of wetlands and deep water habitats occur across the SLV, including riverine (i.e., rivers, streams, irrigation ditches), lacustrine (i.e., ponds, lakes, and reservoirs), and palustrine (i.e., wet meadows, marshes, shallow ponds, and playas) systems (Cowardin et al. 1979). The Rio Grande River is the most prominent water course, running southeasterly across the Colorado portion of the SLV. Numerous deep water lakes and reservoirs occur across the SLV, most designated as State Wildlife Areas (SWAs) managed by Colorado Parks and Wildlife (CPW). Marsh, wet meadow, shallow pond, and playa environments also occur on SWAs, BLM lands, and the SLV National Wildlife Refuge (NWR) complex, consisting of Alamosa, Baca, and Monte Vista NWRs.

In 2015, we targeted five wetland habitat types with potential to attract migrating waterbirds and shorebirds—1) shallow emergent wetlands, 2) wet meadows, 3) riparian areas, 4) playas, and 5) deep-water lakes/reservoirs. By sampling a variety of wetland types of varying size, vegetative type/cover, and water level/flow, this approach would maximize data collection across a broad array of shorebird and waterbird species with potential to migrate and stopover in the SLV. We coordinated with BLM biologists to select two survey locations within each of these habitat types and with strategic proximity to the four SEZs. To maximize our survey effort with the available budget, BLM biologists suggested that we drop lacustrine habitats (i.e., lakes and reservoirs) from the survey plan in 2015 because the suite of species that utilizes these habitats also typically utilizes emergent wetlands and playas during migration. Thus, in 2015 we surveyed emergent wetlands, wet meadows, riparian areas, and playas only. However, our 2015 results indicated that wet meadows supported comparatively low densities of waterbirds and shorebirds compared with the other habitat types and did not provide much meaningful data. Therefore, in 2016 we modified our approach to drop wet meadow sites and add new deep-water sites.

Our 2016 monitoring approach included surveying two representative sites per each of the target wetland habitat types (shallow emergent, riparian, playa, and deep water) multiple times across the spring and fall migratory periods. We selected representative survey sites, occurring on both federal and state lands, through coordination with the BLM as well as CPW and NWR biologists.

Shallow Emergent Wetlands

Shallow emergent wetlands include shallow ponds and marshes with short or tall herbaceous emergent vegetation, such as rushes (*Juncus* spp.), sedges (*Carex* spp.), bulrushes (*Scirpus* spp.,

Schoenoplectus spp.), and cattails (*Typha angustifolia*), and/or submergent or floating vegetation. While water levels may vary, shallow emergent wetlands may hold water year-round and provide critical migratory stopover, foraging, and nesting habitat for a variety of waterbirds (e.g., grebes, ducks, geese), wading birds (e.g., herons, egrets, ibises, cranes), and secretive marsh birds (e.g., bitterns, rails). Because they are permanent to semi-permanent wetlands, these habitats likely host the highest densities of migratory waterbirds and shorebirds in the SLV.

As in 2015, we selected Russell Lakes SWA and Monte Vista NWR as representative shallow emergent wetland sites (Fig. 2). Russell Lakes SWA is an ~1218 ha wetland complex comprised of shallow lakes and marshes and located about 40 km north of Monte Vista and 16 km south of Saguache. The site includes almost 50 game management units (GMUs) of varying size and habitat type, including some upland (i.e., non-wetland) habitat. We selected a sample of GMUs with emergent wetland habitat for spring and fall migration surveys. Due to changes in water levels and available wetland habitats between the spring and fall migration periods, we did not sample the same GMUs during each season (see Map 1 in Appendix A). The GMUs sampled ranged in size from approximately 2.3 to 86.2 ha. Monte Vista NWR, our second shallow emergent sampling area, is part of the San Luis Valley NWR complex comprising approximately 5991 ha of intensively managed habitat for a variety of waterbirds and shorebirds. The refuge is located approximately 10 km south of Monte Vista and includes both short and tall emergent wetlands. We selected two adjacent shallow emergent management units on Monte Vista NWR for study, totaling approximately 655 ha (Map 2 in Appendix A).

Deep-water Reservoirs

Reservoirs are permanent artificial lakes in which the water level may fluctuate according to a combination of seasonal precipitation as well as applied management and releases. These large impoundments often do not have extensive shoreline vegetative communities. They typically contain fish and provide deep water foraging opportunities for fish-eating waterbirds. (e.g., ducks, herons, pelicans, cormorants, and grebes). During lower water levels, extensive mud flats and gravel shoreline also provide habitat for wading birds (e.g., sandpipers, avocets, and ibises).

We selected Smith Reservoir SWA and Homelake SWA for surveying reservoir habitat in the SLV (Fig. 2). Smith Reservoir includes 386 ha of lake and shoreline habitat located approximately 4 miles south of Blanca (Map 3 in Appendix A). The smaller Homelake, at 131 ha, flanks the western portion of Rio Grande State Wildlife Area, about 1.5 miles east of Monte Vista (Map 4 in Appendix A).

Riparian Areas

Riparian habitats include rivers, streams, and creeks typically flanked by cottonwoods (*Populus* spp.), willows (*Salix* spp.), or other woody vegetation. Riparian corridors but may serve as stopover habitat for a variety of waterbirds and shorebirds. The woody margins around water courses are also suitable nesting habitat for shorebirds such as herons and egrets. The Rio Grande River is the most prominent water course in the SLV, but other notable rivers include the Conejos and Alamosa rivers, and San Luis and La Garita creeks. Irrigation ditches also provide narrow stringers of riparian habitat across the valley floor.

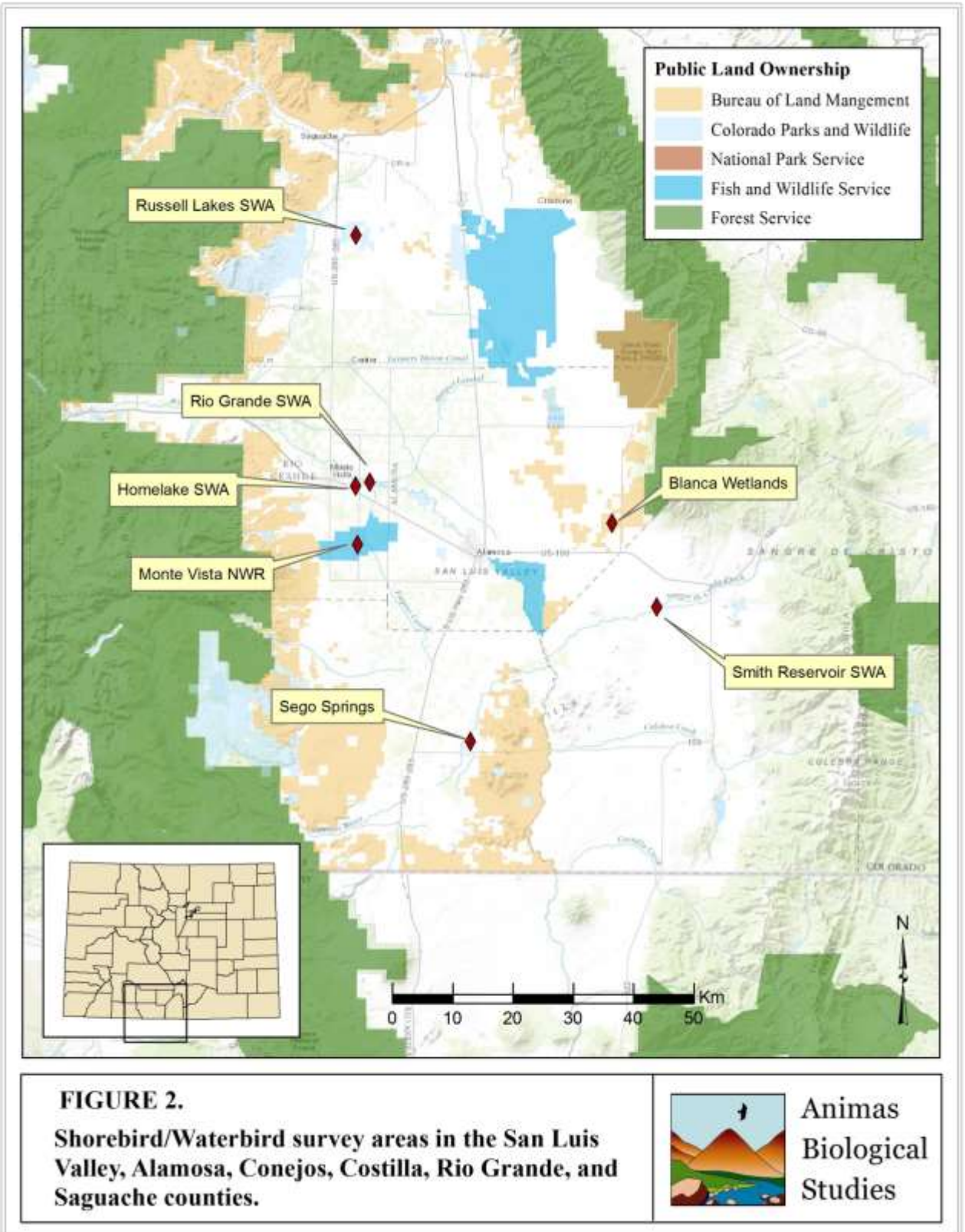

FIGURE 2.

Shorebird/Waterbird survey areas in the San Luis Valley, Alamosa, Conejos, Costilla, Rio Grande, and Saguache counties.

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We selected two representative riparian areas in the SLV for waterbird and shorebird surveys in 2015 and 2016. The first site is the western portion of the Rio Grande SWA, an approximately 5 km corridor along the Rio Grande River, beginning about 5 km east of Monte Vista (Fig. 2). The site includes mature cottonwood overstory, understory vegetation of willows (dense in some areas), as well as sloughs and oxbows with emergent vegetation (Map 5 in Appendix A). Additionally, we selected a riparian zone in the southern San Luis Valley along the Conejos River, Sego Springs SWA, an approximate 1.5 km stretch of riparian habitat located approximately 12 km southeast of La Jara. This site is also dominated by mature cottonwoods and willows, with adjacent emergent wetland habitat (Map 6 in Appendix A).

Playas

Playas are flat-bottomed desert basins that form shallow lakes during periods of abundant waters. They are ephemeral wetlands, typically water covered during spring runoff, and then dry by early summer, depending on annual precipitation and snowpack conditions. SLV playas also hold water in mid- to late summer, during the monsoon season. The SLV includes an abundance of historic playas, some of which have been dry over the past decade due to extended drought conditions. However, one of the most extensive, historic playa environments in the SLV, the BLM's Blanca Wetlands, is currently managed to provide water during the critical migratory and breeding periods for waterbirds and shorebirds. A large (>3500 ha) complex with over 200 lakes, the site offers ideal opportunities for surveying playa habitats in this study. We selected Blanca Wetlands as the primary playa survey area. The site is located approximately 24 km southeast of Saguache and 24 km southwest of Crestone (Fig. 2). In coordination with the BLM, we selected a sample of five playa lakes of varying size (12–35 ha), water level, salinity, and extent and composition of shoreline habitat (Map 7 in Appendix A).

Additionally, we selected Alta Lake, a small (~4 ha) playa located on BLM lands within the Antonito Southeast SEZ, approximately 3.6 km north of the Colorado–New Mexico border (Fig. 2). Although only a single and small playa, its location within the SLV's largest SEZ renders it an important area to survey. Alta Lake contained water during the spring surveys in 2015; however, the playa was completely dry during fall 2015 surveys. We revisited Alta Lake in spring and fall of 2016, and it was also dry. BLM biologists also suggested Cove Lake, located ~5.5 miles southeast of Antonito, as an alternate playa habitat for survey. Similar to Alta Lake, cove Lake was also dry during spring and fall of 2016. Thus, we only surveyed one play location in 2016, Blanca Wetlands.

METHODS

SURVEY WINDOWS

The International Shorebird Survey (ISS) and the Program for Regional and International Shorebird Monitoring (PRISM) have established protocols for surveying shorebirds on their migratory stopover grounds (see http://ebird.org/content/iss/). Surveys consist of counts or estimates, depending on bird density, spread across the spring (mid-March–mid-June) and fall (mid-July–late October) migratory periods, with one survey conducted about every 10 days.

Multiple visits spread across the migratory periods provide a broad understanding of waterbird and shorebird use of stopover habitats compared with only a single survey per season. Due to funding constraints, we followed a modified ISS/PRISM schedule for surveying migratory shorebirds and waterbirds in the SLV, to maximize the probability of encountering the greatest number of species and individuals at various wetland complexes across the spring and fall migratory periods. Length of waterbird/shorebird migration periods, as well as local water availability, varies from spring to fall; thus, our survey schedule also differed seasonally.

Spring Migration

Spring water levels in the SLV are typically higher than fall due to run-off from snowmelt as well as water management (by state and federal agencies) to benefit migratory and nesting waterbirds/shorebirds. Within family taxonomical groups, spring migration typically occurs more rapidly and over a shorter timeframe than fall, with peak waterfowl movement in March, and most other waterbirds and shorebirds migrating from mid-April through late May. However, spring leaf-out is delayed until late May due to the relatively high elevation. Considering these factors, our approach during spring migration included five field surveys at the shallow emergent and playa sites, and three field surveys in the wet meadow and riparian areas. We staggered spring surveys across five 2–3 week periods, from mid-March through mid-June (Table 1, in Appendix A), to insure adequate sampling across the spectrum of migratory waterbirds/shorebirds using the SLV. Surveys occurred about 2–3 weeks apart. We visited shallow emergent wetlands, playas, and reservoirs during all five survey periods (mid-March–late May) to accommodate peak migration of waterfowl (earlier than other waterbirds/shorebirds) as well as migration of other waterbirds, wading birds, and marsh birds (Table 1, in Appendix A). Riparian surveys commenced in the third survey period (around mid-April) and continued through mid-June, coinciding with water management (wet meadow) and spring leaf-out (riparian) at selected survey sites (Table 1, in Appendix A).

Fall Migration

Fall migration generally occurs over a longer time frame than spring, beginning in mid-July and continuing through late October; however, the bulk of individuals typically move through by the end of September. Some SLV wetlands may be dry in fall due to a combination of factors including low spring run-off, drought, and competing water demands from agriculture and human consumption. These include some shallow emergent habitats and most playas in the SLV. Taking these factors (and available funding) into account, our approach to fall migration involved conducting four surveys in playa and deep-eater habitats, beginning in mid-July, and three surveys in shallow emergent and riparian areas, beginning in early August, with each survey approximately 2–3 weeks apart, similar to the spring schedule (Table 1, in Appendix A).

SAMPLING APPROACH

We employed a combination of sampling methods within the varying wetland habitat types to collect data efficiently and effectively. These included area counts, point counts, and line transects (see below). We used binoculars and high-powered spotting scopes to view, identify, and count/estimate birds during each survey. All surveys were conducted during daylight hours.

We identified individuals to family group and species, where possible. Identification to species was not possible for some individuals for the following reasons: 1) birds in large flocks were concealed by other birds; 2) vegetation or other physical features partially concealed some birds; 3) birds moved in and out of the study area too quickly for species identification; and 4) in fall, immature birds of several species may exhibit similar plumages.

Area Counts

We conducted area counts at playa habitats (Blanca Wetlands), deep-water reservoirs (Smith and Homelake), and at Russell Lakes SWA (shallow emergent), where we could clearly define our sampling area. We conducted area counts one or more viewing points per site and/or by slowly walking/driving along the edge of the habitat. We conducted direct counts at sites with relatively small numbers of birds (generally <100) or where birds exhibit little movement. In areas with greater bird abundance or bird movement, we employed an estimation method. The estimation method involved first counting a small number of birds (typically 10) in a large flock to develop a count image for 10 birds. Following, we applied the count image to the flock by 10's, counting up to 100 birds and developing a new count image for 100 birds. We applied the count image of 100 to the entire flock, or, for very large flocks, we continued to increase the count image to 500 or even 1,000 birds or more. Once we established a set count image appropriate for the flock, we estimated the number of birds in the flock visible at the viewing station.

We made every effort to produce as little disturbance as possible when conducting area counts. We minimized disturbance by following these guidelines: 1) we observed birds from a distance; 2) did not approach flocks directly; 3) we made as little noise as possible; and 4) we avoided sudden movements. During field surveys in spring and fall, we estimated the proportion of each area count survey site we could not adequately view due to vegetative cover for extrapolation during data analysis (see Methods: Data Analysis and Reporting).

Line Transects

We sampled the migratory population of shorebirds/waterbirds via line transect surveys, following a distance sampling methodology (Buckland et al. 1993), at Monte Vista NWR. After some field reconnaissance, we established six one-sided line transects in shallow emergent habitat on Monte Vista NWR. Both of the selected management units on the refuge were too large to conduct accurate area counts. There, various levies flank emergent wetlands, providing appropriate conditions for walking straight line transects and sampling the habitats. We established the 0.5-km transects (totaling 3 km) flanking shallow emergent habitats to sample as much area as possible within the two management units. Survey methods followed wet meadow transects, except we only surveyed along one side of the line transect. We chose the one-side line transect instead of a standard line transect approach to account for the difficulty in detecting and recording a high density of birds/flocks that may flush in large numbers simultaneously on both sides of a transect. A standard line transect approach could have resulted in observers failing to detect or correctly identify some birds and/or recording imprecise distances or bearings.

We surveyed each site by slowly walking along transects and recording each bird observed. We measured the distance and radial bearing to each single bird or cluster of birds using a laser

range-finder and compass. We anticipated the detection of a large number of birds and flocks, and to make data recording more efficient we assigned detections to a distance interval rather than reporting exact distances. Distance categories were as follows: 0–10 m, 11–25 m, 26–50 m, 51–100 m, 100–200 m, and >200 m.

Point Counts

We conducted point count surveys within our selected riparian survey areas, Rio Grande and Sego Springs SWAs. Riparian areas lend themselves well distance sampling because of their accessibility for pedestrian transects within the habitat and their; however, riparian corridors are rarely linear. Thus, riparian corridors are better-suited for point count rather than line transect surveys. Accordingly, we sampled the migratory population of shorebirds/waterbirds in selected riparian areas via point counts, following a distance sampling methodology (Buckland et al. 1993). Since visibility is often restricted in riparian areas due to woody vegetation and the meandering nature of water courses, we spaced survey points along riparian corridors at intervals of approximately 250 m. At each point, we identified and counted birds for a period of 5 minutes, measuring the distance (via rangefinder) and bearing (via compass) to each bird/flock from the point. We also recorded birds observed between points, though separated those data from point count data. Similar to line transects, we utilized pre-defined distance intervals rather than exact distances for bird detections. Distance categories were as follows: 0–10 m, 11–25 m, 26–50 m, 51–100 m, 100–200 m, and >200 m.

Supplemental Data

In addition to counting/estimating waterbirds and shorebirds at each study site, during field surveys we also noted individuals of species flying over survey areas or utilizing habitat adjacent to survey areas. We also recorded the presence (but not abundance) of other (non-waterbird/shorebird) avian species using or flying over each wetland site during migration.

Using handheld GPS units, we recorded the locations of sampling points and transect start and end points. Additionally, we took representative photographs of each study area.

DATA ANALYSIS AND REPORTING

We pooled area count data within and across sites and calculated total individuals, individuals per species, and individuals per family for each survey period and across all survey periods. We extrapolated our count data to account for habitat not viewable within sampling areas during each survey. At Russell Lakes SWA, we were unable to adequately view 60% of the shallow emergent habitat in selected GMUs in spring and 45% in fall. At Blanca Wetlands and Smith Reservoir we were unable to adequately view 5% of during spring and fall surveys. Thus, we calculated an extrapolated total number of individuals, number of individuals per species, and number of individuals per family during each survey and across all survey periods. We then calculated an extrapolated mean per species and family across the spring and fall survey periods. Following that, we calculated mean bird density (birds/ha) for each species and family by dividing the extrapolated means by the total sampling area. We did not extrapolate data at Homelake SWA because we were able to view the entire site unobstructed during each survey.

We analyzed line transect and point count data using program Distance (Thomas et al. 2010). We modeled the mean overall bird density (and abundance) across the spring and fall sampling periods as well as within each survey period (where possible, see Results). Additionally, we modeled mean density per species and family across spring and fall. For both line transect and point count data, we compared models integrating 1) half normal, 2) hazard rate, and 3) negative exponential detection functions, with cosine and/or simple polynomial adjustments. Preliminary analyses indicated the uniform detection function resulted in too many errors for reliable density and abundance estimates, so we eliminated the uniform detection function our analyses. For each analysis, we selected the best model using Akaike's Information Criterion (AIC); the model with the lowest AIC represents the most competitive model.

Because we surveyed only a sample of wetland habitats in the SLV, we extrapolated density and abundance estimates for the four wetland types defined in this study (shallow emergent, riparian, playa, and deep water) across the total area of these wetland types in the SLV. These data provide our best estimate of overall abundance of migratory waterbirds and shorebirds during spring and fall migration. We derived the area of SLV wetlands using GIS data from the U.S. Fish and Wildlife Service's National Wetland Inventory (NWI; available at http://www.fws.gov/wetlands/index.html). The NWI identifies six wetland types in Colorado: 1) freshwater emergent wetland, 2) freshwater forested/scrub wetland, 3) freshwater pond, 4) lake, 5) riverine, and 6) other. The other category consists of shorelines of cobble, sand, mud, or organic/vegetative material. In ARCGIS, we clipped the NWI wetland layer to fit the approximate boundary of the SLV and calculated the total area of each of the six wetland types. Based on our clipped GIS layer, the total area of wetlands in the SLV is 87 473.1 ha, with 78 924.8 ha of freshwater emergent wetland, 2223.9 ha of freshwater forested/scrub wetland, 1377.2 ha of freshwater pond, 2490.7 ha of lake, 1947.8 ha of riverine, and 508.7 ha of cobble.

Our defined wetland habitats varied somewhat from the NWI categories; therefore, to extrapolate our data appropriately, we examined the NWI map to determine proper placement of our defined wetland types into NWI categories. We determined that shallow emergent habitat types mostly overlapped the NWI's freshwater emergent wetland category; thus, we extrapolated bird densities across shallow emergent sites to the known area of freshwater emergent wetland habitat across the SLV (78 924.8 ha). NWI classified playas as either ponds, freshwater lakes, or shorelines (other); thus, we extrapolated bird density data from our playa (Blanca Wetlands) and deep-water sites (Smith Reservoir and Homelake) to the known area of total ponds, freshwater lakes, and shoreline habitat in the SLV (4376.6 ha). We determined our riparian survey areas generally encompassed both the NWI's riverine and freshwater forested/scrub wetland classification; thus, we extrapolated the mean density of riparian areas across the know area of riverine and freshwater forest/scrub wetland in the SLV (4171.7 ha).

RESULTS

We detected individuals of 62 waterbird and shorebird species of 12 families during spring and fall surveys across the SLV in 2016. In spring, we observed 50 species and in fall we detected 52 species (Table 2, in Appendix B).

SPRING MIGRATION

Shallow Emergent Area Counts

Russell Lakes SWA

During five spring migration surveys at Russell Lakes, ABS biologists detected 3,484 individuals comprising 33 species of 11 families (mean=696.8 birds/survey). We detected the greatest number of individuals (1,443) during Survey 1 and the least (215) during Survey 5. Green-winged Teal (588; 16.7% of total detections), American Coot (564; 16.2%) and Sandhill Crane (450; 12.5 %) comprised the three most abundant species detected across all spring surveys. The Anatidae family by far comprised the majority (65%) of total detections.

Extrapolated data estimates a low of 537.5 birds in the five GMUs during Survey 5 and a high of 3,607.5 birds during Survey 1 (mean=1,742.0 birds/survey; Table 3 in Appendix B). Overall density of waterbirds and shorebirds in the five GMUs surveyed in spring ranged from a low of 3.07 birds/ha (Survey 5) to a high of 20.64 birds/ha (Survey 1; mean density=9.97 birds/ha). Table 3 (in Appendix B) provides extrapolated total, mean, and mean density estimates per species at Russell Lakes SWA across the spring migration period. Figure 3 (in Appendix B) shows the mean density per family across spring migration.

Shallow Emergent Line Transects

Monte Vista NWR

Across five surveys at Monte Vista NWR, we tallied 741 detections of 32 species and nine families of waterbirds/shorebirds. For all three model sets analyzed in program Distance (i.e., stratified by survey period, species, and family), the best model estimating bird density included the negative exponential function plus either a cosine or simple polynomial adjustment (Table 4 in Appendix B). Overall density of waterbirds/shorebirds was highest during Survey 1 (18.40 birds/ha) and lowest during Survey 4 (2.78 birds/ha). Mean density across spring migration was 5.18 birds/ha (Table 5 in Appendix B). Table 6 (in Appendix B) provides mean density and abundance estimates per species across all spring surveys, and Figure 4 (in Appendix B) shows the mean density per family across spring surveys. Northern Pintail, Mallard, Cinnamon Teal, and American Coot had the highest mean densities across the spring migration period; density for all other species was <1 birds/ha. The family Anatidae again had the highest density (75% of detections) during spring migration.

Playa Area Counts

Blanca Wetlands

During five spring migration surveys, we detected 8,791 individuals of 40 species and 9 families (mean=1,758.2 birds/survey). We detected the greatest number of individuals (3,120) during Survey 1 and the least (807) during Survey 4. Ruddy Duck (1,725; 19.6%), American Coot (1,347; 15.3%), and Redhead (786; 8.5%) were the most abundant species detected. Anatidae

comprised the majority (66%) of total spring detections.

Extrapolated data estimates a low of 849.5 birds during Survey 4 and a high of 3,284 during Survey 1 (mean=1,850.7 birds/survey; Table 7 in Appendix B). Overall density of waterbirds and shorebirds ranged from a low of 7.89 birds/ha (Survey 4) to a high of 30.49 birds/ha (Survey 1; mean density=17.18 birds/ha). Table 7 (in Appendix B) provides extrapolated totals, mean, and mean density estimate per species at Blanca Wetlands across the spring migration period. Figure 5 (in Appendix B) shows the mean density per family across spring migration.

Riparian Area Point Counts

Rio Grande SWA and Sego Springs SWA

Low encounter rate ($n \leq 20$ detections) at Sego Springs SWA in spring and fall precluded analysis of this site separately; thus, we pooled the data from the two riparian sites and modeled mean density across spring and fall as well as density within each survey period. We detected 14 species of six families of waterbirds/shorebirds (from 69 total detections) during three spring migration surveys (Survey Periods 3–5) at Rio Grande and Sego Springs SWAs. One species of a unique family detected, American White Pelican (Pelicanidae), was observed as a flyover only and is not represented in density and abundance estimates. The detection function and adjustment terms for the best models estimating bird density stratified by survey period, family, and species varied for the three model sets analyzed. The best model for survey period and family included a hazard rate with either a simple polynomial or cosine adjustment (both adjustments faired equally well). For data stratified by species, the half normal function with a simple polynomial adjustment represented the best model (Table 8, in Appendix B).

Overall density for pooled data at Rio Grande and Sego Springs SWAs ranged from a low of 1.07 birds/ha during Survey 3 (Survey Period 5) to a high of 2.04 birds/ha during Survey 1 (Survey Period 3). Mean density across the three surveys was 1.38 birds/ha (Table 9, in Appendix B). Table 10 (in Appendix B) provides mean density and abundance estimates per species across spring surveys, and Figure 6 (in Appendix B) shows mean density per family across spring surveys. Common Merganser by far was reported with the highest density compared to all other species. Anatidae again was the most frequently detected family group, with 79% of total observations (Fig. 6, in Appendix B).

Reservoir Area Counts

Smith Reservoir SWA

During five spring migration surveys at Smith Reservoir, ABS biologists detected 3,543 individuals comprising 26 species of 8 families (mean=708.6 birds/survey). We detected the greatest number of individuals (1,448) during Survey 2 and the least (102) during Survey 4. American Coot (1,396; 39.4% of total detections), Lesser Scaup (478; 13.5%) and Eared Grebe (366; 10.3 %) comprised the three most abundant species detected across all spring surveys. The Rallidae family comprised 39.4 % of total detections, slightly more than Anatidae (38.6%).

Extrapolated data estimates a low of 107 birds present at Smith Reservoir during Survey 4 and a high of 1,524 during Survey 2 (mean=745.9 birds/survey; Table 11 in Appendix B). Overall density of waterbirds and shorebirds ranged from a low of 1.17 birds/ha (Survey 4) to a high of 16.59 birds/ha (Survey 2; mean density=8.12 birds/ha). Table 11 (in Appendix B) provides extrapolated totals, mean, and mean density estimate per species at Smith Reservoir SWA across the spring migration period. Figure 7 (in Appendix B) shows the mean density per family across spring migration.

Homelake SWA

During five spring migration surveys at Homelake, we detected 897 individuals of 24 species and 9 families (mean=179.4 birds/survey). We detected the greatest number of individuals (339) during Survey 1 and the least (51) during Survey 5. Ruddy Duck (241; 26.7%), American Coot (229; 25.5%), and Western Grebe (113; 12.6%) were the most abundant species detected. Anatidae(54%) comprised a majority of total spring detections. Overall density of waterbirds and shorebirds ranged from a low of 1.84 birds/ha (Survey 5) to a high of 12.24 birds/ha (Survey 1; mean density=6.48 birds/ha). Table 12 (in Appendix B) provides totals, mean, and mean density estimate per species at Homelake SWA across the spring migration period. Figure 8 (in Appendix B) shows the mean density per family across spring migration.

FALL MIGRATION

Shallow Emergent Area Counts

Russell Lakes SWA

During three fall migration surveys at Russell Lakes SWA, we detected 1,612 individuals of 28 species and 10 families (mean=537.3 birds/survey). We detected the most birds (572) during Survey 3 (Fall Survey Window 4) and the fewest (494) in Survey 2 (Fall Survey Window 3. American Coot was by far the most frequently detected species (735 individuals; 45.6%), followed by Blue-winged Teal (145; 9.0%), and Green-winged Teal (140, 8.6%). Rallidae comprised 46% of detections and Anatidae, 40%.

Extrapolated data estimates a low of 1,235 birds during Survey 2 and a high of 1,430 birds during Survey 3 (mean=1,343.33 birds/survey; Table 13 in Appendix B). Overall density of waterbirds and shorebirds ranged from a low of 7.07 birds/ha (Survey 2) to a high of 8.18 birds/ha (Survey 3; mean density=7.68 birds/ha). Table 13 (in Appendix B) provides extrapolated totals, means, and mean density estimate per species at Russell Lakes SWA across the fall migration period. Figure 9 (in Appendix B) shows the mean density per family across fall migration.

Shallow Emergent Line Transects

In three fall surveys at Monte Vista National Wildlife refuge, we tallied 351 detections of 25 species and eight families. The best models estimating bird density stratified by survey period,

species, and family included the hazard rate function plus either a cosine or simple polynomial adjustment (Table 14, in Appendix B).

Overall density of waterbirds/shorebirds was highest (3.612 birds/ha) during Survey 1 (Fall Survey Period 2) and lowest during Survey 3 (Fall Survey Period 4; 2.273 birds/ha). Mean density across fall migration was 3.160 birds/ha (Table 15, in Appendix B). Table 16 (in Appendix B) provides mean density and abundance estimates per species across all fall surveys, and Figure 10 (in Appendix B) shows the mean density per family across fall surveys. Blue-winged Teal, American Coot, and Mallard had the highest mean densities across the fall migration period; teal not identified to species also factored high in the density estimates. The family Anatidae again had the highest density (71%) during fall migration, followed by Rallidae (23%).

Playa Area Counts

Blanca Wetlands

Due to weather constraints, we surveyed Blanca Wetlands during three of the four defined Fall Survey Windows—1, 2, and 3. We identified 15,018 individuals of 34 species and 10 families (mean=5006.0 birds/survey). We detected the greatest number of individuals (5,648) during Survey 1 (Survey Window 2) and the least (3,882) during Survey 3 (Survey Window 4). American Avocet (2,637; 17.6%), Wilson's Phalarope (2,044; 13.6%), American Coot (1,936; 12.9%), and Northern Shoveler (1,876; 12.5%) were the most abundant species detected. Anatidae made up 39% of detections; Scolopacidae, 29%; and Recurvirostridae, 18%.

Extrapolated data estimates a low of 4,086 birds in the five playa lakes during Survey 3 and a high of 5,945 during Survey 1 (mean=5,269.47 birds/survey; Table 17, in Appendix B). Overall density of waterbirds and shorebirds ranged from a low of 37.94 birds/ha (Survey 3) to a high of 55.20 birds/ha (Survey 1; mean density=48.93 birds/ha). Table 17 (in Appendix B) provides extrapolated totals, mean, and mean density estimate per species at Blanca Wetlands across fall migration. Figure 11 (in Appendix B) shows the mean density per family across fall migration.

Riparian Area Point Counts

We detected 13 species of six families during fall migration surveys in Rio Grande and Sego Springs SWAs. The number of detections (45) was about one-third less than that of spring migration (69). Due to small sample size, results from program Distance are less reliable than results from spring surveys. As in spring surveys, the detection function and adjustment terms for the best models estimating bird density stratified by survey period, family, and species varied for the three model sets analyzed. The best model estimating bird density per survey period included the negative exponential function with cosine adjustment. For density per species, the hazard rate function with simple polynomial adjustment was the best model. For density per family, the negative exponential function with simple polynomial adjustment represented the top model (Table 18, in Appendix B).

Overall density of waterbirds/shorebirds was highest (11.56 birds/ha) during Survey 3 (Fall

Survey Period 4) and lowest (0.76 birds/ha) during Survey 2 (Fall Survey Period 3). Mean density across fall migration was 6.26 birds/ha (Table 19, in Appendix B). Table 20 (in Appendix B) provides mean density and abundance estimates per species across fall migration; Figure 12 (in Appendix B) shows the mean density per family across fall surveys. Common Merganser had by far the highest (4.492 birds/ha) mean density across the fall migration period. All other species had densities of <1. The family Anatidae comprised the majority of detections (57%), followed by Ardeidae (23%) and Scolopacidae (16%; Figure 12, in Appendix B).

Reservoir Area Counts

Smith Reservoir SWA

During four fall migration surveys at Smith Reservoir, ABS biologists detected 17,144 individuals comprising 28 species of 12 families (mean=4,286.0 birds/survey). We detected the greatest number of individuals (7,905) during Survey 3 and the least (1,440) during Survey 1. American Coot by far comprised the greatest proportion of detections (64.2%), with 11,013 individuals, followed by Canada Goose (3,249; 19.0%) and Ruddy Duck (1,095; 6.4 %). The Rallidae family comprised 64 % of total detections, while Anatidae totaled 32%.

Extrapolated data estimates a low of 1,516 birds present at Smith Reservoir during Survey 1 and a high of 8,321 during Survey 4 (mean=4,511.6 birds/survey; Table 21 in Appendix B). Overall density of waterbirds and shorebirds ranged from a low of 16.49 birds/ha (Survey 1) to a high of 90.54 birds/ha (Survey 3; mean density=49.09 birds/ha). Table 21 (in Appendix B) provides extrapolated totals, mean, and mean density estimate per species at Smith Reservoir SWA across the fall migration period, and Figure 13 (in Appendix B) shows the mean density per family.

Homelake SWA

During four fall migration surveys at Homelake, we detected 3,913 individuals of 18 species and 7 families (mean=978.3 birds/survey). We detected the greatest number of individuals (1,672) during Survey 3 and the least (350) during Survey 1. American Coot by far comprised the majority of detections (3,399; 86.9%), followed by Ruddy Duck (263; 6.7%). All other species made up less than 5% of detections. Accordingly, Rallidae(87%) comprised a large majority of total fall detections.

Overall density of waterbirds and shorebirds ranged from a low of 12.64 birds/ha (Survey 1) to a high of 60.36 birds/ha (Survey 3; mean density=35.32 birds/ha). Table 22 (in Appendix B) provides totals, mean, and mean density estimate per species at Homelake SWA across the fall migration period, and Figure 14 (in Appendix B) shows the mean density per family.

EXTRAPOLATED ABUNDANCE OF WATERBIRDS/SHOREBIRDS

Based on our density estimates from shallow emergent, playa, deep-water reservoir, and riparian sampling, we estimate a total of approximately 3.417 million waterbirds/shorebirds moving through the SLV during spring migration. Spring abundance estimates ranged from a low of 258,681 in Survey Period 5 to a high of ~1.62 million birds in Survey Period 1 (Table 23).

During fall migration, we estimate a total of ~2.096 million migrating waterbirds/shorebirds, with a low of 63,744 in Survey Period 1 and a high of 724,558 during Survey Period 3 (Table 24). These estimates are considerably lower than that reported Year 1 of this study— ~6.653 million birds in spring and ~3.539 million in fall (Animas Biological Studies 2016).

DISCUSSION

Our density and abundance estimates varied across the two years of the study; however, the combined data confirm that the SLV serves as an important flyway for a diverse array of migratory waterbirds and shorebirds in both spring and fall, providing stopover and staging habitat for millions of birds each season. Most of the species we observed in this study breed in Colorado, though we reported several species that only migrate through the state on their way to more northerly breeding grounds in spring, and/or more southerly wintering grounds in fall. Combining years these included Common Loon (2015), Greater Scaup, Common Goldeneye, Horned Grebe, Solitary Sandpiper, Greater and Lesser Yellowlegs, Marbled Godwit, Sanderling, Baird's Sandpiper, Semipalmated Sandpiper, Long-billed and Short-billed Dowitcher, Red-necked Phalarope, Bonaparte's Gull, Ring-billed Gull, and Western Gull. In addition, we observed a few Colorado breeders that occur rarely or irregularly in the San Luis Valley, such as Wood Duck, Barrow's Goldeneye, Cattle Egret (2015), Green Heron, Willet, Long-billed Curlew (2015), Snowy Plover (2015), Franklin's Gull, and Forster's and Black Tern.

Our data suggest the abundance of waterfowl (Anatidae) generally far outnumbers other waterbird and shorebird groups, especially during spring migration; however, these habitats also support a diversity of waterbird and shorebird family groups and species. Rallidae was highly represented at deep-water sites in spring and at shallow emergent and deep-water sites in fall, mainly attributed to high densities of one species, American Coot.

Generally, deep-water reservoirs and playas supported the highest density and diversity of waterbirds/shorebirds and seemed to represent the most important stopover habitat for migrating birds in the SLV in both spring and fall. While shallow emergent, wet meadow (2015 only), and riparian areas also provide habitat for a variety of species, lower density estimates suggest these habitat attract considerably fewer migratory waterbirds and shorebirds during migration.

Though our data are based on sound sampling techniques across a range of wetland habitat types, deriving species diversity and accurate estimates of abundance of migratory waterbirds and shorebirds poses a number of challenges. First, due to the size of the study area and scope of work, we were only able to sample one or two sites per habitat type, and at each site sample a subset of available wetlands. Likely, we missed some species not present at our sampling locations but at other wetlands within the SLV. Additionally, extrapolating abundance estimates across the area of wetlands in the SLV (as defined by the NWI) assumes wetlands of the same classification are relatively uniform across the SLV. In reality, variation in water level and vegetation from site-to-site and year-to-year, in addition to wetland patch size, may influence presence/absence and density of species. Without more detailed habitat maps and current data on water levels and vegetation, we cannot determine with certainty how well the area of extrapolation aligns with our sampling sites. Nonetheless, our extrapolation method using NWI

data represents the best possible estimate of abundance across such a large landscape.

Length of stopover period poses another challenge to estimating density and abundance for migratory waterbirds and shorebirds. Our available budget allowed us to develop survey windows approximately twice the length (~20 days) of those recommended by ISS/PRISM (10 days). Little information exists on length of waterbird and shorebird stopover duration in the SLV, and this study did not address this. Likely, stopover duration for most individuals did not align with the duration of our survey windows. Consequently, we may have underestimated density and abundance for some species and overestimated these metrics for others.

Finally, our sampling approach may have influenced differences in overall abundance estimates between the spring and fall migratory periods. We extrapolated abundance from five survey periods in spring, but only four in fall, the latter period ending in September. Though the bulk of individual waterbirds and shorebirds probably move through the SLV by the end of September, fall migration generally occurs over a longer period of time beginning in July and continuing well into the latter fall. Thus, density and abundance at any given time may be lower than that in spring because of the drawn-out length of the season and variation in timing of movement across individuals and species. Further, our fall abundance estimate does not take into account the latter phase of migration, in October and beyond.

Differences in our extrapolated abundance estimates across years likely reflect some or all of these factors, as estimates in 2015 were nearly twice that reported in 2016. Notwithstanding, our data also show some consistency across years. Specifically, our abundance estimate in spring was almost twice that in fall in both years, probably also due, in part, to the differences in sampling schemes between the two seasons. Additional years of study, coupled with additional funding to sample sites more frequently during the spring and fall migratory periods, may provide more robust estimates of migratory waterbird and shorebird density and abundance across the SLV.

Despite the difference across years, the combined dataset provides critical information on the diversity of species and abundance of individuals traveling through the SLV flyway in advance of the development of the four approved SEZs. These data will guide planning of construction and operation of solar facilities to reduce impacts to migratory waterbirds and shorebirds.

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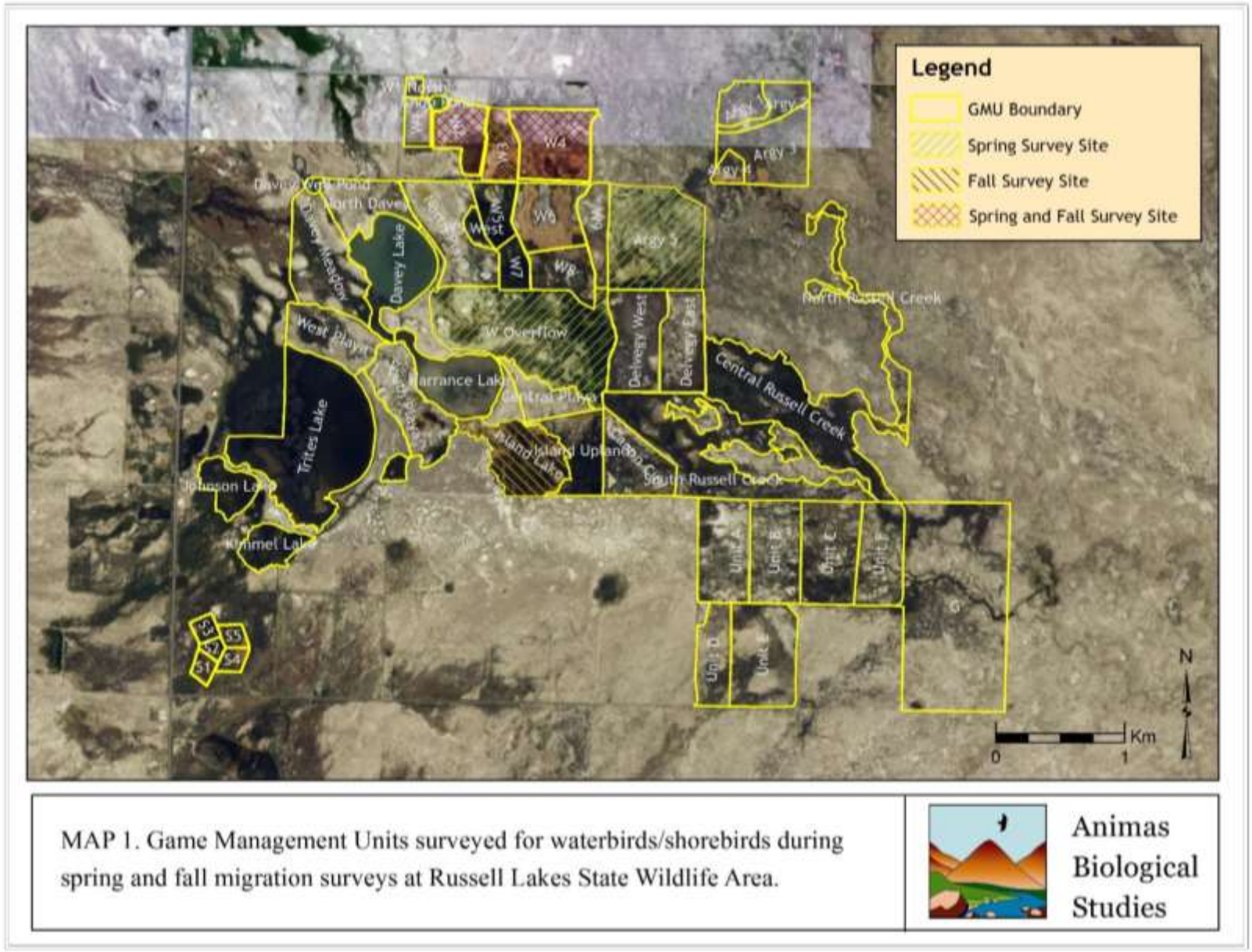
APPENDIX A.

SURVEY AREA MAPS



MAP 1. Game Management Units surveyed for waterbirds/shorebirds during spring and fall migration surveys at Russell Lakes State Wildlife Area.

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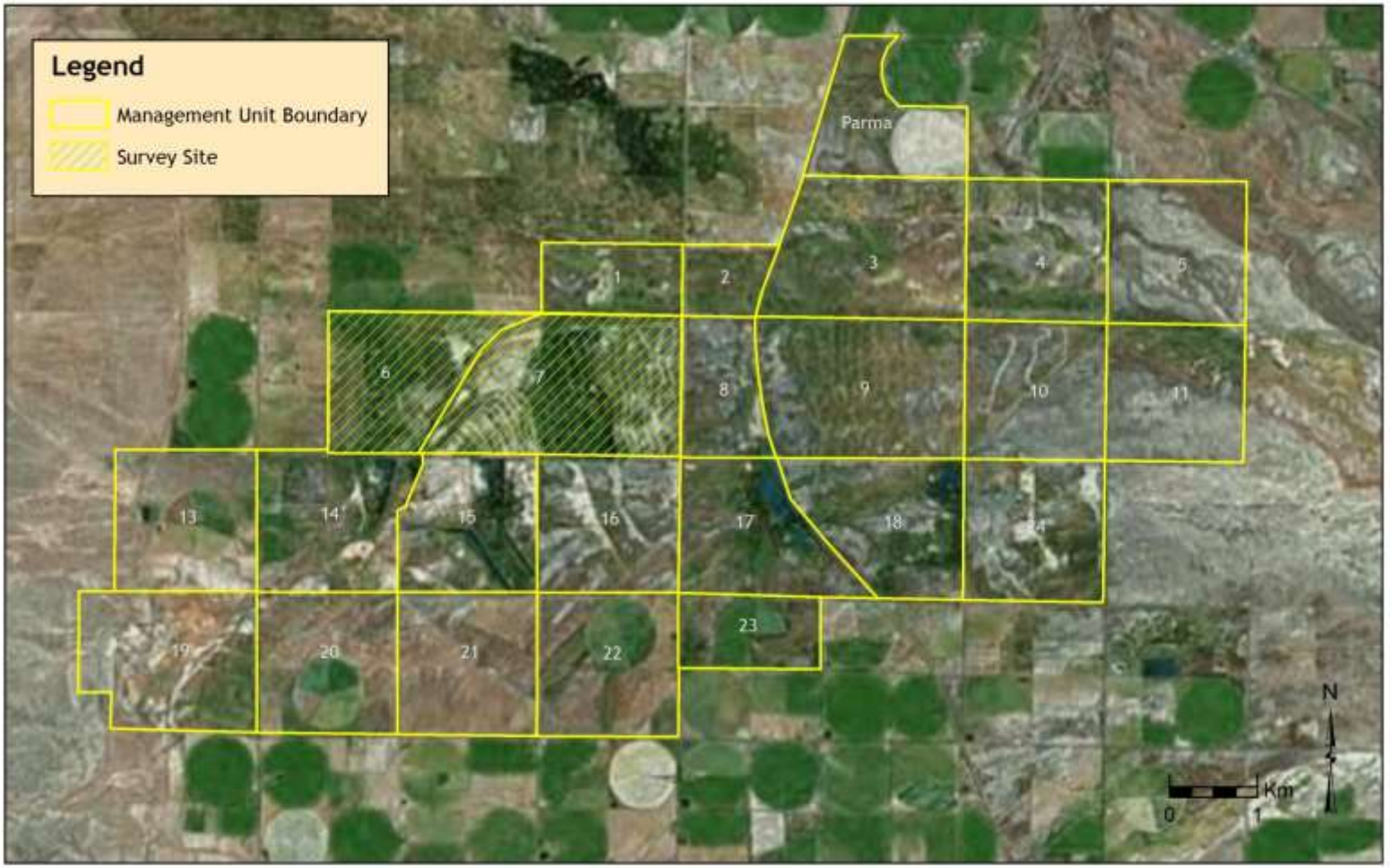

MAP 2. Management Units surveyed for waterbirds/shorebirds at Monte Vista National Wildlife Area.

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MAP 3. Deep-water reservoir habitat surveyed for waterbirds and shorebirds at Smith Reservoir SWA

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MAP 4. Deep-water reservoir habitat surveyed for waterbirds and shorebirds at Homelake SWA

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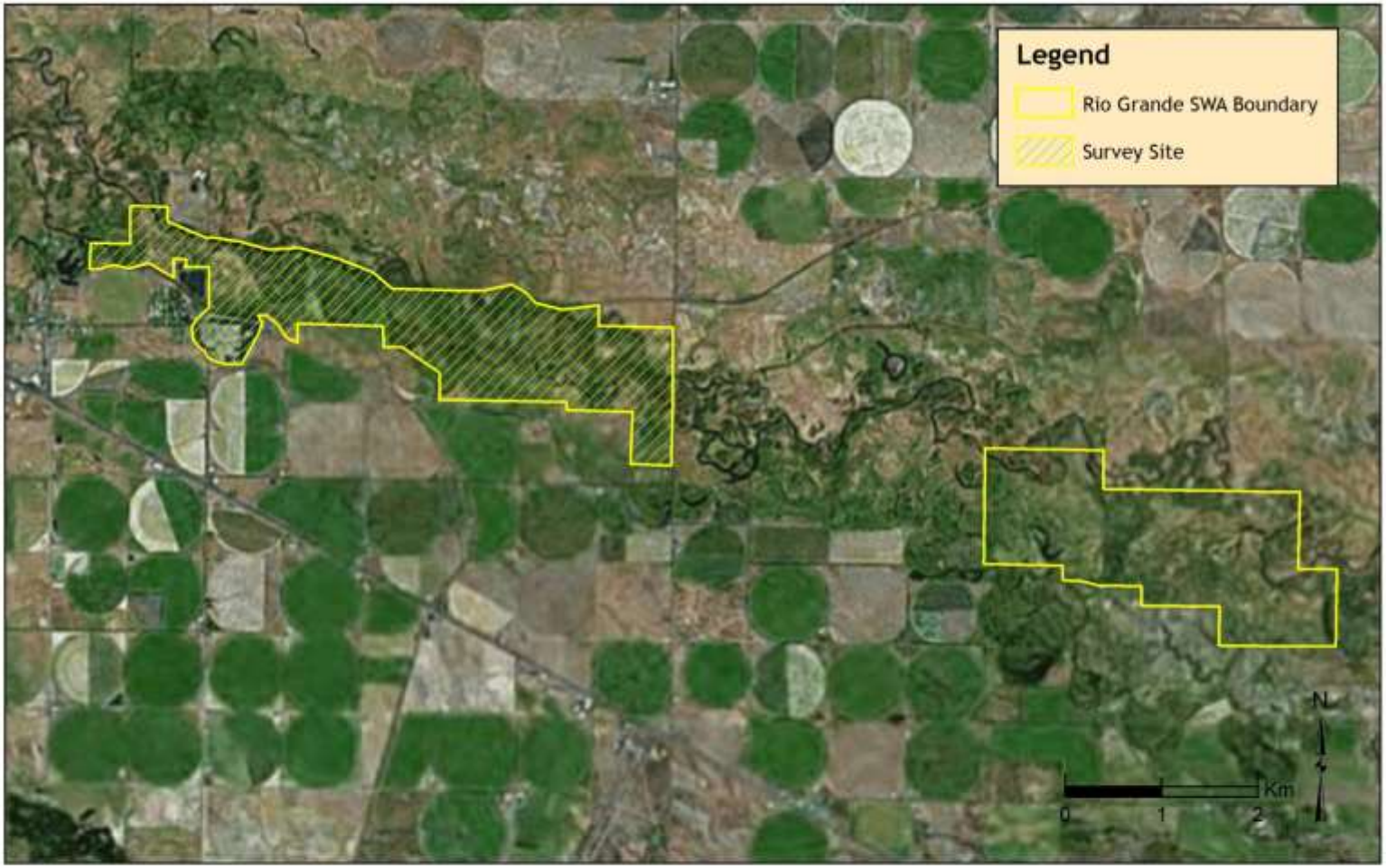

MAP 5. Riparian corridor surveyed for migratory waterbirds and shorebirds at Rio Grande State Wildlife Area.

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MAP 6. Riparian corridor surveyed for migratory waterbirds and shorebirds at Sego Springs State Wildlife Area.

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MAP 7. Playa lakes surveyed for migratory waterbirds and shorebirds at Blanca Wetlands Area.

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APPENDIX B.

TABLES AND GRAPHS

Table 1. Windows for shorebird/waterbird surveys during spring and fall migration in the San Luis Valley, 2016.

Season	Wetland Type	Survey Window/Survey Number				
		15–31 Mar	1–20 Apr	21 Apr–10 May	11–31 May	1–20 Jun
Spring	Shallow emergent	1	2	3	4	5
	Playa	1	2	3	4	5
	Deep water	1	2	3	4	5
	Riparian	[a]	[a]	1	2	3
		15–31 Jul	1–20 Aug	21 Aug–9 Sep	10–30 Sep	
Fall	Shallow emergent	[a]	1	2	3	
	Playa	1	2	3	4	
	Deep water	1	2	3	4	
	Riparian	[a]	1	2	3	

[a] No survey conducted during this period

Table 2. List of waterbird and shorebird species detected during spring and fall migration surveys at San Luis Valley wetlands, 2016.

Species	Family	Spring	Fall
Canada Goose (*Branta canadensis*)	Anatidae	X	X
Wood Duck (*Aix sponsa*)	Anatidae		X
Gadwall (*Anas strepera*)	Anatidae	X	X
American Wigeon (*Aix sponsa*)	Anatidae	X	X
Mallard (*Anas platyrhynchos*)	Anatidae	X	X
Blue-winged Teal (*Anas discors*)	Anatidae	X	X
Cinnamon Teal (*Anas cyanoptera*)	Anatidae	X	X
Northern Shoveler (*Anas clypeata*)	Anatidae	X	X
Northern Pintail (*Anas acuta*)	Anatidae	X	X
Green-winged Teal (*Anas crecca*)	Anatidae	X	X
Canvasback (*Aythya valisineria*)	Anatidae	X	X
Redhead (*Aythya americana*)	Anatidae	X	X
Ring-necked Duck (*Aythya collaris*)	Anatidae	X	
Greater Scaup (*Aythya marila*)	Anatidae	X	
Lesser Scaup (*Aythya affinis*)	Anatidae	X	X
Bufflehead (*Bucephala albeola*)	Anatidae	X	
Common Goldeneye (*Bucephala clangula*)	Anatidae	X	
Barrow's Goldeneye (*Bucephala islandica*)	Anatidae	X	
Common Merganser (*Mergus merganser*)	Anatidae	X	X
Ruddy Duck (*Oxyura jamaicensis*)	Anatidae	X	X
Pied-billed Grebe (*Podilymbus podiceps*)	Podicipedidae	X	X
Eared Grebe (*Podiceps nigricollis*)	Podicipedidae	X	X
Western Grebe (*Aechmophorus occidentalis*)	Podicipedidae	X	X
Clark's Grebe (*Aechmophorus clarkii*)	Podicipedidae	X	
Horned Grebe (*Podiceps auritus*)	Podicipedidae		
Double-crested Cormorant (*Phalacrocorax auritus*)	Phalacrocoracidae	X	X
American White Pelican (*Pelecanus erythrorhynchos*)	Pelecanidae	X	X
American Bittern (*Botaurus lentiginosus*)	Ardeidae	X	X
Great Blue Heron (*Ardea herodias*)	Ardeidae	X	X
Snowy Egret (*Egretta thula*)	Ardeidae		X
Green Heron (*Butorides virescens*)	Ardeidae		X
Black-crowned Night-Heron (*Nycticorax nycticorax*)	Ardeidae	X	X

Species	Family	Spring	Fall
White-faced Ibis (*Plegadis chihi*)	Threskiornithidae	X	X
Virginia Rail (*Rallus limicola*)	Rallidae	X	X
Sora (*Porzana carolina*)	Rallidae	X	X
American Coot (*Fulica americana*)	Rallidae	X	X
Sandhill Crane (*Grus canadensis*)	Gruidae	X	X
Black-necked Stilt (*Himantopus mexicanus*)	Recurvirostridae	X	X
American Avocet (*Recurvirostra americana*)	Recurvirostridae	X	X
Killdeer (*Charadrius vociferus*)	Charadriidae	X	X
Spotted Sandpiper (*Actitis macularius*)	Scolopacidae	X	X
Solitary Sandpiper (*Tringa solitaria*)	Scolopacidae		X
Greater Yellowlegs (*Tringa melanoleuca*)	Scolopacidae		X
Willet (*Tringa semipalmata*)	Scolopacidae	X	X
Lesser Yellowlegs (*Tringa flavipes*)	Scolopacidae	X	X
Long-billed Curlew (*Numenius americanus*)	Scolopacidae		X
Marbled Godwit (*Limosa fedoa*)	Scolopacidae	X	
Sanderling (*Calidris alba*)	Scolopacidae		X
Baird's Sandpiper (*Calidris bairdii*)	Scolopacidae		X
Semipalmated Sandpiper (*Calidris pusilla*)	Scolopacidae		X
Short-billed Dowitcher (*Limnodromus griseus*)	Scolopacidae	X	X
Long-billed Dowitcher (*Limnodromus scolopaceus*)	Scolopacidae	X	X
Wilson's Snipe (*Gallinago delicata*)	Scolopacidae	X	X
Wilson's Phalarope (*Phalaropus tricolor*)	Scolopacidae	X	X
Red-necked Phalarope (*Phalaropus lobatus*)	Scolopacidae	X	X
Bonaparte's Gull (*Chroicocephalus philadelphia*)	Laridae	X	
Franklin's Gull (*Leucophaeus pipixcan*)	Laridae		X
Ring-billed Gull (*Larus delawarensis*)	Laridae	X	X
California Gull (*Larus californicus*)	Laridae	X	X
Western Gull (*Larus occidentalis*)	Laridae	X	
Black Tern (*Chlidonias niger*)	Laridae		X
Foster's Tern (*Sterna forsteri*)	Laridae	X	X

Table 3. Extrapolated total, mean, and mean density of waterbird and shorebirds detected during spring migration surveys at Russell Lakes SWA, 2016.

	Extrapolated Totals							Mean Density
Species	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Total	Mean	(No. birds/ha)
Canada Goose	117.5	30.0	25.0	10.0	0.0	182.5	36.50	0.21
Gadwall	122.5	240.0	120.0	35.0	45.0	562.5	112.50	0.64
American Wigeon	107.5	27.5	10.0	2.5	0.0	147.5	29.50	0.17
Mallard	227.5	137.5	117.5	57.5	0.0	540.0	108.00	0.62
Blue-winged Teal	2.5	0.0	52.5	10.0	127.5	192.5	38.50	0.22
Cinnamon Teal	97.5	260.0	397.5	102.5	72.5	930.0	186.00	1.06
Northern Shoveler	445.0	397.5	67.5	35.0	20.0	965.0	193.00	1.10
Northern Pintail	120.0	25.0	22.5	2.5	0.0	170.0	34.00	0.19
Green-winged Teal	950.0	382.5	87.5	30.0	20.0	1470.0	294.00	1.68
Redhead	30.0	22.5	92.5	57.5	32.5	235.0	47.00	0.27
Ring-necked Duck	20.0	5.0	0.0	2.5	0.0	27.5	5.50	0.03
Lesser Scaup	5.0	42.5	0.0	5.0	0.0	52.5	10.50	0.06
Bufflehead	12.5	7.5	0.0	0.0	0.0	20.0	4.00	0.02
Ruddy Duck	2.5	20.0	62.5	17.5	15.0	117.5	23.50	0.13
Unknown Duck	0.0	25.0	0.0	5.0	0.0	30.0	6.00	0.03
Pied-billed Grebe	0.0	5.0	0.0	2.5	0.0	7.5	1.50	0.01
Eared Grebe	0.0	0.0	17.5	2.5	2.5	22.5	4.50	0.03
Western Grebe	0.0	0.0	7.5	0.0	0.0	7.5	1.50	0.01
American White Pelican	0.0	0.0	0.0	0.0	45.0	45.0	9.00	0.05
American Bittern	0.0	0.0	5.0	2.5	2.5	10.0	2.00	0.01
Black-crowned Night-Heron	0.0	5.0	17.5	2.5	5.0	30.0	6.00	0.03
White-faced Ibis	0.0	0.0	55.0	0.0	7.5	62.5	12.50	0.07
Sora	0.0	5.0	5.0	5.0	5.0	20.0	4.00	0.02
American Coot	222.5	457.5	537.5	102.5	90.0	1410.0	282.00	1.61

Species	Extrapolated Totals					Total	Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5			
Sandhill Crane	1125.0	0.0	0.0	0.0	0.0	1125.0	225.00	1.29
Black-necked Stilt	0.0	0.0	30.0	15.0	7.5	52.5	10.50	0.06
American Avocet	0.0	70.0	35.0	45.0	22.5	172.5	34.50	0.20
Killdeer	0.0	5.0	0.0	10.0	2.5	17.5	3.50	0.02
Willet	0.0	0.0	10.0	0.0	0.0	10.0	2.00	0.01
Lesser Yellowlegs	0.0	2.5	0.0	0.0	0.0	2.5	0.50	0.00
Wilson"s Snipe	0.0	2.5	0.0	0.0	0.0	2.5	0.50	0.00
Wilson's Phalarope	0.0	0.0	17.5	7.5	15.0	40.0	8.00	0.05
Red-necked Phalarope	0.0	0.0	0.0	17.5	0.0	17.5	3.50	0.02
Foster's Tern	0.0	0.0	12.5	0.0	0.0	12.5	2.50	0.01
TOTAL	3,607.5	2,175.0	1,805.0	585.0	537.5	8,710.0	1,742.00	9.97

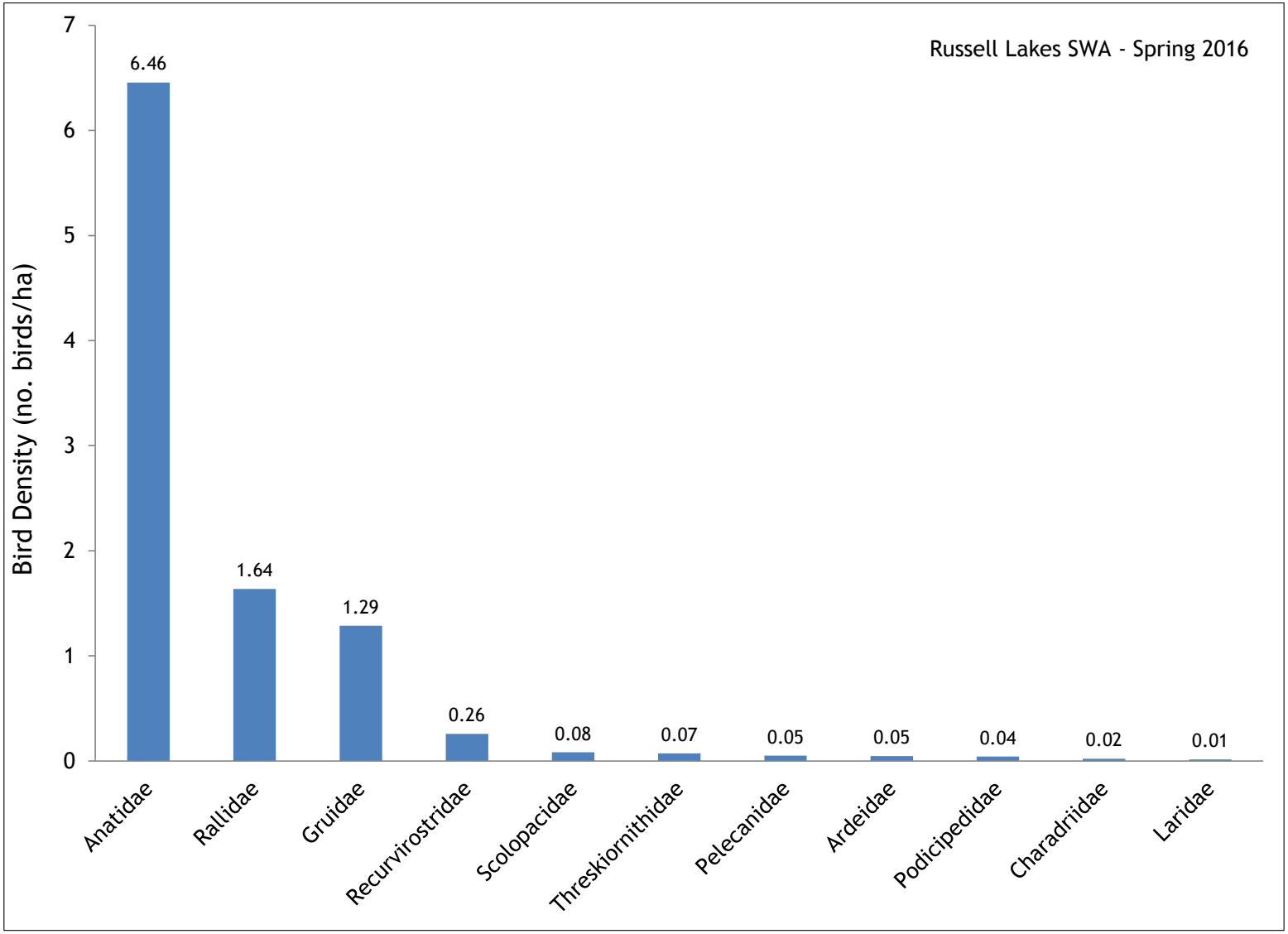

Figure 3. Mean density of waterbird and shorebird families across spring migration surveys at Russell Lakes SWA, 2016.

Table 4. Models estimating density of shorebirds and waterbirds during spring migration surveys at Monte Vista NWR, 2016.

Stratification	Model	No. of Param.	AIC	Delta AIC	Mean Density	CV	95% CI LCL	95% CI UCL
Survey Period	Neg. Exp. + Cos.	9	2432.200	0.000	5.180	0.188	3.578	7.500
	Haz. Rate + Poly.	15	2432.477	0.277	4.827	0.241	3.019	7.718
	Neg. Exp. + Poly.	7	2434.403	2.203	5.116	0.173	3.632	7.207
	Half Norm. + Poly.	12	2443.558	11.358	3.985	0.157	2.916	5.445
	Half Norm. + Cos.	7	2449.628	17.428	3.731	0.155	2.739	5.082
	Haz. Rate + Cos.	13	2449.900	17.700	4.464	0.239	2.798	7.122
Species	Neg. Exp. + Poly.	37	2433.686	0.000	7.955	0.753	1.640	38.575
	Neg. Exp. + Cos.	37	2439.437	5.751	8.015	0.747	1.669	38.496
	Half Norm. + Poly.	41	2454.169	20.483	3.948	0.268	2.154	7.237
	Haz. Rate + Poly.	68	2462.545	28.859	7.057	0.782	1.459	34.133
	Half Norm. + Cos.	34	2465.716	32.030	3.910	0.271	2.121	7.207
	Haz. Rate + Cos.	61	2470.742	37.056	6.533	0.842	1.225	34.841
Family	Neg. Exp. + Poly.	11	2458.324	0.000	3.943	0.096	3.269	4.756
	Neg. Exp. + Cos.	11	2461.460	3.136	3.929	0.096	3.258	4.740
	Haz. Rate + Poly.	20	2461.990	3.666	3.847	0.110	3.101	4.773
	Half Norm. + Poly.	13	2468.152	9.828	3.522	0.092	2.939	4.220
	Half Norm. + Cos.	9	2490.131	31.807	2.963	0.085	2.509	3.500
	Haz. Rate + Cos.	18	2492.110	33.786	3.466	0.153	2.509	4.788

Table 5. Overall density and abundance estimates for waterbird and shorebird species during spring migration surveys at Monte Vista NWR, 2016.

	Density	95% CI				Abundance	95% CI	
Survey Period	**Estimate**	**LCL**	**UCL**	**%CV**	**df**	**Estimate**	**LCL**	**UCL**
Survey 1	18.40	9.12	37.11	36.32	72.38	15,785	7,826	31,840
Survey 2	3.35	2.23	5.04	20.58	63.77	2,877	1,915	4,323
Survey 3	2.98	2.07	4.30	18.36	49.33	2,558	1,774	3,688
Survey 4	2.78	1.78	4.34	22.49	58.32	2,387	1,530	3,723
Survey 5	2.92	2.18	3.90	14.63	71.19	2,501	1,871	3,344
Pooled Mean	5.18	3.58	7.50	18.77	82.84	4,445	3,070	6,435

Table 6. Mean density and abundance of waterbird and shorebird species detected across spring migration surveys at Monte Vista NWR, 2016.

	Density	95% CI				Abundance	95% CI	
Species	Estimate	LCL	UCL	% CV	df	Estimate	LCL	UCL
Northern Pintail	3.129	0.165	59.204	186.730	6.530	77,855	4,115	1.E+06
Mallard	1.186	0.727	1.936	25.270	247.720	29,516	18,082	48,182
Cinnamon Teal	0.717	0.522	0.984	16.210	380.250	17,832	12,993	24,475
American Coot	0.710	0.514	0.981	16.570	330.240	17,663	12,777	24,417
Ring-necked Duck	0.466	0.000	76,814.000	266.920	1.230	11,585	<1	2.E+09
Green-winged Teal	0.356	0.148	0.855	46.420	88.290	8,846	3,677	21,283
Gadwall	0.282	0.141	0.563	36.060	125.910	7,010	3,509	14,004
Redhead	0.211	0.128	0.347	25.630	160.220	5,245	3,187	8,631
Northern Shoveler	0.207	0.109	0.394	33.590	180.170	5,147	2,700	9,812
Wilson's Phalarope	0.165	0.059	0.464	55.200	53.900	4,106	1,460	11,548
Canada Goose	0.142	0.081	0.249	28.890	124.710	3,541	2,022	6,201
Ruddy Duck	0.080	0.043	0.149	32.120	101.750	1,993	1,071	3,711
Killdeer	0.078	0.021	0.291	69.200	16.880	1,934	517	7,245
Sora	0.043	0.019	0.095	40.750	35.300	1,065	481	2,360
White-faced Ibis	0.033	0.011	0.093	54.750	30.190	811	285	2,307
Blue-winged Teal	0.032	0.016	0.063	35.790	93.420	787	395	1,569
American Avocet	0.028	0.010	0.075	52.700	56.680	690	256	1,859
Canvasback	0.020	0.003	0.125	92.510	7.810	504	82	3,112
Lesser Scaup	0.016	0.004	0.068	78.820	15.630	386	88	1,688
Black-necked Stilt	0.015	0.005	0.049	62.540	46.060	381	120	1,212
Black-crowned Night-Heron	0.015	0.008	0.028	34.290	144.190	367	190	709
Wilson's Snipe	0.014	0.005	0.037	49.550	23.330	346	131	910
Bufflehead	0.005	0.000	1.825	157.890	1.660	125	<1	45,409
Short-billed Dowitcher	0.005	0.000	0.091	130.490	3.420	117	6	2,269

Species	Density Estimate	95% CI LCL	95% CI UCL	% CV	df	Abundance Estimate	95% CI LCL	95% CI UCL
American Wigeon	0.001	0.000	0.003	100.000	127.000	16	3	81
Eared Grebe	0.001	0.000	0.003	100.000	127.000	16	3	81
Pied-billed Grebe	0.001	0.000	0.003	100.000	127.000	16	3	81
Willet	0.001	0.000	0.003	100.000	127.000	16	3	81
American Bittern	0.000	0.000	0.002	100.000	127.000	8	1	40
Virginia Rail	0.000	0.000	0.002	100.000	127.000	8	1	40

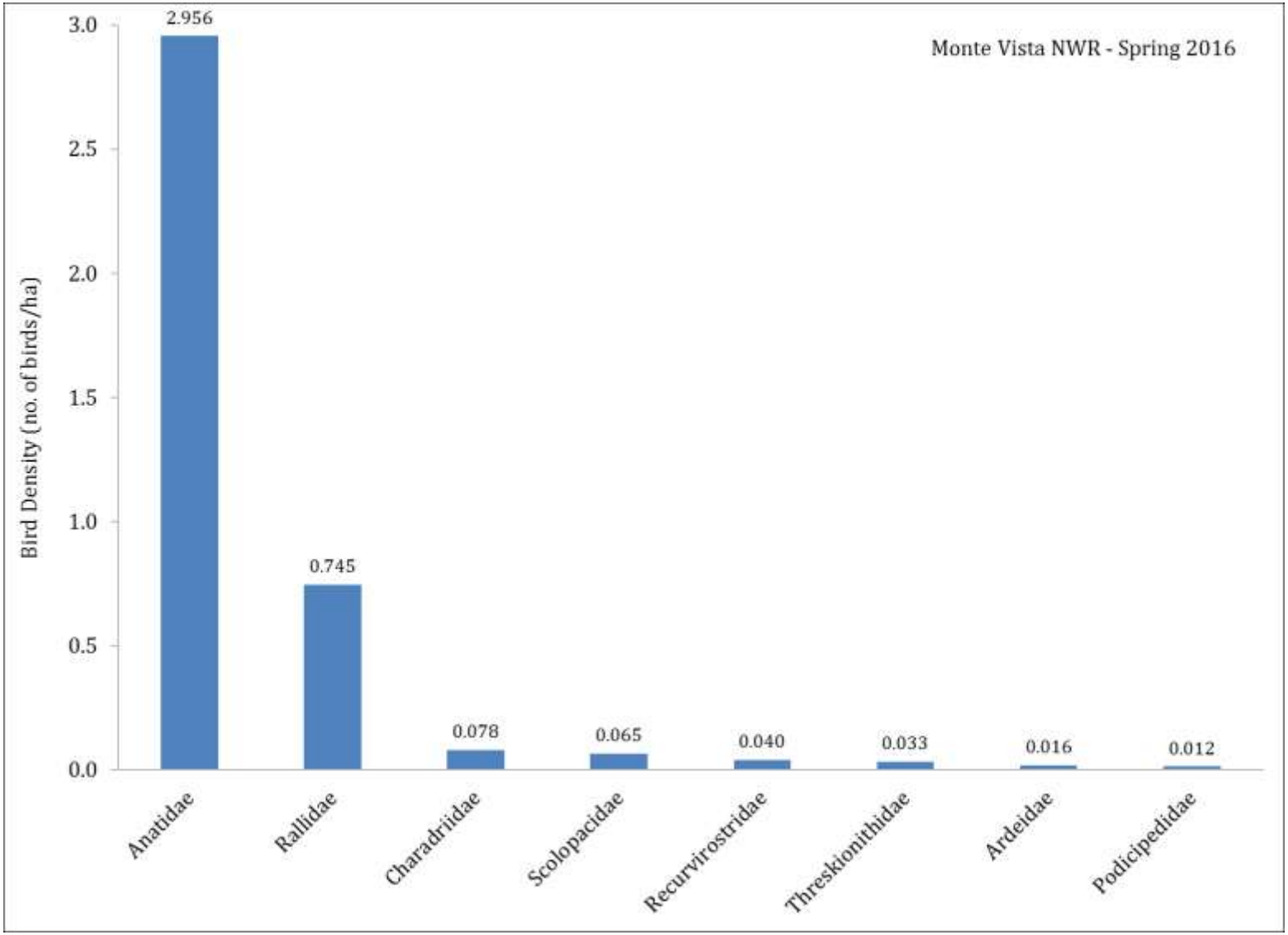

Figure 4. Mean density of waterbird and shorebird families across spring migration surveys at Monte Vista NWR, 2016.

Table 7. Extrapolated total, mean, and mean density of waterbirds and shorebirds detected during spring migration surveys at Blanca Wetlands, 2016.

	Extrapolated Totals							Mean Density
Species	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Total	Mean	(No. birds/ha)
Canada Goose	53.7	30.5	11.6	2.1	8.4	106.3	21.26	0.20
Gadwall	332.6	107.4	51.6	91.6	87.4	670.5	134.11	1.25
American Wigeon	204.2	0.0	2.1	3.2	4.2	213.7	42.74	0.40
Mallard	44.2	3.2	5.3	16.8	26.3	95.8	19.16	0.18
Blue-winged Teal	9.5	0.0	8.4	0.0	15.8	33.7	6.74	0.06
Cinnamon Teal	33.7	48.4	51.6	11.6	12.6	157.9	31.58	0.29
Northern Shoveler	27.4	537.9	90.5	11.6	10.5	677.9	135.58	1.26
Northern Pintail	2.1	2.1	0.0	0.0	0.0	4.2	0.84	0.01
Green-winged Teal	483.2	121.1	58.9	23.2	17.9	704.2	140.84	1.31
Canvasback	191.6	3.2	0.0	1.1	154.7	350.5	70.11	0.65
Redhead	521.1	105.3	57.9	74.7	68.4	827.4	165.47	1.54
Ring-necked Duck	0.0	12.6	0.0	1.1	0.0	13.7	2.74	0.03
Greater Scaup	1.1	0.0	0.0	0.0	0.0	1.1	0.21	0.00
Lesser Scaup	277.9	154.7	1.1	6.3	2.1	442.1	88.42	0.82
Bufflehead	185.3	104.2	11.6	1.1	0.0	302.1	60.42	0.56
Common Goldeneye	26.3	0.0	0.0	0.0	0.0	26.3	5.26	0.05
Barrow's Goldeneye	1.1	0.0	0.0	0.0	0.0	1.1	0.21	0.00
Common Merganser	2.1	0.0	0.0	0.0	0.0	2.1	0.42	0.00
Ruddy Duck	202.1	735.8	548.4	171.6	157.9	1,815.8	363.16	3.37
Unknown Duck	6.3	0.0	4.2	0.0	0.0	10.5	2.11	0.02
Pied-billed Grebe	0.0	6.3	1.1	0.0	0.0	7.4	1.47	0.01
Eared Grebe	0.0	6.3	481.1	89.5	45.3	622.1	124.42	1.16
Western Grebe	0.0	2.1	14.7	0.0	1.1	17.9	3.58	0.03
Clark's Grebe	0.0	0.0	1.1	0.0	2.1	3.2	0.63	0.01

Species	Extrapolated Totals					Total	Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5			
American White Pelican	0.0	0.0	0.0	1.1	2.1	3.2	0.63	0.01
Black-crowned Night-Heron	0.0	0.0	2.1	0.0	0.0	2.1	0.42	0.00
Sora	0.0	0.0	0.0	1.1	0.0	1.1	0.21	0.00
American Coot	645.3	204.2	211.6	200.0	156.8	1,417.9	283.58	2.63
Black-necked Stilt	0.0	1.1	0.0	0.0	0.0	1.1	0.21	0.00
American Avocet	16.8	121.1	148.4	87.4	112.6	486.3	97.26	0.90
Killdeer	16.8	1.1	5.3	0.0	3.2	26.3	5.26	0.05
Spotted Sandpiper	0.0	0.0	0.0	6.3	3.2	9.5	1.89	0.02
Willet	0.0	0.0	40.0	0.0	0.0	40.0	8.00	0.07
Marbled Godwit	0.0	2.1	5.3	0.0	0.0	7.4	1.47	0.01
Wilson's Phalarope	0.0	2.1	8.4	4.2	0.0	14.7	2.95	0.03
Red-necked Phalarope	0.0	0.0	0.0	31.6	0.0	31.6	6.32	0.06
Franklin's Gull	0.0	0.0	0.0	1.1	8.4	9.5	1.89	0.02
Ring-billed Gull	0.0	0.0	38.9	11.6	8.4	58.9	11.79	0.11
California Gull	0.0	0.0	0.0	0.0	34.7	34.7	6.95	0.06
Western Gull	0.0	0.0	0.0	0.0	1.1	1.1	0.21	0.00
Forster's Tern	0.0	0.0	1.1	0.0	0.0	1.1	0.21	0.00
TOTAL	3,284.2	2,312.6	1,862.1	849.5	945.3	9,253.7	1,850.74	17.18

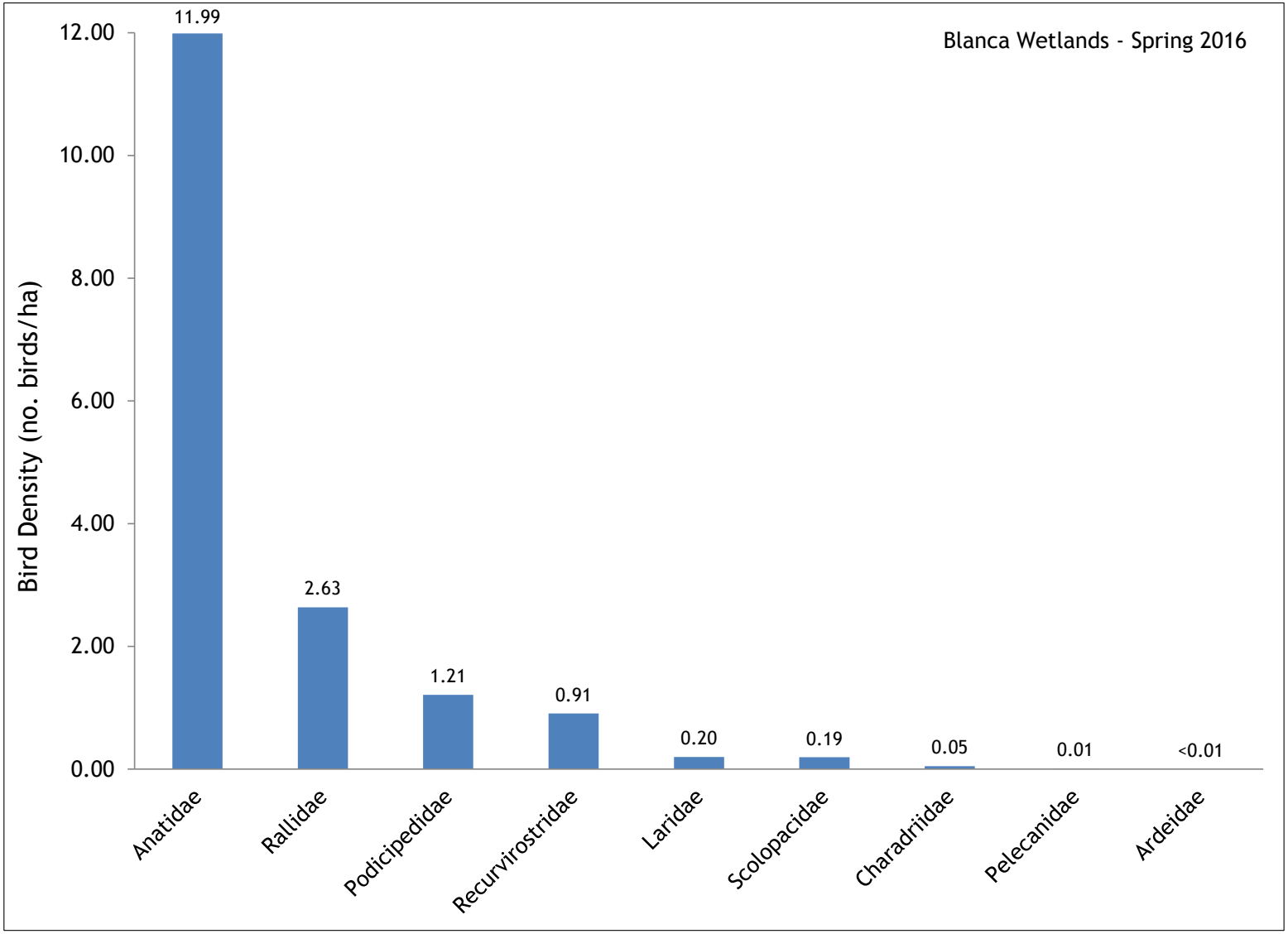

Figure 5. Mean density of waterbird and shorebird families across spring migration surveys at Blanca Wetlands, 2016.

Table 8. Models estimating density of waterbirds and shorebirds during riparian spring migration surveys at Rio Grande and Sego Springs SWAs, 2016.

Stratification	Model	No. of Param.	AIC	Delta AIC	Mean Density	CV	95% CI LCL	95% CI UCL
Survey Period	Haz. Rate+ Cos.	6	202.201	0.000	1.375	0.254	0.836	2.263
	Haz. Rate+ Poly.	6	202.201	0.000	1.375	0.254	0.836	2.263
	Neg. Exp.+ Cos.	3	203.783	1.582	2.736	0.251	1.673	4.476
	Neg. Exp.+ Poly.	3	203.783	1.582	2.736	0.251	1.673	4.476
	Half Norm. + Cos.	5	204.696	2.495	1.319	0.236	0.829	2.097
	Half Norm. + Poly.	3	211.423	9.223	0.955	0.215	0.624	1.462
Species	Half Norm. + Poly.	14	199.945	0.000	12.058	2.575	0.000	3.031E+06
	Haz. Rate + Poly.	25	202.389	2.444	2.042	0.433	0.490	8.509
	Haz. Rate + Cos.	25	202.393	2.448	2.042	0.435	0.497	8.385
	Neg. Exp. + Cos.	12	203.062	3.117	4.685	0.345	2.344	9.363
	Neg. Exp. + Poly.	12	203.062	3.117	4.685	0.345	2.344	9.363
	Half Norm. + Cos.	12	209.216	9.271	11.773	2.637	0.000	3.368E+06
Family	Haz. Rate + Poly.	10	197.575	0.000	1.522	0.274	0.890	2.603
	Haz. Rate + Cos	10	197.575	0.000	1.522	0.274	0.890	2.603
	Half Norm. + Cos	7	204.909	7.334	1.591	0.284	0.905	2.798
	Half Norm. + Poly.	7	206.176	8.600	1.376	0.284	0.776	2.439
	Neg. Exp. + Poly.	5	209.389	11.814	3.530	0.267	1.996	6.241
	Neg. Exp. + Cos	5	209.389	11.814	3.530	0.267	1.996	6.241

Table 9. Overall density and abundance estimates for waterbird and shorebird species during spring migration surveys at Rio Grande and Sego Springs SWA, 2016.

Survey Period	Density Estimate	95% CI		% CV	df	Abundance Estimate	95% CI	
		LCL	UCL				LCL	UCL
Survey 1	2.041	0.906	4.599	41.510	31.660	429	190	966
Survey 2	1.161	0.481	2.801	45.460	34.140	244	101	588
Survey 3	1.069	0.470	2.433	41.440	23.760	225	99	511
Pooled Mean	1.376	0.836	2.263	25.420	82.900	289	176	475

Table 10. Mean density and abundance of waterbird and shorebird species detected across spring migration surveys at Rio Grande and Sego Springs SWA, 2016.

	Density	95% CI				Abundance	95% CI	
Species	Estimate	LCL	UCL	% CV	df	Estimate	LCL	UCL
Common Merganser	10.557	0.000	5.381E+06	294.050	1.190	9,343	0	4.76E+09
Mallard	0.759	0.379	1.522	35.460	40.650	672	335	1347
Killdeer	0.205	0.014	3.080	105.700	3.100	182	12	2725
Green-winged Teal	0.159	0.030	0.857	100.000	39.000	141	26	759
American Coot	0.126	0.026	0.614	84.260	13.220	112	23	543
American Bittern	0.080	0.015	0.429	100.000	39.000	70	13	379
Ruddy Duck	0.043	0.006	0.317	109.300	9.570	38	5	281
Spotted Sandpiper	0.037	0.006	0.233	86.170	5.900	33	5	206
Sore	0.032	0.011	0.094	54.790	15.720	28	9	83
Great Blue Heron	0.029	0.005	0.182	86.250	5.890	26	4	161
Canada Goose	0.016	0.003	0.090	85.680	7.710	14	3	80
Wilson's Snipe	0.014	0.004	0.049	63.190	11.860	12	3	43

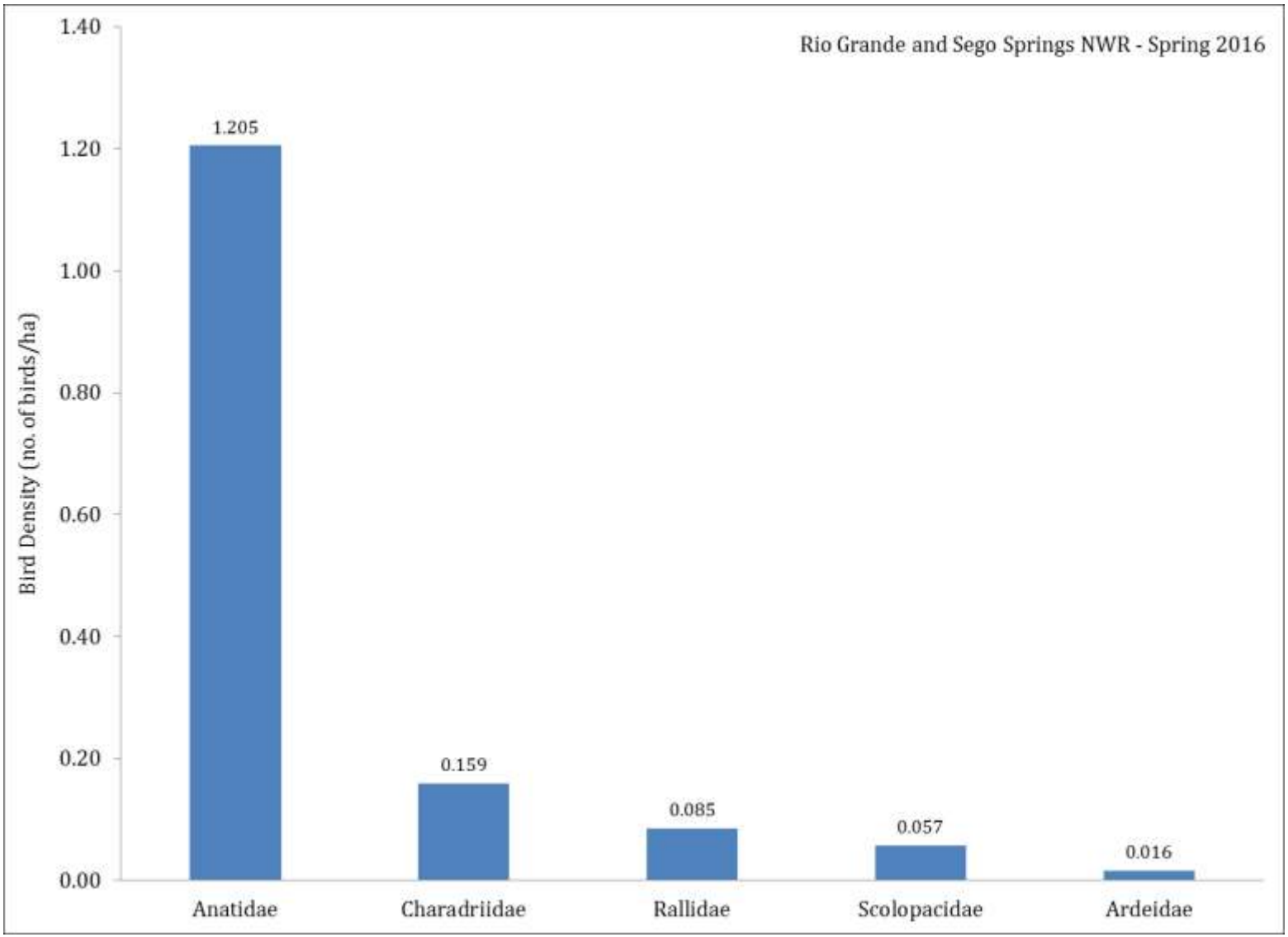

Figure 6. Mean density of waterbirds and shorebird families across spring migration surveys at Rio Grande and Sego Springs SWAs.

Table 11. Extrapolated total, mean, and mean density of waterbirds and shorebirds detected during spring migration surveys at Smith Reservoir SWA, 2016.

Species	Extrapolated Totals					Total	Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5			
Canada Goose	17.9	11.6	16.8	0.0	0.0	46.3	9.26	0.10
Gadwall	33.7	0.0	55.8	0.0	0.0	89.5	17.89	0.19
American Wigeon	2.1	0.0	0.0	0.0	0.0	2.1	0.42	0.00
Mallard	58.9	2.1	9.5	0.0	0.0	70.5	14.11	0.15
Northern Shoveler	12.6	93.7	17.9	0.0	0.0	124.2	24.84	0.27
Green-winged Teal	148.4	0.0	0.0	0.0	0.0	148.4	29.68	0.32
Canvasback	3.2	0.0	0.0	0.0	0.0	3.2	0.63	0.01
Redhead	6.3	0.0	1.1	3.2	0.0	10.5	2.11	0.02
Ring-necked Duck	7.4	0.0	0.0	0.0	0.0	7.4	1.47	0.02
Lesser Scaup	248.4	221.1	33.7	0.0	0.0	503.2	100.63	1.10
Bufflehead	17.9	6.3	3.2	0.0	0.0	27.4	5.47	0.06
Common Goldeneye	5.3	0.0	0.0	0.0	0.0	5.3	1.05	0.01
Common Merganser	14.7	10.5	1.1	0.0	0.0	26.3	5.26	0.06
Ruddy Duck	55.8	101.1	69.5	17.9	9.5	253.7	50.74	0.55
Unknown Duck	0.0	105.3	12.6	2.1	0.0	120.0	24.00	0.26
Eared Grebe	0.0	8.4	307.4	52.6	16.8	385.3	77.05	0.84
Western Grebe	0.0	38.9	32.6	23.2	34.7	129.5	25.89	0.28
Horned Grebe	0.0	0.0	11.6	0.0	0.0	11.6	2.32	0.03
Great Blue Heron	0.0	0.0	2.1	0.0	0.0	2.1	0.42	0.00
American Coot	398.9	684.2	303.2	8.4	74.7	1,469.5	293.89	3.20
Sandhill Crane	0.0	32.6	0.0	0.0	0.0	32.6	6.53	0.07
Killdeer	1.1	1.1	0.0	0.0	0.0	2.1	0.42	0.00
Lesser Yellowlegs	0.0	2.1	0.0	0.0	0.0	2.1	0.42	0.00
Bonaparte's Gull	0.0	9.5	0.0	0.0	0.0	9.5	1.89	0.02
Ring-billed Gull	18.9	195.8	30.5	0.0	0.0	245.3	49.05	0.53

Species	Extrapolated Totals					Total	Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5			
Unknown Gull	0.0	0.0	2.1	0.0	0.0	2.1	0.42	0.00
TOTAL	1,051.6	1,524.2	910.5	107.4	135.8	3,729.5	745.89	8.12

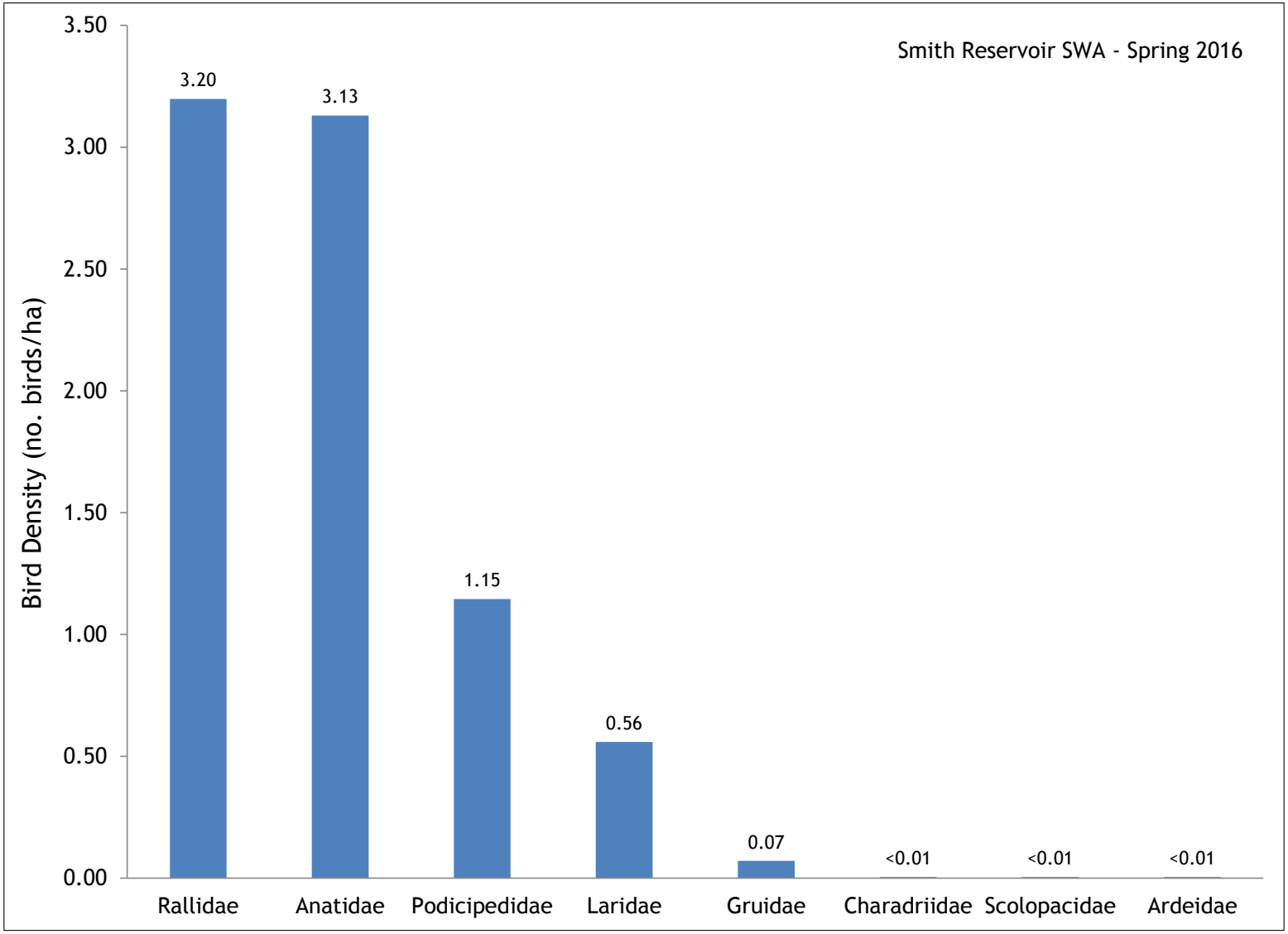

Figure 7. Mean density of waterbird and shorebird families across spring migration surveys at Smith Reservoir SWA, 2016.

Table 12. Total, mean, and mean density of waterbirds and shorebirds detected during spring migration surveys at Homelake SWA, 2016.

Species	Survey Totals					Total	Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5			
Canada Goose	1	2	0	3	0	6	1.20	0.04
Gadwall	14	2	0	0	0	16	3.20	0.12
Mallard	1	2	0	0	0	3	0.60	0.02
Blue-winged Teal	8	0	0	0	0	8	1.60	0.06
Cinnamon Teal	19	0	0	0	0	19	3.80	0.14
Northern Shoveler	84	8	8	0	0	100	20.00	0.72
Green-winged Teal	41	2	0	0	0	43	8.60	0.31
Redhead	0	1	2	0	0	3	0.60	0.02
Ring-necked Duck	0	0	8	0	0	8	1.60	0.06
Lesser Scaup	7	0	0	0	0	7	1.40	0.05
Bufflehead	0	1	0	0	0	1	0.20	0.01
Common Merganser	31	0	0	0	0	31	6.20	0.22
Ruddy Duck	33	71	97	13	27	241	48.20	1.74
Pied-billed Grebe	0	0	1	0	0	1	0.20	0.01
Eared Grebe	0	3	23	0	0	26	5.20	0.19
Western Grebe	0	12	52	28	21	113	22.60	0.82
Double Crested Cormorant	0	0	0	0	2	2	0.40	0.01
American White Pelican	3	0	6	1	0	10	2.00	0.07
White-faced Ibis	0	1	0	0	0	1	0.20	0.01
American Coot	92	77	45	14	1	229	45.80	1.65
American Avocet	0	3	8	0	0	11	2.20	0.08
Killdeer	3	0	0	0	0	3	0.60	0.02
Bonaparte's Gull	0	0	4	0	0	4	0.80	0.03
Ring-billed Gull	2	1	8	0	0	11	2.20	0.08
TOTAL	339	186	262	59	51	897	179.40	6.48

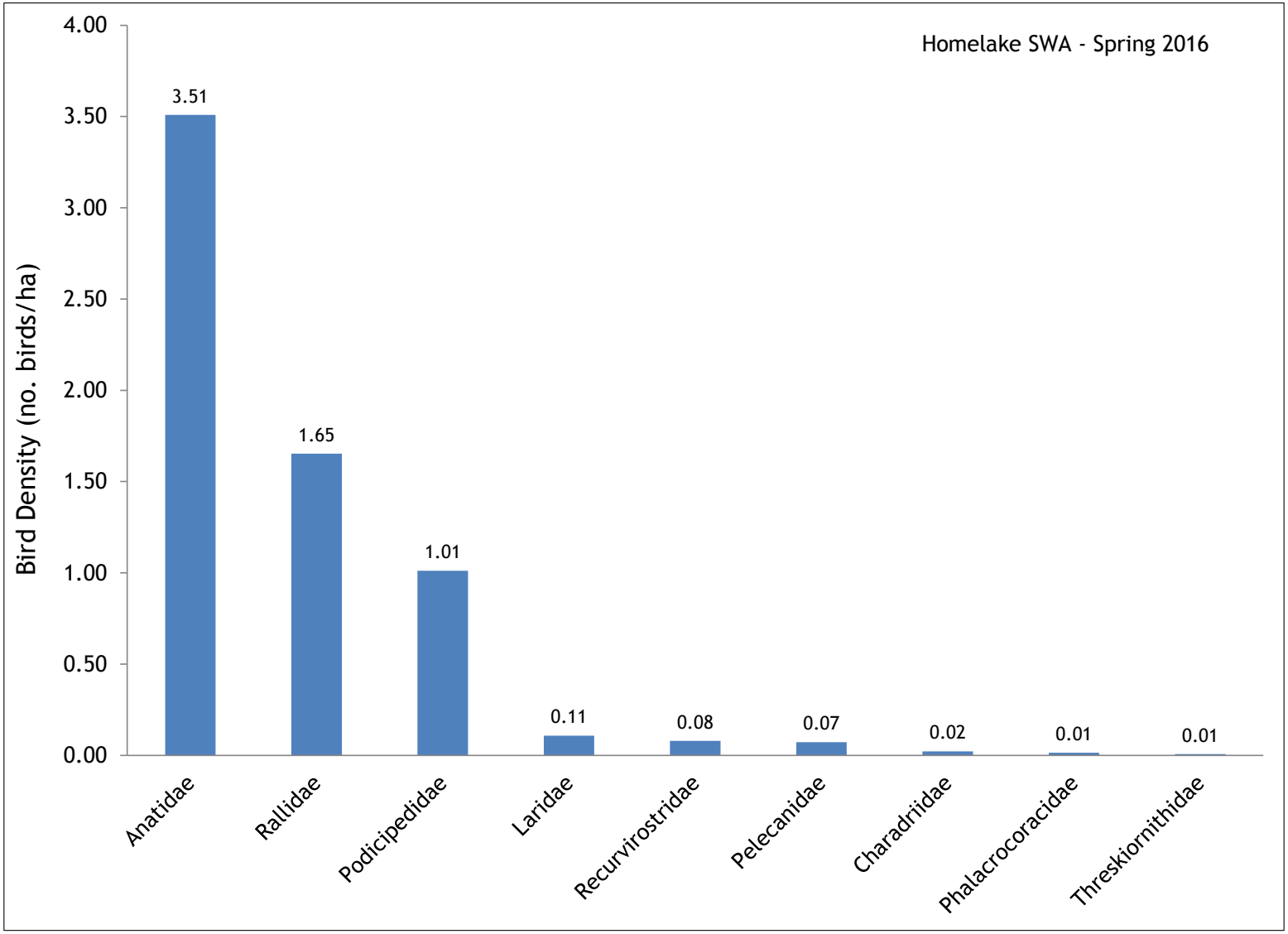

Figure 8. Mean density of waterbird and shorebird families across spring migration surveys at Homelake SWA, 2016.

Table 13. Extrapolated total, mean, and mean density of waterbirds and shorebirds detected during fall migration surveys at Russell Lakes SWA, 2016.

Species	Extrapolated Total				Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Total		
Gadwall	5.0	27.5	22.5	55.0	18.33	0.10
American Wigeon	0.0	15.0	7.5	22.5	7.50	0.04
Mallard	105.0	50.0	77.5	232.5	77.50	0.44
Blue-winged Teal	20.0	212.5	130.0	362.5	120.83	0.69
Cinnamon Teal	50.0	62.5	0.0	112.5	37.50	0.21
Northern Pintail	0.0	0.0	5.0	5.0	1.67	0.01
Green-winged Teal	340.0	10.0	0.0	350.0	116.67	0.67
Unknown Teal	0.0	0.0	225.0	225.0	75.00	0.43
Canvasback	2.5	5.0	2.5	10.0	3.33	0.02
Redhead	15.0	37.5	10.0	62.5	20.83	0.12
Common Merganser	2.5	0.0	0.0	2.5	0.83	0.00
Ruddy Duck	40.0	92.5	57.5	190.0	63.33	0.36
Pied-billed Grebe	75.0	15.0	20.0	110.0	36.67	0.21
Eared Grebe	0.0	0.0	5.0	5.0	1.67	0.01
Western Grebe	0.0	0.0	10.0	10.0	3.33	0.02
American White Pelican	7.5	0.0	0.0	7.5	2.50	0.01
American Bittern	15.0	0.0	2.5	17.5	5.83	0.03
Great Blue Heron	0.0	0.0	2.5	2.5	0.83	0.00
Snowy Egret	10.0	5.0	17.5	32.5	10.83	0.06
Black-crowned Night-Heron	30.0	0.0	0.0	30.0	10.00	0.06
White-faced Ibis	15.0	95.0	105.0	215.0	71.67	0.41
American Coot	522.5	592.5	722.5	1837.5	612.50	3.50
Black-necked Stilt	40.0	0.0	0.0	40.0	13.33	0.08
American Avocet	10.0	7.5	0.0	17.5	5.83	0.03
Baird's Sandpiper	12.5	7.5	0.0	20.0	6.67	0.04

Species	Extrapolated Total				Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Total		
Wilson's Snipe	10.0	0.0	0.0	10.0	3.33	0.02
Wilson's Phalarope	32.5	0.0	0.0	32.5	10.83	0.06
Unknown Sandpiper	2.5	0.0	0.0	2.5	0.83	0.00
Black Tern	2.5	0.0	0.0	2.5	0.83	0.00
Forster's Tern	0.0	0.0	7.5	7.5	2.50	0.01
TOTAL	1,365.0	1,235.0	1,430.0	4,030.0	1,343.33	7.68

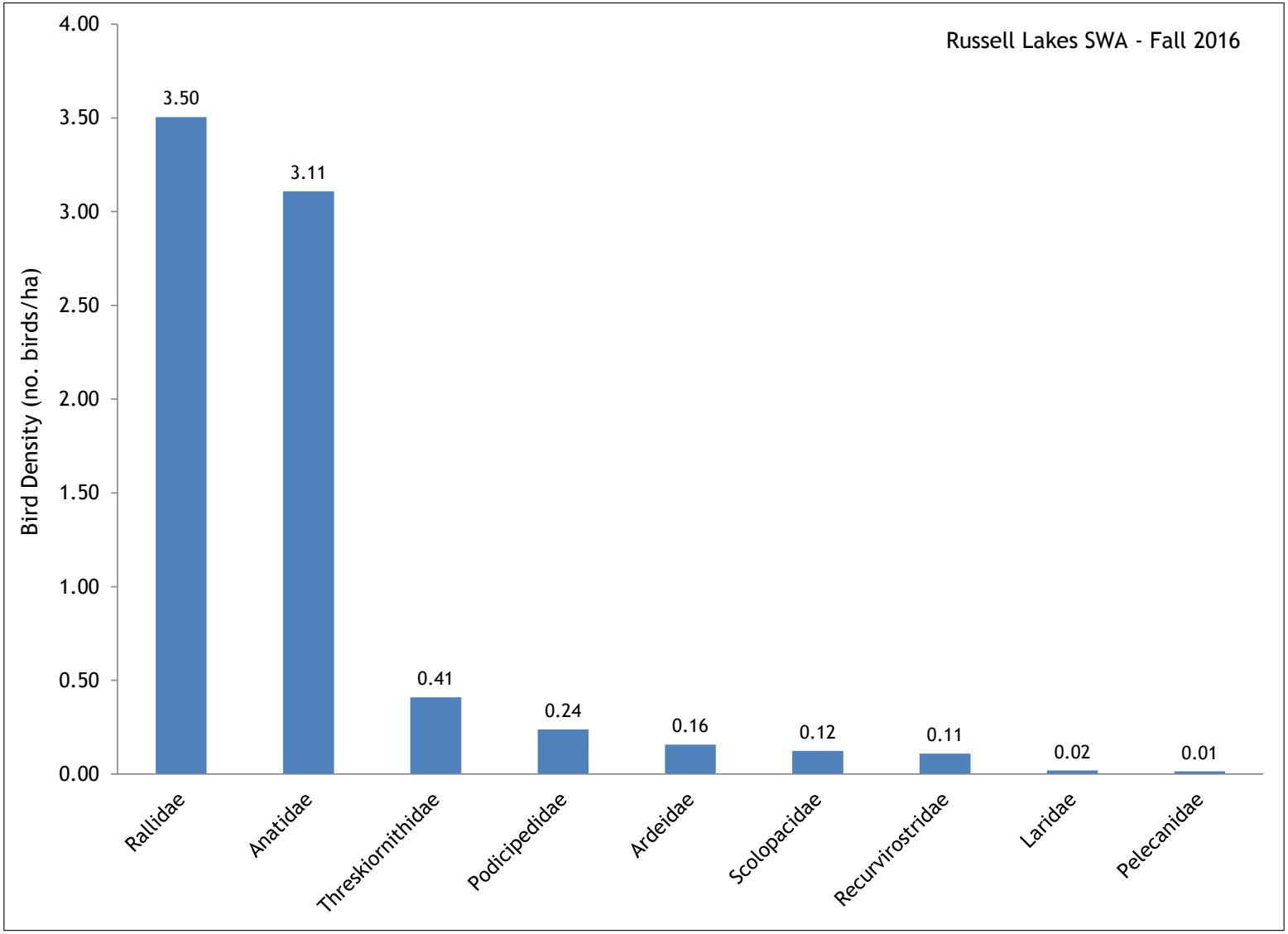

Figure 9. Mean density of waterbird and shorebird families across fall migration surveys at Russell Lakes SWA, 2016.

Table 14. Mean density and abundance of waterbird/shorebird species detected across fall migration surveys at Monte Vista NWR, 2016.

Stratification	Model	No. of Param.	AIC	Delta AIC	Mean Density	CV	95% CI LCL	95% CI UCL
Survey Period	Haz. Rate. + Cos.	6	1,033.899	0.000	3.160	0.148	2.361	4.230
	Haz. Rate. + Poly.	6	1,033.899	0.000	3.160	0.148	2.361	4.230
	Half Norm. + Poly.	5	1,037.154	3.255	3.414	0.148	2.550	4.569
	Half Norm. + Cos.	3	1,042.161	8.262	3.248	0.146	2.433	4.336
	Neg. Exp. + Cos.	4	1,044.183	10.284	4.744	0.159	3.468	6.488
	Neg. Exp. + Poly.	4	1,044.294	10.395	4.749	0.159	3.473	6.493
Species	Haz. Rate + Poly.	50	982.595	0.000	4.527	0.225	2.865	7.151
	Haz. Rate + Cos.	48	983.606	1.011	4.424	0.228	2.783	7.033
	Half Norm. + Poly.	25	1,015.582	32.987	6.134	0.446	2.453	15.339
	Half Norm. + Cos.	24	1,018.851	36.256	6.136	0.446	2.454	15.340
	Neg. Exp. + Poly.	35	1,021.940	39.345	7.700	0.292	4.248	13.958
	Neg. Exp. + Cos.	28	1,039.641	57.046	18.157	1.918	0.132	2488.597
Family	Haz. Rate + Poly.	18	1,016.283	0.000	3.686	0.148	2.762	4.918
	Haz. Rate + Cos.	16	1,017.209	0.926	3.496	0.137	2.675	4.570
	Half Norm. + Poly.	11	1,019.890	3.607	3.691	0.131	2.855	4.773
	Neg. Exp. + Poly.	14	1,025.118	8.835	4.492	0.142	3.405	5.927
	Half Norm. + Cos.	9	1,034.391	18.108	3.271	0.126	2.557	4.184
	Neg. Exp. + Cos.	12	,1041.643	25.360	4.737	0.137	3.626	6.188

Table 15. Overall density and abundance estimates for waterbird and shorebird species during fall migration surveys at Monte Vista NWR, 2016.

	Density	95% CI				Abundance	95% CI	
Survey Period	**Estimate**	**LCL**	**UCL**	**% CV**	**df**	**Estimate**	**LCL**	**UCL**
Survey Period 1	3.612	2.174	6.002	25.490	38.380	3,099	1,865	5,149
Survey Period 2	3.596	2.179	5.936	25.250	43.460	3,085	1,869	5,093
Survey Period 3	2.273	1.420	3.636	23.900	70.990	1,950	1,219	3,119
Pooled Mean	3.160	2.361	4.230	14.790	108.720	8,135	6,077	10,889

Table 16. Mean density and abundance of waterbirds and shorebirds detected across fall migration surveys at Monte Vista NWR, 2016.

	Density			95% CI		Abundance	95% CI	
Species	Estimate	% CV	df	LCL	UCL	Estimate	LCL	UCL
Blue-winged Teal	1.167	32.890	131.030	0.619	2.200	20,029	10,625	37,755
American Coot	0.791	31.180	180.280	0.434	1.443	13,574	7,442	24,760
Unknown Teal	0.690	123.950	12.790	0.086	5.565	11,838	1,468	95,492
Mallard	0.613	24.970	176.950	0.377	0.995	10,513	6,470	17,082
Cinnamon Teal	0.246	48.940	60.640	0.097	0.622	4,224	1,672	10,670
Green-winged Teal	0.211	69.720	25.070	0.058	0.770	3,615	989	13,214
Sora	0.184	49.110	46.220	0.072	0.470	3,164	1,242	8,063
Northern Shoveler	0.127	56.630	26.890	0.043	0.376	2,184	740	6,447
Redhead	0.111	114.850	4.330	0.009	1.313	1,903	161	22,531
Gadwall	0.089	72.910	15.310	0.022	0.357	1,528	381	6,129
Wilson's Snipe	0.078	48.560	59.570	0.031	0.195	1,335	532	3,350
Ruddy Duck	0.049	44.560	84.470	0.021	0.115	847	363	1,974
Black-crowned Night-Heron	0.044	64.910	80.890	0.014	0.143	756	232	2,459
American Wigeon	0.036	111.180	4.900	0.004	0.366	617	61	6,280
White-faced Ibis	0.033	45.740	61.140	0.014	0.079	565	236	1,350
Canada Goose	0.017	70.300	73.280	0.005	0.059	288	81	1,017
Unknown Duck	0.017	116.970	2.430	0.001	0.494	288	10	8,484
Killdeer	0.014	44.210	42.520	0.006	0.032	236	100	552
Baird's Sandpiper	0.004	100.000	73.000	0.001	0.020	65	12	341
Pied-billed Grebe	0.002	77.730	23.290	0.000	0.007	28	7	115
Wilson's Phalarope	0.002	105.410	47.400	0.000	0.009	28	5	158
American Bittern	0.001	70.220	73.000	0.000	0.004	19	5	66
Sandhill Crane	0.001	100.000	73.000	0.000	0.006	19	4	97
Semipalmated Sandpiper	0.001	70.220	73.000	0.000	0.004	19	5	66

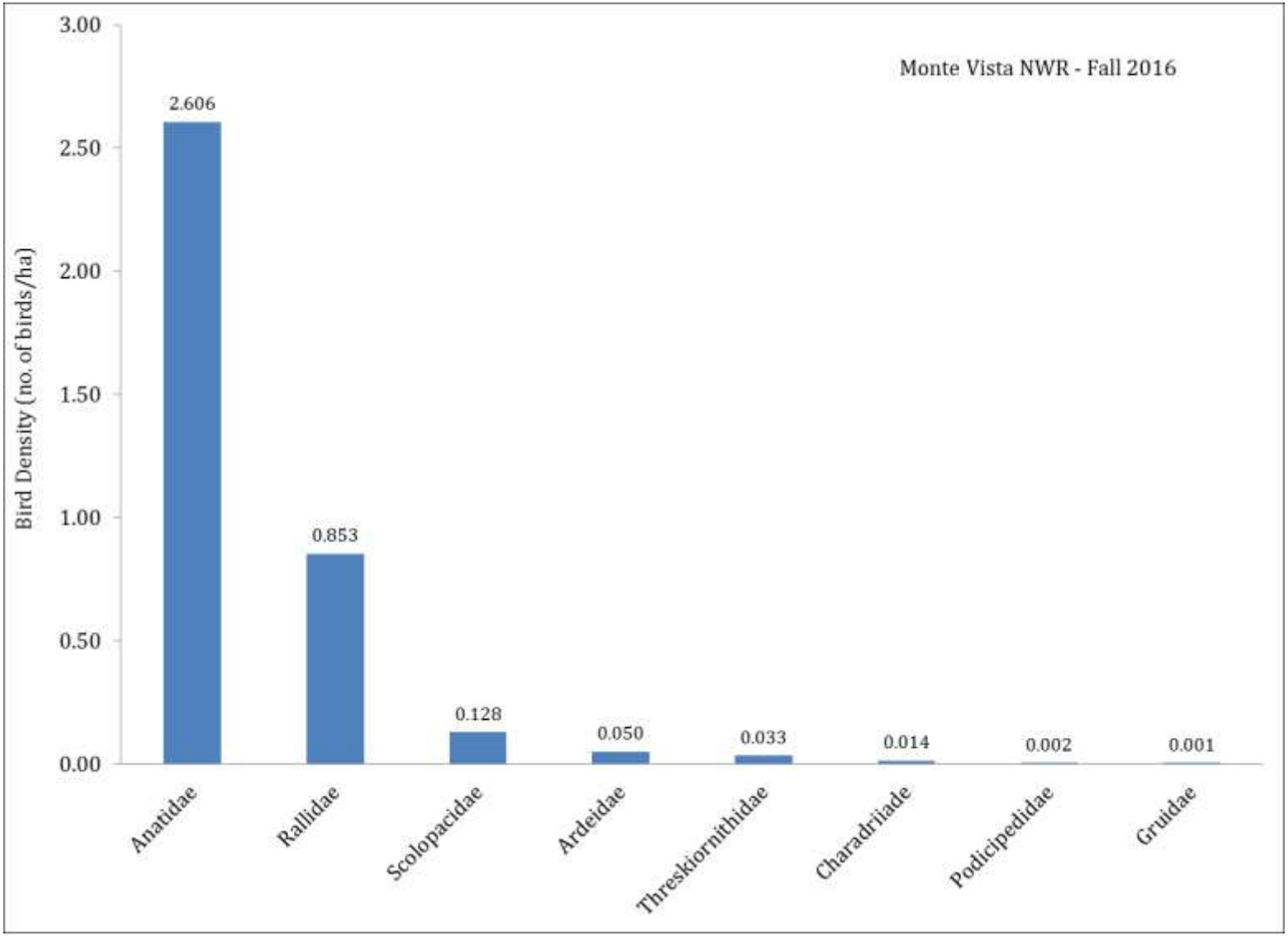

Figure 10. Mean density of waterbird and shorebird families across fall migration surveys at Monte Vista NWR, 2016.

Table 17. Extrapolated total, mean, and mean density of waterbirds and shorebirds detected during fall migration surveys at Blanca Wetlands, 2016.

Species	Extrapolated Total					Mean	Mean Density (No. birds/ha)
	Survey 1 [a]	Survey 2	Survey 3	Survey 4	Total		
Canada Goose		28.4	0.0	0.0	28.4	9.47	0.09
Gadwall		126.3	170.5	29.5	326.3	108.77	1.01
American Wigeon		0.0	47.4	35.8	83.2	27.72	0.26
Mallard		48.4	50.5	403.2	502.1	167.37	1.55
Blue-winged Teal		442.1	84.2	258.9	785.3	261.75	2.43
Cinnamon Teal		273.7	567.4	3.2	844.2	281.40	2.61
Unknown Teal		0.0	78.9	204.2	283.2	94.39	0.88
Northern Shoveler		0.0	,1087.4	887.4	1,974.7	658.25	6.11
Northern Pintail		1.1	17.9	68.4	87.4	29.12	0.27
Green-winged Teal		156.8	87.4	167.4	411.6	137.19	1.27
Canvasback		0.0	9.5	21.1	30.5	10.18	0.09
Redhead		26.3	14.7	17.9	58.9	19.65	0.18
Lesser Scaup		0.0	0.0	9.5	9.5	3.16	0.03
Common Merganser		1.1	1.1	0.0	2.1	0.70	0.01
Ruddy Duck		110.5	122.1	454.7	687.4	229.12	2.13
Pied-billed Grebe		15.8	6.3	0.0	22.1	7.37	0.07
Eared Grebe		10.5	6.3	50.5	67.4	22.46	0.21
Western Grebe		0.0	0.0	3.2	3.2	1.05	0.01
American White Pelican		7.4	4.2	0.0	11.6	3.86	0.04
Great Blue Heron		0.0	0.0	1.1	1.1	0.35	0.00
White-faced Ibis		8.4	64.2	2.1	74.7	24.91	0.23
American Coot		348.4	620.0	1,069.5	2,037.9	679.30	6.31
American Avocet		1,702.1	712.6	361.1	2,775.8	925.26	8.59
Killdeer		1.1	4.2	4.2	9.5	3.16	0.03
Solitary Sandpiper		0.0	1.1	0.0	1.1	0.35	0.00

Species	Extrapolated Total					Mean	Mean Density (No. birds/ha)
	Survey 1 [a]	Survey 2	Survey 3	Survey 4	Total		
Lesser Yellowlegs		4.2	35.8	0.0	40.0	13.33	0.12
Sanderling		37.9	0.0	0.0	37.9	12.63	0.12
Baird's Sandpiper		483.2	454.7	0.0	937.9	312.63	2.90
Semi-palmated Sandpiper		0.0	2.1	0.0	2.1	0.70	0.01
Long-billed Dowitcher		0.0	0.0	10.5	10.5	3.51	0.03
Wilson's Phalarope		1,729.5	421.1	1.1	2,151.6	717.19	6.66
Red-necked Phalarope		167.4	0.0	0.0	167.4	55.79	0.52
Unknown Sandpiper		13.7	1,210.5	11.6	1,235.8	411.93	3.82
Franklin's Gull		0.0	0.0	1.1	1.1	0.35	0.00
Ring-billed Gull		18.9	62.1	8.4	89.5	29.82	0.28
California Gull		13.7	1.1	1.1	15.8	5.26	0.05
TOTAL		5,776.8	5,945.3	4,086.3	1,5808.4	5,269.47	48.93

[a] Not surveyed in Period 1

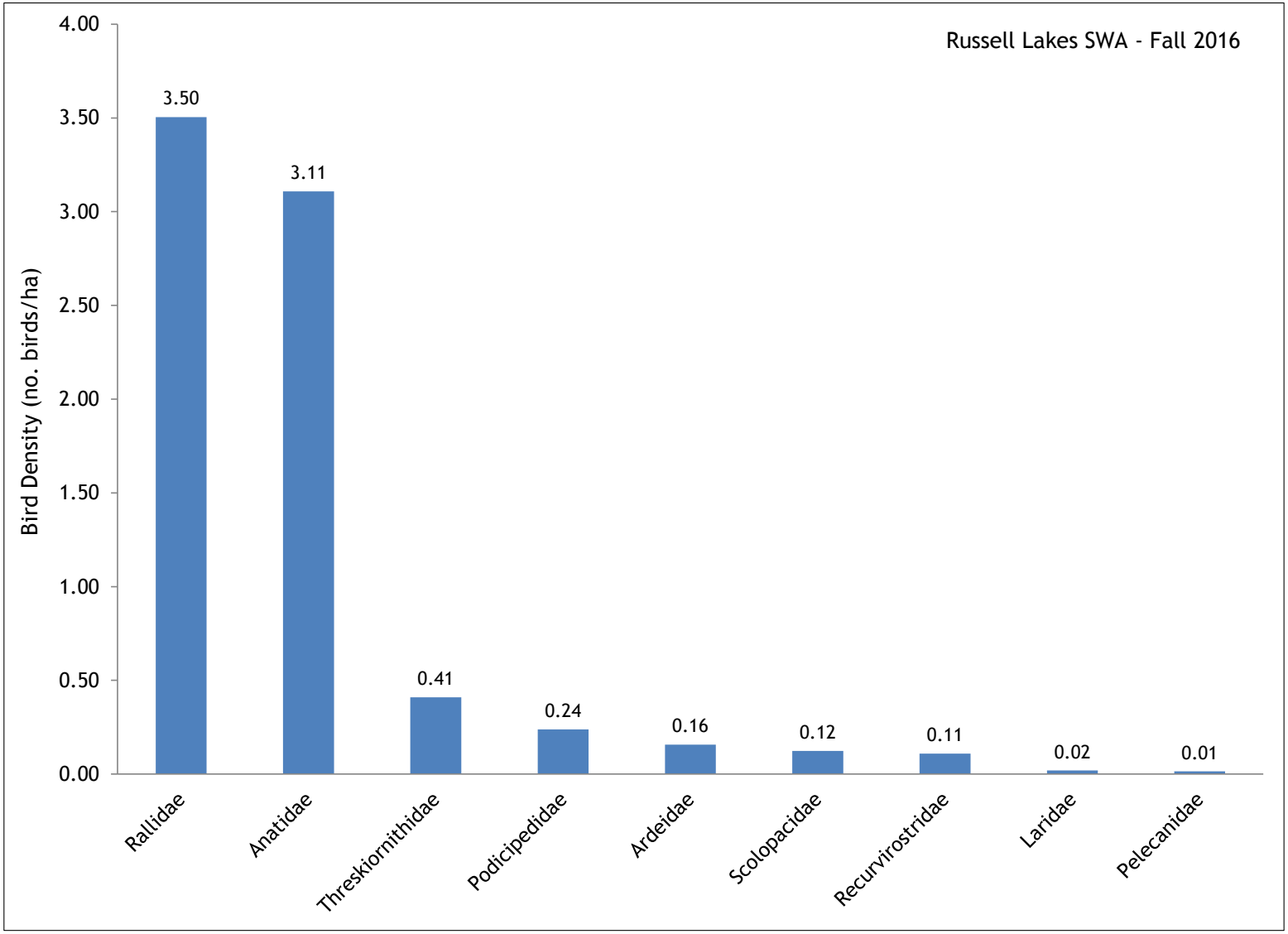

Figure 11. Mean density of waterbird and shorebird families across fall migration surveys at Blanca Wetlands, 2016.

Table 18. Mean density and abundance of waterbirds and shorebirds detected across fall migration surveys in riparian habitat at Rio Grande and Sego Springs SWAs, 2016.

Stratification	Model	No. of Param.	AIC	Delta AIC	Mean Density	CV	95% CI LCL	95% CI UCL
Survey Period	Neg. Exp. + Poly.	4	122.939	0.000	6.257	0.433	2.716	14.413
	Neg. Exp. + Cos.	4	124.148	1.209	6.417	0.421	2.844	14.478
	Half Norm. + Poly	3	124.480	1.540	3.365	0.295	1.886	6.003
	Half Norm. + Cos.	3	124.480	1.540	3.365	0.295	1.886	6.003
	Haz. Rate + Poly.	6	126.612	3.672	3.175	0.327	1.674	6.020
	Haz. Rate + Cos.	6	126.612	3.672	3.175	0.327	1.674	6.020
Species	Haz. Rate + Poly.	32	111.712	0.000	7.447	0.924	0.965	57.469
	Haz. Rate + Cos	28	111.811	0.099	7.397	0.928	0.947	57.807
	Half Norm. + Poly.	14	120.486	8.773	22.195	1.369	1.217	404.677
	Half Norm. + Cos	14	120.486	8.773	22.195	1.369	1.217	404.677
	Neg. Exp. + Cos.	14	120.501	8.789	1.7E+05	4.558	0.003	8.3E+12
	Neg. Exp. + Poly.	14	120.501	8.789	1.7E+05	4.558	0.003	8.3E+12
Family	Neg. Exp. + Cos.	6	137.846	0.000	8.005	0.484	3.111	20.598
	Neg. Exp. + Poly.	6	137.846	0.000	8.005	0.484	3.111	20.598
	Haz. Rate + Poly.	15	142.899	5.053	4.918	0.442	2.103	11.502
	Half Norm. + Poly.	6	145.838	7.992	3.704	0.401	1.681	8.161
	Half Norm. + Cos.	6	145.838	7.992	3.704	0.401	1.681	8.161
	Haz. Rate + Cos.	12	146.330	8.484	4.673	0.357	2.337	9.342

Table 19. Overall density and abundance estimates for waterbird and shorebird species during fall migration surveys at Rio Grande and Sego Springs SWAs, 2016.

Survey	Density	95% CI				Abundance	95% CI	
Period	Estimate	LCL	UCL	% CV	df	Estimate	LCL	UCL
Survey 1	7.782	1.947	31.104	75.070	22.260	1,634	409	6,532
Survey 2	0.757	0.115	4.959	109.830	16.620	159	24	1,041
Survey 3	11.557	4.214	31.695	52.460	28.670	2,427	885	6,656
Pooled Mean	6.257	2.716	14.413	43.290	45.790	1,314	570	3,027

Table 20. Mean density and abundance of waterbirds and shorebirds detected across fall migration surveys at Rio Grande and Sego Springs SWAs, 2016.

	Density	95% CI				Abundance	95% CI	
Species	Estimate	LCL	UCL	% CV	df	Estimate	LCL	UCL
Common Merganser	4.492	0.252	79.988	151.610	4.620	5,165	290	91,986
Spotted Sandpiper	0.646	0.108	3.882	94.960	9.740	743	124	4,465
Lesser Yellowlegs	0.579	0.064	5.257	96.380	4.210	666	73	6,046
Mallard	0.392	0.078	1.978	78.800	7.570	451	89	2,275
Wood Duck	0.289	0.069	1.216	77.170	18.020	333	79	1,399
American Coot	0.193	0.035	1.052	100.000	32.000	222	41	1,209
Wilson's Phalarope	0.193	0.035	1.052	100.000	32.000	222	41	1,209
Wilson's Snipe	0.193	0.054	0.694	69.600	32.000	222	62	798
American Bittern	0.096	0.018	0.526	100.000	32.000	111	20	605
Green Heron	0.096	0.018	0.526	100.000	32.000	111	20	605
Pied-billed Grebe	0.096	0.018	0.526	100.000	32.000	111	20	605
Solitary Sandpiper	0.096	0.018	0.526	100.000	32.000	111	20	605
Great Blue Heron	0.058	0.028	0.121	37.180	25.170	67	32	140
Killdeer	0.026	0.006	0.122	74.800	8.020	30	6	140

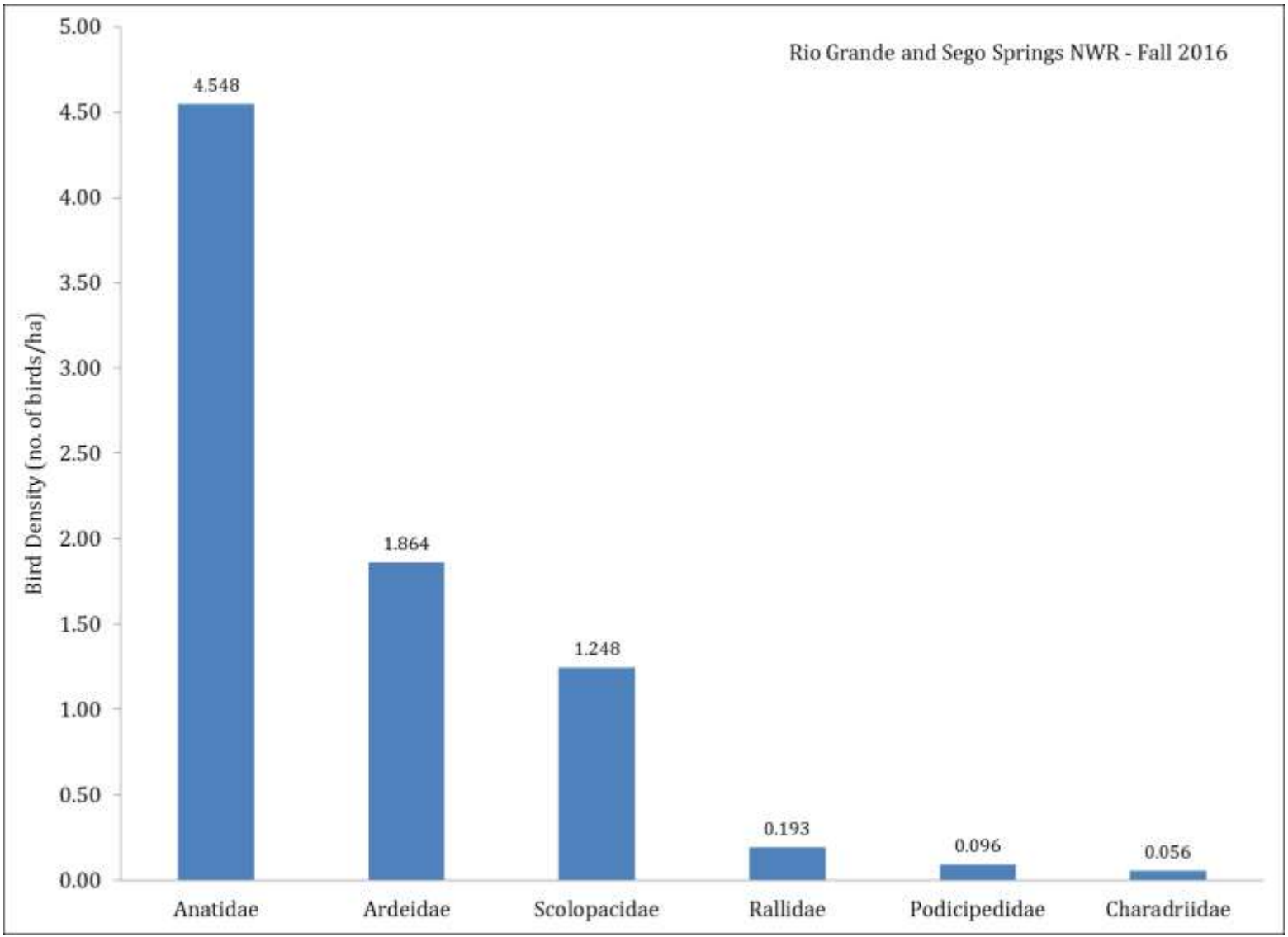

Figure 12. Mean density of waterbird and shorebird families across fall migration surveys at Rio Grande and Sego Springs SWAs, 2016.

Table 21. Extrapolated total, mean, and mean density of waterbirds and shorebirds detected during fall migration surveys at Smith Reservoir SWA, 2016.

Species	Extrapolated Total					Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Survey 4	Total		
Canada Goose	60.0	406.3	2086.3	867.4	3420.0	855.00	9.30
Gadwall	6.3	65.3	252.6	0.0	324.2	81.05	0.88
American Wigeon	0.0	0.0	3.2	0.0	3.2	0.79	0.01
Mallard	0.0	26.3	170.5	216.8	413.7	103.42	1.13
Blue-winged Teal	11.6	3.2	45.3	74.7	134.7	33.68	0.37
Cinnamon Teal	0.0	5.3	73.7	0.0	78.9	19.74	0.21
Unknown Teal	0.0	0.0	107.4	0.0	107.4	26.84	0.29
Northern Shoveler	12.6	0.0	4.2	97.9	114.7	28.68	0.31
Green-winged Teal	0.0	55.8	2.1	0.0	57.9	14.47	0.16
Lesser Scaup	0.0	1.1	0.0	0.0	1.1	0.26	0.00
Common Merganser	6.3	0.0	0.0	1.1	7.4	1.84	0.02
Ruddy Duck	50.5	180.0	432.6	489.5	1,152.6	288.16	3.14
Unknown Duck	0.0	0.0	6.3	0.0	6.3	1.58	0.02
Pied-billed Grebe	0.0	1.1	0.0	1.1	2.1	0.53	0.01
Eared Grebe	69.5	25.3	0.0	0.0	94.7	23.68	0.26
Western Grebe	15.8	33.7	14.7	1.1	65.3	16.32	0.18
Double-crested Cormorant	0.0	0.0	0.0	1.1	1.1	0.26	0.00
American White Pelican	11.6	49.5	26.3	21.1	108.4	27.11	0.29
Great Blue Heron	0.0	0.0	3.2	0.0	3.2	0.79	0.01
Black-crowned Night-Heron	0.0	7.4	0.0	0.0	7.4	1.84	0.02
White-faced Ibis	0.0	40.0	123.2	3.2	166.3	41.58	0.45
American Coot	1,268.4	1,781.1	4,853.7	3,689.5	11,592.6	2,898.16	31.54
Sandhill Crane	0.0	0.0	0.0	2.1	2.1	0.53	0.01
Killdeer	2.1	2.1	3.2	7.4	14.7	3.68	0.04
Lesser Yellowlegs	0.0	3.2	0.0	0.0	3.2	0.79	0.01

Species	Extrapolated Total					Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Survey 4	Total		
Baird's Sandpiper	0.0	0.0	42.1	0.0	42.1	10.53	0.11
Semi-palmated Sandpiper	0.0	1.1	0.0	0.0	1.1	0.26	0.00
Long-billed Dowitcher	0.0	0.0	0.0	6.3	6.3	1.58	0.02
Wilson's Phalarope	0.0	27.4	63.2	3.2	93.7	23.42	0.25
Unknown Sandpiper	1.1	0.0	0.0	0.0	1.1	0.26	0.00
Ring-billed Gull	0.0	0.0	0.0	1.1	1.1	0.26	0.00
Unknown Gull	0.0	0.0	7.4	10.5	17.9	4.47	0.05
TOTAL	1,515.8	2,714.7	8,321.1	5,494.7	18,046.3	4,511.58	49.09

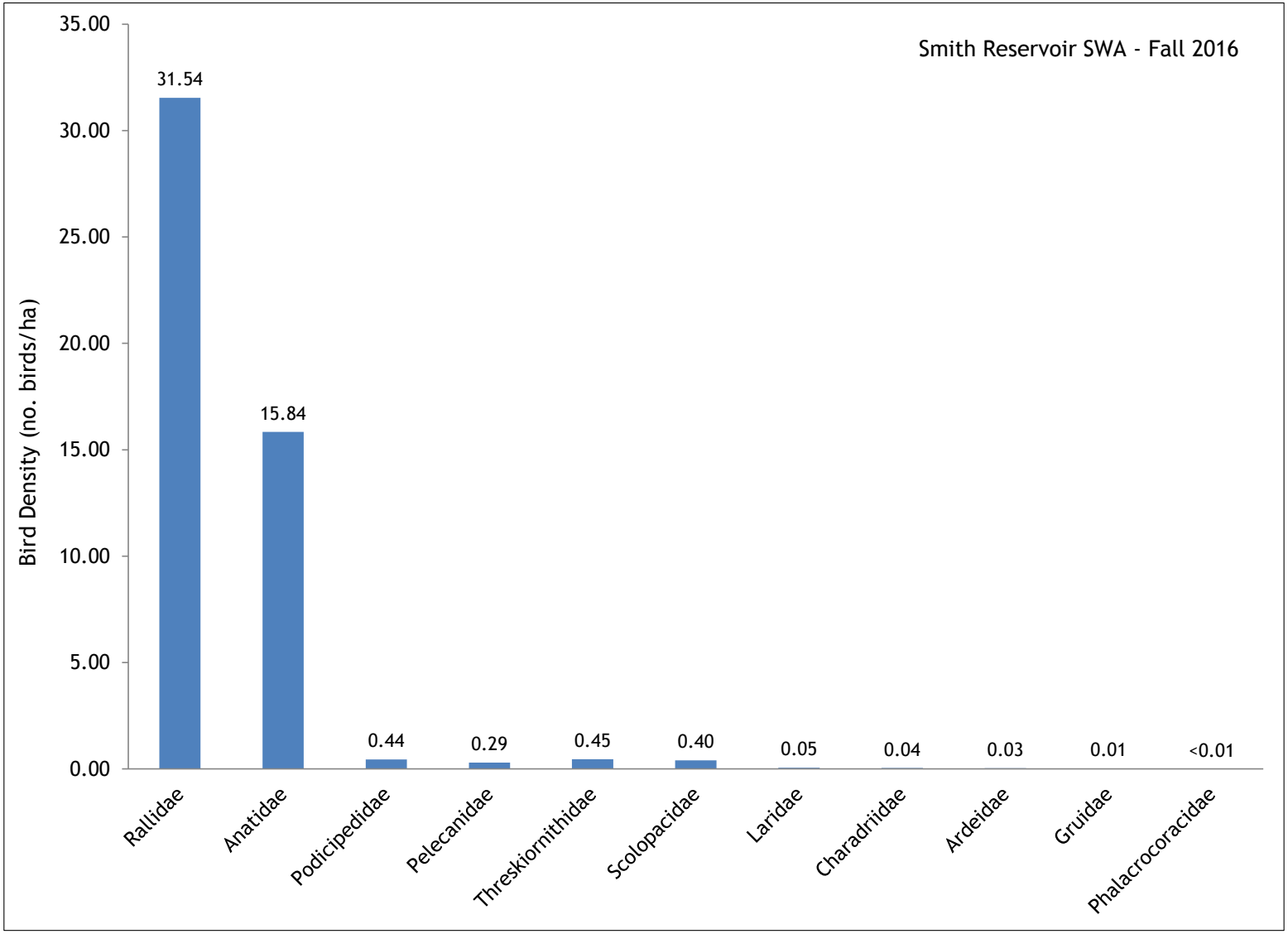

Figure 13. Mean density of waterbird and shorebird families across fall migration surveys at Smith Reservoir SWA, 2016.

Table 22. Total, mean, and mean density of waterbirds and shorebirds detected during fall migration surveys at Homelake Reservoir SWA, 2016.

Species	Survey Totals					Mean	Mean Density (No. birds/ha)
	Survey 1	Survey 2	Survey 3	Survey 4	Total		
Canada Goose	23	0	0	0	23	5.8	0.21
Gadwall	0	0	7	4	11	2.8	0.10
American Wigeon	4	0	0	0	4	1.0	0.04
Mallard	0	0	2	12	14	3.5	0.13
Blue-winged Teal	13	0	10	17	40	10.0	0.36
Unknown Teal	0	7	0	0	7	1.8	0.06
Northern Shoveler	0	0	1	0	1	0.3	0.01
Green-winged Teal	0	14	0	0	14	3.5	0.13
Redhead	0	7	1	13	21	5.3	0.19
Ruddy Duck	44	28	53	138	263	65.8	2.37
Pied-billed Grebe	8	6	7	1	22	5.5	0.20
Eared Grebe	2	0	1	0	3	0.8	0.03
Western Grebe	8	17	15	12	52	13.0	0.47
Double-crested Cormorant	1	11	7	6	25	6.3	0.23
American White Pelican	0	6	4	0	10	2.5	0.09
American Coot	247	619	1,561	972	3,399	849.8	30.68
Killdeer	0	0	0	1	1	0.3	0.01
Ring-billed Gull	0	0	1	0	1	0.3	0.01
Forster's Tern	0	0	2	0	2	0.5	0.02
TOTAL	350	715	1,672	1,176	3,913	978.3	35.32

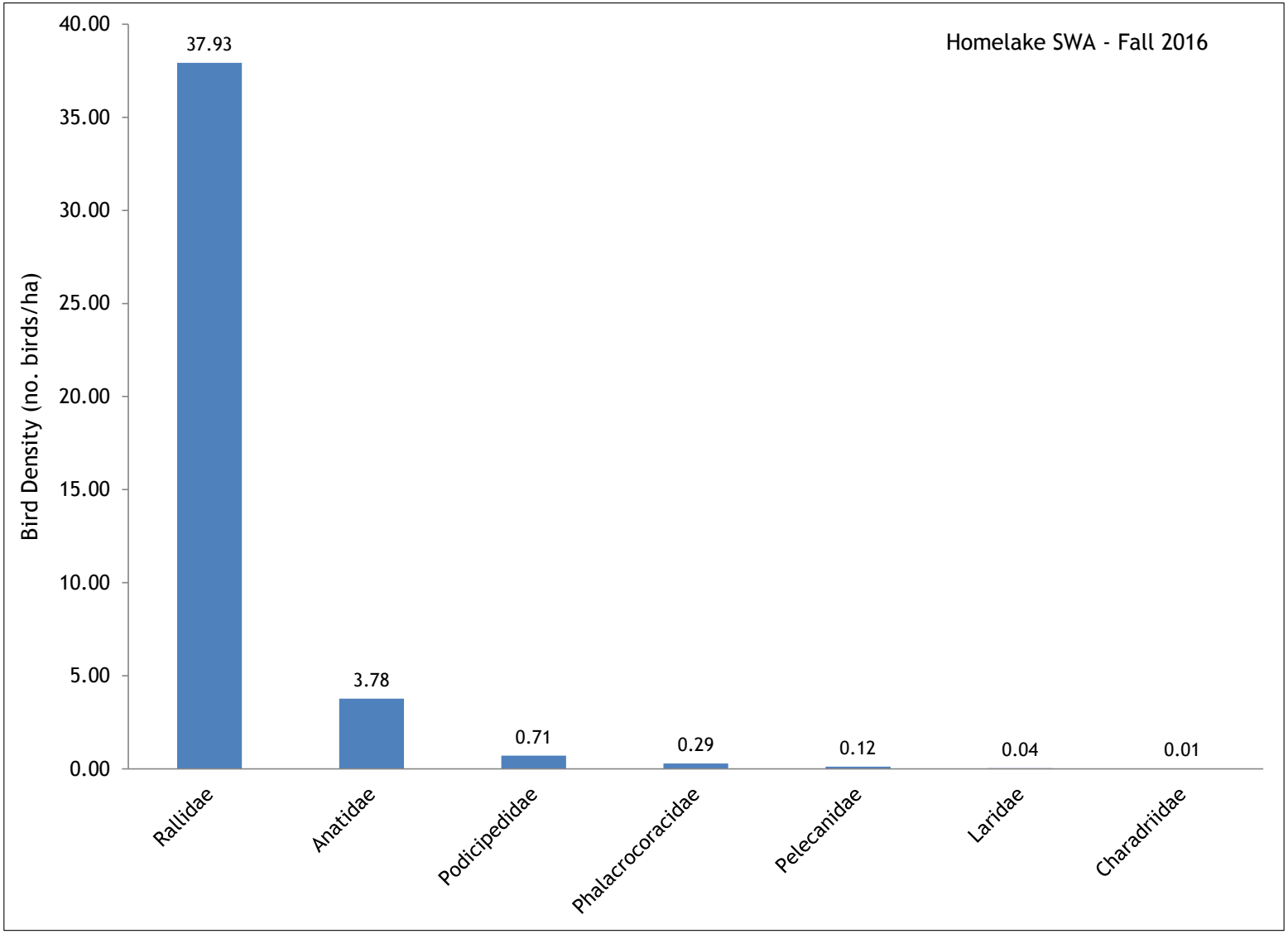

Figure 14. Mean density of waterbird and shorebird families across fall migration surveys at Homelake SWA, 2016.

Table 23. Extrapolated abundance of waterbirds and shorebirds during spring migration surveys in the San Luis Valley, 2016.

	Density Estimate (No. birds/ha) [a]			SLV Abundance Estimate [a]			
Survey Period	**Shallow Emergent**	**Playa/ Reservoir**	**Riparian**	**Shallow Emergent**	**Playa/ Reservoir**	**Riparian**	**Total Abundance**
1	19.519	18.058	[b]	1,540,528	79,034	[b]	1,619,562
2	7.896	14.924	[b]	623,221	65,318	[b]	688,540
3	6.653	12.219	2.041	525,090	53,476	8,514	587,081
4	3.063	3.729	1.161	241,774	16,318	4,843	262,935
5	2.997	4.032	1.069	236,575	17,646	4,461	258,681
Pooled Mean	7.573	10.592	1.376	597,685	46,359	5,738	683,360
Total				3,167,188	231,793	17,819	3,416,799

[a] Mean estimate across sampling sites

[b] No survey conducted during this survey period

Table 24. Extrapolated abundance of waterbirds and shorebirds during fall migration surveys in the San Luis Valley, 2016.

Survey Period	Density Estimate (No. birds/ha) [a]			SLV Abundance Estimate [a]			Total Abundance
	Shallow Emergent	Playa/ Reservoir	Riparian	Shallow Emergent	Playa/ Reservoir	Riparian	
1	[b]	14.565	[b]	[b]	63,744	[b]	63,744
2	5.711	36.330	7.782	450,709	159,003	32,465	642,177
3	5.331	68.703	0.757	420,717	300,684	3,157	724,558
4	5.227	46.729	11.557	412,511	204,514	48,212	665,238
Pooled Mean	5.423	44.445	6.257	427,981	194,519	26,102	648,601
Total				1,283,938	727,944	83,834	2,095,716

[a] Mean estimate across sampling sites

[b] No survey conducted during this survey period

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APPENDIX C.

REPRESENTATIVE PHOTOS OF HABITATS AND BIRDS AT SAN LUIS VALLEY WETLANDS

Shallow emergent habitat at Russell Lakes SWA, 23 March 2016

Shallow emergent habitat at Russell Lakes SWA, 10 Aug 2016

Shallow emergent habitat at Russell Lakes SWA, 4 May 2016

Shallow emergent habitat at Russell Lakes SWA, 30 August 2016

Shallow emergent habitat at Russell Lakes SWA, 9 June 2016

Shallow emergent habitat at Russell Lakes SWA, 21 September 2016

Shallow emergent habitat at Monte Vista NWR, 24 March 2016

Shallow emergent habitat at Monte Vista NWR, 11 August 2016

Shallow emergent habitat at Monte Vista NWR, 3 May 2016

Shallow emergent habitat at Monte Vista NWR, 1 September 2016

Shallow emergent habitat at Monte Vista NWR, 10 June 2016

Shallow emergent habitat at Monte Vista NWR, 22 September 2016

Playa habitat at Blanca Wetlands, 24 March 2016

Playa habitat at Blanca Wetlands, 25 May 2016

Playa habitat at Blanca Wetlands, 13 April 2016

Playa habitat at Blanca Wetlands, 31 August 2016

Playa habitat at Blanca Wetlands, 4 May 2016

Playa habitat at Blanca Wetlands, 21 September 2016

Smith Reservoir SWA, 12 April 2016

Smith Reservoir SWA, 31 August 2016

Gulls on sandbar at Smith Reservoir SWA, 12 April 2016

American White Pelicans and America Coots at Smith Reservoir SWA, 31 August 2016

Smith Reservoir SWA, 25 May 2016

Smith Reservoir SWA, 21 September 2016

Homelake SWA, 12 April 2016

Double-crested Cormorants and American White Pelicans at Homelake SWA, 11 August 2016

Western Grebe at Homelake SWA, 12 April 2016

Homelake SWA, 11 August 2016

Riparian habitat at Rio Grande SWA, 5 May 2016

Riparian habitat at Sego Springs SWA, 25 May 2016

Riparian habitat at Rio Grande SWA, 9 June 2015

Riparian habitat at Sego Springs SWA, 30 August 2016

Riparian habitat at Rio Grande SWA, 30 August 2016

Riparian habitat at Sego Springs SWA, 20 September 2016

Male Northern Shoveler at Blanca Wetlands

American Avocets at Blanca Wetlands

Mixed group of waterfowl at Blanca Wetlands

American Coots at Monte Vista NWR

Franklin's Gull at Blanca Wetlands

Black-necked Stilt at Monte Vista NWR

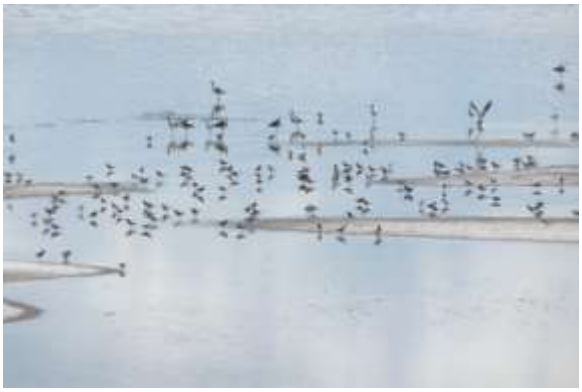
Peregrine Falcon eating an American Coot at Monte Vista NWR

Wilson's Snipes at Monte Vista NWR

White-faced Ibis at Monte Vista NWR

American White Pelicans at Blanca Wetlands

Redheads and Ruddy Duck at Monte Vista NWR



Mixed group of American Avocets and sandpipers at Blanca Wetlands