Playa Lakes Joint Venture
Waterbird Team Report

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A Contribution to the
Waterbird Conservation for the Americas
(North American Waterbird Conservation Plan)
and the
Playa Lakes Joint Venture Implementation Plan

by the Playa Lakes Joint Venture
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Background, Purpose, and Intended Audience

Waterbird Conservation for the Americas

The vision of Waterbird Conservation for the Americas is that the distribution, diversity, and abundance of populations and habitats of breeding, migratory, and nonbreeding waterbirds are sustained or restored throughout the lands and waters of North America, Central America, and the Caribbean (Kushlan et al. 2002). This "waterbird initiative" was launched in 1998 to link ongoing efforts addressing threats to waterbirds and their habitats.

The waterbird initiative encourages integration with other bird initiatives, and development of conservation strategies based on rigorous scientific and practical knowledge. It has formed several regional waterbird working groups and plans. The Central Prairies regional group currently is inactive and has not produced a plan. The initiative encourages the habitat Joint Ventures to create waterbird advisory committees, to undertake explicit planning, habitat and population goal setting, and to develop waterbird conservation strategies.

Playa Lakes Joint Venture

The Playa Lakes Joint Venture (PLJV) was formed in 1989 to implement the North American Waterfowl Management Plan in the Playa Lakes Region (PLR). The original PLR included northwestern Texas and portions of southeastern Colorado, southwestern Kansas, eastern New Mexico, and western Oklahoma. The PLJV has expanded geographically to include most of the Short-grass and Mixed-grass Bird Conservation Regions (BCRs) (Fig. 1), and has expanded its focus to include all birds. The PLJV has accepted the challenge of the waterbird initiative to develop explicit conservation objectives for waterbirds. The PLJV updated its Implementation Plan in 2006 (PLJV 2006a); the adaptive approach to planning used by the PLJV requires maintaining up-to-date waterbird population and habitat objectives.

PLJV Waterbird Team

The PLJV Monitoring, Evaluation, and Research Team (MERT) formed a Waterbird Team in 2003 to develop waterbird population and habitat objectives. The 8-member team is comprised of volunteer waterbird experts from around the PLJV region and 2 PLJV staff members. One co-chair (D. Klute) is a member of the PLJV's MERT.

Goal, Purpose, and Intended Audience

Our goal was to create a biological foundation for PLJV waterbird conservation actions by developing waterbird objectives in a manner consistent with the guidance and needs of the waterbird initiative and the PLJV. Specifically, we developed (1) regional waterbird *population* objectives (stepped-down from continental objectives where possible), and (2) regional waterbird *habitat* objectives that are linked with the best possible science to population objectives. The primary purpose of this report is to document the steps taken to guide PLJV waterbird planning.

The intended audience is biologists with technical orientation that are interested in the scientific underpinnings of PLJV waterbird conservation objectives.

Relationship of this Report to other PLJV Biological Planning Reports and Products

This report serves as a technical companion document to the PLJV's Implementation Planning Guide (PLJV 2006a), which describes the PLJV's overall approach to integrated bird biological planning. Herein we describe the processes for establishing priority waterbird species, important geographic areas and habitats for each species, and biological relationships between priority species and their habitats (including bird density, habitat availability and suitability, etc.). Some users may want to consult other sources of additional information relevant to PLJV waterbird conservation planning:

- *Planning Guide* (PLJV 2006a). This document describes the PLJV's approach to biological planning, and describes in detail the *Hierarchical All Bird System* (HABS) database. This database stores the biological data used to model the current carrying capacity of the PLJV for waterbirds, and to design a landscape that supports desired numbers of all priority bird species, including waterbirds. Users interested in the current carrying capacity of the PLJV for waterbirds (relative to population goals) should consult this database.
- *Habitat Assessment Procedures* (PLJV 2006b). This document describes the PLJV's habitat classification system and procedures for estimating acreages of important waterbird habitats as described in this document. These acreages were determined from the PLJV's GIS database and additional non-spatial data.
- *Area Implementation Plans (*AIPs*).* The PLJV maintains an AIP for each of 9 areas (Bird Conservation Region portions of states). These plans give recommendations for changing or maintaining the landscape so it will support desired numbers of priority bird species, including waterbirds. Current habitat acreage estimates also are found in these plans.

The PLJV in the Context of North American Waterbirds

The PLJV region largely corresponds to BCRs 18 (Shortgrass Prairie) and 19 (Mixed-grass Prairie) in the Southern Great Plains region of the continent (Fig. 1) and contains expansive areas of cropland and rangeland. The region is bisected by several major riparian corridors and is dotted with natural and man-made lakes, ponds, and wetlands (often highly ephemeral). Waterbirds in the PLJV use a wide range of wetland and upland habitats for nesting, foraging, and roosting. Important habitats for priority waterbird species are identified in this report.

There have been few research studies of waterbirds in the region, and monitoring data generally are sparse. These factors complicate waterbird conservation planning by reducing the quantity and quality of biological data.

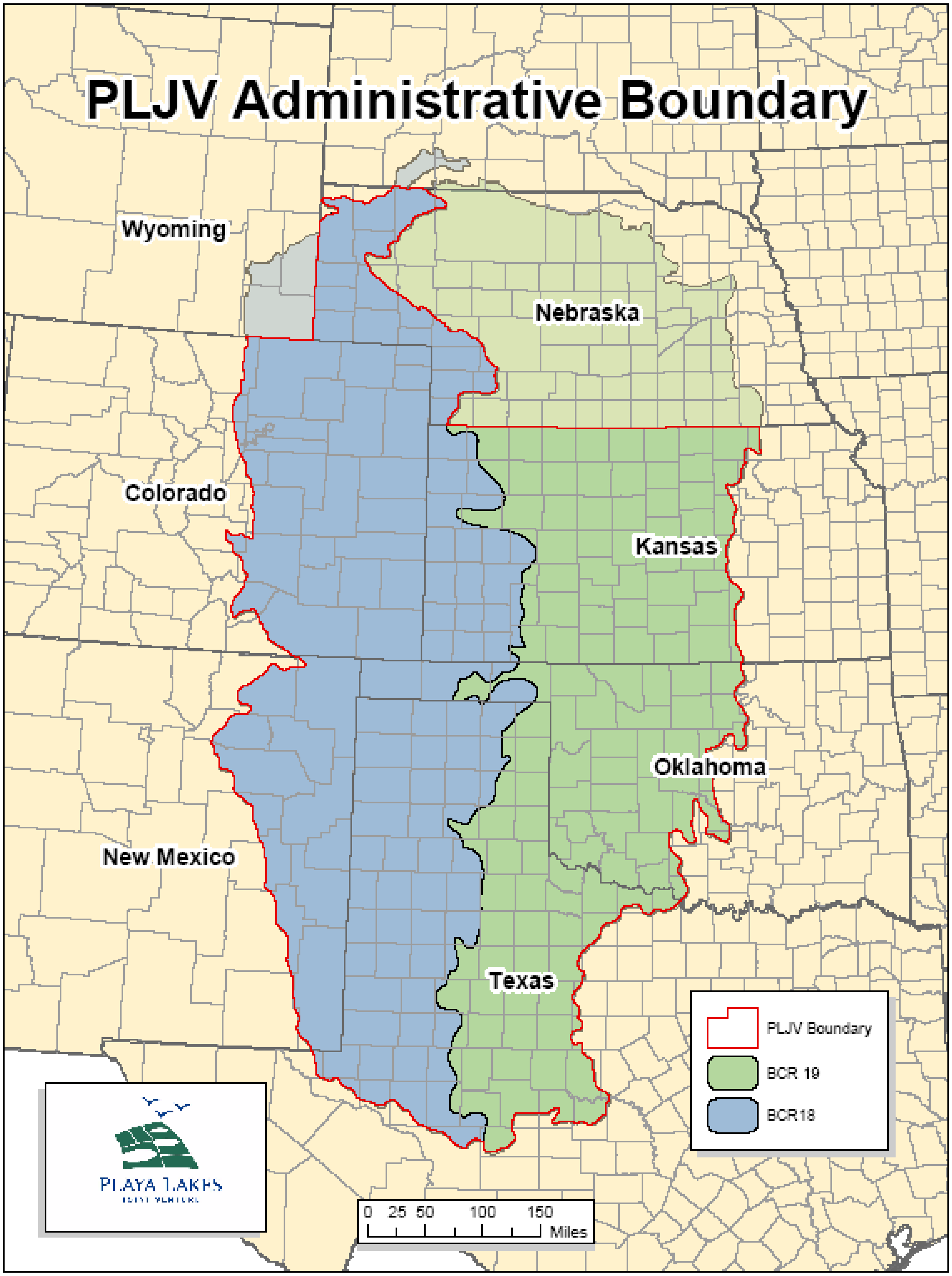

Figure 1. PLJV administrative boundary.

Approach for Developing Habitat Objectives

We used the following approach to develop waterbird habitat conservation objectives:

1. Determine planning scale (geographic areas).
2. Determine priority species and seasons.
3. Develop abundance objectives.
4. Develop vital rate (i.e., population performance) objectives.
5. Determine limiting factors for #3-4.
6. Develop habitat objectives:
    a) determine important habitats and carrying capacity per acre (i.e., define relationships between abundance/vital rates and habitat characteristics)
    b) measure habitats to determine current quantity and quality (availability and suitability)
    c) model current landscape carrying capacity for waterbirds and determine if current habitat can support the abundance/vital rate objectives
    d) analyze habitat trends to determine if current habitat quantity/quality is likely to change
    e) based on results of c) and d), develop conservation strategy to increase or maintain landscape carrying capacity for waterbirds

Step 1: Determine planning scale (geographic areas)

Geographic planning areas for this strategy are the BCR portions of states (e.g., BCR 18-Texas) (n = 9; see Fig. 1). Planning and implementation for waterbirds at this scale ensures (1) that the desired distribution of waterbirds and their habitats throughout the states and BCRs within the PLJV is achieved; and (2) that planning boundaries are consistent with other bird conservation initiatives and political boundaries (states).

Step 2: Determine priority species and seasons

Priority waterbird species for habitat work within the PLJV were selected based on at least one of the following two sets of criteria:

Criteria 1: High conservation concern status in the waterbird initiative, and threshold population within the PLJV. Specifically, we selected species with “moderate” or higher level of conservation concern in the waterbird initiative, and $\geq$ 10% of the continental population within the PLJV.

Criteria 2: High PLJV responsibility and a declining population. High PLJV responsibility was established at $\geq$ 10% of the species population in BCRs 18/19 during any season. Declining trend determination was taken from the waterbird initiative (population trend “PT” score $\geq$ 4) or local surveys (e.g., fall/winter Sandhill Crane surveys in New Mexico). We assumed species federally listed as threatened or endangered have declining trends over the long term.

Priority seasons (breeding or nonbreeding) were determined based on the period of highest relative abundance in the PLJV. We attempted to develop appropriate population and habitat objectives only for these seasons.

PLJV priority waterbird species and seasons are shown in Table 1.

Table 1. PLJV waterbird priority species and seasons.

Species Name	Species Code	Season
Eared Grebe	EAGR	Nonbreeding
Western Grebe	WEGR	Nonbreeding
American White Pelican	AWPE	Nonbreeding
Sandhill Crane	SACR	Nonbreeding
Whooping Crane	WHCR	Nonbreeding
Franklin's Gull	FRGU	Nonbreeding
Forster's Tern	FOTE	Nonbreeding
Black Tern	BLTE	Nonbreeding

Step 3: Develop abundance objectives

General

If a recovery or management plan was available for a species, we developed procedures to step down abundance objectives to the PLJV. Otherwise, we obtained the best available population survey and trend data, and developed abundance objectives scaled to 1970s levels. Trend information was from the Breeding Bird Survey. If the population trend for an area was ≥ 0, the abundance objective equals the current population estimate. If the population trend was < 0, we applied the following formula to determine a population goal:

$$\textit{Population Estimate} / (1-\textit{Absolute Value [Trend]})^{29}$$

Breeding Species

No breeding waterbirds were selected based on the species prioritization criteria described above.

Nonbreeding Species

For nonbreeding waterbirds we used a bionergetics approach to develop habitat objectives, and we developed abundance objectives accordingly.

Midcontinent Sandhill Cranes - We stepped down continental abundance objectives to the PLJV region from the *Management Guidelines for the Mid-Continent Population of Sandhill Cranes* (Central Flyway Council 2006). This population is abundant in the PLJV from October through March; whereas Sandhill Cranes from other populations rarely are seen in the PLJV.

A majority of this population stages in the central Platte region of Nebraska during spring, where photo-corrected aerial surveys are conducted annually. The management plan specifies an objective level for this population of 349,000 – 472,000 birds based on the 3-year running average of the spring survey. We took the midpoint of this range (410,500 birds) and divided by 0.90 to correct for 10% mortality (assumed) between October and the March survey period. This resulted in a new population objective of 456,111 birds, corresponding to the time when birds are most abundant in the PLJV.

To develop area-specific abundance objectives, we used distribution data from Midcontinent Sandhill Cranes marked with satellite transmitters (USGS unpubl. data). We assumed the distribution of marked birds represented the true distribution pattern of the entire population. For each 2-week period from October 1 – March 31, we compared the number of locations of marked birds in each PLJV planning area to the total number of locations for all marked birds in the population. This proportion was multiplied by the new population objective (456,111 birds) to derive abundance objectives for each area for each 2-week period (Table 2). Details of these analyses are available from the PLJV upon request.

To facilitate developing habitat objectives for cranes using a bioenergetics approach (see Step 6a and Appendix A), we translated abundance objectives into crane use-day objectives by multiplying the abundance objective by 15 (the approximate number of days in each period). We combined bi-weekly use-days into 3 seasons (fall-winter-spring). Fall corresponds to the period Oct 1 until the average date of first freezeup. Winter corresponds to the average period when wetlands are frozen (shaded cells in Table 2). Spring corresponds to the period between the average date of first thaw and March 31. State biologists provided freezup dates, which vary substantially within the large PLJV region. Wetlands do not consistently freeze in BCR 19 – TX, so no winter season was established (see Appendix A for justification), and January 1 was established as the cutoff date between the fall and spring seasons.

Most Sandhill Cranes use the PLJV as a stopover region during fall and spring, and birds are depositing lipid reserves for subsequent migrations. Therefore, we multiplied the seasonal use-day objectives by 1.05 (fall and spring) to account for additional energy demands needed to allow 5% body mass gain (Table 3).

In future updates of this report, we recommend developing a carrying capacity model that incorporates the juxtaposition of foraging and roosting habitats for *wintering* Sandhill Cranes (e.g., saline lake roosting sites and sorghum feeding sites in BCR 18 – TX). Shallow wetlands often are unavailable for foraging during winter, and birds utilize primarily waste grain (e.g., Iverson et al. 1985a, b). This will require developing spatial data on crop types (currently not available for PLJV crane wintering areas) and geo-referencing crane winter roost locations (which in many cases are known).

Table 2. PLJV abundance objectives (by period) for nonbreeding Sandhill Cranes. Shaded cells correspond to *winter* season (see text for explanation).

	Area								
Period	NE18	CO18	KS18	KS19	NM18	OK18	OK19	TX18	TX19
Oct. 1-15	1,322	9,915	1,322	3,305	4,627	0	5,949	7,932	661
Oct. 16-31	2,080	2,773	4,159	18,716	2,773	0	17,329	162,897	25,648
Nov. 1-15	0	3,167	2,376	46,720	5,543	1,584	24,548	180,544	61,765
Nov. 16-30	0	0	0	26,830	0	0	22,806	187,810	64,392
Dec. 1-15	0	0	0	9,122	1,824	0	25,542	182,444	47,436
Dec. 16-31	0	0	0	6,757	0	0	21,961	153,726	40,543
Jan. 1-15	0	0	0	8,486	2,121	0	19,093	161,230	46,672
Jan. 16-31	0	0	0	12,245	0	0	18,367	110,201	64,284
Feb. 1-15	0	0	0	9,356	0	0	9,356	107,595	51,459
Feb. 16-29	0	0	0	15,884	0	0	9,077	72,615	38,577
Mar. 1-15	2,092	8,369	2,092	31,384	2,092	0	16,738	66,952	18,830
Mar. 16-30	14,526	0	4,358	13,073	0	0	2,905	8,715	4,358

Whooping Cranes - We stepped down continental abundance objectives to the PLJV region from the *Whooping Crane International Recovery Plan* (CWS and USFWS 2005). This plan specifies a recovery objective of 160 breeding pairs (320 breeding birds). We developed a PLJV population objective using the following formula: 320 + (320 * 0.94) = **621**, where 0.94 is the average ratio of nonbreeding birds (adult and young) to breeding adults as measured on winter surveys during 1968-2003 (CWS and USFWS 2005:page C-4).

We assumed the entire population migrates through the PLJV and stops for 2 weeks (14 days) during both fall and spring. As for Sandhill Cranes, we developed use-day objectives by multiplying the abundance objective by the length of stay (621 * 14 = 8,694 use-days for both fall and spring). We assumed the distribution of these use-days would be 60% in BCR 19 – KS, 30% in BCR 19 – OK, 5% in BCR 18 – TX, and 5% in BCR 19 - TX. This distribution approximates the distribution of Whooping Crane sightings in the PLJV (Austin and Richert 2001). We also increased use-day objectives by 1.05 to allow for body mass increases during spring and fall (Table 3).

Table 3. PLJV use-day objectives (by season) for nonbreeding cranes.

	Season		
Area	**Fall**	**Winter**	**Spring**
BCR18-CO	SACR = 249,726		SACR = 131,812
BCR18–KS	SACR = 123,743		SACR = 101,588
BCR18-NE	SACR = 53,575		SACR = 261,735
BCR18-NM	SACR = 232,586	SACR = 31,822	SACR = 32,953
BCR18-OK	SACR = 24,944		
BCR18-TX	SACR = 11,365,642 WHCR = 456 Total = 11,366,098	SACR = 6,377,365	SACR = 4,030,074 WHCR = 456 Total = 4,030,530
BCR19-KS	SACR = 1,648,914 WHCR = 5,477 Total = 1,654,391	SACR = 552,656	SACR = 950,379 WHCR = 5,477 Total = 955,856
BCR19-OK	SACR = 1,112,453 WHCR = 2,739 Total = 1,115,192	SACR = 1,414,787	SACR = 452,340 WHCR = 2,739 Total = 455,079
BCR19-TX	SACR = 3,787,002 WHCR = 456 Total = 3,787,458	No winter season for planning due to lack of persistent ice cover; all use-days allocated to fall and spring.	SACR = 3,530,823 WHCR = 456 Total = 3,531,279

For other nonbreeding priority species (grebes, pelicans, gulls, and terns listed in Table 1), we lacked any meaningful information to relate abundance and/or vital rates to habitat conditions. Therefore, we defer developing population and habitat objectives for these species until such information becomes available. However, we note that conservation recommendations were made for wetland habitats used by these species during the PLJV planning process for nonbreeding waterfowl, shorebirds, and cranes. Until more explicit planning can be conducted, we assume that fulfilling habitat needs for waterfowl, shorebirds, and cranes will also fulfill habitat needs for other nonbreeding waterbirds.

Step 4: Develop vital rate (i.e., population performance) objectives

To address the question of how waterbird populations should "perform" or "be influenced" while in the PLJV, we believe abundance objectives should be complemented by vital rate objectives (recruitment, survival, body condition, etc.). For example, it would not be prudent for managers to attract large numbers of birds to the PLJV region if recruitment or survival rates are below levels needed to sustain continental population objectives.

Ideally, regional vital rate objectives for waterbirds in the PLJV would be developed as part of broader, continental strategies, but we are unaware of such strategies for any species. Therefore, we defer developing *recruitment* (breeding) and *survival* (nonbreeding) objectives.

For nonbreeding cranes, *body condition objectives* were established as part of the bioenergetics approach to developing habitat objectives. For fall and spring, the objective is for cranes to increase body mass by 5% while in the PLJV (see Step 3 and Table 3). This is to allow lipid deposition for subsequent migrations. For winter, the objective is for cranes to maintain body mass.

Step 5: Determine limiting factors

Given the population abundance objectives described above, and our desire to develop meaningful vital rate objectives, we considered a range of factors thought to influence the abundance, recruitment, survival, and body condition of waterbirds in the PLJV. Based on the expert opinion of our team, we believe that habitat (for nesting, foraging, and roosting) is the major factor limiting waterbird abundance and vital rates in the PLJV.

Tacha et al. (1992) concluded that habitat availability is the single most important factor regulating Sandhill Crane populations. Iverson et al. (1985a,b) demonstrated the importance of saline lakes (roosting) and sorghum (foraging) for wintering Sandhill Cranes in western Texas. Just east of the PLJV boundary in western Nebraska, Folk and Tacha (1990) found crane use of riverine roost sites was correlated to the abundance of wet meadow and palustrine wetlands nearby. In central Nebraska, Krapu et al. (2004) showed long-term declines in Sandhill Crane body condition corresponding to decreases in available waste corn. Migrating Whooping Cranes also make extensive use of wetlands and upland, agricultural habitats for foraging and roosting (Lingle et al. 1991, Austin and Richert 2001).

Studies within the PLJV for other wetland-dependent birds also support the team's conclusions. Waterfowl abundance (Texas Parks and Wildlife Dept. unpubl. data) and Northern Pintail survival and body condition (Moon 2004) are higher during winters with more flooded playas. Guthery et al. (1984) demonstrated that the amount of water on the landscape was the primary determinant of duck abundance.

Step 6a: Determine important habitats and carrying capacity per acre (i.e., define relationships between abundance/vital rates and habitat characteristics)

We conducted literature reviews of waterbird habitat use (Dobbs 2006). We used information from pertinent studies (sometimes conducted outside the PLJV) along with our own expert opinion to assign priority waterbird species to specific habitat types. Within these habitats we assigned densities (breeding birds or nonbreeding bird use-days) of expected use by priority species. See Appendix A for details by species and for literature citations.

In several cases we could not locate extant densities of species in any habitat type. In those cases, a density estimate was determined by other estimation techniques using existing data, or an assumption of density within a habitat type was made.

Step 6b: Measure habitats to determine current quantity and quality (availability and suitability)

We obtained the available spatial and nonspatial data to develop a GIS and to estimate current acreage of important waterbird habitats in the PLJV (see PLJV 2006b for the PLJV's habitat classification system and habitat assessment procedures). Habitat acreage estimates for all habitats for all priority species (including waterbirds) are found in the PLJV's *Area Implementation Plans*. In some cases we believed the total estimated acreage of these habitats was not fully *available* or *suitable* to waterbirds, so we developed adjustment factors for these parameters. Also, known ranges of some species did not cover an entire planning area, so adjustment factors also were developed for those species (see Appendix A for all habitat adjustment factors). More detailed explanations of habitat availability and suitability are found in PLJV 2006a.

Step 6c: Model current landscape carrying capacity for waterbirds and determine if current habitat can support the abundance and/or vital rate objectives

We used the following model to estimate the current carrying capacity of each habitat for each priority waterbird species in each planning area:

Current Carrying Capacity =
*Bird Density * Acres of habitat * Habitat adjustment factors (availability and suitability)*

Carrying capacities for all habitats were summed, resulting in total carrying capacity of each planning area for each priority species (expressed as breeding birds or nonbreeding bird use-days). Total carrying capacity was compared to the population objective (Table 3) to determine whether an area meets the population objective. These calculations are performed within the PLJV's HABS database (PLJV 2006a); interested readers should consult this database for the current PLJV waterbird carrying capacities relative to population goals.

Step 6d: Analyze habitat trends to determine whether current habitat quantity and/or quality is likely to change

As in other regions (Higgins et al. 2002), we believe the quantity and quality of some important waterbird habitats is declining in the PLJV region, primarily due to more intensive land use or conversion for human needs (urban expansion, agricultural intensification, water diversions, etc.). For example, playa hydroperiods are reduced due to sedimentation (Luo et al. 1997), thereby reducing playa value to wetland-dependent birds. The PLJV conducted an initial assessment of habitat trends (Melcher 2006), but quantitative trend information was lacking for most habitats in most areas. For future waterbird conservation planning, we believe carrying capacity models should be based on projected future habitat conditions, rather than current conditions. This will require a concerted effort by the PLJV to develop new programs for monitoring trends in habitat quantity and quality.

Step 6e: Based on results of Steps 6c and 6d, develop a conservation strategy to increase or maintain landscape carrying capacity for waterbirds

Based on estimated waterbird carrying capacities relative to population goals, we made specific waterbird habitat conservation recommendations for each planning area. For species below goal, we calculated the amount of specific habitat types that would needed to be "added" (e.g., restored) to support enough additional birds to alleviate the deficit and allow the population to reach desired levels (see HABS database). For species at or above goal, we made more general recommendations to protect or maintain important habitats so that populations do not fall below desired levels in the future. Please see the PLJV's *Area Implementation Plans* for waterbird habitat conservation recommendations.

Measuring Success

We believe the follow statement describes when success at waterbird conservation has been achieved in the PLJV:

"When habitat in the PLJV is not limiting waterbirds from reaching population objectives, and is not expected to be limiting in the future, because conservation actions in the PLJV are sufficient to offset any negative trends in important habitats."

More specifically, the current carrying capacity of each PLJV planning area should be maintained at ≥100% of the goal for each priority species. We recommend using *current carrying capacity* as the performance measure for waterbird conservation in the PLJV.

Monitoring and Evaluation

Numerous information gaps and uncertainties arose during this planning process, which required us to make assumptions and subjective decisions in developing waterbird conservation objectives. Hopefully some of these information gaps will be addressed through future research, which will allow improvements in PLJV waterbird conservation planning. Specifically, we encourage work to:

1. *Assess accuracy of estimates for current waterbird habitat quantity and quality.* Current habitat estimates represent a compilation of data and assumptions from many sources. Accuracy of acreage, availability, and suitability estimates should be tested for important waterbird habitats. This will improve accuracy of carrying capacity models and will lead to better habitat conservation recommendations.
2. *Develop quantitative trend estimates for important waterbird habitats.* Habitat trend information is needed to develop appropriate waterbird habitat conservation actions that will maintain populations at desired levels over the long term. In a few habitats, there may be existing data that could be analyzed (e.g., agricultural statistics). For most habitats, this will require development of new, long-term periodic habitat surveys.

3. *Improve understanding of the relationship between priority waterbirds and their habitats in the PLJV.* To model waterbird carrying capacity, we often had to borrow this information from studies outside the PLJV or make assumptions. Better information would improve estimation of carrying capacities. Studies should address densities of breeding birds in important habitats, and food densities in important habitats for nonbreeding birds.

Report Updates

The PLJV's biological planning is an ongoing initiative (see PLJV 2006a, c). This report represents the PLJV's first attempt to step down waterbird population objectives from continental objectives, and its first attempt to develop habitat objectives that are linked biologically to population objectives. Waterbird conservation objectives should be updated and revised as new information becomes available, and as desired by partners. Also, further critical thinking and discussion about habitat conservation strategies will create a desire to revise these objectives.

We encourage critical review of this waterbird planning initiative, and we welcome suggestions for improvement. Please send comments to:

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Appendix A. Important habitats for PLJV priority waterbird species, including parameters used in modeling carrying capacity.

Sandhill and Whooping Cranes:

Areas	Season	Habitat Association	Habitat Condition	Energetic Carrying Capacity[A]	Energetic Carrying Capacity Reference	Availability	Suitability
All	Fall and Spring	Other Wetlands	Emergent marsh	396	Assumed same as corn	1.0000	1.0000
All	Fall and Spring	Other Wetlands	Moist-soil unit	1,253	Haukos & Smith 1993, Anderson & Smith 1998; 1999	1.0000	1.0000
All	Fall and Spring	Other Wetlands	Saline	396	Assumed same as Emergent Marsh	1.0000	1.0000
All	Fall and Spring	Playas	Wet	127	Haukos & Smith 1993, Anderson & Smith 1998; 1999	1.0000	1.0000
All	Fall and Spring	Riverine Systems	Floodplain marsh	396	Assumed same as Emergent Marsh	1.0000	1.0000
All	Fall and Spring	Riverine Systems	Wet meadow	396	Assumed same as Emergent Marsh	1.0000	1.0000
All	Winter	Cropland	Corn	396	Baldassarre & Bolen 1984; Reinecke & Loesch 1996; Krapu et al. 2004	1.0000	1.0000
All	Winter	Cropland	Peanuts	252	Assumed same as sorghum	1.0000	1.0000
All	Winter	Cropland	Sorghum	252	Reinecke & Loesch 1996	1.0000	1.0000
All	Winter	Cropland	Wheat	396	Assumed same as corn	1.0000	1.0000

[A] = Expressed as crane use-days per acre.

Notes: Although cranes often feed in cropland during *fall* and *spring*, we desire cranes to obtain all of their energy needs from wetland habitats during these seasons. Cranes also spend a substantial amount of time feeding in wetlands, where they likely obtain important nutrients from invertebrate and plant foods (Reinecke and Krapu 1986, Davis 1991, Austin and Richert 2001). In *winter*, most shallow wetlands are frozen and unavailable for foraging, so we modeled only croplands during this season. This approach is consistent with PLJV waterfowl planning. While foraging in wetlands, cranes consume foods (larger terrestrial invertebrates, earthworms, tubers, fish, small mammals, etc.) that largely differ from foods consumed by waterfowl (seeds, smaller aquatic invertebrates, etc.). One study measured biomass of invertebrate foods used by cranes in wetlands (Davis 1991), but we are unaware of studies that assessed energetic content of these foods, or the energetic needs of cranes. Therefore, we assumed that the energetic needs of cranes and the energy content of crane foods (on a per-acre basis) were similar to waterfowl (see Prince 1979). For PLJV planning purposes, we divided energetic carry capacities of various habitats for waterfowl by 3.37 to account for differences in body mass between cranes and waterfowl (adult male Sandhill Crane [weighted by subspecific proportions in the population] compared to adult male Mallard). I.e., energetic carrying capacity of various habitats expressed as duck use-days were converted to crane use-days, and these results are reflected in the table above.