Studies in Avian Biology No. 27:52–60, 2004.

WATERBIRD COMMUNITIES AND ASSOCIATED WETLANDS OF THE COLORADO RIVER DELTA, MÉXICO

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Abstract. Despite extensive losses of wetlands caused by water diversions upstream, the Colorado River Delta in northwestern México remains an important wetland system in the Sonoran Desert. The purpose of our study was to describe waterbird communities across a variety of wetland habitat types and zones that exist in the Delta. We measured species richness and abundance of waterbirds from September 1999 to August 2000. We observed a total of 11,918 individuals of 71 species at sites within seven wetland areas. The waterbird communities differed with respect to guild composition and species abundances among the wetland zones. Wetlands along the eastern portion of the Delta (Ciénega and Indio), which are supported by agricultural drains and managed under conservation initiatives, exhibited the highest species richness in our summer and winter censuses, and highest abundance in summer. Shorebirds were the dominant guild in the summer period, while waterfowl were dominant during winter. Breeding marshbirds were also abundant, with the Yuma Clapper Rail (*Rallus longirostris yumanensis*) being most notable. Wetlands along the western Delta (Hardy and Cucapá) were also supported by agricultural drains, but were not managed specifically for wildlife. The Double-crested Cormorant (*Phalacrocorax auritus*) and American Coot (*Fulica americana*) were dominant during winter, while long-legged waders (Ardeidae) were dominant in summer. The composition of waterbird communities along the mainstem of the Colorado River was similar to that of wetlands along the western portion of the Delta. The shallow and ephemeral Laguna Salada, along the western boundary of the Delta, exhibited the highest waterbird abundance among our winter censuses when it was flooded in 2000. The results of our study suggest that even minimal levels of instream flows would lead to habitat improvements for waterbirds in the Delta floodplain. A bi-national wetland management program for the Delta should consider the impacts of flood control measures and diversions for agricultural and urban uses to the health of wetland habitats on both sides of the international border.

Key Words: avian communities; Baja California; Colorado River delta; migratory birds; Sonora; water management; waterbirds; wetlands.

COMUNIDADES DE AVES ACUÁTICAS Y HUMEDALES ASOCIADOS DEL DELTA DEL RIÓ COLORADO, MÉXICO.

Resumen. A pesar de las amplias perdidas de humedales causadas por la desviación de cauces aguas arriba, el Delta del Río Colorado en el noroeste de México continua siendo un importante sistema de humedales en el Desierto Sonorense. El propósito de nuestro estudio fue describir comunidades de aves acuáticas a través de una variedad de tipos de hábitat y zonas de humedales que existen en el Delta. Medimos la riqueza de especies y la abundancia de aves acuáticas desde septiembre 1999 hasta agosto 2000. Observamos un total de 11,918 individuos pertenecientes a 71 especies en sitios comprendidos entre siete áreas de humedales. Las comunidades de aves acuáticas difirieron con respecto a la composición de gremio y abundancia de especies entre las zonas de humedales. Los humedales a lo largo de la porción este del Delta (Cienaga e Indio), los cuales están mantenidos por drenajes agrícolas y manejados bajo iniciativas de conservación, exhibieron la más alta riqueza de especies en nuestros censos de verano e invierno, y la abundancia más alta en verano. Las aves playeras fueron el gremio dominante en el periodo de verano, mientras que los Anseriformes fueron los dominantes durante el invierno. Las aves de marisma que se reproducen en el área fueron también abundantes, siendo el Rascón Picudo de Yuma (*Rallus longirostris yumanensis*) el más notable. Los humedales a lo largo de la porción oeste del Delta (Hardy y Cucapa) fueron también mantenidos por drenajes agrícolas, pero no fueron manejados específicamente para vida silvestre. El Cormorán Orejudo (*Phalacrocorax auritus*) y la Gallareta Americana (*Fulica americana*) fueron dominantes durante el invierno, mientras que aves zancudas de patas largas (Ardeidae) fueron las dominantes en verano. La composición de las comunidades de aves acuáticas a lo largo del cauce principal del Río Colorado fue similar a la de los humedales a lo largo de la porción oeste del Delta. La poco profunda y efímera Laguna Salada, a lo largo del limite oeste del Delta, exhibió la mayor abundancia de aves acuáticas entre nuestros censos de invierno cuando fue inundada en 2000. Los resultados de nuestro estudio sugieren que incluso niveles mínimos de flujo en el torrente conduciría a mejoras en el hábitat de aves acuáticas en el área de inundación del Delta. Un programa binacional de manejo de humedales para el Delta debería considerar los impactos de las medidas de control de inundaciones y desviaciones de caudales para uso agrícola y urbano en la salud de los hábitats de humedales a ambos lados de la frontera internacional.

Palabras claves: aves acuáticas; aves migratorias; Baja California; comunidades de aves; Delta del Río Colorado; humedales; manejo de aguas; Sonora.

Many waterbirds have suffered population declines around the world since the beginning of the twentieth century (Rosenberg et al. 1991, DeGraaf and Rappole 1995). Causes for these declines are thought to include the degradation and loss of wetlands, which provide breeding, wintering, and migratory stopover habitats (National Research Council 1995). On a regional scale, wetland loss has been significant along the Pacific Flyway, where up to 50% of coastal wetlands in the western U.S. (Helmers 1992) and some 35% of wetlands in western Mexico (Hails 1996) have been destroyed, while losses in the interior of California have been estimated at 95% (Zedler 1988). Brown (1985) and Ohmart et al. (1988) indicate that wetland loss along the Lower Colorado River in Arizona and California has also been substantial.

The Colorado River Delta had long been recognized as one of the richest regions for wildlife in the southwestern United States and northwestern Mexico (Grinnell 1928, Sykes 1937, Leopold 1966, Glenn et al. 2001). Despite substantial reductions in wetland area (approximately 76% has been lost), and the modification of vegetation communities by non-native, invasive plant species (Glenn et al. 1996, Zamora-Arroyo et al. 2001), the Delta is thought to be a critical area for a variety of resident and migratory waterbirds within the Pacific Flyway (Anderson et al. 2003).

The modification and degradation of waterbird habitats is often related to intensive management practices that divert water supplies away from their source for use by more distant urban and agricultural centers (Lemly et al. 2000). Perhaps nowhere is this more apparent than in the arid basin of Colorado River Delta region (Lemly 1994, Morrison et al. 1996). However, in recent years agricultural runoff, sporadic flood flows, and their interaction with the tidal regime of the upper Gulf of California seem to have restored and maintained portions of the Delta wetlands (Glenn et al. 1996). The importance of the Colorado River Delta to wildlife has been recognized by a variety of conservation initiatives at multiple geographic scales. The Delta has been identified as a conservation priority within the Sonoran Desert Ecoregion (Briggs and Cornelius 1998), an Important Area for Bird Conservation in Mexico (Román-Rodríguez et al. 2000), and a wetland of international (Ramsar Convention Bureau 2003) and hemispheric importance (Western Hemisphere Shorebird Reserve Network 2002). A portion of the Delta wetlands has been designated as a natural area under the category of Biosphere Reserve, which is recognized by the United Nations as part of a global network of natural reserves (SEMARNAP 1995).

While some workers have focused on the seasonal status and abundance of birds at particular wetlands in the Delta (Mellink et al. 1996, 1997; Ruiz-Campos and Rodriguez-Meraz 1997) we sought to characterize and compare a variety of wetland habitat types across the Colorado River Delta and describe the waterbird communities that use them. Here we present information on species richness and relative abundance of waterbirds across various wetland zones of the Delta, identify areas with high wildlife habitat value, and make recommendations for restoration.

STUDY AREA AND METHODS

We surveyed wetlands in the Colorado River Delta in Baja California and Sonora, Mexico, from September 1999 through August 2000. We categorized these wetlands into seven zones (modified from Valdés-Casillas et al. 1998) according to their environmental characteristics (Fig. 1; Table 1). The zones included riparian areas maintained by flooding events, shallow lagoons and mudflats influenced by tidal action of the Gulf of California, marshes with emergent vegetation fed by agricultural run-off and natural springs, and channelized rivers, streams, and agricultural drains. Vegetation was composed of emergent plants (mostly cattail, *Typha domengensis*), monotypic stands of introduced tamarisk (*Tamarix ramosissima*), native saltgrass (*Distichlis palmerii*), and stands of cottonwood (*Populus fremontii*) and willow (*Salix gooddingii*). A description of each zone is included in Glenn et al. (2001).

We grouped species into seven waterbird guilds based on characteristics of foraging behavior: divers; long-legged waders; gulls, terns, and skimmers; pelicans and cormorants; marshbirds; shorebirds; and waterfowl (Table 2; Weller 1988, 1995; Croonquist and Brooks 1991).

We censused birds using a circular station/point count procedure (Ralph et al. 1996). Survey stations were circular plots located 500–600 m apart, and grouped into mini-routes (five to 14 stations per mini-route; Bystrak 1980), depending on the size of the zone. We used ArcView 3.1 NT (ESRI 1998) and an existing spatial database for the Colorado River Delta (Valdés-Casillas et al. 1998) to determine the location of mini-routes. Routes were selected non-randomly to maximize coverage of the different zones in the Delta and the different wetland environments at each zone. The number of mini-routes varied for each wetland zone. We established four routes each at the Hardy and Ciénega wetlands, and two routes each at the Indio and Colorado River wetlands. Because access was limited, we could establish only a single route each at the Cu-

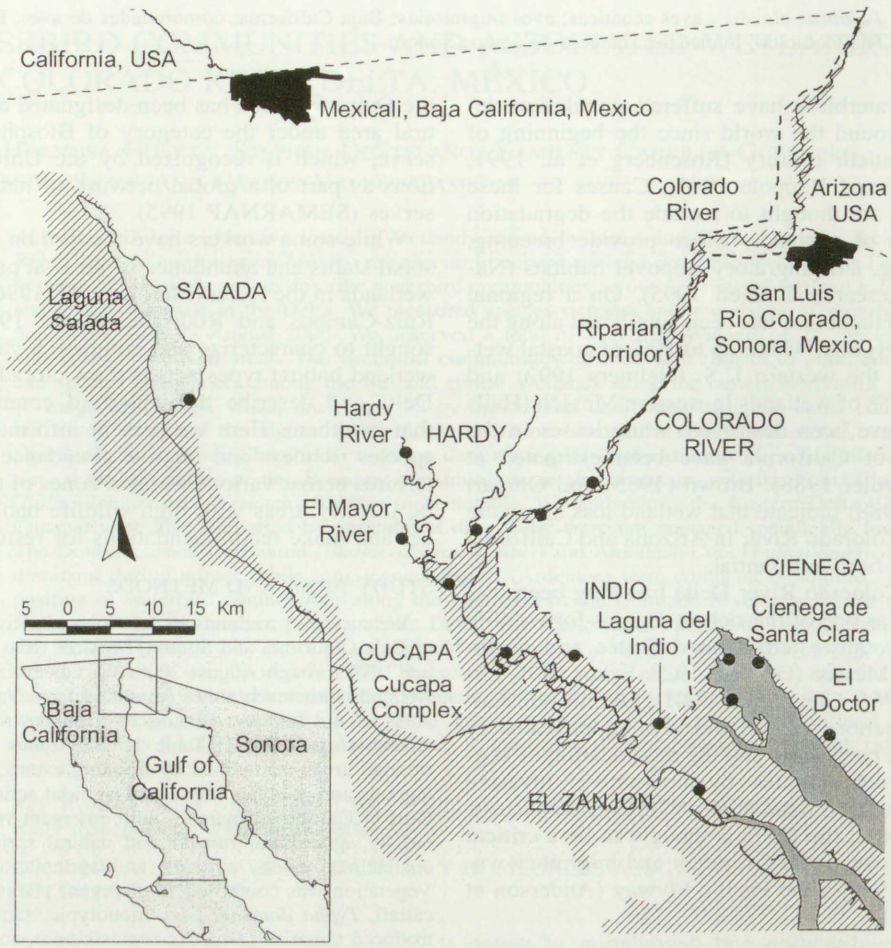

FIGURE 1. Zones (uppercase) and wetland areas (lowercase) of the Colorado River Delta included in our study. The location of mini-routes are shown by solid circles. The Delta floodplain (diagonal shading) is surrounded by a system of levees (dashed line). Major streams are depicted by solid lines.

capá, El Zanjón, and Salada wetland zones. The last wetland contained water only during the winter period.

To elucidate general patterns of waterbird occurrence, we surveyed each wetland zone once during the winter period (mid November through late February) and once during the summer period (late May to early August; Table 3). We recorded all waterbird species that were detected within a 200-m radius for a five min duration at each station. We used playback recordings at each station to aid in the detection of secretive marshbirds, following the protocol used for rail surveys in the Colorado River Delta (Hinojosa-Huerta et al. 2001a).

RESULTS

We observed 11,918 individuals of 71 species of waterbirds during our study. Among zones, species richness was highest at Indio (in winter) and at Ciénega (in summer). Waterbird abundance was greatest at Ciénega (in summer) and at Salada (in winter; Fig. 2). Species richness and abundance were greater during our winter censuses for all zones except Ciénega, where they were greater in summer (Fig. 2). Suitable waterbird habitat at Salada was absent during our summer census.

Waterbird Community Composition and Wetland Zones

The guild composition and overall abundance of waterbird communities differed among our wetland zones and between census periods (Fig. 3). Below we provide general descriptions of wetland habitats, dominant guilds, and species that were most abundant among guilds for each zone.

Ciénega

The waterfowl guild was dominant during our winter census at Ciénega (Fig. 3). Here, the most

TABLE 1. WETLAND ZONES OF THE COLORADO RIVER DELTA INCLUDED IN OUR STUDY

Zone	Included wetlands	Water sources	Habitat types
Ciénega	Ciénega de Santa Clara and El Doctor	Agricultural run-off and natural springs	*Typha*-dominated marshes and mudflats
Cucapá	Cucapá Complex in Hardy/ Colorado floodplain	Agricultural runoff and flood flows	Alkali flats dominated by halophytes/*Tamarix*, transected by natural channels; river banks dominated by *Tamarix*
Hardy	Hardy and El Mayor rivers	Agricultural runoff	Open water canals and *Typha-Phragmites-Tamarix* marshes
Indio	Laguna del Indio and eastern drains	Agricultural runoff	*Typha-Tamarix* marshes and shallow lakes
El Zanjón	Intertidal flats	Tidal inundation, agricultural runoff, and flood flows	Mudflats, broad tidal channels, and saltgrass banks
Colorado River	Riparian corridor	Flood flows and agricultural runoff	*Populus-Salix-Tamarix* corridor, river channel, and backwater lakes and ponds
Salada	Laguna Salada	Flood flows and tidal intrusions	Extensive shallow lagoon and mudflats

abundant species were the Greater White-fronted Goose, Canada Goose, and Snow Goose, which used the inner lagoons, salt grass flats, and adjacent agricultural fields. Northern Shoveler, Northern Pintail, and Cinnamon Teal were numerous along the inner lagoons of the Ciénega. The pelican and cormorant guild, of which American White Pelicans were most numerous, was also fairly abundant during this period in the deeper (>0.8 m) open water areas of the Ciénega (Fig. 3).

During the summer census a diverse guild of shorebirds was dominant (Fig. 3). The most common species of migratory shorebirds included Western Sandpipers, dowitchers, and Red-necked Phalaropes, which foraged along the outer shallow (<0.5 m) lagoons and mudflats. The most abundant breeding shorebirds were the Black-necked Stilt and Killdeer. As our summer censuses in the Ciénega were conducted in late May, well after the spring migration peak for most shorebirds, this guild is likely even more dominant earlier in this period provided that habitat conditions are suitable.

The marshbird guild was well represented here in the summer census as we recorded a total of eight species. The dominant species were Yuma Clapper and Virginia rails, American Coots, and Least Bitterns. Black Rails and American Bitterns were also detected, but in lower numbers.

The long-legged waders, of which White-faced Ibises, Snowy Egrets, and Great Egrets were most abundant, used mainly the outer shallow lagoons. Eight White Ibis, a previously unrecorded species for the delta region in Mexico (Russell and Monson 1998, Patten et al. 2001), were observed on the shallow lagoons at the eastern side of the Ciénega de Santa Clara on 21 May 2000.

Cucapá

The Cucapá wetland zone was dominated by species that benefit from open water habitats or by those not strongly dependent upon native vegetation. Double-crested Cormorants were most abundant here in meandering river channels and floodplain lagoons during our winter census (Fig. 3). Although not abundant, ten species of waterfowl were present (Fig. 3), including Blue-winged Teal, American Widgeon, and Mallard. Marshbirds were also abundant, with American Coots being most numerous.

During the summer census, species comprising the long-legged wader guild were most abundant (Fig. 3), with Snowy Egrets, Great Blue Herons, Black-crowned Night-Herons, Great Egrets, and Green Herons being most numerous. Marshbirds were rare; only two Yuma Clapper Rail pairs were found nesting in tamarisk and common reed (*Phragmites* spp.).

Hardy

The divers, particularly grebes, and long-legged waders, consisting primarily of Snowy Egrets, Black-crowned Night-Herons, and Great Egrets, were the most abundant guilds during our winter census of the Hardy River (Fig. 3). Here the river channel running adjacent to the floodplain is deep, steep-sided, and sparsely vegetated. The gulls, terns, and skimmers guild of which California Gulls, and Caspian and Forster's terns predominated, was also abundant here.

TABLE 2. COMPOSITION OF WATERBIRD GUILDS INCLUDED IN OUR STUDY

Guild	Species	Common name
Divers	*Gavia pacifica*	Pacific Loon
	Podiceps auritus	Horned Grebe
	Podiceps nigricollis	Eared Grebe
	Podilymbus podiceps	Pied-billed Grebe
	Aechmophorus occidentalis	Western Grebe
	Aechmophorus clarkii	Clark's Grebe
Pelicans/cormorants	*Pelecanus erythrorhynchos*	American White Pelican
	Pelecanus occidentalis	Brown Pelican
	Phalacrocorax auritus	Double-crested Cormorant
Long-legged waders	*Ardea herodias*	Great Blue Heron
	Ardea alba	Great Egret
	Egretta thula	Snowy Egret
	Bubulcus ibis	Cattle Egret
	Butorides virescens	Green Heron
	Nycticorax nycticorax	Black-crowned Night-Heron
	Egretta tricolor	Tricolored Heron
	Eudocimus albus	White Ibis
	Plegadis chihi	White-faced Ibis
Waterfowl	*Branta canadensis*	Canada Goose
	Anser albifrons	Greater White-fronted Goose
	Chen caerulescens	Snow Goose
	Anas platyrhynchos	Mallard
	Anas strepera	Gadwall
	Anas acuta	Northern Pintail
	Anas americana	American Wigeon
	Anas clypeata	Northern Shoveler
	Anas cyanoptera	Cinnamon Teal
	Anas discors	Blue-winged Teal
	Anas crecca	Green-winged Teal
	Aythya valisineria	Canvasback
	Aythya americana	Redhead
	Aythya affinis	Lesser Scaup
	Bucephala clangula	Common Goldeneye
	Bucephala albeola	Bufflehead
	Oxyura jamaicensis	Ruddy Duck
Marshbirds	*Botaurus lentiginosus*	American Bittern
	Ixobrychus exilis	Least Bittern
	Gallinula chloropus	Common Moorhen
	Fulica americana	American Coot
	Rallus longirostris	Clapper Rail
	Rallus limicola	Virginia Rail
	Porzana carolina	Sora
	Laterallus jamaicensis	Black Rail
Shorebirds	*Charadrius alexandrinus*	Snowy Plover
	Charadrius vociferus	Killdeer
	Recurvirostra americana	American Avocet
	Himantopus mexicanus	Black-necked Stilt
	Tringa melanoleuca	Greater Yellowlegs
	Tringa flavipes	Lesser Yellowlegs
	Catoptrophorus semipalmatus	Willet
	Actitis macularia	Spotted Sandpiper
	Numenius phaeopus	Whimbrel
	Numenius americanus	Long-billed Curlew
	Limosa fedoa	Marbled Godwit
	Calidris mauri	Western Sandpiper
	Calidris minutilla	Least Sandpiper
	Limnodromus scolopaceus	Long-billed Dowitcher
	Limnodromus griseus	Short-billed Dowitcher
	Phalaropus lobatus	Red-necked Phalarope

TABLE 2. CONTINUED

Guild	Species	Common name
Gulls, terns, and skimmers	*Larus philadelphia*	Bonaparte's Gull
	Larus delawarensis	Ring-billed Gull
	Larus californicus	California Gull
	Larus argentatus	Herring Gull
	Larus heermanni	Heerman's Gull
	Sterna caspia	Caspian Tern
	Sterna maxima	Royal Tern
	Sterna forsteri	Forster's Tern
	Sterna nilotica	Gull-billed Tern
	Chlidonias niger	Black Tern
	Rynchops niger	Black Skimmer

In summer, the long-legged wader guild was again most common (Fig. 3), especially in the northern stretches where the river forms sandbars, and patches of tamarisk and cattail line the river's edge. The most abundant species included Snowy Egrets, Black-crowned Night-Herons, and Great Egrets. Marshbirds were also abundant with American Coots as the most common species. Yuma Clapper Rails, Least Bitterns, and American Bitterns were also present to a lesser degree. Rails were found in a few areas along the northern stretches of the El Mayor and Hardy rivers (Fig. 1) that supported cattails.

Indio

Waterfowl was the most abundant guild during winter at the Indio zone (Fig. 3). The most abundant species were Northern Shoveler, Canvasback, and Ruddy Duck. The shorebird and marshbird guilds were also common, with the Long-billed Dowitcher and American Coot being the most abundant species of their respective groups. Double-crested Cormorants were also fairly numerous. The shorebird guild dominated the summer census (Fig. 3) with Whimbrel, Black-necked Stilt, and Killdeer being the most abundant species. Long-legged waders were also common, particularly the Snowy Egret, Black-crowned Night-Heron, and Great Blue Heron. Breeding marshbirds were abundant and included six pairs of Yuma Clapper Rails.

El Zanjón

Species richness was relatively low in our surveys of the intertidal zone of El Zanjón. Here larids were the dominant guild overall, but the species composition differed between censuses (Fig. 3). In our winter census, the dominant species were Ring-billed Gulls, California Gulls, and Heermann's Gulls; in summer, the dominant species was the Ring-billed Gull. Representatives of the shorebird guild, especially Black-necked Stilts and American Avocets, were fairly abundant in winter. Brown Pelicans were abundant, and long-legged waders were fairly abundant during our summer census (Fig. 3).

Colorado River

The American Coot was the dominant species during our winter census along the Colorado River (Fig. 3), especially within various backwater lagoons. Double-crested Cormorants were abundant along the main channel of the river. Long-legged waders, primarily Snowy Egrets and Great Blue Herons, were also common in backwater lagoons and in riparian habitats along the banks of the river.

The long-legged waders dominated this zone during our summer census (Fig. 3); the most abundant species were Cattle Egrets and Snowy Egrets, which roosted in the dense willow stands of backwater lagoons, while White-faced Ibises

TABLE 3. SURVEY DATES AT EACH WETLAND ZONE IN THE COLORADO RIVER DELTA

Zone	Summer	Winter
Ciénega	May 21–22, 2000	January 10, 2000
Cucapá	May 28, 2000	November 13, 1999
Hardy	May 26–27, 2000	January 8–9, 2000
Indio	June 6, 2000	November 12, 1999
El Zanjón	May 25, 2000	February 26, 2000
Colorado River	August 8, 2000	November 11, 1999
Salada	May 29 and August 9, 2000	February 27, 2000

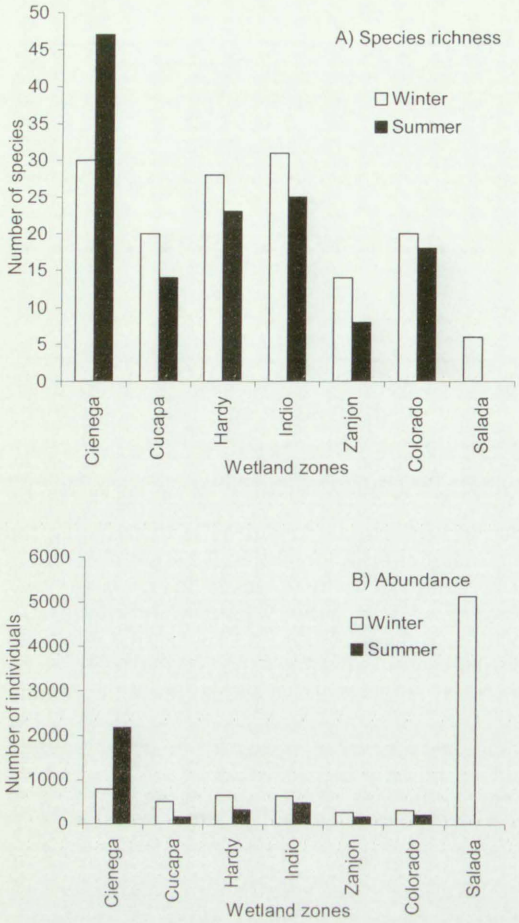

FIGURE 2. Species richness (A) and abundance (B) at each wetland zone by season in the Colorado River Delta. Laguna Salada contained water and shorebirds only during our winter survey.

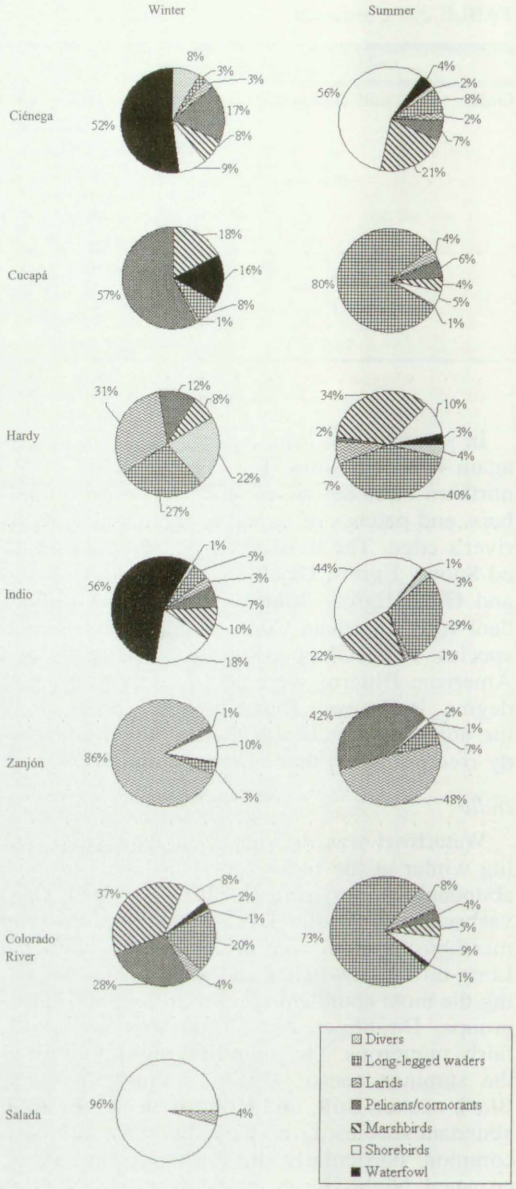

FIGURE 3. Proportions by guild for each census period at wetland zones of the Colorado River Delta.

were found on sandbars and riverbanks of the main channel of the Colorado. Other common species along the main river channel were Black-necked Stilts and Caspian Terns.

Salada

The Laguna Salada, an ephemeral shallow lake, contained water only during our winter census. Here the shorebird guild, composed primarily of nearly 5000 American Avocets, dominated the flooded salt flats (Fig. 3). Ring-billed Gulls, feeding along the shore, were also numerous. A few Lesser Scaup, Eared Grebes, and cormorants were found in the deeper waters of the inflow canal to the Laguna Salada.

DISCUSSION

On a global scale, water and wetland management practices have been found to be key factors in shaping waterbird communities (Weller 1988, 1995; Kingsford et al. 1999, Lemly et al. 2000). Our preliminary data show that wetland zones in the Colorado River Delta provide a variety of wetland habitat types supporting waterbird communities of varying composition. Differences in community composition among zones are likely associated with variation in a number of physical characteristics including topography, water depth and salinity, vegetation

composition and structure, and flood control and agricultural practices in these areas.

The general pattern of a greater abundance and diversity of waterbirds in the eastern wetlands of the Delta, in contrast to the western areas, is likely due to the more consistent supply of water in the east and perhaps also to the inclusion of the eastern wetlands in the core zone of the Upper Gulf of California and Colorado River Delta Biosphere Reserve. As such, these wetlands are managed under conservation objectives and environmental review protocols to preserve habitat for migratory birds and endangered marsh birds, and limit human activities to research, education, and artisanal hunting, fishing, and agriculture (SEMARNAP 1995).

Many of the wetlands in the Delta have been stressed by the lack of adequate flows for most of the last 50 yrs (Valdés-Casillas et al. 1998). Except in years of high precipitation in the Colorado River watershed, most of the Delta remains dry (Cohen et al. 2001). The invasion of tamarisk throughout the Delta was a result of manipulated water regimes that subjected the region to long periods of reduced freshwater flows or flows of higher salinity (Glenn et al. 1998, Vandersande et al. 2001). In spite of this, those habitats that remain in the Colorado River Delta continue to support large numbers of waterbirds. In recent surveys, over 160,000 shorebirds have been found wintering in the Delta (Morrison et al. 1992), along with tens of thousands of waterfowl (Payne et al. 1992), making it one of the critical sites for migratory waterbirds in northwestern Mexico (Massey and Palacios 1994) and along the entire Pacific Flyway (Anderson et al. 2003). The delta also provides important breeding habitat for at least 12 species of waterbirds at Isla Montague (Peresbarbosa-Rojas and Mellink 2001) and north of the headwaters of the Hardy River at Campo Geotérmico Cerro Prieto (Molina and Garrett 2001). Furthermore, documented seasonal and inter-annual movements of some species between wetlands in the delta and the Salton Sea demonstrate a close connectivity between these areas (Molina *this volume*).

Recent periodic flooding has increased the extent of wetland habitat along the Hardy and Colorado rivers by restoring more than 10,000 ha of marshes and riparian thickets in these drainages. More continuous flows of brackish water from agricultural drainage over the last 20 yrs has helped create the Ciénega de Santa Clara wetlands, an extensive system of marshes and flooded salt flats that now total over 6000 ha (Glenn et al. 1992, 2001). These examples suggest that the permanent allocation of dedicated flows to these and other areas, at even minimal volumes, will further enhance wildlife habitat quality and quantity.

The Laguna Salada probably best represents the impacts of long-term reduced flows to the Delta, as it more commonly remains a dry salt flat than a lake. Nevertheless, the Laguna Salada has been inundated on several occasions over the last 20 yrs (Luecke et al. 1999). This was the case during our study when average winter flows of 230 m^3/s in the main stem of Colorado River were recorded at the international boundary (IBWC 2000), which flooded the Laguna Salada salt flats, attracting thousands of shorebirds.

The low and salty plains, traversed by meandering canals, of the Hardy, El Indio, and Cucapá zones present additional opportunities for the restoration of marsh areas with the use of drainage water, although their design and operation will need to consider the potential for the accumulation of selenium and other contaminants that may adversely affect wildlife. Community-based restoration projects, currently underway at each of these zones, expect to restore approximately 1500 ha of habitat for waterbirds (O. Hinojosa-Huerta, unpubl. manuscript).

Nevertheless, the future of continuing conservation and restoration efforts in the region is insecure. Most of the Delta wetlands exist today largely as a result of flood control and agricultural practices. Plans recently proposed to permanently reduce flows to the Ciénega (Glenn et al. 1996, U.S. Bureau of Reclamation 1996) will likely reduce important habitat for breeding Yuma Clapper Rails (Hinojosa-Huerta et al. 2001a) and California Black Rails (Hinojosa-Huerta et al. 2001b), as well as for myriad migratory shorebirds and waterfowl. Although the restoration of the Delta to conditions that existed before the construction of dams is neither likely nor practicable, the expansion of wetland habitat and associated use by waterbirds after recent periodic flooding highlights opportunities for the restoration of wetlands in the Colorado River Delta. An awareness of the importance of conserving and enhancing wetland habitat for the maintenance of wildlife populations in the region is developing among the local rural communities. However, the success of these habitat restoration projects will ultimately depend on obtaining adequate supplies of water over the long term.

A bi-national wetland management and restoration program for the Colorado River Delta should consider the impacts of water management and flood control on wildlife (Luecke et al. 1999, Nagler et al. 2000). Even small volumes of periodically released flows of freshwater (<2.5 ppt) that allow for the maintenance of perennial shallow lakes and ponds with some

emergent vegetation, and the restoration and maintenance of native riparian vegetation in the floodplain (Glenn et al. 2001), would lead to habitat improvements for waterbirds as well as for riparian nesting landbirds in the region. Directing the more constant flows of agricultural drainage waters (3 to 8 ppt) to areas with established emergent vegetation could also sustain wildlife habitat. Successful wildlife habitat restoration will also require that drain maintenance and flood control operations be designed to avoid damaging riparian and emergent vegetation and the closing of secondary streams.

Wetland restoration in the Delta should re-create a variety of habitat types including shallow pools, extensive marsh areas, mud flats, and backwater lagoons. A successful program of restoration would also identify sustainable approaches for enhancing the artisanal economies of local communities while maintaining and enhancing ecosystem functions and the biological richness of the Colorado River Delta.

ACKNOWLEDGMENTS

This project was funded by the North American Wetlands Conservation Council, through the Grant Agreement No. 14-48-98210-99-G349. Our special gratitude to O. Gonzalez, M. Gonzalez, J. Butrón, J. J. Butrón, M. Butrón, J. Mosqueda, D. J. Mosqueda, and J. García for their help during fieldwork. J. Campoy, M. J. Martínez, and M. Román provided helpful information and support with logistics. We thank K. Molina, M. Patten, K. Garrett, and W. D. Shuford for their invaluable comments on earlier drafts of this manuscript.