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-

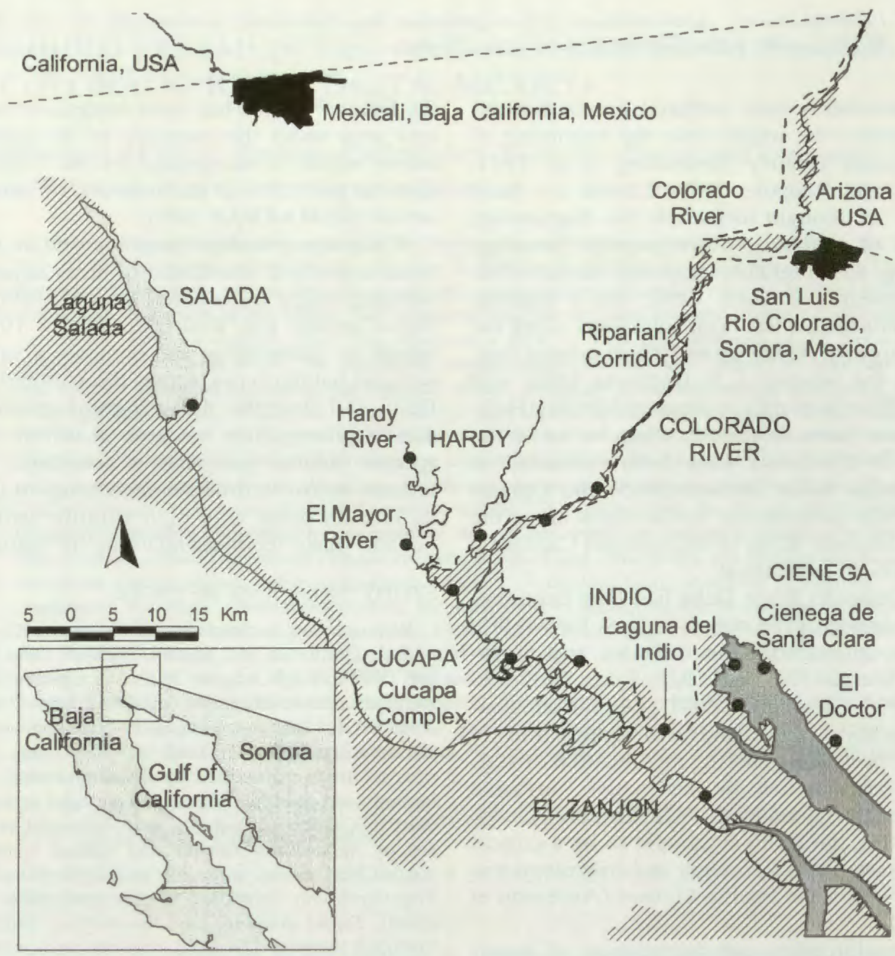

FIGURE 1. Zones (uppercase) and wetland areas (lowercase) of the Colorado River Delta included in our study. The location of mini-routes are shown by solid circles. The Delta floodplain (diagonal shading) is surrounded by a system of levees (dashed line). Major streams are depicted by solid lines.

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

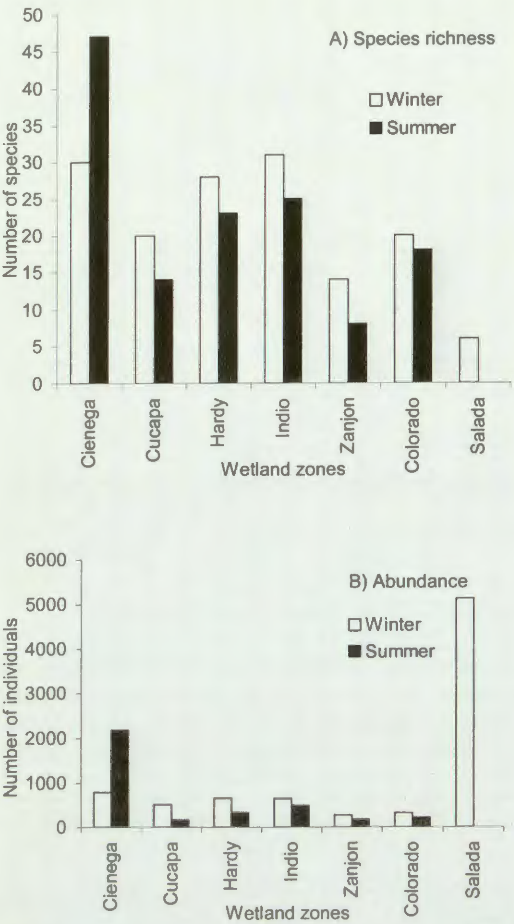

FIGURE 2. Species richness (A) and abundance (B) at each wetland zone by season in the Colorado River Delta. Laguna Salada contained water and shorebirds only during our winter survey.

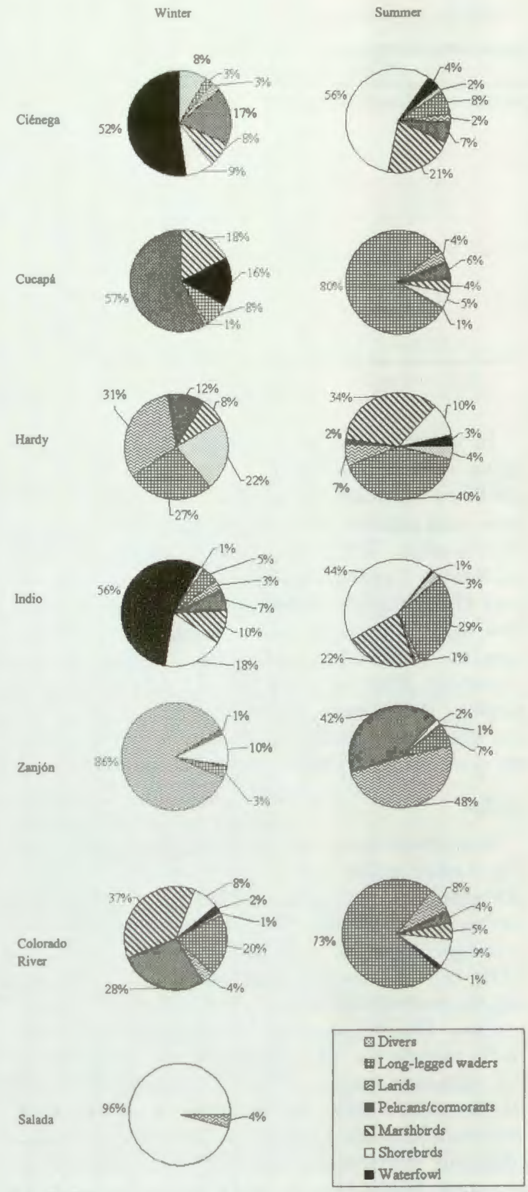

FIGURE 3. Proportions by guild for each census period at wetland zones of the Colorado River Delta.

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.

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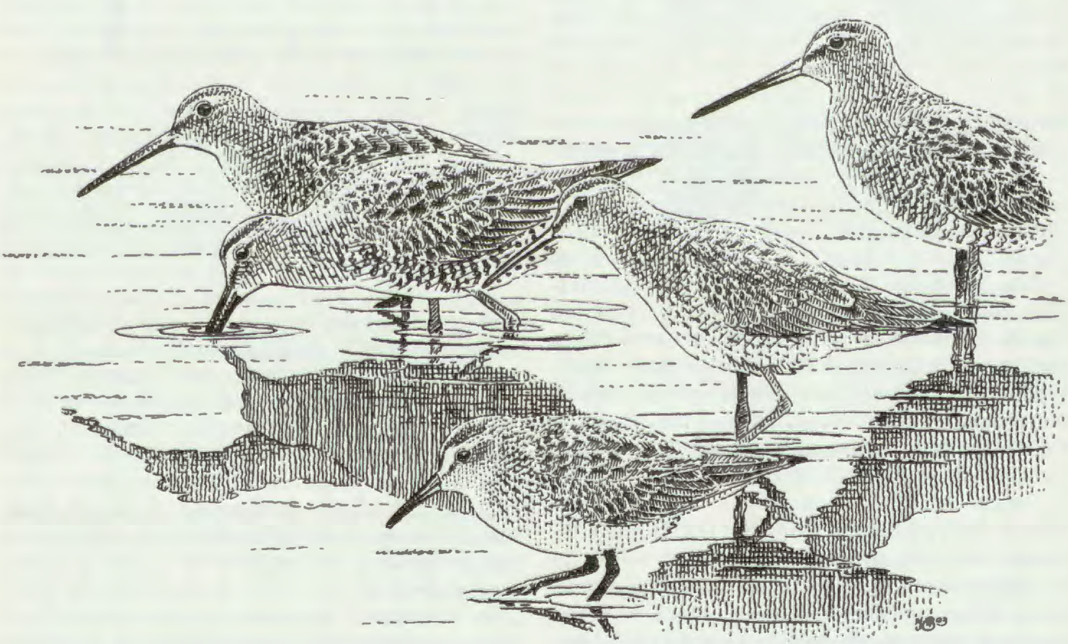

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PATTERNS OF SHOREBIRD USE OF THE SALTON SEA AND ADJACENT IMPERIAL VALLEY, CALIFORNIA

W. DAVID SHUFORD, NILS WARNOCK, AND ROBERT L. MCKERNAN

Abstract. From 1989–1995 and in 1999, we recorded 34 species on shorebird surveys at the Salton Sea and adjacent Imperial Valley, California. Of 27 regularly occurring species, 4 were primarily year-round residents and breeders, 12 winter residents, and 11 migrants. Median shorebird totals were 78,835 in fall, 68,281 in spring, and 27,796 in winter; maximum counts on single surveys exceeded 100,000 in spring and fall. The only taxa exceeding 10,000 individuals in spring or fall were the Black-necked Stilt (*Himantopus mexicanus,* fall), American Avocet (*Recurvirostra americana,* fall), Western Sandpiper (*Calidris mauri,* spring and fall), and dowitchers (*Limnodromus* spp., spring). The American Avocet and Long-billed Dowitcher (*L. scolopaceus*) were the only species exceeding 5000 in winter. The Salton Sea remains an important breeding and wintering area for the Snowy Plover (*Charadrius alexandinus*). Increased coverage of agricultural fields in 1999 revealed 2486–3758 Mountain Plovers (*C. montanus*), representing 30% to 38% of the species' estimated world population. At all seasons, shorebirds concentrated primarily along the south and secondarily along the north and west shorelines. Still, distribution patterns around the Sea varied greatly among species, and several relied extensively on freshwater and brackish ponds. The Mountain Plover, Whimbrel (*Numenius phaeopus*), and Long-billed Curlew (*N. americanus*), primarily used agricultural fields of the Imperial Valley. The shorebird community at the Salton Sea shows affinities with coastal sites in California and west Mexico. Despite many similarities, the Salton Sea contrasts with other intermountain sites by serving as a stopover for several primarily coastal species, hosting large numbers of Whimbrels (spring) and Mountain Plovers (winter), and, for many species, acting mainly as a wintering area rather than a breeding area or migratory stopover. Shorebirds at the Salton Sea face potential threats from high salinity, disease outbreaks, contaminants, and eutrophication. Large restoration projects proposed to reduce salinity may have negative impacts if placed in shallow water or alkali flat habitats where large numbers of shorebirds or sensitive species concentrate.

Key Words: distribution patterns; habitat use; migratory stopover; Mountain Plover; Pacific Flyway; Colorado River Delta; wintering area.

PATRONES DE USO DEL MAR SALTON Y EL ADYACENTE VALLE IMPERIAL, CALIFORNIA POR AVES PLAYERAS

Resumen. De 1989–1995 y en 1999, documentamos 34 especies en censos de aves playeras en el Mar Salton y el adyacente Valle Imperial, California. De 27 especies que ocurren regularmente, 4 fueron primariamente residentes anuales de reproducción en la zona, 12 fueron residentes de invierno, y 11 migratorias. La mediana total de aves playeras fue 78,835 en otoño, 68,281 en primavera, y 27,796 en invierno; en primavera y otoño los conteos máximos de censos simples excedieron 100,000 individuos. Los únicos taxones que excedieron los 10,000 individuos en primavera u otoño fueron el Candelero Americano (*Himantopus mexicanus,* otoño), la Avoceta Americana (*Recurvirostra americana,* otoño), el Playero Occidental (*Calidris mauri,* primavera y otoño), y los Costureros (*Limnodromus* spp., primavera). La Avoceta Americana y el Costurero Pico Largo (*Limnodromus scolopaceus*) fueron las únicas especies que superaron los 5000 individuos en invierno. El Mar Salton sigue siendo un área importante de reproducción e invernada para el Chorlo Nevado (*Charadrius alexandrinus*). El aumento en cobertura de campos agrícolas en 1999 reveló 2486–3758 Chorlos Llaneros (*C. montanus*), representando entre 30% y 38% de la población mundial estimada para la especie. Durante todas las estaciones, las aves playeras se concentraron principalmente a lo largo de la costa sur y secundariamente a lo largo de las costas norte y oeste. Aún así, los patrones de distribución alrededor del Mar Salton variaron grandemente entre las especies, y varias dependieron extensamente de charcas de agua dulce y salobre. El Chorlo Llanero, el Zarapito Trinador (*Numenius phaeopus*), y el Zarapito Pico Largo (*Numenius americanus*) usaron principalmente campos agrícolas del Valle Imperial. La comunidad de aves playeras en el Mar Salton muestra afinidades con sitios costeros de California y el oeste de México. A pesar de muchas similitudes, el Mar Salton contrasta con otros sitios ubicados entre montañas sirviendo como un sitio de parada temporal para varias especies de aves principalmente playeras, albergando un gran número de Zarapitos Trinadores (primavera) y Chorlos Llaneros (invierno), y, para muchas especies, actuando básicamente como área de invernada en vez de área de reproducción o parada durante la migración. Las aves playeras en el Mar Salton enfrentan potenciales amenazas por la alta salinidad, brote de enfermedades, contaminantes, y eutrofización. Grandes proyectos de restauración propuestos para reducir la salinidad pueden tener impactos negativos si son llevados a cabo en aguas de poca profundidad o hábitats llanos alcalinos, donde se concentran grandes números de especies de aves playeras o de aves sensibles.

Palabras claves: área de invernada; Chorlo Llanero; Delta del Río Colorado; patrones de distribución; ruta de vuelo del Pacífico; sitios de parada durante la migración; uso de hábitat.

Shorebirds increasingly are a focus of conservation concern because of population declines and habitat loss (Page and Gill 1994, Brown et al. 2001). Although recent papers provide broad overviews of shorebird use of wetlands and agricultural habitats in western North America (Shuford et al. 1998, 2002a; Page et al. 1999), few data have been published on the patterns of shorebird use at individual sites (e.g., Stenzel et al. 2002), where most conservation and management efforts will be implemented. The Salton Sea recently has been given long overdue recognition for its great importance to populations of Pacific Flyway waterbirds (Shuford et al. 2002b, chapters in *this volume*). Shorebirds are among the most numerous groups of waterbirds at the Salton Sea during migration and winter, yet, other than for the Snowy Plover (Page et al. 1991, Shuford et al. 1995), few quantitative data have been published on their patterns of use of this site. Such data are needed to address concerns for the health of the Salton Sea ecosystem (USFWS 1997, Tetra Tech, Inc. 2000, Shuford et al. 2002b).

PRBO Conservation Science (PRBO) conducted surveys of shorebird use at the Salton Sea via the Pacific Flyway Project from 1989 to 1995 and the Salton Sea Reconnaissance Survey in 1999 (Shuford et al. 2000). Here we report the abundance and distribution patterns of shorebirds at the Salton Sea and adjacent Imperial Valley, highlight threats to these populations, suggest conservation measures for shorebirds, and identify future research needs.

STUDY AREA AND METHODS

The study area included the Salton Sea, Riverside and Imperial counties, California, and the adjacent Imperial Valley, Imperial County. We used several methods to characterize shorebird use in this area. From 1989 to 1995 and in 1999, we conducted comprehensive surveys of most shorebird habitat at the Salton Sea over short periods up to four times a year. We conducted a total of eight comprehensive surveys in fall (mid-August to mid-September), eight in spring (mid-April), five in early winter (mid-November to early December), and four in mid-winter (late January to early February). On each census, a team of professional biologists and skilled volunteers attempted to survey the entire Salton Sea shoreline, adjacent marshes and impoundments (Fig. 1, Areas 1–21) and various sites in the Imperial Valley, including the Finney-Ramer Unit of Imperial Wildlife Area (WA) south of Calipatria (Areas 22a–b) and private duck clubs near Brawley (Areas 22c–g). Except on winter surveys of Mountain Plovers (scientific names of all species are listed in Table 1) described below, we covered agricultural habitat of the Imperial Valley only on a limited and opportunistic basis. To obtain data on their patterns of distribution and habitat use around the Sea, observers kept separate tallies of shorebirds within 19 shoreline segments and three complexes of freshwater marshes and impoundments (Fig. 1). Observers generally conducted surveys with the aid of binoculars and spotting scopes and traveled by vehicle or on foot. During summer 1999, observers used an airboat to survey the shoreline from Iberia Wash at Salton City (boundary of Areas 5 and 6) south to, and including, the New River (Area 11b) to reduce the risk of heat exhaustion while covering this long, isolated stretch. Observations from aerial surveys conducted for other species of waterbirds found very few shorebirds away from the immediate shoreline where they were readily counted by ground based observers.

We instructed observers, when possible, to identify all shorebirds to species. Groups of unidentified shorebirds fell mostly into four categories: yellowlegs, either Greater or Lesser (*Tringa melanoleuca* or *T. flavipes*); small sandpipers of the genus *Calidris*, primarily Western and Least sandpipers (*C. mauri* and *C. minutilla*), and Dunlin (*C. alpina*); dowitchers, either Short-billed or Long-billed (*Limnodromus griseus* or *L. scolopaceus*); and phalaropes, either Wilson's or Red-necked (*Phalaropus tricolor* or *P. lobatus*). For analyses, we grouped identified and unidentified dowitchers as dowitcher spp. owing to the difficulty of identifying most individuals to species on surveys. Observations indicate that all wintering dowitchers are long-billeds, as no short-billeds have been recorded at the Sea from 29 November to 3 March (Patten et al. 2003). Although the Long-billed Dowitcher is the most numerous of the two species during migration, the Short-billed also occurs in substantial numbers seasonally (M. Patten, pers. comm.). We assigned unidentified shorebirds to species using methods described in Page et al. (1999).

We used the median numbers of shorebirds on comprehensive surveys to estimate the seasonal abundance of various taxa. Because of limited coverage on some surveys, we used only five fall, three early winter, one late winter, and five spring surveys to characterize shorebird abundance, and only four surveys in 1999 to analyze patterns of distribution around the Salton Sea and nearby wetlands. We excluded the November 1999 survey when calculating medians for winter, as comparisons with other winter counts suggested that shorebirds were still migrating in November. For graphing the distribution patterns of shorebird within study area wetlands in 1999, we grouped data for six subareas: west shore (Areas 3–10), north shore (Areas 1–2 and 19), east shore (Areas 13–18), south shore (Areas 11 and 12), nearshore ponds (Areas 20 and 21), and Imperial Valley ponds (Area 22; Fig. 1).

To document seasonal occurrence patterns of shorebirds, in 1999 we surveyed a subset of shoreline segments (1A–B, 8, 11A–D, 12A, 20A–D, and 21B; Fig. 1) once a month during winter and mid-summer and twice a month during spring and fall. We did not cover Area 8 on the 4–7 October survey because of adverse winds, but we estimated data for this segment by taking the mean of the two counts on either side of this survey. Finally, we combined data from the same subset of areas surveyed on the four comprehensive surveys in 1999 with the 14 partial surveys for a total of 18 surveys used to describe annual phenology. We characterized the seasonal occurrence patterns of 27

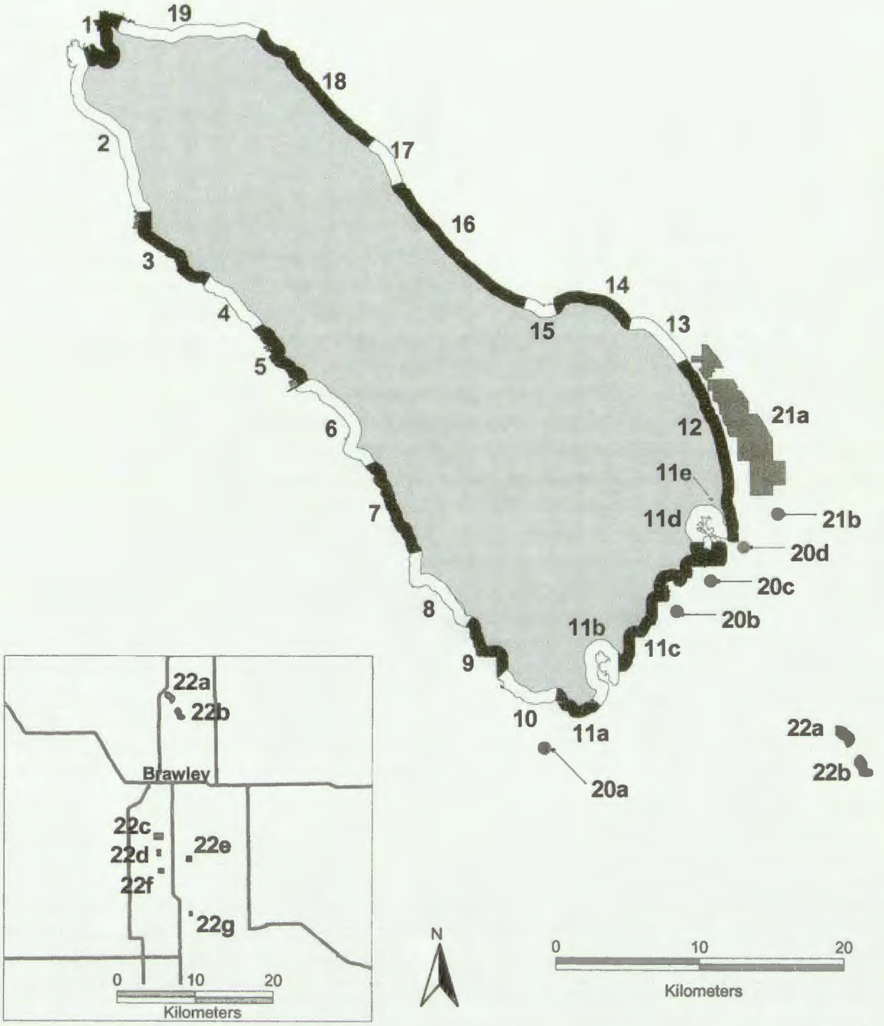

FIGURE 1. Numbered areas of the shoreline and inshore zone (within 1 km of shore) of the Salton Sea, California, and adjacent freshwater impoundments. Inset shows locations of duck clubs near Brawley in the Imperial Valley.

regularly occurring species, i.e., those recorded on at least three comprehensive surveys in any season. Although not meeting this latter criterion, we included the Mountain Plover in this characterization as it would have occurred on all comprehensive winter surveys if they had included most agricultural habitat in the Imperial Valley.

In 1999, we conducted three comprehensive surveys of Snowy Plovers at the Salton Sea to compare to prior data on this species (Shuford et al. 1995). We conducted the 22–30 January and 11–14 November surveys, when plovers are flocking and easiest to detect, as part of the comprehensive surveys described above and the 21–31 May survey as a separate census focusing entirely on Snowy Plovers. At that season, surveying is made more difficult by adults sitting cryptically on nests and by adults with chicks sometimes moving long distances to mob observers. To minimize these problems, we instructed observers to use both binoculars and spotting scopes to repeatedly scan long distances up and down beaches and alkali flats to try to detect incubating adults before the plovers sneaked off nests and scattered. We also asked observers to zigzag back and forth across beaches and alkali flats to try to detect roosting or incubating plovers or those foraging behind shoreline berms where they otherwise might be invisible from the upper beach. On very wide beaches and alkali flats, two observers worked in tandem, one covering the upper beach or alkali flats, the other the immediate shoreline, zigzagging as needed.

In 1999, we estimated the winter population size of the Mountain Plover via comprehensive surveys of 80% to 90% of the agricultural lands in the Imperial Valley on 14–15 February, 13–14 November, and 11–

12 December. Adjusting for individuals participating on both days of two-day survey periods, the number of observers ranged from 11 observers in eight parties on the 14–15 February survey to 26 observers in 15 parties on the 11–12 December survey. Observers drove all accessible roads and used binoculars and spotting scopes to carefully scan fields with appropriate plover habitat of barren ground or sparse low growth. On all surveys, observers recorded and mapped the location of all flocks and described the types of fields on which plovers occurred. In November and December, observers gathered additional data on the behavior (foraging, roosting, or flying) of plovers and on characteristics of fields where plovers were observed (% cover of vegetation vs. bare ground, dominant plant species, average plant height, burned or grazed vs. unburned or ungrazed, etc.). We also collected limited data on the Long-billed Curlew, particularly in November and December.

RESULTS

Species Richness and Overall Abundance

We detected 34 species of shorebirds on comprehensive surveys of the Salton Sea area (Tables 1, 2). Median shorebird totals were 78,835 (N = 5 surveys, min–max = 59,512–105,570) in fall, 68,281 (N = 5 surveys, min–max = 36,675–129,538) in spring, and 27,796 (N = 4 surveys, min–max = 19,724–70,059) in winter. The relatively low numbers in April 1999 compared with other springs may represent a lack of coincidence of the 1999 survey dates with the peak passage of Western Sandpipers, which can move through rapidly in large numbers. The high shorebird numbers in November 1999 likely reflects protracted migration through that period, as other winter counts were taken later in the season. In 1999, we counted 275 Snowy Plovers at the Salton Sea in January, 221 in May, and 170 in November, and 2486 Mountain Plovers in agricultural fields of the Imperial Valley in February, 2790 in November, and 3758 in December. The increase in Mountain Plover numbers across surveys may reflect a parallel increase in observer coverage.

Median counts of shorebirds at the Salton Sea were >1000 and <10,000 for six and four taxa and >10,000 for three and two taxa in fall and spring, respectively (Table 1). Median counts in winter were >1000 and <5000 for five taxa and >5000 for two taxa. The only taxa exceeding 10,000 individuals in spring or fall were the Black-necked Stilt (fall), American Avocet (fall), Western Sandpiper (spring and fall), and dowitcher spp. (spring). The only species exceeding 5000 in winter were the American Avocet and Long-billed Dowitcher.

Seasonal Occurrence Patterns

Seasonal occurrence patterns varied greatly among species of regularly occurring shorebirds (Figs. 2–5; Tables 1, 2). Of 27 such species, four were primarily year-round residents and breeders, 12 primarily winter residents, and 11 primarily migrants. Of year-round residents, the Black-necked Stilt and American Avocet also showed large peaks, representing fall migrants, in July and August and August to early November, respectively. Of species occurring primarily as migrants, the Semipalmated Plover, Ruddy Turnstone, Red Knot, Sanderling, and, particularly, the Whimbrel were more numerous in spring than fall, whereas this pattern was reversed for the Baird's Sandpiper and Wilson's and Red-necked phalaropes. Of primarily winter residents, dowitcher numbers were swelled the most by migrants in spring and fall.

Patterns of Distribution

At all seasons, shorebirds concentrated primarily along the south shoreline and secondarily along the north and west shorelines (Fig. 5 in Warnock et al. *this volume*). Shorebird densities were particularly impressive at all seasons along the shoreline (Area 12) of the Wister Unit of Imperial WA (Fig. 6). Still, many numerous species varied in their patterns of distribution (Fig. 7). The Marbled Godwit and Western Sandpiper concentrated heavily on the south shore of the Salton Sea; the Semipalmated Plover also concentrated there, except in April when it was widespread. The Black-necked Stilt and American Avocet were generally widespread but tended to concentrate more on the west and south shores and the south shore, respectively. By contrast, though fairly widespread, the Willet and Dunlin tended to concentrate on the west shore. The two yellowlegs species and the Least Sandpiper were widespread but tended to rely more on ponds than other species. Dowitchers were most numerous on the south shore and in adjacent nearshore ponds. The distribution patterns of the Black-bellied Plover and Long-billed Curlew in wetlands were influenced by their use of agricultural fields. Plovers foraged extensively along the Salton Sea shoreline, but their seasonal concentrations in Imperial Valley ponds reflected birds using these sites for roosting after foraging in nearby fields. The curlew was found primarily along the south shore and in Imperial Valley ponds; the curlews appeared to be primarily roosting rather than foraging in these habitats.

Several less numerous species also showed differential distribution patterns along the Salton Sea shoreline. In 1999, the Snowy Plover concentrated in areas similar to those used in prior years (see Shuford et al. 1995). At all seasons, plovers concentrated primarily on sandy beaches and sand or alkali flats along the western and southeastern shorelines of the Sea (Table 3; Figs. 1, 7). Areas of particular importance included the shoreline and expansive alkali flats of the western shoreline from Iberia Wash south through the northern portion of the Salton Sea Test Base and San Felipe Creek Delta (Area 6, northern part of 7, and 8) and the southeastern shoreline, breached impoundments, and sand spit paralleling Davis Road and the Wister Unit of Imperial WA (Area 12). In 1999, these areas, respectively, held about 44% and 33% of all plovers in January and 55% and 18% in May. Other species particularly concentrated on the west shoreline in spring were the Ruddy Turnstone (84% in Area 6), Red Knot (87% in Areas 5 and 6), and Sanderling (81% in Area 6). The Stilt Sandpiper concentrated primarily along the Wister shoreline (Area 12) and in brackish or freshwater ponds of or adjacent to the Salton Sea National Wildlife Refuge (Area 20). In 1999, 73% and 18% of Stilt Sandpipers in January and 43% and 52% in November were in Areas 12 and 20, respectively. Away from the Sea, small numbers also occurred in freshwater ponds of duck clubs near Brawley in the Imperial Valley.

Opportunistic coverage of agricultural fields of the Imperial Valley showed that several species were much more numerous there than in shoreline or other wetland habitats at or near the Salton Sea. The high count of 9837 Whimbrels at the Salton Sea in April 1989 was almost exclusively from agricultural fields in the Imperial Valley, which received only limited coverage. The magnitude of Long-billed Curlew abundance in the Imperial Valley is indicated by counts of about 2655 individuals in a single flock near Calipatria on 13 November 1999, a total of 5593 from coverage of about 60% of the Imperial Valley by six observers involved in a Mountain Plover survey on 11–12 December 1999, and 7476 on a multi-observer survey of the Salton Sea and portions of the Imperial Valley in August 1995. A mixed flock of shorebirds in a single flooded field in the Imperial Valley on 11 Dec 1999 held 153 Greater and 20 Lesser yellowlegs, which, respectively, represent 188% and 69% of the median number of these species found on three winter counts of the entire Salton Sea (Table 2). Similarly, G. McCaskie (pers. comm.) recorded about 150 Greater and 100 Lesser yellowlegs in one flooded field near Calipatria on 2 December 2000. The Black-bellied Plover also is fairly numerous in agricultural fields, and a roosting flock of 758 individuals at the New River Delta on 2 February 1999 likely moved there after foraging in nearby fields.

Overall, wintering Mountain Plovers were distributed widely over the Imperial Valley with no consistent areas of concentration (Fig. 8), presumably reflecting the shifting availability of suitable fields with the temporal and spatial variation in cultivation practices. The concentration of plovers in a relatively few sites in February appeared to reflect a preference by plovers for burned fields at that season as described below.

The types of fields used by Mountain Plovers varied by season. In February, 81% of all plovers were in stubble hayfields burned after harvest; the remainder, except for three individuals in an asparagus stubble field, were in short-stature, stubble hayfields yet to be burned. Most of the burned fields had some sparse new green growth. In three complexes of burned stubble hayfields holding about 1184 plovers, residual stubble about 3–5 cm tall covered about 50% of the ground with the remainder bare of vegetation. In November, 35% of the plovers were in bare tilled fields and 65% in fields of various crop types with new growth averaging <3 cm in height and ranging up to 95% vegetative cover. In December, 47% were in bare tilled fields and 53% in fields of various crop types, primarily in new stages of growth, ranging from <5% to 100% vegetative cover. Of plovers in fields with new crops, 69% were in fields in which plant height averaged <5 cm, 10% in which it averaged 5–10 cm, and 21% in which it averaged >10–20 cm. Additional practices that produced the low stature and sparse cover of vegetation attractive to plovers included grazing and mowing or harvesting of hay crops. Plovers using bare fields appeared to prefer actively or recently tilled fields. This appeared particularly to be the case in December when at least 649 (37%) of 1777 plovers in bare fields were in ones in which tractors were actively working; an additional but unknown percent were in fields that had recently been tilled. Tilled fields used by plovers tended to be relatively flat and smooth rather than extensively furrowed, undulating, or with large dirt clods. Although many fields with growing crops used by plovers were relatively flat throughout, many others had raised beds with flat tops and narrow intervening furrows in which plovers often stood or crouched.

DISCUSSION

Species Richness

In addition to the 34 shorebird species found on our surveys, an additional 11 rare to extremely rare species have been recorded in the Salton Sea area (Patten et al. 2003). Although it is difficult to compare species richness across wetlands with unequal observer coverage, by any measure the Salton Sea has a rich shorebird fauna that rivals or exceeds that of most sites in

TABLE 1. NUMBERS OF SHOREBIRDS ON SURVEYS OF THE SALTON SEA, CALIFORNIA, IN FALL AND SPRING, 1989–1995 AND 1999

	19 Aug 1989	14 Sep 1990	23 Aug 1991	21 Aug 1992	13 Aug 1999	23 Apr 1989	21 Apr 1990	27 Apr 1991	25 Apr 1992	17 Apr 1999
Black-bellied Plover *Pluvialis squatarola*	98	138	267	462	253	579	297	456	256	575
Pacific Golden-Plover *Pluvialis fulva*	0	0	0	0	0	1	0	0	0	1
Snowy Plover *Charadrius alexandrinus*	84	102	389	125	351	113	261	179	312	285
Semipalmated Plover *Charadrius semipalmatus*	131	38	89	67	139	811	483	607	232	131
Killdeer *Charadrius vociferous*	132	263	579	777	259	130	182	144	408	215
Mountain Plover *Charadrius montanus*	0	0	5	0	0	0	0	0	0	0
Black-necked Stilt *Himantopus mexicanus*	10,167	3,825	7,555	19,255	15,857	1,171	3,114	3,184	10,467	3,465
American Avocet *Recurvirostra americana*	19,382	16,545	14,121	12,717	10,037	5,926	3,111	7,052	14,356	7,001
Greater Yellowlegs *Tringa melanoleuca*	41	56	65	39	113	14	40	9	61	14
Lesser Yellowlegs *Tringa flavipes*	0	174	14	36	28	28	3	2	7	12
Solitary Sandpiper *Tringa solitaria*	0	0	0	0	1	0	0	0	0	0
Willet *Catoptrophorus semipalmatus*	781	1,147	1,093	566	582	208	337	197	104	682
Wandering Tattler *Heteroscelus incanus*	1	1	0	0	0	0	0	0	0	0
Spotted Sandpiper *Actitis macularia*	7	10	41	82	19	6	17	8	4	7
Whimbrel *Numenius phaeopus*	0	2	116	0	31	9,837	3,243	7,860	0	43
Long-billed Curlew *Numenius americanus*	3,761	1,374	670	2,425	394	102	31	48	34	33
Marbled Godwit *Limosa fedoa*	724	3,190	2,413	371	1,036	73	630	877	3,170	928
Ruddy Turnstone *Arenaria interpres*	2	3	5	29	10	11	26	37	46	44
Black Turnstone *Arenaria melanocephala*	0	0	0	0	0	4	0	0	0	0
Surfbird *Aphriza virgata*	0	0	0	0	0	5	0	0	0	0

TABLE 1. CONTINUED

	19 Aug 1989	14 Sep 1990	23 Aug 1991	21 Aug 1992	13 Aug 1999	23 Apr 1989	21 Apr 1990	27 Apr 1991	25 Apr 1992	17 Apr 1999
Red Knot *Calidris canutus*	22	0	0	0	1	502	366	365	126	371
Sanderling *Calidris alba*	0	70	0	0	39	135	265	132	0	249
Western Sandpiper *Calidris mauri*	9,336	54,374	34,961	35,653	34,394	36,053	38,225	58,444	67,343	14,700
Least Sandpiper *Calidris minutilla*	1,154	422	3,556	4,149	942	197	793	2,574	3,476	1,226
Baird's Sandpiper *Calidris bairdii*	23	0	6	6	1	0	0	0	0	0
Dunlin *Calidris alpina*	0	1	0	14	1	53	212	48	2,258	141
Stilt Sandpiper *Calidris himantopus*	0	48	85	40	15	0	10	35	0	1
Ruff *Philomachus pugnax*	0	0	0	0	3	0	0	0	0	0
Dowitcher spp. *Limnodromus griseus* or *L. scolopaceus*	5,939	10,704	9,320	15,533	7,153	12,109	10,126	14,624	26,443	6,492
Wilson's Snipe *Gallinago delicata*	0	0	0	0	2	3	7	3	0	1
Wilson's Phalarope *Phalaropus tricolor*	7,577	818	2,346	1,003	3,065	133	416	83	334	23
Red-necked Phalarope *Phalaropus lobatus*	150	12,265	1,139	4,350	32	77	754	1,816	101	32
Red Phalarope *Phalaropus fulicarius*	0	0	0	0	0	0	0	0	0	3
Totals	59,512	105,570	78,835	97,699	74,758	68,281	62,949	98,784	129,538	36,675

TABLE 2. NUMBERS OF SHOREBIRDS ON SURVEYS OF THE SALTON SEA, CALIFORNIA, IN WINTER, 1993, 1994, AND 1999

	6 Dec 1993	5 Dec 1994	11 Nov 1999	22 Jan 1999
Black-bellied Plover	982	430	1,381	1,310
Snowy Plover	285	214	170	275
Semipalmated Plover	29	31	122	73
Killdeer	451	175	228	277
Mountain Plover	169	52	0	0
Black-necked Stilt	4,012	2,159	5,938	3,941
American Avocet	5,836	3,363	18,800	7,318
Greater Yellowlegs	103	27	82	81
Lesser Yellowlegs	29	3	69	62
Yellowlegs spp.	0	30	0	0
Willet	1,834	1,540	1,531	1,162
Spotted Sandpiper	5	8	11	7
Long-billed Curlew	402	108	1,380	373
Marbled Godwit	1,381	1,283	1,205	1,297
Ruddy Turnstone	5	6	0	17
Red Knot	0	0	20	0
Sanderling	102	106	37	52
Western Sandpiper	3,273	4,714	22,526	1,573
Least Sandpiper	3,225	1,464	3,773	2,006
Dunlin	609	454	964	799
Stilt Sandpiper	12	134	206	164
Ruff	1	0	0	1
Dowitcher spp.[a]	5,671	3,419	11,589	6,356
Wilson's Snipe	6	4	5	24
Wilson's Phalarope	0	0	2	1
Red-necked Phalarope	0	0	20	0
Totals	28,422	19,724	70,059	27,169

[a] These are almost exclusively Long-billed Dowitchers. Only a few Short-billed Dowitchers were recorded on the November survey, and no short-billeds have been recorded at the Sea from 29 November to 3 March (Patten et al. 2003).

western North America. This richness appears to reflect the large size of the Sea, its varied saline and freshwater habitats (in proximity to extensive irrigated fields), its mild winter climate, and its location along a pathway to and from the Gulf of California. For comparison, species richness, for migration and winter, was 43 species for 56 wetlands of the Pacific Coast of the contiguous United States (Page et al. 1999), 38 species in the San Francisco Bay estuary (Stenzel et al. 2002), 35 species at Great Salt Lake (Paton et al. 1992), 33 species in the Central Valley (Shuford et al. 1998), and 29 and 27 species, in winter, at two and five large estuaries on the west coasts of Mexico (Engilis et al. 1998) and Baja California (Page et al. 1997), respectively. Hence, generally large wetlands with diverse habitats will have the highest species richness; all else being equal, coastal sites will hold more species than interior sites.

SEASONAL OCCURRENCE PATTERNS

Although it would have been ideal to have based our characterization of seasonal occurrence patterns solely on comprehensive surveys, on more frequent partial surveys, or on more years of data, we think our methods provide reasonable approximations of these patterns for most species. Still, our lack of surveys in early to mid-May appeared to truncate the depiction of the period of declining numbers of many wintering and migrant shorebirds in spring, when passage typically is more rapid than in fall. Generally this did not greatly distort the occurrence patterns of species reaching peak numbers in mid- to late April. The pattern was distorted, though, for the Red-necked Phalarope, which reaches peak numbers in early to mid-May (e.g., 3000+ on 11 May 2000, 5000+ on 9 May 2001; G. McCaskie, pers. comm.); the period of peak numbers appears to be slightly later at Great Salt Lake, where up to 20,000 were recorded on 19 May 1991 (Paton et al. 1992).

Because of its very mild winter climate and close proximity to the ocean, the Salton Sea's shorebirds have seasonal occurrence patterns with a greater affinity to those on the Pacific Coast than the interior of the West. Of 12 species that are primarily winter residents at the Salton Sea, nine are primarily winter residents and three are rare to uncommon migrants on the California coast (Shuford et al. 1989). By con-

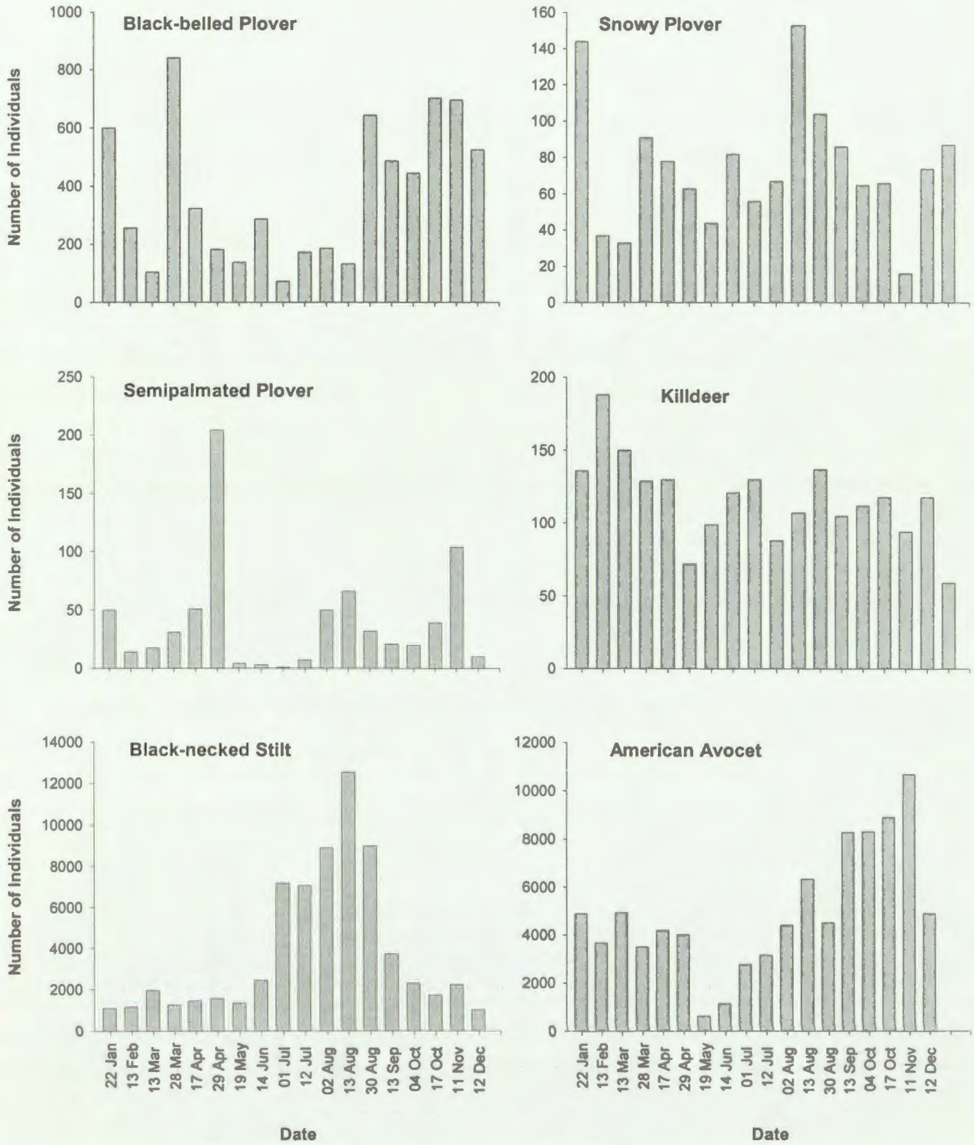

FIGURE 2. Seasonal occurrence patterns of the Black-bellied Plover, Snowy Plover, Semipalmated Plover, Killdeer, Black-necked Stilt, and American Avocet at the Salton Sea, California, in 1999. Data from 18 surveys of five areas of shoreline and freshwater ponds (see METHODS).

trast, none of the species wintering at the Salton Sea do so in even moderate numbers in the Intermountain West (Paton et al. 1992, Taylor et al. 1992). Many species of passage migrants at the Salton Sea, however, had patterns of occurrence similar to those both at sites in the Intermountain West (Paton et al. 1992, Taylor et al. 1992) and on the California coast (Shuford et al. 1989). Because of the Salton Sea's southerly location, migrants there generally appear to arrive earlier and depart sooner in spring and vice versa in fall compared with the central California coast and the northern Intermountain West, though more work is needed to document these patterns.

IMPORTANCE OF THE SALTON SEA

Regional comparisons indicate the Salton Sea ranks second, after Great Salt Lake, of the ten sites in the Intermountain West of western North

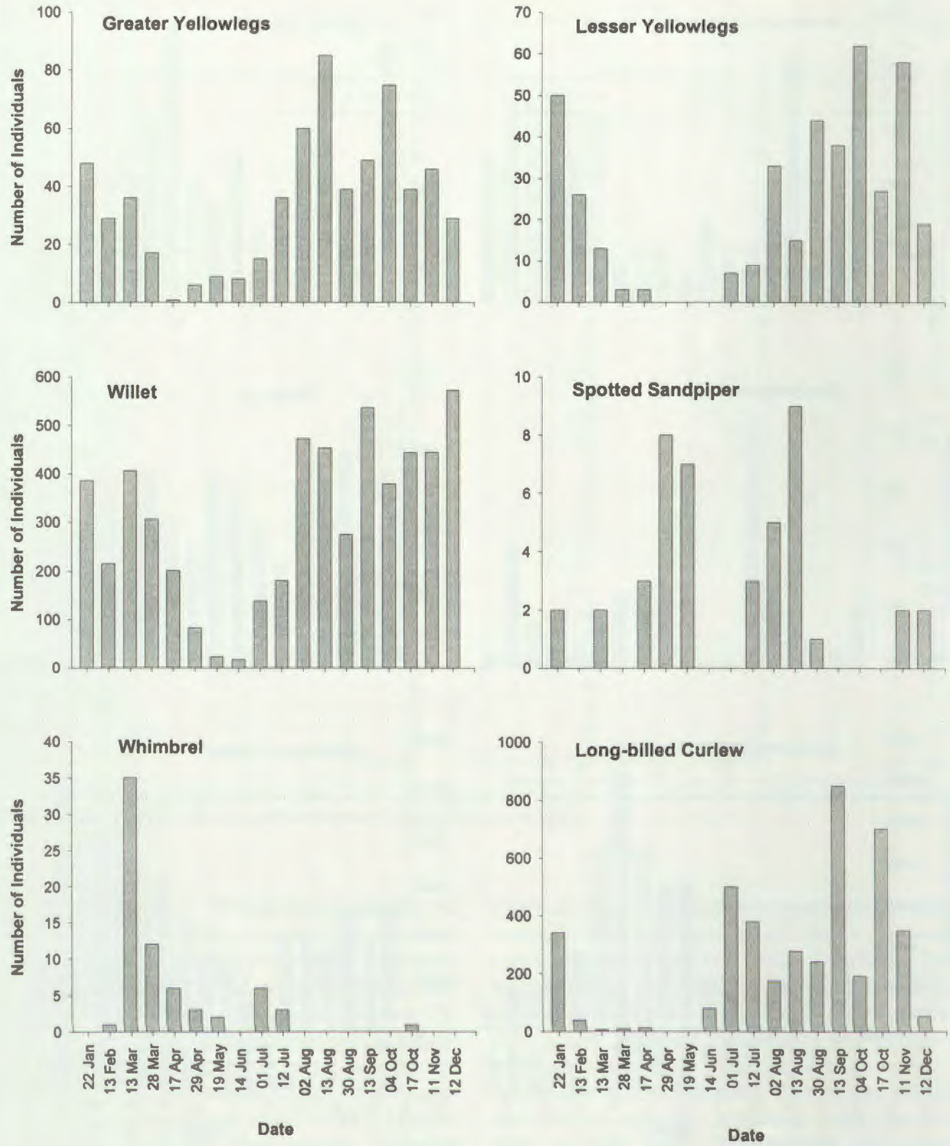

FIGURE 3. Seasonal occurrence patterns of the Greater Yellowlegs, Lesser Yellowlegs, Willet, Spotted Sandpiper, Whimbrel, and Long-billed Curlew at the Salton Sea, California, in 1999. Data from 18 surveys of five areas of shoreline and freshwater ponds (see METHODS).

America that hold >10,000 shorebirds (based on medians) in fall, first of three such sites in spring, and is the only one in winter (Shuford et al. 2002a; PRBO, unpubl. data). Unlike many interior sites that hold their largest numbers of shorebirds in fall—particularly saline lakes where large numbers of American Avocets and Wilson's Phalaropes stage—the Salton Sea holds comparable numbers in both spring and fall. Because annual and seasonal fluctuations in water levels are small at the Salton Sea, annual variation in shorebird numbers appears to be dampened there compared with other sites in the Intermountain West, such as the Lahontan Valley, Nevada (Neel and Henry 1997), that show great variation in the extent of shallow water habitat. Although its shorebird numbers in winter are much smaller than in migration, the Salton Sea is one of only three sites in the interior of the West, along with California's Central Valley and

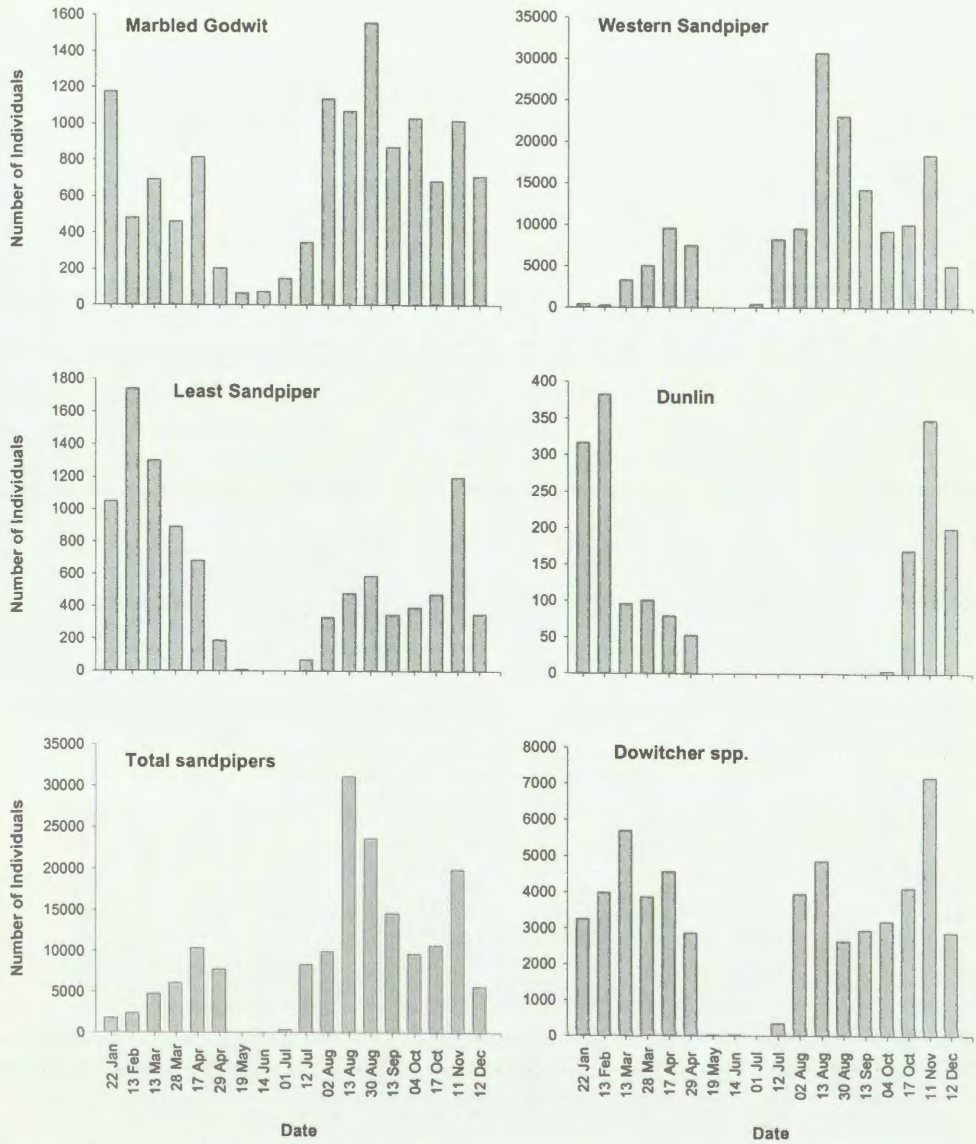

FIGURE 4. Seasonal occurrence patterns of the Marbled Godwit, Western Sandpiper, Least Sandpiper, Dunlin, total sandpipers, and dowitcher spp. at the Salton Sea, California, in 1999. Data from 18 surveys of five areas of shoreline and freshwater ponds (see METHODS).

Oregon's Willamette Valley, that hold tens of thousands of shorebirds in winter (Shuford et al. 1998; PRBO, unpubl. data).

Of common to abundant intermountain shorebirds, the Salton Sea held particularly high proportions of the estimated regional populations of the Black-necked Stilt (31%), Whimbrel (88%), small sandpipers (33%), and dowitchers (33%) in spring, and of the Willet (77%) and Long-billed Curlew (87%) in fall (Shuford et al. 2002a). Of uncommon to rare intermountain shorebirds, the Salton Sea held over 90% of the estimated populations of the Ruddy Turnstone, Red Knot, and Stilt Sandpiper in spring. Although not numerically dominant, the population of the Stilt Sandpiper wintering at the Salton Sea is one of few substantial ones of that species in the United States; the nearest known wintering site to the Sea is on the Sinaloa coast of west Mexico (Klima and Jehl 1998).

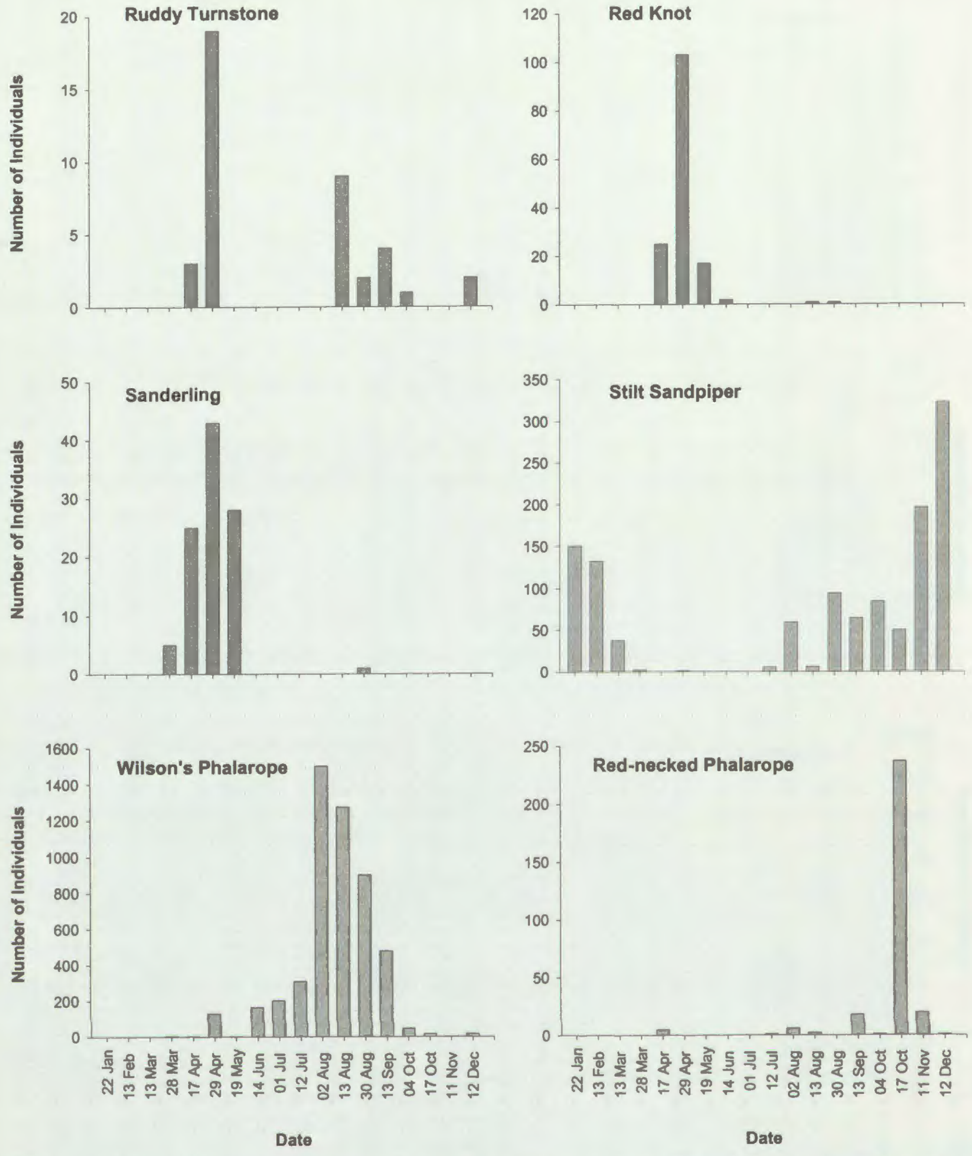

FIGURE 5. Seasonal occurrence patterns of the Ruddy Turnstone, Red Knot, Sanderling, Stilt Sandpiper, Wilson's Phalarope, and Red-necked Phalarope at the Salton Sea, California, in 1999. Data from 18 surveys of five areas of shoreline and freshwater ponds (see METHODS).

The Salton Sea also holds important populations of the Snowy and Mountain plovers. Surveys in 1999 reconfirmed that the Salton Sea supports the largest population of wintering Snowy Plovers in the interior of western North America (Shuford et al. 1995) and is one of a handful of key breeding areas in the interior of California (Page et al. 1991). Although California's Central and Imperial valleys are widely considered the primary wintering areas for the Mountain Plover (Knopf and Rupert 1995), our surveys suggest the latter area may be of much more crucial importance than previously thought. Regardless, the mean number for these three surveys represents about 30% to 38% of the species' estimated population of 8000 to 10,000 individuals (Anonymous 1999). On prior surveys across the California wintering range, the 2072 and 755 Mountain Plovers recorded in the Imperial Valley in 1994 and 1998, respectively, represented 61% and 35% of the totals of 3390 and 2179 individuals found statewide (B.

FIGURE 6. The juxtaposition of shallow waters along the Salton Sea shoreline, backwater embayments, and freshwater impoundments of the Wister Unit of Imperial Wildlife Area attract large numbers of migrant and wintering shorebirds (Photo by W. D. Shuford, 12 February 1999).

Barnes, pers. comm.; California Department of Fish and Game, unpubl. data; K. Hunting, pers. comm.). The higher totals in the Imperial Valley in 1999 almost surely reflect an increase in observer coverage there over prior years rather than a population increase. Counts of Mountain Plovers on the Salton Sea (south) Christmas Bird Count, covering only part of the northern Imperial Valley, have ranged from 0–1003 birds (median = 197 birds; N = 35) from 1965 to 2001 (http://www.audubon.org/bird/cbc/hr/index.html).

Affinities and Connectivity

. Comparisons of winter shorebird populations at the Salton Sea with those of California's Central Valley and Mexico's Río Colorado Delta, the closest marine shorebird habitat, indicates the Salton Sea has a closer affinity with the latter area (Table 4). The Salton Sea and the Río Colorado Delta both hold relatively high numbers of wintering American Avocets, Willets, and Marbled Godwits, relatively low numbers of Dunlin, and small numbers of wintering Sanderling. Unlike the Río Colorado Delta, and more like the Central Valley, the Salton Sea hosts relatively large numbers of wintering Black-necked Stilts and Long-billed Dowitchers, presumably because the Sea has a substantial amount of freshwater habitat and the Delta does not.

On a broader scale, the winter shorebird community at the Salton Sea also has a close affinity to that of the coasts of California (Page et al. 1999), western Baja California (Page et al. 1997), and the west coast of Mexico (Engilis et al. 1998). This affinity is shown by the occurrence at all sites of many species found wintering in both coastal (references above) and interior habitats (e.g., Shuford et al. 1998) and the substantial wintering populations at the Sea of the Semipalmated Plover, Willet, and Marbled Godwit, and small numbers of the Sanderling and Ruddy Turnstone, all of which are typical of coastal areas but rare or absent in winter in the interior. Conversely, several species found on the coasts of California, Baja California, and west Mexico in winter are lacking (Short-billed Dowitcher) or very rare (Whimbrel, Red Knot) at the Salton Sea then, though not in migration (Patten et al. 2003). Also, some strictly marine species found on the California coast are lacking (Black Oystercatcher, *Haematopus bachmani*; Wandering Tattler) or extremely rare (Black Turnstone) at the Sea in winter; small numbers

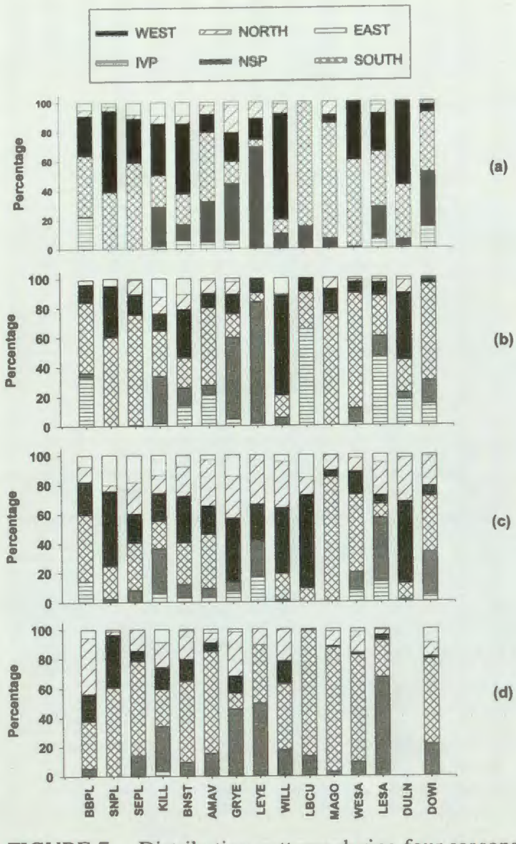

FIGURE 7. Distribution patterns during four seasons for 15 shorebird taxa by six major subdivisions of the Salton Sea study area. (a) = January, (b) = November, (c) = April, and (d) = August; East = east shore, IVP = Imperial Valley ponds, North = north shore, NSP = nearshore ponds, South = south shore, and West = west shore (see METHODS; Fig. 1); AMAV = American Avocet, BBPL = Black-bellied Plover, BNST = Black-necked Stilt, DOWI = dowitcher spp., DUNL = Dunlin, GRYE = Greater Yellowlegs, KILL = Killdeer, LBCU = Long-billed Curlew, LESA = Least Sandpiper, LEYE = Lesser Yellowlegs, MAGO = Marbled Godwit, SEPL = Semipalmated Plover, SNPL = Snowy Plover, WESA = Western Sandpiper, WILL = Willet.

of the latter two species also occur on the western Baja coast. Likewise, though found in western Baja California and west Mexico, the Wilson's Plover (*Charadrius wilsonia*) and American Oystercatcher (*Haematopus palliatus*) do not winter at the Sea. Finally, the Stilt Sandpiper winters at both the Salton Sea and the west coast of Mexico but not on the coasts of California or western Baja California.

Based on their known ranges, species that winter at, or migrate through, the Salton Sea come from diverse breeding areas ranging from the western North American arctic (e.g., Western Sandpiper) to the high plains of the United States (e.g., Mountain Plover). Yet, anecdotal evidence suggests a strong migrant connection between the Salton Sea and the west coast of Mexico, the Gulf of California, and the Pacific Coast of the United States, particularly in spring. Butler et al. (1996) reported a Western Sandpiper banded in Panama was found at the Salton Sea in spring. The large numbers of Whimbrels in the Imperial Valley in spring appear to represent a movement of birds from coastal Mexico (Howell and Webb 1995) that continues north to the west of the Sierra Nevada and through California's Central Valley (Shuford et al. 1998); very few move east of that range through the Great Basin (Shuford et al. 2002a). An even tighter coastal passage, linked by the Salton Sea, is suggested by moderate numbers of migrant Ruddy Turnstones, Red Knots, Sanderlings, and Short-billed Dowitchers found at the Sea (Table 1; Patten et al. 2003). These species move along the Pacific Coast of Mexico (Howell and Webb 1995) and the United States (Page et al. 1999), but away from the Salton Sea are rare elsewhere in the interior of California and much of the West (Shuford et al. 1998, 2002a).

Although the shorebird faunas of the Salton Sea and sites in the Intermountain West also have affinities, only the Sea serves as a stopover site for several primarily coastal species and hosts large numbers of migrant Whimbrels in spring and wintering Mountain Plovers. Also many species that occur primarily at other sites in the Intermountain West as breeders or migrants occur at the Sea primarily or extensively as winter residents (e.g., Willet, Long-billed Curlew, Marbled Godwit).

Threats and Conservation

Great concern has recently been expressed about the health of the Salton Sea ecosystem because of increasing salinity, large bird die-offs from diseases and unknown causes, potential harm from contaminants, and hyper-eutrophication (USFWS 1997, Setmire 2001, Shuford et al. 2002b, Meteyer et al. *this volume*, Rocke et al. *this volume*). Although the greatest threat to shorebird habitat in the Intermountain West is the scarcity of high quality fresh water (Engilis and Reid 1997, Oring et al. 2000), this threat is manifest in various ways. Many intermountain wetlands suffer from water diversions that reduce inflows and hence wetland acreage (e.g., Owens Lake, California). By contrast, the Salton Sea is the largest intermountain wetland threatened by an inflow of water of relatively high salinity, greatly increased at the Sea by high evaporation rates, and from contaminants from agricultural and urban sources. The salinity of

TABLE 3. NUMBERS OF SNOWY PLOVERS COUNTED IN VARIOUS AREAS AT THE SALTON SEA, CALIFORNIA (FIG. 1), IN 1999, WITH COMPARISONS TO PRIOR YEARS (DATA FROM SHUFORD ET AL. 1995)

	Breeding season			Winter			
Area	4–12 May 1978	4–14 May 1988	21–31 May 1999	3–8 Dec 1993	1–9 Dec 1994	22–27 Jan 1999	4–15 Nov 1999
1	2	4	4	14	3	7	0
2	0	0	5	10	0	1	0
3	12	8	4	0	1	0	0
4	7	14	2	46	16	17	4
5	32	18	7	21	9	0	0
6	38	14	71	102	31	84	37
7	0	24	16	17	16	6	6
8	29	38	35	26	18	30	13
9	3	3	5	0	7	2	0
10	0	0	4	15	3	14	0
11[a]	2	7	3	3	0	18	0
12	16	17	39	10	89	90	102
13	33	11	24	0	0	3	8
14	29	26	0	13	7	2	0
15	4	1	2	0	1	1	0
16	6	0	0	0	0	0	0
17	6	0	0	0	0	0	0
18	2	0	0	5	4	0	0
21B	5	13	0	3	9	0	0
Totals	226	198	221	285	214	275	170

[a] Also includes impoundments of Salton Sea National Wildlife Refuge (Area 20A–D) not tallied separately prior to 1999.

inflowing water may further increase, and water levels decrease, if water conservation measures allow transfers to urban southern California of water now reaching the Sea (CH2M HILL 2002). Within one to two decades, increasing salinity could cause a major shift at the Salton Sea to a brine shrimp (*Artemia* spp.)–brine fly (*Ephydra* spp.) dominated system (Tetra Tech, Inc. 2000). Such a change likely would favor species, such as phalaropes and avocets, that are especially adapted to exploit such food resources. It is unclear, though, if this might impact species at the Sea that favor freshwater habitats or shorebirds as a whole. Also, if water conservation measures alter current irrigation practices or lead to fallowing of substantial acreage of agricultural fields in the Imperial Valley, this may reduce shorebird use of these fields.

. Setmire et al. (1990, 1993) and the Imperial Irrigation District (1994) reviewed the results of bird contaminant studies at the Salton Sea. Most studies of the effects of contaminants on shorebirds at the Sea have focused on the Black-necked Stilt. Setmire et al. (1993) reported that 5% of the Black-necked Stilt eggs collected at the Salton Sea had at least a 10% probability of embryotoxicity, versus 60% at Kesterson NWR, an area of high selenium contamination. Stilt eggs also had boron concentrations as much as double the threshold levels associated with reduced gain in mass in ducklings, and stilt growth rates at the Sea were lower than those of stilts on the coast in an area not affected by agricultural wastewater. Also, high DDE concentrations in stilt eggs were thought to cause significant eggshell thinning. Although contaminants have not been shown to cause large-scale die-offs or reproductive problems, there is still ongoing concern for their potential impacts on waterbirds at the Salton Sea (C. Roberts, pers. comm.).

Substantial numbers of shorebirds have died at the Salton Sea from botulism and avian cholera (Shuford et al. 1999, Friend 2002). It is unclear, though, whether mortality rates of shorebirds from these diseases at the Sea are high compared with other sites in western North America or if factors contributing to the overall concern for the ecosystem's health are enhancing disease outbreaks at the Sea.

Proposals to restore the health of the Salton Sea ecosystem focus disproportionately on reducing salinity (Tetra Tech, Inc. 2000), as knowledge so far is inadequate for implementing effective disease reduction measures. One proposed method for reducing salinity involves construction of large within-sea evaporation ponds, which, if implemented, likely would displace substantial amounts of current shorebird habitat. Our results showing the highly concentrated distribution patterns of shorebirds as a whole and of some sensitive species, such as the Snowy Plover, indicate that large-scale evaporation

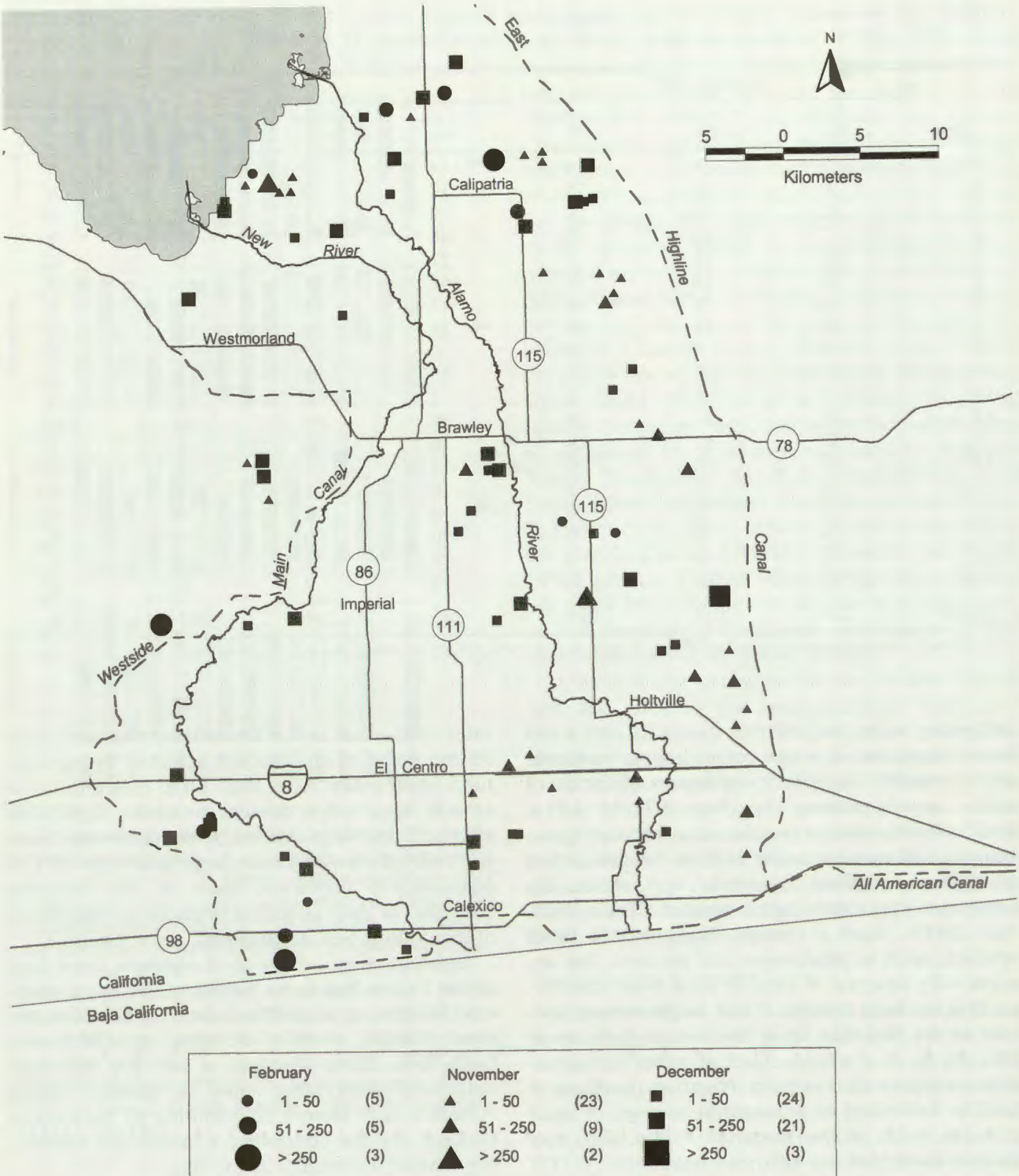

FIGURE 8. Distribution and relative size of Mountain Plover flocks on three surveys of the Imperial Valley, California, in 1999.

ponds or other similar projects should not be constructed along the southeastern, southern, western, or northern shorelines unless measures can be taken to maintain current shorebird habitats or adequately mitigate for their loss. It is unclear if large-scale evaporation ponds at the Sea might concentrate selenium at levels that have caused reproductive harm to shorebirds nesting at such ponds in the Central Valley (Skorupa and Ohlendorf 1991, Ohlendorf et al. 1993).

Although the U.S. Shorebird Conservation Plan shows great promise for conserving North American shorebirds (Brown et al. 2001), efforts

TABLE 4. Comparison of Peak Winter Shorebird Populations at the Salton Sea (Table 2), Río Colorado Delta (Morrison et al. 1992, Mellink et al. 1997), and Central Valley (Shuford et al. 1998)

Species	Salton Sea	Río Colorado Delta	Central Valley
Black-bellied Plover	1,300	4,600	10,200
Black-necked Stilt	4,000	380	13,400
American Avocet	7,300	9,400	4,000
Willet	1,800	8,000	110
Marbled Godwit	1,400	9,100	140
Western Sandpiper	4,700	75,000	8,400
Dunlin	800	100	176,000
Dowitcher spp.	6,400	2,900	118,000
Total shorebirds	28,000	164,000	374,000

to protect shorebirds and other waterbirds at the Salton Sea will be very expensive, lengthy, and difficult. Given the high demand for water in this arid region with a large and rapidly expanding human population, long-term success ultimately may hinge on our ability to stabilize or reduce the human population, conserve water resources, and elevate the priority of wildlife when allocating limited water supplies.

Research Needs

Much remains to be learned about the ecology of shorebirds at the Salton Sea. Studies lacking at the Salton Sea include ones on shorebird diets, the possible effect of selenium and other contaminants on shorebird reproductive success, and population sizes and habitat use patterns of shorebirds in agricultural fields. Long-term research is needed to compare the potential effects of salt and metals on immune function and survivorship of shorebirds at the Sea with populations at sites lacking these stresses. Banding and radio-telemetry studies also are needed to establish patterns of connectivity of the Salton Sea with other wetlands to focus conservation efforts at the appropriate scale. Finally, long-term monitoring is needed, particularly to document the effect of proposed restoration projects.

ACKNOWLEDGMENTS

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DISTRIBUTION PATTERNS OF WATERBIRDS AT THE SALTON SEA, CALIFORNIA, IN 1999

NILS WARNOCK, W. DAVID SHUFORD, AND KATHY C. MOLINA

Abstract. As part of a multi-disciplinary reconnaissance survey, we used a variety of survey methods to describe the distribution patterns of waterbirds at and around the Salton Sea in 1999. Waterbirds were not equally distributed around the Sea. Our studies documented the great importance to a variety of birds of habitats along the northern, southwestern, southern, and southeastern shorelines of the Salton Sea. These areas hosted large numbers of birds, important nesting, roosting, and foraging sites, and habitats for various species of conservation concern. Inshore waters within a kilometer of the entire shoreline were also important to a variety of diving waterbirds. Certain wading birds and shorebirds were much more numerous in agricultural fields of the Imperial Valley than in wetland habitats at the Salton Sea. Projects to restore the ecosystem's health by reducing salinity and limiting bird mortalities should be carefully assessed to ensure they do not have unintended impacts and are not placed where breeding, roosting, or foraging birds concentrate.

Key Words: conservation concerns; Imperial Valley; migratory stopover; nesting colonies; wintering area.

PATRONES DE DISTRIBUCIÓN DE AVES ACUÁTICAS EN EL MAR SALTON, CALIFORNIA, EN 1999

Resumen. Como parte de un muestreo de reconocimiento multidisciplinario, usamos una variedad de métodos de muestreo para describir los patrones de distribución de aves acuáticas en y alrededor del Mar Salton en 1999. Las aves acuáticas no estuvieron distribuidas igualmente alrededor del Mar Salton. Nuestro estudio documentó la gran importancia de hábitats a lo largo de las costas norte, suroeste, sur y sureste del Mar Salton para una variedad de aves. Estas áreas albergaron un gran número de aves, sitios importantes de anidamiento, sitios de descanso y sitios de alimentación, y hábitats para varias especies de interés para la conservación. Aguas dentro de la costa incluidas dentro de un kilómetro de la línea de costa fueron también importantes para una variedad de aves acuáticas zambullidoras. Ciertas aves vadeadoras y aves playeras fueron mucho más numerosas en campos agrícolas del Valle Imperial que en hábitats de humedales en el Mar Salton. Los proyectos para restaurar la salud del ecosistema, por medio de la reducción de la salinidad y limitando la mortalidad de aves, deberían ser cautelosamente evaluados para asegurar que no provoquen impactos no intencionales y que no sean llevados a cabo donde se concentran aves en reproducción, en sitios de descanso o en sitios de alimentación.

Palabras claves: área de invernada; colonias de anidamiento; interés en conservación; sitios de parada durante la migración; Valle Imperial.

The Salton Sea and its surrounding area has long been recognized as a strategic breeding, migratory stopover, and wintering location for waterbirds (e.g., Grinnell 1908, McCaskie 1970b, Heitmeyer et al. 1989, Patten et al. 2003). This site supports populations of many species of waterbirds that are of conservation concern either because they have small overall populations or the proportion of their populations at the Sea are of regional, national, or continental stature (Shuford et al. 2002b). Yet, no comprehensive data have been published on the distribution patterns and concentration areas of all waterbirds at the Salton Sea. Spawned by concern over high salinity, large bird mortalities, disease outbreaks, and risks of contaminants (Tetra Tech 2000), current efforts to restore the health of the Salton Sea's ecosystem need such information to design restoration projects that will benefit the Sea's bird populations. Efforts to increase recreation and revitalize commerce at the Sea also might impact breeding or non-breeding birds if human activities encroach on areas where birds concentrate.

As part of a year-long reconnaissance survey, we gathered data on the abundance, distribution, seasonal phenology, and broadscale habitat associations of birds at the Salton Sea and adjacent habitats. Here we report the patterns of distribution of the key groups and species of waterbirds at the Salton Sea in 1999 and identify areas of the Sea where particularly large bird concentrations or sensitive species occur. We also identify a list of needed research on the distribution of waterbirds at the Salton Sea.

STUDY AREA AND METHODS

We used a suite of survey methods to document the distribution of waterbirds at the Salton Sea, adjacent wetland habitats, and irrigated agricultural fields of the Imperial Valley. As our primary method of documenting the distributions of most waterbirds, we conducted

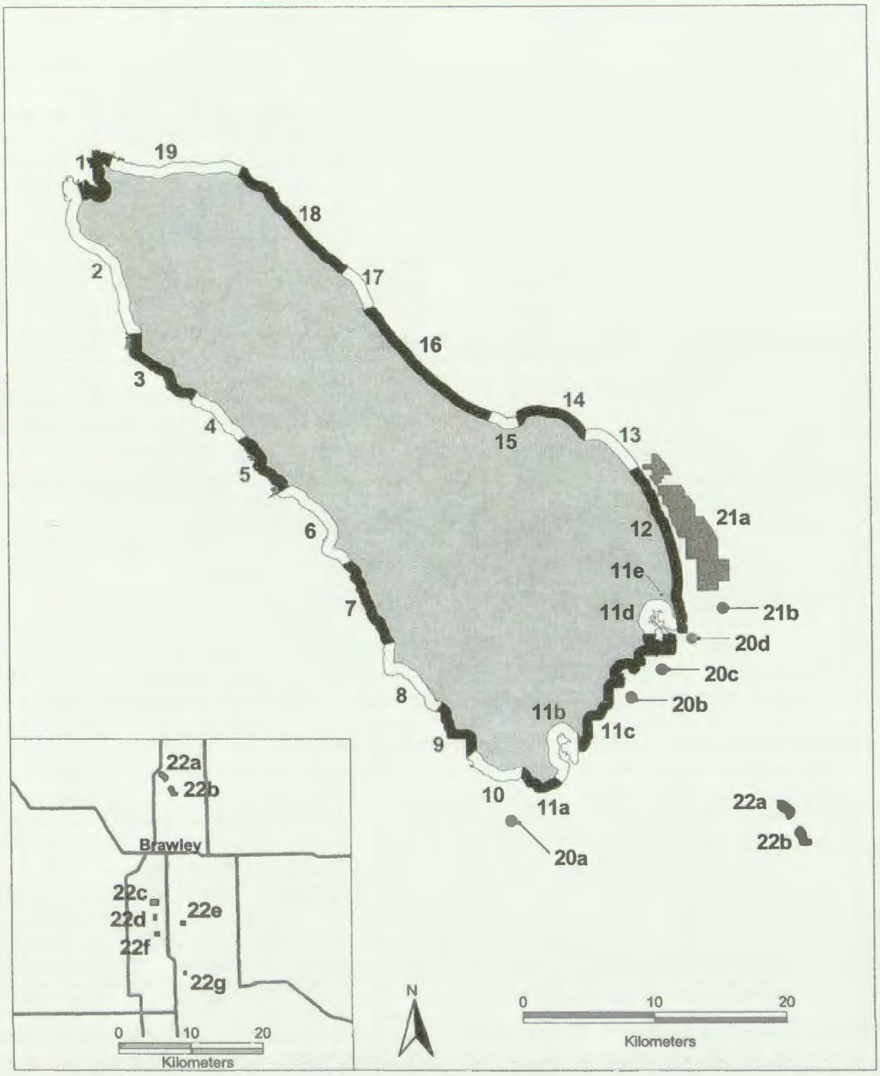

FIGURE 1. Shoreline segments of the Salton Sea, California, and adjacent wetlands used in the 1999 study.

four comprehensive surveys of waterbirds at the Salton Sea and nearby wetlands and marshes. We conducted these surveys primarily from the ground, but used aerial surveys to gather information on certain species (see below). Survey periods were during mid-winter (22 January–5 February), spring migration (17–18 April), fall migration (13–16 August), and early winter (11–15 November). To obtain data on the patterns of waterbird distribution in particular, observers tallied birds separately within 19 shoreline segments (with adjacent open water zone) and three complexes of freshwater marshes and impoundments (Fig. 1). See Shuford et al. (2000) for a comprehensive list of the species surveyed and for further descriptions of areas and areas boundaries.

We also conducted aerial surveys for various waterbirds using the inshore (<1 km from shore) and offshore waters (>1 km) of the Salton Sea. We sampled the latter area with two north-south transects (each transect 45–50 km long), 6–10 km in from the east–west shorelines (see Shuford et al. 2000 for more details). Species surveyed on aerial transects included the Eared Grebe (*Podiceps nigricollis*), Western (*Aechmophorus occidentalis*) and Clark's (*A. clarkii*) grebe (lumped as *Aechmophorus* spp.), American White Pelican (*Pelecanus erythrorhynchos*), Brown Pelican (*P. occidentalis*), Double-crested Cormorant (*Phalacrocorax auritus*), and Ruddy Duck (*Oxyura jamaicensis*). We assessed spatial distribution patterns by tallying all birds within the 19 shoreline and inshore segments, and for Eared Grebes, *Aechmophorus* grebes, and Ruddy Ducks, also within the two offshore transects. Aerial survey dates were: 28 January, 12 February, 5 March, 19 March, 28 March, 16 April, 28 May, 16 August, 29 November, and 17 December. On the 16 August survey, we also counted all Black Terns (*Chlidonias niger*) seen within the 19 shoreline and inshore segments and along six parallel transects about 25–30 km long and spaced 5 km apart over irrigated agricultural fields in the Imperial Valley.

For geese and ducks, we report distribution data collected by the Sonny Bono Salton Sea National Wildlife Refuge (SSNWR) biologists on aerial surveys of the Salton Sea and Imperial Valley on 8 January, 9 March, 3 April, 27 May, and 18 November 1999. SSNWR biologists tallied waterfowl numbers separately for two areas of the Salton Sea (Imperial County shoreline, Riverside County shoreline) and seven impoundment complexes (SSNWR Unit 1, SSNWR Unit 2, south shore duck clubs, Wister Unit of Imperial Wildlife Area (Wister Unit), Finney and Ramer lakes, duck clubs and reservoirs south of Brawley, and northshore/Coachella duck clubs and fish farms).

We documented the distribution patterns of breeding rails in a variety of marsh habitats around the periphery of the Salton Sea. The Yuma Clapper Rail (*Rallus longirostris yumanensis*), and the Black Rail (*Laterallus jamaicensis*) were targeted and surveyed through their response to taped play backs of their breeding calls following established protocol (USFWS 1983, Evens et al. 1991). We focused survey efforts at previously known Clapper Rail areas, particularly the Wister Unit and SSNWR, but also covered four areas not traditionally covered in previous years. Surveys within both the Wister Unit and SSNWR followed established transects from previous years and were conducted by personnel of the respective refuges. Point Reyes Bird Observatory (PRBO) biologists conducted surveys at all new off-refuge sites. Biologists surveyed all transects twice between 24 April and 15 May. On each transect, observers picked listening stations within appropriate marsh habitat. At each station, they played a tape for two min, stopped to listen for responses for two min, and then played the tape again for two min. Observers recorded birds responding to the tapes as well as incidental sightings of rails. In general, stations along a transect were 70 to 100 m apart depending on the habitat. Observers conducted all rail surveys between 0500–0900 except for one Black Rail survey done at Finney Lake between 1800–1930.

We counted various wading birds (herons, egrets, ibis, cranes) that came to nighttime roosts at up to six wetlands in the Imperial Valley on 27 January, 13 February, 13 March, 14 August, 15 September, 21 October, 11 November, and 16 December. Although these counts mainly provided data on the population sizes and annual phenology patterns of these species, they also documented the importance of agricultural areas and alternative wetland habitats as roost sites for certain species in the Imperial Valley.

To sample the distribution of birds in agricultural fields near the Salton Sea, we conducted monthly surveys along five 8.05-km long roadside transects located in the northern Imperial Valley just south of the Salton Sea. Because these transects covered only a small portion of the Imperial Valley, they provided only limited data on patterns of bird distribution in this area.

PRBO and SSNWR biologists used a combination of airboat, aerial photographic, ground, and kayak surveys (varying by logistical constraints or species) to document the distribution, abundance, nesting chronology, and nesting success of colonial waterbird colonies at the Salton Sea in 1999. We conducted most surveys between 22 January and 16 July but continued some through 8 September. On each survey, observers recorded the number of active nests, the general stage of nesting, and the location of each active colony. See Shuford et al. (2000) for brief descriptions of the colony sites surveyed and their nesting substrates.

Although we recorded a total of 107 species of waterbirds on our surveys, in most cases we describe distribution patterns only for species groups. We discuss patterns of distribution of individual species or taxa mainly when these are of conservation concern or when the patterns they exhibit are particularly striking compared to those of related species. We briefly touch on distribution patterns of shorebirds, as these data are presented in Shuford et al. (*this volume*).

ANALYSES

To better understand which areas around the Sea were used more often than expected by waterbirds, we calculated expected numbers of birds (by waterbird group) in each of the 19 shoreline areas and compared these to our observed numbers. For example, to calculate the expected number of gulls and terns in Area 1 in January we multiplied the number of gulls and terns seen in all 19 shoreline segments around the Sea in January (N = 41,327) by the ratio of the length of Area 1 (5476 m) to the total length of the shoreline around the Sea (270,006 m).

We used general linear models to test whether densities of different groups of waterbirds (gulls and terns, pelican and cormorants, shorebirds, and wading birds) varied among counts (Jan, Apr, Aug, and Nov) and areas (1–19). We examined data for departures from normality and used Levene's test to examine the assumption of homogeneity of variances (Snedecor and Cochran 1989). Significance was set at $P \leq 0.05$, and statistical analyses were performed using STATA (STATA Corp. 1999).

RESULTS

Linear models indicated that densities of all groups of waterbirds varied significantly by area. For shorebirds, however, Levene's test indicated significant heterogeneity even after transformations (Table 1). While test scores are highly significant for shorebirds for the overall model and the effect of area (Table 1), results should be interpreted as suggestive rather than definitive, and further studies on these effects on shorebirds are warranted. Densities of gull, pelican, and wader groups varied significantly by count period, but we failed to detect a significant difference in densities of shorebirds among counts (Table 1). However, no comprehensive surveys were conducted in May and June when

TABLE 1. RESULTS OF GENERAL LINEAR MODEL (ANOVA) TESTING DENSITIES (ARC-SIN TRANSFORMED) OF WATERBIRDS AT THE SALTON SEA, CALIFORNIA, IN 1999, BY AREA OF THE SEA AND COUNT PERIOD

		Gulls[a] (N = 73 counts)		Pelicans[b] (N = 76 counts)		Shorebirds[c] (N = 76 counts)		Waders[d] (N = 73 counts)	
	df	F	P	F	P	F	P	F	P
Model	21	6.0	<0.001	4.03	<0.001	7.59	<0.001	3.76	<0.001
Area	18	3.19	<0.001	2.00	0.026	8.65	<0.001	3.27	<0.001
Count	3	21.64	<0.001	16.23	<0.001	1.21	0.316	7.41	<0.001

[a] Gulls includes gulls, terns, and skimmers.
[b] Pelicans includes pelicans and cormorants.
[c] Levene's test indicated significant heterogeneity even after transformations.
[d] Waders include herons, egrets, ibis, and cranes.

most shorebirds depart the area (Shuford et al. *this volume*).

GREBES

Over four surveys, an average of 88.9% (SE = 4.3, min–max = 78–99%) of all Eared Grebes occurred in the inshore zone of the Sea within 1 km of land. In spring and winter, inshore areas of shoreline segments 6 and 7 held a high proportion of the small grebes that were observed (Table 2). Eared Grebes generally were widely distributed on offshore transects, especially in the late March survey. In general, few Eared Grebes were counted along the northeastern shoreline of the Sea. Over the four aerial surveys, an average of 78.5% (SE = 6.3, min–max = 64–92%) of all Western and Clark's grebes occurred in the inshore zone within 1 km of land. Overall, *Aechmophorus* grebes were widely distributed within the inshore zone, except for a tendency for reduced numbers along the western and southwestern shorelines in March and the southeastern and northwestern shorelines in November (Table 2). Ground observations for the inshore zone indicated a fairly even split between Western and Clark's grebes in April (379 Western Grebes, 340 Clark's Grebes) and August (363 Western Grebes, 371 Clark's Grebes), and a roughly 3:1 ratio in November (714 Western Grebes, 222 Clark's Grebes). In November and December, about 85% of *Aechmophorus* grebes in the offshore zone were at the northern end of transect 3 in the northeastern section of the Sea.

PELICANS AND CORMORANTS

For pelicans and cormorants, areas 9, 12, and 17 were particularly important in August, January, and November, respectively (Table 3). Densities of pelicans and cormorants were highest at the south end in January and among the lowest there in November, when many areas showed high densities (Fig. 2).

WADERS

For wading birds (primarily herons, egrets, and night-herons), highest densities were at the north and south ends of the Sea (Fig. 3). Ob-

TABLE 2. PROPORTION OF TOTAL NUMBER OF GREBES AND RUDDY DUCKS COUNTED DURING AERIAL SURVEYS OF INSHORE AND OFFSHORE AREAS OF THE SALTON SEA, CALIFORNIA, IN 1999

	Eared Grebe				*Aechmophorus* Grebes[a]				Ruddy Ducks			
Area[b]	19 Mar	28 Mar	29 Nov	17 Dec	19 Mar	28 Mar	29 Nov	17 Dec	19 Mar	28 Mar	29 Nov	17 Dec
Inshore												
1–2	**0.15**	0.10	0.05	0.04	0.09	0.09	0.04	0.02	**0.24**	**0.25**	0.11	0.08
3–5	**0.20**	0.14	0.07	0.14	0.14	**0.28**	**0.15**	0.12	**0.21**	**0.17**	0.09	0.08
6–7	**0.23**	**0.19**	**0.25**	**0.18**	0.00	0.01	0.07	0.03	0.05	0.07	0.09	0.09
8–10	0.12	0.07	0.10	0.13	0.03	0.05	**0.18**	**0.15**	**0.18**	0.03	0.06	0.08
11	0.08	0.04	**0.18**	0.10	0.00	0.00	0.04	0.06	0.11	0.02	**0.15**	0.12
12–15	0.13	**0.16**	0.14	**0.17**	**0.28**	**0.17**	0.02	0.02	0.02	0.01	**0.19**	**0.16**
16–17	0.06	0.06	0.04	0.06	0.14	**0.17**	**0.18**	**0.15**	0.00	0.00	0.08	0.07
18–19	0.02	0.02	0.05	0.07	**0.17**	0.14	0.03	0.09	0.00	0.00	**0.21**	**0.23**
Offshore	0.01	**0.22**	0.11	0.11	0.14	0.08	**0.28**	**0.36**	**0.18**	**0.46**	0.01	0.09
Total	47,561	58,412	172,550	321,575	8620	7123	1508	3830	5120	3924	26,584	32,680

Notes: Data for areas accounting for ≥15% of birds in a particular group or species on a particular date are denoted in bold.
[a] *Aechmophorus* grebes = Clark's and Western grebes.
[b] The inshore zone is <1 km of the shore and the offshore zone is 1 km (see Shuford et al. 2000 for more details).

TABLE 3. Ratio of Observed to Expected Numbers of Birds (by Waterbird Group) in Each of 19 Areas Around the Salton Sea, California in 1999

	Gulls and terns				Pelicans and cormorants				Shorebirds				Waders			
Area	Jan	Apr	Aug	Nov	Jan	Apr	Aug	Nov	Jan	Apr	Aug	Nov	Jan	Apr	Aug	Nov
1													2.42	**3.17**	**3.43**	
2		**3.78**		**4.46**									2.14	2.56		
3																
4			2.34					2.69								
5																
6									2.51	2.73						
7			**3.16**													
8	2.83		2.39					2.05								
9							**6.76**									
10																
11						2.37										
12			**3.96**		**4.99**				**5.80**	**7.00**	**9.39**	**9.76**			2.45	
13	**3.61**	**3.21**		2.42				2.49								
14																
15	**4.27**							2.31								
16																
17								**6.84**								
18																
19		2.75														**4.36**

Notes: Expected number of birds per segment per count calculated by multiplying the total number of birds per count by the ratio of the segment length to the entire shoreline length (see Methods). Data only reported for segments with at least twice the expected number of birds. Segments with three times or more the expected numbers of birds are denoted in bold.

served numbers were more than double than expected numbers in areas 1, 2, 12, and 19 (Table 3). Two species of wading birds were much more numerous in agricultural areas of the Imperial Valley than suggested by our comprehensive surveys of the Sea. Peak counts of Cattle Egrets (*Bubulcus ibis*) and White-faced Ibis (*Plegadis chihi*) coming to night-time roosts in the Imperial Valley were 33 and 45 times greater, respectively, than peak counts at the Salton Sea and adjacent wetlands (see also Shuford et al. 2002b).

Waterfowl

Distribution patterns of waterfowl varied among regions of the study area. As is typical, Snow (*Chen caerulescens*) and Ross's (*C. rossii*) geese in 1999 were found exclusively at the south end of the Sea in or around SSNWR, the Wister Unit, and nearby duck clubs. Diving ducks predominated on the inshore waters of the Sea at all seasons (Fig. 4). By contrast, dabbling ducks predominated on freshwater impoundments adjacent to and primarily at the south end of the Sea. Diving ducks numbers also exceeded or equaled those for dabbling ducks in the Imperial Valley because Ruddy Ducks also concentrate there in modest numbers on reservoirs. Over four aerial surveys, an average of 81.6% (SE = 9.8, min–max = 54–99%) of all Ruddy Ducks occurred in the inshore zone, especially during fall periods when higher numbers were on the Sea. In November and December, they appeared primarily in the inshore zone with highest concentrations along the eastern inshore shoreline (Table 2). Of the 2899 Ruddy Ducks in the offshore zone in December, 96% were in the northeastern section of the Sea. Ruddy Ducks concentrated near the northern and western shorelines and offshore zone in March.

Rails

Observers detected a total of 279 Clapper Rails in the Salton Sea area in 1999, 271 in marshes immediately around the Salton Sea, three at Lower Finney Lake, and five at Holtville Main Drain in the central Imperial Valley (Table 4). Highest concentrations were in the Wister Unit and Unit 2 of SSNWR. Smaller numbers were in Unit 1 of SSNWR and a few small marshes along the east side of the Sea. No birds were detected at the north end or along the west side of the Sea. The northern third of Wister Unit (section A) supported the highest numbers of Clapper Rails on both the April and mid-May surveys (Table 4), but there appeared to be movement of birds from sections B and C into A between these surveys. We did not detect any Black Rails on our surveys in 1999.

Shorebirds

In all seasons, Area 12, the Wister Unit shoreline, held the highest densities of shorebirds (Fig. 5, Table 3; Shuford et al. 2000). During

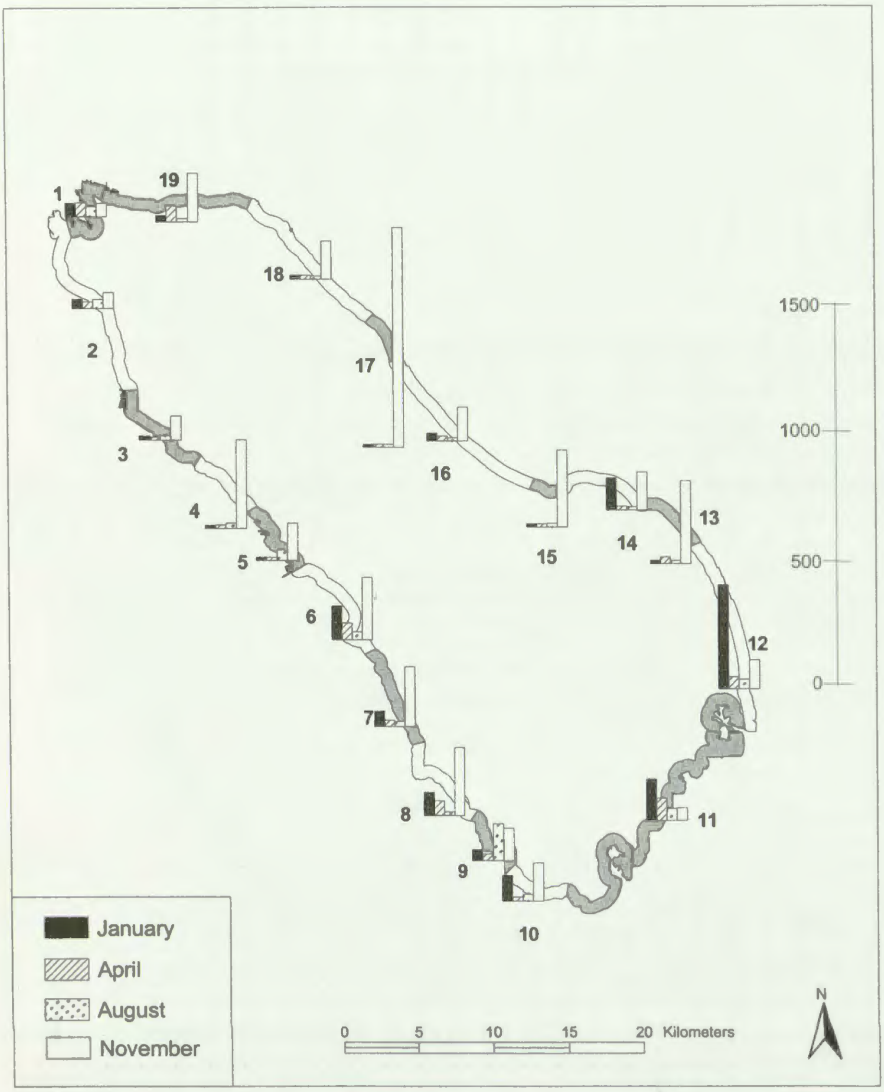

FIGURE 2. Comparison of the density (individuals/km) of all pelicans and cormorants within 19 shoreline segments for four comprehensive surveys of the Salton Sea, California, in 1999.

January and April comprehensive surveys, Area 6, the shoreline around Iberia Wash on the west side of the Sea, attracted higher shorebird numbers than expected (Table 3). In all seasons, Snowy Plovers (*Charadrius alexandrinus*) concentrated primarily on sandy beaches and sand or alkali flats along the western and southeastern shorelines of the Sea.

Gulls and Terns

Certain areas attracted more gulls and terns than expected, including areas 12, 13, and 15 on the southeast side of the Sea, area 7 and 8 on the southwest side of the Sea, and areas 2 and 19 on the north side of the Sea (Fig. 6, Table 3; Shuford et al. 2000). During the comprehensive August survey along the shoreline of the Sea, of Black Terns counted (N = 4011), 45% occurred in Area 12, and 34% in areas 7 and 8 (Shuford et al. 2000). Totals of 31 and 539 Black Terns were recorded during agricultural field transects in the northern Imperial Valley on 16 May and 11 August, respectively. In contrast, we did not see any Black Terns on a 16 August aerial survey of agricultural fields further south in the Imperial Valley.

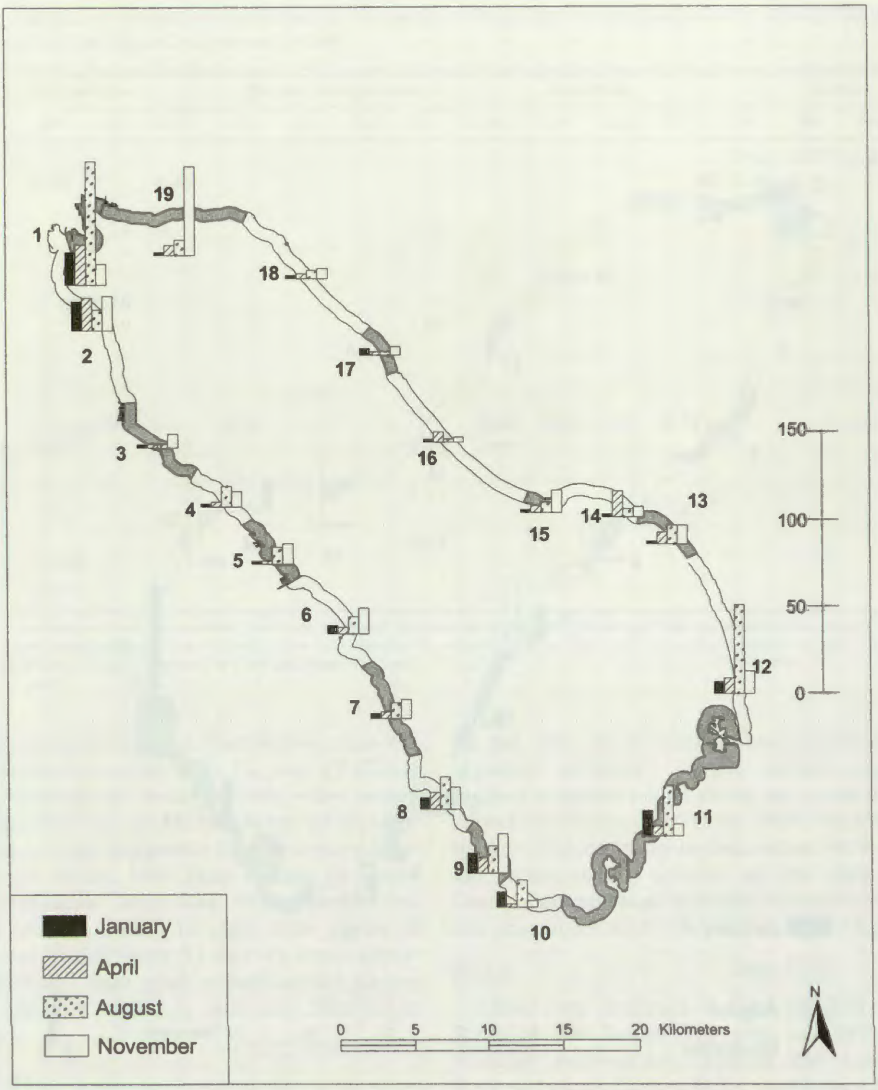

FIGURE 3. Comparison of the density (individuals/km) of all waders (herons, egrets, ibis, storks) within 19 shoreline segments for four comprehensive surveys of the Salton Sea, California, in 1999. * = survey data lacking for January.

Colonial Breeders

The 14,000 pairs of colonial breeders in 1999 bred at 21 sites on or near the shoreline of the Salton Sea, at Ramer Lake, and near Westmorland in the Imperial Valley (Fig. 7; Shuford et al. 2000). Of the 23 sites, 21 provided substrate suitable for arboreal nesters, whereas only five offered suitable habitat for obligate ground nesters. Most nesting sites and concentrations were near the Whitewater River mouth at the north end of the Sea or between, and including, the New and Alamo river deltas along the southeastern shoreline. Great Blue Heron (*Ardea herodias*), Double-crested Cormorant, and Great Egret (*A. alba*) nested at 18, eight, and six sites, respectively, whereas all other species nested at one to four sites. Species richness was highest at Johnson Street, where seven of the 11 species nested. Species richness of ardeids also was high at the Alamo River and 76th Avenue, where four species bred at each site. Species richness of larids was highest at Rock Hill on the Salton Sea NWR, where four species bred in an area managed specifically for terns and skimmers. Large

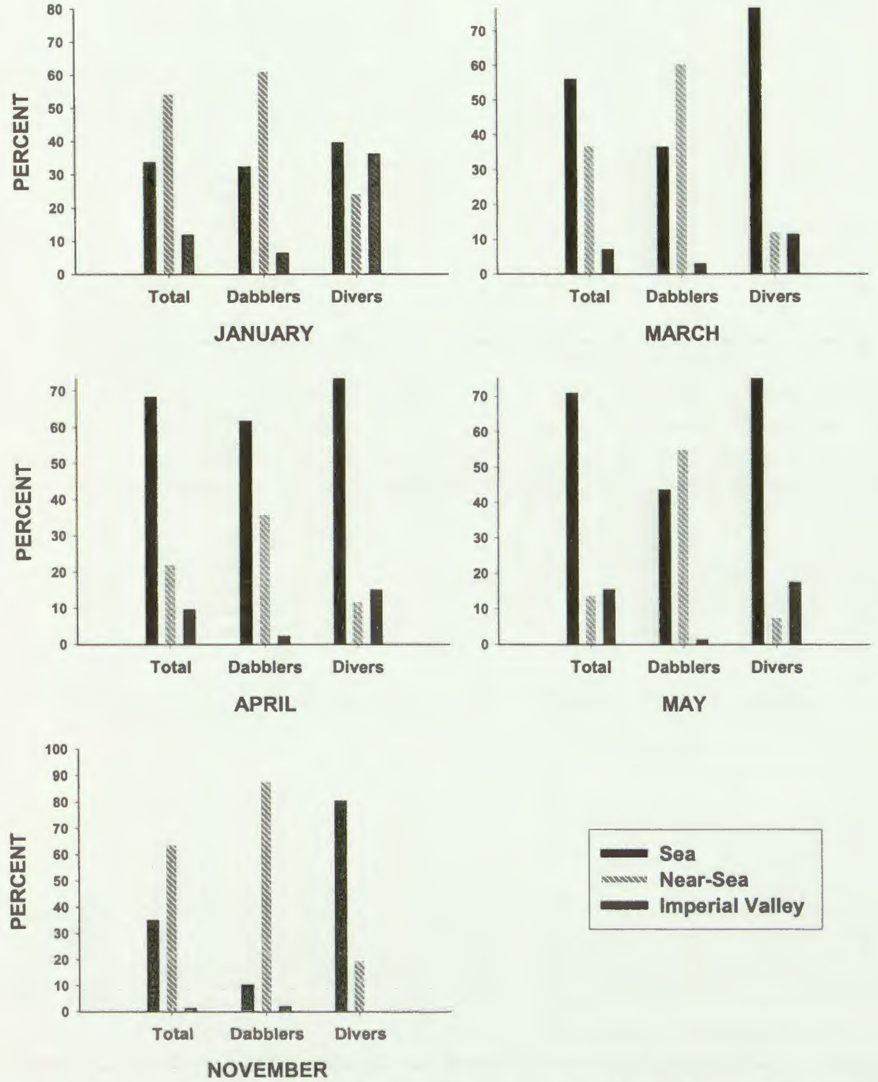

FIGURE 4. Percent of total numbers of all ducks, dabbling ducks, and diving ducks on the inshore waters of the Salton Sea, California, near-Sea freshwater impoundments, and Imperial Valley duck clubs and reservoirs from aerial surveys in 1999. Data courtesy of Sonny Bono Salton Sea National Wildlife Refuge.

colonies dominated primarily by cormorants and Cattle Egrets formed at Mullet Island and the Westmorland eucalyptus grove, respectively.

DISCUSSION

NON-BREEDING BIRDS

The non-random distribution of non-breeding birds around the Salton Sea is likely influenced by a variety of factors. In almost all months, the north end of the Sea, including areas 1, 2, and 19, were particularly important to wading birds and gulls, collectively. Undoubtedly, for these fish eaters, part of this distribution pattern is influenced by access to fish prey. Whether these sites have a greater abundance of fish is unknown, but the concentration of fish farms near the Sea in this area may also influence this pattern. For waders in particular, the presence of snags in the north end of the Sea that are suitable for nesting and roosting are presumably a major influence on their distribution.

Twenty-nine percent of all the birds counted at the Salton Sea during comprehensive surveys were found in Area 12, the Wister Unit shore-

TABLE 4. YUMA CLAPPER RAIL TOTALS AT WETLANDS AROUND THE SALTON SEA, CALIFORNIA, FROM BREEDING RAIL SURVEYS CONDUCTED IN APRIL AND MAY 1999 (EACH SITE SURVEYED TWICE)

Area	1990–1998[a] (mean ± SD)	1999 Total
Johnson St.	NC	0
King's Road Marsh	NC	0
81st Drain	NC	0
SSNWR—Unit 1		
Trifolium 1 Drain		0
A-1 Pond		6
B-1 Pond		10
Reidman 3		2
Reidman 4		3
Bruchard Bay		0
New River Delta		0
Lack and Grumble (off refuge)		2
SSNWR—Unit 2 and Hazard		
Barnacle Bar Marsh		2
Headquarter 'B' Pond		2
Union Pond		9
McKindry Pond		2
Hazard 6		12
Hazard 7		6
Hazard 8 (east)		2
Hazard 9 and Ditch		2
Hazard 10		6
Alamo River (east)		3
Alamo River (west)		0
SSNWR (total)	62 ± 33	67
Off Refuge		
Walt's Club (McDonald Rd.)		2
"T" Drain Marsh		6
Wister Wildlife Area		
Section C (S and T units)[b]		27 (35)[c]
Section B (U, W, and Y units)[b]		25 (54)[c]
Section A (100, 300–500 units)[b]		139 (90)[c]
Wister (total)	248 ± 77	191 (179)
North of Wister Wildlife Area		
Bombay Marsh		3
Salt Creek	1 ± 2	0
Barnacle Beach (total)[d]	16 ± 10	13
Imperial Valley sites		
Lower Finney Lake[e]	NC	3
Holtville Main Drain	7 ± 5	5

[a] Averages of Yuma Clapper Rail Survey results from 1990–1998; NC = not counted in that period; means calculated from data supplied by Yuma Clapper Rail Recovery Team, USFWS, Phoenix, AZ.
[b] Units numbered according to Imperial Wildlife Area designation.
[c] Number of rails from 12 May count, numbers in parentheses are from 26 Apr count.
[d] Barnacle Beach total = Lack and Grumble + Walt's Club (McDonald Rd.) + 'T' Drain Marsh + Bombay Marsh.
[e] Clapper Rails detected during Black Rail survey.

line, which accounts for only 6% of the total Salton Sea shoreline. Shorebirds were particularly clumped in areas 12 and 11, which respectively held 53% and 25% of total shorebird numbers. A combination of shallow waters, soft substrate, river deltas, islands for foraging and roosting, and nearby access to fresh water sources for bathing and drinking appeared to be especially important to the distribution of nonbreeding waterbirds in these areas. Shoreline segments that were little used by waterbirds around the Salton Sea in 1999, such as 3, 4, 10, 16, and 18, tended to be ones with narrow beaches and lacked shallow water and close ac-

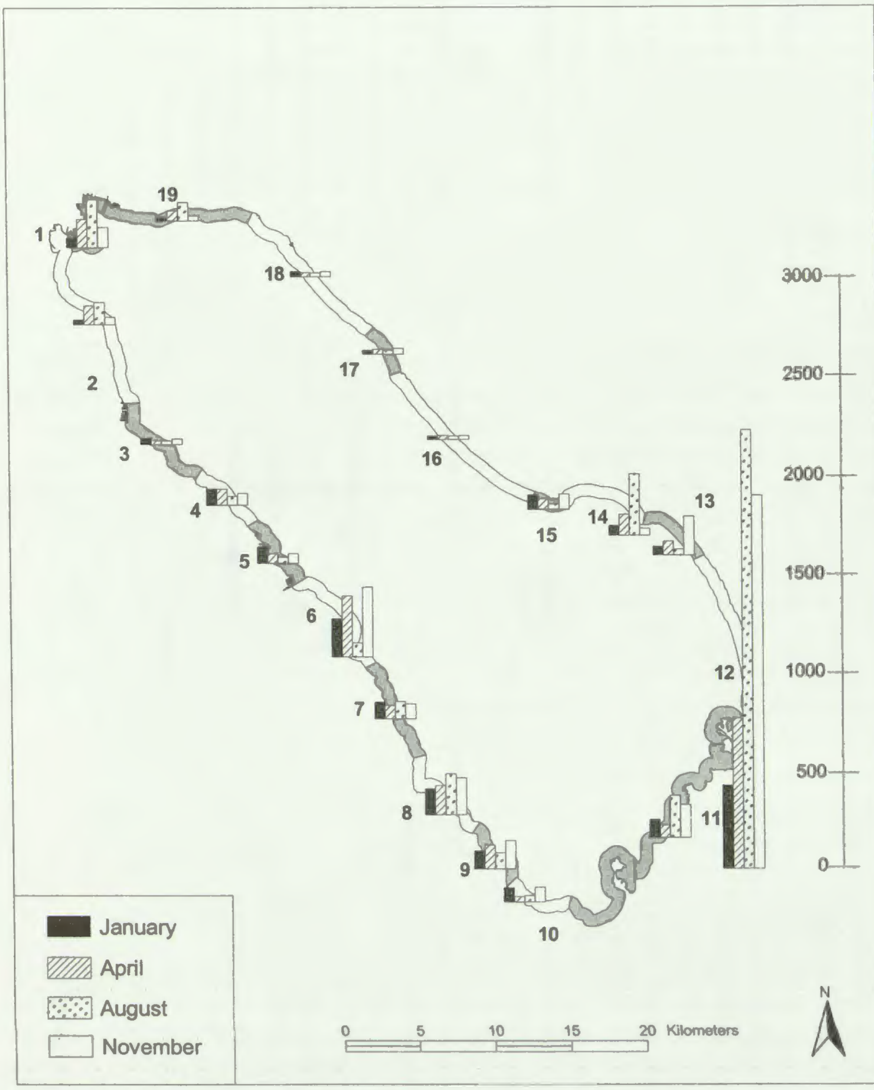

FIGURE 5. Comparison of the density (individuals/km) of all shorebirds within 19 shoreline segments for four comprehensive surveys of the Salton Sea, California, in 1999.

cess to freshwater sources such as rivers, irrigation outflows, or nearby ponds.

Within the Sea itself, distribution of waterbirds was also non-random, although explanations of patterns are less obvious. In general, largest numbers of these waterbirds occurred within 1 km of the shore. Except for the Pied-billed Grebe (*Podilymbus podiceps*), which mainly occurred on freshwater impoundments, other grebes primarily used the open waters of the Salton Sea, as did pelicans, cormorants, and Ruddy Ducks. Pelicans on the water were widely distributed around the Sea, especially during November, but large numbers of roosting pelicans and cormorants were found at the far reaches of the New and Alamo river deltas, particularly in January (Fig. 8a, b). Overall, small and large grebes were widely distributed within the inshore zone of the Sea. At Mono Lake, the distribution of Eared Grebes on the water was influenced by population size, age and molt condition of individual birds, availability of prey, season, and time of day (Jehl 1988). The pattern for grebes at Mono Lake was for birds to feed close to shore and move offshore when molting or when particular prey declined. How these variables influence grebes and other waterbirds at the Salton Sea is presently unknown. Eared

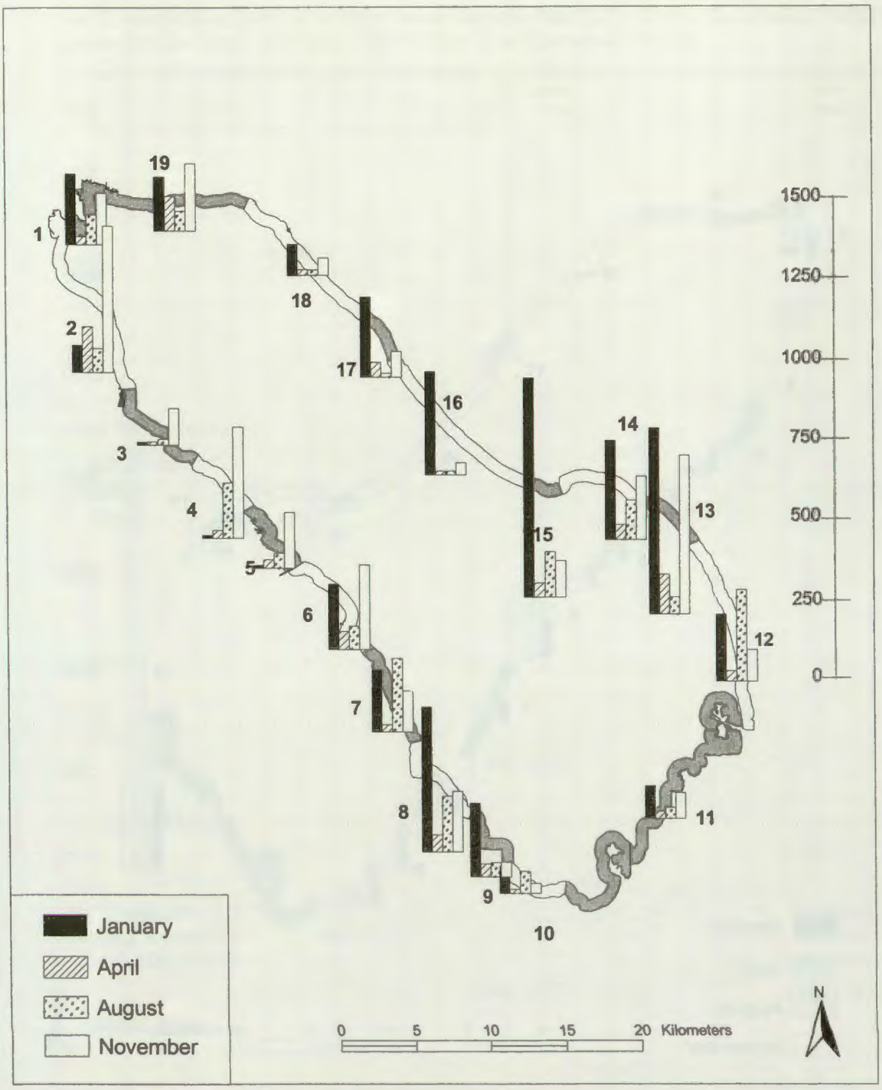

FIGURE 6. Comparison of the density (individuals/km) of all gulls and terns within 19 shoreline segments for four comprehensive surveys of the Salton Sea, California, in 1999. * = no survey data for January.

Grebes tended to be the main species on offshore transects.

Many waterbirds at the Salton Sea also used adjacent habitats, particularly agricultural fields in the Imperial Valley. Throughout California, Mountain Plovers (*Charadrius montanus*) use heavily grazed and burned fields and cultivated landscapes (Knopf and Rupert 1995). The Mountain Plover, Whimbrel (*Numenius phaeopus*), and Long-billed Curlew (*N. americanus*) all were much more numerous in agricultural fields in the Imperial Valley than along shoreline or other wetland habitats at or near the Salton Sea (Shuford et al. *this volume*). Some shorebirds may switch between using the shores of the Salton Sea and agricultural lands, but the extent of this is unknown. Shorebirds switching between coastal bodies of water and adjacent agricultural fields has been documented at a variety of sites around the world (Townshend 1981, Colwell and Dodd 1995, Warnock et al. 1995). For some egrets and gulls, their use of habitats adjacent to the Sea was also striking (Shuford et al. 2002b). During monthly agricultural field surveys in areas adjacent to the Sea in 1999, 66% of the over 38,000 birds detected consisted of Ring-billed Gulls (*Larus delawarensis*), Cattle Egrets, and White-faced Ibis (PRBO, unpubl.

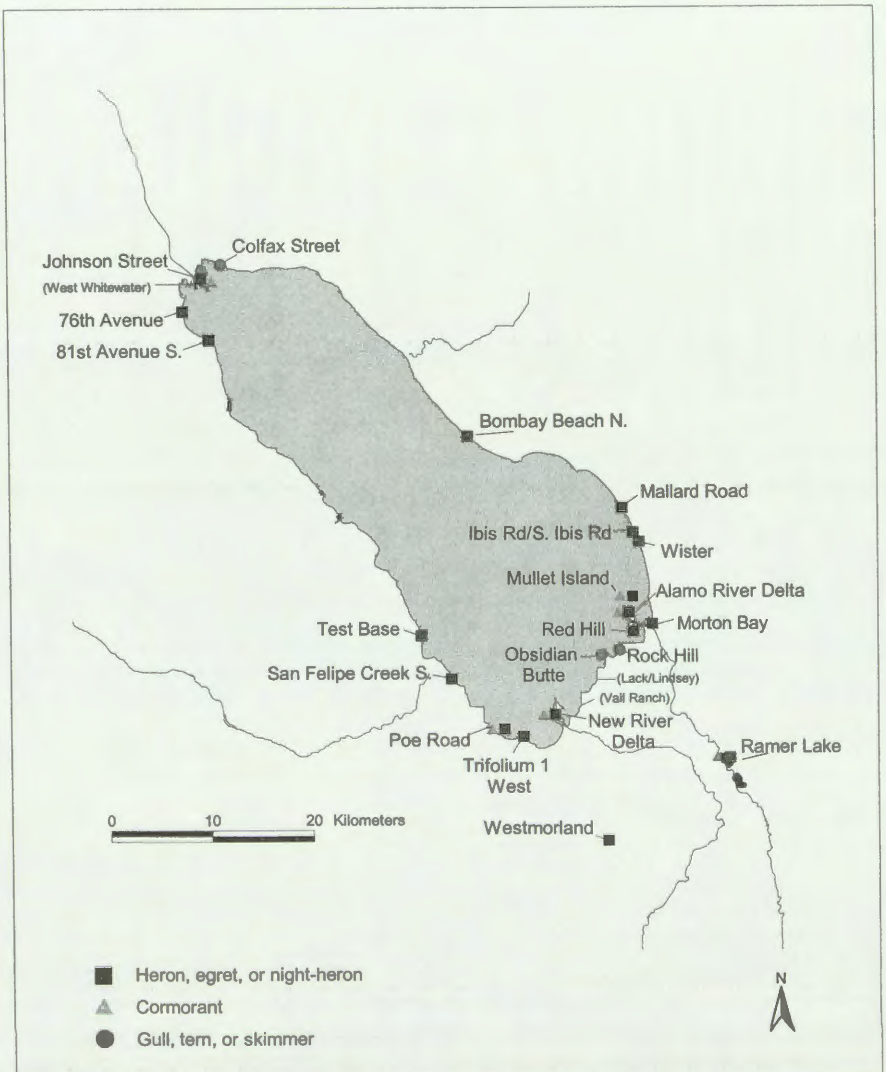

FIGURE 7. Location of nesting colonies of cormorants, ardeids (herons, egrets, and night-herons), and larids (gulls, terns, and skimmers), at the Salton Sea, California, in 1999. Arboreal sites previously used but unoccupied in 1999 are listed in parentheses. New River Delta includes three sites associated with that area (see Shuford et al. 2000).

data). For Black Terns, nearby agricultural fields also appear to be important foraging areas, although the Sea also attracts thousand of these birds (Small 1994, Shuford et al. 2002b, this study).

BREEDING BIRDS

Although nesting colonies often shift locations at the Salton Sea, our 1999 survey results concur with prior data (SSNWR files), indicating that the areas around the Whitewater, New, and Alamo rivers continue to be important focal points for colonial nesting waterbirds. During the 1990s, these birds have regularly nested at about 22 sites around the Salton Sea perimeter. In recent years, cormorants and ardeids have not established colonies at the extant sites of Lack/Lindsey and Vail Ranch, and larids have not reestablished nesting on the islets of Morton Bay or at Ramer Lake (Molina *this volume*). Cormorants bred at fewer colony sites in 1999 than in 1998, and Great Blue Herons, after deserting the New River Delta, dispersed to colonize snag stands offering marginal nesting substrate, and

FIGURE 8. Upper panel: aerial overview of the New River mouth, an important roosting area and shallow-water foraging area for waterbirds, looking northwesterly over the Salton Sea to the Santa Rosa Mountains. Lower panel: aerial view of the west side of the New River mouth showing large concentrations of American White Pelicans and Double-crested Cormorants (Photos by W. D. Shuford, 12 February 1999).

to artificial structures not previously used (SSNWR files). In 1999, Great Egrets, Cattle Egrets, and Black-crowned Night-Herons (*Nycticorax nycticorax*) nested at fewer sites than in 1998, whereas Snowy Egrets (*Egretta thula*) nested at the same number of sites. Colonial ground nesters requiring bare earthen islets, such as terns and skimmers, have experienced a net loss of suitable nesting habitat from the complete erosion or vegetative overgrowth of several previously used sites. Gull-billed Terns (*Sterna nilotica*), Caspian Terns (*S. caspia*), and Black Skimmers (*Rynchops niger*) all have undergone recent contractions in nest site occupancy (Molina *this volume*). The California Gull (*Larus californicus*), a recent but now annual breeder at the Salton Sea, continues to nest at a single site, although recent observations indicate that they may be attempting to expand to Rock Hill (Molina 2000a). The Salton Sea NWR currently manages a few impoundments with small earthen islets, the only such protected habitat for colonial ground nesters at the Salton Sea. All other sites, except for the Finney-Ramer lakes colony, occur on private lands.

With minor exceptions, our Clapper Rail surveys documented a distribution pattern similar to that observed from 1990 to 1998 (unpublished data, Yuma Clapper Rail Recovery Team, USFWS, Phoenix, Arizona). The Yuma Clapper Rail is a bird of the cattail-bulrush marsh edge, preferring mature stands of cattail-bulrush in shallow water near high ground (USFWS 1983), and major concentrations of the Yuma Clapper Rail around the Salton Sea reflected the distribution and extent of this marsh habitat.

Study Implications

Projects to restore the health of the Salton Sea's ecosystem should be carefully assessed to ensure they do not have unintended impacts. Those projects with potentially negative impacts should not be placed where large numbers of breeding, roosting, or foraging birds currently concentrate. However, caution must be used in interpreting the results of a one-year study. Even within a year, our results indicate a variable and dynamic distribution of birds around the Salton Sea, which will complicate efforts to mitigate the effects of its changing hydrology (e.g., Tetra Tech 2000).

Our study on the distribution of waterbirds around the Salton Sea suggests avenues of future research. While our 1999 study revealed gross patterns of waterbird distributions, finer scale studies on the mechanisms influencing bird distributions would be beneficial and facilitate mitigation efforts. Fruitful topics of research would be studies of how the distribution and abundance of prey, substrate, water depth, and salinity affect waterbird distributions. Additional information is needed on the daily and seasonal use patterns and movements of birds between agricultural fields and wetlands in the Imperial, Coachella, and Mexicali valleys and the Salton Sea proper. Finally, a better picture of how human disturbance may impact waterbird distribution at the Salton Sea is needed to effectively understand and plan for future changes there, especially as related to recreational and commercial activities.

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BREEDING LARIDS OF THE SALTON SEA: TRENDS IN POPULATION SIZE AND COLONY SITE OCCUPATION

KATHY C. MOLINA

Abstract. The Salton Sea, a large saline lake in southeastern California, and its surrounding agricultural lands and wetlands are rapidly becoming recognized as important habitats for migratory and resident birds in western North America. Apart from early ornithological explorations, little published information exists on the breeding of colonial waterbirds there. From 1991 through 2001, I surveyed suitable nesting habitat for breeding larids at the Salton Sea, and from 1992 through 2001 I estimated their population sizes. Composed of six species, this community regularly includes California Gulls (*Larus californicus*), Gull-billed (*Sterna nilotica*) and Caspian (*S. caspia*) terns, and Black Skimmers (*Rynchops niger*). Up to 20 pairs of Forster's Terns (*S. forsteri*) nest in some years and several pairs of Laughing Gulls (*L. atricilla*) have become regular breeders. Of the five species that nested regularly, the mean annual number of breeding pairs of Laughing and California gulls was 1 and 32, that of Gull-billed and Caspian terns was 119 and 480, respectively, and that of Black Skimmers was 360 pairs. Colony site availability and occupancy by breeding larids was variable between years, with a total of nine sites used over the study period. With growing populations of breeding gulls and abundant populations of breeding and roosting Double-crested Cormorants (*Phalacrocorax auritus*), the site occupancy of smaller species such as the Gull-billed Tern and Black Skimmer is now restricted to a fraction of the few existing sites. However, these two species have readily colonized newly available habitats, suggesting that their populations would benefit immediately from the creation of additional nest sites. Any plan to restore wildlife habitat at the Salton Sea should include the creation of nesting habitat suitable for breeding larids.

Key Words: breeding population trends; gulls; Laridae; skimmers; Salton Sea; terns.

LÁRIDOS ANIDANTES DEL MAR SALTON: TENDENCIAS EN TAMAÑO POBLACIONAL Y OCUPACIÓN DEL SITIO DE LA COLONIA

Resumen. El Mar Salton, un lago salino extenso en el sureste de California, y los campos agrícolas y ciénegas que lo rodean, están siendo reconocidos rápidamente como hábitats importantes para las aves residentes y migratorias del oeste de Norteamérica. Aparte de las primeras exploraciones ornitológicas, existe muy poca información publicada sobre la reproducción de las aves acuáticas coloniales en este lugar. De 1991 al 2001, se buscaron en el Mar Salton, todos los sitios potenciales adecuados para la anidación de láridos, y de 1992 al 2001 se estimaron sus tamaños poblacionales. La comunidad de aves acuáticas estuvo compuesta por seis especies que incluye regularmente a la Gaviota Californiana (*Larus californicus*), a los Charrán Pico Grueso (*Sterna nilotica*) y Caspio (*S. caspia*), y al Rayador Americano (*Rynchops niger*). Hasta 20 parejas del Charrán de Forster (*S. fosteri*) anidan en algunos años y varias parejas de la Gaviota Reidora (*Larus atricilla*) se han convertido en anidantes regulares. De las cinco especies que anidaron regularmente, el número anual promedio de parejas reproductoras de las Gaviotas Californiana y Reidora fue de 1 y 32, para los Charrán Pico Grueso y Caspio fue de 119 y 480, respectivamente y para el Rayador Americano fue de 360 parejas. La disponibilidad de sitios para las colonias y su ocupación por los laridos anidantes fue variable entre años, con un total de nueve sitios utilizados durante el período de estudio. Con poblaciones en aumento de gaviotas anidantes y poblaciones abundantes del Cormorán Orejudo (*Phalacrocorax auritus*) anidantes y de descanso, la ocupación de los sitios por especies mas pequeñas tales como el Charrán Pico Grueso y el Rayador Americano se restringe ahora a una fracción de los pocos sitios existentes. Sin embargo, estas dos especies han colonizado rápidamente nuevos hábitats disponibles, lo que sugiere que sus poblaciones se beneficiarían inmediatamente con la creación de nuevos sitios de anidación. Cualquier plan para restaurar el hábitat de la fauna silvestre en el Mar Salton deberá incluir la creación de hábitats de anidación adecuados para los láridos anidantes.

Palabras clave: Charránes; gaviotas; Laridae; Mar Salton; rayadores; tendencias de poblaciones reproductoras.

The Salton Sea, a large saline lake spanning the Coachella and Imperial valleys of southeastern California, and its surrounding agricultural lands and wetlands are rapidly becoming recognized as important habitats for waterbirds in western North America (Shuford et al. 2000). Whereas previous work has documented the area's importance to particular wintering species such as the Eared Grebe (*Podiceps nigricollis*; Jehl 1994), Snowy Plover (*Charadrius alexandrinus*; Shuford et al. 1995), White-faced Ibis (*Plegadis chihi*; Shuford et al. 1996), and Mountain Plover (*C. montanus*; Knopf and Rupert 1995, Shuford et al. *this volume*), surveys over the last two decades indicate that it also supports a diverse community of colonial nesting waterbirds comprising several families, including the Phalacrocoracidae and Ardeidae (Molina and Sturm *this volume*) and Laridae (this paper). Of the last group, the recent breeding populations of the Gull-billed Tern, Caspian Tern, and Black Skimmer at the Sea are of regional significance in terms of their abundance (Shuford et al. 2000). The Salton Sea Laughing Gull population is significant as it is the only breeding population of this species in the western U.S. (Molina 2000a).

Breeding colonies of larids at the Salton Sea were first documented in 1927 for the Gull-billed and Caspian terns (Pemberton 1927) and 1928 for the Laughing Gull (Miller and van Rossem 1929). Subsequent reports of breeding larids have focused on additional colonizations (Forster's Tern, McCaskie 1970c; Black Skimmer, McCaskie et al. 1974; California Gull, Molina 2000a) or recolonizations (Laughing Gull, Molina 2000a), on aspects of nesting behavior (Black Skimmer, Grant and Hogg 1976; Forster's Tern, Grant 1982; Gull-billed Tern and Black Skimmer, Molina 1999), and on breeding biology (Black Skimmer, Molina 1996), yet no report has detailed recent population trends for the entire breeding larid assemblage. Here I report recent population trends for six species of larids breeding at the Salton Sea from 1992 through 2001, and patterns of colony site occupation from 1991 through 2001. I also review their historical status at the Salton Sea and discuss their regional significance and conservation.

METHODS

I surveyed suitable areas of the entire Salton Sea shoreline from mid-April through July 1991 through 2001 to detect and monitor active larid colonies. Such habitats were generally limited to near-shore islands along the northern, eastern, and southern shoreline, and to islets within managed impoundments concentrated along the southern and eastern shorelines (Fig. 1). Beginning in 1992, I recorded complete counts of breeding pairs for all species at each site, except for Forster's Terns, which only rarely nested in the vicinity of other larids. Efforts to survey Forster's Terns were extensive in 1995 and 1999 only. In the hot environment of the Salton Sea, incubating adults are readily detected and monitored at all islets from the nearest shore, except Mullet Island and Johnson Street, which required offshore observations from a boat. During these extra-colony visits, I counted the number of sitting adults during mid-day, when ambient temperatures were greatest, at one- to two-week intervals at each site. I continued to monitor colonies that were prematurely abandoned to detect any reestablishment at two- to three-week intervals. I assumed that the presence of an incubating adult during the hottest portion of the day represented an active nest, and thus a breeding pair. During the peak incubation period (usually 10–14 d post-colony establishment), I made intra-colony visits in the early morning to all sites to determine nest contents. Except for 2001, nests of Gull-billed Terns and Black Skimmers were uniquely marked to facilitate companion studies of nest success (Molina 2000b, unpubl. data) and of parental behavior (Molina 1999), enhancing my ability to monitor nest activity.

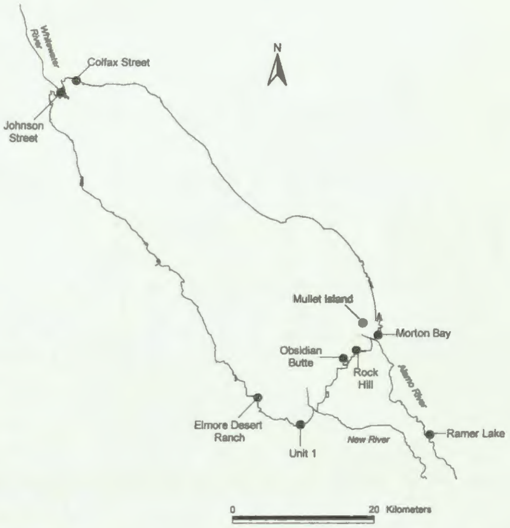

FIGURE 1. Location of colony sites of larids breeding at the Salton Sea, 1991–2001.

Failures of individual nests and of complete colonies were common throughout the study period, particularly for Gull-billed Terns. New nest initiations were regularly observed at continuously active colonies throughout the nesting period. Because I could not determine whether these new nest attempts represented new breeders or re-nesting pairs, the use of the total number of nest attempts in a season could lead to inflated estimates of the size of the breeding population. To minimize overestimation of population size, I report the maximum number of active nests recorded on a single visit to each colony for each season, rather than the total number of nest attempts tallied throughout a season. Although this technique may underestimate population size if new attempts represented new breeders, the number of new nest attempts generally corresponded to the number of abandoned nests. I then estimated the total number of breeding pairs for each species in each year by summing these colony maxima. Colony increases clearly due to an influx of nesters from other, prematurely abandoned sites, as occurred with Gull-billed Terns in most years, were excluded from the total.

I used linear regression analyses (Minitab 1998) performed on ranks to identify increasing or decreasing trends. The lack of regular focal surveys of Forster's Terns precluded population trend analysis for that species.

TABLE 1. ANNUAL NUMBER OF BREEDING PAIRS OF LARIDS AT THE SALTON SEA FROM 1992 THROUGH 2001

Year	Laughing Gull	California Gull	Gull-billed Tern	Caspian Tern	Forster's Tern[a]	Black Skimmer
1992			106	30[b]	≤20	100
1993			121	60	≤20	300
1994	1[b]		101	150	≤15	450
1995	0		72	313	?	487
1996	0	2[b]	155	1500	?	351
1997	0	22	152	1200	nd	300
1998	0	39	123	800	nd	270
1999	1	44	101	211	0	423
2000	3	44	115	207	nd	453
2001	5	42	143	327	nd	464
Mean ± sd	1 ± 2	32 ± 17	119 ± 26	480 ± 511		360 ± 121

[a] Summary statistics for Forster's Tern were not calculated as information for them is incomplete. They rarely nested in association with other larids and focal surveys for them were conducted only in 1995 and 1999. In 1995 and 1996 Forster's Terns were suspected of breeding along an inaccessible portion of the mouth of the New River, but nesting was not confirmed. nd = no data.

[b] These values indicate the year of colonization by the California Gull, or re-colonization by the Laughing Gull and Caspian Tern.

RESULTS

POPULATION SIZE AND TRENDS

From three to six species of larids bred at the Salton Sea each year from 1992 through 2001, with an annual average of nearly 1,000 total pairs (Table 1). In the present study Caspian Terns and Black Skimmers have been the most abundant species with mean annual populations of 480 and 360 pairs, respectively, followed by Gull-billed Tern (119 pairs). Although Forster's Terns were not consistently surveyed, small colonies (≤20 pairs) of this species were detected in some years of the study. Up to 44 pairs of California Gulls (annual mean 32 pairs) nested, beginning in 1996, and up to five pairs of Laughing Gulls (mean = 1) were noted beginning in 1994 (Table 1).

The breeding populations of the California Gull (df = 5, P = 0.03) and Laughing Gull (df = 7, P = 0.05) increased significantly in abundance over the study period (Fig. 2). The Caspian Tern (df = 9, P = 0.14) and the Black Skimmer (df = 9, P = 0.23) exhibited non-significant increases, whereas the Gull-billed Tern (df = 9, P = 0.49) showed no directional trend over the period examined (Fig. 2).

HISTORICAL REVIEW

Three species, the Gull-billed Tern, Caspian Tern, and Laughing Gull, were the first species to colonize the Salton Sea. Gull-billed Terns colonized the southwestern end by 1927, with an estimated 500 pairs breeding on a series of sandy islets, some of which were occupied by breeding American White Pelicans (*Pelecanus erythrorhynchos*; Pemberton 1927). At this time, Caspian Terns were also documented as breeders (Pemberton 1927). Although the size of their population was not quantitatively assessed by Pemberton, the number of breeding Caspian pairs appeared to be relatively few. Nesting by a few pairs of Laughing Gulls was first documented in 1928 (Miller and van Rossem 1929). Of these earliest colonizing species, the Gull-billed Tern appeared to be the most consistent nester, although its numbers were believed to have dwindled to only 17 pairs by the 1976 (McCaskie 1976). Unpublished notes of personnel of the Sonny Bono Salton Sea National Wildlife Refuge (SSNWR) indicated that 36 pairs of Caspian Terns nested in 1940, and up to 40 birds nested until 1957 (Small 1957). The last documentation of breeding Caspian Terns occurred in 1959 (Small 1959); after a hiatus of over 30 yrs this species recolonized in 1992 with 30 pairs on Mullet Island (Molina 1996). Throughout its breeding history at the Sea, this species was most abundant between 1996 and 1997, when they formed large colonies (≥400–1000 pairs) at up to three sites.

A few pairs of Laughing Gulls were also believed to nest annually until at least 1957 (Small 1957, Remsen 1978). Their recolonization of the Salton Sea by a single pair was documented in 1994 (Molina 2000a). Since 1999, a mean of three pairs have nested annually. The California Gull colonized the Salton Sea in 1996 (Molina 2000a), when two pairs nested. It has nested annually since with the population exhibiting a sharp increase between 1997 and 1999 (Fig. 2).

Forster's Terns were first documented as breeding near the New River in 1970 (McCaskie 1970c), although unpublished records indicated that "a few nested in 1939" (L. Goldman, SSNWR files). Little quantitative information about nesting Forster's Tern is available since the late 1970s and Patten et al. (2003) considered it an irregular breeder at the Sea. A maxi-

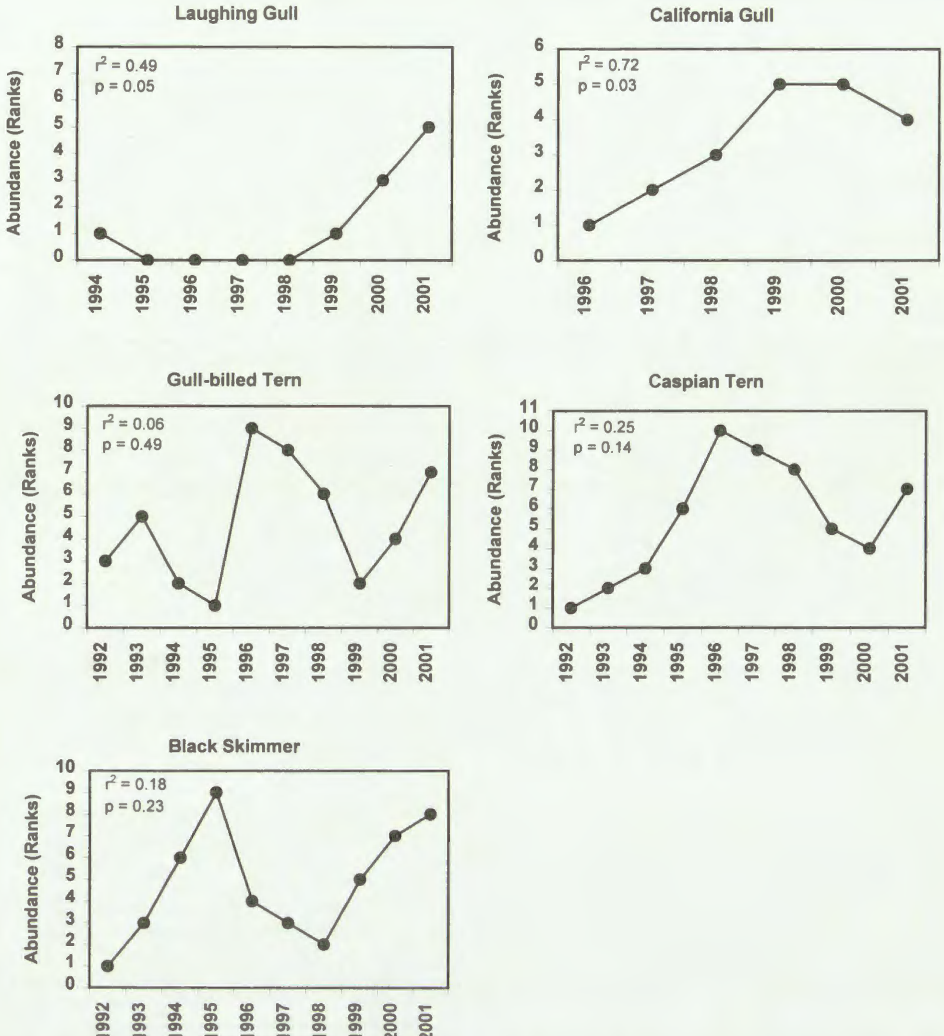

FIGURE 2. Trends in the number of pairs of five larid species that bred regularly at the Salton Sea, 1992–2000, using linear regressions on ranks.

mum of 200 pairs nested at the north end of the Sea in 1978 (McCaskie 1978). During the present study, about 20 pairs nested along the inner aspect of the perimeter levee of Morton Bay in 1992 (Table 1). In 1993 and 1994, 15–20 pairs attempted to nest on hummocks of vegetation on the shallowly flooded mudflats along the southeastern shoreline. In both years these attempts were inundated by water driven by high winds. Forster's Terns were suspected of nesting in an area inaccessible by foot or boat near the mouth of the New River in 1995 and 1996 (K. Molina, pers. obs.). In 1999 comprehensive foot, boat, and aerial surveys did not detect the species as breeder (Shuford et al. 2000).

Black Skimmers were first documented breeding at the Salton Sea in 1972 (McCaskie et al. 1974) and were thought to have bred nearly annually since, with an apparent hiatus in the early 1980s (Remsen 1978, Molina 1996). By 1988, Black Skimmers had increased to several hundred pairs (Collins and Garrett 1996).

SITE OCCUPANCY

From 1991 through 2001, breeding larids occupied nine colony sites at the Salton Sea (Table 2). Except for the sites near the northern shoreline at Johnson and Colfax streets, all sites were islets located at or near the south end of the Sea (Fig. 1). Only two, Unit 1 and Rock Hill, lie on federal lands and are managed by the SSNWR. All islets are less than 0.3 ha in area and subject

TABLE 2. PHYSICAL CHARACTERISTICS, PERIODS OF OCCUPATION, AND COLONY SUCCESS AT SITES USED BY AT LEAST ONE LAIRD SPECIES DURING THE PERIOD 1991–2001

Colony site	Habitat type	Nesting substrate	Period of occupation	Colony success[a]
Colfax St.	sea shoreline	barnacle	1999–2001	0
Elmore	eroded levee, near shore islet	bare earth	1991–1992	0.5
Johnson St.	eroded levee, near shore islet	bare earth	1991–2000	0.6
Morton Bay	eroded levee, near shore islet	bare earth	1991–1994	0.75
Mullet I.	offshore islet	bare earth, rock	1992[b]–1997	1
			2000–2001	0
Ramer Lake	islet in impoundment	earth with perimeter of vegetation	1995–1996	1
Rock Hill (NWR)	islet in impoundment	bare earth, rock	1995–2001	1
Obsidian Butte[c]	near shore islet	sand, barnacle, rock	1993–2001	1
Unit 1[d] (NWR)	islet in impoundment	bare earth, rock	2001	1

[a] The proportion of years of colony site use in which at least some young fledged.
[b] First year of colonization by larids although site was present as an island for >30 years. It was abandoned by larids after 1997 but re-colonized in 2000.
[c] The islet near Obsidian Butte was available since at least 1991; however, it is not certain that it was occupied by breeding larids in years prior to 1992.
[d] Site first available in 2001.

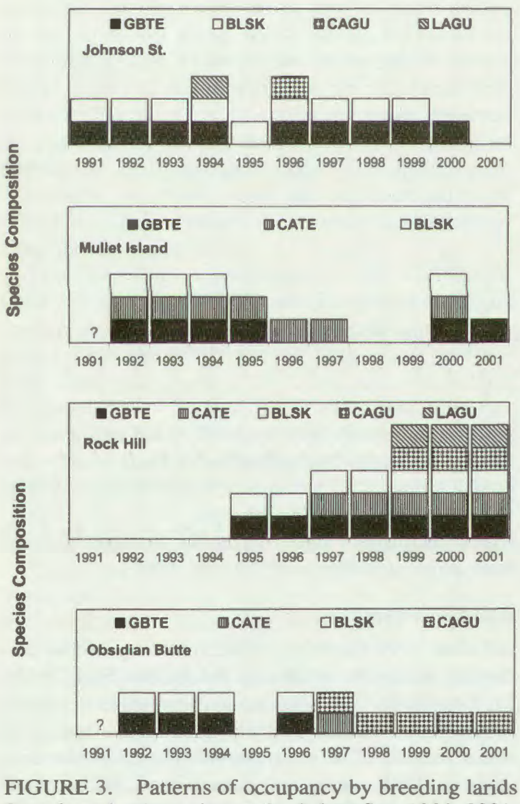

FIGURE 3. Patterns of occupancy by breeding larids for selected colony sites at the Salton Sea, 1991–2001. "?" indicates lack of data for that colony.

to continual erosion, except for Mullet Island, which lies well offshore and covers ~4.5 ha. Those islets in fresh or brackish water impoundments are subject to encroachment by vegetation such as tamarisk (*Tamarix ramosissima*) or iodine bush (*Allenrolfea* spp.)

All sites except the ones near Colfax and Johnson streets were isolated from the shoreline by water during the study period. Only four of these (Rock Hill, Mullet Island, Morton Bay, and Obsidian Butte) remained consistently available for nesting, although Obsidian Butte was unoccupied in 1995 as severe winds caused it to be inundated (Fig. 3). The islet near Elmore Desert Ranch was eroded away by wave action in 1993. The islet used by skimmers at Ramer Lake, a recreation area within the Imperial Wildlife Area approximately 5 km south of the Sea, was rendered unsuitable for nesting in 1997 by encroaching tamarisk. The remnants of levees near Johnson Street, isolated from the shore previously, became intermittently connected to the shoreline by 1999. As had occurred years earlier at Colfax Street, this connection to the mainland facilitated access to the colonies by mammalian predators. Gull-billed Terns and Black Skimmers ceased to breed at Morton Bay after 1994, although the nesting islets were intact. The extent to which widespread nest failures experienced by skimmers there in 1993 and 1994 (Molina 1996) may have influenced site occupancy in subsequent years is not known. An impact on colony establishment by the presence of large congregations of roosting Double-crested Cormorants (*Phalacrocorax auritus*) and American

White and Brown (*Pelecanus occidentalis*) pelicans on the islet in spring also seems likely.

Of the extant sites, colony success, as measured by the absence of colony-wide nest failures or desertions, has been greatest at Rock Hill, a site managed for nesting larids since 1995 by the SSNWR, and at an islet just offshore of Obsidian Butte (Fig. 1; Table 2). In contrast, the relatively small colonies (± 50 nests) of Black Skimmers and, occasionally, of Gull-billed Terns established on the shoreline near Colfax Street have never been successful. Colony size and success at Johnson Street, once highly productive for both Gull-billed Terns and Black Skimmers, have declined for these species since 1996 (Molina 2000b). Currently, no suitable colony sites exist at the north end of the Salton Sea. Another SSNWR site, established at Unit 1 at the south end in 2001 (Fig. 1; Table 2), was immediately colonized by Gull-billed Terns and Black Skimmers; both species appeared to have been successful in that year (Molina 2001).

Of the four colony sites active for ≥5 yrs during the study period (Johnson Street, Rock Hill, Mullet Island, and Obsidian Butte), Rock Hill had the greatest species richness, followed by Obsidian Butte and Mullet Island (Fig. 3). From 1999 through 2001, Rock Hill supported all five larid species that now breed regularly at the Sea. The largest colonies of Gull-billed Terns (up to 70 pairs) and Black Skimmers (up to 400 pairs) have consistently established here, and it was the sole nesting site for Laughing Gulls and Caspian Terns during that period. The islet near Obsidian Butte supported Gull-billed and Black Skimmers until 1996. Caspian Terns and California Gulls colonized the islet in 1997; since 1998 only California Gulls have occupied it (Fig. 3). The colonization of Mullet Island by Gull-billed and Caspian terns and Black Skimmers occurred in 1992 (Molina 1996). As this site had likely been isolated from the shore since the 1960s, the apparent delay of its colonization by breeding waterbirds may have been related to disturbances associated with high levels of boating and fishing activity in 1970s and 1980s (Molina 1996). Black Skimmers experienced a complete nesting failure in 1994 and did not occupy the island again until 2000. Several thousand pairs of Double-crested Cormorants colonized Mullet Island beginning in 1996 and may have displaced Gull-billed Terns from the site; Caspian Terns ceased nesting there in 1997 (Fig. 3). Although cormorants have continued to breed annually on Mullet Island, they have been much less numerous since 1999 and have departed the island earlier in spring. Gull-billed and Caspian terns and Black Skimmers reestablished there 2000 (Fig. 3).

DISCUSSION

Today, the breeding larid community of the Salton Sea, including two gulls, three terns, and the Black Skimmer, is diverse and well-established. The Salton Sea is the only interior nesting site for Gull-billed Terns, Black Skimmers, and Laughing Gulls in western North America north of Mexico. Additionally, the community forms an unique mix of species with the usually coastal breeding Gull-billed Terns, Black Skimmers, and Laughing Gulls reaching the northern extreme of their interior breeding range, while California Gulls reach their southern extreme there.

A combination of factors have influenced larid colonization and population trends at the Salton Sea, including prey availability, suitable colony sites, and possibly factors operating outside the immediate region such as climatic change and large-scale population dynamics. The colonization by the California Gull (Molina 2000a) and Brown Pelican (Sturm 1998) and the re-colonization of the Laughing Gull and Caspian Tern all occurred in a relatively short period during the mid-1990s. In addition, several of the piscivorous waterbird species breeding at the Sea reached peak population sizes during this time (Shuford et al. 1999, Molina and Sturm *this volume*). These events coincided with the development of a highly productive population of tilapia (*Oreochromis mossambicus*) during the 1990s (Costa-Pierce and Riedel 2000). My qualitative observations of foraging larids suggest that yearling tilapia are important prey for most Salton Sea larids, in particular Caspian Terns and Black Skimmers; California Gulls feed tilapia to chicks, and adults routinely forage on dead or dying tilapia along the shoreline.

The availability and suitability of colony sites at the Salton Sea is dynamic and related to the Sea's surface elevation. None of the historic sites first described by early ornithologists currently exist as islands. The sandy islets (Miller and van Rossem 1929) once shared by American White Pelicans, Caspian Terns, and Laughing Gulls off the southwestern shore eroded away in the 1950s, and the rocky ledges of Volcano I (= Black Butte or Obsidian Butte), present during the Sea's early formation (Grinnell 1908), are also no longer isolated from the mainland as sea surface elevation declined in later years.

Competition among species for suitable nesting and roosting habitat appears to have increased with the growing assemblage of breeding larids and abundant pelecaniform populations. Large-scale nest losses of Gull-billed Terns and Black Skimmers due to the crushing of eggs by loafing pelicans has occurred on the islet near Elmore Desert Ranch in 1992 and, to a lesser degree, at Rock Hill in 1998. Crushed nest contents on Mullet Island and at Unit 1 in 2001 also coincided with the presence of large numbers of cormorants or pelicans using these areas for loafing (K. Molina, pers. obs.).

Gull-billed Terns and Black Skimmers once nested regularly at up to four sites (Fig. 3). A sustained reduction in species richness was observed at Obsidian Butte after the colonization by California Gulls. The contraction of colony site occupation exhibited by the smaller and less aggressive Gull-billed Terns and Black Skimmers is likely to continue as gull populations continue to grow and expand to other sites. At Rock Hill these two species now commonly experience the once novel losses of eggs and chicks to Laughing and California gulls. The decrease, and earlier departure, of breeding cormorants on Mullet Island may have allowed larids to immediately reestablish nesting there in 2000, though these reestablished colonies have been unsuccessful, at least in part due to interference by large aggregations of pelicans and cormorants that continue to loaf there. The reproductive losses suffered by Gull-billed Terns and Black Skimmers as a result of gull predation and interspecific competition for space at some colony sites may be offset by their ability to rapidly colonize new sites, provided that these are of suitable size, form, and location. With the decline of the Johnson Street colony, productive sites are now concentrated at the two SSNWR colonies at south end of the Sea. This consolidation of breeding sites increases the susceptibility of these populations to local disturbances and catastrophic events.

The population dynamics of Salton Sea larids may in part be related to larger-scale phenomena operating in the eastern Pacific Ocean. For example, Ainley and Divoky (2001) link colonizations and population growth of the Black Skimmer at the Salton Sea and in coastal California to increasing ocean temperatures following a series of El Nino/Southern Oscillation events since the early 1970s; such a relationship is imperfect at best, as skimmers were absent from the Sea and scarce along the coast of southern California (Collins and Garrett 1996) during the largest (1982–1983) ENSO event. The sporadic nesting presence of Laughing Gulls at the Salton Sea might reflect population dynamics within the breeding range in western Mexico.

The present study indicates that breeding larid populations have generally flourished in the last decade, remaining largely unaffected by diseases that have afflicted other large piscivores such as pelicans, Double-crested Cormorants, herons, and egrets (SSNWR, unpubl. data). Setmire et al. (1993) reported a 40% decrease in the numbers of breeding Black Skimmers during 1988–1990 from 1987 levels and suspected that contaminants played a major role in their perceived decline. This conclusion by Setmire et al. (1993) was likely flawed as reports of population size for that period were based on incomplete assessments (Molina 1996). Efforts to survey the entire population of Black Skimmers and other larids at the Salton Sea did not begin until this study, in 1992.

The construction of additional nesting habitats for larids should be considered in any restoration plan for the Salton Sea. Predation of nests by coyotes (*Canis latrans*), feral dogs (*C. familiaris*), and raccoons (*Procyon lotor*) is relatively rare at the Sea. Despite frequent observations of these mammals or their tracks, predation by these species has been confined to sites located on, or connected to, the shore. Any newly constructed habitats should be in the form of islets (or artificial materials such as rafts) completely isolated by water in order to minimize disturbances to nesting. Because all species feed in inshore waters, or in agricultural and estuarine habitats, nesting islets placed near the shore or within impoundments near the shore would be appropriately located.

The Salton Sea is an integral component of the lower Colorado River watershed. Its breeding larid assemblage shares affinities with those at two wetland sites in northern Baja California, Mexico: Isla Montague in the delta of the Colorado River (Palacios and Mellink 1992, 1993) and Cerro Prieto in the Mexicali Valley (Molina and Garrett 2001). Many of the breeding species are also shared with colonies in San Diego Bay on the California coast (Patton 1999). Recent opportunistic observations indicate that Gull-billed Terns and Black Skimmers hatched at the Salton Sea have moved, at least for one breeding season, to other nesting colonies in the southern California/Gulf of California region (K. Molina, unpubl. data). The degree of mixing among these populations remains to be quantified and more study is needed to fully understand their metapopulation dynamics and associated management implications.

The Salton Sea breeding colonies of some species of larids seem to be of particular importance in the region. For example, the population size and nesting success of Salton Sea Gull-billed Terns and Black Skimmers appear to be markedly greater than of those breeding on Isla Montague (Peresbarbosa-Rojas 1995, Peresbarbosa-Rojas and Mellink 2001) or at San Diego Bay (Patton 1999; Molina 2000b, 2001), the only other site of breeding for the Gull-billed

Tern in the western United States. This success, coupled with the growing evidence of the dispersal of Salton Sea hatched individuals to other breeding sites within the southern California-Río Colorado Delta region, suggests that the Salton Sea populations may play an important regional role as source populations for these species. To help maintain this potentially critical relationship, plans to restore wildlife habitat at the Salton Sea should include protection of productive foraging habitats, creation of additional nesting habitat suitable for breeding larids, and monitoring of the efficacy of its implementation.

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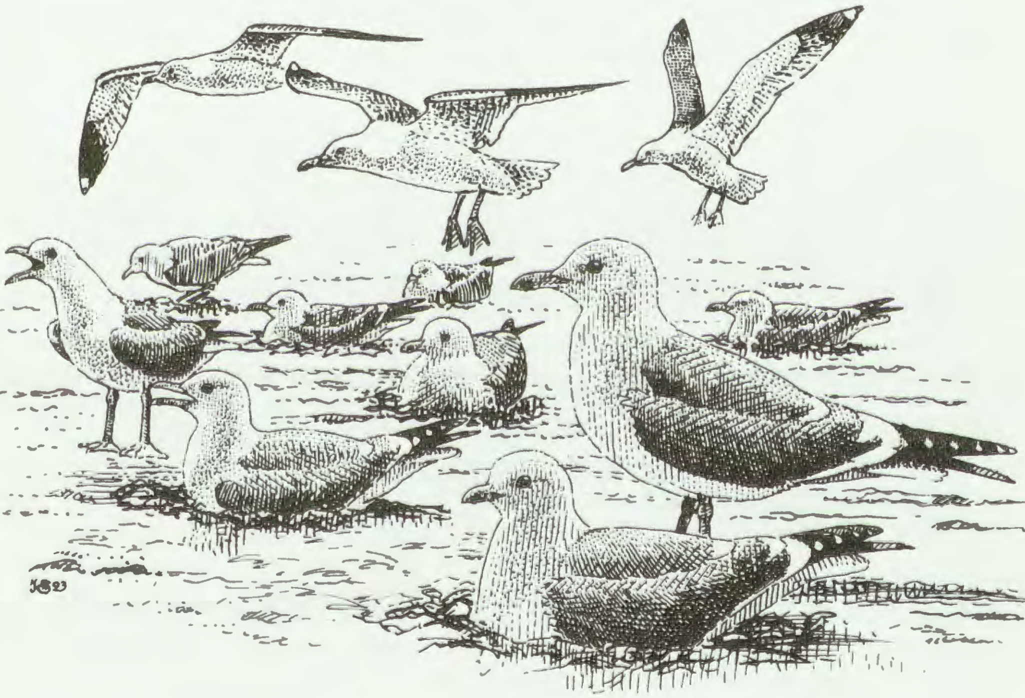

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THE SALTON SEA AS IMPORTANT WATERFOWL HABITAT IN THE PACIFIC FLYWAY

DOUGLAS A. BARNUM AND STEVEN JOHNSON

Abstract. The Salton Sea region, including the Imperial and Coachella valleys, is an important component of the Pacific Flyway for migrating and wintering waterfowl. From 1986 through 2000, the average midwinter count of waterfowl in the Salton Sea region was 100,714 (N = 13, range = 60,845–133,597) birds. Although some estimates for average waterfowl use of the Salton Sea region are in the range of 125,000 birds annually, they fail, as does our analysis of midwinter counts, to account for the large number of migrants passing through the area and hence greatly underestimate the actual number of waterfowl using the Salton Sea. The midwinter waterfowl counts for 11 states of the Pacific Flyway, from 1986–2000, tallied an average population of 5,421,707 birds. The Salton Sea midwinter waterfowl population thus represents <2% of the Pacific Flyway total. Freshwater marshes on duck hunting clubs and Federal wildlife refuge lands held greater densities of waterfowl and geese than other areas, including Salton Sea shorelines. Analysis of returns for birds banded at the Salton Sea demonstrates that the region is an important crossroads for both the Pacific and Central flyways. A comparison of mean counts for the periods 1978–1987 and 1986–2000 indicate significant declines in Canvasback (*Aythya valisineria*) and Canada Goose (*Branta canadensis*), whereas Ruddy Duck (*Oxyura jamaicensis*) exhibited a significant increase in numbers.

Key Words: aerial survey; bird banding; dabbling ducks; diving ducks; geese; habitat use; wintering area.

EL MAR SALTON COMO UN IMPORTANTE HÁBITAT DE AVES ACUÁTICAS EN LA RUTA DE VUELO DEL PACIFICO

Resumen. La región del Mar Salton incluyendo los valles Imperial y Coachella, es un componente importante de la ruta de vuelo del Pacifico para aves acuáticas (Anseriformes) migratorias e invernantes. Entre los años 1986 y 2000 el número promedio de aves acuáticas a mediados de invierno en la región del Mar Salton fue de 100,714 (N = 13, rango = 60,845–133,597) aves. Aunque algunas estimaciones del uso promedio de la región del Mar Salton por aves acuáticas están en el rango de las 125,000 aves anuales, éstas, de la misma manera que nuestro análisis de los conteos a mediados de invierno, no toman en cuenta el gran número de migratorias que pasan por el área. Por lo tanto, subestiman en gran medida el número real de aves acuáticas que usan el Mar Salton. Entre 1986 y 2000, los conteos de Anseriformes a mediados de invierno en 11 estados sobre la ruta de vuelo del Pacifico, reunieron una población promedio de 5,421,707 aves. De modo que, la población de Anseriformes en el Mar Salton a mediados de invierno representa menos del 2% del total de la ruta de vuelo del Pacifico. Los pantanos de agua dulce en clubes de caza de patos y las tierras federales de refugio de vida silvestre, albergaron densidades mayores de Anseriformes y gansos que otras áreas incluyendo las costas del Mar Salton. El análisis de los retornos de aves anilladas al Mar Salton demuestra que la región es una intersección importante de la ruta de vuelo del Pacifico y de la ruta del Centro. La comparación de conteos promedio entre los períodos 1978–1987 y 1986–2000 indica disminuciones significativas en el Pato Coacoxtle (*Aythya valisineria*) y el Ganso Canadiense (*Branta canadensis*) mientras que el Pato Tepalcate (*Oxyura jamaicensis*) manifestó un incremento significativo en el número de individuos.

Palabras claves: anillamiento de aves; área de invernada; gansos; muestreos aéreos; patos chapuceadores; patos zambullidores; uso del hábitat.

The Salton Sea and its adjacent wetlands are important components of the Pacific Flyway, providing habitat and seasonal refuge to millions of birds of hundreds of species (Heitmeyer et al. 1989). Several endangered species and species of special concern, including the Yuma Clapper Rail (*Rallus longirostris yumanensis*), Brown Pelican (*Pelecanus occidentalis*), and Western Snowy Plover (*Charadrius alexandrinus nivosus*) inhabit the Salton Sea ecosystem (Shuford et al. 1999). The Sea was initially formed in modern times (1905–1907) when flooding on the Colorado River breached an irrigation control structure allowing virtually the full flow of the river into the Salton Sink (Setmire et al. 1993). The Sea's current level is maintained primarily by agricultural drainage from the Imperial, Coachella, and Mexicali valleys, and smaller volumes of municipal effluent and storm water runoff. The aquatic ecosystem of the Salton Sea is extremely eutrophic and supports highly productive fish populations (Setmire 2001, Riedel et al. 2002).

The Salton Sea ecosystem is under stress as evidenced by periodic large-scale die-offs of fish and birds. A variety of diseases have been diagnosed as causes of the bird mortality, and several pathogenic microbes and parasites have been isolated from sick and dead fish (Friend 2002). Also, increasing salinity (currently about 44 ppt) may be threatening the reproductive ability of some fish species (Riedel et al. 2002). High nutrient loading from tributaries creates high productivity but also causes frequent algal blooms that contribute to periods of low oxygen and possibly blooms of toxic algae (Setmire 2001). Selenium, derived from Colorado River water used to irrigate agricultural areas of the basin, is found in elevated concentrations within bottom sediments and some biota (Setmire et al. 1993). Pesticide and heavy metal residues in Salton Sea sediments, and the use of agricultural chemicals that reach irrigation drains leading to the Sea, may also contribute to overall ecosystem stress. Nevertheless, recent information suggests that although the Salton Sea does have a problem with salinity and excessive nutrients, the image of the Sea as a "toxic soup" appears to be unwarranted (Barnum et al. 2002). The Salton Sea is an integral part of both the Pacific and Central flyways and is on the migratory pathway of birds moving to and from the Colorado River Delta and the Gulf of California (Shuford et al. 2002b, Patten et al. 2003).

To date limited information has been published on the status and regional importance of birds at the Salton Sea. Recent work suggests that the Salton Sea may be the single most important wintering area for Eared Grebes (*Podiceps nigricollis*) in North America, as estimates of over 3.5 million birds have been recorded (R. McKernan, pers. comm. in Jehl 1988). Shuford et al. (2002b, *this volume*) indicated that the Salton Sea is an area of international importance for migrating and wintering shorebirds. The U.S. Fish and Wildlife Service (USFWS) routinely collects information on numbers of waterfowl at the Salton Sea through aerial surveys, but the midwinter count is the only one published by the Migratory Bird Management Office (USFWS 1999). Here we assemble all of the winter aerial survey counts conducted by the USFWS at the Salton Sea from 1986–2000, use midwinter counts to compare the relative importance of waterfowl populations at the Salton Sea to that of California and the Pacific Flyway, and describe habitat relationships at the Salton Sea for the major waterfowl groups.

STUDY AREA AND METHODS

The Salton Sea, the largest inland body of water in California, is a saline lake located in a closed desert basin known as the Salton Sink in Imperial and Riverside counties (Setmire et al. 1993). The USFWS routinely conducts aerial counts of waterfowl in many parts of the United States, including the Salton Sea. Locally, staff at the Sonny Bono Salton Sea National Wildlife Refuge (SSNWR) conduct these counts. National wildlife refuges throughout the western United States conduct monthly aerial surveys for waterfowl on the wintering grounds, but this is entirely dependent on budgetary constraints, availability of qualified personnel, and weather. However, a region-wide effort to count waterfowl in the Pacific Flyway annually in January is coordinated by USFWS. This "midwinter" count gathers aerial survey data on waterfowl species, numbers, and distribution throughout the 11 western states of the Pacific Flyway. Midwinter count data are assembled, analyzed, and published by the Office of Migratory Bird Management. USFWS protocol for monthly and midwinter counts at the Salton Sea recommend using a single-engine, fixed-wing aircraft with two observers (when possible) viewing off opposite sides of the aircraft. In the case of a single observer, the pilot serves as the second observer. For areas of wetlands with definite boundaries, a flight path is followed, generally under 50 m altitude, insuring total coverage of the wetland. Overlap of counting is minimized by restricting each observer to a field of view from the midpoint of the aircraft out to about 0.4 km, and the flight path is adjusted accordingly. Unlike most interior wetlands, the Salton Sea also has a shoreline of over 100 km and extensive open water. Department of Interior regulations prohibit use of single-engine aircraft for low-level surveys over water beyond its glide path; thus the flight path generally is about 0.4 km offshore following the shoreline (Fig. 1.). We determined acreages of wetlands from records of management agencies. For shorelines we multiplied the entire length of the shoreline by 0.8 km (the effective combined viewing distance of both observers) then converted to acreage. We defined survey areas around the Salton Sea as: (1) South and Eastern Shoreline, (2) Wister Unit, Imperial Wildlife Area, (3) SSNWR Unit 1, (4) SSNWR Unit 2, (5) Duck clubs South and East, (6) Finney/Ramer Unit, Imperial Wildlife Area, (7) Brawley duck clubs, (8) Coachella Valley duck clubs, and (9) North and Western Shoreline. We calculated a density value for each of the major waterfowl groups (dabbling ducks, diving ducks, and geese) in each of these nine areas. We used data from the midwinter counts for total waterfowl in the Salton Sea region and for all of California to calculate their proportion relative to the total Pacific Flyway population for each year. We also examined waterfowl density by year, month, and survey area and the interaction of month × survey area for the major waterfowl groups from 1986–2000. We used a General Linear Model and Duncan Multiple Range Test (Statsoft 1999) to explore main effects and interactions to evaluate potential area affinities for each major group. Significance was set at $P \leq 0.05$. Two of the survey areas, Coachella Valley duck clubs and North and Western Shoreline, were omitted from this analysis for all years because counts were not made with sufficient consistency. Similarly, we included only the months of October, November, December, and January, as counts for other months were not consistently available for all years.

Heitmeyer et al. (1989) presented mean counts of

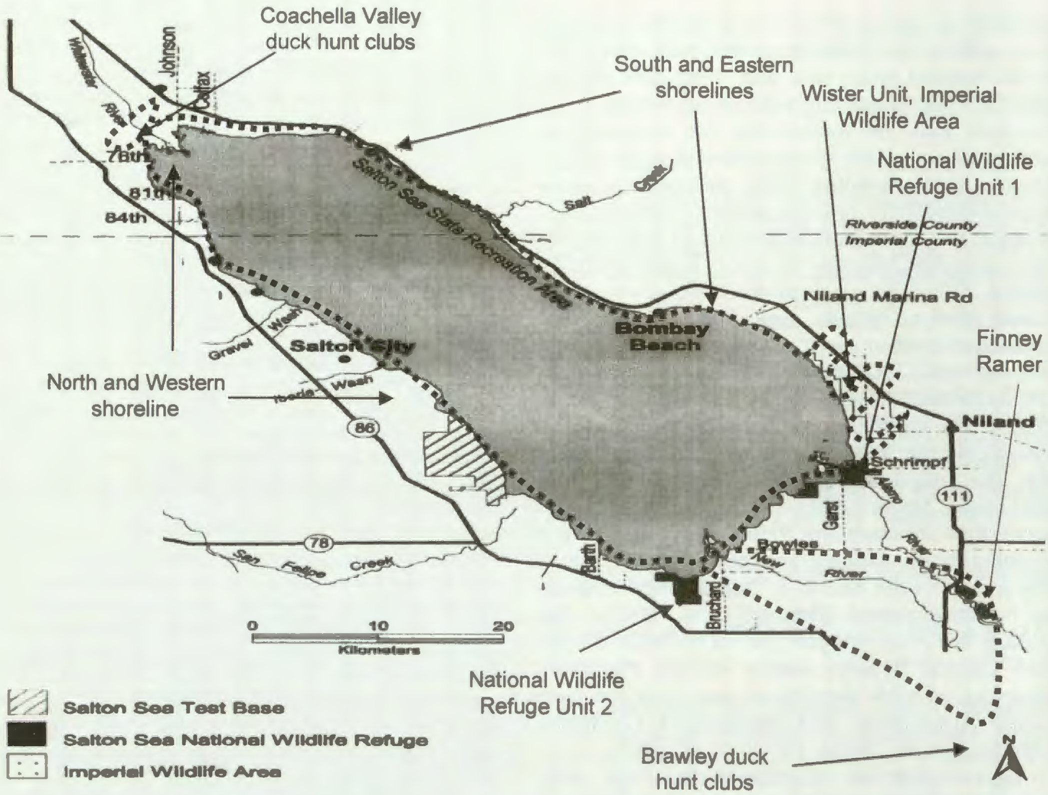

FIGURE 1. Generalized flight path (dashed line) and survey locations around the Salton Sea.

wintering waterfowl for the Salton Sea region by species for the period 1978–1987. For the period 1986–2000, we calculated similar means and a 95% confidence interval for each species' mean. These confidence intervals were then used to measure changes between the two survey periods. Any species for which the 1978–1986 mean fell within the 1986–2000 95% confidence interval was judged to have no significant change in numbers.

To gain a larger scale picture of the Salton Sea relative to the Pacific Flyway and other areas, we queried

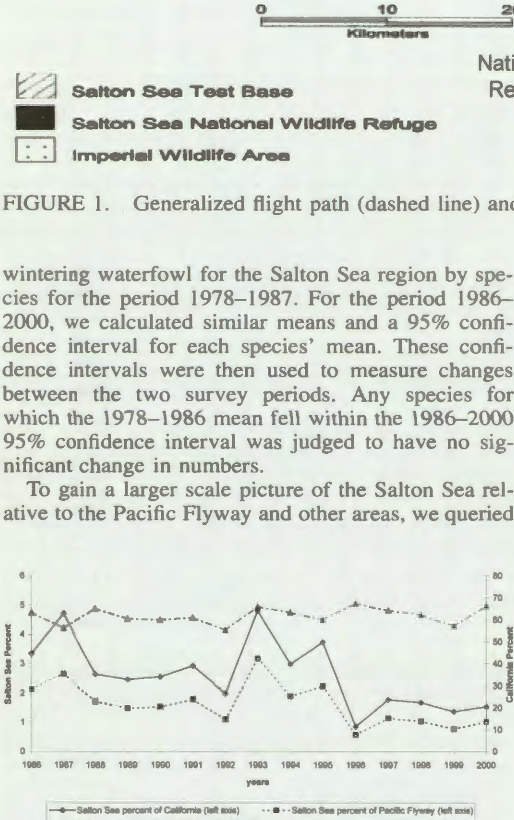

FIGURE 2. Plot of total waterfowl counted on USFWS midwinter surveys at the Salton Sea, in California, and in the Pacific Flyway. Values are adjusted by year relative to the California and Pacific Flyway total count.

the U.S. Geological Survey Bird Banding Laboratory for all birds banded at the Salton Sea and recovered or encountered in the continental United States. These data were entered into the Salton Sea GIS database managed by the University of Redlands.

RESULTS

Midwinter waterfowl counts for the Salton Sea averaged 100,714 (N = 13, range = 60,845–133,597) total waterfowl. These values represented <2% of the midwinter waterfowl population for the Pacific Flyway (Fig. 2), whereas California as a whole held >60% of the Pacific Flyway total, mostly in the Central Valley and Klamath Basin.

General Linear Models for dabbling ducks, diving ducks, and geese were significant (dabbling ducks F = 10.92, df 38, 297; diving ducks F = 5.1, df 38, 297; geese F = 9.17, df 38, 297). Main effects for year, habitat, and month were all significant, but the interaction of month and habitat was not for each of the groups. Duncan's Multiple Range Test indicated that onshore areas represented by duck clubs and SSNWR management units had greater densities of dabbling ducks, diving ducks, and geese than did open water areas such as the Salton Sea shoreline and

TABLE 1. MEAN DENSITY OF WINTERING WATERFOWL (NUMBER/HA) BY HABITAT FOR THE SALTON SEA 1985–1986 TO 1999–2000

Survey area[a]	Dabbling ducks	Diving ducks	Geese
South and Eastern Shoreline	1.7 A	2.0 A	0 A
Wister Unit, Imperial Wildlife Area	2.5 A	0.5 B	2.0 B
Salton Sea NWR Unit 1	9.6 B	3.0 C	7.2 C
Salton Sea NWR Unit 2	7.2 B	2.2 AC	6.4 C
Southeastern duck clubs	34.6 C	1.2 A	2.2 B
Finney-Ramer Unit, Imperial Wildlife Area	0.3 A	0 B	0 A
Brawley duck clubs	11.6 B	2.5 AC	0 A

Note: Northern and Western shorelines and Coachella valley duck clubs were not surveyed with sufficient consistency to include in this analysis.
[a] Values within a column followed by a different letter are significantly different ($P < 0.05$).

Finney-Ramer Unit, Imperial Wildlife Area, a deep freshwater area (Table 1). Plots of mean yearly density for each group showed a general downward trend over the period for dabbling and diving ducks, whereas geese remained fairly constant (Fig. 3).

Many species of waterfowl exhibited declines in mean wintering counts for the recent survey period on a percentage basis (Table 2) as compared to the counts reported in Heitmeyer et al. (1989). However, only the Canvasback (*Aythya valisineria*) and Canada Goose (*Branta canadensis*) exhibited significant declines, and only the Ruddy Duck (*Oxyura jamaicensis*) exhibited a significant increase according to our criteria. Important sport species such as Northern Pintail (*Anas acuta*) showed virtually no difference between the two survey periods, and species such as white geese (Snow and Ross's; *Chen caerulescens* and *C. rossii*) and Northern Shoveler (*Anas clypeata*) approached significant increases.

Waterfowl band returns showed large numbers of dabbling ducks banded at the Salton Sea were recovered not only in the Pacific Flyway, as expected, but also in the Great Basin, Northern Great Plains, and the Texas Gulf Coast (Fig. 4). Few band returns were available for diving ducks and geese, but these tended to be concentrated in the Pacific Flyway.

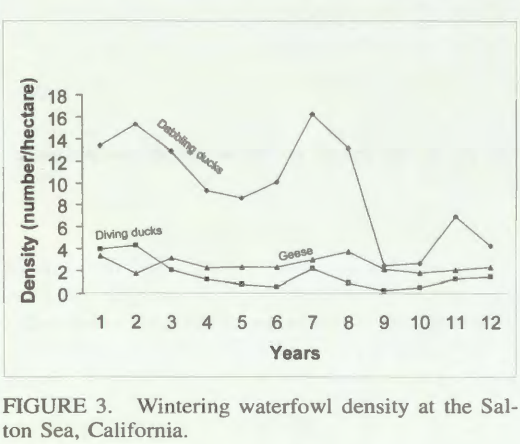

FIGURE 3. Wintering waterfowl density at the Salton Sea, California.

DISCUSSION

Recent information indicates that 36 of the more than 400 species of birds that have been recorded at the Salton Sea and its surrounding environs are waterfowl (Patten et al. 2003). Although the results presented here confirm that the Coachella and Imperial valleys encompassing the Salton Sea are important for wintering waterfowl, they fail to portray the full value and importance of this region. In particular, open water areas of the Salton Sea provide habitat for large numbers of Ruddy Ducks and Eared Grebes (Shuford et al. 2002b) and probably provide resting areas for many waterfowl and geese. These birds generally are missed during routine near-shore surveys. Jehl (1988) contended that the Salton Sea may be the most important wintering area for Eared Grebes in the Pacific Flyway, and it also may be very important for Ruddy Ducks (R. McKernan, pers. comm.). Heitmeyer et al. (1989) considered the Salton Sea region, with average waterfowl counts exceeding 75,000 birds, to be the second most important area for wintering waterfowl in California. The recent data presented here of average waterfowl numbers >100,000 individuals confirm this observation. However, densities of dabbling and diving ducks at the Salton Sea have declined over the period 1986 to 2000 whereas those of geese have remained relatively constant (Fig. 3).

Waterfowl density varied among survey areas of the Salton Sea (Table 1). Duck clubs on the southeastern shoreline and in the Brawley area had the greatest density of dabbling ducks, followed by SSNWR units, then other areas. Surprisingly, the Wister Unit of Imperial Wildlife Area, an area managed specifically for ducks, yielded very low densities of waterfowl. This may be real, or it could be caused by calculating densities on the basis of the entire management

TABLE 2. MEAN COUNTS AND RELATIVE % CHANGE OF WATERFOWL FROM MIDWINTER SURVEYS FOR IMPERIAL AND COACHELLA VALLEYS, CALIFORNIA

	1978–1987[a] mean	1986–2000 mean (N = 13)	95% confidence interval	SD	% change
Mallard *Anas platyrhynchos*	389	257	123–391	222	−34
Gadwall *A. strepera*	465	522	262–782	430	12
American Wigeon *A. americana*	5623	5080	2491–7668	4282	−10
Green-winged Teal *A. crecca*	3092	4301	2508–6095	2967	39
Cinnamon/Blue-winged Teal *A. cyanoptera/A. discors*	242	172	59–284	185	−29
Northern Shoveler *A. clypeata*	12,670	20,044	12,483–27,604	12,511	58
Northern Pintail *A. acuta*	14,091	14,108	8988–19,227	8471	−1
Redhead *Aythya americana*	336	262	75–450	310	−22
Canvasback *A. valisineria*	1691	488	65–910	699	−71
Scaup spp. *A. affinis/A. marila*	1760	1662	753–2571	1504	−6
Ring-necked Duck *A. collaris*	110	112	−70–294	301	2
Bufflehead *Bucephala albeola*	49	49	19–79	49	0
Ruddy Duck *Oxyura jamaicensis*	16,269	10,363	5665–15,060	7773	−37
Canada Goose *Branta canadensis*	3296	1663	427–2900	2046	−50
Snow/Ross's Goose *Chen* spp.	16,835	21,435	16,161–26,710	8728	27

[a] Data for the period 1978–1987 from Heitmeyer et al. (1989).

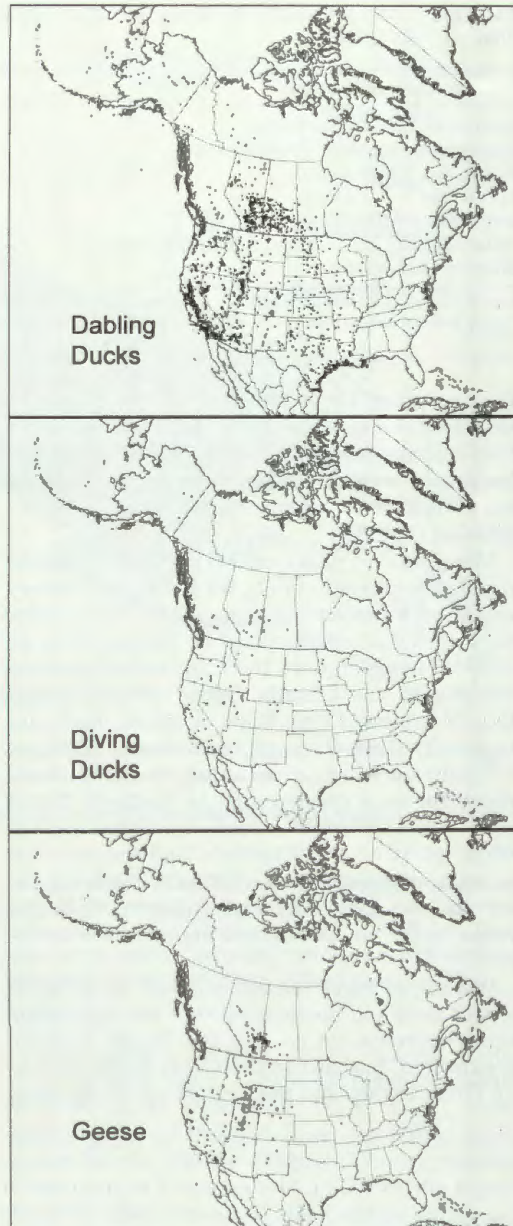

FIGURE 4. Band return locations for waterfowl banded at the Salton Sea. Top: dabbling ducks; Middle: diving ducks; Bottom: geese.

area rather than simply those areas flooded for waterfowl, also a potential source of bias for SSNWR density values. Estimates of flooded acreage are not routinely included as part of aerial survey information. SSNWR and Wister units abut the shoreline of the Sea, and this proximity allows birds to move freely between freshwater managed ponds and the Salton Sea, thus diluting densities of one area over another. The Brawley duck clubs are small discrete areas of known, flooded acreage located among agricultural lands far removed from other areas frequented by ducks. This probably serves to concentrate waterfowl at these sites. Still, the density values we report here for the duck clubs are two to three times greater than units intensively managed on wildlife areas. Until the practice was declared illegal in the early 1990s, federal regulations allowed baiting of waterfowl in the Imperial and Coachella valleys. This could explain greater concentrations of waterfowl at duck clubs, but only through the period into the early 1990s.

Certain nearshore areas of the Salton Sea are undoubtedly important to waterfowl, especially the shallow areas at the south near the Alamo River and New River deltas and at the north near the Whitewater River delta. The importance of these areas is not reflected in our analysis, though, because on aerial surveys data for these areas was combined with that for long shoreline segments, much of which tends to be deep water with a steep shoreline gradient.

Another inadequacy of the monthly aerial surveys is the inability to document the great numbers of migrants that pass through the Salton Sea and remain just long enough to rest and recuperate before continuing further south into México and Central America. The large size of the Sea (48 km long, 19–24 km wide) makes it difficult to gather information on birds using the open water, and at best only a snapshot of the use of various habitats can be derived. Jehl and McKernan (2002) commented on the large numbers of Eared Grebes that will suddenly appear almost overnight, increasing from hundreds to hundreds of thousands of birds, then just as rapidly vanish. Concurrent observations in the Gulf of California indicate that the increase in numbers of grebes there is roughly equivalent in magnitude to the decreases observed at the Salton Sea. Although certain species have experienced percentage gains or losses in numbers at the Salton Sea, midwinter waterfowl population totals have been relatively consistent at about 2% of the Pacific Flyway total for the period of 1975 to present.

Recently the Salton Sea has been the subject of intense scientific evaluations (Melack et al. 2001, Barnum et al. 2002) to provide information necessary for a restoration project proposed by the U.S. Department of Interior and the Salton Sea Authority. A great emphasis has been placed on quantifying the importance of the Salton Sea within larger regional or flyway contexts, without which planning efforts cannot adequately assess impacts of restoration alternatives and be held accountable for providing sufficient mitigation measures. The geographic location of the Salton Sea is a key factor to its importance. Biogeographically, the Salton Sea and its adjacent valleys behave as a northern extension of the Gulf of California. The Sea and its adjoining valleys lie below sea level. A slight rise south of the Salton Sea from ancient alluvial flows of the Colorado River serves as the only physical barrier to the Gulf of California. Surrounding the Salton Sea on three sides are high mountains. Strong winds through this geographic setting probably acts as a natural funnel for migratory birds. Because of its strategic location and the loss of over 95% of California's historic wetlands (Frayer et al. 1989, Dahl et al. 1991), the Salton Sea provides exceptionally high values for birds as a migratory stopover, wintering area, and breeding habitat. Loss of the Salton Sea as viable habitat because of failure or delay in stabilizing salinity and nutrient reduction would be a severe setback to efforts for waterfowl conservation and would result in further loss of valuable wetlands for innumerable migrating, wintering, and resident waterbirds. The continued decline in wetland acreage will only exacerbate problems such as disease and contaminant exposure by forcing more and more birds into smaller and smaller areas.

ACKNOWLEDGMENTS

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LANDBIRD MIGRATION AT THE SALTON SEA: THE VALUE OF DESERT RIPARIAN HABITAT

MAUREEN E. FLANNERY, SUSAN L. GUERS, THOMAS GARDALI, NADAV NUR, AND GEOFFREY R. GEUPEL

Abstract. The detection of long-term population declines in some species of Neotropical migrant passerines has prompted recent efforts to better understand the use of stopover habitats by birds. Such investigation is important in the development of comprehensive conservation strategies for migrants. In 1999, we mist-netted birds at the Salton Sea during spring and fall migration periods to determine the use of this area's desert riparian habitats by landbirds as migratory stopover sites. During spring, we captured 51 species at an overall rate of 215.6 birds/100 net-hrs, while in fall we captured 49 species at an overall rate of 73.4 birds/100 net-hrs. Migrants accounted for 89% of the spring and 80% of the fall captures. The capture rates for some migrant species were higher at the Salton Sea than at other migration monitoring stations in California during the month of May and in the fall. Over half of recaptured individuals showed positive changes in mass during the stopover period. Warbling Vireo (*Vireo gilvus*), and Orange-crowned (*Vermivora celata*), Yellow (*Dendroica petechia*), and Wilson's (*Wilsonia pusilla*) warblers showed a negative relationship between mass change and date of capture in spring. In fall, Orange-crowned and Yellow warblers showed a positive relationship for mass change and time of day. These preliminary results suggest that the desert riparian areas of the Salton Sea serve as important stopover sites for passerines during migration.

Key Words: desert riparian habitat; migration; mist-netting; neotropical migrants; Orange-crowned Warbler; Salton Sea; stopover ecology; Warbling Vireo; Wilson's Warbler; Yellow Warbler.

MIGRACIÓN DE AVES TERRESTRES EN EL MAR SALTON: EL VALOR DE HÁBITATS RIBEREÑOS DE DESIERTO

Resumen. La detección de reducciones a largo plazo en las poblaciones de algunas especies de paseriformes migratorias del Neotrópico ha impulsado recientes esfuerzos para entender mejor el uso de hábitats de parada por estas aves. Dicha investigación es importante para el desarrollo de amplias estrategias de conservación de aves migratorias. En 1999, capturamos aves con redes de niebla en el Mar Salton durante los periodos de migración de primavera y otoño para determinar el uso de los hábitats ribereños de desierto como sitios de parada. Durante la primavera, capturamos 51 especies a una tasa total de 215.6 aves/100 horas/red, mientras que durante el otoño capturamos 49 especies a una tasa total de 73.4 aves/100 horas/red. Las aves migratorias constituyeron 89% de las capturas de primavera y 80% de las de otoño. La tasa de captura de algunas especies fue mayor en el Mar Salton que en otras estaciones de monitoreo de migración en California durante el mes de Mayo y durante el otoño. Más de la mitad de los individuos recapturados mostraron cambios positivos en la masa corporal durante el período de parada. El Vireo Gorjeador (*Vireo gilvus*) y los Chipes Corona Naranja (*Vermivora celata*), Amarillo (*Dendroica petechia*) y Corona Negra (*Wilsonia pusilla*) mostraron una relación negativa entre el cambio de masa corporal y la fecha de captura en la primavera. En el otoño, los Chipes Corona Naranja y Amarillo mostraron una relación positiva entre el cambio de masa corporal y la hora del día. Estos resultados preliminares sugieren que las áreas ribereñas de desierto en el Mar Salton sirven como importantes sitios de parada para paseriformes durante la migración.

Palabras claves: captura con redes de niebla; Chipe Amarillo; Chipe Corona Naranja; Chipe Corona Negra; ecología de sitios de parada; hábitats ribereños de desierto; Mar Salton; migración; migratorias Neotropicales; Vireo Gorjeador.

Long-term population declines detected in some species of neotropical migrant passerines (Robbins et al. 1989, Askins et al. 1990, Finch and Stangel 1993) have helped to focus recent research efforts on the migration ecology of these species. In addition to events on the wintering grounds and during the breeding season, changes in habitat at migration stopover sites contribute to the pressures affecting the population dynamics of migrant birds (Moore 2000). Information on stopover habitat use by birds is important in the development of comprehensive strategies to reverse these population declines. The identification of high quality habitat types and specific sites as well as understanding the habitat use, behavioral ecology, and energy constraints on passerines during migration may be critical to long-term conservation efforts (Moore 2000, Petit 2000).

The Salton Sea, located within the Colorado Desert of southern California, is well known as an important migratory stopover and wintering site for many species of shorebirds and waterbirds (Garrett and Dunn 1981, Rosenberg et al.

1991, Shuford et al. *this volume*), yet little is known about the value of surrounding riparian areas to migrating passerines. Here, we present species capture rates by site and age obtained during mist-netting operations in 1999 to assess the use of the area as a stopover site for migrant landbirds. We examined changes in mass to determine the extent to which birds were able to replenish their fat reserves at the Salton Sea. Since most transients at stopover sites are not recaptured, changes in mass cannot always be compared over a stopover period (Winker et al. 1992a). Thus, similar to studies by Woodrey and Moore (1997) and Yong et al. (1998), we examined the relationship between body mass and time of day, making the prediction that birds at a stopover site will show diel fluctuations in mass. We also predicted that changes in mass would differ between migrating individuals and birds overwintering in the area, as migrants replenish and store fat reserves necessary to meet the energetic requirements of migration. We also examined the relationship between changes in mass and date of capture to determine if they reflected differences in individual condition.

METHODS

STUDY AREA

The Salton Sea lies within the Coachella and Imperial valleys of California (Fig. 1), one of the most important agricultural areas in the state (Hurlbert 1997). Here an elaborate network of irrigation canals and a few natural waterways support a highly modified but extensive riparian system, especially along the southeastern shore.

We monitored passerine migration at two sites along the southeastern shoreline of the Salton Sea (Fig. 1). In spring our study area was located at the Wister Unit of the Imperial Wildlife Area (33°18′N, 115°35′W). Here, the riparian habitat was dominated by exotic tamarisk (*Tamarix ramosissima*), with some saltbush (*Atriplex lentiformes*) in the understory. In fall we mist-netted at the Sonny Bono Salton Sea National Wildlife Refuge (SSNWR) headquarters (33°10′N, 115°37′W). The habitat at this site consisted predominantly of native species including Fremont cottonwood (*Populus fremontii*), blue palo verde (*Cercidium floridium*), honey and screwbean mesquite (*Prosopsis glandulosa* and *P. pubescens*), and willow (*Salix* spp.), with an understory of arrow weed (*Tessaria sericea*), saltbush, and tamarisk. Both study locations were approximately 70 m below sea level.

NETTING PROTOCOL

We operated ten standard mist-nets in spring from 6 April to 26 May and in fall from 3 September to 29 October 1999. Nets were at least 10 m apart within contiguous and homogenous habitat, and were opened 15 min after sunrise and checked every 30 min for five hrs during the spring. In fall, to avoid heat stress, nets were opened at first light, usually 15 min before sunrise, and checked every 20 min for five hrs. Each bird received a standard United States Geological Service (USGS) aluminum leg-band, and was identified to species, age, and, when possible, subspecies and sex following Pyle (1997). Each individual was weighed on a Pesola spring scale to the nearest 0.1 g.

DATA ANALYSIS

We standardized our results by calculating the number of initial captures/100 net-hrs of mist-netting effort, which allowed us to compare capture rates between sites at the Salton Sea and with other sites in California.

We estimated the stopover length for three species in each season following the methods by Biebach et al. (1986). Minimum stopover length was estimated by calculating the time interval between the date of initial capture and final capture (Moore and Kerlinger 1987). Hence, our estimate of stopover length is conservative. We omitted from recapture analysis two individual Orange-crowned Warblers (see Appendix for scientific names) with stopover lengths of 13 d and 40 d, assuming that birds with a stopover length greater than 10 d are most likely winter residents, based on previously published data and stopover duration of known migrants at the Salton Sea (see references in Gardali et al. 2000; PRBO, unpubl. data). We estimated change in body mass as the difference between mass at initial capture and mass at final capture.

We restricted our analysis of the relationship between mass change and time of day and between mass change and date of capture to six species with a sample size of at least 50 captures in a season. We used linear regression to describe the relationships between mass and date of capture and mass and age at capture. We then examined the relationship between mass and time of capture controlling for date in the spring and age in the fall because linear regression revealed a relationship between these factors and changes in mass. We investigated whether these relationships were non-linear by testing for a significant quadratic coefficient for time of capture in the presence of a linear term. In no case was there a significant quadratic coefficient for time of capture. Data were log transformed when necessary to satisfy assumptions of normality and variance homogeneity. All regression analyses were carried out using the program STATA (STATA Corp. 1997). Significance was assumed at the $P < 0.05$ level. Values presented are mean ± SE.

RESULTS

During spring 1999, we mist-netted for a total of 723.5 net-hrs. We captured 1,560 individuals of 51 species, for a total capture rate of 215.6 birds/100 net hrs. In addition, 106 individuals were recaptured. Migrants accounted for 89% of total captures, while residents accounted for 11%. The most numerous spring migrant species were Warbling Vireos and Orange-crowned, Yellow, Audubon's, and Wilson's warblers (Appendix).

In fall 1999, we mist-netted for a total of 1161 net-hrs. We captured 852 individuals of 49 species, for a total capture rate of 73.4 birds/100

FIGURE 1. Mist-netting locations at the Salton Sea, California, in spring and fall 1999.

net-hrs. In addition, 88 individuals were recaptured. Migrant birds accounted for 80% of all captures, while resident birds accounted for 20%. The most numerous fall migrant species were Orange-crowned, Yellow, Audubon's, and Wilson's warblers (Appendix). In fall, hatch-year birds accounted for 45% of total captures, after-hatch-year birds 35%, and birds that could not be reliably aged 20%.

Capture rates of Yellow and Audubon's warblers were similar at the Wister Unit and the SSNWR, but capture rates of Warbling Vireos and Orange-crowned and Wilson's warblers were much greater at the Wister Unit than at the SSNWR (Table 1). At the Wister Unit, Wilson's Warblers were mist-netted at a rate of 84.31 birds/100 net-hrs representing 39% of total captures, whereas at SSNWR they accounted for only 5.4% of captures at a rate of 3.96 birds/100 net-hrs.

The timing of migration varied among species (Fig. 2a–e). In spring, peak capture rates of Warbling Vireos and Yellow and Wilson's warblers occurred in May, while higher rates for Orange-crowned and Audubon's warblers occurred in April. In fall, migration for all species peaked in

TABLE 1. CAPTURE RATES (BIRDS/100 NET-HRS) OF FIVE OF THE MOST COMMON MIGRANT SPECIES AT THE SALTON SEA DURING SPRING (723.5 NET-HRS) AND FALL (1161.0 NET-HRS) 1999

Species	April	May	Spring mean	September	October	Fall mean
Warbling Vireo	6.09	42.00	19.21	0.34	0.00	0.17
Orange-crowned Warbler	35.70	7.56	25.43	12.96	12.01	12.49
Yellow Warbler	1.74	29.51	11.89	16.88	3.66	10.34
Audubon's Warbler	13.28	0.00	8.43	0.68	29.59	14.47
Wilson's Warbler	99.28	171.77	84.31	6.48	1.39	3.96

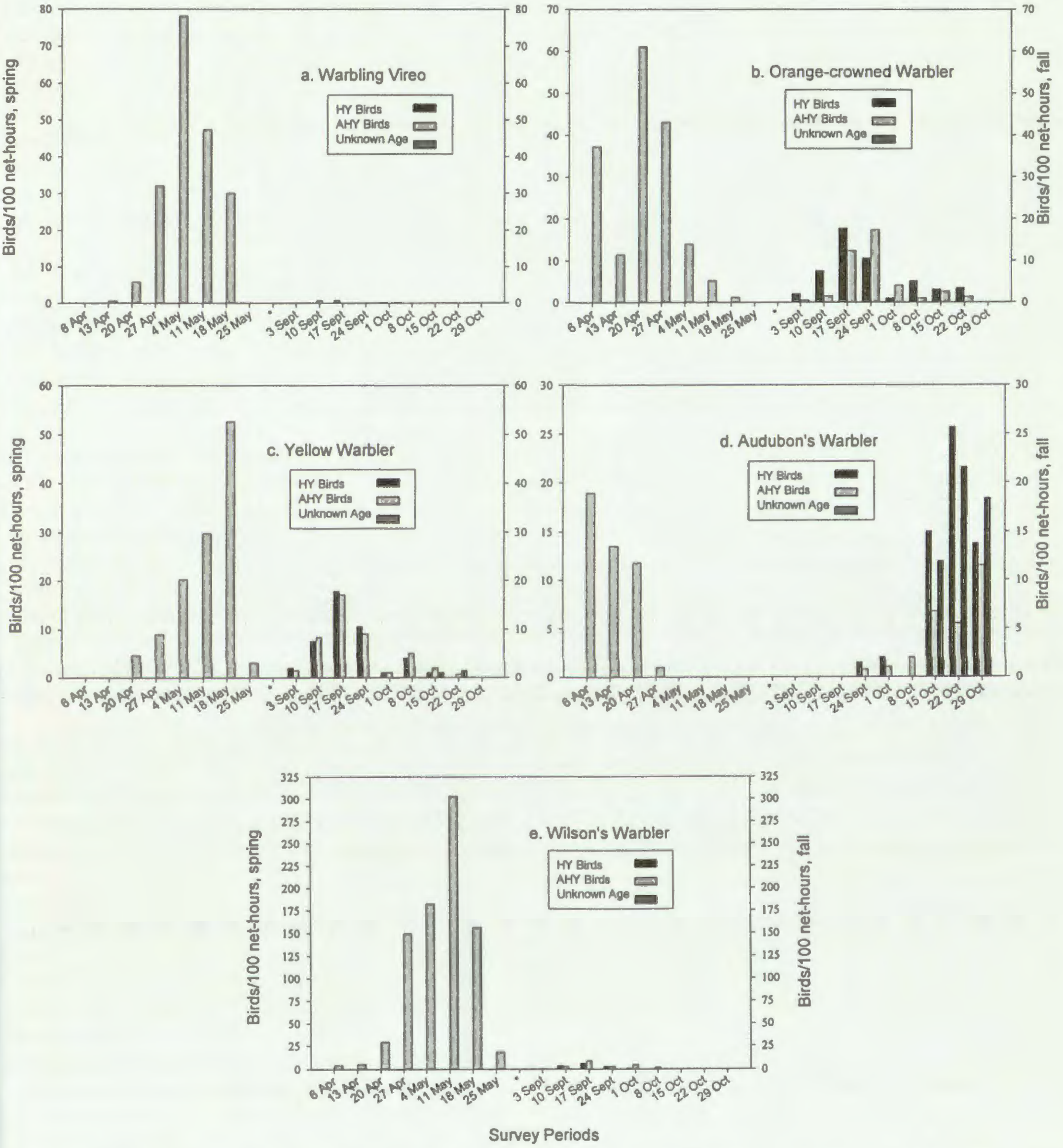

FIGURE 2. Phenology of the (a) Warbling Vireo, (b) Orange-crowned Warbler, (c) Yellow Warbler, (d) Audubon's Warbler, and (e) Wilson's Warbler at the Salton Sea in spring and fall 1999.

mid-September except for Audubon's Warblers, which peaked in late October.

In spring, the average stopover length for Warbling Vireo (N = 3), Orange-crowned Warbler (N = 5), and Wilson's Warbler (N = 12) was 4 d ± 1.53, 6.4 d ± 1.40, and 3.9 d ± 0.50, respectively. In fall, stopover lengths averaged 4.6 d ± 0.69 for Orange-crowned Warbler (N = 9), 3.7 d ± 0.67 for Yellow Warbler (N = 3), and 3.8 d ± 1.11 for Wilson's Warbler (N = 5). The overall mean gain in mass for all recaptures was 0.67 g ± 0.12 while overall loss was 0.37 g ± 0.06. Of the 37 recaptured individuals, 51.4% gained mass, 32.4% lost mass, and 16.2% had no change in mass (Fig. 3a–f). Maximum gains of 1.6 g were observed in one Wilson's Warbler in spring and two Orange-crowned Warblers in fall.

In spring, Audubon's Warblers exhibited a positive relationship between mass and date of capture while all others exhibited a negative relationship (Table 2). In fall, we found no such relationship for any species. In spring, no species showed a relationship between mass and time of capture (Table 3) except for Warbling Vireo, which approached significance and exhibited a positive relationship ($P = 0.057$). In fall, we also examined the relationship between mass and age at capture and found the only significant relationship in Wilson's Warblers ($\beta = 0.74 \pm 0.17$, $P < 0.001$, $N = 51$), with a mean mass of 7.9 g ± 0.10 for adults and 7.2 g ± 0.14 for young birds. Both adult and young Yellow Warblers exhibited significant positive relationships between mass and time of capture. Orange-crowned Warblers overall showed a significant relationship between mass and time of capture, but when examined separately by age class only adults demonstrated a significant positive relationship (Table 4).

DISCUSSION

Capture rates showed differences in overall abundance between the two mist-netting sites with three times as many birds captured at the Wister Unit than at the SSNWR. But because differences in capture rates may be attributed to differences in season, habitat type, migratory route, annual weather patterns, and/or methodology, we cannot conclude whether these differences in abundance represent site-differences, seasonal-differences or an interaction of both site and season. However, in both seasons and at both sites, species richness and composition were similar and positive changes in mass occurred overall, suggesting that our study sites were of similar quality.

Peak periods of migration varied among species with the majority of spring migrants recorded during the month of May (Fig. 2a–e). The patterns that we observed for Yellow and Wilson's warblers are similar to those recorded for these species in the Colorado River Valley, a desert riparian area also recognized as an important migratory stopover site (Rosenberg et al. 1991).

The relatively high percent of after-hatch-year birds (35%) recorded in the fall at the Salton Sea contrasts markedly with sites along coastal routes in California where percentages of after-hatch-year birds ranged from 5–15% (Ralph 1971, Stewart et al. 1974). The higher proportion of young migrating along the coast, termed the "coastal effect," suggests that the majority of young migrants occupy the periphery of a migration route (Ralph 1981, Woodrey 2000). The more equitable proportions of young and adult migrants captured at the Salton Sea indicates that the area may be located within the mainstream of an important migratory pathway for many species, rather than lying along the periphery.

Our capture rates of Warbling Vireos and Yellow and Wilson's warblers (Table 1) were higher than those observed at five other mist-netting stations in California (two coastal, two central valley, and one eastern Sierra) in May 1999 (Big Sur Ornithology Lab, unpubl. data; PRBO, unpubl. data) and at one station in the Mojave Desert in fall 1999 (S. J. Myers, pers. comm.). In May, our capture rate for Wilson's Warbler (171.8 birds/100 net-hrs) was particularly high compared to the range (5.3 to 24.0 birds/100 net-hrs) recorded at these other sites. While we acknowledge that variation in capture rates can be influenced by factors other than abundance (Remsen and Good 1996), these large differences suggest that in May of 1999, several migrant species were more abundant at the Salton Sea than at other riparian mist-netting sites in California.

One of the greatest constraints to migrants is the ability to obtain enough food to build fat stores (Moore et al. 1995, Woodrey and Moore 1997). Many neotropical migrants are unable to carry enough fat reserves to allow them to make the entire journey between their wintering and breeding grounds in a single flight, and therefore need to stop at various points along the way (Berthold 1975, Winker et al. 1992a). These stopover sites are important for migrating landbirds, especially if those birds are facing significant ecological barriers. Many studies have shown that accumulation of fat reserves for birds migrating over vast deserts is similar to that over large bodies of water, such as the Gulf of Mexico (Moore and Kerlinger 1987, Moore et al. 1995, Finch and Yong 2000). Thus, the desert riparian habitat surrounding the Salton Sea may

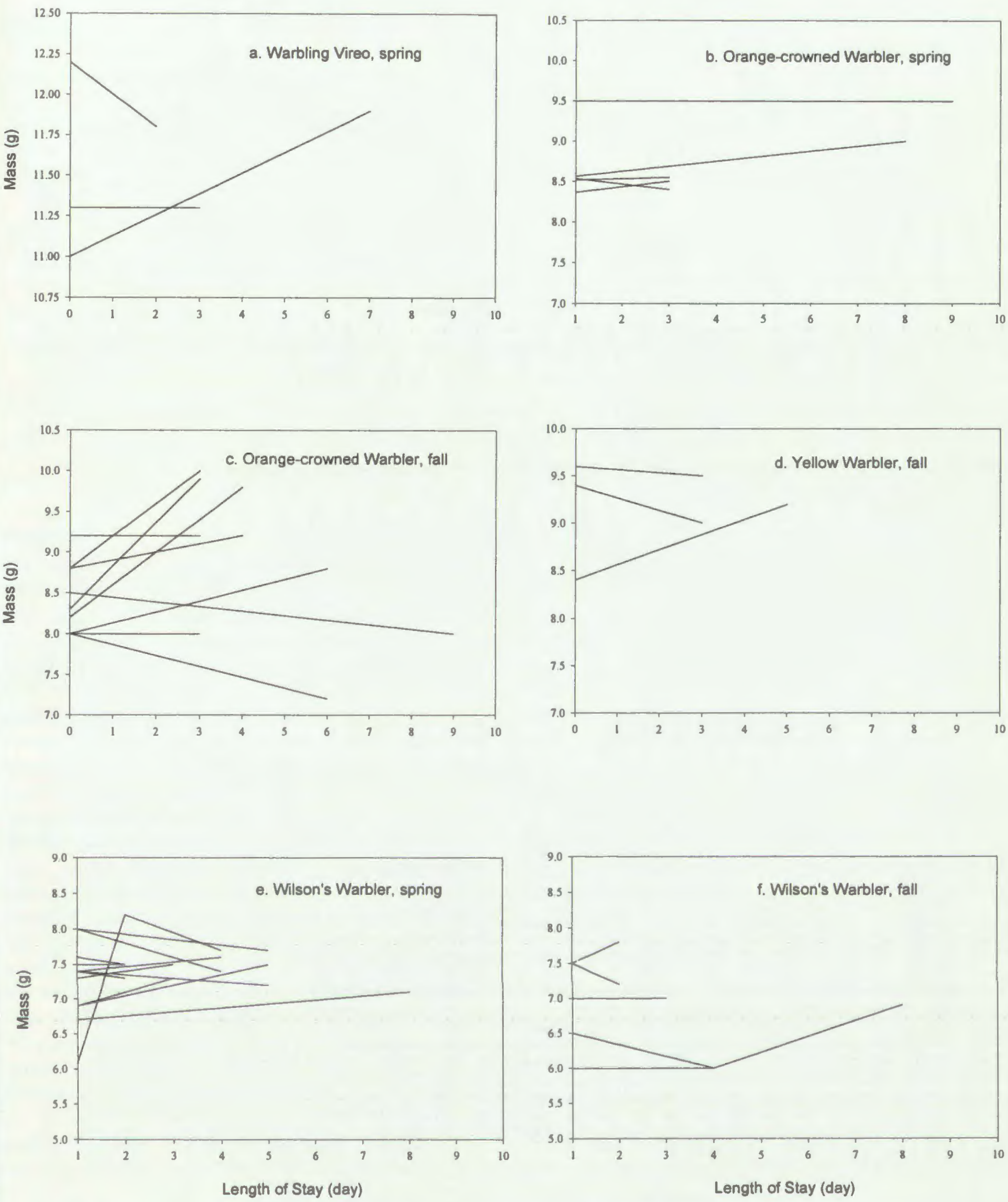

FIGURE 3. Changes in mass of recaptured individuals of (a) Warbling Vireo in spring, (b) Orange-crowned Warbler in spring, (c) Orange-crowned Warbler in fall, (d) Yellow Warbler in fall, (e) Wilson's Warbler in spring, and (f) Wilson's Warbler in fall during their stopover period at the Salton Sea.

be especially important for western birds during migration since it may be one of the last stopover sites before encountering major ecological barriers—the Sonoran Desert if heading south, or the Mojave Desert if heading north.

Based on our recapture analysis, most individuals showed average gains in mass from the time of their initial capture to their final capture while at the Salton Sea (Fig. 3a–f). In Wilson's Warbler, our most common spring migrant, we detected no relationship between mass change and stopover length. As has been suggested in other studies (Bibby and Green 1980, Moore and Yong 1991, Petit 2000), the late arrival of Wil-

TABLE 2. RELATIONSHIP BETWEEN MASS AND DATE OF CAPTURE FOR SPECIES WITH ≥50 INDIVIDUALS; SALTON SEA SPRING AND FALL, 1999

Species	N	Slope (g/d)	SE	P	Adjusted[a] R^2
Spring					
Warbling Vireo	106	−0.031	0.0095	0.002	0.082
Orange-crowned Warbler	165	−0.018	0.0052	0.001	0.060
Yellow Warbler	79	−0.032	0.0080	<0.001	0.160
Audubon's Warbler	57	0.004	0.0017	0.020	0.078
Wilson's Warbler[b]	515	−0.027	0.0021	<0.001	0.250
Fall					
Orange-crowned Warbler	158	0.005	0.005	0.35	−0.001
Yellow Warbler	123	0.004	0.008	0.59	−0.006
Audubon's Warbler	167	−0.018	0.011	0.11	0.016
Wilson's Warbler	51	0.016	0.014	0.24	0.009
Gambel's White-crowned Sparrow	63	0.024	0.027	0.38	−0.004

[a] Adjusted R^2 refers to the statistical model that includes the effect of date.
[b] Adjusted R^2 and P-values reported are derived from statistical tests carried out on log transformed mass (see text).

son's Warblers relative to other species (Fig. 2e) and their high concentration may have increased competition for already diminished food resources at the Salton Sea in spring. Wilson's Warblers in fall were the only species that showed a significant relationship between age and mass, with older birds heavier than younger birds, which may have been another confounding factor affecting trends in mass change. More study is needed to examine the relationships among phenology, abundance, and food resources for birds during migration.

In spring, birds that arrived later at the Salton Sea had significantly less mass than those that arrived earlier, suggesting that physical condition declined with arrival date (Marra et al. 1998). No such relationship was observed for any species in fall. Factors that may have confounded our results, however, include variation in body size due to age, sex, and subspecies. In fall, the Salton Sea area appeared to provide suitable foraging opportunities to replenish fat reserves over the course of a day for Orange-crowned and Yellow warblers (Table 4). We did not find similar trends for any other species in either season. The fact that Orange-crowned Warblers, Audubon's Warblers, and Gambel's White-crowned Sparrows are common winter residents at the Salton Sea may have confounded our results (Garrett and Dunn 1981). We expected the rate of mass gain for birds still on their migratory journey to be larger than those at or near their winter residence; thus the fact that Orange-crowned Warblers in fall showed a positive trend in change in mass over time of day suggests that our sample consisted mostly of transients.

Our preliminary results show a diverse community of landbirds using the Salton Sea during spring and fall migration. Our high capture rates in conjunction with an overall positive change in mass suggest that the desert riparian habitats of the Salton Sea, although highly modified, are valuable to many species of migrant passerines. Because abundance data alone cannot assess the suitability of habitats (Hutto 2000), we recommend seasonal, long-term monitoring efforts be established at the Salton Sea to examine songbird use of a variety of native and exotic habitats (Hutto 1985, Winker et al. 1992b, Yong et al. 1998). Desert riparian habitats of the Salton Sea should be considered in all conservation and res-

TABLE 3. RELATIONSHIP BETWEEN MASS AND TIME OF CAPTURE, CONTROLLING FOR LINEAR TREND IN DATE; SALTON SEA SPRING, 1999

Species	N	Slope (g/hr)	SE	P	Adjusted[a] R^2
Warbling Vireo	106	0.012	0.0062	0.057	0.100
Orange-crowned Warbler	165	0.0021	0.0040	0.61	0.056
Yellow Warbler	79	−0.0026	0.0060	0.67	0.150
Audubon's Warbler[b]	57	0.0020	0.0078	0.76	0.063
Wilson's Warbler[b]	515	0.0003	0.0017	0.85	0.250

[a] Adjusted R^2 refers to the statistical model that includes the effect of time of capture and date (df = 2).
[b] Adjusted R^2 and P-values reported are derived from statistical tests carried out on log transformed mass (see text).