E [illegible] D CONSERVATION OF BIRDS OF THE SALTON SINK: AN ENDANGERED ECOSYSTEM

W. DAVID SHUFORD AND KATHY C. MOLINA, EDITORS

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PREFACE

This volume is the result of two symposia held on the past and present status of the avifauna of the Salton Sea: the first in the Imperial Valley in the summer of 1997, sponsored by the Western Field Ornithologists, the second in Riverside in spring of 2000, hosted by the Cooper Ornithological Society. In the introductory chapter that follows we summarize the dynamic history of the Salton Sink and Colorado River Delta, the key environmental issues in the region, and the genesis of these symposia and the papers in this volume.

Financial support for the volume was provided by the Cooper Ornithological Society, PRBO Conservation Science, U.S. Environmental Protection Agency (grant #X-98955101-0), and Western Field Ornithologists. We are grateful to Philip Unitt and Michael A. Patten for organizing the symposia in 1997 and 2000, respectively. We are greatly indebted to John Rotenberry, STUDIES IN AVIAN BIOLOGY editor, for his professional and collegial guidance during this project, and to Eugenia McNaughton, EPA Environmental Scientist, for support of this volume. We thank Dan Anderson for his early encouragement for the volume, Eduardo Palacios, Susana Peluc, and Jill Deppe for the Spanish translation of abstracts, and Viola Toniolo for editorial assistance. We also thank Lisa Lewis and the University of Redlands for assistance with maps, David Janiger and Claire Peaslee for help with images, and Sarah Warnock for modifying logos. We are grateful to the following individuals for critical reviews of manuscripts: Dan Anderson, Doug Barnum, Charles Collins, Sam Fitton, Milton Friend, Kimball L. Garrett, Steve N. G. Howell, Stuart Hurlbert, Joseph R. Jehl, Jr., John Kelly, Guy McCaskie, Miguel Mora, Brian Millsap, Steve Myers, Lewis Oring, Eduardo Palacios, Michael Patten, Marilyn Spalding, Larry Spear, Lynne Stenzel, Ken Sturm, John Takekawa, Philip Unitt, and Brian Walton. We are indebted to N. John Schmitt and Jonathan Alderfer for contributing original artwork, and to John Whitehead for the cover photo. We thank Tim Manolis for sharing his artwork as well.

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We dedicate this volume to Norman D. Hogg (1947–1996). Norm grew up in the Coachella Valley and continued to hunt, farm, and conduct bird studies at the north end of the Salton Sea throughout his all too brief adult life. His knowledge and appreciation of the Salton Sea's habitats and avifauna was vast and profound. Norm was a natural and gifted teacher; the humor and enthusiasm with which he shared his keen insight on the Sea will always be treasured.

Kathy C. Molina
W. David Shuford

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INTRODUCTION

KATHY C. MOLINA AND W. DAVID SHUFORD

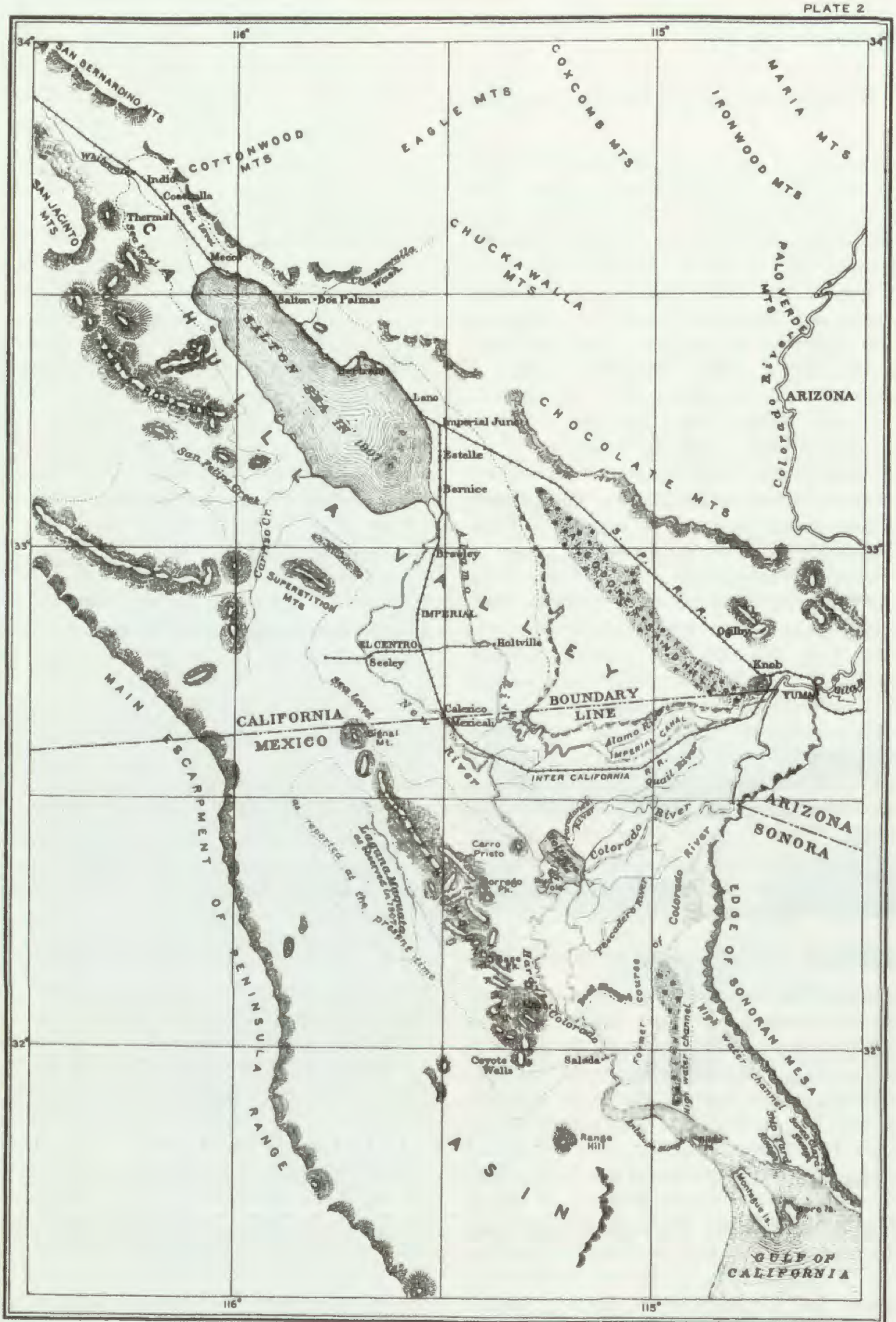
The ecosystems of the Colorado River Delta Region (Sykes 1937), from California's Salton Sea to the delta of the Colorado River in Sonora and Baja California, Mexico, are characterized by abundant and species-rich avifaunas, a history of massive natural and anthropogenic environmental changes, and intense scientific and political discourse regarding the region's near and long-term future. Given today's imperiled status of the ecosystems of the Salton Sink (the below-sea-level basin within which the Sea lies) and Colorado River Delta, and the recent focus on the maintenance and enhancement of natural resource values in this broad region, current and historical biological data are an especially valuable commodity. As few published accounts of recent faunal investigations exist for this area, we recognized the need for such baseline documentation. Hence, our objectives for this volume were (1) to organize into a single publication a series of contributions that not only complement recent efforts to establish baseline data on the Sea's avifauna (Shuford et al. 1999, 2000; Patten et al. 2003) but also impart additional depth and long-term perspective to these works, and (2) to emphasize the continued importance of the Salton Sink to avian populations and its connectivity to important avian habitats throughout the Colorado River Delta Region, the arid West, and the larger Pacific Flyway.

GEOGRAPHIC AND ECOLOGIC SETTING

To highlight the complexity of the unique Salton Sink ecosystems, and their often forgotten relationship to the greater Colorado River Delta Region, we review the geography and physical characteristics of the region, the historical patterns of land use in the Sink, and a chronology of events culminating in the proposal of various engineering projects to maintain the Salton Sea.

The Colorado River Delta Region, of which the Salton Sink occupies the northwestern portion, is a narrow rift valley or trough extending from San Gorgonio Pass, at the foot of the San Jacinto and San Bernardino mountains, southward to the mouth of the Colorado River and into the Gulf of California (Fig. 1). It is bordered on the west by the peninsular ranges of southern California and northern Baja California, and on the east by the Little San Bernardino, Orocopia, and Chocolate mountains of California and the Gran Desierto (or Sonoran Mesa) in northwestern Sonora, Mexico. The Colorado River Delta Region occupies an area of some 8612 km^2 (3325 mi^2; Sykes 1937). Here the main course of the Colorado River follows the region's southeastern flank.

The present day Salton Sea, a large saline lake lying between the Coachella and Imperial valleys (the northern and southern portions of the Salton Sink, respectively), is the largest permanent water body found in the Colorado River Delta Region, apart from the Gulf itself. The path of the Colorado River has historically meandered, and at various times it flowed northwestward directly into the Salton Sink (Sykes 1937), creating a large ephemeral body of water called Lake Cahuilla (Patten and Patten-Smith *this volume*). The highest surface elevation of the most recent lake was about −60.7 m in 1905–1907, when the Salton Sink last received the entire flow of the river as winter floods overran the banks of the earthen diversion channel to the Imperial Valley (Sykes 1937); its present day elevation is about −69.2 m (Imperial Irrigation District, unpubl. data). The Salton Sea is approximately 56 km in length and nearly 24 km across at its widest point, with a surface area of about 984 km^2 and a maximum depth of about 15.2 m (U.S. Bureau of Reclamation 1997). Water level in this terminal lake is maintained today by an equilibrium between agricultural and municipal wastewater inflows and an evaporation rate of about 1.8 m per year. Salinity of the Sea has risen over time and today ranges from 38 to 44 mg l^{-1}, which is about 25% saltier than the Pacific Ocean (U.S. Bureau of Reclamation 1997). Important permanent inflows to the Sea occur from the Whitewater (Fig. 2), Alamo, and New rivers, and a number of agricultural drainage canals that terminate mainly along the southeastern border of the Sea. Seasonal freshwater flows from Salt Creek and, especially, San Felipe Creek and Wash can be substantial, depending on rainfall in the watershed. The climate of the Sink is characterized by mild dry winters (mean minimum temperature of 7°C for November through February) and extremely hot, dry summers (mean maximum temperature of 40°C, June through September; http://www.wrcc.dri.edu). Annual precipitation (measured at Imperial, 30 km south of the Sea) averages about 7.5 cm and occurs mainly from August through March. An extensive system of irrigation canals allows intensive flood-irrigated agriculture to be practiced year round.



Compiled by G. Sykes

MAP OF THE DESERT OF THE COLORADO

FIGURE 1. Map of the Colorado River Delta Region adapted from that compiled by G. Sykes in MacDougal (1914) depicting the extent of the Salton Trough.

FIGURE 2. Aerial view of the west (foreground) and east levees of the Whitewater River delta at the north end of the Salton Sea. Photo by K. C. Molina, January 1993.

The initial fish fauna of the Salton Sea consisted of freshwater species present in the Colorado River drainage, such as carp (*Cyprinus carpio*) and striped mullet (*Mugil cephalus*), which were introduced during the filling of the basin in 1905–1907 (Walker et al. 1961). Although a variety of species of game fish were released into the Sea beginning in 1929 in an effort to establish a sportfishery, the present day fish community was largely a result of introductions of three marine species, orangemouth corvina (*Cynoscion xanthulus*), bairdiella (*Bairdiella icistius*), and sargo (*Anisotremus davidsoni*), made by the California Department of Fish and Game in 1950 and 1951 (Walker et al. 1961), and later of tilapia (*Oreochromis mossambicus*; Riedel et al. 2002).

Because of the Salton Sea's challenging environment with its wide annual range in water temperature, seasonal anoxia in deeper waters, and the odd chemical composition of its marine-like waters, the invertebrate fauna of the Salton Sea is limited to a few numerically important species (Linsley and Carpelan 1961). These are the pileworm *Neanthes succinea,* the copepod *Cyclops dimorphus,* and the barnacle *Balanus amphitrite. Neanthes,* believed introduced in 1930 along with other faunal introductions by California Fish and Game, was the most important prey of carnivorous fish. *Cyclops* was probably an important food source, especially in summer and fall, for filter feeders such as young bairdiella. The larval stage of *Balanus,* although prevalent, was probably not an important food source for fish (Linsley and Carpelan 1961). A 1999 investigation of invertebrate fauna (Detwiler et al. 2002) found *Neanthes* and *Balanus* to still predominate. These authors reported two amphipods (*Gammarus mucronatus* and *Corophium louisianum*) and the polychaete *Streblospio benedicti* to also be numerous; all were thought to be established after 1956.

Several other important permanent wetlands are associated with the Salton Sea. The Finney-Ramer Unit of the Imperial Wildlife Area (Fig. 3), containing recreation lakes north of Brawley, and the Wister Unit along the southeastern shore are managed by the California Department of Fish and Game. The key components of wildlife habitat at the Sonny Bono Salton Sea National Wildlife Refuge include the Hazard Unit (Fig. 4) and impoundments at Units 1 and 2 (Fig. 5). Fig Lagoon, near Seeley, is managed by the Imperial Irrigation District. Several experimental projects in various stages of development along the New River (Miller 2002) provide riparian

FIGURE 3. Heronry, comprised of mainly Cattle Egrets, at Finney Lake of the Imperial Wildlife Area. Photo by A. Small, May 1992.

and additional wetland habitats in the Imperial Valley, as do a number of seasonal wetlands on private lands.

Important avian habitats in the Salton Sink are not limited to the Sea or its associated wetlands. Water was first diverted from the Colorado River to farmland in the Imperial Valley in 1901, and by 1927 it was being delivered to about 1575 km^2 of cropland (http://www.iid.com/aboutiid/history-how.html; Imperial Irrigation District, unpubl. data). Today an average of nearly 1900 km^2 of land in the Imperial Valley alone are irrigated annually (http://www.iid.com/water/irr-agriculture.html). Although the extent of irrigated agriculture has leveled off in recent decades, agricultural practices have intensified with more multi-cropping on the same land in a single year (C. Sidhu, Imperial Irrigation District, pers. comm.). Because of the great extent of flood-irrigated land combined with the high rates of crop turnover, particularly in the Imperial Valley, a large and varied array of feeding and resting habitats are nearly continuously available to many waterbird and shorebird species. Some of these, such as the Cattle Egret (*Bubulcus ibis*), White-faced Ibis (*Plegadis chihi*), Long-billed Curlew (*Numenius americanus*), and Ring-billed Gull (*Larus delawarensis*), congregate in these flooded fields in large numbers. Agricultural lands, especially in the Imperial Valley, support significant populations of several species that have declined elsewhere in the state. For example, a substantial proportion of California's wintering population of the Mountain Plover (*Charadrius montanus*), representing 30–50% of this species' global population, finds sustenance in the many disked, burned, and grazed fields that are readily available in the valley (Wunder and Knopf 2003, Shuford et al. *this volume*). Resident Burrowing Owls (*Athene cunicularia*), exploiting the vast network of earthen drainage canals and abundant food supplies, also reach high densities here (DeSante et al. *this volume*). Although the extensive irrigated agriculture in the Imperial Valley appears to have benefited many species of birds for many decades, conversion to cropland has probably displaced some landbirds that once occupied and depended upon the sparse alkali scrublands in this area.

Some native mesquite (*Prosopis* spp.) woodland was present in the wetter and more alkaline portions of the Sink, particularly to the north between the towns of Indio and Mecca (MacDougal 1914). Mesquite was apparently never widespread or extensive prior to the conversion of land to agriculture or urban development, and

FIGURE 4. A freshwater impoundment of the Hazard Unit near the southeast shore of the Sea where gulls, terns, skimmers, and shorebirds loaf and feed. Photo by K. C. Molina, July 1997.

only a few remnant patches remain (Patten et al. 2003). Riparian habitat, now almost exclusively dominated by exotic *Tamarix*, exists in the Imperial Wildlife Area, and along extensive reaches of the New, Alamo, and Whitewater rivers, where it is highly degraded by channel maintenance activities; small bosques of mesquite, willow (*Salix*), and cottonwood (*Populus*) are established and managed on some state and federal refuge lands (K. Molina, pers. obs.) as well as in some parks in Brawley near the New River (Patten et al. 2003).

South of the Imperial Valley in the northeastern corner of Baja California and adjacent Sonora, Mexico, lies the Mexicali Valley. Together these two valleys form a nearly contiguous swath of highly productive farmland. Although its avifauna and habitats are less well known than those north of the border, the Mexicali Valley region has recently received increasing attention (Patten et al. 1993, 2001; Hinojosa-Huerta et al. 2001, 2002, *this volume*; Anderson et al. 2003). The Río Colorado corridor (Fig. 6) snakes southward to the Delta along the valley's eastern border. Although degraded by reduced instream flows as a result of upstream diversions and dominated in most areas by exotic *Tamarix*, the river provides expanses of important riparian habitat, including significant stands of mature cottonwood/willow gallery forest (Cohen et al. 2003, Hinojosa-Huerta et al. *this volume*). The Río Hardy drainage (Fig. 7) and the wetlands associated with it along the valley's western border in Baja California are generally supported by agricultural return flows and are largely vegetated by *Tamarix* and other salt-tolerant species (Hinojosa-Huerta et al. *this volume*). The extensive marshes of the Ciénega de Santa Clara, maintained by agricultural drain flows from Arizona, and the pocket wetlands near El Doctor (Fig. 8), formed by a series of artesian wells or pozos along the escarpment of the Gran Desierto south of the Ciénega, provide a variety of permanent or near-permanent wetland and riparian habitats along the delta's eastern edge in Sonora (Glenn et al. 1996). The ponds at the Campo Geotérmico Cerro Prieto (Fig. 9), at the head of the Río Hardy drainage, and Isla Montague, at the mouth of the Río Colorado, provide important nesting habitat for colonial breeding waterbirds and other taxa such as the Large-billed Savannah Sparrow (*Passerculus sandwichensis rostratus*; Palacios and Mellink 1992, 1993; Peresbarbosa-Rosa and Mellink 1994, Molina and Garrett 2001).

FIGURE 5. Nesting islets in the freshwater impoundment (Rock Hill ponds) of the Sonny Bono Salton Sea National Wildlife Refuge headquarters. Photo by K. L. Garrett, July 2001.

ENVIRONMENTAL ISSUES AND THE RESTORATION PROCESS

The Salton Sea lies within a closed basin and receives large inputs of agricultural and municipal wastewater heavily laden with salts and nutrients. Because of the Sea's high evaporation rates, which effectively concentrate dissolved substances, issues of water quality have long been of concern. The Sea's continued and permanent existence as a repository for agricultural drainage is mandated by federal decrees enacted in 1924 and 1928, and by a State of California statute in 1968 (Salton Sea Authority and U.S. Bureau of Reclamation 1998). The agricultural industry of the Coachella and Imperial valleys, valued at over $1 billion annually (www.iid.com/water/irr-agriculture.html; Salton Sea Authority and U.S. Bureau of Reclamation 1998), is dependent on its ability to sequester agricultural drainage and discharge it to the Salton Sea (Salton Sea Authority and U.S. Bureau of Reclamation 1998). Feasibility studies focusing on the control of salinity and surface elevation began in the 1960s (Salton Sea Authority and U.S. Bureau of Reclamation 1998), but the lake's rising surface elevation and apparent stabilization of salinity, at least for the time being, allayed concerns and postponed further efforts (U.S. Bureau of Reclamation 2003). Water quality again became a concern when apparent declines in the Salton Sea's introduced sportfishery in the 1980s stimulated the establishment in 1988 of the Salton Sea Task Force, a public entity representing county governments and water districts (Salton Sea Authority and U.S. Bureau of Reclamation 1998). In response to the enactment of Public Law 102-575 in 1992 directing the Bureau of Reclamation to conduct studies of salinity control, the agency adopted a set of five goals to serve as criteria against which potentially suitable restoration projects would be evaluated (Salton Sea Science Subcommittee 2000, U.S. Bureau of Reclamation 2003). These criteria, some potentially at odds with others, were to (1) maintain the Sea as a repository for agricultural discharge, (2) reduce and control salinity and lake surface elevation, (3) provide endangered species habitat, (4) enhance the fisheries, and (5) protect human recreational values—hence, the genesis of the present-day Salton Sea Restoration Project. In 1993 the Salton Sea Authority, composed of county, water district, and tribal representation, was created as the local co-lead agency to act in tandem with the Bureau of Reclamation on a restoration project for the Sea. The Salton Sea Project Draft Evaluation of Salinity

FIGURE 6. Mature cottonwood-willow gallery forest (background) along stretch of the Río Colorado south of Carranza (= Ledon), Baja California. Photo by K. L. Garrett, June 1998.

and Elevation Management Alternatives was released in 1996 (Salton Sea Authority 1996), although its public distribution was limited and it did not garner widespread attention. These alternatives, mostly centered on the construction of diked impoundments within the Sea to sequester and remove salts from the remainder of the Sea, lacked consideration of water quality issues other than salinity, such as eutrophication and potential selenium, heavy metal, and organochlorine contamination. They also inadequately addressed the proposed projects' impacts to wildlife from potential loss and degradation of significant habitats as a result of surface elevation declines and increased development and recreational use at the Sea.

The Salton Sea Reclamation Act, enacted by Congress in 1998, directed the Department of the Interior to complete studies of restoration options complying fully with the five criteria set forth by the Bureau of Reclamation in 1992 (U.S. Bureau of Reclamation 2003). During this process the agency was to consider all options under a scenario of reduced inflows to the Salton Sea. Moreover, the Act explicitly deemed ineligible projects that relied on additional supplies of water from the Colorado River. This stipulation reflected a provision of previous legal compacts and federal court decisions that limited the beneficial use of Colorado River water to domestic and irrigation purposes (U.S. Bureau of Reclamation 2003).

In the 1990s the Salton Sea seemed to be experiencing a surge in the frequency and size of mortality events involving fish and birds, indicating an ecosystem increasingly under stress (Friend 2002). Historically, periodic fish die-offs at the Sea had been poorly documented. Most were attributed to anoxic conditions associated with high ambient temperatures and high nutrient loading stimulating seasonal algal blooms (U.S. Fish and Wildlife Service 1997). In 1992, an estimated 150,000 dead Eared Grebes (*Podiceps nigricollis*) littered the Sea's shores and shallow bays; the cause of this mass mortality has never been completely understood and will likely remain unresolved (Meteyer et al. *this volume*). Such large die-offs are not novel as grebe mass mortalities not associated with adverse weather conditions, but rather with disease or unknown causes, have been documented elsewhere in western North America since 1880 (Jehl 1996). However, in 1996 the loss of over 15,000 pelicans and other waterbirds was attributed to a particular strain of avian botulism not previously known to involve piscivorous birds

FIGURE 7. Stretch of the Río Hardy corridor in Baja California vegetated with *Tamarix* and the common reed, *Phragmites*. Photo by K. L. Garrett, September 1996.

(Rocke et al. *this volume*). Intense mass media interest in the bird die-offs fueled predictions of the Sea's imminent collapse and stimulated increasingly frequent and strident public outcries for immediate actions to "fix" the ailing body of water. Such media coverage also served to polarize public opinion, with equally strident voices proposing that the Sea be simply allowed to dry up or that the waters now nourishing the Sea be redirected to the more deserving "natural" wetland habitats of the Colorado River Delta. Paradoxically, during the late 1990s, tilapia populations in the Salton Sea exploded to form one of the most highly productive fisheries described for the species (Costa-Pierce and Riedel 2000), although an apparent reversal of this boom began around 2000 (Riedel et al. 2002).

As a result of Congress's 1998 enactment of the Salton Sea Reclamation Act, the Salton Sea Science Subcommittee was established in 1999 (and later became the Salton Sea Science Office). This entity was charged with facilitating baseline studies of the physical and biological characteristics of the Sea, identifying data gaps, and coordinating all scientific endeavors undertaken on behalf of the Restoration Plan, including scientific review of all proposed restoration alternatives (Salton Sea Science Subcommittee 2000). The results of many of these reconnaissance studies were published in 2002 in volume 473 of the journal *Hydrobiologia*. Two such investigations (Schroeder et al. 2002, Vogl and Henry 2002) indicated that past suspicions regarding high contamination loads of pesticides and selenium in the water column and in sediments of the Sea were largely unsupported. The efforts of the Science Office continue to the present and have been broadened recently to include consideration and study of issues such as eutrophication, salt precipitation, fugitive dust generation, and potential actions for their remediation.

Any such project to maintain the Salton Sea will necessarily be of massive proportion and require long-term monitoring. Although an initial Environmental Impact Statement and Report has been completed, a preferred project alternative was not identified (Salton Sea Authority and U.S. Bureau of Reclamation 2000). The environmental assessment process continues with more detailed analyses of potential alternatives and the refinement of their designs (U.S. Bureau of Reclamation 2003). Although the state legislature has approved funds for a project feasibility study, funding for project construction and

FIGURE 8. Pozos or artesian wells near El Doctor, supporting native wetland and riparian vegetation, along the escarpment of the Sonoran Mesa. K. L. Garrett, October 1997.

an adaptive monitoring program has yet to be appropriated.

Adding considerably to the significant challenges inherent in the restoration of the Salton Sea is the impending allocation of a greater proportion of Colorado River water to urban uses. These water transfers, along with reductions in the total allotment of Colorado River to California, will necessitate stark conservation measures by agricultural users and will greatly reduce freshwater inflows to the Salton Sea. These diminished flows may make any proposed engineering project to sustain the present extent of the Salton Sea a financial impossibility. Similarly, adequate freshwater flows to the Colorado River Delta lack long-term assurances. Massive human population growth expected to continue on both sides of the border will present ever-greater challenges for the sustainability of the region's wildlife habitat. Interestingly, several of the most recently proposed restoration options for the Salton Sea include desalinization of the New, Alamo, and Whitewater rivers, an engineering component whose cost until recently was considered prohibitive. Ironically, however, these plans propose to export any of the freshwater produced by this technology to urban centers (Salton Sea Authority 2003), and it is unclear how much will be returned to sustain aquatic habitats at the Sea. Ultimately, an innovative interpretation of laws governing the "beneficial uses" of water in the region and the acquisition of long-term water leases (Cohen et al. 2003, Gold 2003) dedicating freshwater flows to the Sea and Delta will be necessary to help ensure that the needs of wildlife and wetland habitats are accommodated.

One of the initial obstacles to a more complete understanding of the significance of the Salton Sea's aquatic and agricultural habitats to wildlife stems from the negative connotation society attaches to artificial features that serve as wildlife habitat. Artificial habitats are sometimes viewed as less valuable than pristine or near pristine habitats. However, most of California's natural wetlands have been highly modified by human development, existing now in various stages of impairment or having been lost completely (Dahl et al. 1991). When faced with the pervasive loss and degradation of wildlife habitats in our increasingly urbanized landscape, a society that espouses the value of wildlife may not have the luxury of distinguishing between natural and pristine wetlands, and those that are highly modified yet still function effectively as wildlife habitat such as those of the Salton Sink.

FIGURE 9. The impoundments and nesting islets of Campo Geotérmico Cerro Prieto, Baja California. K. L. Garrett, September 1996.

Unlike many other saline bodies of water in the arid West that dried up almost entirely (e.g., Owens Lake) or have fluctuated greatly in their water volume (Jehl 1994), the Salton Sea has persisted over the last century as a large, intact lake. In fact, one consistent goal reflected in any of the various plans to restore the Sea has been to stabilize its surface elevation and curb its encroachment onto private property. While it is unlikely that the Sea will ever again experience flood flows directly from the Colorado River as it last did in 1905–1907, its designation as a repository for agricultural drainage in a region with an economy that will likely continue to be dominated by irrigated agriculture ensures that some form of the Salton Sea will continue to occupy the Salton Sink for some time to come.

The bird life of the Salton Sea has inspired awe since its formation, as indicated by Grinnell's observation on his inaugural visit to the Sea in 1908, when he wrote:

"As we neared the Island, a curious frosted patch became conspicuous on the highest hill. This soon proved to be a great colony of American White Pelicans ... The sight of the great white birds rising in masses from their nesting grounds was exciting in the extreme; for I had never seen this species under such circumstances before. They wheeled in great circles overhead, crossing and re-crossing over their breeding grounds, or glided out to sea in intersecting V's. When flapping, their wings gave out a loud swish, and the many at once produced a roar" ... (Grinnell 1908, pp. 186–187).

Despite the well-publicized bird mortalities in recent years, today's visitor to the Salton Sea can still marvel at the sight of huge masses of pelicans wheeling overhead, loafing at the river mouths, or feeding in innumerable groups dotting the Sea's surface during the non-breeding season, when as many as 20,000 individuals typically have been recorded there. Similarly, one can be overwhelmed by thousands of Western Sandpipers (*Calidris mauri*) probing into the rich organic mud along the southeastern shoreline, or revel in wave after wave of White-faced Ibis undulating across the darkening sky as they pile into their nighttime roosts about the Imperial Valley.

GENESIS OF THIS VOLUME

The first stirring of interest for this volume began in 1997, when the Western Field Ornithologists (WFO) convened its 22nd stated meeting in late August in the Imperial Valley. In recognition that the basic status and distribution of birds at the Salton Sea were now fairly well known, but that very little had been published since the earliest explorations of the region, the meeting presented a symposium addressing the current state of knowledge of the Sea's avifauna. Because it was unclear whether the final project alternatives identified in 1997 (U.S. Bureau of Reclamation 1997) would adequately protect the Sea's wildlife, in March 1998 WFO ratified a resolution entitled "The Salton Sea as Significant Wildlife Habitat." This resolution supported "rehabilitation and conservation efforts at the Salton Sea that are responsive to the needs of wildlife and based on sound and thorough biological data; that recognize the importance of freshwater, delta, brackish, saline, and agricultural habitats; that improve water quality and guarantee continued adequate sources of freshwater; and that seek to minimize threats to wildlife potentially resulting from urban and recreational development" (Garrett 1998). In April 1998, four major ornithological societies—the American Ornithologists' Union, Cooper Ornithological Society, Wilson Ornithological Society, and the Association of Field Ornithologists—adopted a similar resolution for the Salton Sea at the North American Ornithological Conference in St. Louis, Missouri. This joint resolution noted a "lack of consensus on what is meant by restoring the Salton Sea" and supported "an approach that allows sufficient time to study the situation, including all feasible options, that any additional research funds are added to agency core budgets, that no money be spent on 'emergency action' before a full environmental impact statement is completed, including studies of the impacts of brine or salt disposal from all pumped water, and that the implementation of whatever action be recommended must meet all environmental laws, including the National Environmental Policy Act and the Clean Water Act, and that judicial review of proposed actions be allowed without restraint" (AOU 1999).

With concern by ornithologists for the Salton Sea's avifauna and habitats increasing in the years following the WFO symposium in 1997, the Cooper Ornithological Society convened its 70th annual meeting in April 2000 in Riverside, California, which included a symposium entitled "The Ecology and Conservation of the Avifauna of the Salton Trough." Recognizing the strategic role the Salton Sea plays in avian migration systems of western North America and, in particular, its importance as a component of wildlife habitat in the Colorado River Delta region (Shuford et al. 2002), the conveners sought to broaden the scope of the previous WFO symposium and invited the participation of Mexican ornithologists working in the Delta region. The symposium, organized by Michael A. Patten, featured 14 presentations, including two pertaining to the Mexican portion of the Colorado River Delta region. It served as the basis for the collection of papers appearing in this volume.

We begin this symposium volume with two introductory papers that trace the development of knowledge of the avifauna of the Salton Sea region: Patten and Smith-Patten describe what is known of the Salton Sea avifauna prior to modern exploration by reviewing zooarchaeological data as well as the physical history of the Salton Sink, and Garrett et al. highlight the history of ornithological exploration around the Sea. We then present contributions that focus on the patterns of occurrence at the Salton Sea of several important avian groups, including migratory shorebirds (Shuford et al.), waterbirds (Warnock et al.), waterfowl (Barnum and Johnson), subtropical waterbirds (Patten et al.), and migratory passerines (Flannery et al.). Patten et al. detail avian range expansions and population changes in the Sink over the last 50 years, and Hinojosa-Huerta et al. describe the waterbird communities of the Colorado River Delta. Two papers describe the colonial breeding avifauna, concentrating on larids (Molina) and cormorants, ibis and ardeids (Molina and Sturm), and two others treat the status and distribution (DeSante et al.) and ecology (Rosenberg and Haley) of Burrowing Owls. Two papers focus on avian mortality: Meteyer et al. detail the investigation of the die-off of Eared Grebes in 1992, and Rocke et al. describe the losses of pelicans and other piscivorous birds to Type C botulism. Finally, Shuford and Molina bring avian research in the region into the context of conservation biology by stressing the need for scientists to engage more directly in political and regulatory processes.

Regardless of the "unnatural" water sources that sustain it, the Salton Sea has long served as a complex mosaic of important avian habitats and a necessary link in the migratory pathways of birds along the Pacific Flyway (Shuford et al. 2002), and it continues to do so today. It is our hope that the papers in this volume will not only augment the published record of avian biology of the Salton Sea and the greater Colorado River Delta region but will also underscore the interconnectedness of these areas, highlight the complexities of the threats they face, and above all stimulate further study, innovative dialogue, and action to preserve these internationally important bird habitats.

ACKNOWLEDGMENTS

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LINKING THE SALTON SEA WITH ITS PAST: THE HISTORY AND AVIFAUNA OF LAKE CAHUILLA

MICHAEL A. PATTEN AND BRENDA D. SMITH-PATTEN

Abstract. The Salton Sea is a large, shallow, saline lake in the Sonoran Desert of southeastern California. It was created by flooding of irrigation channels under construction in 1905, during the effort to bring agriculture to the Imperial Valley. But to view the Salton Sea as merely an engineering mistake misses the rich history of lakes in the region. Large periodic floods on the Colorado River created a vastly larger fresh-water lake in the Salton Sink. This body of water, called Lake Cahuilla, had formed as recently as the mid-1600s. Lesser floods on the Colorado River continued to carry water to the Salton Sink as recently as 1891, when a small lake was formed. The Salton Sea is thus the latest in a long series of lakes that have occupied the region, going back thousands of years. Available evidence, largely from midden sites of local Native Americans, implies that the avifauna of Lake Cahuilla was quite similar to the avifauna of the Salton Sea, forging another link with the past. Yet the Sea has many non-natural elements, such as a constant surface level rather than periodic desiccation, a highly saline environment, and an exotic fish fauna. These elements (and others) have changed the character of this otherwise natural ecosystem. The Sea's presence is a boon to birds, particularly given the extensive loss of wetlands throughout California, but problems have arisen that threaten its future. By taking a biogeographically, historically, and ecologically broader view of the Salton Sea's avifauna, we can gain a more thorough understanding of the Sea's past that will lead to a better approach to conservation needs in the future.

Key Words: Colorado River; historical ecology; Lake Cahuilla; Salton Sea; Salton Sink.

ENLAZANDO AL MAR SALTON CON SU PASADO: LA HISTORIA Y AVIFAUNA DEL LAGO CAHUILA

Resumen. El Mar Salton es un lago salino, extenso y superficial localizado en el Desierto Sonorense del sureste de California. Fue creado en 1905 por inundación de los canales de irrigación en construcción, cuando se intento traer la agricultura al Valle Imperial. Pero si vemos al Mar Salton como un error de ingenieria nos perdemos de la rica historia sobre los lagos de la región. Inundaciones periódicas extensas del Río Colorado crearon un vasto lago de agua dulce dentro de la Cuenca del Salton. Este cuerpo de agua, conocido como Lago Cahuilla, se había formado a mediados de 1600. Inundaciones menores del Río Colorado continuaron trayendo agua hacia la Cuenca del Salton hasta aproximadamente 1891, cuando se formó un pequeño lago. De esta forma, el Mar Salton es el más reciente de una serie de lagos que han ocupado la región, que data de hace miles de años. La evidencia disponible, a partir principalmente de sitios de concheros de los Americanos Nativos, implica que la avifauna del Lago Cahuilla fue muy similar a la avifauna del Mar Salton, forjando otro enlace con su pasado. Sin embargo el Mar Salton tiene varios elementos no naturales, tales como un nivel constante en su superficie en vez de desecaciones periódicas, un medioambiente con una alta salinidad, y una ictiofauna exótica. Estos elementos (y otros) han cambiado el carácter de lo que sería de otra manera un ecosistema natural. La presencia de este mar es un beneficio para las aves, particularmente por la pérdida de grandes extensiones de humedales en California, pero han surgido problemas que amenazan su futuro. Si echamos un vistazo más amplio a la biogeografía, historia y ecología de la avifauna del Mar Salton, podemos aprender y entender mejor el pasado del mar lo cual nos guiará a un mejor enfoque sobre las necesidades de conservación en el futuro.

Palabras claves: Cuenca del Salton; ecología histórica; Lago Cahuilla; Mar Salton; Río Colorado.

The Salton Sea is worthy of conservation and protection as a *natural* resource. To say otherwise ignores the biology, geography, and history of the region. Nonetheless, the contrary view has been expressed by some biologists, conservationists, and resource managers whose expert opinions will help policy makers decide the fate of the Salton Sea (see Kaiser 1999, Morrison and Cohen 1999, Cohn 2000). The current Sea was formed shortly after the turn of the twentieth century, but its history extends much further into the past. Many aspects of the Salton Sea are anthropogenic, especially its fisheries and the maintenance of a relatively constant surface level. But much about the Salton Sea and its ecosystem is natural, and would be all the more were it not for severe anthropogenic alteration of the water regime along the Colorado River. Indeed, upon reviewing the geographical and biological history of the region, one could just as easily conclude that the Salton Sea is merely the latest in a long line of shallow lakes that has occupied at least a portion of the Salton Sink over the past several millennia, and is thus obviously natural.

It is important, therefore, that conservationists and resource managers have a complete understanding about the Salton Sea's place in the region. It is in this spirit, in an attempt to provide data for a more balanced view—a view that would consider both natural and manmade aspects of the ecosystem—that we present a summary of the geographic history of the Salton Sink and provide a glimpse of how the avifauna looked before written history, and thus before the Salton Sea came into existence. The Salton Sea is important habitat for birds regardless of its perceived naturalness, but we hope to show that much of this naturalness is not just perceived; it is real.

THE GULF AND THE RIVER

The geography of the Salton Sea cannot be explored without taking a broader view that includes the Gulf of California and the lower Colorado River. As recently as the Pliocene, the Salton Sink was part of the Gulf of California (Kennan 1917, Durham and Allison 1960). Moreover, the Salton Trough, the trench formed by uplift of the Peninsular Ranges (the San Jacinto Mountains south through the Sierra Juarez) to the west and of the Chocolate and Orocopia mountains to the east, extends from the present day Coachella Valley into the gulf (Sykes 1937).

The Colorado, once the mightiest river in western North America, empties into the Gulf of California. Anyone who has seen the Grand Canyon realizes that this river transports a tremendous amount of sediment. Most of this sediment was deposited in a broad flood plain where a funneled bench, a deltaic "bar," eventually formed that isolated the uppermost portion of the gulf (Blake 1915, Kennan 1917). Thus was formed the first lake that occupied the Salton Sink. This "trapped" inland sea was present tens of thousands of years ago, and was positioned only a short distance from what was then the head of the Gulf of California. Barring additional inflow from some unknown source, this sea likely dried within a few decades, as evaporation rates in the Salton Sink are extremely high (Blake 1914), particularly compared to the cooler Great Basin, where post-Pleistocene lakes of similar dimensions dried much more slowly (Hubbs and Miller 1948).

As the present day delta was forming, presumably over many millennia, the lower Colorado River did not have a definite course, but instead meandered across a vast area south of what is now the Mexicali Valley (Blake 1915, Sykes 1937). In some years the river followed a course similar to its current, controlled one. In other years it swung westward, forming a distinct river channel named Hardy's Colorado (Sykes 1937), now called simply the Río Hardy.

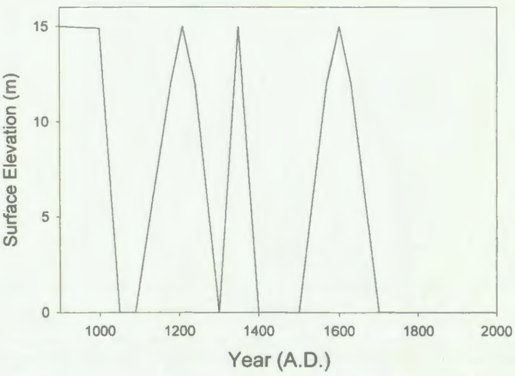

FIGURE 1. Above sea level highstands (m) of Lake Cahuilla over the past millennium (after Smith 1999). When dry, the lakebed is at about −100 m below sea level.

In still other years, particularly during major (100- to 200-yr) flood events, the Colorado River flowed almost due westward, through courses now called the Alamo (formerly the Salton) and New rivers. During such years much of the voluminous flow never reached the Gulf of California, instead emptying into the Salton Sink. This flow formed an expansive lake, evidence of which was first noted by modern explorers in the mid-1850s, when the lake was dubbed "Cahuilla" after the Native Americans that lived along its northern flank (Blake 1858, 1914).

LAKE CAHUILLA

That Lake Cahuilla existed at all might be testament enough to the Salton Sea's ties with the past. But the lake was not present continuously. The Salton Sink is one of the hottest locales in North America, rivaling Death Valley and the northern Gulf of California for that dubious claim (Turner et al. 1995). With mid-summer temperatures generally over 43°C and often topping 50°C, resultant rates of evaporation are enormous, with an estimated drop in surface level of between 1.8 m and 2.4 m/yr (Blake 1914, Tetra Tech 2000). Because flood events on the Colorado River are sporadic and evaporation rates in the Salton Sink are substantial, we would predict that Lake Cahuilla was ephemeral . . . and indeed it was. This huge lake came and went over the millennia, ranging from five times the current size of the Salton Sea to a dry, salt-encrusted pan. Its random oscillations persisted into modern times, including a highstand (the maximum volume of water) as recently as the mid-1600s (Fig. 1; Wilke 1978, Laylander 1997, Smith 1999). Many of these lakes were fresh at highstand (Hubbs and Miller 1948:108), but as they gradually subsided they become more

FIGURE 2. Maximum extent of Lake Cahuilla at highstand, with the current Salton Sea superimposed.

brackish as a result of heavily alkaline soils within the basin. At highstand, Lake Cahuilla was substantially larger than the Salton Sea (Fig. 2), being over twice as long (160 km vs. 72 km), twice as wide (56 km vs. 27 km), four times as deep (100 m vs. 25 m), five times the surface area (5400 km^2 vs. 1150 km^2), and rising to a much higher surface elevation (+15 m vs. −69 m).

Although the cycle of flooding and desiccation had taken place for thousands of years, the full extent of Lake Cahuilla was never realized again after the mid-1600s. Still, occasional floods brought water from the Colorado River to the Salton Sink through the 1800s, including in 1840, 1842, 1852, 1859, 1862, and 1867 (Blake 1914). The last flood of any consequence occurred in 1891—it formed a lake about half the size of the current Salton Sea (Blake 1914, Kennan 1917). The presence of a large fresh-water or brackish lake, especially combined with its wetlands and floodplains, undoubtedly had a profound effect on regional avifauna. We know little about the avifauna of Lake Cahuilla, however, for its existence predates scientific exploration on the continent. Below we present what knowledge has been gained from archaeological evidence, albeit scant, to provide a comparison between our glimpse of the birdlife of Lake Cahuilla to that of the Salton Sea.

The Salton Sea

With the tremendous impact humans have had on the Colorado River (Sykes 1937), its capacity to flood has been diminished severely. We have constructed numerous dams and hydroelectric plants along its length, tapped much of its water to quench the thirst of burgeoning desert cities (e.g., the large metropolitan areas of Phoenix, Las Vegas, and Los Angeles depend on river water), and diverted even more of its water to support agriculture in the lower Colorado River valley and the Salton Sink. Major floods are now essentially nonexistent, as most of the water is trapped in one of numerous reservoirs (e.g., Lake Havasu, Lake Mead). By the turn of the twentieth century, the loss of the river's capacity to flood meant the loss of Lake Cahuilla, and of the important flood plains around the river's delta (see Murphy 1917, Sykes 1937).

But the river had one last hurrah. In 1905, during construction of canals to bring irrigation water to the Imperial Valley, the Colorado River swelled. It was another major flood year. Water gushed down channels through the Alamo River (and to some extent the New River) and began to flood the Salton Sink (Kennan 1917), just as it has countless times before. By the time flow was halted some 18 months later, the "Salton Sea" was born. Blake (1914) cogently argued for use of the current moniker over "Lake Cahuilla" so that we might distinguish the larger freshwater forerunner from its smaller saline heir.

Even though the Salton Sea was created by the same natural process that gave rise to Lake Cahuilla every century or two, its maintenance and current conditions are decidedly less natural. Were it not for voluminous runoff of irrigation wastewater, the Sea would have desiccated decades ago. Indeed, Blake (1914) estimated it would be dry by 1920, but he could not foresee the agricultural boom that enveloped the region because of a steady, controlled flow of irrigation water from the Colorado River. By 1924 the surface elevation had stabilized, then it increased steadily until 1980. It is now maintained at −69 m, mostly by farm runoff in the Imperial Valley (Fogelman et al. 1986), although runoff from the Coachella and Mexicali valleys also contributes.

Moreover, fishes carried to the Salton Sea during the initial 1905 flood were fresh-water species from the Colorado River (Evermann 1916), just as fish fauna had been at Lake Cahuilla (Gobalet 1992). With no outlet, water was lost from the Sea only by evaporation, so the Sea's salinity steadily increased. The Sea now supports introduced species of marine and freshwater fishes along with a native pupfish (Saiki 1990, Riedel et al. 2002, Sutton 2002). We can only speculate what effects this change in resources may have had on fish-eating birds.

METHODS

Physical evidence of bird use of Lake Cahuilla comes from middens at camps and villages of the Cahuilla and Kumeyaay indians who occupied the northern and southern shorelines, respectively. Both tribes fished and hunted birds at the lake. We summarized published data from the northern shore around Myoma Dunes and the vicinity of La Quinta in the southern Coachella Valley (Wilke 1978, Brock et al. 1999), the eastern shore at Wadi Beadmaker and Bat Caves Buttes, near the mouth of Salt Creek (Wilke 1978), and the southwestern shore at the Elmore site north of the New River mouth (Beezley 1995, Laylander 1997). We reevaluated some specimens when a published species-level identification seemed at odds with our present understanding of bird distribution in the region. We sorted and identified additional avian skeletal remains (housed in the Archaeological Curation Unit, Department of Anthropology, University of California, Riverside) that were part of previously unanalyzed Myoma Dunes midden samples (sites CA-RIV-1766, CA-RIV-1767, CA-RIV-1768). We identified specimens by using standard keys (e.g., Gilbert et al. 1996) and by comparing them to the reference collection at the San Diego Natural History Museum. All samples date from the past one to two thousand years before present.

Status at the Salton Sea of species identified in midden samples was taken directly from Patten et al. (2003). We used current (2000) status for all species, save for the Canvasback (*Aythya valisineria*). This diving duck was a common to fairly common winter visitor to the Salton Sea as recently as the 1970s (Patten et al. 2003) but has declined precipitously since, to the point that it is now uncommon. Because its sharp decline has been so recent, we used its status in the 1970s in our analysis. Data from Lake Cahuilla are confounded by differential hunting preferences, differences in ease of capture, and potentially by variation in preservation. We thus did not use parametric statistics when comparing status at the Salton Sea to status at Lake Cahuilla. Instead we relied on non-parametric statistics that examine differences in central tendency. We thus compared current status with historical status using a Kruskal-Wallis test, adjusted for ties in rank. Three groups were defined by current status: common (abundant to fairly common), uncommon, and rare (see Patten et al. 2003 for details and definitions). Ranks of midden samples were derived from tallies of minimum number of individuals (MNI) from specimens identified to species or species group (e.g., genus *Anas*, scaup spp.).

RESULTS AND DISCUSSION

With two exceptions, every species recorded in midden samples from Lake Cahuilla has been recorded frequently at the Salton Sea. The exceptions were reports of a Red-necked Grebe (*Podiceps grisegena*) and a Band-tailed Pigeon (*Columba fasciata*) from the Coachella Valley (Wilke 1978). The Red-necked Grebe has not been recorded at the Salton Sea (Patten 1999, Patten et al. 2003) and is casual anywhere inland in southern California (Garrett and Dunn 1981), so we reexamined the specimen (a tibiotarsus). After careful comparison to the reference material, we concluded that on the basis of size and subtleties of shape it was in fact a Pied-billed Grebe (*Podilymbus podiceps*). The Band-tailed Pigeon is a casual visitor to the deserts of California (Garrett and Dunn 1981), and has been recorded in the Salton Sink only four times (Patten et al. 2003). We were unable to locate the specimen; however, we tentatively accept the identification and suggest that the specimens may have been captured in the foothills of the Santa Rosa Mountains, rising above the western edge of the Coachella Valley, and transported to the site where they were consumed or otherwise used.

We found a good match between bird species collected at Lake Cahuilla and the current status of those species at the Salton Sea (Kruskal-Wallis $H_{adj} = 7.21$, df = 2, $P < 0.05$). For both species richness and relative abundance, common species were better represented than uncommon ones, and uncommon ones better than rare ones (Table 1; Fig. 3). The American Coot (*Fulica americana*) was especially well represented; many of our unidentified specimens ($N \approx 200$) likely pertain to this species. The Elmore site in particular has a large number of coot remains (Beezley 1995). This species is common at the Salton Sea and appears to have been common at Lake Cahuilla. Perhaps it was also easier to capture than many of the ducks and grebes that frequented the lake.

We do not expect a perfect match between avian diversity (i.e., a combination of richness and abundance) at Lake Cahuilla and the Salton Sea. The lake was larger, deeper, and contained fresh or brackish water, and thus a different sort of lacustrine habitat. Furthermore, the status of most species is dynamic, and could easily have changed substantially over the past several millennia. Considering how many species' statuses have changed at the Salton Sea since only 1950 (Patten et al. *this volume*), these changes may have been great. Nonetheless, the most common species then tend to be the most common species now, implying that the avifauna of Lake Cahuilla, particularly the waterbirds, was quite similar to the avifauna of the present day Salton Sink, an impressive link when considering our time frame of the past 2000 yrs. As far as its birdlife is concerned, the Salton Sea is just another in a series of lakes occupying the basin.

TABLE 1. BIRD SPECIES RECORDED FROM MIDDEN SITES AND COPROLITE SAMPLES AT SITES AROUND LAKE CAHUILLA (SEE TEXT), WITH A COMPARISON TO PRESENT DAY STATUS AT THE SALTON SEA (FROM PATTEN ET AL. 2003)

Species	Minimum number of individuals	Status at the Salton Sea (principal pattern of occurrence only)
Pied-billed Grebe (*Podilymbus podiceps*)	2	fairly common breeding resident
Eared Grebe (*Podiceps nigricollis*)	8	abundant winter visitor, transient
Aechmophorus spp.	13	fairly common breeding resident
American White Pelican (*Pelecanus erythrorhynchos*)	2	common winter visitor, transient
Double-crested Cormorant (*Phalacrocorax auritus*)	4	common breeding resident
American Bittern (*Botaurus lentiginosus*)	1	uncommon winter visitor
Great Blue Heron (*Ardea herodias*)	12	common breeding resident
Black-crowned Night-Heron (*Nycticorax nycticorax*)	4	fairly common breeding resident
Wood Stork (*Mycteria americana*)	1	rare summer/fall visitor
Turkey Vulture (*Cathartes aura*)	3	common transient
Canada Goose (*Branta canadensis*)	2	fairly common winter visitor
Tundra Swan (*Cygnus columbianus*)	1	casual winter visitor
Mallard (*Anas platyrhynchos*)	3	fairly common winter visitor
Cinnamon Teal (*A. cyanoptera*)	7	common transient
Northern Pintail (*A. acuta*)	4	common winter visitor
Green-winged Teal (*A. crecca*)	6	common winter visitor
Anas spp.	4	generally common winter visitors
Canvasback (*Aythya valisineria*)	16	uncommon winter visitor (see text)
Redhead (*A. americana*)	11	fairly common breeding resident
Greater Scaup (*A. marila*)	7	uncommon/rare winter visitor
Lesser Scaup (*A. affinis*)	17	fairly common winter visitor
Aythya spp.	3	generally fairly common winter visitors
Bufflehead (*Bucephala albeola*)	1	uncommon winter visitor
Common Goldeneye (*B. americana*)	1	uncommon winter visitor
Ruddy Duck (*Oxyura jamaicensis*)	5	common breeding resident
Red-tailed Hawk (*Buteo jamaicensis*)	1	common winter visitor
American Kestrel (*Falco sparverius*)	1	common breeding resident
Gambel's Quail (*Callipepla gambelii*)	2	common breeding resident
American Coot (*Fulica americana*)	182	common breeding resident
Sandhill Crane (*Grus canadensis*)	1	uncommon winter visitor
Willet (*Catoptrophorus semipalmatus*)	1	common transient and winter visitor
Long-billed Dowitcher (*Limnodromus scolopaceus*)	1	abundant transient and winter visitor
Band-tailed Pigeon (*Columba fasciata*)	2	casual visitor (see text)
Mourning Dove (*Zenaida macroura*)	3	abundant breeding resident
Barn Owl (*Tyto alba*)	1	fairly common breeding resident
Great Horned Owl (*Bubo virginianus*)	1	uncommon perennial visitor; breeds
Burrowing Owl (*Athene cunicularia*)	1	fairly common breeding resident
Common Raven (*Corvus corax*)	2	fairly common breeding resident
Red-winged Blackbird (*Agelaius phoeniceus*)	1	abundant breeding resident

THE FUTURE OF THE SALTON SEA

The maintenance of a permanent lake in the Sonoran Desert of California has both benefits and costs. On the positive side, the Sea's very existence provides wetland habitat in a state that has destroyed or degraded >90% of its wetlands (Mitsch and Gosselink 1993). As a result, the Salton Sea is now an extremely important stopover for migratory waterfowl and shorebirds (Shuford et al. 2002b, Patten et al. 2003, Barnum and Johnson *this volume*, Shuford et al. *this volume*). Permanent water also provides breeding habitat for uncommon or rare waterbirds such as the Snowy Plover (*Charadrius alexandrinus nivosus*), Gull-billed Tern (*Sterna nilotica vanrossemi*), and Black Skimmer (*Rynchops niger niger*). Lastly, what riparian vegetation remains in the region can thrive thanks to a continuous flow of water through the rivers.

Unfortunately, costs are also high. Continuous inflow of irrigation water coupled with extremely high evaporation rates has greatly increased salinity of the Salton Sea (Setmire and Schroeder 1998). Runoff from agriculture and from industry carries numerous pesticides and detergents into the Sea. The New River, for example, ranks as the most polluted river in the United States (Gruenberg 1998). Although concern has been expressed about the potential accumulation in the Sea of heavy metals, organochlorine pes-

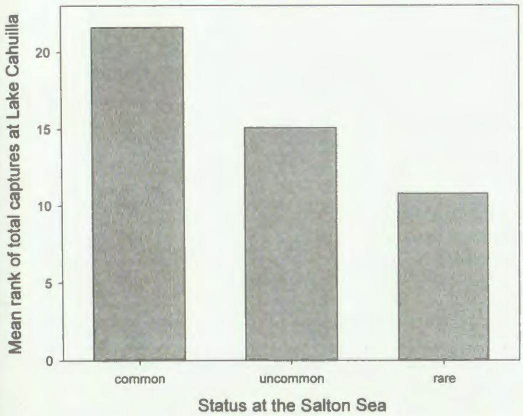

FIGURE 3. A comparison of the avifauna of Lake Cahuilla and the Salton Sea. Bars represent the average rank of bird taxa from middens around Lake Cahuilla (from data in Table 1). Categories are the current status of the same taxa at the Salton Sea. The taxa captured most often at Lake Cahuilla are the most numerous today at the sea.

ticide residues, and selenium, and for their respective negative impacts to wildlife, results of recent investigations have not fully supported these concerns (Holdren and Montano 2002, Schroeder et al. 2002). However, high nutrient levels and the resulting seasonal decreases in dissolved oxygen probably impose significant stresses on the Salton Sea ecosystem.

So whereas we can forge a link between the Salton Sea and its past, visions of the Sea's future are murky. It is possible that the costs incurred by maintenance of the Sea are manifesting themselves in recent catastrophic avian die-offs (see Jehl 1996, Shuford et al. 2002b). These events are not new (see Gilman 1918), and perhaps have occurred for centuries (D. W. Anderson, pers. comm.), but the loss of hundreds of thousands of Eared Grebes (Jehl 1996) or thousands of pelicans (Shuford et al. 2002b) in single years cannot be ignored. That similar mass mortalities have recently occurred in and around the Gulf of California (Vidal and Gallo-Reynoso 1996) suggests that the whole of the Salton Trough may need the help and attention of conservationists and resource managers.

Knowledge is power. We must understand the Salton Sea's ecosystem before we can hope to protect it. The Environmental Impact Report/Statement process (Tetra Tech 2000) and ongoing work by the Salton Sea Science Office and the Salton Sea Authority are moving in that direction. Understanding the Salton Sea's birds—its most numerous and visible animals—will allow us to construct a more complete picture of the Sea's ecosystem. With recent reports by the Point Reyes Bird Observatory (Shuford et al. 2002b), a recent book detailing the status and distribution of the avifauna of the Salton Sink (Patten et al. 2003), and the contents of this symposium volume, we have laid a sound foundation on which to build sound conservation plans. But surely more work is needed. Only with increased knowledge of habitat requirements (both for foraging and breeding), migratory and nesting phenology, dispersal patterns, specific threats, and community ecology will the future picture of the Salton Sink's birdlife come into focus. And with this focus, we can begin to forge a comprehensive and workable plan to conserve the Salton Sea and its myriad birds (see Shuford et al. *this volume,* Shuford and Molina *this volume*).

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HISTORY OF ORNITHOLOGICAL EXPLORATION OF THE SALTON SINK

KIMBALL L. GARRETT, KATHY C. MOLINA, AND MICHAEL A. PATTEN

Abstract. Ornithological exploration of the Salton Sink began prior to the formation of the present-day Salton Sea with collecting efforts by E. A. Mearns and F. X. Holzner, E. W. Nelson and E. A. Goldman, F. Stephens, and others from 1894 to 1905. The first exploration of the Sea itself was reported by Joseph Grinnell in 1908. Additional studies by W. L. Dawson, A. J. van Rossem, L. H. Miller, J. R. Pemberton, and others helped establish the uniqueness of the Sea's avifauna. Significant egg collections were also made in these early years. Among new taxa described from the Salton Sink, *Butorides virescens anthonyi* is based on a Mearns' specimen from 1894, *Melospiza melodia saltonis* on Grinnell's 1908 collection, and *Gelochelidon [= Sterna] nilotica vanrossemi* on birds taken by Pemberton and described by G. Bancroft in 1929. B. and M. Clary published several distributional records in the 1930s, and important collections were made by E. A. Cardiff in the 1940s through 1960s. A fuller understanding of the diversity of birds using the Salton Sink, including an array of post-breeding visitors from the subtropics, developed with work by serious amateur field ornithologists, notably G. McCaskie, beginning around 1960–1965 and continuing to the present. Also, from the 1950s to the present, birds breeding in the thermally challenging Salton Sea environment have served as subjects for research on avian physiological ecology and behavioral adaptations. The Salton Sea National Wildlife Refuge has maintained files on the avifauna of the region since the 1930s. Federal and state agency census and management work has concentrated on harvestable waterfowl, but especially since the 1970s research has expanded to non-game species, including listed species such as the Yuma Clapper Rail (*Rallus longirostris yumanensis*). The role of the Salton Sink in the migration ecology of shorebirds, grebes, and pelicans has received considerable recent study, as have breeding colonial waterbirds, Burrowing Owls (*Athene cunicularia*), and polytypic landbirds. Present day research is largely focused on baseline data and predicted effects of various proposed remedial actions to stabilize the Sea.

Key Words: history of ornithology; Salton Sea; Salton Trough.

HISTORIA DE LA EXPLORACIÓN ORNITOLÓGICA DE LA CUENCA DEL SALTON

Resumen. La exploración ornitológica de la Cuenca del Salton comenzó antes de la formación de lo que es hoy en día el Mar Salton, con los esfuerzos de colecta de E. A. Mearns y F. X. Holzner, E. W. Nelson y E. A. Goldman, F. Stephens, y otros entre los años 1894 y 1905. La primera exploración del Mar Salton en sí mismo fue reportada por Joseph Grinnell en 1908. Estudios adicionales conducidos por W. L. Dawson, A. J. van Rossem, L. H. Miller, J. R. Pemberton, y otros ayudaron a establecer la singularidad de la avifauna del Mar Salton. Significativas colecciones de huevos fueron hechas también durante estos primeros años. Entre las descripciones de nuevos taxones para la Cuenca del Salton, *Butorides virescens anthonyi* es basada en un espécimen de Mearns de 1894, *Melospiza melodia saltonis* basada en la colección de Grinnell de 1908, y *Gelochelidon [= Sterna] nilotica vanrossemi* en aves capturadas por Pemberton y descritas por G. Bancroft en 1929. B. y M. Clary publicaron varios records de distribución en los años 1930, e importantes colecciones fueron hechas por E. A. Cardiff entre las décadas del '40 al '60. Un entendimiento más completo de la diversidad de aves que usan la Cuenca del Salton, incluyendo un grupo de aves visitantes post-reproductivas del subtrópico, se desarrolló con el trabajo de serios ornitólogos de campo aficionados, particularmente G. McCaskie, comenzó alrededor de 1960–1965 y continúa al presente. También, desde la década del '50 al presente, aves que se reproducen en desafiantes ambientes termales del Mar Salton han servido como sujetos de investigación en ecofisiología de aves y adaptaciones de comportamiento. El Refugio Nacional de Vida Silvestre del Mar Salton ha mantenido archivos de la avifauna de la región desde los años '30. Los censos y el trabajo de manejo de agencias federales y estatales se han concentrado en aves acuáticas de caza, pero especialmente desde la década del '70 la investigación se ha expandido a otras especies, incluyendo especies listadas como importantes para la conservación como el Rascón Picudo de Yuma *Rallus longirostris yumanensis.* El rol de la Cuenca del Salton en la ecología de migración de aves costeras, zambullidores, y pelícanos ha sido estudiado recientemente en forma considerable, de la misma manera que aves acuáticas coloniales, los Tecolotes Llaneros (*Athene cunicularia*), y diversas aves terrestres. La investigación actual está principalmente enfocada en datos base y la predicción de los efectos de varias acciones remediadoras conducidas para estabilizar el Mar Salton.

Palabras claves: Depresión de Salton; historia de la ornitología; Mar Salton.

The current prominence of the Salton Sea in bird research, management, and conservation efforts has been preceded by a long history of profound change in the landscapes of the Salton Trough (the modern-day Coachella and Imperial valleys south through the delta of the Colorado River) as well as an interesting, if not entirely thorough, eleven decades of ornithological exploration. Avifaunal change in response to changing habitats has been a hallmark of this region, from the periodic flooding of the Salton Sink (most recently embodied by the present-day Salton Sea), through the destruction of much of the native riparian and desert vegetation, the large scale importation of water for agriculture, the ongoing dynamics of the Salton Sea's aquatic ecosystems, and the recent extensive urbanization and industrialization of the Mexicali, Imperial, and Coachella valleys.

In the context of this symposium volume on the Salton Sink we provide a historical account of the development of knowledge about the region's avifauna. We take the approach of examining a series of broadly overlapping periods corresponding to (1) the initial exploration of the general biota of the Salton Sink region prior to the formation of the modern Salton Sea, (2) the early explorations and collecting efforts after the Salton Sea's formation in 1905–1907, (3) the establishment of game management areas and wildlife refuges and their associated research and management, (4) a long period of refinement of distributional and ecological information that continues to the present day, (5) behavioral and ecophysiological studies from the 1950s to the present using the Salton Sea as a laboratory of avian adaptation to a thermally challenging environment, and (6) recent (generally post-1970) focused research on sensitive and declining bird species and on ecosystem health, which has intensified greatly within the last decade.

Early Exploration of the Salton Trough Prior to the Formation of the Salton Sea

Knowledge of the avifauna of the Salton Trough prior to the formation of the modern Salton Sea is quite limited and reflected primarily in collections of exploratory parties from the United States government, and in particular those collections housed in the National Museum of Natural History (formerly United States National Museum, hereafter USNM). Edgar A. Mearns, assisted by Frank X. Holzner, collected for the United States and Mexican Boundary Commission from 7 April to 6 May 1894 with an itinerary that included the following sites in the Salton Trough: Cooks Wells, Seven Wells, Gardner's Laguna, Salton River, Laguna del Alamo, Unlucky Lake, Indian Wells, New River, Laguna Station, and Mesquite Lake (Mearns 1907). Edward W. Nelson and Edward A. Goldman collected specimens, primarily for USNM, around 1905 to 1907. Frank Stephens collected in the general region in the 1890s, including some important collections from the Salton Sink itself; in later years he made additional important collections from the Salton Sink for the San Diego Natural History Museum, an institution whose interest in that area continues today with the collecting efforts of Philip Unitt, Roger Higson, and others.

The prehistoric avifauna of the Salton Sink has also been studied through the collection and identification of zooarchaeological remains along the shores of Lake Cahuilla, the forerunner of the modern Salton Sea that intermittently occupied the Salton Sink (see Patten and Smith-Patten *this volume* and references therein). The formation and early history of the Salton Sea, its antecedent lakes in the Salton Sink, and the relationship of the Salton Sink to the Colorado River are detailed by Sykes (1937).

Exploration of the Salton Sea and the Compilation of Avifaunal Records Through Collections of Skins and Eggs

The first ornithological exploration of the Salton Sea itself was made on 19 April 1908 when Joseph Grinnell rode the *Vinegaroon* from a starting point near Mecca at the Sea's north end some 65 km to Echo Island near the southeast end, about 20 km south of the railroad stop of Lano, "near Volcano"; it is unclear whether "Echo Island" refers to modern-day Obsidian Butte (Black Rock) or perhaps Mullet Island. The results of the voyage of the *Vinegaroon* were published in *The Condor* (Grinnell 1908).

Loye H. Miller collected a specimen of Louisiana Waterthrush, *Seiurus motacilla,* on 17 August 1908 "while passing the time between trains at the station at Mecca, Riverside County, in search of the English Sparrow [*Passer domesticus*] to determine its western progress along the Southern Pacific route" (Miller 1908). This constituted the first record of this waterthrush for California, and remained the only record until 1985 (Dunn 1988).

William L. Dawson visited the north end of the Salton Sea in 1913 and documented the Double-crested Cormorant (*Phalacrocorax auritus*) colony there in that species' account in his *Birds of California* (Dawson 1923). Dawson wrote of fish kills he encountered: "Fish of four or five kinds struggled feebly in the shallow waters or else lined the shores in windrows . . . . It was impossible to determine what was causing the demise of these fish, whether the increasing saltiness of the water, or the exertions of the spawning season."

Dawson was referring, of course, to various species of freshwater fish that had entered the Sea from the Colorado River (Walker 1961), but this early observation was a portent of the abundant fish "necromass" that was to characterize the Sea in later years.

John R. Pemberton (1927) discovered a unique land-locked breeding colony of the Gull-billed Tern (*Sterna nilotica*) at the south end of the Sea in 1927; follow-up visits to this colony were made in the following and subsequent years by Loye Miller, Adrian J. van Rossem, Raymond B. Cowles, Donald R. Dickey, and others. Pemberton's Gull-billed Terns, several of which were collected by J. Stuart Rowley, who accompanied him, proved to be an undescribed subspecies, named two years later by Griffing Bancroft (Bancroft 1929). The Salton Sink, in fact, is the type locality for at least six avian subspecies: *Ardea virescens anthonyi* (Mearns 1895; now *Butorides virescens anthonyi*); *Dendrocygna bicolor helva* (Wetmore and Peters 1922) from "Unlucky Lake" (*helva* is now universally considered a junior synonym of nominate *bicolor*, rendering the species monotypic); *Melospiza melodia saltonis* (Grinnell 1909; best merged with *M. m. fallax*; Patten 2001, Arcese et al. 2002); *Gelochelidon nilotica vanrossemi* (Bancroft 1929) from the south end of Salton Sea [= *Sterna nilotica vanrossemi*]; *Pyrocephalus rubinus flammeus* (van Rossem 1934) from Brawley; and *Cistothorus palustris deserticola* (Rea 1986) from the New River, 3.2 km north-northwest of Seeley (best synonymized with *aestuarinus*; Unitt et al. 1996).

Oologists found profitable collecting in the Salton Sea region. Wilson Hanna made extensive egg collections, mainly between 1920 and 1950; over 500 egg sets from the Salton Sea area are housed at the San Bernardino County Museum (R. L. McKernan, pers. comm.), representing Hanna's efforts as well as those of Joseph P. Norris earlier in the 20th century. Other egg collectors worked the Salton Sea and vicinity, with most of their collections now housed at the Western Foundation of Vertebrate Zoology in Camarillo, California.

Establishment of Wildlife Refuges, 1930—An Era of Waterfowl Management and Habitat Enhancement

The federal refuge at the south end of the Salton Sea was established in 1930 as the "Salton Sea Migratory Waterfowl Refuge." It later became known as the Salton Sea National Wildlife Refuge (SSNWR), now amended to the Sonny Bono Salton Sea National Wildlife Refuge. Maintenance of habitat for migratory waterfowl and game species was the overriding mission through much of the existence of this refuge, as well as for the State Waterfowl Management Area (now Imperial Wildlife Area) neighboring the federal refuge. Much of the early work by refuge personnel was in waterfowl management, with the goal of reducing crop depredations by grain-feeding waterfowl (O'Neill 1999).

Annual refuge narratives were begun by Luther C. Goldman, refuge manager, in 1939. They reveal the predictable emphasis on waterfowl and game birds, with Ring-necked Pheasant (*Phasianus colchicus*) releases, for example, documented in 1939. Even as early as that year, however, there was mention of Yuma Clapper Rails (*Rallus longirostris yumanensis*) on the refuge, a taxon which was to become of great management concern there. A card file of bird observations was also kept by Goldman.

Much of the originally designated federal refuge was soon submerged by rising water levels, and the refuge narratives plaintively read, "Until we do get lands above the water level, little can be done toward development on the Salton Sea Refuge." When Edward J. O'Neill arrived as refuge manager in 1947 the entire original 32,400-acre refuge was underwater (O'Neill 1999). The refuge narratives contain interesting instances of human as well as avian behavior, such as the following entry: "One hunting tragedy occurred during the last day of the open season when a woman accidentally shot and killed her husband who was in a blind only a few feet from her own."

O'Neill remained as refuge manager until 1958 and detailed his experiences there in a memoir (O'Neill 1999). During his tenure an emphasis on waterfowl management continued, but he also described some work with colonial waterbirds and landbirds. His book describes efforts directed toward habitat management, bird banding, the regulation of gamebird hunting and the enforcement of those regulations, noteworthy bird records, development of early bird lists, and nesting-biology studies. Signs of conservation problems abounded; for example, an Atomic Energy Commission installation usurped one former nesting islet in 1950. The 1955 refuge narrative contains a pointed comment regarding the abandonment of a Gull-billed Tern colony from disturbance by a photographer and egg-collector.

From 1959 to 1967 there were four different federal refuge managers, and biological information in the narratives became a bit more sketchy, with renewed emphasis on waterfowl and game bird management. Starting in the early

1960s many sightings from Guy McCaskie and other birders were entered into the refuge files. In 1985 and 1986, under Gary Kramer as refuge manager and William Henry as assistant refuge manager (and later wildlife biologist), the first real work on contaminants was reported and focused studies of the Burrowing Owl (*Athene cunicularia*) were initiated. After the 1980s additional long-term projects on non-game species were conducted, including those on colonial waterbirds, Yuma Clapper Rails, contaminant analysis of waterbirds using agricultural drains, and Burrowing Owls. The Salton Sea National Wildlife Refuge narratives are now available in CD-ROM format from the University of Redlands [http://www.institute.redlands.edu/salton].

The state of California's Imperial Wildlife Area, with its component Wister and Finney-Ramer units, also manages both game and non-game species. The Finney-Ramer Unit acreage was purchased from two professional baseball players in the early 1930s, and land for the Wister Unit was acquired in 1956 (Gillilan 1971, Nathenson 1972).

Refining Distributional Information by Collectors and Field Ornithologists

Various collectors worked the Salton Sea and surrounding areas from the period after the Sea's formation through the 1920s and beyond. Important collections of birds from the Salton Trough are housed at the Natural History Museum of Los Angeles County (mainly through the efforts of Frank Daggett and Luther Wyman), Museum of Vertebrate Zoology (University of California, Berkeley), San Bernardino County Museum, San Diego Natural History Museum, Dickey Bird and Mammal Collections (University of California, Los Angeles), University of Michigan Museum of Zoology, and Western Foundation of Vertebrate Zoology, with significant further collections in at least 16 additional major institutions.

Seven distributional notes regarding birds around the Coachella Valley and the north end of the Salton Sea were published in *The Condor* by Ben L. and Marjorie Clary of the Coral Reef Ranch, Coachella, between 1930 and 1936. These notes included documentation of California's first Blue-footed Booby (*Sula nebouxii*) on the Sea in November 1929, a species whose irregular irruptions into the Salton Sink from the Gulf of California are now well known. Regarding the booby record, Mrs. Clary (1930) wrote: "Frequently it lit on the levees within a few feet of him ["Mr. Hartley"], and on several occasions he was able to pick the bird up and carry it about. But if not in the mood for such demonstrations of affection, it did not hesitate to prod him with its long, sharp bill." The Clarys also obtained the first Salton Sink specimen of Large-billed Savannah Sparrow (*Passerculus sandwichensis rostratus*) on 23 February 1930, an occurrence published by Willett (1930); this endemic subspecies of the Colorado River Delta and adjacent coasts has proven to be a regular non-breeding visitor to the Sea from late summer through early winter (Patten et al. 2003) and has recently expanded its breeding range to the southern tip of the Salton Sink (Molina and Garrett 2001).

Distributional information and specimen collections were obtained regularly from the 1940s through the 1980s by Eugene A. Cardiff (often with his brother Bruce E. Cardiff). Testifying to the continually changing nature of the Salton Sea, the tree in which California's first Cerulean Warbler (*Dendroica cerulea*) was collected by Eugene Cardiff on 1 October 1947 (Hanna and Cardiff 1947) is now well below the surface of the Sea. Scientific collecting in the Salton Sea area has continued through the efforts of Cardiff (and son Steven W. Cardiff, now with the Louisiana State University Museum of Natural Science), Robert L. McKernan, and Gerald Braden of the San Bernardino County Museum. Additional collecting, particularly with an eye toward the assessment of polytypic species, has also been conducted by Philip Unitt, Roger Higson, and others connected with the San Diego Natural History Museum.

Guy McCaskie made the first of his >850 visits to the Salton Sea in 1961. Born in Scotland, McCaskie brought his passion and efficient field-birding techniques to California in 1957 (Drennan 1992). McCaskie's efforts exemplify those of a host of talented amateur birders who have refined distributional information and increased our knowledge of breeding birds, post-breeding dispersal, vagrants, and rare migrants in the Salton Sea region. By 1962 McCaskie had discovered large numbers of Stilt Sandpipers (*Calidris himantopus*), a species represented previously in the region by only a handful of specimens and sight records. This prompted then *Audubon Field Notes* regional editor Arnold Small to write: "What must be regarded as a truly phenomenal number of Stilt Sandpipers for California was found by McCaskie and Stallcup on the Salton Sea National Wildlife Refuge August 31 (1961) . . . 99 birds." The results of decades of field records by McCaskie and others, along with an analysis of specimens, have recently been compiled into an avifaunal study of the Salton Sea (Patten et al. 2003).

The California Bird Records Committee of the Western Field Ornithologists has reviewed 425 records of vagrant and scarce migrant bird species from the Salton Sink in Imperial and Riverside counties through 2001, accepting 338 of them (California Bird Records Committee files, maintained at the Western Foundation of Vertebrate Zoology in Camarillo, CA); the vast majority of these are photographic or sight records.

Annual scheduled field trips to the Salton Sea and Imperial Valley by numerous southern California chapters of the National Audubon Society and various bird clubs continue to generate distributional information. The first and, to date, only meeting of an ornithological society to be held in the Salton Sink was that of the Western Field Ornithologists in Imperial in August 1997. A Salton Sea International Bird Festival was initiated in 1998 and has been held nearly annually since at a resort in Holtville.

Research on the Ecophysiological Challenges of Thermoregulating in the Salton Sea Area

With mid-summer temperatures frequently exceeding 45°C, the Salton Sea area has proven to be a popular field laboratory for the study of avian behavioral and physiological responses to a thermally challenging environment. William L. Dawson speculated that the January nesting of Double-crested Cormorants he observed on his 1913 visit to the north end of the Salton Sea was an adaptation to the heat: "The remarkably early nesting may have been induced not only by the movements of the fish, but by the disciplinary experience of the effect upon young squabs of the Colorado Desert sun in, say, April (equivalent to July anywhere else)" (Dawson 1923).

George A. Bartholomew and William R. Dawson (along with refuge manager Edward J. O'Neill) investigated thermoregulation in American White Pelicans (*Pelecanus erythrorhynchos*) nesting on sandy islets near the southwestern shore of the Salton Sea (Bartholomew et al. 1953). Gilbert S. Grant of the University of California, Los Angeles, conducted his doctoral dissertation on behavioral adaptations to high temperatures in incubating recurvirostrids, *Charadrius, Sterna,* Black Skimmers (*Rynchops niger*), and Lesser Nighthawks (*Chordeiles acutipennis*) (Grant 1979, 1982), and Kathy C. Molina of California State University, Northridge, investigated parental care in Gull-billed Terns and Black Skimmers in the hot Salton Sea environment (Molina 1999).

Focused Management for Sensitive, Threatened, and Endangered Species—Reconnaissance Studies and "Saving the Salton Sea"

Particularly in the last decade of the 20th century, concerns about the Salton Sea's elevation, salinity, contaminants, and disease outbreaks, coupled with regional and continental concerns about the conservation status of a suite of sensitive, threatened, or endangered bird species, led to a variety of focused species studies and larger-scale reconnaissance projects. Ecological problems and increasing demands from urban and agricultural regions outside the Salton Sink for Colorado River water (the source of nearly all of the Salton Sea's water) fostered the involvement of conservation organizations, universities, agrobusinesses, local commerce, various government agencies, and politicians. Having entered the political arena, the Salton Sea took a leap forward in the consciousness of politicians with the death on 5 January 1998 of Congressman Sonny Bono (R-Palm Springs). Bono had championed the cause of environmental cleanup and economic development of the Salton Sea, and "saving the Salton Sea" became something of a political mantra in his honor. A corollary of this political interest in the Salton Sea was governmental funding for various reconnaissance studies of the Sea's biota, ecology, and environmental health.

Studies on particular species or groups in recent years have included surveys of migratory shorebirds in 1989–1995 and again in 1999 (Shuford et al. *this volume*); the migration ecology of Eared Grebes (Jehl and McKernan 2002); the migration ecology of White and Brown (*Pelecanus occidentalis*) pelicans (ongoing work by Daniel W. Anderson, University of California, Davis); breeding herons (the late Norman D. Hogg; Molina and Sturm *this volume*); White-faced Ibis (Shuford et al. 1996); breeding larids (Molina *this volume*); Song Sparrows (Patten 2001); subtropical waterbirds and "pelagic" birds (Patten and McCaskie *this volume*); polytypic landbirds (Patten et al. 2003, *this volume*); rails (e.g., Laymon et al. 1990); Burrowing Owls (York et al. 2002, Rosenberg and Haley *this volume*); and Mountain Plovers (Knopf and Rupert 1995, Wunder and Knopf 2003, Shuford et al. *this volume*).

General avian reconnaissance studies were conducted in 1999 by workers from Point Reyes Bird Observatory (Shuford et al. 2000), forming a baseline against which anticipated avifaunal changes could be measured. A popular account of the Salton Sea's avifauna from the same time period, based on surveys at a number of sites around the Sea, was published by Massey and Zembal (2002).

Among numerous recent studies on avian diseases and ecosystem health in the Salton Sea region, that of Rocke and Friend (2003) is noteworthy for having relied heavily on the narratives and other records maintained at the SSNWR.

CLOSING REMARKS

The current trend of management-oriented research is likely to continue as long as a biologically viable Salton Sea continues to exist. In fact, it is likely that long-term monitoring of avian populations and habitats will be mandated in conjunction with the testing and implementation of engineering solutions to the instability of the Sea. Increasingly, the Salton Sea and adjacent agricultural areas and riparian systems are being perceived as an inter-related unit, and these areas are in turn recognized as part of the larger unit of the entire Salton Trough, including the lower Colorado River and its delta. Therefore, future research is likely to involve collaborations with workers on the Mexican side of the Trough. On an even larger scale the Salton Sea is but one of a series of shallow inland lakes throughout western North America (Jehl 1994), and part of a suite of migration systems that link far-flung regions throughout the Americas.

The Salton Sink of the future may ultimately appear as foreign to us as the present-day situation might have looked to Joseph Grinnell as he journeyed on the *Vinegaroon* in 1908, and most certainly to Mearns as his party collected specimens and explored the border region before the modern Salton Sea even existed.

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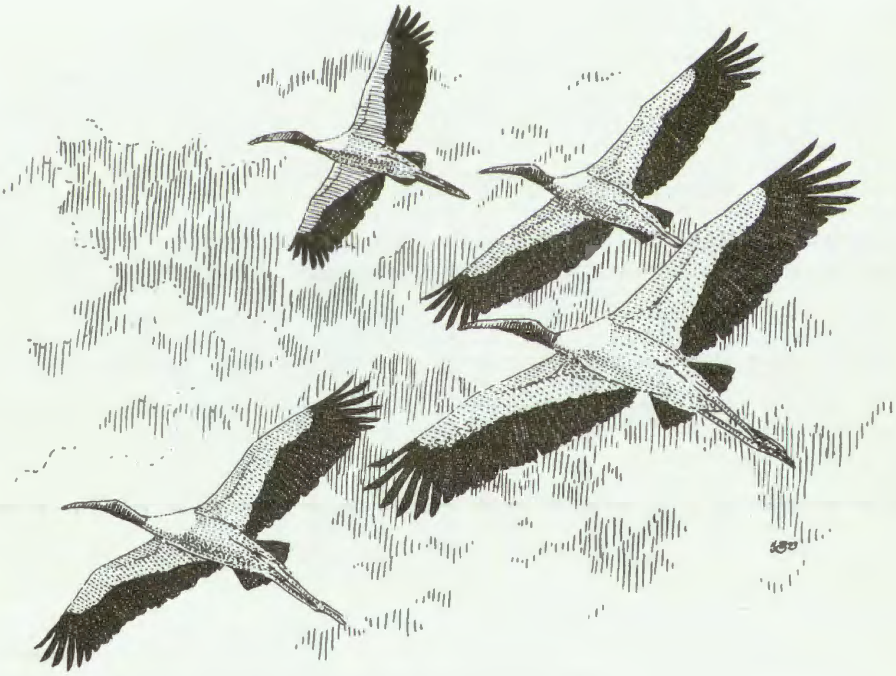

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POPULATION CHANGES AND BIOGEOGRAPHIC AFFINITIES OF THE BIRDS OF THE SALTON SINK, CALIFORNIA/ BAJA CALIFORNIA

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Abstract. Since the Salton Sea's formation in 1905, permanent water, introduced aquatic prey, and extensive habitat conversion have altered its birdlife greatly. A number of waterbird and landbird species colonized the Sea and the associated Salton Sink early in the twentieth century. Other landbirds suffered from the loss of desert scrub and, particularly, mesquite (*Prosopis* spp.) thickets, with the Vermilion Flycatcher (*Pyrocephalus rubinus*), Le Conte's Thrasher (*Toxostoma lecontei*), and Lucy's Warbler (*Vermivora luciae*) eventually extirpated as breeders. Although some waterbird species have declined since 1950, many have increased or held steady. Populations of 60% of breeders that colonized or increased markedly originated in the Gulf of California or adjacent western Mexico. Since 1950, the Wood Stork (*Mycteria americana*), Fulvous Whistling-Duck (*Dendrocygna bicolor*), American Wigeon (*Anas americana*), and Northern Pintail (*A. acuta*) are the only waterbirds, and the Crissal Thrasher (*Toxostoma crissale*) the only landbird, that have declined markedly. After a decline in the 1930s, the Large-billed Savannah Sparrow (*Passerculus sandwichensis rostratus*) has increased since the 1980s and began nesting in the Mexicali Valley in the late 1990s. Landbird species that colonized the Salton Sink since 1950 include the Inca Dove (*Columbina inca*), Great-tailed Grackle (*Quiscalus mexicanus*), and Bronzed Cowbird (*Molothrus aeneus*)—species that have increased dramatically throughout the American Southwest—and the White-tailed Kite (*Elanus leucurus*), Anna's Hummingbird (*Calypte anna*), and the non-native European Starling (*Sturnus vulgaris*). Landbird species colonizing the Salton Sink generally have colonized from the Colorado River Valley, whereas landbird subspecies generally have colonized from coastal California.

Key Words: avian biogeography; colonization; population changes; Salton Sea.

CAMBIOS POBLACIONALES Y AFINIDADES BIOGEOGRÁFICAS DE LAS AVES DE LA CUENCA DEL SALTON, CALIFORNIA/BAJA CALIFORNIA

Resumen. Desde la formación del Mar Salton en 1905, agua permanente, la introducción de presas acuáticas y extensiva conversión de hábitats han alterado en gran medida su avifauna. Un número de especies de aves acuáticas y terrestres colonizaron el Mar y la asociada Cuenca del Salton a principios del siglo veinte. Otras especies terrestres sufrieron de la pérdida del hábitat arbustivo de desierto y, particularmente, de densos mezquites (*Prosopis spp.*) con la consiguiente pérdida de la reproducción del Mosquero Cardenal (*Pyrocephalus rubinus*), el Cuitlacoche Pálido (*Toxostoma lecontei*) y el Chipe Rabadilla Rufa (*Vermivora luciae*). Aunque algunas especies de aves acuáticas han reducido sus poblaciones desde 1950, muchas han aumentado o se han mantenido constantes. Las poblaciones de 60% de aves reproductivas que colonizaron o se incrementaron marcadamente, fueron originadas en el Golfo de California o en tierras adyacentes del oeste de México. Desde 1950, la Cigüeña Americana (*Mycteria Americana*), el Pijije Canelo (*Dendrocygna bicolor*), el Pato Chalcuán (*Anas americana*) y el Pato Golondrino (*Anas acuta*), son las únicas aves acuáticas, y el Cuitlacoche Crisal (*Toxostoma crissale*) la única ave terrestre, que han disminuido marcadamente. Después de una reducción en los años 1930, el Gorrión Sabanero de Pico Largo (*Passerculus sandwichensis rostratus*) ha incrementado desde los años 1980 y comenzó a anidar en el Valle de Mexicali a fines de los años 1990. Las especies de aves terrestres que colonizaron la Cuenca del Salton a partir de 1950 incluyen la Tórtola Cola Lagra (*Columbina inca*), el Zanate Mexicano (*Quiscalus mexicanus*), el Tordo Ojo Rojo (*Molothrus aeneus*)—especies que han incrementado dramáticamente a lo largo del sureste de los Estados Unidos—y el Milano Cola Blanca (*Elanus leucurus*), el Colibrí Cabeza Roja (*Calypte anna*), y el introducido Estornino Pinto (*Sturnus vulgaris*). Las especies de aves terrestres que colonizan la Cuenca del Salton generalmente lo han hecho desde el Valle del Río Colorado, mientras que las subespecies de aves terrestres generalmente han colonizado desde la costa de California.

Palabras claves: biogeografía de aves; colonización; cambios poblacionales; Mar Salton.

Lake Cahuilla, the vast precursor of the Salton Sea, was ephemeral. Floodwaters from the Colorado River filled this lake periodically. But intense heat and direct sunlight removed its water at a rapid rate, producing an alkaline flat within a few decades. The ebb and flow of surface water implies an ebb and flow of habitats, with bird communities presumably changing in kind. We know little about the avifauna of Lake Cahuilla and nothing of patterns of range expansion and retraction around that lake. Yet we do know that various waterbird species that occur at the Salton Sea also occurred at Lake Cahuilla (Patten and Smith-Patten *this volume*). Logic dictates that these species vacated the region when the lake dried, although we do not know how soon before desiccation they departed, let alone how long after flooding they colonized, although some species likely colonized rapidly (Grinnell 1908; see below).

The Salton Sea is essentially a miniature version of Lake Cahuilla, created by the same processes and harboring, so far as we know, similar species of birds (Patten and Smith-Patten *this volume*). A key difference is that the Salton Sea receives a substantial influx of irrigation runoff, effectively maintaining the Sea's surface level—an ephemeral lake has become permanent. Runoff is the result of broad-scale conversion of desert scrub to agriculture; for decades the Imperial and Coachella valleys have been among the greatest crop-producing regions in the United States (Steere 1952). The sudden emergence of a mesic environment in the heart of the western Sonoran Desert (the Sea was created in under two years), coupled with the subsequent introduction—deliberate and accidental—of various fishes and invertebrates (see Walker 1961, Jehl and McKernan 2002) led to drastic changes in the region's birdlife. Perhaps equally profound in impact was the piecemeal clearing of riparian habitats and the methodical irrigation and development of agriculture in the valleys surrounding the Salton Sea.

Patterns of avian colonization and retreat at Lake Cahuilla are likely to remain unknown. Yet ornithological exploration of the Salton Sink since its inception (Garrett et al. *this volume*) has provided some insight into how habitat alteration generally, and the existence of the Salton Sea specifically, permitted various species to colonize and forced others to evacuate. On the basis of habitat descriptions near the turn of the twentieth century, such as those of Mearns (1907) and Parish (1914), it appears that the amount of both open water and of parks, ranches, and suburbia increased greatly after 1900, whereas the amount of desert scrub and of mesquite (*Prosopis* spp.) thickets decreased greatly as land was converted to agriculture. Likewise, the amount of marshes and riparian vegetation appears to have held steady, although the character of each has changed, the former now heavily managed, the latter now dominated by non-native tamarisk (*Tamarix ramosissima*) rather than native willow (*Salix* spp.), Fremont cottonwood (*Populus fremontii*), and bordering mesquite.

In this paper we summarize often scant data on range expansions into the Salton Sink. We focus particularly on range changes in the last half of the twentieth century, during which the surface level of the Sea has been relatively stable and conversion to agriculture was largely complete. We use these data to explore colonization patterns for species of waterbirds, species of monotypic landbirds, and subspecies of polytypic landbirds. We summarize biogeographic affinities of avian taxa occupying the Salton Sink and compare these affinities with patterns of colonization.

METHODS

The Salton Sea National Wildlife Refuge and Point Reyes Bird Observatory have censused various waterbirds since the early 1980s, and volunteers have conducted Christmas Bird Counts regularly at the north and south ends of the Salton Sea since 1970, sporadically before then. Our efforts to examine trends since 1900 were thus constrained by the virtual lack of quantitative data on population sizes prior to the 1960s. Given this constraint, and because our goal was to deduce and outline general patterns, we often attempted to make only qualitative statements about range expansion and biogeographic affinities. Therefore, the information we present in the tables and figures is often qualitative, meant only to provide a heuristic guide to general patterns and to summarize the more obvious trends. Nonetheless, we did examine waterfowl and other data from the Salton Sea (south) Christmas Bird Count, conducted in the winters of 1939/1940–1941/1942, 1955/1956–1957/1958, 1965/1966, and 1968/1969–present, and we gathered and present some additional quantitative data. Numerous small fluctuations or trends in range or population size, and probably some larger ones, likely went undetected.

We gathered data from a variety of sources, detailed by Patten et al. (2003). In summary, we relied mainly on published sources (particularly regional reports in *North American Birds* and its predecessors and notes in the *Condor*), specimen data (chiefly from the San Diego Natural History Museum), and our field notes and those of Guy McCaskie. Taxonomy follows Patten et al. (2003). Tables list scientific names not in the text. We derived data for our pie charts from accounts of subspecies' occurrences in the Salton Sink (Patten et al. 2001, 2003), which we chiefly based on comparisons of specimens. We created pie charts for heuristic comparison; they do not reflect exact percentages of occurrences.

RANGE AND POPULATION CHANGES 1900–1950

Shortly after the turn of the twentieth century, permanent surface water and extensive habitat conversion for agriculture greatly altered the avifauna of the Salton Sink. Many waterbird species colonized the Salton Sea within a few years of its formation; both the American White Pelican (*Pelecanus erythrorhynchus*) and Double-crested Cormorant (*Phalacrocorax auritus*) were breeding there by the time Grinnell (1908) conducted the first ornithological exploration of the Sea. Over the next two decades the Sea was colonized by various other waterbird species, such as the Gull-billed Tern (*Sterna nilotica*) by

TABLE 1. STATUS AND PROVENANCE OF SELECTED SPECIES OF WATERBIRDS THAT HAVE COLONIZED OR APPEAR TO BE COLONIZING THE SALTON SEA

Species[a]	Appearance	Current status	Provenance
American White Pelican	1907	common visitor; former breeder	Great Basin
Brown Pelican	1951	common post-breeder; breeds	Gulf of California
Double-crested Cormorant	1907	common breeder	?
Neotropic Cormorant	1982	rare post-breeder; increasing	west Mexico
Cattle Egret	1970[b]	common breeder	west Mexico
White-faced Ibis	1954[b]	common visitor; breeds	Great Basin
Black-bellied Whistling-Duck	1951	rare post-breeder; increasing	west Mexico
Fulvous Whistling-Duck	ca. 1906	former breeder	west Mexico
Laughing Gull	1928[b,c]	common post-breeder; breeds	Gulf of California
Heermann's Gull	1967	rare post-breeder; increasing?	Gulf of California
California Gull	1996[b]	common visitor; breeds	Great Basin
Yellow-footed Gull	1965	common post-breeder	Gulf of California
Western Gull	1969	increasing perennial visitor	Pacific coast
Gull-billed Tern	1927	fairly common breeder	Gulf of California
Caspian Tern	1927[b,c]	common breeder	?
Elegant Tern	1985	increasing post-breeder	Gulf of California
Forster's Tern	1970[b]	common visitor; breeds	?
Least Tern	1964	uncommon visitor; increasing?	Gulf of California
Black Skimmer	1968	fairly common breeder	Gulf of California

[a] Scientific names in text or Table 2, except: Neotropic Cormorant (*Phalacrocorax brasilianus*), Black-bellied Whistling-Duck (*Dendrocygna autumnalis*), and Elegant Tern (*Sterna elegans*).
[b] Date of first breeding, not of first occurrence.
[c] Extirpated as a breeder in 1950s; recolonized in 1992 (Caspian Tern) and 1994 (Laughing Gull).

1927 (Pemberton 1927) and the Laughing Gull (*Larus atricilla*) by 1928 (Miller and van Rossem 1929).

During the early decades of the twentieth century a host of landbird species also colonized the Salton Sink, presumably drawn to the greener, wetter habitats of ranch yards, towns, orchards, and agricultural fields. Notable among the early landbirds colonizing were the White-winged Dove (*Zenaida asiatica*), Gila Woodpecker (*Melanerpes uropygialis*), Northern Mockingbird (*Mimus polyglottos*), and Brown-headed Cowbird (*Molothrus ater*), each of which reached the region before the close of the 1930s (Hoffmann 1927, Arnold 1935, Rothstein 1994, Patten et al. 2003). Even the non-native House Sparrow (*Passer domesticus*), introduced on the east coast of North America, marched across the continent and reached the Salton Sink by the early 1910s (van Rossem 1911). Of these species, only the mockingbird reached the Salton Sea from the west (see below).

With the loss of desert scrub, particularly thickets of mesquite, various species of landbirds paid the price. Notable among these species were the Vermilion Flycatcher (*Pyrocephalus rubinus*), Le Conte's Thrasher (*Toxostoma lecontei*), and Lucy's Warbler (*Vermivora luciae*), each of which showed sizeable declines by the 1930s and are now extirpated from the region as breeders (Patten et al. 2001, 2003). Neither the thrasher nor the warbler occurs regularly anymore, whereas the flycatcher occurs only as a sparse winter visitor. The Vermilion Flycatcher's decline is curious in light of this species' tolerance of human-altered habitat, such as agricultural areas and golf courses, in other parts of its range (Wolf and Jones 2000). Moreover, the species occasionally summers in northeastern Baja California along the Río Colorado (where it bred in 2002; O. Hinojosa-Huerta, pers. comm.) and Río Hardy (Patten et al. 2001).

RANGE AND POPULATION CHANGES 1950–2000

WATERBIRDS

In the past half century numerous species of breeding and non-breeding waterbirds have either colonized the Salton Sea or increased there markedly (Tables 1, 2). By contrast, two species, the Wood Stork and Fulvous Whistling-Duck, have decreased so much that each may soon be extirpated in California. The stork occurs principally as a post-breeding visitor to the Salton Sink, with the largest numbers in late summer and early fall (August and September). It used to occur in the thousands, but the 1990s brought ≤75 individuals every year, with as few as 12 in the most austere (Fig. 1). In 2002 the species again was scarce (G. McCaskie, pers. comm.), although a remarkable 36 storks were in the southern Mexicali Valley in July (E. Mellink, pers. comm.). Similarly, the multitude of whis-

TABLE 2. SELECTED WATERBIRD SPECIES THAT HAVE SHOWN MARKED DECREASES, OR INCREASES AS NONBREEDERS, AT THE SALTON SEA SINCE 1950

Species	Change[a]	Season	Since
Brown Pelican (*Pelecanus occidentalis*)	↑↑↑	summer/fall	1951
Cattle Egret (*Bubulcus ibis*)	↑↑↑	year round	1963
White-faced Ibis (*Plegadis chihi*)	↑↑	winter	1970s
Wood Stork (*Mycteria americana*)	↓↓↓	summer/fall	mid-1960s
Fulvous Whistling-Duck (*Dendrocygna bicolor*)	↓↓↓	summer/breeder	1980s
Ross's Goose (*Chen rossii*)	↑↑↑	winter	mid-1960s
Canada Goose (*Branta canadensis*)	↓↓↓	winter	1980s
Brant (*Branta bernicla*)	↑↑	spring	1962
Gadwall (*Anas strepera*)	↑	winter	1970s
American Wigeon (*Anas americana*)	↓↓↓	winter	1960s
Northern Shoveler (*Anas clypeata*)	↑↑	winter	1950s
Northern Pintail (*Anas acuta*)	↓↓↓	winter	1950s
Canvasback (*Aythya valisineria*)	↓↓	winter	1970s
Ruddy Duck (*Oxyura jamaicensis*)	↑	winter	1970s
Western Gull (*Larus occidentalis*)	↑	year round	1969
Yellow-footed Gull (*Larus livens*)	↑↑	summer/fall	1965

[a] Each arrow is a rough guide to the magnitude, such that a single arrow signifies a relatively small change, two a relatively moderate change, and three a relatively substantial change.

tling-ducks is gone; the species used to occur in the hundreds as a post-breeding visitor in the 1950s, and at least 20 pairs bred there in the 1960s (Patten et al. 2003). Although breeding numbers declined markedly, dozens of post-breeding birds continued to visit into the early 1990s (Patten et al. 2003). Only one pair was known to have bred in the Salton Sink in 2000; none were known to breed there in 2001 or 2002 (G. McCaskie, pers. comm.). Non-breeders and post-breeding visitors have declined as well; only four were located in 2000 and only one was noted in 2001 (Patten et al. 2003).

Four other species of waterfowl, the Canada Goose, American Wigeon, Northern Pintail, and Canvasback, have also declined (Patten et al. 2003; cf. Barnum and Johnson *this volume*), the goose and the Canvasback steadily (Figs. 2, 3), the wigeon and pintail abruptly after the 1950s (Table 3). The bulk of the populations of the goose and the Canvasback may now winter farther north, such that a few hundred rather than a few thousand now winter in the Salton Sink. This hypothesis requires the gathering and testing of long-term population data throughout California. These two species have declined or were

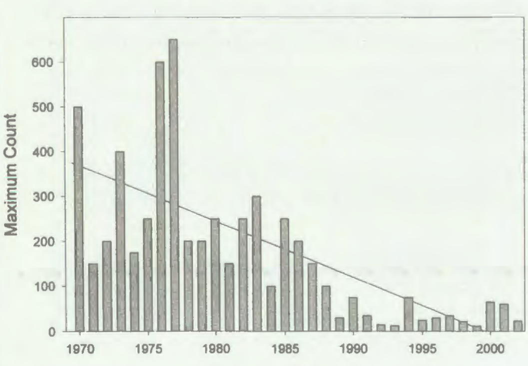

FIGURE 1. Decline of the Wood Stork (*Mycteria americana*) at the Salton Sea since 1970 (Spearman rank correlation: $r_s = -0.82$, $P < 0.001$); thousands of storks used to occur in the 1960s (Garrett and Dunn 1981). The trend line is from a linear regression ($y = -12.48x + 24{,}958.55$, $r^2 = 0.52$). Count data courtesy of G. McCaskie.

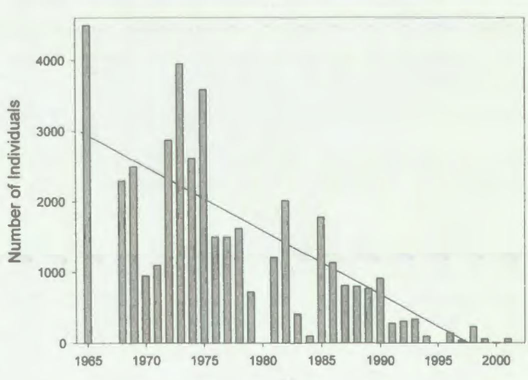

FIGURE 2. Decline of the Canada Goose (*Branta canadensis*) at the Salton Sea since 1965 (Spearman rank correlation: $r_s = -0.87$, $P < 0.001$). The trend line is from a linear regression ($y = -90.42x + 180{,}614.46$, $r^2 = 0.65$). Data are from the Salton Sea (south) Christmas Bird Count.

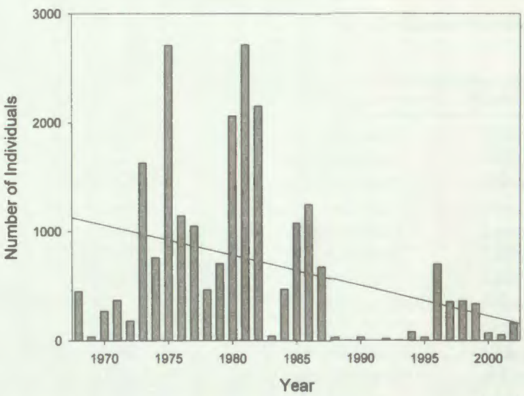

FIGURE 3. Decline of the Canvasback (*Aythya valisineria*) at the Salton Sea since 1968 (Spearman rank correlation: $r_s = -0.42$, $P < 0.01$). The trend line is from a linear regression ($y = -27.77x + 55{,}765.29$, $r^2 = 0.14$). Data are from the Salton Sea (south) Christmas Bird Count.

always scarce in northern Baja California and Sonora (Russell and Monson 1998, Patten et al. 2001). The downward trend of the pintail has been noted across North America (Banks and Springer 1994). Only three species of waterfowl, the Ross's Goose, Northern Shoveler, and Ruddy Duck, have increased markedly since 1970 (Fig. 4, Table 3; Patten et al. 2003, Barnum and Johnson *this volume*). Breeding populations of the goose have burgeoned across the Canadian arctic (Ryder and Alisauskas 1995). Similar broad-scale population increases for the Brown Pelican (Anderson and Gress 1983), Cattle Egret (Larson 1982), White-faced Ibis (Shuford et al. 1996), and Black Skimmer (Collins and Garrett 1996) have been mirrored at the Salton Sea.

The status of larids in the Salton Sink has also changed considerably since 1970, with five species colonizing or recolonizing as breeders (Tables 1, 2). Both the Laughing Gull and Caspian Tern colonized the Sea in the late 1920s, disappeared within in a few decades, and recolonized in the 1990s, the latter species' increase in concert with growing populations across the West (Wires and Cuthbert 2000). Similarly, numbers of the Double-crested Cormorant plummeted in the 1970s and 1980s, until it may have been extirpated (census data are lacking) as a local breeder (K. C. Molina, pers. comm.; W. D. Shuford, pers. comm.). By the mid-1990s, concomitant with increases across the continent (Carter et al. 1995), the species was again breeding in large numbers at the Salton Sea (Shuford et al. 2002b). Even so, breeding populations of both the tern and the cormorant have varied con-

TABLE 3. MEAN (± SE) NUMBERS, BY DECADE, OF DABBLING DUCKS (*ANAS* SPP.) REGULARLY WINTERING AT THE SALTON SEA

Species[a]	1939–1941	1955–1957	1965, 1968–1969	1970–1979	1980–1989	1990–1999	2000–2002
Gadwall	2	25	15	33	100	144	67
	(0.5)	(14.5)	(10.9)	(12.8)	(18.6)	(36.1)	(25.1)
American Wigeon	113,667	33,847	405	389	149	926	849
	(14,983.9)	(5,749.8)	(198.1)	(114.7)	(37.7)	(226.8)	(25.6)
Mallard	20	116	18	36	48	51	46
	(13.1)	(62.9)	(9.6)	(23.0)	(8.0)	(9.1)	(8.3)
Cinnamon Teal	89	134	16	24	50	26	44
	(65.9)	(44.8)	(9.7)	(10.0)	(30.4)	(5.2)	(19.9)
Northern Shoveler	164	6,367	1,417	4,073	6,442	8,743	5,914
	(101.1)	(562.4)	(688.1)	(834.6)	(2,025.4)	(975.9)	(1,635.3)
Northern Pintail	123,000	9,693	5,357	4,278	1,537	4,365	1,062
	(18,779.4)	(5,459.8)	(2,159.6)	(759.7)	(404.7)	(1,396.7)	(202.1)
Green-winged Teal	566	11,043	1,283	1,388	1,731	1,836	2,486
	(296.1)	(3,447.2)	(555.2)	(181.3)	(495.9)	(340.1)	(658.0)

Note: Data are from all available Salton Sea (south) Christmas Bird Counts (N = 42).
[a] Scientific names in text and Table 2.

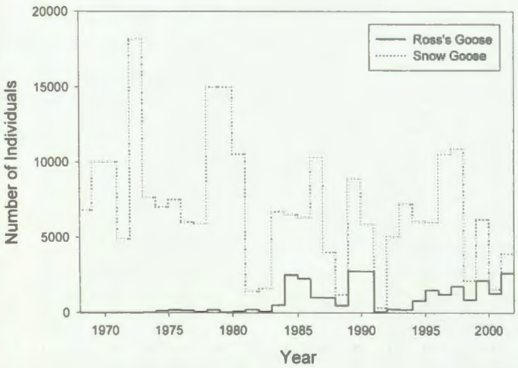

FIGURE 4. Population trends of the Snow Goose (*Chen caerulescens*) and Ross's Goose (*C. rossii*) in the Imperial Valley since 1968. The wintering population of the Snow Goose has been fairly constant since the 1950s (Patten et al. 2003), but wintering population of Ross's Goose has increased since the late 1970s. Data are from the Salton Sea (south) Christmas Bird Count.

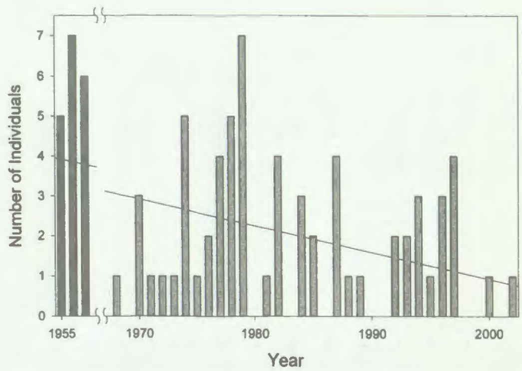

FIGURE 5. Decline of the Crissal Thrasher (*Toxostoma crissale*) at the Salton Sea since 1955 (Spearman rank correlation: $r_s = -0.33$, $P < 0.05$). The trend line is from a linear regression ($y = -0.07x + 134.12$, $r^2 = 0.17$). Data are from the Salton Sea (south) Christmas Bird Count.

siderably from year to year (Molina *this volume,* Molina and Sturm *this volume*).

In addition to the breeders, two species, the Western and Yellow-footed gulls, first appeared at the Salton Sea in the 1960s but are regular now, the former a rare but increasing perennial visitor (Patten et al. 2003), the latter occurring in the thousands as a post-breeding visitor (Patten 1996). Two others, Heermann's Gull (*L. heermanni*) and the Least Tern (*Sterna antillarum*), appear to be increasing although each remains rare enough that changes in status are difficult to judge. Even so, we predict that these two species and the Yellow-footed Gull are the most likely additions to the breeding avifauna of the Salton Sea. Since 1990, pairs of Heermann's Gulls have summered and pairs of Yellow-footed Gulls have been observed performing mating displays (Patten et al. 2003). In July 2002, two adult Least Terns accompanied by a juvenile were at the same location where a pair of adults had been observed in May (Patten et al. 2003).

Populations of most (63%) species that colonized or appear to be colonizing the Salton Sea and adjacent irrigated valleys have their origins in the Gulf of California or adjacent western Mexico (Table 1; see Patten and McCaskie *this volume*). Nine of these 12 southerly species have colonized since 1950 (Table 1), with all but the Cattle Egret and Black Skimmer still on the increase at the Salton Sea (Patten et al. 2003). Of the southerly species, only the Wood Stork and Fulvous Whistling-Duck have undergone steep declines at the Salton Sea, mirroring their declines in Sonora and elsewhere in western Mexico (Russell and Monson 1998, Hohman and Lee 2001).

Landbirds

Population changes

Since the middle of the twentieth century, the Crissal Thrasher (*Toxostoma crissale*) is the only species of landbird that has declined markedly in the Salton Sink, most noticeably after the mid-1980s (Fig. 5). Extensive removal of thickets of honey mesquite (*Prosopis glandulosa*) and screwbean (*P. pubescens*) presumably precipitated this mesquite-dependent thrasher's decline. Nonetheless, populations of the thrasher have persisted longer than those of other mesquite-dwelling species, such as the Vermilion Flycatcher and Lucy's Warbler (see above). The Phainopepla (*Phainopepla nitens*) has had an intermediate response, declining as a breeder but persisting commonly in some small areas, especially during winter (Patten et al. 2003). The Summer Tanager (*Piranga rubra*) no longer breeds in the Salton Sink (Table 4), though its population in the region was likely always small (Patten et al. 2001, 2003).

The multitude of specimens from the 1910s through the 1930s indicates that the Large-billed Savannah Sparrow (*Passerculus sandwichensis rostratus*), a Gulf of California endemic, was formerly a common post-breeding visitor to the Salton Sea. For reasons unknown, potentially related to damming of the Colorado River (*fide* K. L. Garrett), by the 1960s and 1970s this sparrow was "virtually accidental" everywhere in California (McCaskie 1988). Again for reasons un-

TABLE 4. STATUS AND PROVENANCE OF SPECIES OF LANDBIRDS KNOWN TO HAVE COLONIZED THE SALTON SINK SINCE FORMATION OF THE SALTON SEA AND DEVELOPMENT OF AGRICULTURE IN THE COACHELLA, IMPERIAL, AND MEXICALI VALLEYS

Species[a]	Appearance[b]	Breeding status	Provenance
White-winged Dove	1920	common	Colorado River
Inca Dove	1984	rare	Colorado River
Anna's Hummingbird	1980s	uncommon, local	Pacific coast
Gila Woodpecker	1927	uncommon	Colorado River
Black Phoebe	1949	fairly common	?
Brown-crested Flycatcher	1978	rare, irregular	Colorado River
Cliff Swallow	1977	common	Colorado River?
Barn Swallow	1973	extirpated	?
American Robin	1992	rare, irregular	Pacific coast?
Northern Mockingbird	1911	common	Pacific coast
Summer Tanager	1928	extirpated	Colorado River
Lark Sparrow	1970s	fairly common	Pacific coast
Savannah Sparrow (*rostratus*)	1997	rare, local	Gulf of California
Yellow-headed Blackbird	1952	fairly common	Colorado River
Brewer's Blackbird	1988	fairly common, local	Pacific coast
Great-tailed Grackle	1973	common	Colorado River
Bronzed Cowbird	1989	rare, local	Colorado River
Brown-headed Cowbird	1900s	common	Colorado River

[a] Scientific names in text, except: Black Phoebe (*Sayornis nigricans*), Brown-crested Flycatcher (*Myiarchus tyrannulus*), Cliff Swallow (*Petrochelidon pyrrhonota*), Barn Swallow (*Hirundo rustica*), American Robin (*Turdus migratorius*), and Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*).
[b] Date of first breeding, not of first occurrence.

known, this sparrow staged an impressive comeback beginning in the late 1980s. It is again fairly common at the Salton Sea, mainly as a postbreeding visitor (July through February). Moreover, in the late 1990s it bred at Campo Geotérmico Cerro Prieto (Molina and Garrett 2001), a locale in the southern Mexicali Valley roughly midway between the Sea and the Gulf, and singing males (harbingers of breeding at the Sea?) were at the south end of the Salton Sea in early June 1998 and in late December 1999 (Patten et al. 2003).

Other landbirds that have recently colonized or increased markedly in the Salton Sea region (Table 4; Patten et al. 2003) include species emblematic of rapid expansion in the southwestern United States (see Phillips 1968): the Inca Dove (*Columbina inca*), Great-tailed Grackle (*Quiscalus mexicanus*), and Bronzed Cowbird (*Molothrus aeneus*). The dove was first recorded in the region in 1984; it is now an uncommon breeding resident in the Imperial Valley. Records of the cowbird date back to 1956 (Cardiff 1961), but only since the mid-1980s has the species increased sufficiently to establish itself. Most dramatic has been the spread of the grackle. It was first recorded in California and the Salton Sink in 1964 (McCaskie and DeBenedictis 1966), was breeding around the Salton Sea by 1970, and is now a common to abundant resident. The Anna's Hummingbird (*Calypte anna*), Lark Sparrow (*Chondestes grammacus*), and Brewer's Blackbird (*Euphagus cyanocephalus*) also colonized in the 1980s, and the non-native European Starling (*Sturnus vulgaris*) colonized in the 1950s (Rainey et al. 1959, Zimmerman 1973). The White-tailed Kite (*Elanus leucurus*) expanded its range into the Salton Sink in the past three decades, following a trend throughout western North America (see Eisenmann 1971). The species colonized the Imperial Valley in the 1990s, as it did the Mexicali Valley sometime during the 1980s (Patten et al. 1993). Its breeding in the Imperial Valley has been documented on several occasions (Patten et al. 2003), whereas its breeding in the Mexicali Valley is strongly suspected (Patten et al. 2001).

Biogeographic affinities

Whether recent arrivals or not, affinities of landbirds breeding in the Salton Sink are typically with the Sonoran Desert avifauna (Fig. 6). Over 60% of the species known to have colonized the Salton Sink in the twentieth century are from the Sonoran Desert or Colorado River; the remainder is from the Pacific Coast and none is from the Great Basin (Table 4). The key novel habitat appears to be the lawns and planted broadleaf trees (and palms) associated with parks, ranches, and suburbia, for many colonists are human commensals (e.g., the Inca Dove, Anna's Hummingbird, and Great-tailed Grackle). Colonization presumably followed the now permanent rivers and continuous agricultural belt sprawling from the Colorado River through the Mexicali Valley to the Imperial Valley.

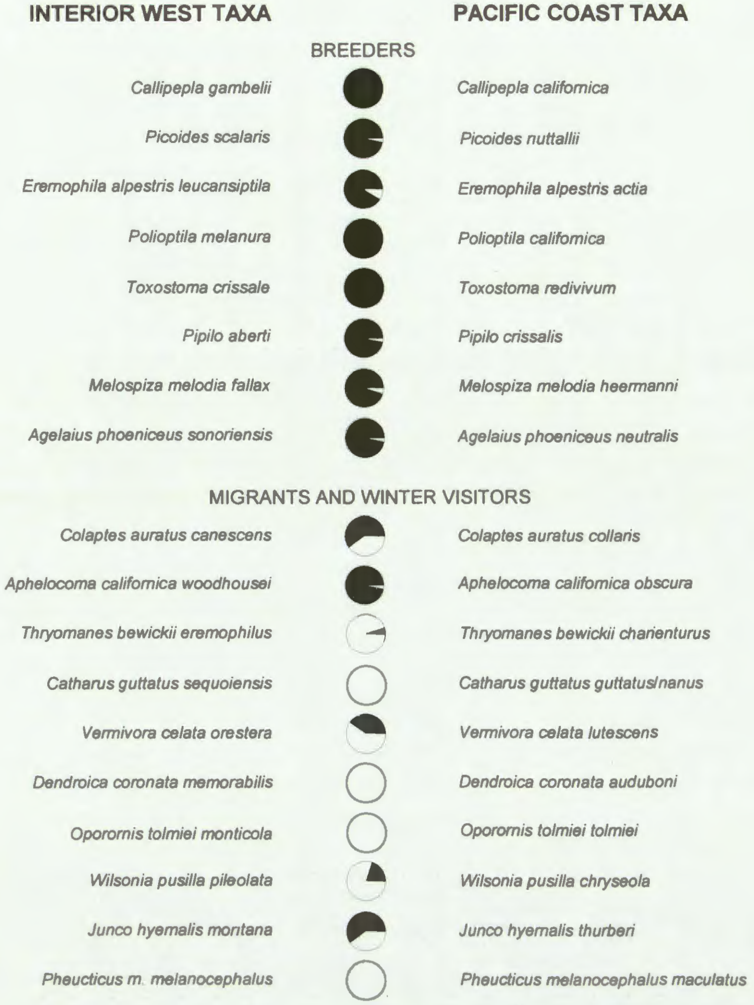

FIGURE 6. Qualitative comparison of biogeographic affinities of landbirds in the Salton Sink. A wholly black pie signifies complete affinity with the interior west avifauna, whereas a wholly white pie signifies complete affinity with the Pacific Coast avifauna. The heading "interior west" refers to the Sonoran Desert for breeders, the Great Basin for migrants and winter visitors.

Subspecies show a different pattern (Fig. 6). As with species, the common breeding subspecies is typically of Sonoran Desert affinity; examples include the Song Sparrow (*Melospiza melodia fallax*) and Red-winged Blackbird (*Agelaius phoeniceus sonoriensis*; see Patten 2001, Patten et al. 2003). The common migrating or wintering subspecies, however, is typically of Pacific Coast affinity (Fig. 6), with few from the Great Basin. In some cases, the Great Basin subspecies provides most records (e.g., 30 records of *Aphelocoma californica woodhousei* to only one of *A. c. obscura*), but in most cases these subspecies provide only a small percentage (e.g., 23 specimens of *Thryomanes bewickii charienturus* to only two of *T. b. eremophilus*) or none (e.g., *Agelaius phoeniceus nevadensis*; N > 300 specimens). Subspecies that appear to have colonized since 1950, such as *Lanius ludovicianus gambelii* and *Eremophila alpestris actia,* are from coastal California and generally have reached only the Coachella Valley (Patten et al. 2003), mirroring the pattern of *Melospiza melodia heermanni* (Patten 2001). These more "mesic-adapted" forms apparently moved southeast through the San Gorgonio Pass, where extensive irrigation of the Salton Sink provided novel habitat that could sustain their populations. Thus, the preponderance of evidence is that colonizing landbird subspecies are chiefly representatives of the cismontane California fauna.

Landbirds colonizing or occurring regularly in the Salton Sink show a different pattern than waterbirds, with breeding species and subspecies typically associated with the Colorado River Valley and migrants and winter visitors typically associated with coastal California. These different patterns underscore the complexity of biogeographic analyses. Had we analyzed all birds as a single group or had we ignored subspecific variation, we likely would have missed the patterns that we uncovered.

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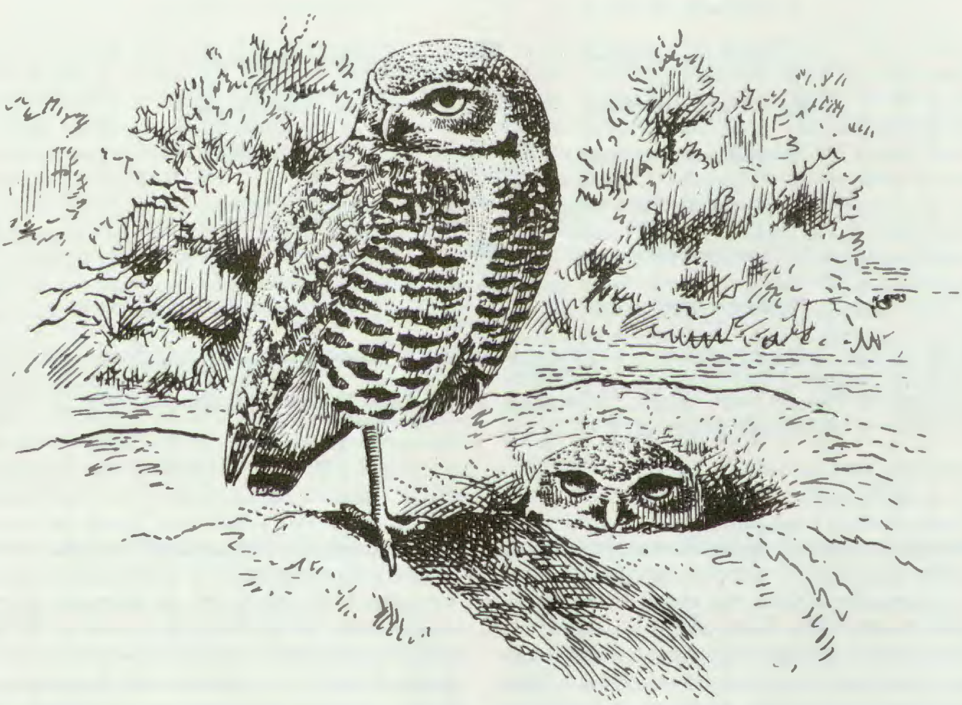

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PATTERNS AND PROCESSES OF THE OCCURRENCE OF PELAGIC AND SUBTROPICAL WATERBIRDS AT THE SALTON SEA

MICHAEL A. PATTEN AND GUY MCCASKIE

Abstract. The Salton Sea attracts a higher diversity of pelagic and subtropical waterbirds than do any other lakes, saline or fresh water, in the interior of western North America. All recorded species of Procellariiformes and subtropical species of Pelecaniformes, Ciconiiformes, Anatidae, and Laridae occur by far most frequently between late April and early October. Several factors appear to facilitate the species' dispersal to the Salton Sink, but restrict their dispersal to other inland bodies of water. Proximity to the Gulf of California, the source of most species, is clearly important. There are no prominent geographic barriers separating the Sea from the Gulf; instead, the intervening region is low-lying and easily crossed. Such barriers do exist in the form of mountain ranges to the west and to the north, and as an expanse of arid land of moderate relief to the east of the Salton Sea, presumably discouraging dispersal beyond the Sink. Seasonality of occurrence coincides with general periods of monsoonal winds, which develop annually in May through October in the Gulf of California and push northward through the Salton Sink. Winds blow predominantly in the opposite direction in winter. During summer months, the presence of thermal air currents in the warm northern gulf and the relatively uniform sea surface temperatures between it and the waters further south along the mainland coast of Mexico may aid movements northward. Such factors probably have a strong influence on dispersal of only some species (e.g., Procellariiformes, pelicans, and frigatebirds). The high diversity of subtropical waterbirds at the Salton Sea appears to result from a combination of factors, which include proximity to the Gulf of California, lack of barriers to dispersal from the Gulf due to the continuous low delta topography, and presence of mountains surrounding the Sea that may act to funnel birds toward the Sink, though the Sea's ecology and size also contribute to the observed patterns.

Key Words: dispersal; procellariiformes; Salton Sea; subtropical waterbirds; vagrants.

PATRONES Y PROCESOS DE OCURRENCIA DE AVES ACUÁTICAS PELÁGICAS Y SUBTROPICALES EN EL MAR SALTON

Resumen. El Mar Salton atrae una diversidad mayor de aves acuáticas pelágicas y subtropicales que cualquier otro lago, ya sea de agua salada o dulce, en el interior del oeste de Norteamérica. Todas las especies de Procellariiformes y especies subtropicales de Pelecaniformes, Ciconiiformes, Anatidae y Laridae registradas ocurren más frecuentemente entre finales de abril y principios de octubre. Varios factores parecen facilitar la dispersión de especies a la Cuenca del Salton, pero restringen su dispersión a otros cuerpos de agua en el interior. La proximidad al Golfo de California, la fuente de la mayoría de las especies, es claramente importante. No hay barreras geográficas prominentes que separen el Mar Salton del Golfo; por el contrario, la región intermedia es un sitio bajo y fácil de cruzar. Dichas barreras existen en forma de cadenas montañosas hacia el oeste y el norte, y como una expansión de tierras áridas de moderado relieve hacia el este del Mar Salton, presumiblemente desalentando la dispersión más allá de la Cuenca. La ocurrencia estacional coincide con períodos generales de vientos monsónicos, que se desarrollan anualmente de mayo a octubre en el Golfo de California y soplan hacia el norte a través de la Cuenca del Salton. En invierno los vientos soplan predominantemente en la dirección opuesta. Durante los meses de verano, la presencia de corrientes térmicas de aire en la cálida zona norte del Golfo y las temperaturas relativamente uniformes entre la superficie de la zona norte y las aguas hacia el sur a lo largo de la costa continental de México, podría propiciar movimientos hacia el norte. Dichos factores probablemente tienen una gran influencia en la dispersión de algunas especies (por ejemplo: Procellariiformes, pelícanos y aves fragatas). La alta diversidad de aves acuáticas subtropicales en el Mar Salton parece resultar de una combinación de factores, los cuales incluyen la proximidad al Golfo de California, la ausencia de barreras para la dispersión desde el Golfo debido a la topografía baja del delta, y la presencia de montañas rodeando el Mar Salton que podrían actuar para dirigir las aves hacia la Cuenca, aunque la ecología del lago y su tamaño también contribuyen al patrón observado.

Palabras claves: dispersión; Procellariiformes; Mar Salton; aves acuáticas subtropicales; migratorias accidentales.

The Salton Sea is one of a number of large saline lakes in the interior of the western United States. There are also numerous large fresh-water lakes and reservoirs in the region, particularly along dammed portions of the Colorado River. Each saline lake has much in common (Hammer 1986, Jehl 1994), with Bayly (1972) noting that "despite their chemical diversity" land-

TABLE 1. THE STATUS OF SPECIES OF PELAGIC AND SUBTROPICAL WATERBIRDS AT THE SALTON SEA IN COMPARISON TO THEIR STATUS IN ARIZONA AND NEVADA

	Approximate number of records		
Species	Salton Sea	Arizona	Nevada
Laysan Albatross (*Phoebastria immutabilis*)	4	2	0
Cook's Petrel (*Pterodroma cookii*)	3	0	0
Wedge-tailed Shearwater (*Puffinus pacificus*)	1	0	0
Buller's Shearwater (*P. bulleri*)	1	0	0
Sooty Shearwater (*P. griseus*)	8	1	0
Black-vented Shearwater (*P. opisthomelas*)	0	2	0
Leach's Storm-Petrel (*Oceanodroma leucorhoa*)	2	0	0
Black Storm-Petrel (*O. melania*)	3	2	0
Least Storm-Petrel (*O. microsoma*)	3	2	1
White-tailed Tropicbird (*Phaethon lepturus*)	0	1	0
Red-billed Tropicbird (*P. aethereus*)	0	5	0
Blue-footed Booby (*Sula nebouxii*)	>100	15	2
Brown Booby (*S. leucogaster*)	27	7	2
Neotropic Cormorant (*Phalacrocorax brasilianus*)	7	>100	1
Brown Pelican (*Pelecanus occidentalis*)	1000s	>50	30
Magnificent Frigatebird (*Fregata magnificens*)	100s	>50	5
Little Blue Heron (*Egretta caerulea*)	>100	±40	5
Tricolored Heron (*E. tricolor*)	±40	±40	2
Reddish Egret (*Egretta rufescens*)	10	6	1
Yellow-crowned Night-Heron (*Nyctanassa violacea*)	1	3	0
White Ibis (*Eudocimus albus*)	1	5	0
Glossy Ibis (*Plegadis falcinellus*)	1	1	0
Roseate Spoonbill (*Ajaia ajaja*)	>100	23	1
Wood Stork (*Mycteria americana*)	1000s	17	2
Black-bellied Whistling-Duck (*Dendrocygna autumnalis*)	21	100s	4
Fulvous Whistling-Duck (*D. bicolor*)	1000s	100s	2
Laughing Gull (*Larus atricilla*)	1000s	12	3
Heermann's Gull (*L. heermanni*)	100s	±40	5
Yellow-footed Gull (*L. livens*)	1000s	2	1
Gull-billed Tern (*Sterna nilotica*)	1000s	1	0
Royal Tern (*S. maxima*)	5	0	0
Elegant Tern (*S. elegans*)	17	4	0
Least Tern (*S. antillarum*)	100s	±25	5
Black Skimmer (*Rynchops niger*)	1000s	6	1

Note: Some records involved several (e.g., Elegant Tern, Least Tern) to thousands (e.g., Least Storm-Petrel) individuals.

locked saline lakes "possess a real biological unity." Yet the Salton Sea differs drastically from all of these lakes and reservoirs in its avian diversity (Hammer 1986). Over 400 species have been recorded in the Salton Sink (Patten 1999)—about 160 of them waterbird species—and the millions of birds frequenting the area annually (Patten et al. 2003) is as great an abundance as anywhere on the continent (see Page and Gill 1994). In particular, as we show here, a greater variety and number of pelagic and subtropical waterbirds occur at the Salton Sea than at any other inland lake or waterway in western North America. This pattern is typified by several species that regularly visit the Salton Sea, such as the Brown Pelican (see Table 1 for scientific names), Wood Stork, and Yellow-footed Gull, but are virtually unknown elsewhere in the interior of western North America. In addition, many more pelagic and subtropical waterbirds have occurred as vagrants to the Salton Sea than to these other lakes.

The large size of the Salton Sea might be viewed as the chief reason for the observed diversity, but size alone is not a particularly satisfying explanation. After all, the Great Salt Lake is a vastly larger body of water, several saline lakes in the Great Basin are nearly as large as the Salton Sea (Jehl 1994), and the combined surface area of the lower Colorado River and its anthropogenic reservoirs exceeds that of the Sea (Rosenberg et al. 1991). It thus appears that one or several other factors contribute to the disproportionately high occurrence of waterbirds at the Salton Sea.

Here we detail the pattern of occurrences and the relative abundances of pelagic and subtropical waterbird species recorded in the Salton Sink, grouped by avian order or family. We present data on both the higher overall diversity of these species, in comparison with the whole states of Arizona and Nevada (chiefly to demonstrate the much higher diversity at the Sea relative to other parts of inland western North America), and on the seasonality of occurrence of these species. We then explore a number of geographic, topographic, and climatic factors, most of which are not mutually exclusive, that appear to explain the Salton Sea's extraordinary diversity of pelagic and subtropical waterbirds, along with their temporal pattern of occurrence. We take a broad-brush approach, so that we might elucidate what geographic and climatic factors affect the occurrence of all subtropical waterbirds in the Salton Sink. The potential effects we posit probably drive the occurrence of some species more than others, but a broad view adds an important perspective to region-wide patterns of occurrence, and emphasizes the place held by the Salton Sea in the greater lower Colorado River region (Fig. 1). In many ways the Salton Sea is less like an isolated lake in the interior of western North America and more like an extension of the Gulf of California and Colorado River delta.

METHODS

We concentrated on five orders or families of waterbirds: Procellariiformes (albatrosses, shearwaters, and storm-petrels), Pelecaniformes (boobies, pelicans, cormorants, and frigatebirds), Ciconiiformes (herons, ibises, and storks), Anatidae (ducks and geese), and Laridae (gulls and terns). We restricted our analyses to bird species that are truly pelagic, or that are coastal but with breeding ranges and niches that are essentially subtropical.

We gathered data through an exhaustive review of regional reports published in *American Birds* and its successors (*Field Notes* and *North American Birds*), of reports of the California Bird Records Committee, of specimens in all major museum collections in the United States, and of our own field notes. Upon compilation of the data (details of which can be found in Patten et al. 2003), we plotted seasonality of occurrence and relative abundance. We also scanned *American Birds* and other published sources (McCaskie 1970a, Lawson 1977, Monson and Phillips 1981, Alcorn 1988, Rosenberg et al. 1991, Rosenberg and Witzeman 1998) to compile the approximate number of records of species of subtropical waterbirds for Arizona and Nevada. We examined topographic maps and the literature (especially Anderson et al. 1977 and Patten and Minnich 1997) to determine which processes might generate the observed patterns of occurrence of waterbirds at the Salton Sea.

We performed non-parametric statistical analyses for comparing diversity among Arizona, Nevada, and the Salton Sea. Our null hypothesis is biased in favor of finding larger numbers of waterbirds in Arizona and Nevada, both vastly larger than the Sea. Naturally, waterbirds concentrate at isolated wetlands in arid western North America, so such locales tend to receive a disproportionate amount of observer coverage in each region, but particularly in southeastern California, western and southern Nevada, and southern Arizona. We performed a Kruskal-Wallis test on ranked abundances for all species, corrected for ties. We examined seasonality by performing goodness of fit tests on sums of records in each taxonomic group for each season, with winter defined as December–February, spring as March–May, summer as June–August, and fall as September–November.

RESULTS

In general there have been more species and more individuals of pelagic and subtropical waterbirds recorded at the Salton Sea than elsewhere inland in the southwestern United States (Table 1). Arizona and Nevada, although substantially larger in area than the Salton Sea, have significantly lower diversity of these species (Kruskal-Wallis H_{adj} = 15,256.0, df = 2, $P < 0.001$), although a few pelagic and subtropical species, such as the Black-vented Shearwater and the tropicbirds, have been recorded in those states but not at the Sea.

Seasonal patterns of occurrence at the Salton Sea are remarkably similar across taxonomic groups (Fig. 2). Whether the species is recorded frequently or rarely, and regardless of its order or family, each of the pelagic and subtropical birds we reviewed occurs almost exclusively between late spring (May) and early fall (September). There are exceptions, with one to a few winter records of some species (see below), but the preponderance of records are for the summer months ($G = 84.6$, df = 12, $P < 0.001$).

PROCELLARIIFORMES

The occurrence at the Salton Sea of species of Procellariiformes has been previously summarized and analyzed (Patten and Minnich 1997). Not surprisingly, all species are vagrants at the Salton Sea, occurring well outside the species' established ranges. Eight species have been recorded (Table 2), with all birds first detected between late April and late September. Some birds remained for lengthy periods, but none stayed later than 9 November (Patten et al. 2003). Two occurrences of storm-petrels, involving dozens (*Nora* in 1998) to thousands (*Kathleen* in 1977) of birds, were associated with tropical storms that moved north into southeastern California from the Gulf of California (Patten 1998). The only storm-petrels to reach Arizona were associated with these two storms (Jones 1999).

SUBTROPICAL PELECANIFORMES

Totipalmate birds are common at the Salton Sea, with the two temperate species, the American White Pelican (*Pelecanus erythrorhynchos*)

FIGURE 1. Topographic relief of the Salton Sink and Colorado River Delta. Stippling signifies the area below sea level. Prepared by L. Lewis, Redlands Institute.

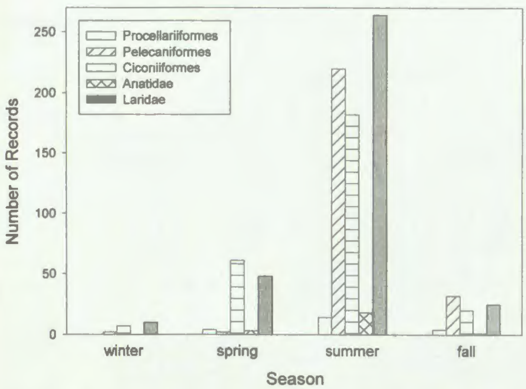

FIGURE 2. Seasonality of occurrence of pelagic and subtropical waterbirds at the Salton Sea (data are for species in Tables 2 and 3). For all five groups peak occurrence is from late spring through early fall. Breeders and regular visitors (e.g., Brown Pelican, Gull-billed Tern, Black Skimmer) show the same seasonal pattern of occurrence.

and Double-crested Cormorant (*Phalacrocorax auritus*), occurring regularly. Five subtropical pelecaniforms have been recorded at the Salton Sea: the Blue-footed and Brown boobies, Brown Pelican, Neotropic Cormorant, and Magnificent Frigatebird. The two boobies and the cormorant are vagrants to the Salton Sea (Table 3), having occurred well outside the species' established ranges. All boobies have arrived at the Sea between mid-July and mid-September, with a few remaining into winter. The cormorant has been recorded only seven times, all but once between 24 April and 1 September. The exception was an adult occasionally present as early as 27 February and as late as 10 September during its six summers at the Sea, which included a breeding attempt (Patten et al. 2003).

The Brown Pelican is common in summer and fall, mainly from early May through mid-November, and has recently attempted nesting, once successfully. Year-round numbers have increased substantially since the 1970s (Patten et al. *this volume*), but the species nonetheless continues to have a tenfold to hundredfold higher abundance in summer. The Magnificent Frigatebird occurs nearly annually in small numbers, with all records between early June and mid-September, save for one in February (the species level identification of which is tentative; Patten et al. 2003). Numbers present in any given summer vary from none to 25 or more.

Subtropical Ciconiiformes

The Wood Stork is the only subtropical ciconiiform that occurs regularly at the Salton Sea, and it has declined markedly over the past 50 years (Patten et al. *this volume*). Nevertheless, despite its sharp decrease in numbers, its seasonality of occurrence has changed little, with almost all birds found 2 May–29 October and a decided peak in July and August (Patten et al. 2003).

Four southerly herons have occurred at the Salton Sea. The Little Blue and Tricolored herons are both casual spring and summer visitors to the Salton Sea that have nested, the former twice, the latter probably once (Patten et al. 2003). Apart from one in winter, all records of Little Blue Herons fall between early May and mid-September, and most Tricolored Heron records fall between mid-April and late September. The Reddish Egret has reached the Salton Sea ten times, nine between mid-July and early September, and once in winter. The only Yellow-crowned Night-Heron was present 27 April–18 June 1996.

Three other subtropical ciconiiforms have been recorded at the Salton Sea. The Roseate Spoonbill is a highly irregular and a declining summer and fall vagrant to the Salton Sea, with virtually all records between early May and the end of October (most mid-May to late September); only three birds have been recorded in the past 20 years (Patten et al. 2003). The only White Ibis recorded was one present 10 July–5 August 1976 that returned 25 June–14 July 1977. The first record of Glossy Ibis at the Salton Sea occurred from 27 May–8 August 2000 (Patten et al. 2003). The last species has expanded its range into North America during the twentieth century, first colonizing Florida, spreading west to Texas and reaching west Mexico in the 1990s and Arizona in 2001 (Patten and Lasley 2000, Rosenberg and Jones 2001). It is possible that birds wandering to the Salton Sea and southern Arizona originate from western Mexico, although it is perhaps equally likely

TABLE 2. A Summary of Dates for Procellariiformes Records at the Salton Sea

Species	First detection date
Laysan Albatross	02–21 May
Cook's Petrel	10–24 July
Wedge-tailed Shearwater	31 July
Buller's Shearwater	06 August
Sooty Shearwater	28 April–24 August
Leach's Storm-Petrel	30 June–15 September
Black Storm-Petrel	14 August–28 September
Least Storm-Petrel	10 July–27 September

Notes: "First detection" refers to the date a bird was first detected at the Salton Sea (for a given record); the span is of dates of first detection for multiple records. Note the strong seasonal aspect of occurrence (records are exclusively from late spring through early fall).

TABLE 3. A TEMPORAL SUMMARY OF OCCURRENCES OF VAGRANT SUBTROPICAL PELECANIFORMS, CICONIIFORMS, ANATIDS, AND LARIDS AT THE SALTON SEA

Species	First detection date	Peak
Blue-footed Booby	12 July–18 October*	August/September
Brown Booby	12 July–06 September	August/September
Neotropic Cormorant	27 February–10 September	May–July
Magnificent Frigatebird	04 June–23 September	July/August
Little Blue Heron	07 May–15 September*	June–August
Tricolored Heron	17 April–01 October*	May–August
Reddish Egret	11 July–04 September*	August
Yellow-crowned Night-Heron	27 April	—
White Ibis	25 June–10 July	—
Glossy Ibis	27 May	—
Roseate Spoonbill	5 May–28 October*	July–September
Black-bellied Whistling-Duck	20 April–15 October	June–August
Heermann's Gull	02 March–04 November*	July/August
Royal Tern	12 June–20 July	July
Elegant Tern	24 April–24 August	May–July
Least Tern	15 April–17 August	May/June

Notes: "First detection" refers to the date a bird was first detected at the sea (for a given record); the span is of dates of first detection for multiple records. "Peak" refers to the period when most records have accumulated. An asterisk signifies that the species has wintered at the Salton Sea once or twice (see Patten et al. 2003). Note the strong tendency for birds to appear between late spring and early fall.

they originated from southeastern North America.

SUBTROPICAL ANATIDAE

Both subtropical whistling-ducks found in continental North America occur at the Salton Sea. The Fulvous Whistling-Duck was formerly a fairly common resident, most abundant in summer and fall. It is now rare and declining as a breeder (Patten et al. *this volume*), occurring between early April and early November, with a minor influx of birds from the south in June through August. The Black-bellied Whistling-Duck, which has been increasing in numbers in northwestern Mexico (Russell and Monson 1998) and Arizona (Rosenberg and Witzeman 1998), is a casual summer and fall visitor to the Salton Sea, primarily between late May and late August, with two records for mid-April and another 15 October–4 November.

Various essentially seagoing waterfowl occur regularly at the Salton Sea (Patten et al. 2003), particularly the Brant (*Branta bernicla*), scoters (*Melanitta* spp.), and Red-breasted Merganser (*Mergus serrator*), but these north-temperate breeders do not have the same pattern of occurrence as their subtropical relatives. Most occur principally as uncommon or rare spring migrants, moving through the Salton Sink concomitant with the passage of spring shorebirds (Patten et al. 2003).

SUBTROPICAL LARIDAE

An impressive number and variety of gulls and terns nesting north of the Salton Sea pass through the area as migrants, or spend the winter on the Sea. The same variety can be expected to occur at any saline lake in the West. It is the more southerly gulls and terns and the Black Skimmer that we consider subtropical.

Both the Gull-billed Tern and Black Skimmer nest fairly commonly at the Salton Sea, the former since 1927 (Pemberton 1927; Molina *this volume*), the latter since 1972 (McCaskie et al. 1974; Molina *this volume*). Gull-billed Terns arrive in mid-March (earliest 5 March 1995), and most have departed by September. Skimmers arrive in early April (earliest 1 April 1978), and most have departed by mid-October. The Laughing Gull formerly nested (until 1957) at the Salton Sea, and has attempted to do so recently (since 1994; Molina 2000a, *this volume*), but it is now primarily a fairly common post-breeding visitor from nesting colonies in the Gulf of California. Most occur between mid-June and late-September, with counts as high as 800+ in late July 1979. The Yellow-footed Gull is a common post-breeding visitor from the Gulf of California. Most are present between late May and the end of August, with hundreds or even thousands present in July (Patten 1996).

Heermann's Gull and the Least Tern are both rare visitors to the Salton Sea. The gull generally occurs between early April and early October, with most records from July and August. All records of the Least Tern fall between mid-April and mid-August, with most from June. The Elegant Tern is a casual visitor, with most occurring between mid-May and mid-June, but with single records for late April and mid-August. The Royal Tern is even rarer, with four or five records between mid-June and mid-July.

DISCUSSION

The five orders and families we considered are taxonomically unrelated, yet species in each group show the same general pattern of seasonal occurrence in the Salton Sink. Namely, most records are between late April and early October, with peak numbers from June through early September (Fig. 1). Several species have never reached other areas in inland western North America (Table 1), and there are many fewer records for some that have (e.g., Brown Pelican, Magnificent Frigatebird, Heermann's Gull, Least Tern), with southern Arizona generally having more records than southern Nevada (see McCaskie 1970a, Monson and Phillips 1981, Alcorn 1988, Rosenberg et al. 1991). Only two species occurring in substantial numbers show a contrary pattern; the Neotropic Cormorant and Black-bellied Whistling-Duck have expanded into southeastern Arizona from Sonora (Rosenberg and Witzeman 1998) but remain rare farther west and north. Patterns in our data lead us to two questions: (1) why are pelagic and subtropical waterbirds encountered so much more frequently at the Salton Sea than at the other inland lakes in the West (saline or not)? and (2) why do pelagic and subtropical waterbirds occur in the Salton Sink almost exclusively between late spring and early fall?

OCCURRENCE

Although the Salton Sea provides a relatively large target for passing waterbirds, we suggest that the geography and climate of the region also figure prominently in understanding the disparity observed in subtropical waterbird diversity between the Salton Sea and other inland locations in western North America. The topography of the Salton Sink and its proximity to the Gulf of California (Fig. 1), and weather patterns in the region as a whole combine to affect bird movement and occurrence.

The Salton Sea is farther south than the other saline lakes in the West, and considerably closer to the Gulf of California, where seabirds and subtropical waterbirds regularly occur. The Gulf supports nesting colonies of four of the five subtropical Pelecaniformes, and the Neotropic Cormorant nests commonly in those parts of Mexico adjacent to the eastern shore of the Gulf (Palacios and Mellink 1992, 1993; Mellink and Palacios 1993, Patten et al. 2001). Wood Storks and Roseate Spoonbills nest, formerly commonly, in the western parts of Mexico adjacent to the Gulf of California (Russell and Monson 1998). All four of the subtropical herons nest in southern Baja California as well as in mainland west Mexico (Russell and Monson 1998, Howell et al. 2001), and all seven of the subtropical Laridae found at the Salton Sea nest in the northern Gulf of California (Palacios and Mellink 1992, 1993; Patten et al. 2001). Of the eight Procellariiformes recorded on the Salton Sea, only the Black and Least storm-petrels are known to nest in the Gulf of California, the other six originating from farther south.

Brown Pelicans regularly disperse northward along the Pacific coast after nesting, evidenced from records from as far north as British Columbia (Campbell et al. 1990). Large numbers of Brown Pelicans also move northward in the Gulf of California at this same time (Anderson et al. 1977), and small numbers of boobies and Magnificent Frigatebirds sporadically do so as well. Subtropical Ciconiiformes in the eastern United States and Canada show a similar northward pattern of dispersal after nesting (Palmer 1962). Breeding populations of Elegant Terns and Laughing and Yellow-footed gulls in the Gulf commonly disperse northward after nesting (Garrett and Dunn 1981, McCaskie 1983, Burness et al. 1999). Each of these species is coastal and seldom occurs even a short distance away from the ocean, except for at the Salton Sea.

However, mere proximity to the Gulf of California may not fully explain these patterns (Fig. 1). After all, southwestern Arizona, including many large reservoirs on the Colorado River, is equally close to the Gulf, but has had a small fraction of the number of records and the number of individuals that occur regularly. If subtropical species simply tended to wander northward after breeding, one might expect them to occur on a broader front throughout southern Nevada and Arizona, rather than concentrated in a single locale. Topography at the head of the Gulf of California and surrounding the Salton Sink is probably an important factor in explaining the observed patterns of occurrence. Land is low-lying and flat between the head of the Gulf of California and the Salton Sink (the elevation not exceeding 50 m), and there are mountains on the other three sides: the Peninsular Ranges to the west, the Transverse Ranges to the north, and the Orocopia and Chocolate mountains to the east. If a major mountain range separated the Gulf from the Sea, dispersal between them would likely be much lower. Instead, the low-lying area, much of it below sea level, does not function as a barrier to dispersal. In addition to the vast expanse of aquatic habitat at the Salton Sea and its environs, northbound birds leaving the shores of the Gulf of California immediately encounter numerous wetlands in northeastern Baja California and northwestern Sonora that offer suitable habitat for seabirds and other species associated with freshwater. Some of these important wetlands include the Ciénega de Santa Clara, Laguna Salada, oxbow lakes on the Río Hardy (Fig. 1; Hinojosa-Huerta et al. *this volume*), and the extensive pond system at Campo Geotérmico Cerro Prieto (Molina and Garrett 2001; Patten et al. 2001, 2003), which likely facilitate movement between the Gulf of California and Salton Sink. Similar linkages of aquatic habitat extend from the Gulf up the lower Colorado River to Arizona and Nevada, but many fewer subtropical waterbirds follow this route northward (Rosenberg et al. 1991, Patten et al. 2003). This eastern portion of the lower Colorado River drainage and the surrounding Sonoran Desert has relatively greater topographic relief compared to the Sink, likely limiting dispersal in that direction. Once pelagic and subtropical waterbirds move north into the Salton Sea, they find an environment in which they can survive, but may be inhibited from moving farther north, west, or east by mountains. Although some birds certainly do move over these mountains, or through passes between them, these mountain ranges and the arid lands lying beyond probably discourage movement by some species.

Finally the Salton Sea's ecology probably also contributes to its distinction as an area of high diversity and abundance. Bayly (1972) noted that many species of fish do not tolerate high levels of salinity. The Sea is highly saline (about 40–44 ppt), although its level of salinity is not nearly as great as that of some other inland lakes in western North America such as Mono (89 ppt), Salada (100 ppt), and Great Salt (280 ppt), none of which supports fish (Hammer 1986). Other saline lakes in this region, such as Pyramid (6 ppt), Little Quill (20 ppt), and Walker (11 ppt), do support fish or even sport fisheries (Hammer 1986), but lag well behind the Salton Sea in avian diversity. Still, it is evident that the salinity of the Salton Sea, about 25% above that of the ocean, allows fish to survive and therefore obviously provides habitat for piscivorous birds.

None of the hypothesized factors that we have discussed are mutually exclusive, and each probably plays a role in producing the high waterbird diversity at the Salton Sea relative to surrounding areas.

Seasonality

The predominant flow of air into the Salton Sink in fall and winter is from the north and west. However, monsoonal flows from the south occur annually in the late spring and summer, with a strong flow of air pushing northward from the Gulf of California into the Salton Sink at this time (Patten and Minnich 1997). Monsoonal flows no doubt aid the passage of pelagic and subtropical birds from the Gulf of California to the Salton Sea (Anderson et al. 1977, Patten and Minnich 1997), as most migrating or dispersing birds are known to follow favorable tailwinds (see Gauthreaux and Able 1970). If wind flow were persistently from the north throughout the year, dispersal to the Salton Sea from the Gulf would doubtless be hampered. Additionally, high summer temperatures in the Gulf create strong thermals (Anderson et al. 1977), on which at least large soaring birds (e.g., Brown Pelicans, Magnificent Frigatebirds) can ride with ease. Such thermals, in concert with the predominant northward wind flow, probably aid summer dispersal to the Sea by these species that normally do not stray away from the immediate coast.

One other factor, seasonal changes in ocean temperature, is likely to play a role for at least some species, principally the highly oceanic procellariiforms. Sea surface temperatures in the northern Gulf of California remain constantly high, while those off west Mexico are normally low (Soto-Mardones et al. 1999). During monsoonal flows, sea surface temperatures off the central coast of west Mexico increase to create an expanse of pelagic habitat that is thermally uniform with warm waters of the northern Gulf, thus enabling Procellariiformes and other birds moving northward off western México to more easily enter the Gulf of California and stray north to the Salton Sea (Patten and Minnich 1997).

CONCLUSION

Because of its geographic setting, ecology, and climate, the Salton Sea is a unique component of the desert Southwest. Waterbirds, many of which occur sparingly or not at all elsewhere inland in arid western North America, are abundant at the Sea. There is probably no single hypothesis that best explains the Sea's remarkably high diversity of waterbirds relative to other inland areas, although its proximity to the Gulf of California and the low-lying terrain between it and the Gulf are excellent candidates. Even so, the Sea's large size and persistent populations of fish, as well as its location—bordered by mountains in nearly all directions except to the south, toward the Gulf—and the region's seasonal wind patterns, likely contribute to the patterns we described.

The patterns of occurrence of the various birds we have considered, in concert with processes of dispersal we have hypothesized, solidify the physical and biological connections between the Salton Sink and the Gulf of California recognized by previous workers (Sykes 1937, Anderson et al. 2003). Most of the Procellariiformes and some of the subtropical waterbirds we discuss do not regularly occur in the northern Gulf, and many that do occur there are found in the Salton Sink only as vagrants. However, for a few species, most notably the Brown Pelican, Wood Stork, Fulvous Whistling-Duck, and several breeding larids, we should take the broader geographic view; plans for their management and conservation at the Salton Sea must also consider their well-being in the adjacent Gulf of California.

ACKNOWLEDGMENTS

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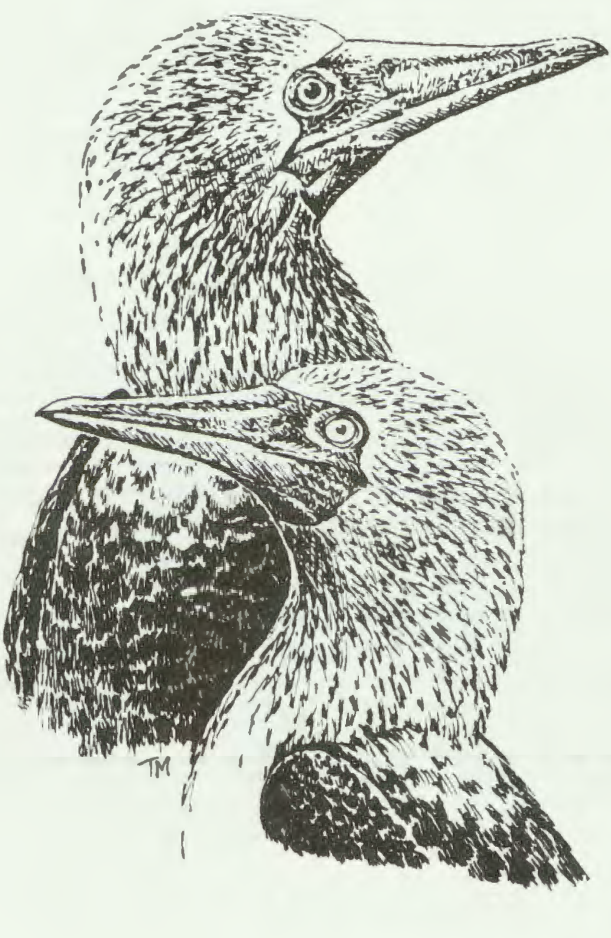

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ANNUAL COLONY SITE OCCUPATION AND PATTERNS OF ABUNDANCE OF BREEDING CORMORANTS, HERONS, AND IBIS AT THE SALTON SEA

KATHY C. MOLINA AND KEN K. STURM

Abstract. The Salton Sea, a large saline lake in southeastern California, supports sizeable populations of colonial breeding herons, cormorants, and ibis. Although concern recently has been expressed over the Sea's highly saline and eutrophic waters and its continued ability to support large breeding populations of piscivorous birds, little information has been published on these birds' distribution and abundance there. We summarize data on species abundance, species composition, and annual patterns of colony site occupation derived from surveys conducted by the Salton Sea National Wildlife Refuge from 1986–1999. The Great Blue Heron (*Ardea herodias*), Great Egret (*Ardea alba*), Snowy Egret (*Egretta thula*), and Cattle Egret (*Bubulcus ibis*) bred annually. The Black-crowned Night-Heron (*Nycticorax nycticorax*), Double-crested Cormorant (*Phalacrocorax auritus*), and White-faced Ibis (*Plegadis chihi*) bred in 13, 8, and 4 years, respectively. Two species, the Brown Pelican (*Pelecanus occidentalis*) and Little Blue Heron (*E. caerulea*), bred only in a single year, and the Tricolored Heron (*E. tricolor*) was suspected to have bred in one year. The mean (± SD) annual number of breeding colonial waterbirds during the study period was 8228 ± 9513 pairs. Cattle Egrets and Double-crested Cormorants were most numerous with mean annual abundances of 6149 ± 8674 and 1531 ± 2027 pairs, respectively. Great Blue Herons were most widespread, breeding at a mean of 7.2 ± 5 colony sites (N = 14 years), whereas White-faced Ibis were confined to a single nesting site in each year that they bred. Although colony sites were distributed over the entire shoreline, most were concentrated near river deltas where significant stands of dead snags were isolated from the shoreline. Our data suggest that Salton Sea colonies of these species are regionally important in size and species richness and the information we provide could aid habitat management and enhancement strategies for an important component of the Salton Sea avifauna.

Key Words: ardeids; colonial breeding waterbirds; colony site occupation; cormorants; ibis.

OCUPACIÓN ANUAL DEL SITIO DE COLONIA Y PATRONES DE ABUNDANCIA DE CORMORANES, GARZAS E IBISES QUE SE REPRODUCEN EN EL MAR SALTON

Resumen. El Mar Salton, un extenso lago salino en el sureste de California, mantiene poblaciones de cormoranes, garzas e ibises de reproducción colonial de tamaño considerable. Aunque recientemente se ha expresado interés en la alta salinidad y eutrofización de las aguas del lago y su habilidad continua para soportar extensas poblaciones reproductivas de aves piscívoras, muy poca información ha sido publicada acerca de la distribución y abundancia de estas aves en el área. Resumimos los datos de la abundancia de especies, composición de especies y patrones anuales de ocupación del sitio de colonia derivados de muestreos conducidos por el Refugio Nacional de Vida Silvestre del Mar Salton entre los años 1986–1999. La Garza Morena (*Ardea herodias*), la Garza Blanca (*Ardea alba*), la Garceta Pie Dorado (*Egretta thula*) y la Garza Ganadera (*Bubulcus ibis*) se reprodujeron anualmente. El Pedrete Corona Negra (*Nycticorax nycticorax*), el Cormorán Orejudo (*Phalacrocorax auritus*) y el Ibis Cara Blanca (*Plegadis chihi*) se reprodujeron en 13, 8 y 4 años, respectivamente. Dos especies, el Pelícano Pardo (*Pelecanus occidentalis*) y la Garceta Azul (*E. caerulea*) se reprodujeron solo en un año, y se sospecha que la Garceta Tricolor (*E. tricolor*) se reprodujo en un año. El número promedio (± DS) anual de aves acuáticas coloniales que se reprodujeron en la zona durante el periodo de estudio fue de 8228 ± 9513 parejas. La Garza Ganadera y el Cormorán Orejudo fueron los más abundantes con abundancias promedio de 6149 ± 8674 y 1531 ± 2027 parejas, respectivamente. Las Garzas Morenas fueron las más diseminadas, reproduciéndose en un promedio de 7.2 ± 5 sitios de colonia (N = 14 años), mientras que los Ibises de Cara Blanca estuvieron confinados a un único sitio de anidamiento en cada año que se reprodujeron. Aunque los sitios de colonia estuvieron distribuidos sobre toda la línea de costa, la mayoría de los sitios estuvieron concentrados cerca de deltas donde groupos significativos de troncos muertos se encontraban aislados de la línea de costa. Nuestros datos sugieren que las colonias de estas especies en el Mar Salton son regionalmente importantes en tamaño y riqueza de especies, y la información que proveemos podría ayudar en el manejo del hábitat y mejoramiento de estrategias para un componente importante de la avifauna del Mar Salton.

Palabras claves: ardeidos; aves acuáticas de reproducción colonial; cormoranes; ibises; ocupación de sitio de colonia.

The Salton Sea, a large saline lake in southeastern California, provides important habitat for a diverse suite of migratory and resident waterbirds (Shuford et al. 2000, 2002b). Abundant populations of colonial breeding herons (Ardeidae), gulls, terns, and skimmers (Laridae), cormorants (Phalacrocoracidae), and ibis (Threskiornithidae) occur widely around the Salton Sea and at other associated wetlands and agricultural lands (Shuford et al. 2000). However, increasing concern has been expressed recently over the Sea's highly saline (41–44 ppt; Setmire et al. 1993, Schroeder et al. 2002) and eutrophic conditions (Holdren and Montaño 2002). Additional concern arises from anticipated water transfers from the Imperial Valley to urban regions, which are expected to reduce freshwater inflows to the Salton Sea, accelerate increases in salinity, and exacerbate threats to existing fish and invertebrate prey populations (Riedel et al. 2002) and to the avifauna which depend on them.

Grinnell (1908) and Dawson (1923) provided the first historical accounts of the apparently abundant breeding populations of American White Pelicans (*Pelecanus erythrorhynchos*) and Double-crested Cormorants (*Phalacrocorax auritus*) that colonized the Sea soon after its formation in 1906–1907. Subsequently, however, little information has been published about the community of colonial breeding waterbirds. Whereas Molina (1996, 2000a, *this volume*) has recently detailed the status of breeding larids during the 1990s, and Warnock et al. (*this volume*) and Shuford et al. (2000) documented the distribution and abundance of breeding waterbirds at the Salton Sea in a single year, no report has yet documented the status of non-larid colonial breeding waterbirds over a longer term. Here we report the species composition, species abundance, and annual patterns of site occupation of breeding cormorant, heron, and ibis colonies at the Salton Sea from 1986 through 1999.

METHODS

We used annual census data collected by personnel of the Sonny Bono Salton Sea National Wildlife Refuge (hereafter SSNWR or refuge) from 1986 through 1999 to summarize population trends and site occupancy of colonial nesting herons, cormorants, and ibis. SSNWR personnel began surveys of all active colony sites along the Salton Sea shoreline in 1991 (Fig. 1). Because regular censuses of the two large colonies at the north end of the Sea, Johnson Street and 76th Avenue, did not begin until then, we included the data collected by N. Hogg (in Setmire et al. 1993) at these locations from 1986 to 1990 with those collected by refuge personnel to form a more complete estimate of the annual number of breeding pairs for the study area. Because Hogg's 1986–1990 data did not differentiate between the Johnson Street and 76th Avenue locations, we lumped our 1991 through 1999 census results for these two colonies, as "North End," to facilitate comparisons of colony size and species richness for the study area over the longer term. Finney and Ramer lakes were first censused in 1992, although Finney Lake was also occupied in 1991 (Fig. 1). The refuge conducted censuses, usually performed on foot or by boat, at at least monthly intervals from late March through June. Aerial surveys, at irregular intervals, were used to identify colony locations and to sometimes augment foot and boat censuses of Great Blue Herons (*Ardea herodias*) and Double-crested Cormorants in 1992, 1993, and 1997. In 1999, counts of Great Blue Herons, Great Egrets (*Ardea alba*), and Double-crested Cormorants at the New and Alamo river deltas were derived from a combination of aerial and boat surveys conducted by Point Reyes Bird Observatory as described by Shuford et al. (2000). Censuses took place from distances sufficient to prevent colony flushing, and the number of active nests was recorded. Active nests were those attended by a reclining (or incubating) adult or containing young.

Differences in nesting behavior among species influence the ease with which species are detected and censused. We are least certain of our population estimates for Cattle Egrets (*Bubulcus ibis*) because of this species' tendency to nest in dense aggregations well within structurally complex vegetation. We are confident that we detected all colonies of Black-crowned Night-Herons along the shoreline, but we may have failed to detect small aggregations of this species and of White-faced Ibis in well-vegetated wetlands away from the Sea.

To estimate the annual number of pairs for each species, we summed the peak number of active nests at each colony site, taking into account the timing of whole colony desertions and the establishment of new colonies late in the season. Because we could not differentiate between the attempts of late nesters and those of failed nesters that may have relocated to different colonies, the numbers we report best reflect the minimum number of pairs. Means were calculated with non-zero data only and are reported with $\pm$ 1 SD.

We note two additional departures from the coverage efforts described above. In 1994 the Alamo River delta was not surveyed because it became inaccessible during dredging activity conducted by the Imperial Irrigation District. Although aerial surveys were not conducted to confirm the presence or absence of colonies in 1994, we suspect that disruption posed by dredging, which occurred simultaneously with the onset of the breeding season, was sufficiently high to deter the formation of any large colonies. In 1995, our censuses of Great, Snowy (*Egretta thula*), and Cattle egrets may have been incomplete at the Alamo and New river deltas as these sites were not visited after mid-May. The breeding chronology of egrets and cormorants nesting at the river deltas and at Ramer Lake during our study was reasonably synchronous, with the onset and peak of incubation occurring by mid-April and early May, respectively (refuge records; K. Molina, pers. obs.), whereas Great Blue Herons initiated incubation by late March. Because both the New and Alamo river deltas had not traditionally attracted large numbers of nesting cormorants or ardeids other than Great Blue Herons, we suspect that these deviations of survey coverage would not have substantially altered the peak nest totals there.

Herons and egrets were known to nest at two locations in the Imperial Valley outside of our study area.

FIGURE 1. Location of breeding colony sites in study area from 1986–1999.

One was Brunt's Corner, a small stand of tamarisk southeast of Brawley in which only Cattle Egrets nested; this site was abandoned by 1992. The other was a eucalyptus grove south of Westmorland, a site known to be occupied by "700 egrets" in 1994 (SSNWR files); this site was also occupied in 1999 (Shuford et al. 2000). Despite the lapses described above, we believe these data remain useful in describing the annual abundance and patterns of occupancy of major colony sites for breeding ardeids, cormorants, and ibis at the Salton Sea over the last 14 years.

RESULTS AND DISCUSSION

POPULATION SIZE AND TRENDS

Nine species of colonial waterbirds were detected breeding and one species was suspected to have bred in the study area from 1986 through 1999. The Great Blue Heron, Great Egret, Snowy Egret, and Cattle Egret bred annually; the Black-crowned Night-Heron (*Nycticorax nycticorax*) bred in all years except one. The Double-crested Cormorant was not detected as a breeder from 1988 through 1994, and the White-faced Ibis (*Plegadis chihi*) was detected breeding only from 1991 through 1994 (Table 1). The Brown Pelican (*Pelecanus occidentalis*) and Little Blue Heron (*E. caerulea*) bred in only one year of the study, and the Tricolored Heron (*E. tricolor*) was suspected of breeding once. At least three pairs of pelicans bred and successfully raised young in 1996 at the Alamo River delta among elevated mats of dead cane (*Phragmites* sp.; Sturm 1998). Although three to five pelican nests were constructed on the rocky islet off of Obsidian Butte (Fig. 1) in 1997, no eggs were documented (K. Sturm, pers. obs.). A pair of Little Blue Herons nested at Brunt's Corner

TABLE 1. PEAK ANNUAL NUMBER OF BREEDING PAIRS OF COLONIAL WATERBIRDS AND NUMBER OF OCCUPIED SITES (IN PARENTHESES) AT THE SALTON SEA AND FINNEY AND RAMER LAKES FROM 1986 TO 1999

Year	Double-crested Cormorant	Great Blue Heron	Great Egret	Snowy Egret	Cattle Egret	Black-crowned Night-Heron	White-faced Ibis	Totals
1986	24 (1)	399 (2)	49 (1)	76 (1)	2,094 (1)	5 (1)	0	2,647
1987	63 (1)	284 (2)	109 (2)	112 (2)	2,957 (2)	12 (1)	0	3,537
1988	57 (1)	248 (2)	297 (2)	52 (2)	2,428 (2)	0	0	3,082
1989	0	10 (1)	117 (2)	340 (2)	896 (2)	35 (1)	0	1,398
1990	0	27 (3)	118 (1)	226 (1)	42 (1)	98 (1)	0	511
1991	0	62 (6)	554 (4)	295 (2)	150 (2)	160 (2)	100[a] (1)	1,321
1992	0	116 (17)	361 (6)	198 (2)	30,055 (2)	1,417 (2)	370 (1)	32,517
1993	0	59 (9)	265 (7)	1,981 (4)	19,035 (2)	921 (3)	320 (1)	22,581
1994	0	51 (6)	497 (5)	322 (2)	800 (1)	14 (2)	50 (1)	1,734
1995	48 (2)	126 (8)	418 (4)	120 (1)	4,000 (1)	15 (1)	0	4,727
1996	758 (4)	118 (9)	972 (5)	524 (5)	1,320 (3)	88 (6)	0	3,780
1997	2,590 (3)	199 (10)	514 (6)	100 (4)	8,506 (3)	456 (4)	0	12,365
1998	3,284 (5)	369 (8)	227 (5)	337 (4)	11,138 (5)	232 (4)	0	15,587
1999	5,425 (6)	888 (18)	165 (6)	167 (3)	2,660 (1)	100 (2)	0	9,405
No. of pairs[b]	1,531 ± 2,027	211 ± 231	333 ± 247	346 ± 489	6,149 ± 8,674	273 ± 428	210 ± 159	8,228 ± 9,513
Coefficient of variation	132	109	74	141	141	157	76	
No. of occupied sites[b]	2.9 ± 2	7.2 ± 5	4 ± 2	2.5 ± 1	2.0 ± 1	2.3 ± 2	1 ± 0	

[a] Source: McCaskie (1991).
[b] Mean ± SD on non-zero data only.

FIGURE 2. Aerial overview (upper photo) and close-up view (lower photo) of the Alamo River delta, where large numbers of colonial waterbirds nested in exotic riparian and marsh vegetation (Photos: W. D. Shuford, April–May 1999).

FIGURE 3. Aerial overview (upper photo) and close-up view (lower photo) of Mullet Island, near the mouth of the Alamo River, where a large colony of Double-crested Cormorants formed during the late 1990s (Photos: W. D. Shuford, February 1999).

in 1991 (McCaskie 1991), and a pair of Tricolored Herons was suspected to have bred in 1994 at Finney Lake (Patten et al. 2003).

A mean annual total of 8228 ± 9513 pairs of cormorants, herons, egrets, and ibis bred during the study (Table 1). The Cattle Egret and Double-crested Cormorant showed the greatest mean annual abundances. Although the number of breeding pairs for all species fluctuated annually throughout the period, coefficients of variation were greatest for the Black-crowned Night-Heron, Snowy Egret, Cattle Egret, and Double-crested Cormorant (Table 1). Cattle Egrets are highly terrestrial and gregarious, may wander extensively, and temporarily colonize sites depending on environmental conditions (Telfair 1994). These behaviors, the difficulty in censusing nesting colonies, and the fact that nesting colonies may have formed at times in numerous eucalyptus or *Tamarix* woodlands and small wetlands dispersed throughout the Imperial Valley outside of our study area, may have further biased our observations of this species. Such confounding factors (namely difficulty in censusing colonies) might also hold for the Black-crowned Night-Heron.

The general pattern of abundance for the Double-crested Cormorant, a species whose population size increased by nearly two orders of magnitude from 1995 to 1997, was noteworthy. Cormorants were apparently abundant at the Sea from shortly after its formation until at least 1913 (Grinnell 1908, Dawson 1923). Although data are few, their numbers diminished during subsequent decades (Remsen 1978). Cormorants were not censused after 1999, when over 5000 pairs nested on Mullet Island (Shuford et al. 2002b), but their numbers have clearly declined in subsequent years (K. Molina, pers. obs.), with none observed nesting at Mullet Island in 2001 and 2002 (C. Pelizza, pers. comm.).

The dynamic nature of Double-crested Cormorant populations in North America over the past century (Hatch 1995) suggests that they

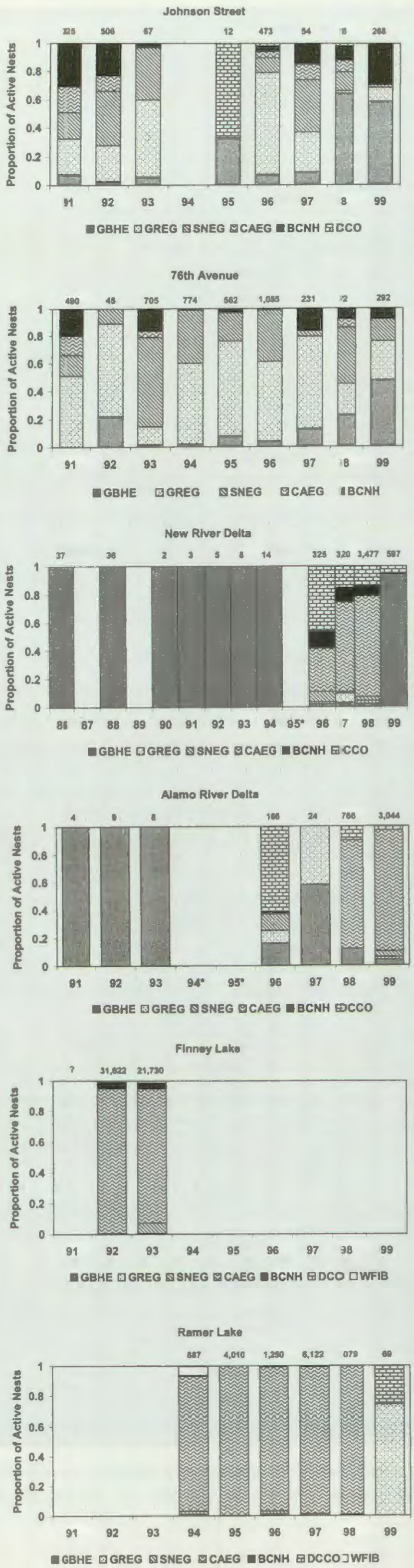

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FIGURE 4. Size and relative nesting abundance at six main colony sites surveyed during the study period. Species names and codes are Double-crested Cormorant (DCCO), Great Blue Heron (GBHE), Great Egret (GREG), Snowy Egret (SNEG), Cattle Egret (CAEG), Black-crowned Night-Heron (BCNH), and White-faced Ibis (WFIB). Johnson Street was unoccupied in 1994, as was the New River Delta in 1987 and 1989. Finney Lake was occupied from 1991 to 1993, and Ramer Lake was first colonized in 1994. Values at the top of each bar are the peak number of active nests. Asterisk indicates an incomplete census (see Methods).

TABLE 2. MEAN NUMBER OF ACTIVE NESTS AND SPECIES RICHNESS (± SD) FOR CORMORANT, HERON, EGRET, AND IBIS COLONY SITES ALONG SALTON SEA SHORELINE AND AT FINNEY AND RAMER LAKES

Colony site	Nests	Species richness	Years occupied
North End[a]	1,106 ± 791	5.1 ± 0.7	14
76th Avenue[b]	513 ± 306	4.1 ± 0.6	9
Johnson Street[b]	228 ± 194	4.8 ± 1.3	8
State Recreation Area[c,d]	5	1	1
Bombay Beach[d]	7 ± 4	1 ± 0	9
Mallard Road	4 ± 3	1.3 ± 0.5	6
Ibis Road	26 ± 14	1.8 ± 0.5	7
Wister Unit[d,e]	7	1	1
Mullet Island	2,129 ± 2,158	1.2 ± 0.4	5
Morton Bay[d,e]	1	1	1
Alamo River Delta	173 ± 273	2.3 ± 1.6	8
Red Hill Bay[d]	11 ± 9	1 ± 0	2
Obsidian Butte	295 ± 450	2.1 ± 1.5	7
Lack/Lindsay	25 ± 14	1.5 ± 0.6	4
New River Delta	703 ± 1,414	2.4 ± 2.2	12
Trifolium Drain[d]	59 ± 78	1 ± 0	2
Poe Road	28 ± 25	2 ± 0.6	6
Elmore Desert Ranch[c]	18	2	1
San Felipe Creek South[d]	5 ± 2	1 ± 0	2
Salton Sea Test Base[d]	16 ± 17	1 ± 0	2
81st Avenue[d]	2 ± 2	1 ± 0	5
Ramer Lake	3,403 ± 3,216	4.3 ± 1.9	6
Finney Lake	26,776 ± 7,136	5 ± 0	2

Note: Means ± SD calculated on non-zero data and only for sites occupied for >2 years.
[a] North End combines data from refuge and N. Hogg (unpubl. data) for 76th Avenue and Johnson Street colonies from 1986–1999.
[b] Derived from separate censuses conducted at each site from 1991–1999.
[c] Single year of occupation = 1992.
[d] Sole nestling species was the Great Blue Heron.
[e] Single year of occupation = 1999.

readily respond to changes in environmental conditions. Factors intrinsic to the Salton Sea, such as prey abundance and nest site availability, are likely to be important influences on their population growth and contraction. Although the sportfishery has lacked continuous and rigorous examination since the initial investigations by Walker et al. (1961), the period of dramatic increase of breeding cormorants at the Sea coincided with an apparent explosive increase in the number of tilapia (*Oreochromis mossambicus*), as well as with several large mortality events of fish and fish-eating birds (USFWS 1997, Riedel et al. 2001, Rocke et al. *this volume*).

The current sportfishery was established through introductions of marine species (primarily orangemouth corvina, *Cynoscion xanthulus*; bairdiella, *Bairdiella icistius*; and sargo, *Anisotremus davidsoni*) by California Department of Fish and Game in the early 1950s. Populations of these species flourished as indicated by the impressive recreational catch rates of 1.88 fish/angler/hr reported by the state during the 1970s and 1980s (Black 1988, as cited by Riedel et al. 2001). By the 1980s tilapia, an exotic genus well suited to the warm saline waters of the Sea, became established (Riedel et al. 2001). During studies conducted in 1999 and 2000, Riedel et al. (2002) reported tilapia as the most abundant species. This apparent change in the relative abundance among species may have signaled the approach or attainment by some marine species of the upper limits of expected salinity tolerances (Matsui et al. 1991, 1992). Further, Reidel et al. (2002) reported a skew in the distribution of fish age classes, with the majority of tilapia samples representing the 1995 cohort and most *Bairdiella*, the other abundant species, representing the 1996 cohort. The mean air temperature in fall and winter (November–February) in 1995–1996 at Imperial, about 20 km south of the Sea, was the second mildest recorded since 1931 (mean = 16.5°C, compared with a 70-year mean of 14.7°C; range = 11.4–16.8°C); water temperatures were presumably correspondingly higher as well, promoting increased growth and perhaps winter survival and recruitment of young tilapia, and possibly of *Bairdiella* (Riedel et al. 2002).

Because potentially suitable nesting habitat for cormorants and other colonial waterbirds remained constant throughout the study (sea elevation was relatively stable and all major nesting sites remained isolated by water), it appears that food availability, rather than nest site availability, explains the recent dynamics of breeding cormorants at the Sea.

In addition to Double-crested Cormorants, Salton Sea breeding populations of several other species of piscivorous birds, such as Great Blue Herons, Caspian Terns (*Sterna caspia*), and Black Skimmers (*Rynchops niger*; Molina *this volume*) also exhibited rapid population growth during the mid- to late 1990s, suggesting that the abundant population of recently introduced tilapia (Riedel et al. 2001) may have also influenced the trend in abundance for these species.

Recent survey work indicates a striking reversal in the trends of the mid to late 1990s, with declines in fish populations beginning in 2000 (Riedel et al. 2002) and becoming increasingly apparent in 2002 and 2003 (J. Crayon, pers. comm.). Concurrent marked declines have occurred in numbers of pelicans and cormorants (C. Pelizza, pers. comm.) as well as greatly reduced breeding effort in skimmers and low reproductive success in Caspian Terns (K. Molina, pers. obs.). No comparable data for Great Blue Herons and Great and Snowy egrets are available since 1999, so we cannot evaluate their response to current conditions of fish prey availability.

Colony Sites

The mean number of occupied colony sites (or prevalence) per species was greatest for the Great Blue Heron, which nested at up to 18 locations (Table 1). It was lowest for the White-faced Ibis, which was confined to a single site (Finney Lake in 1991–1993, and Ramer Lake in 1994) in each of the four years in which the species was detected breeding (Table 1).

While breeding colony sites for cormorants and ardeids at the Salton Sea were distributed along the entire shoreline (Fig. 1), many were aggregated at the north and south ends, near the mouths of the Whitewater, Alamo (Fig. 2a, b), and New rivers, where the largest tracts of snags and live vegetation occur. Finney and Ramer lakes, adjacent to the Alamo River and about 8 km from the southern shoreline of the Sea (Fig. 1), also contained dense stands of snags. Because of their proximity to freshwater inflows, the deltas and other areas along the southeast shoreline lying adjacent to the outlets of numerous agricultural drains are less saline than the main body of the Sea (Carpelan 1961). Variation in salinity, water depth, bottom substrate, and other physical characteristics likely influence patterns of vegetation growth in these areas; this same heterogeneity of aquatic habitats is likely reflected in the patchy distribution of fish (Reidel et al. 2001), which might also influence the location of nesting colonies.

At most locations, colonial waterbirds nested on stands of dead tamarisk (*Tamarix* spp.) in calm backwater lagoons. Great Blue Herons and cormorants also used artificial structures such as blinds and barges at the south end and a line of flooded power poles at the north end. All species but ibis used live tamarisk and cane along the Alamo and New river deltas. Cattle Egrets primarily, but also a few Great and Snowy egrets and Black-crowned Night-Herons, nested in a mature grove of eucalyptus south of the town of Westmorland. On Mullet Island, a 3-ha island north of the Alamo River delta, herons and cormorants constructed nests on the rocky terraces and outcrops along the upper reaches of the island (Fig. 3a, b). Tree-like platforms constructed of large diameter PVC pipe erected specifically for breeding ardeids at Johnson Street and in a refuge impoundment in the Hazard Unit of the SSNWR were not used during the study, nor were wooden nesting platforms placed just offshore of the Salton Sea Test Base.

The largest breeding colonies formed at Finney and Ramer lakes and on Mullet Island (Table 2, Fig. 4). Cattle Egrets dominated the breeding community at Ramer and Finney lakes (Fig. 4), whereas Double-crested Cormorants were numerically most important at Mullet Island (mean = 2651 ± 2064 active nests, N = 4 years), where their breeding effort comprised 99–100% of all active nests. Great Blue Herons nested at Mullet only intermittently (K. Molina, pers. obs.). Mean species richness was greatest at Finney Lake, Ramer Lake, and the North End (the composite site combining the colonies at Johnson Street and 76th Avenue; Table 2). Although nesting habitat at Finney Lake seemed to be nearly continually available, the site was not occupied in most years. Breeding waterbirds immediately colonized Ramer Lake in 1994 when it was re-flooded after a prolonged dry period, and simultaneously ceased to nest at Finney Lake in that and subsequent years.

Relatively small colonies of Great Blue Herons formed infrequently at several sites: Salton Sea State Recreation Area in 1992, Salton Sea Test Base in 1998 and 1999, Trifolium Drain, San Felipe Creek South, and Red Hill Bay in 1992 and 1999, and Wister Unit and Morton Bay in 1999 (Table 2; refuge files).

Only the North End site was continuously active during the entire period. Other consistently occupied sites included the New River Delta (12 years) and Bombay Beach (9 years; Table 2).

Apart from sites overwhelmingly dominated by a single species, such as the Cattle Egret at Finney and Ramer lakes and Double-crested Cormorant at Mullet Island, the colonies at 76th Avenue, Johnson Street, New River Delta, and

Alamo River Delta were notable in exhibiting high species richness and total waterbird abundance (Fig. 4; Table 2). Of these four sites, abundance and species richness were greatest at 76th Avenue and Johnson Street, where species composition and colony size were also most stable. Although the mean number of nests at Obsidian Butte was fairly large and the site was active for seven years (from 1987–1993; Table 2, refuge files) with a maximum of four nesting species (Great Blue Heron and Great, Snowy, and Cattle egrets), by 1990 it was occupied only by a few Great Blue Herons.

Since 1996, species richness and overall abundance at the New River and Alamo River deltas increased from the small monospecific colonies of Great Blue Herons that previously characterized these sites (Fig. 4). Nesting activity was easily ascertained on foot or by car at most sites each year, except at the New and Alamo river deltas in 1994, when accessibility was made difficult by dredging. Survey access to these deltas improved in 1997 with the use of airboats. However, because increases at the New and Alamo river deltas (Fig. 4) began a year prior to the implementation of airboat surveys, we suggest that these increases are real and not merely the result of improved census methods; it is likely that diminished access to these areas by conventional vehicles and foot traffic enhanced their isolation from human disturbance. It is possible that other delta and island breeding sites have experienced less human disturbance in recent years as reduced boating activity accompanied a declining interest in the recreational fishery (Molina 1996).

In summary, our data suggest that the Salton Sea supports a significant and diverse breeding community of colonial waterbirds. Whereas the occupation of colony sites by breeding waterbirds has been dynamic, certain sites have supported large and species-rich colonies over a relatively long time period. Although contemporaneous counts of breeding colonies of these species in western North America are not available, it is clear that the Salton Sea colonies are of regional importance; their population sizes and species richness exceed those of northern Baja California (Massey and Palacios 1994, Molina and Garrett 2001), coastal southern California (Unitt 1984, Hamilton and Willick 1996, Gallagher 1997, Los Angeles County Breeding Bird Atlas files), and the lower Colorado River Valley (Rosenberg et al. 1991), and rival or perhaps also exceed those of the San Francisco Bay region (Shuford 1993, Kelly et al. 1993).

We suggest that additional studies examining reproductive success and juvenile survival, diet and food availability (including the importance of colony site proximity to commercial fish farms and other aquaculture), characteristics of nest sites and substrates, and metapopulation dynamics be undertaken, along with continued census efforts, to promote a better understanding of these regionally important colonies. Such data should play a crucial role in habitat management and enhancement strategies for the Salton Sea region.

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

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

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

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

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