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

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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.

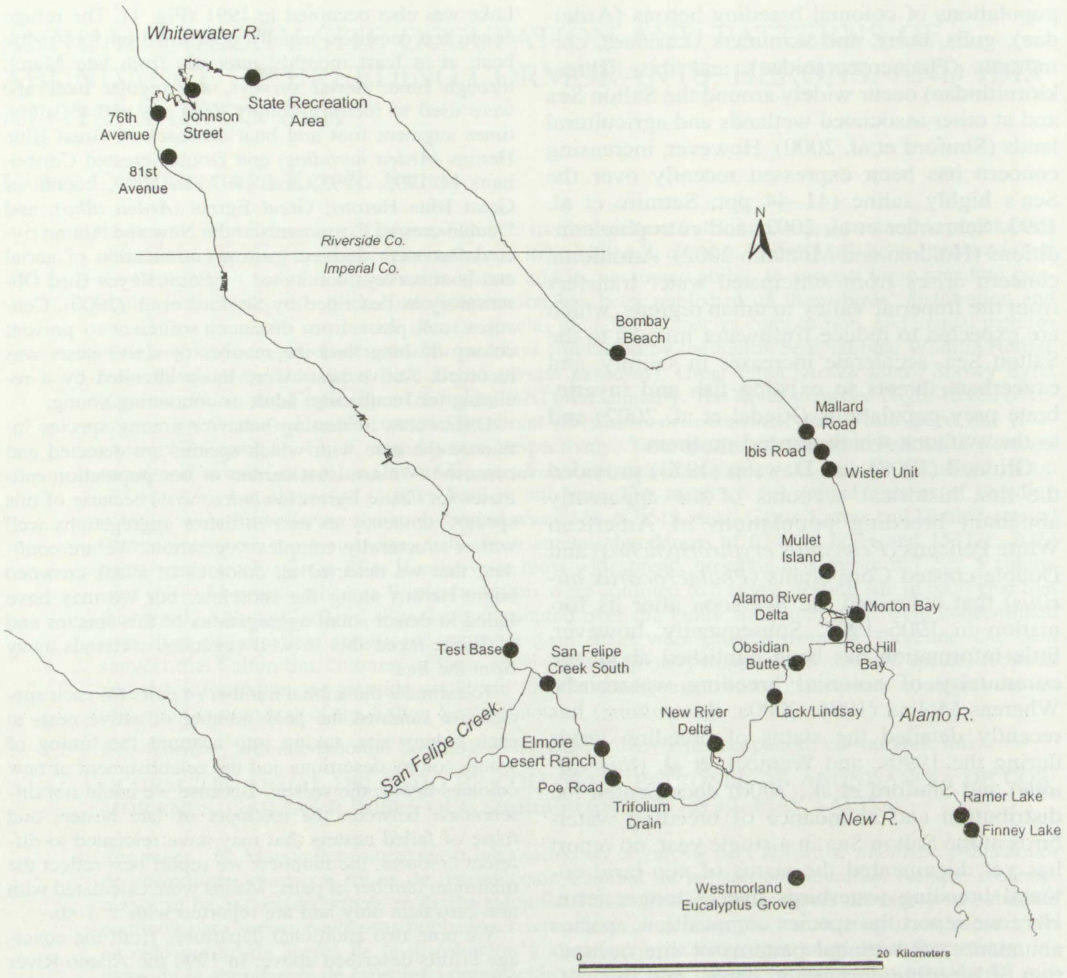


FIGURE 1. Location of breeding colony sites in study area from 1986–1999.

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).

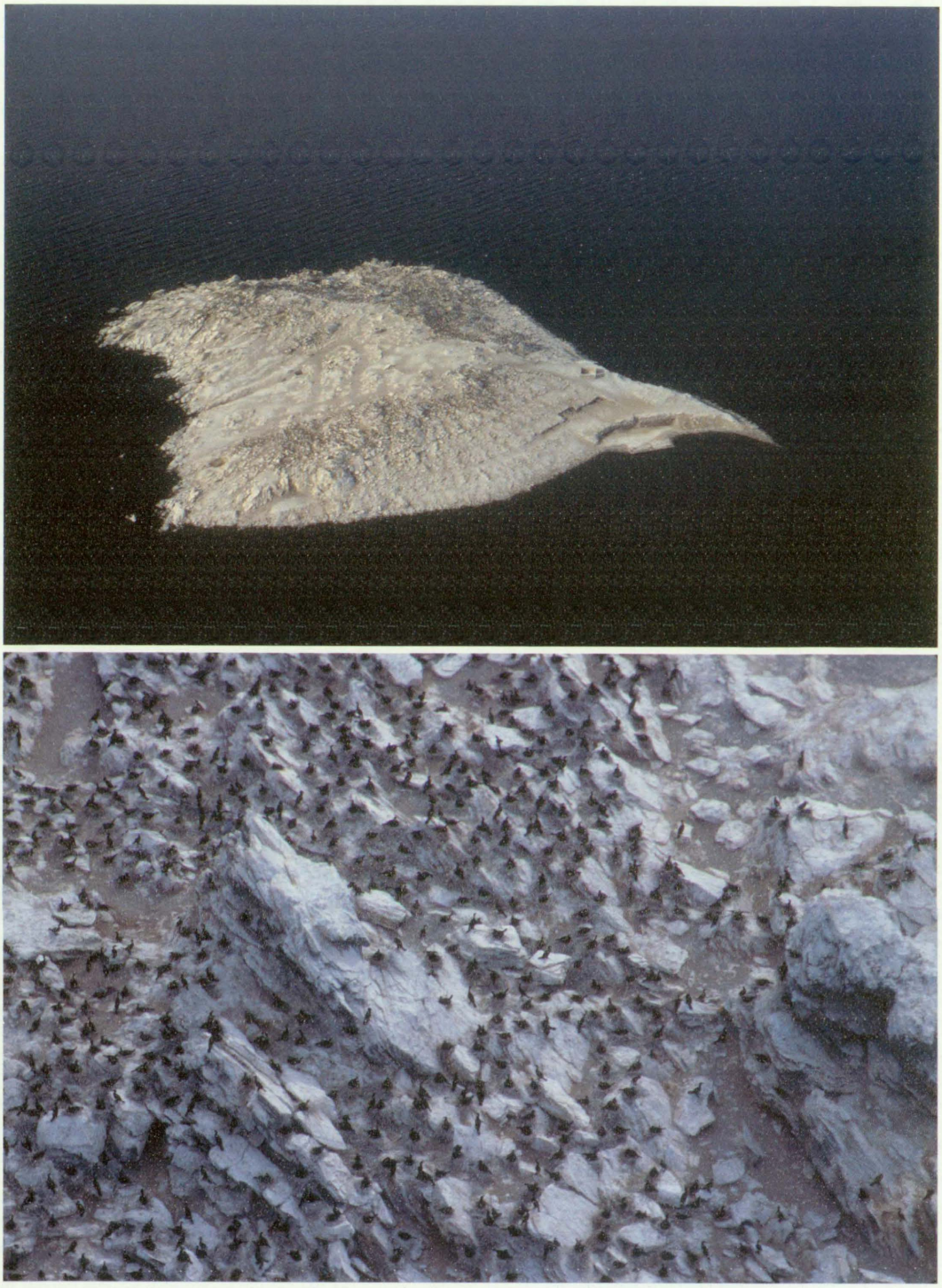
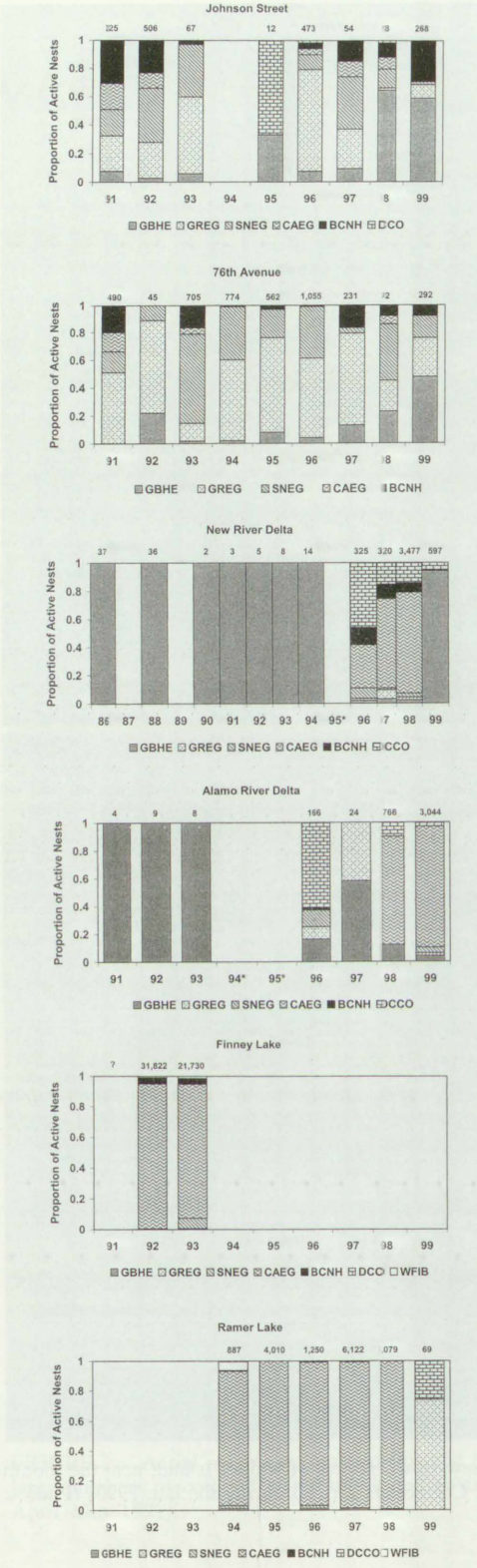


FIGURE 3. Aerial overview (upper photo) and close-up view (lower photo) of Mullet Island, near the mouth of the Alamo River, where a large colony of Double-crested Cormorants formed during the late 1990s (Photos: W. D. Shuford, February 1999).



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 availabil-

ity, 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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