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THE SALTON SEA AS IMPORTANT WATERFOWL HABITAT IN THE PACIFIC FLYWAY

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

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

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

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

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

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

The Salton Sea ecosystem is under stress as evidenced by periodic large-scale die-offs of fish and birds. A variety of diseases have been di-

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

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

STUDY AREA AND METHODS

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

Heitmeyer et al. (1989) presented mean counts of

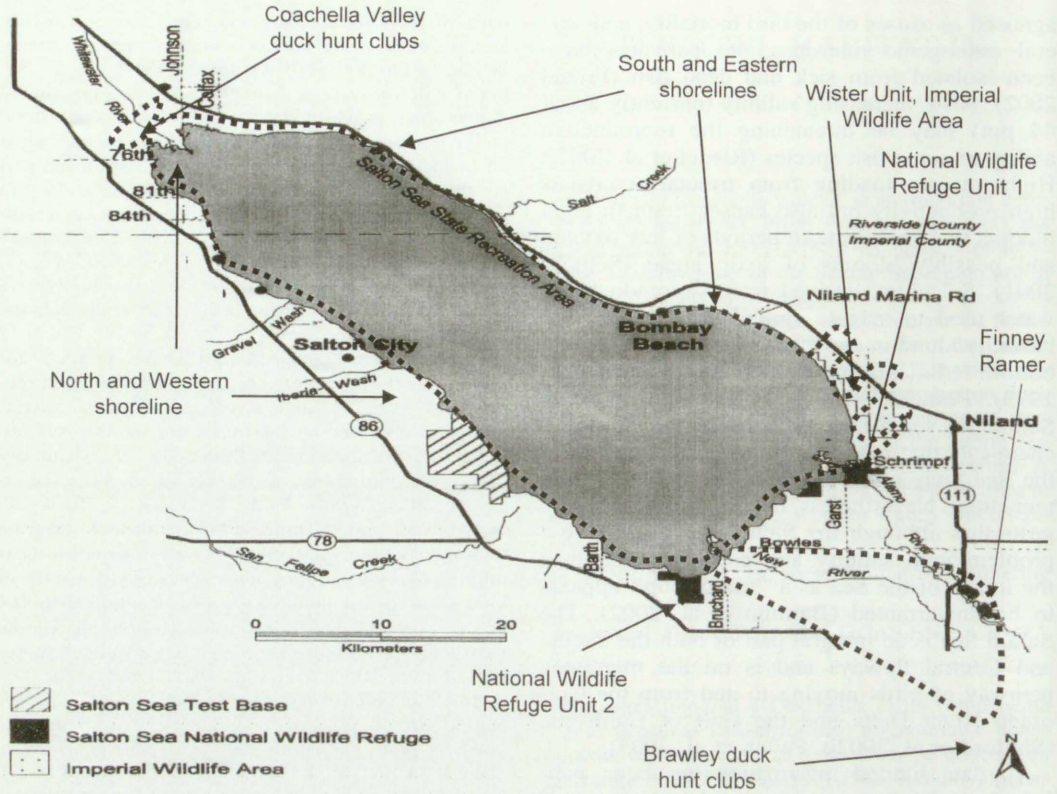

FIGURE 1. Generalized flight path (dashed line) and survey locations around the Salton Sea.

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

To gain a larger scale picture of the Salton Sea relative to the Pacific Flyway and other areas, we queried the U.S. Geological Survey Bird Banding Laboratory for all birds banded at the Salton Sea and recovered or encountered in the continental United States. These data were entered into the Salton Sea GIS database managed by the University of Redlands.

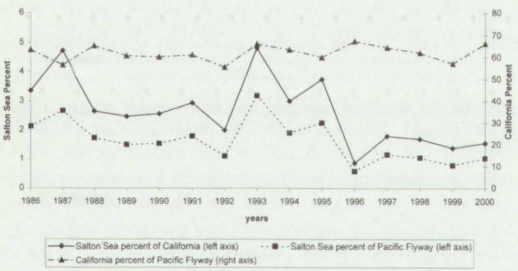

FIGURE 2. Plot of total waterfowl counted on USFWS midwinter surveys at the Salton Sea, in California, and in the Pacific Flyway. Values are adjusted by year relative to the California and Pacific Flyway total count.

RESULTS

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

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

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

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

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

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

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

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

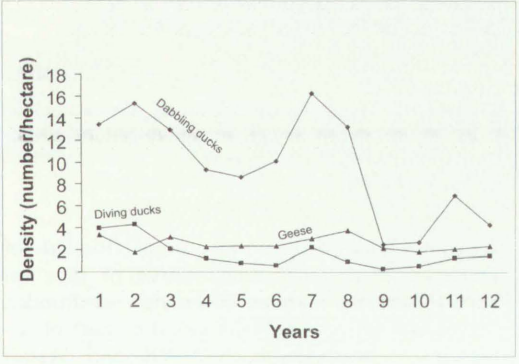

FIGURE 3. Wintering waterfowl density at the Salton Sea, California.

DISCUSSION

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

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

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

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

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

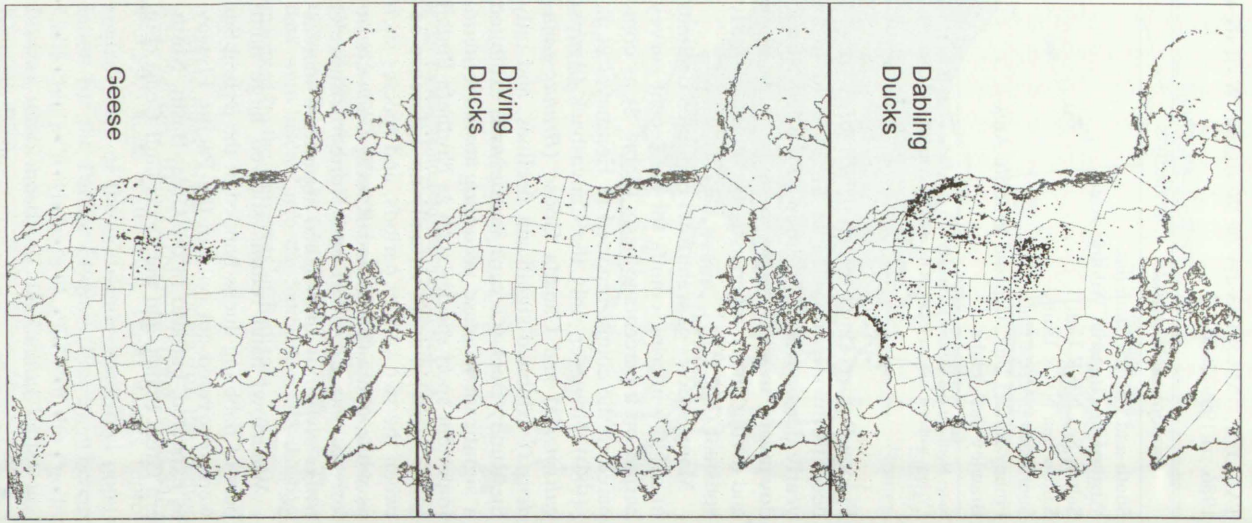

FIGURE 4. Band return locations for waterfowl banded at the Salton Sea. Top: dabbling ducks; Middle: diving ducks; Bottom: geese.

area rather than simply those areas flooded for waterfowl, also a potential source of bias for SSNWR density values. Estimates of flooded acreage are not routinely included as part of aerial survey information. SSNWR and Wister units abut the shoreline of the Sea, and this proximity allows birds to move freely between fresh-

water managed ponds and the Salton Sea, thus diluting densities of one area over another. The Brawley duck clubs are small discrete areas of known, flooded acreage located among agricultural lands far removed from other areas frequented by ducks. This probably serves to concentrate waterfowl at these sites. Still, the density values we report here for the duck clubs are two to three times greater than units intensively managed on wildlife areas. Until the practice was declared illegal in the early 1990s, federal regulations allowed baiting of waterfowl in the Imperial and Coachella valleys. This could explain greater concentrations of waterfowl at duck clubs, but only through the period into the early 1990s.

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

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

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

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