Studies in Avian Biology No. 27:12–17, 2004.

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

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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.

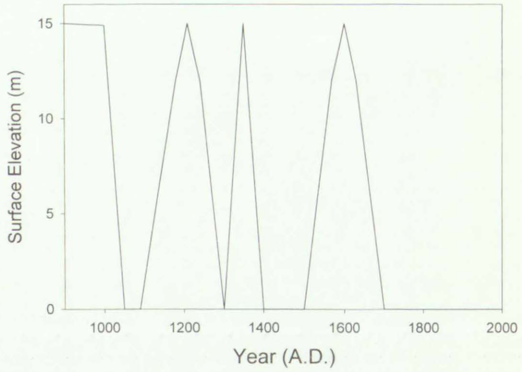

FIGURE 1. Above sea level highstands (m) of Lake Cahuilla over the past millennium (after Smith 1999). When dry, the lakebed is at about −100 m below sea level.

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

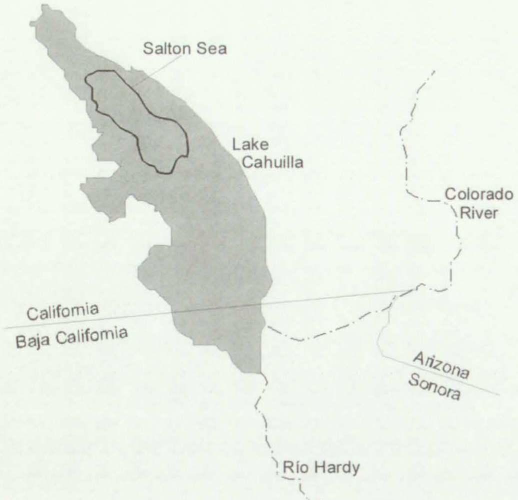

FIGURE 2. Maximum extent of Lake Cahuilla at highstand, with the current Salton Sea superimposed.

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-

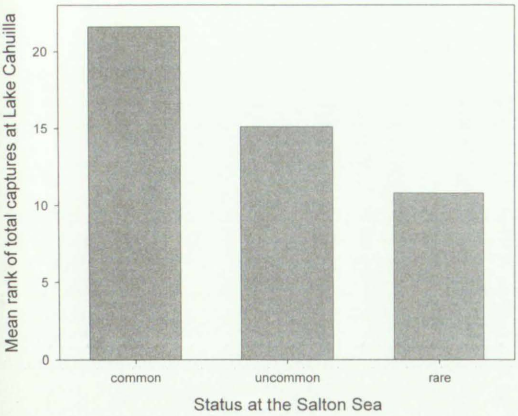

FIGURE 3. A comparison of the avifauna of Lake Cahuilla and the Salton Sea. Bars represent the average rank of bird taxa from middens around Lake Cahuilla (from data in Table 1). Categories are the current status of the same taxa at the Salton Sea. The taxa captured most often at Lake Cahuilla are the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

ACKNOWLEDGMENTS

P. Unitt assisted with the identification of some skeletal remains. R. A. Minnich and P. J. Wilke provided insights into the geography and ethnohistory, respectively, of Lake Cahuilla. M. C. Hall, K. White, and P. J. Wilke of the Department of Anthropology at the University of California, Riverside, kindly allowed examination of archaeological faunal specimens. We thank D. W. Anderson, S. H. Hurlbert, K. C. Molina, J. T. Rotenberry, and W. D. Shuford for comments on a draft of this paper.