A Synthesis of Information on California Gulls to Further Attainment of Salt Pond Restoration Goals in South San Francisco Bay

Photo by Tom Grey

18 November 2008

Report to the Coastal Conservancy Association and the South Bay Salt Pond Restoration Project

W. David Shuford
PRBO Conservation Science
3820 Cypress Drive # 11
Petaluma, CA 94954
707-781-2555
www.prbo.org

ACKNOWLEDGMENTS

Thanks to the following individuals for providing unpublished data, references, or insight on California Gulls and potential options for their management: Parvaneh Abbaspour, Josh Ackerman, Joy Albertson, Russ Bradley, Sherry Hudson, Aidona Kakouros, Danielle Le Fer, John Neill, David Riensche, Jennifer Roth, Carly Schacter, Dick Seamons, Nanette Seto, Cheryl Strong, Julie Thayer, Steve Vasconcellos (Wingmaster Falconry Services), and Pete Warzybok. Ann Buell, Nils Warnock, and Lynne Trulio have been supportive of this work. Tom Grey generously shared the image on the cover showing a Forster's Tern harassing a California Gull in defense of nests at the tern colony at salt pond A16 in Alviso. Thanks to Doug Bell (East Bay Regional Park District), Cheryl Strong and Clyde Morris (U.S. Fish and Wildlife Service), John Krause (California Department of Fish and Game), Lynne Trulio (San Jose State University), and Ann Buell (California State Coastal Conservancy) for thoughtful reviews of an earlier draft of this report. Funding was provided by the South Bay Salt Pond Restoration Project, administered through the Coastal Conservancy Association. This is Contribution Number 1642 of PRBO Conservation Science.

CONTENTS

EXECUTIVE SUMMARY

The California Gull (*Larus californicus*) breeds widely in western North America and its overall population has increased in the 20th century. Exponential increase of the population at the only coastal breeding location in San Francisco Bay since the early 1980s has prompted concern for the gulls' potential impact on other species of nesting waterbirds. Concern is focused particularly in South San Francisco Bay, where a large project will restore tidal action to thousands of hectares of salt ponds occupied by gulls and other waterbirds. Some judge that the South Bay's large gull population threatens the project's ability to meet its objectives to maintain the current abundance and diversity of other breeding birds because the gulls appropriate their nesting sites, harass adults, and prey on eggs and young.

Various species of gulls have increased worldwide. The gulls' augmented populations and increasing reliance on human food sources have brought them into closer association with humans, increasing the potential for conflicts, including impacts on other valued wildlife. Despite widespread use of gull control worldwide, broad-scale and long-term reduction of gull populations has proven elusive. Likewise, few studies have rigorously assessed the effects of control on either the gulls themselves or, more rarely, other species of interest. Well-documented population reductions in valued species attributable to gulls mainly pertain to terns and a few other species. Reductions in gull numbers may not lead to comparable reductions in conflicts, owing to density-dependent recovery of gull populations or the presence of predatory specialist gulls that may escape from a general cull by chance. Still, control efforts have been successful in restoring populations of some terns and other species displaced by gulls usurping their nesting space.

A review of potential impacts of gulls on various species of terns and shorebirds in San Francisco Bay did not reveal any clear or alarming population-level effects at this time. Still, concern is warranted because impacts may deepen if the gull population continues to increase and restoration forces gulls and other waterbirds into even closer association. California Gulls are thought to be limited by the availability of suitable nesting substrate and sufficient food supplies near breeding colonies, but they have not yet reached their carrying capacity in San Francisco Bay.

Efforts to reduce gull conflicts that are most likely to succeed include reducing suitable gull nesting habitat, limiting their access to the concentrated food source of garbage at nearby landfills, and enhancing the habitats of other waterbirds vulnerable to gull impacts. Managers should be aware of the potential that such efforts may not have the desired effect and may just shift problems elsewhere. Also, gull control efforts are likely to be costly and require a long-term commitment of personnel and resources. Because of these difficulties and the complexities of the issue, it would be valuable to form a working group to develop a list of specific goals and actions, a timetable and cost estimate for their implementation, and a strategy to monitor the results of these actions on gulls and other waterbirds that allows for changes to management actions as new information becomes available. It also would be valuable to develop an overall predator management plan to address the full suite of avian and mammalian predators that prey on waterbird nests and young. Further, it will be important to establish research priorities to obtain information that managers can use to refine management actions and to enlist partners and engage stakeholders knowing that gull control will require cooperative actions and may prove controversial to some.

INTRODUCTION

The California Gull (*Larus californicus*) breeds at scattered locations in western North America, primarily in the interior from the south-central taiga of Canada south through the Great Plains to southern Colorado and west and south through the Columbia Plateaus and Great Basin desert to east-central California (Winkler 1996). Jehl (1987) proposed two races: *L. c. californicus*, breeding primarily in the Great Basin of the United States, and *L. c. albertaensis*, breeding in the Great Plains of the north-central United States and south-central Canada. These gulls migrate to winter primarily on the Pacific coast from southern British Columbia south to western Mexico and in near-coastal lowlands, such as the Central Valley (Winkler 1996).

The size of the population has been increasing continent-wide, in California, and, particularly, at the only coastal breeding site in San Francisco Bay (Winkler 1996, Shuford and Ryan 2000, Strong et al. 2004). The nesting population in San Francisco Bay has grown steadily and exponentially from its establishment in the early 1980s to the present (Strong et al. 2004, Ackerman et al. 2006, San Francisco Bay Bird Observatory unpubl. data). The vast majority of the breeding gulls are concentrated in South San Francisco Bay, which includes the >6100 hectares of salt ponds within the South Bay Salt Pond Restoration Project, some of which are managed for shorebirds and waterfowl, breeding birds, and the threatened coastal population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). Current information suggests the large population of California Gulls threatens the Project's ability to meet its objectives to maintain the current abundance and diversity of other breeding birds because the gulls appropriate their nesting sites, harass adults, and prey on eggs and young (Strong et al. 2004, Ackerman et al. 2006).

To enable effective adaptive management of California Gulls, the Project Management Team for the South Bay Salt Pond Restoration Project needs a thorough review of the relevant literature and other authoritative sources. The review that follows here summarizes pertinent information on the importance of the South Bay gull population to the species overall, how gulls have been effectively managed and controlled in other areas, and, ultimately, how the Project Management Team may potentially be able to manage the species within the Project Area at a reduced population level overall and at locations that do not result in major negative effects on other wildlife.

POPULATION STATUS AND GROWTH OF CALIFORNIA GULLS

OVERALL STATUS

The most recent estimate of the size of the North America/worldwide population of nesting California Gulls is roughly 400,000 individuals (Winkler 1996). This is predicated on an estimate of about 276,000 breeding adults in the United States in 1982 (Conover 1983) and the assumption that there are probably at least half this number of birds breeding in Canada (Winkler 1996). Allowing for birds of pre-breeding age, the latter author estimated that the world population was probably between 500,000 to 1 million individuals. Estimates of both the overall population size and its trends over time are crude given the lack of even a single rangewide survey of breeding numbers and the continuous monitoring of only a relatively few colonies.

The species' overall breeding population is widely believed to have increased in the 20th century (Conover 1983, Winkler 1996, Shuford and Ryan 2000), but the full extent or rate of this increase is not well documented. Conover (1983) estimated that the U.S. population has more than doubled since 1930. Weaknesses of this estimate, however, are (1) assumptions about the reliability of historical data, particularly that many colonies were not overlooked by early ornithologists; (2) estimation of both historical or recent population sizes by adding estimates or counts from individual colonies taken in widely varying years, given that numbers at individual sites may vary considerably from year to year and that birds may shift breeding sites with periods of drought or flood; and (3) errors in the reporting of numbers of nesting birds at some colonies (Winkler 1996, Shuford and Ryan 2000, M. Naughton pers. comm.). Regardless, population growth of the species in the 20th century is attributed to near-colony increases in food supplies from expansion of irrigated agriculture and of garbage near human habitation, increased availability of nesting islands in new reservoirs, reduction in harvesting for eggs and feathers, and greater overwinter survival from increased human food sources, particularly at landfills (Conover 1983, Winkler 1996).

STATUS IN CALIFORNIA

In California, comprehensive statewide surveys of nesting colonies from 1994 to 1997 estimated about 66,000 to 79,000 breeding adult California Gulls (Shuford and Ryan 2000). The subsequent continued increase in numbers of breeding gulls in San Francisco Bay and colonization of a few additional sites by small numbers of gulls suggests the statewide population has been increasing in recent years. However, fluctuations in numbers at key colonies and a lack of data from others precludes an accurate assessment of recent trends of the statewide population of California Gulls.

Numbers of breeding gulls at the state's largest colony at Mono Lake, monitored annually from 1983 to the present, have varied considerably but have shown no long-term upward or downward trend (Shuford and Ryan 2000, Wrege et al. 2006, PRBO unpubl. data). Numbers of nesting adults averaged 48,081 individuals from 1983 to 2007 (range = 34,932–64,976, n = 25 yrs). Consistently highest numbers were in the early 1990s when totals exceeded 60,000 in 4 of 5 years from 1990 to 1994 (PRBO unpubl. data), the latter coinciding with the year of the highest statewide count in the period 1994–1997 (Shuford and Ryan 2000). From 1995 to 2007, numbers of nesting adults at Mono Lake have averaged 45,155 (range = 34,932–51,908, n = 13 yrs; PRBO unpubl. data). Analyses of these long-term data for Mono Lake indicated that annual numbers of nesting gulls were most influenced by the potential number of four-year-old gulls returning to breed for the first time, winter conditions associated with the Pacific Decadal Oscillation, the density of brine shrimp (a primary prey item) close to the time of egg-laying, and mean temperature in the month prior to egg-laying (Wrege et al. 2006). The latter two factors, reflecting local conditions near the time of egg-laying, had the most profound direct effect on the number of breeding gulls. Still, annual variation in snow pack and spring runoff affects brine shrimp numbers through changes in limnological conditions, thus regional climate appears to indirectly affect gull numbers.

Because there are only three other colonies in the interior of the state with relatively large numbers—each averaging about 3000 breeding California Gulls from

1994–1997—it seems unlikely that trends at these colonies would have much effect on nesting gull numbers in San Francisco Bay. During drought conditions, the colony at Meiss Lake, Butte Valley Wildlife Area, Siskiyou County, California, was inactive in 2003 and 2004, when it apparently shifted nearby to Swan Lake, Klamath County, Oregon, and similarly the colony at Clear Lake NWR, Modoc County, California, held below average numbers in 2004 when low water levels reduced available island nesting habitat (Shuford et al. 2006). These patterns appear to reflect short-term environmental fluctuations, and there currently do not appear to be any persistent changes at any of the interior colonies that would be likely to greatly reduce or increase breeding numbers in the long-term (D. Shuford pers. obs.).

In California, the main expansion of California Gulls in recent decades has been in San Francisco Bay, with new colonizations elsewhere in the state being small or of limited success. At the Salton Sea, an initial 2 breeding pairs in 1996 increased to 22 in 1997, then leveled off at 39 to 44 from 1998 to 2001 (Molina 2000, 2004). California Gulls have attempted to breed annually at Owens Lake, Inyo County, since 2004, but they do not appear to have raised any young (PRBO unpubl. data, Debbie House pers. comm.). Likewise, small colonies have been active at Lake Davis, Plumas County, since at least 2006 (Glenn Sibbald in litt.) and at Laurel Ponds south of the town of Mammoth Lakes, Mono County, since at least 2007 (perhaps earlier, Kristie Nelson pers. comm.). Probably reflecting continued expansion from San Francisco Bay, California Gulls began nesting offshore on South Farallon Island in 2008, but apparently with little success (Russ Bradley/PRBO unpubl. data). Although about 244 nests were active in mid-June, subsequently few chicks were seen and only about 25 nests were active in mid-July, likely reflecting heavy predation by Western Gulls (*Larus occidentalis*).

STATUS ELSEWHERE IN THE WESTERN UNITED STATES

It is unclear if immigration from colonies outside of California may have contributed to the expansion of California Gulls in San Francisco Bay. Numbers of California Gulls at the world's largest breeding aggregation at Great Salt Lake have been estimated in 9 of 12 years from 1982 to 1993 (John Neill, Great Salt Lake Ecosystem Program under auspices of the Utah Division of Wildlife Resources). The average number of breeding gulls in this period was 105,035 individuals, but numbers varied considerably among individual years (range = 49,842–156,071) and periods of years (Paul et al. 1990, GSLEP unpubl. data). Numbers of nesting gulls increased 60% and 75% from 1982 to 1983 and 1989 to 1990, respectively. Likewise, averages for the two 4-year periods 1983–1987 and 1990–1993 were 78,067 and 145,801 adults, respectively. An incomplete estimate for 1994 was also over 150,000 adults. This period of high nesting gull numbers at Great Salt Lake in the early 1990s coincides closely with a comparable period of elevated gull numbers at Mono Lake, but unfortunately lakewide counts did not continue at Great Salt Lake beyond this period. With a reduction in available nesting habitat from a lake level about four feet lower than in the early 1990s and industrial development at the site of the largest local colony, the Great Salt Lake nesting population is currently estimated to be roughly 73,000 adults (John Neill in litt.).

STATUS AND BIOLOGY OF CALIFORNIA GULLS NESTING IN SAN FRANCISCO BAY

COLONIZATION AND POPULATION GROWTH

Until 2008, when small numbers of the species began to breed on Southeast Farallon Island (PRBO unpubl. data), San Francisco Bay was the only known coastal breeding site for the California Gull (Jones 1986, Winkler 1996). After establishment in the South Bay in the early 1980s, the overall nesting population has increased exponentially to almost 37,000 adults in 2007 and 47,000 in 2008 (Strong et al. 2004, Ackerman et al. 2006, San Francisco Bay Bird Observatory unpubl. data). Likewise, the number of breeding sites has increased, and their distribution has broadened to now include a few sites in the Central Bay (e. g., Brooks Island, Alcatraz Island). Still, currently the vast majority of the gulls nest on islands or levees of salt ponds at three sites: Alviso A6 (Knapp property), Mowry M1/M2, and Coyote Hills, which, respectively, held 67%, 20%, and 12% of the South Bay total in 2007.

FACTORS CONTRIBUTING TO POPULATION GROWTH

The main limiting factors in the regulation of population growth in California Gulls appear to be the availability of suitable nesting substrate (islands, levees) free of ground predators and sufficient food supplies near breeding colonies (Winkler 1996). Because the population of gulls in the South Bay has continued to steadily increase, it appears that the gulls have not reached the limits to the carrying capacity of the South Bay with respect to available nesting substrate and food.

Intrinsic growth versus immigration. Although no long-term data are available on reproductive success of California Gulls in San Francisco Bay, it seems likely that the pattern of exponential growth has been fueled to some degree both by immigration, at least initially, and by intrinsic growth from recruitment of young gulls raised in the bay. It would be valuable to have more information on this topic, as management to reduce numbers of nesting gulls in San Francisco Bay will be more difficult if the population continues to be substantially augmented by immigration.

Gull Diet in San Francisco Bay

Overall, California Gulls are generalist, opportunistic foragers with a diverse diet varying greatly by location and season (Winkler 1996). Two studies, both conducted shortly after colony establishment, have investigated the diet of California Gulls breeding at the Alviso (Knapp property) colony in south San Francisco Bay on the basis of chick regurgitations. Currently, biologists from the U.S. Geological Survey are conducting a stable isotope study to determine the proportion of their diet that nesting gulls in the South Bay obtain from landfills adjacent to their colonies, but results are not yet available (Josh Ackerman pers. comm.).

Jones (1986) sampled 58 and 48 boli of gull chicks, all at night, at Alviso in 1983 and 1984, respectively. Garbage was the most important food item by percent volume in both years, but the relative proportion of other natural food items varied substantially between years. Key food items by volume in 1983 and 1984, respectively, were 42% and 38% garbage, 38% and 0% brine flies, 8% and 21% other insects, 5% and 6% rodents, 0.2% and 21% fish, 6% and 0% miscellaneous items, and 0% and 4% vegetation. Jones (unpubl. data in Dierks 1990) found brine flies dominating (62% by volume) in early season (25 May–12 June) samples (*n* = 25) versus garbage (58% by volume) in late-season (13 June–9 July) samples (*n* = 33). Overall, warm-blooded prey were of minor importance, with mammals more evident than birds (Jones 1986). Mammalian prey included Norway rat (*Rattus norvegicus*), pocket gopher (*Thomomys townsendii*), California ground squirrel (*Spermophilus beechyi*), and California vole (*Microtus californicus*). Avian prey included duckling (*Anas* sp.), American Coot (*Fulica americana*), California Gull, and swallow species (probably Cliff Swallow *Petrochelidon pyrrhonota*).

In 1987 and 1988, Dierks (1990) used chick regurgitations at the Alviso colony to examine annual, seasonal, and diurnal differences in gull diet. Overall, chick diet by volume was 40% garbage, 15% midges, 15% brine shrimp, 13% fishes, and 10% brine flies. Chick diet varied little between years, with the main difference being consumption of polychaetes in 1987 only. Key items by volume in 1987 and 1988, respectively, were 35% and 47% garbage, 14% and 16% midges, 14% and 15% brine shrimp, 13% and 13% fishes, 11% and 9% brine flies, 9% and 0% polychaetes, and 4% and 1% other insects. Young chicks ($\leq$10 days old) were fed more brine flies than older chicks, but other differences between the diet of young and old chicks were not consistent between years. Most difference between early season (before 14 June) and late-season diets were small and not consistent among years. Similarity of morning and evening diets was only 50%, with garbage, fishes, and polychaetes more common in the morning, and brine shrimp and insects in the evening.

It is valuable to gather additional information on gull diet beyond that obtained from boli or stomach samples. At Honey Lake, Lassen County, stomach samples of California Gulls (*n* = 56, adults and chicks) and Ring-billed Gulls (*n* = 29, adults) contained no significant remains of waterfowl eggs or young, although field observations documented gulls preying on some ducklings (Anderson 1965). Likewise, in accounts that follow there are observations of California Gulls preying on the eggs or chicks of shorebirds and terns, though the studies above show only limited evidence of waterfowl or waterbird remains in diet samples collected in the bay.

Ackerman et al. (2006) documented declining numbers of gulls at South Bay landfills from April to August and posited that the gulls likely decreased their reliance on landfills as a food resource and instead switched to foraging on more natural prey, including avocet chicks, as the gull chick-rearing season progressed. This interpretation is not supported by available data on diet or gull phenology in the area.

First, the diet information from the studies at the Alviso colonies presented above does not show a decline in the proportion of garbage fed to chicks as the season progresses. In 1983, Jones (in Dierks 1990) found brine shrimp accounting for 62% of the early season chick diet, garbage for 58% of the late-season diet. For 1987 and 1988, Dierks (1990) reported that overall most differences between young and old chicks and between early and late-season samples were small or not consistent when both years were compared. In 1987, however, garbage was more prevalent by volume in samples from older (39%) versus younger (28%) chicks and those collected later (41%) versus earlier (31%) in the season. At Mono Lake, where garbage is only a minor component of the diet, Hite et al. (2004) documented garbage being fed to chicks mainly by males in the afternoon, and at a higher frequency late in the season than early in the season. More study is needed, particularly in San Francisco Bay, but a higher frequency of garbage fed to chicks late in the season may possibly reflect the larger food items fed to larger chicks and a greater frequency with which such large items may be obtained in landfills than elsewhere.

Second, patterns of seasonal abundance of gulls at landfills, as described below, are variable and open to other interpretations independent of gull diet.

Gull Use of South San Francisco Bay Landfills

There currently are three municipal solid waste landfills in close proximity to the shoreline of South San Francisco Bay (CIWMB 2008). San Jose's Newby Island landfill, slated to be operational through 2025, should remain the most important landfill for gulls. Not only is it the largest of the three landfills, but it is located adjacent to salt pond levees (ponds A18, A19) that are used extensively by gulls (Ackerman et al. 2006, Hudson and Le Fer 2008). Open since the mid-1960s, the Tri-Cities landfill was closed on 30 June 2007 to dumping by the general public, but it still receives compacted waste from a transfer station operated by the City of Fremont. Hence, it still provides foraging opportunities for gulls and is located next to salt ponds used by roosting and nesting gulls. The City of Palo Alto's landfill will continue to host few gulls, as most of the city's solid waste is hauled to a transfer station and disposed of elsewhere. There are also two landfills in south San Jose, one of which does abatement, but it is unclear if large numbers of gulls from the local colonies forage at these dumps in the breeding season (Cheryl Strong pers. comm.).

Since 2006, biologists from San Francisco Bay Bird Observatory have surveyed gull numbers at the three landfills near the California Gull colonies in the South Bay. Results to date indicate that the seasonal pattern of gull numbers at landfills appears to vary both between years and among landfills in the same year (cf. Ackerman et al. 2006, Hudson and Le Fer 2008).

Totals (and monthly means) of California Gulls on five monthly surveys from April to August 2006 were 19,386 (3877), 8691 (1738), and 245 (49) at the Newby Island, Tri-Cities, and Palo Alto landfills, respectively (Ackerman et al. 2006). In 2006, total numbers of California Gulls at landfills decreased from April to June, increased in July, then decreased again in August. From February to August 2007, biologists conducted seven monthly surveys at two of the landfills and six surveys at Tri-Cities and found fewer gulls than in 2006 (Hudson and Le Fer 2008). In 2007, landfill totals (and monthly means) for California Gulls were 6244 (892), 5805 (968), and 174 (25) for the Newby Island, Tri-Cities, and Palo Alto landfills, respectively. Although patterns of seasonal abundance in 2007 varied between the two landfills with large numbers of California Gulls, after declining from April to May, gull numbers generally increased from May to July (Hudson and Le Fer 2008). At Newby Island, numbers decreased from April to May then increased through August, whereas at Tri-Cities they increased from April to June (no count in July) and decreased in August.

These seasonal abundance patterns at landfills may be influenced by various factors, including overall patterns of seasonal gull abundance and seasonal patterns of attachment of breeding birds to local colonies. Early season gulls numbers may be swelled by migrants (on top of breeders) still passing through the area (March–May; Shuford et al. 1989) and by the ability of both individuals of a pair to simultaneously visit landfills before egg laying (commencing in mid-April in the bay; Jones 1986), after which one bird must continuously incubate eggs or guard small chicks. As the season progresses and some nests fail and the chicks in others reach a size at which they are left alone for long periods by adults, adults freed from nest duties might spend more time at landfills, swelling overall numbers, or, lacking nest attachment, they might range farther afield and thus reduce numbers at local landfills. In July and August after fledging, numbers of gulls at landfills also could be swelled by free-flying juveniles, but, conversely both adults and juveniles could disperse more widely when no longer attached to the nesting colony and its nearby landfills (at a time when ocean productivity is particularly high; Chelton et al. 1982).

Starting in December 2007, as part of a gull abatement project for Waste Management, Inc., biologists began much more intensive surveys (4–8 hrs/day and 1–6 times per week) at the Tri-Cities and Newby Island landfills as well as the Ox Mountain landfill in Half Moon Bay on the outer coast (Sherry Hudson pers. comm.). An additional survey aims to determine the effectiveness of abatement on the gulls by gathering data on how soon they leave after an abatement event, how many leave, how quickly they return, etc. These recent data have not yet been compiled or analyzed.

In 2007 and 2008, biologists from the U.S. Geological Survey radio-tracked over 50 California Gulls, including 30 individuals over two consecutive years, to investigate their movement and use patterns in the South Bay (Josh Ackerman pers. comm.). In addition, they placed fixed automated data logging stations at the three main gull colonies (A6, Coyote Hills, and Mowry) and the two main landfill sites (Newby Island and Tri-Cities) to enable calculation of the proportion of time spent by gulls at each site. In 2007, they found that gulls spent the majority of their time at colonies, landfills, and salt ponds adjacent to landfills (Josh Ackerman/USGS unpubl. data). Continuous monitoring by the automated data loggers documented that as much as 75% of the radio-marked gulls' time was spent at A6 and the landfills. The gulls used landfills heavily between 6 a.m. and 5 p.m., the period when organic refuse is exposed during landfill operations. Gull use of landfills was higher during the pre-breeding season than when they were incubating eggs and rearing chicks. Data for 2008 have not yet been analyzed (Josh Ackerman pers. comm.).

Status of Potential Gull Breeding Habitat in San Francisco Bay

The exponential increase of the California Gull population in south San Francisco Bay through 2008, increasing numbers at the three largest colonies in the South Bay, and the colonization of new sites in the central bay starting in the mid-1990s and early 2000s, all indicate that nesting habitat is not yet limiting the gull's population size in the bay. Extensive potential nesting habitat, not yet occupied by gulls, exists in salt ponds and the miles of surrounding levees in the South Bay (Cheryl Strong pers. comm.).

ASSESSMENT OF IMPACTS

Concern has been expressed about known or potential impacts of breeding California Gulls on various species of breeding waterbirds in the South San Francisco Bay salt pond system (e.g., Ackerman et al. 2006). To evaluate the level of concern that may be warranted, this section summarizes the status, population size, population trends, and evidence of known impacts of gulls on each species for which particular concern has been noted.

Snowy Plover

Broad-scale Population Trends

The coastal population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*) is listed as federally threatened. Numbers have declined historically on the coast, where surveys in the late 1970s did not find plovers nesting at 33 of 53 locations with breeding records prior to 1970 (Page and Stenzel 1981). Comprehensive surveys of breeding plovers on the California coast in 1977–1980 and 1989 recorded totals of 1565 and 1386 adults, respectively (Page and Stenzel 1981, Page et al. 1991). Subsequently, numbers of plovers on coastwide surveys from 2003 to 2007 ranged from 1362 to 1904 adults (mean = 1641; U.S. Fish and Wildlife Service [USFWS] unpubl. data).

Status and Trends in San Francisco Bay

A "great many pairs" of Snowy Plovers were nesting on the dikes separating salt ponds near Alvarado, Alameda County, at least as early as 1914 (L. R. Reynolds in Grinnell et al. 1918). Comprehensive surveys of San Francisco Bay for Snowy Plovers found 351 adults in 1978 and 226 in 1989 (Henderson and Page 1981, Page et al. 1991). In 1984, C. Swath (in Page et al. 1991) counted 270 adults during a May–June survey of South San Francisco Bay. Subsequently, baywide surveys from 2003 to 2007 ranged from 72–207 breeding adults (mean = 124, maximum in 2007), representing about 5% to 7% of the coastal California nesting population in those years (USFWS unpubl. data). Lower numbers since the 1970s and 1980s may in part reflect variation in observer skill and fluctuations in salt pond levels in response to management practices and rainfall patterns (Gary Page pers. comm.).

Mean nesting success (proportion of nests hatching at least one chick) in South San Francisco Bay from 2004 to 2007 was 69%: calculated from 84% of 61 nests, 85% of 20 nests, 58% of 81 nests, and 49% of 89 nests in 2004, 2005, 2006, and 2007, respectively (Tucci et al. 2006; Robinson et al. 2006, 2007). Mean clutch hatching success from six other sites on the California coast reported in Page et al. (1995) was 54% (range = 19%–87%), indicating the rates in San Francisco Bay are in line with expected variation.

Particular concern has been expressed about the risk to plovers of predation by California Gulls (e.g., Robinson et al. 2007), important predators of plover nests in the interior at Mono Lake (Page et al. 1983). Few data are available, however, documenting the specific predators responsible for egg and chick losses of Snowy Plovers in San Francisco Bay. In 2007, biologists observed three such predations: a Northern Harrier (*Circus cyaneus*) taking a nest in one incident and a chick in another, and a Common Raven (*Corvus corax*) taking a nest (Robinson et al. 2007). At pond A8 in Alviso where plovers nest adjacent to the bay's largest gull colony in pond A6, hatching success was 91% (9 of 11 nests) in 2006 and 100% (2 of 2 nests) in 2006 and 2007, respectively. Although the sample sizes are small, these data suggest the gulls may be taking relatively few plover nests. It is possible, however, that the gulls are taking plover nests before they are discovered by biologists or they may be discouraging some plovers entirely from nesting in close proximity to the gull colony. Although data are lacking, the gulls may be taking a higher proportion of plover chicks than eggs, as has been documented for avocets nesting in the South Bay (Ackerman et al. 2006; see summary below).

Patterns of Occupancy in San Francisco Bay

In 1978, the vast majority of plovers were on the east side of the bay south of the San Mateo Bridge (91% of total in Alameda Co.), on levees around full evaporator ponds and on levees and flats in partly dry evaporators (Henderson and Page 1981). From 2005 to 2007, 73% to 82% of all plovers in San Francisco Bay, counted as part of a coastwide survey, were in the Baumberg/Eden Landing area south of the San Mateo Bridge, with the remainder mainly in the Warm Springs, Ravenswood, and Alviso areas (USFWS unpubl. data at www.fws.gov/arcata/es/birds/WSP/plover.html). These plovers were located predominantly in dry salt evaporator ponds, with very few on islands or on levees around ponds containing water (Cheryl Strong pers. comm.).

Conclusions

Depressed plover numbers in San Francisco Bay may mainly reflect variable habitat conditions in recent years, as plovers appear not to have ever nested in large numbers in the areas where the largest gull colonies are now located near Alviso, Mowry, and Coyote Hills. Active management in the Eden Landing area, the plover's stronghold in the bay, to remove non-native red foxes (*Vulpes vulpes regalis*), feral cats (*Felis domesticus*), skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), Common Ravens, American Crows (*Corvus brachyrhynchos*), and Northern Harriers may be helpful in maintaining plover populations at recent levels. Given, however, that little information is available on the causes of the loss of plover chicks, it is unclear if management is adequate for enhancing overall fledging success. The main predators of plover chicks on the California coast are usually harriers, shrikes, kestrels, and probably owls (G. Page pers. comm.). If present and not controlled, these predators may depress plover fledging success. Neuman et al. (2004) found removal of mammalian predators and erecting nest exclosures in the Monterey Bay area increased plover hatching success but not fledging success; the latter probably was limited by avian predators. It would be valuable to gather additional information on predator effects on plovers in South San Francisco Bay, as increasing numbers of gulls potentially could reduce plover nesting success.

BLACK-NECKED STILT AND AMERICAN AVOCET

Broad-scale Population Trends

Historically, numbers of both the Black-necked Stilt (*Himantopus mexicanus*) and American Avocet (*Recurvirostra americana*) likely declined rangewide with extensive loss of wetland habitat. For both species, Breeding Bird Survey data for 1968–2007 show statistically significant increasing trends for both California and the Pacific states (Sauer et al. 2008).

Status and Trends in San Francisco Bay

Stilts and avocets were first known to nest in San Francisco Bay by at least the mid-1920s, and numbers increased with the expansion of salt ponds (references in Rintoul et al. 2003). Surveys of both species in 2001 estimated 590 and 1380 pairs of stilts and avocets, respectively, in South San Francisco Bay (Rintoul et al. 2003). These numbers are within the range of prior estimates of 400–650 and 650–1800 pairs of stilts and avocets, respectively, in the early 1970s and 1980s, suggesting that the breeding populations of these species in the bay have been relatively stable for the last three decades.

Ackerman et al. (2006) studied rates of predation on the eggs and chicks of stilts and avocets in the South Bay. The most reliable South Bay data from infra-red video cameras found 54% of 54 avocet nests and 48% of 21 stilt nests were depredated. Avian predators accounted for 46% and mammalian predators for 54% of egg loss in avocets. California Gulls were responsible for 33% of avian predation and 15% of total nest predation of avocets documented by cameras. Mammalian predators accounted for all egg loss in this sample of stilt nests. Of another sample of nests to which fake eggs were added, 41% of 51 avocet nests and 64% of 33 stilt nests were depredated. For nests with fake eggs for which predator type could be distinguished, mammalian predators outweighed avian predators for both avocets and stilts.

Nest and egg loss rates for avocets and stilts in the bay were modest relative to published figures for other sites, including many in the interior of California. Over a range of studies, the proportion of nests hatching at least one egg and the proportion of eggs laid that hatched were, respectively, 0.00–0.51 and 0.00–0.55 for avocets (Robinson et al. 1997) and 0.38–0.67 and 0.33–0.63 for stilts (Robinson et al. 1999). In the San Joaquin Valley, predation accounted for the loss of 45% and 48% of avocet and stilt nests, respectively (Hothem 1989 in Davis et al. 2008). In New Mexico, evidence of predation was found in 80% and 37% of avocets and stilts nests, respectively (Smith et al. 2003 in Davis et al. 2008).

Survival rates to fledging of radio-tracked chicks studied in the South Bay were 32% and 56% for stilts and 14% and 5% for avocets in 2005 and 2006, respectively (Ackerman et al. 2006). California Gulls accounted for the loss of 61% of all avocet chicks and 23% of stilt chicks; a high number of radio-transmitters were recovered in the Alviso A6 and Coyote Hills gull colonies. The higher survival rates of stilt chicks were attributed to their tendency to use habitats with more emergent vegetation cover than those used by avocets. It is unclear if the radios placed on chicks had any influence on their survival rates. Transmitter weights were low relative to chick body weights, but it is possible that the 12-cm-long antennas used might increase detectability by predators when chicks are crouched and relying on cryptic coloration to avoid predation.

Patterns of Occupancy in San Francisco Bay

In 2001, breeding stilts and avocets were concentrated on the east side of the bay from the San Mateo Bridge to just south of the Dumbarton Bridge and secondarily in the Alviso area, especially around New Chicago Marsh (Rintoul et al. 2003). Salt ponds accounted for more than half of stilt and three-quarters of avocet observations; fewer were in a combination of fresh and salt marshes. Stilts showed greater use of marshes and the vegetated areas within them than did avocets. Since the 1970s, stilts and avocets breeding in salt ponds appear to have increased their use of islands relative to levees, perhaps because levee nests are particularly vulnerable to mammalian predators such as the non-native red fox (Rintoul et al. 2003), which was first recorded in the South Bay in 1986 (Harding 2000).

Conclusions

Recent studies in the South Bay document high rates of chick predation, particularly on avocets, by California Gulls. Egg loss coupled with low survival rates of chicks is a cause for concern, but population estimates of adult nesting stilts and avocets in 2001 suggest that their numbers have not declined appreciably during the period of rapid gull population increase beginning in the early 1980s. Still, actions are well warranted to increase nesting success of stilts and avocets during salt pond restoration.

CASPIAN TERN

Broad-scale Population Trends

Since the early 20th century, the Pacific Coast population of the Caspian Tern (*Hydroprogne caspia*) has shifted from nesting at numerous small colonies in the interior of California and Oregon to nesting primarily in large colonies on human-created habitats along the coast (Gill and Mewaldt 1983, Suryan et al. 2004). Since the 1960s, the size of the Pacific Coast population has increased dramatically (Gill and Mewaldt 1983, Suryan et al. 2004), as has the continental population (Wires and Cuthbert 2000). Conflicts with populations of threatened and endangered salmonids in the vicinity of the world's largest colony of Caspian Tern's at the Columbia River mouth in Oregon has lead to efforts to redistribute a portion of that population by increasing or enhancing tern nesting habitat at other sites in Oregon and California (USFWS 2005, 2006). The enhancement sites in California are all in San Francisco Bay: Brooks Island and Hayward Regional Shoreline in the central bay and the Don Edwards San Francisco Bay National Wildlife Refuge in the South Bay.

Status and Trends in San Francisco Bay

Eggs of this species were first collected in south San Francisco Bay in 1916, and the first description of a colony was of one on a salt pond levee, in the area now known as the Coyote Hills salt ponds, in 1922 (Grinnell and Miller 1944). Colony numbers and total population size in the bay increased through about 1980 (Gill and Mewaldt 1983), but baywide numbers have been relatively stable from the early 1980s to the present (Shuford and Craig 2002, Strong et al. 2004, USFWS unpubl. data). During the period 1997–2007, when counts were conducted at most colonies annually, numbers ranged from 790–1365 breeding pairs, with counts <1000 mainly at the beginning and end of the period (Shuford and Craig 2002, USFWS unpubl. data).

Patterns of Colony Occupancy in San Francisco Bay

Colony locations of Caspian Terns within San Francisco Bay have been dynamic from the time of first colonization to the present, which is emblematic of the pattern for the Pacific Coast population as a whole (see Appendix 1 in Shuford and Craig 2002). Nesting terns initially concentrated in the South Bay, but the central bay, colonized in the 1980s, now hosts the largest numbers in the San Francisco Bay estuary, including San Pablo Bay.

Colony locations have likely shifted for many reasons, but the main ones identified have been predation by the non-native red fox, levee maintenance, and plant succession (Ryan 2000a, Shuford and Craig 2002, Strong et al. 2004). A large tern colony at Bair Island was abandoned in the early 1990s following episodes of predation by red foxes and erosion of levees that lead to tidal inundation of the colony. A colony near the town of Drawbridge (aka Mowry colony) was abandoned in the mid-1990s in response to repeated red fox and feral cat predation and, perhaps, disturbance by nesting California

Gulls. Red foxes apparently also caused abandonment or declines of colonies at Baumberg/Eden Landing, Moffett, and Alviso when low water levels formed landbridges to tern nesting sites. In response to levee maintenance, long-standing tern colonies at Coyote Hills and Turk Island were abandoned by at least 1969 and 1986, respectively. A colony established at the Alameda Naval Air Station in 1985 was abandoned after 1999, apparently in response to encroaching vegetation. Strong et al. (2004) concluded that disturbance or predation by California Gulls was not a factor in low site fidelity of Caspian Terns in San Francisco Bay.

Conclusions

Despite declining numbers of nesting Caspian Terns in the South Bay and some speculation that California Gulls may be negatively affecting them (Ackerman et al. 2006), the preponderance of evidence suggests that the overall affect of gulls on the distribution and numbers of these terns in the bay has been relatively minor to date. As noted above, total numbers of Caspian Terns breeding in the San Francisco Bay estuary have been relatively stable during a period of rapid increase in nesting gull numbers, and abandonment of key South Bay tern colonies has been attributed to other factors, particularly red fox predation and habitat modification or succession. That Caspian Terns nest together with California and Ring-billed (*Larus delawarensis*) gulls at many sites in the interior of California (Shuford and Ryan 2000, Shuford and Craig 2002) and that the later-nesting terns often establish their colonies on the periphery of previously established gull colonies (D. Shuford pers. obs.), even when other apparently suitable islands are available, suggests the terns are well adapted to coexist with these gull species. The gulls do prey on the eggs and young of terns, but this may be no more intense than the gulls' predation on the eggs and young of their conspecifics.

If the commitment of the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service to create or enhance nesting habitat for Caspian Terns in San Francisco Bay increases the terns' numbers (USFWS 2005, 2006), management of gulls to offset their potential impact on these terns may become a secondary concern for the South Bay Salt Pond Restoration Project relative to that for some other species.

FORSTER'S TERN

Broad-scale Population Trends

Trends of the continental population of the Forster's Tern (*Sterna forsteri*) are not well known (McNicholl 2001). Breeding Bird Survey (BBS) data for 1966–2007 show no statistically significant trend for Canada and the United States, the Pacific states, or California (Sauer et al. 2008). These data should be interpreted cautiously, however, as the BBS is not well suited for sampling colonial waterbirds (Bystrak 1981, Robbins et al. 1986).

Status and Trends in San Francisco Bay

Although observations of 25–40 Forster's Terns in summer in the mid- to late 1930s suggested breeding in San Francisco Bay, nesting was not documented until 1948 when about 100 nests were found near the east end of the San Mateo Bridge (Sibley 1952, 1953). In the early 1950s, additional colonies were located near the east end of the Dumbarton Bridge and in the vicinity of Newark, and another was suspected near Alviso.

Extensive surveys in 1972 and 1981 estimated 2000 pairs at 10 colonies and 2500 pairs at 6 sites, respectively (summarized in Ryan 2000b). Estimates of nesting tern numbers for the central and South Bays combined from 1982 to 2003 ranged from 1628 to 4312 individuals (mean = 2710; Strong et al. 2004). Numbers of breeding terns declined significantly from 1984 to 2003 (Strong et al. 2004). Given the high year-to-year variability in numbers, however, this trend may not be biologically significant. It also is unclear what the baywide trend would have been if numbers from a large (37% of baywide total in 2002) but infrequently censused colony in the north bay at Knight's Island were available for analysis and if the Central and South Bay total for 1983 had been included in the prior analysis.

Patterns of Colony Occupancy in San Francisco Bay

From 1982 to 2003, Forster's Terns occupied a total of 17 colonies (Strong et al. 2004). Numbers varied substantially at different colony sites, with five colonies increasing, four decreasing, and four remaining stable. Colony site fidelity was higher in Forster's Terns than in Caspian Terns. For Forster's, site fidelity was highest at sites with the largest available areas and that were nearest to California Gull colonies. Forster's colonies were also more persistent at unstable locations than at intermediately stable or stable sites. Nesting success of Forster's Terns averaged 74% at 6 sites in San Francisco Bay in 2005 and 49% at 6 sites in 2006 (Ackerman et al. 2006). Although methods of calculating or reporting nest success are not strictly comparable among various studies, these rates of nest success in the bay seem reasonably high relative to those reported elsewhere in the species' range (McNicholl et al. 2001) and do not appear to be a cause for concern.

Studies of the relationship between tern colony location and intrusions by California Gulls indicate that the location of a tern colony on a flight path of gulls between their colonies and foraging areas at landfills is a better predictor of gull disturbance or attacks on terns than is proximity to a gull colony (Kakouros 2006). The author noted three instances of gull predation on tern chicks and one on eggs, and she suspected one colony was abandoned in response to gull intrusions. Still, there is no solid indication that gulls are having a population-level impact on this species in San Francisco Bay.

Conclusions

Although California Gulls have displaced some Forster's Terns from nesting sites and will prey on their eggs and chicks, Strong et al. (2004) attributed the decline in baywide numbers of Forster's Terns primarily to mammalian predation, human disturbance, and, possibly, annual variation in food availability. It would be valuable to continue to monitor population trends and to better identify causes if the population continues to decline. This small tern may be particularly vulnerable to displacement and predation if large numbers of California Gulls are forced to relocate if their colony sites are lost during restoration. Hence, management should focus on enhancing or creating additional suitable tern nesting habitat, minimizing human disturbance, and managing ponds so nesting islands are not connected to the mainland at low water levels or conversely inundated or overwashed at high levels.

California Least Tern

Broad-scale Population Trends

The California Least Tern (*Sternula antillarum browni*) is listed as state and federally endangered. The statewide breeding population has increased about 10-fold since the early 1970s, with numbers ranging from about 6300–7000 pairs from 2003 to 2007 (Marschalek 2008).

Status, Trends, and Colony Occupancy in San Francisco Bay

Prior to 1944, the California Least Tern reached the northern limit of its breeding range in California on the coast at Monterey Bay (Grinnell and Miller 1944). This tern was first documented breeding in San Francisco Bay in 1967 with the discovery of three nests at Alameda, Alameda County (Bousman 2007). Subsequently, numbers have increased greatly, and colony sites occupied have varied; nesting in the South Bay has been infrequent (H. T. Harvey & Associates 2005). In 2007, the San Francisco Bay estuary, at the extreme northern end of this tern's range, had a total of at least 436 breeding pairs at 6 sites (Marschalek 2008). These included Montezuma Wetlands (32 pairs) and Pittsburg Power Plant (7 pairs) in Suisun Marsh, Green Island (2 pairs) along the Napa River in the north bay, Alameda Point (355 pairs) in the central bay, and Hayward Regional Shoreline (35 pairs) and Eden Landing (5 pairs) in the South Bay. The number of breeding sites has increased markedly in the last few years, with nesting first documented at Hayward Regional Shoreline in 2005, at Montezuma Wetlands in 2006, and at Green Island and Eden Landing in 2007.

Concern has been expressed about predation on California Least Tern eggs and chicks at Hayward Regional Shoreline, where efforts to establish a colony began in 2001 and terns first nested in 2005 (Riensche 2007). In 2005, the terns established eight nests but abandoned after a flock of about 100–150 California Gulls preyed on the eggs. In 2006, the terns established 15 nests, but after a sudden increase of gulls on an adjacent island only 4 fledglings and 20+ adults were subsequently seen. In 2007, with active predator management, 35 tern pairs produced about 49 fledglings, giving Hayward the highest nesting success of any site in the state that year (Marschalek 2008, David Riensche pers. comm.). Intensive restoration and management of this site (Riensche 2007) appears to be paying off.

The smaller Eden Landing colony failed to produce any young in 2007, with all nests thought to be lost to predators (Marschalek 2008). Although 1 of 32 suspected or documented predators (18 avian, 12 mammalian) on Least Terns statewide in 2007, gulls were not among those causing the greatest losses. In San Francisco Bay, a gull took one chick at Hayward, but overall predation was mainly attributed to other avian species, including the Northern Harrier, Red-tailed Hawk (*Buteo jamaicensis*), American Kestrel (*Falco sparverius*), Peregrine Falcon (*Falco peregrinus*), Barn Owl (*Tyto alba*), Great Horned Owl (*Bubo virginianus*), Burrowing Owl (*Athene cunicularia*), and Loggerhead Shrike (*Lanius ludovicianus*). Losses to gulls likely would have been higher without active predator management, as those efforts have generally been successful.

Conclusions

Since the 1970s, the number of nesting Least Terns and colony sites has increased both statewide and in the San Francisco Bay estuary. Although gulls have caused colony abandonment and nest loss at Hayward Regional Shoreline, intensive management enabled the tern colony there to grow in size and reproduce very successfully in 2007. Overall, other species of avian predators are of more concern to Least Tern managers, and, regardless, intensive management at key colony sites, including removal or relocation of predators, should keep predation on the terns at tolerable levels into the foreseeable future.

OTHER SPECIES

Salt Marsh Harvest Mouse

The salt marsh harvest mouse (*Reithrodontomys raviventris*), endemic to the salt marshes and adjacent diked wetlands of San Francisco Bay, is listed as state and federally endangered. Shellhammer (2000) identified habitat loss and degradation as the main threats to this mouse. He noted that lack of escape cover at the upper edges of many marshes may increase predation rates, and mentioned non-native red foxes, cats, and dogs in this regard. During winter surveys of California Clapper Rails (*Rallus longirostris levipes*) at extreme high tides, biologists have seen gulls, mainly the California and Ring-billed, foraging in salt marshes in groups of usually 10–50 individuals and taking rodents, including harvest mice (Joy Albertson pers. comm.). Although this adds to the effect of mammalian predation pressure, it seems unlikely that gull predation alone would have a population-level effect on harvest mice. Because gull numbers in the bay increase substantially in winter, the number of them foraging on harvest mice at high tides may bear no relationship to the number of California Gulls breeding in the bay in spring and summer. In these seasons, the highest tides are at night when gull predation should be minimal or absent, and the available gull diet data for the breeding season indicates very few rodents are taken (see discussion above).

California Clapper Rail

The California Clapper Rail, restricted mainly to San Francisco Bay, is listed as state and federally endangered. Although habitat loss and degradation are responsible for historical population declines, predation is likely the rails' most immediate threat (Albertson and Evens 2000). Although at least 10 native and 3 non-native predators are known to prey on California Clapper Rails and their eggs, the introduced red fox appears to be of particular concern. Free-roaming and feral cats, Norway rats, and raccoons are also important predators. The large size of Clapper Rails, and a lack of observations of attacks on them by gulls during winter high-tide surveys (Joy Albertson pers. comm.), suggests they are not important predators of this rail. Although it is possible that California Gulls might occasionally prey on an exposed rail chick or nest, it is doubtful that gull predation would have any population-level effect on these rails.

MANAGEMENT OPTIONS FOR REDUCING GULL POPULATION SIZE

WORLDWIDE PERSPECTIVE ON GULL CONFLICTS WITH HUMANS

Worldwide, populations of many species of gulls have increased in size or distribution in the 20th century. Numbers increased initially apparently in response to reduction in persecution by humans and later through exploitation of human food sources (such as garbage at landfills, fish offal), introduced prey, or newly available nesting habitat (e.g., Drury 1973, 1974; Drury and Kadlec 1974; Horton et al. 1983; Conover 1983; Blokpoel and Tessier 1986, 1987; Blokpoel and Scharf 1991; Spaans et al. 1991; Vermeer and Irons 1991).

The gulls' augmented populations and increasing reliance on human food sources have brought them into closer association with humans, increasing the potential for conflicts. Gulls are an important strike hazard to aircraft, particularly at airfields located near landfills or nesting colonies (e.g., Dolbeer et al. 1993, 2000; Brown et al. 2001, Sodhi 2002), and potential transmitters or vectors of disease (Butterfield et al. 1983, Coulson et al. 1983, Monaghan et al. 1985, Southern 1986, Ferns and Mudge 2000). Urban nesters can disrupt commercial operations, destroy landscaping, interfere with traffic, and damage buildings by plugging drains and causing flooding (Blokpoel and Scharf 1991, Belant 1997). They also create nuisances from noise, colony smells, and littering and fouling with droppings (Blokpoel and Scharf 1991, Calladine et al. 2006) and sometimes damage crops (Blokpoel and Tessier 1986, Blokpoel and Struger 1988). Conflicts also arise when expanding or colonizing gull populations are known or suspected of affecting the breeding performance of valued bird species nesting in proximity to them (Thomas 1972).

An extensive literature has accumulated on the increasing numbers of gulls, various methods used to control their numbers or impacts, the effectiveness of such methods, and the benefits and advisability of gull control at various scales. Key reviews of gull control and management (Thomas 1972, Owen et al. 2001, Bishop et al. 2003, and Calladine et al. 2006) summarize much of the scientific literature on these topics. Impacts to other species widely cited as justification for gull control include predation of their eggs and young, competitive exclusion (particularly of terns) from nesting sites, and piracy of their food. It is often difficult to determine when or if such impacts are having a population-level effect on desirable species. Because there is limited information, mostly anecdotal, about prior efforts to control numbers of California Gulls, much that follows pertains to techniques used to control other species of gulls, with an emphasis on the numerous studies of other species in North America and Europe. All methods of control are discussed, though some would undoubtedly be precluded from use in controlling California Gulls in San Francisco Bay by current ethical and regulatory standards, as discussed further below.

The full range of control and management methods can generally be divided into active and passive techniques. The former include various types of lethal control and harassment, the latter modifications of habitat features to discourage gull use of targeted areas. Additionally, some management has focused on attracting gulls to areas where concerns for their impacts would be reduced or removed relative to the sites where their impacts are of particular concern.

ACTIVE TECHNIQUES FOR GULL POPULATION REDUCTION

Lethal Control

Adult gulls have been killed by shooting, trapping and killing, and poisoning or baiting with narcotics (Thomas 1972, Belant 1997, Owen et al. 2001, Bishop et al. 2003, Calladine et al. 2006). Some of these lethal methods have been used in combination with each other and also with nonlethal methods of control.

Poison and narcotic baits. Gulls readily accept baits containing a poison or narcotic, but some persistent poisons may cause harm to other organisms. Narcotic baits, such as alpha-chloralose, have been used to kill large numbers of gulls, particularly at colonies but also at landfills. Narcotic baiting has been the most common method of lethal control of adults since first tried in the 1960s (Owen et al. 2001). Inevitably, some nontarget species are narcotized or killed by alpha-chloralose, so great care is cautioned if it is contemplated for use on gulls nesting near rare or protected species (Thomas 1972). Baiting is usually carried out more than once in a season, and take-up by gulls tends to decline on second and subsequent baitings (Owen et al. 2001). Also, culling of gulls by this method has lead to protests from animal rights activists (Calladine et al. 2006), but any population control program is likely to be controversial (Belant 1997). DRC-1339, another narcotic bait used on gulls, appears to be less effective than alpha-chloralose (Blodget and Henze 1992, Seamans and Belant 1999). Gulls have been poisoned with strychnine and phosphorous, but this method is dangerous because it is nonselective and could wreck havoc on nontarget species (Thomson 1972).

Shooting. Shooting adult gulls at colonies has had limited success (Thomas 1972, Owen et al. 2001, Bishop et al. 2003, Calladine et al. 2006). Shooting can be effective when it selectively targets specific problem gulls or focuses on removal of relatively few individuals nesting on small islands. In larger colonies, only a small number of gulls can normally be killed, as persistent shooting may cause gulls to become increasingly wary and difficult to shoot. Noise or disturbance in the use of guns may have the unintended effect of affording the gulls opportunities to steal the unguarded eggs and chicks of other species. The combined killing of adults and disturbance from shooting may cause gulls to shift their nesting to areas where impacts are lessened (with respect to waterfowl; Owen et al. 2001).

In many circumstances, shooting may not reduce overall bird numbers. Mortality may not exceed the rate of recruitment from immigration or breeding, and shooting may just remove the surplus that would have died of natural causes, such as starvation and disease, without any reduction in the overall population size or associated problems (Bishop et al. 2003). Killing of over 50,000 Laughing Gulls (*Leucophaeus atricilla*) on-site at JFK International Airport in New York over an 8-year period resulted in only a 30% decline in gull colony size (7600 to 5200 nests) at adjacent Jamaica Bay Wildlife Refuge, but the effect may have been greater on regional numbers, as the local breeding population may have been bolstered by the recruitment of immigrants (Brown et al. 2001; but see Dolbeer et al. 2000). On-colony control of gulls by shooting or other means may shift failed breeders to the site of concern thereby increasing the problem the shooting was intended to lessen (Brown et al. 2001).

Trapping and netting. Gulls have been killed after being caught with rocket or cannon nets, walk-in traps, or hand nets when spotlighted at night (Thomas 1972, Belant 1997). Cannon netting, which requires expensive equipment and experience to use, is most effective when conducted on level ground at feeding or loafing areas; at colonies, gull densities may be too low or other species may be present (Thomas 1972). Many gull species will enter a trap set over their nest and eggs. Success in capture may vary by trap type and among gull species and individuals, and, overall, trapping may be too laborious and slow. Hand-netting gulls immobilized in bright lights may be effective in capturing small numbers of gulls.

Destruction of nests and eggs. The destruction of nests or eggs has been used frequently to control gulls by reducing attendance of adults at colonies and suppressing breeding success (Thomas 1972, Belant 1997, Owen et al. 2001, Bishop et al. 2003, Calladine et al. 2006). Methods include destruction or removal of nests, eggs, and chicks; replacement of eggs with replicas; puncturing, vigorous shaking, or injecting eggs to kill the embryo; and coating (spraying or dipping) eggs with oil to suffocate the embryo; and baiting gulls with an embryonicide that causes sterility of eggs subsequently laid.

For maximum effect in destroying nests and eggs, repeat visits (e.g., every two weeks) generally are required given the normal variation in egg-laying dates and because gulls losing nests may lay replacement clutches, though less frequently late in incubation or if chicks are destroyed. Treatment of intact eggs to prevent hatching generally keeps gulls from relaying if the adults continue to incubate; they sometimes recognize punctured eggs, leading to rejection and relaying. A drawback to egg removal is that it may cause gulls to disperse to nest in more distant or inaccessible places, thereby increasing the time and difficulty of removing replacement clutches (Thomas 1972). Hypodermic injection of eggs with formalin both kills and preserves the embryo, thereby avoiding putrefaction, which otherwise can lead to the eggs bursting and thus the adults laying a replacement clutch (Thomas 1972). Baiting gulls with food impregnated with capsules of Sudan Black B dye causes formation of black-colored layers in the egg and hence sterility of the eggs and temporarily of females (Thomas 1972). In comparison with nest-and-egg removal or destruction and egg removal or destruction, one study found replacement of gull eggs with plastic eggs was the least effective technique in reducing gull numbers (Ickes et al. 1998).

At Lower Klamath NWR, California, spraying of oil on gull eggs in the 1950s, to reduce gull predation on waterfowl eggs and young, did not appear to have any effect on the populations of California and Ring-billed gulls nesting on the refuge (Jim Hainline pers. comm. in Shuford and Ryan 2000).

Overall, the effectiveness of egg destruction or removal on a local scale depends on the amount of immigration to colonies, the availability of other nesting sites, and other site-specific factors (Owen et al. 2001).

Biological control. Another method to reduce gull numbers is the introduction of mammalian predators to nesting islands. Kadlec (1971) described experimental releases of red foxes and raccoons to nesting islands of Herring Gulls (*Larus argentatus*) off Massachusetts. Annual introductions for 2–4 years effectively eliminated production of young gulls and greatly reduced colony size or, occasionally, caused colony abandonment. The regional breeding population was not reduced, but breeding adults were displaced and shifted elsewhere. The author indicated that the difficulty of maintaining the predators on the islands restricted their use in gull population management. Of greater concern is the likelihood, in many situations, that predators would destroy the nests of other species besides gulls. Domestic pigs were released on a small island in a float plane airport in Alaska to reduce numbers of Mew Gulls (*Larus canus*; Rossi et al. 1995 in Belant 1997).

At Great Salt Lake, managers often regulate water levels to limit nesting by California Gulls and encourage other nesters by flooding potential gull nesting habitat or drawing down water levels to enable land predators to reach the islands; in some cases, manager have put pigs on islands to deter gull nesting (John Neill in litt.).

Overall effectiveness of lethal control. In practice, there appears to be no method of lethal control that has proved effective in controlling gull populations over broad regions (Thomas 1972). Such large-scale efforts at reduction are daunting because they are very time consuming and expensive, require many years of effort before gull numbers noticeably decline, and they may prove unsuccessful because some gulls still fledge and the population may be greatly supplemented by immigration from another region. It is far easier to reduce the number of gulls in a colony than to eliminate them. Even so, reducing numbers in even one colony can take years of persistent effort.

The difficulty in controlling gull numbers is demonstrated by examples at various scales from a single colony to broad regions. In a study at a Long Island, New York, colony of Herring Gulls, it took about three years before intensive nest and egg destruction began to reduce numbers of nesting gulls, and at the end of seven years about 40% of the colony remained (Olijnyk and Brown 1999). Intensive culling of adult Lesser Black-backed Gulls (*Larus fuscus*) and Herring Gulls at a colony in northern England reduced gulls numbers by about 62% from 1978 to 1982, but after further reductions numbers increased back to the 1982 level despite two decades of continuous culling (Wanless and Langslow 1983, Owen et al. 2001). In the Great Lakes, annual egg removal at one site over four years reduced the number of Ring-billed Gull nests by 81%; control efforts of various sorts at a total of 13 sites eliminated local problems but did not reduce the population of adult gulls (Blokpoel and Tessier 1992).

Broad-scale efforts to control the population size of Herring Gulls in New England involved spraying (with high grade oil and formaldehyde) of about 800,000 eggs at a total of 70 islands (Kadlec and Drury 1968, Thomas 1972). During egg-spraying in Maine from 1940 to 1952, the population began to decline after a 4-to- 5-year delay, but after a sharp drop in numbers (ave. 25%–30%/yr, well in excess of adult mortality rate) in the next 5 years the population apparently stopped declining. During the 1940s, gulls spread to islands in Massachusetts, but despite spraying of eggs on several islands there and in New York from 1945 to 1952, that population continued to increase, perhaps from immigrants from Maine. Following abandonment of the egg-spraying program in 1952, the gull population in New England doubled by 1966. A large-scale effort to control Herring Gulls in Holland in the 1950s and 1960s, using various lethal and nonlethal means, had only modest success in reducing numbers (Thomas 1972). An intensive campaign, including poisoning 30,000 adults, reduced numbers from 22,000 pairs in 1954 to 15,000 in 1956, but despite ongoing killing of adults and destruction of eggs the population fluctuated (e.g., 16,000 pairs in 1966; low of 10,000 in 1959, high of 24,000 in 1964).

Harassment

A wide variety of techniques have been used to scare or displace gulls from nesting, feeding, and roosting areas. Many of the techniques now used are derived from efforts to control various species that have caused problems in agriculture, aquaculture, and aviation. The main types of harassment or frightening techniques used in gull control include playback of distress and alarm calls, pyrotechnics or other loud noises, scarecrows, avian predator effigies, flying falcons, trained dogs, tethering raptors, chemical repellants, mylar flags, and human disturbance (Thomas 1972, Belant 1997, Owen et al. 2001, Bishop et al. 2003, Calladine et al. 2006). Lacking negative reinforcement, gulls will rapidly habituate to particular scaring techniques.

Using harassment to deter gulls for conservation purposes has had limited success because gulls typically affect other species in the nesting season when the gulls are more persistent and difficult to discourage at their nesting colonies by scaring alone (Owen et al. 2001). At one site in Britain, intense human disturbance—presence of humans in colonies for virtually all daylight hours March–May over three years—totally cleared about 90% of a target area with about 15,000 large gulls (J. Coulson and M. O'Connell in Calladine et al. 2006). Potentially, harassment may indirectly lower gull numbers, and their effects on other species, if gulls can be deterred from favored feeding areas, such as landfills, and alternative food resources are insufficient to support the current gull population.

In California, harassment has been used to lower the number of gulls at landfills to reduce airstrikes at nearby airfields and to improve water quality at beaches where gulls congregate. Abatement practices at landfills in the South Bay begun recently have not yet been rigorously evaluated, though studies are underway by San Francisco Bay Bird Observatory and U.S. Geological Service for this purpose.

Anecdotal evidence, however, suggests that gull abatement appears to be effective at some landfills where a multifaceted approach has been employed. At the Potrero Hills landfill adjacent to Suisun Marsh and at the Ox Mountain landfill at Halfmoon Bay, Wingmaster Falconry Services has 2-3 people using a combination of ATVs, pyrotechnics (guns and automated), dogs, and falcons to chase gulls, starting before sunrise and continuing throughout the day. Full-scale gull abatement at the two major landfills near the major South Bay colonies of California Gulls is in its infancy and needs improvement. For at least 18 years, Tri-Cities landfill has practiced gull abatement with sporadic pyrotechnics (cannons, pistols, whistles) and falconry (Hudson and Le Fer 2008, Sherry Hudson pers. comm.). Limited gull abatement efforts began at the Newby Island landfill in January 2008, but the sporadic use of only one pyrotechnic gun by a single worker was ineffective. As of June 2008, gull abatement at Newby Island has been conducted by the company Frugal Falconer (Carly Schacter in litt.). They use a combination of techniques (pyrotechnics, dogs, falcons, paintball guns, and a shiny spinner called "the whirligig"), which they vary throughout the day depending on the behavior of the gulls.

PASSIVE TECHNIQUES FOR GULL POPULATION REDUCTION

Instead of, or in combination with, the active techniques described above, managers have used various passive methods to control gull numbers. These generally involve modifications to the environment that deny or reduce access of gulls to important resources, such as nesting space, concentrated food resources, and roosting or loafing areas.

Impediments and Exclusion

Netting and, particularly, overhead lines have been used, with varying success, to exclude gulls from foraging, nesting, and loafing sites (summaries in Pochop et al. 1990, Belant 1997, Owens et al. 2001, Calladine et al. 2006). Placement of impediments to gull nesting may be aimed at reducing gull numbers overall or freeing up nesting space for desirable species otherwise excluded by the gulls. Likewise, overheard lines have been used to reduce numbers of gulls roosting on beaches where the timing of their presence coincides with chick loss of other species.

Success of overhead lines may vary with the type of area and its attractiveness to gulls, line spacing, species of gull, season, length of gull exposure to exclosures, length of prior gull occupancy, and availability to gulls of alternative sites. Overhead lines generally have proven less effective in discouraging nesting gulls than in excluding foraging and roosting gulls at landfills (McLaren et al. 1984, Dolbeer et al. 1988), public places (Blokpoel and Tessier 1984), and reservoirs and fish ponds (McAtee and Piper 1936, Amling 1980). The height of lines above the surface appear to be of lesser importance, although gulls may land on any structures present above the lines and then walk under lines to nest sites (Calladine et al. 2006).

The effectiveness in deterring gull species at landfills varies with the spacing distance between overhead wires, season, and attractiveness of the site to gulls. At a landfill at Niagara Falls, New York, parallel wires at 12-m intervals deterred most Herring Gulls, whereas those at 6-m intervals deterred most Ring-billed Gulls; the 12-m spacing was effective in deterring the latter species when garbage was limited but not when it was abundant (McLaren et al. 1984). When gulls were most abundant at the landfill in summer, the 6-m spacing substantially reduced feeding by Ring-billed Gulls, though deterrence was less marked than at other seasons. A wire system with 12-m spacing reduced Ring-billed Gull numbers by as much as two-thirds at a landfill in South Carolina (Forsythe and Austin 1984). Dolbeer et al. (1988) reported that overhead wires at 3-m intervals at a landfill at Staten Island, New York, excluded Herring Gulls and Great Black-backed Gulls (*Larus marinus*) but not Laughing Gulls. Vermeer and Irons (1991) reported on the effective use of parallel overhead wires to reduced numbers of Glaucous-winged Gulls (*Larus glaucescens*) at a landfill on Vancouver Island, British Columbia; spacing of the wires was not described other than to indicate it was reduced, increasing its effectiveness, since the first year of installation.

Overhead lines have been used to reduce numbers of nesting gulls at colony sites. Parallel monofilament lines at a spacing of about 60 cm effectively reduced the number of nesting Ring-billed Gulls within plots at a colony on Lake Ontario, Canada; success of the treatment may have reflected the availability of unoccupied nesting habitat elsewhere in the vicinity (Blokpoel and Tessier 1983). Placement of stainless steel wires in spoke-like configurations (mean maximum spacing between wires of about 16 m) on a warehouse roof in Ohio was effective in reducing numbers of nesting Herring Gulls but less so for Ring-billed Gulls (Belant and Ickes 1996). Many Ring-billed Gulls displaced by wires on the warehouse relocated to nest on an adjacent building lacking wires. In a two-year study at Southeast Farallon Island, parallel placement of Phillystran cables with 3-m and 5-m intervals in two plots had limited effectiveness in reducing numbers of nesting Western Gulls; exclosures were less effective in excluding nesting gulls in the second year even though additional cables had been placed perpendicular at 3-m intervals and diagonally between poles in the two plots, respectively (PRBO and USFWS unpubl. data). In both years, the number of gulls in the plots tended to increase as the breeding season progressed.

Maxson et al. (1996) obtained mixed results in a test of several designs of elevated lines (spacing ranging from 0.7 m to 2 m) of nylon string, wire, or monofilament to deter nesting Ring-billed Gulls in Minnesota. Brightly colored nylon string was very effective in preventing gull nesting at small or new colonies but not at large, dense colonies with a prior history of successful breeding. Visible wires were ineffective in deterring gulls at a large colony, whereas monofilament was effective at a small colony, though slightly less so than nylon string. They also placed colored nylon string at 2-m intervals on beaches used for loafing by thousands of Ring-billed Gulls and Franklin's Gulls (*Leucophaeus pipixcan*) in a period in summer coinciding with the disappearance of many Piping Plover (*Charadrius melodus*) chicks. The string arrays on beaches were highly effective in deterring Ring-billed Gulls but only marginally effective for Franklin's Gulls.

Wire netting (5-cm mesh) and nylon netting (unreported dimensions) used to discourage nesting of Silver Gulls (*Larus novaehollandiae*) in Tasmania had mixed results (Skira and Wapstra 1990). Wire netting was effective, but two adults caught underneath it perished. Nylon netting prevented nesting for one season, but subsequently gulls nested where the net touched rocks or ground cover vegetation.

Although overhead lines can be effective, maintenance may be necessary to replace lines broken by weather, construction activities, vandalism, and, perhaps, general deterioration (Blokpoel and Tessier 1984, Belant and Ickes 1996). Because of possible entanglement of gulls, or other species meant to be protected by the lines, it is important to select a proper design (spacing, line type) and to check lines regularly for entangled birds (Blokpoel and Tessier 1983, Maxson et al. 1996). Because gulls may habituate or adapt to overhead lines (Gorenzel et al. 1994, Dolbeer et al. 1988, Maxson et al. 1996) adjustments to wire spacing or other aspects of design may be necessary. Also, effective exclusion may just shift the gulls to other nearby nesting or roosting sites (Gosler et al. 1995, Belant and Ickes 1996) and hence may not solve the overall problem. Given a lack of studies of effective means to exclude California Gulls from particular sites, experimentation will likely be needed if this method is used as a management option to exclude this species or to protect other species (e.g., Forster's Terns). That is, proper spacing must be determined that will be effective in excluding California Gulls but not other valued species.

Habitat Alteration

Alteration of nesting, foraging, or roosting habitat can reduce its attractiveness to gulls. A multifaceted approach to controlling Ring-billed and Herring gulls nesting at urban and industrial sites in Ontario incorporated, as one feature, alteration and disturbance of nesting habitat (Blokpoel and Tessier 1992). At a cement company facility, this included filling a pond, bulldozing surrounding vegetation, and developing the main colony site as a storage site for raw materials. At other sites, personnel used heavy equipment to frequently grade, disk, or drag a boom over flat areas to prevent gulls from building their nests; work always began as soon as gulls were establishing territories (i.e., well before egg laying). In Tasmania, pouring hot bitumen (asphalt) on a rocky embankment to create a smooth surface prevented nesting by Silver Gulls (Skira and Wapstra 1990). Elsewhere in Australia, removal of all vegetation and debris at another site reduced chick survival of this species (Van Tets 1977 in Skira and Wapstra 1990). Similarly, mowing grass in some experimental plots just prior to the breeding season reduced the number of adult Silver Gulls that laid eggs there early in the season; the effect was offset, however, as regrowth of the grass as the breeding season progressed was accompanied by nesting later in each breeding season (Smith and Carlile 1993).

At airports, areas of long grass attract many fewer gulls than those with short grass (Brough and Bridgman 1980, Buckley and McCarthy 1994). At Kennedy Airport in New York, Laughing Gulls forage primarily on adult beetles in short grass (despite abundant prey also in long-grass areas) and are prevalent in areas of standing water on pavement (Buckley and McCarthy 1994). Recommendations to reduce gulls included encouragement of long grass, draining standing water, and controlling beetles.

CONSTRAINTS TO EFFECTIVE GULL CONTROL

Difficulty of Gull Control

Gulls are particularly hard to control and manage. They are highly adaptable, generalist and opportunistic foragers, tolerant of human association, long lived, and reproduce at relatively high rates. Additionally, gulls tend to respond in a density-dependent manner to large-scale culling of adults, such that adult mortality can be offset to some degree (Duncan 1978, Coulson et al. 1982, Coulson 1991). A reduction of nesting densities by culling may lower the age at first breeding and increase egg size and, probably, nesting success.

As discussed above, lethal control has not proved effective in reducing gull populations in broad regions over the long term (Thomas 1972, Oro and Martínez-Abraín 2007). Such large-scale efforts typically have been abandoned because they are very time consuming and expensive as well as ethically objectionable. Reducing numbers in even one colony can take years of persistent effort, even with lethal control, which is not a viable option in San Francisco Bay (see below).

To be effective at a landscape level, gull control typically requires an integrated approach that uses a combination of techniques varying among a suite of sites. For example, methods used to control gulls varied among 13 sites in urban and industrial areas in the Canadian Great Lakes, 1987–1990 (Blokpoel and Tessier 1992). Gulls were prevented from nesting by scaring (using tethered birds of prey, moving vehicles, foot patrols firing cracker shells), physically excluding them (installation of monofilament lines), thwarting nest building by frequent disturbance of nesting substrate (grading, disking, dragging a boom), habitat modification (filling in ponds and ditches, obliterating vegetation), and, if nesting couldn't be prevented, by repeated egg removal and spraying eggs with oil. Even so, and with some lethal control, this intensive effort did not reduce the population of adult gulls, although it did eliminate local problems.

Results of these and other studies caution that efforts to control nesting California Gulls in San Francisco Bay likely will be difficult, expensive, and require long-term persistence to be effective. It also may be difficult to measure whether control efforts are having the desired effects of reducing impacts to other species.

Legal and Ethical Constraints

Before evaluating the potential of various management options for reducing the impacts of California Gulls on other nesting waterbirds in San Francisco Bay, it is important to understand the regulatory limitations and permitting that pertain to implementation of gull management in the bay. U.S. Fish and Wildlife Service regulations preclude large-scale lethal control (destruction of adult gulls, nests, egg, or chicks) as a broad-brush option for management of the impacts of California Gulls on other waterbirds (Nanette Seto and Tara Zimmerman pers. comm.). Typically, depredation permits are issued only when gulls or other "pest" species are having major negative impacts on agricultural or aquaculture operations, health and human safety, or threatened or endangered species. Very limited lethal control can be allowed under a Special Purpose Permit if this is targeted at specific gulls that are impacting threatened or endangered species and if the applicant can first demonstrate that all other nonlethal options have been exhausted. On the other hand, harassment of gulls, short of lethal take, requires no permit.

APPROACH TO REDUCING IMPACTS ON OTHER WATERBIRDS

Given the limited options for lethal gull control and the ethical constraints to employing it, controlling the number of gulls and their impacts on other species in San Francisco Bay should take a two-pronged approach. Foremost, efforts should focus on reducing the bay's carrying capacity for gulls by limiting their access to abundant food resources and reducing the size or suitability of known or potential gull nesting habitat. Concurrently, it would be valuable to increase the likelihood of successful nesting by other waterbirds by enhancing their nesting and foraging habitats in locations where they are least likely to be affected by gulls. The latter might include efforts to shift gulls to areas where their presence would be more desirable than at present nesting locations.

REDUCTION OF GULL CARRYING CAPACITY

Assuming the main limiting factors regulating the population growth of California Gulls are the availability of suitable nesting substrate and sufficient food supplies near breeding colonies, reducing the availability or suitability of these factors for gulls appears to be the most practical and ethical way to attempt to control the numbers of this species in San Francisco Bay.

Modification of Nesting Substrate

California Gulls typically nest in areas where the substrate has some roughness or rugosity in the form of rocks, irregular mounds and pockets, debris, small bushes, or the like (Winkler 1996, Shuford and Ryan 2000, D. Shuford pers. obs.). The species typically avoids, or nests in low densities, on smooth substrates. Hence, smoothing or removing the surface features found attractive is likely to reduce numbers of nesting gulls. In San Francisco Bay, many gulls currently nest on the rough surfaces of levees or insular levee fragments, formed by the drying of dredge spoils, and in areas with weeds and woody debris. To reduce the suitability of nesting substrate, it would be valuable to smooth it as much as possible by removing all vegetation and woody debris and by grading it to remove pockets, mounds, or other irregularities in the soil. Early-season use of heavy equipment to frequently grade, disk, or drag a boom over flat areas has proven effective in preventing Ring-billed Gulls from building their nests (Blokpoel and Tessier 1992) and, hence, also warrants consideration for this purpose for California Gulls.

As described above, reducing habitat suitability by placement of overhead wire arrays holds some promise for deterring California Gulls from nesting at particular sites.

In some areas of the bay, it might be valuable to entirely eliminate the nesting sites of California Gulls, which likely will occur to some degree regardless as certain salt ponds are opened to tidal action as part of the planned restoration process. Such actions should receive careful consideration, however, as the gulls will undoubtedly then breed at other sites, which potentially might just shift the problem elsewhere or even increase its intensity. Hence, serious thought should be given to an option currently under consideration to maintain some gull nesting habitat at pond A6, the site of the largest gull colony, when it is opened to tidal action in the near future. This would be accomplished by breaching the outer dike at several places, thereby creating some large insular levee fragments, and by maintaining a low internal levee.

Reduction of Food Availability

It is widely believed, worldwide, that eliminating or greatly reducing access to food sources concentrated by human activities is the action most likely to reduce gull numbers over the long term. Evidence to date indicates that California Gulls nesting at colonies in the South Bay rely heavily on garbage at bayshore dumps as a food source. Although closing the Newby Island and Tri-Cities landfills would likely have the greatest effect in reducing nesting gulls numbers in this area, it is unlikely that this would be politically feasible in the short term given the landfills have permits to operate for many years and the necessity of disposal of solid wastes somewhere in this highly urbanized area. Hence, it seems desirable to work cooperatively with landfill operators and local officials to implement or improve practices to greatly reduce availability of garbage to gulls at landfills. These should include investigation of improvement of on-site methods to limit the amount and period of exposure of organic garbage before it is covered as well as methods to directly deter gulls from exploiting this food resource. Managers should take these actions knowing that it is possible that a significant reduction in garbage available to gulls may in the short term force them to rely more on other food sources, including the eggs and young of other waterbirds that management actions are intended to protect.

Although current legal mandates are sharply reducing the amount of waste sent to landfills, this appears to have had little, if any, effect on nesting California Gulls in San Francisco Bay given their numbers have continued to increase exponentially. Specifically, the Integrated Waste Management Act of 1989 required every city and county in the state to divert from landfills at least 50% of the waste generated within their jurisdiction in 2000 (statute amended in 2000 to require sustained waste diversion efforts into the future). As of 2006, 5 of 6 cities sending waste to the Newby Island landfill have met the 50% mandate, whereas none of the three cities sending waste to the Tri-Cities landfill have done so (www.ciwmb.ca.gov/LGTools/mars/jurdrsta.asp). In the meantime, the City of San Jose is preparing a draft environmental impact report (EIR) on the Newby Island landfill's request to expand its permitted height from 150 to 245 feet (www.sanjoseca.gov/planning/eir/newby_landfill/nop120307.pdf). The EIR process may provide an opportunity to amend the landfill's permit to require intensive efforts to reduce gull use to offset impacts to other wildlife.

Efforts to greatly reduce gull use of garbage at the landfills will require a sustained multifaceted approach entailing a substantial commitment of resources and personnel at both the Newby Island and Tri-Cities landfills. Efforts currently underway at the Newby Island landfill that employ a suite of scaring tactics, as described above, would appear to be a good start. To be effective overall, it seems crucial that comparable intensive gull abatement programs be concurrently and continuously operational at both of the large South Bay landfills, and possibly also at landfills in south San Jose. Given the gulls' tendency to habituate to any harassment techniques these will need to be varied and monitored over time to ensure their effectiveness.

In addition, it would be valuable to investigate the feasibility of installing large-scale netting or an overhead wire system as a more permanent solution for deterring gulls at the landfills (see Forsythe and Austin 1984, McLaren et al. 1984, Dolbeer et al. 1988). Costs are unknown and would depend on the design, size of deterrence area, etc. Some have claimed a wire array for this purpose can be inexpensive to construct and maintain (Forsythe and Austin 1984). One system at a large landfill in New York, however, cost $2 million dollars to install in 1987 but was removed in 1988 because of problems with truck clearance after garbage was stacked higher than planned at one site (Dolbeer et al. 1988). A drawback to using overhead wires to deter gulls at a landfill on Vancouver Island, British Columbia, was the maintenance cost of $10,000 a year, as garbage trucks frequently snapped wires (Vermeer and Irons 1991).

Potential for Limited Effects or Side Effects

It is possible that intensive efforts to manage the California Gull population in San Francisco Bay may not have the desired effect or may just shift problems elsewhere. Eliminating or reducing the suitability of gull nesting habitat and restricted gull access to the concentrated food source at nearby landfills potentially might lead to unintended or undesirable side effects. As noted above, loss of nesting habitat undoubtedly will cause gulls to look elsewhere to nest. With the gull's attachment to the landfill, it seems most likely that they would select nesting sites nearby if those were available. If so, they potentially could have impacts on vulnerable waterbirds nesting in the vicinity of these new nesting sites, and it is uncertain if these would be less or more severe than prior to displacement of the gulls. Likewise, a substantial reduction in gull access to garbage at landfills likely would force them in the short term to rely more heavily on other food sources, including the eggs and young of other waterbirds.

Large reductions in gull numbers may not necessarily lead to lower predation rates on other waterbirds. For example, after a substantial reduction in gull numbers following a long period of culling on the Isle of May, Scotland, Eurasian Oystercatchers (*Haematopus ostralegus*) increased in numbers and breeding density, yet their breeding success was low, due to gull predation, both before and after gull culling (Harris and Wanless 1997). The increase in oystercatchers could not have been sustained without substantial immigration, and though culling gulls made the island more attractive to oystercatchers, breeding conditions for them did not improve markedly. Given individual gulls may be responsible for a high proportion of predation events on specific colonial waterbird colonies and with their removal other chick-specialists may increase their predation rates (Spear 1993, Guillemette and Brousseau 2001), it is not clear that an overall reduction in gull numbers will substantially reduce predation on vulnerable waterbirds if chick-specialists remain in the overall gull population.

It is unclear how predation rates on ground-nesting waterbirds may be affected by changes in numbers of either mammalian or avian predators. A study in South San Francisco Bay indicated that the predator control program in the area has had little impact on reducing certain predators and did not enhance numbers or success of ground-nesting waterbirds (Meckstroth and Miles 2005). Although predator removal programs in the South Bay have been effective in reducing numbers of the red fox, the striped skunk, comprising 84% of all predators removed, remains the commonest nest predator at study sites in the region. Long-term ($\geq$ 5 years) predator removal had mixed results on waterbird nesting success (Meckstroth and Miles 2005). Removal areas had higher nest densities but lower hatching success than at reference sites, such that both areas had similar overall production. Trip cameras documented multiple species sequentially predating eggs at a nest, with up to five different species visiting a single nest (Meckstroth and Miles 2005), so it seems likely that reduction in the numbers of a single predator, such as the California Gull, might have little effect on predation rates on waterbirds nesting in areas accessible to ground predators. The effect, however, might vary substantially between insular and non-insular sites and needs study.

It would be valuable to continue studies on the effects of predators on ground-nesting waterbirds and to update the current predator management plan for refuge lands in the South Bay (Foerster and Takekawa 1991) to address the full suite of native and non-native mammalian and avian predators. A revised plan should place particular emphasize on species of predators, such as the California Gull and Common Raven, that have greatly increased in the South Bay in recent decades.

HABITAT ENHANCEMENT FOR OTHER WATERBIRDS

Any efforts to reduce the carrying capacity of the South Bay for California Gulls should be complimented by efforts to increase the carrying capacity of this region for other waterbirds. In doing so, it would be valuable to take a baywide perspective—of the entire San Francisco Bay estuary—as many of the vulnerable species are not constrained geographically within the bay, and limitations to successful enhancement operating in the South Bay, where most gulls are concentrated, may not be factors elsewhere in the bay system. Although the restoration project may not be able to operate directly outside the South Bay, it would be valuable to work with other partners, particularly those in the San Francisco Bay Joint Venture, to promote projects in the central and northern reaches of the bay that would complement and augment the goals of South Bay restoration.

Because studies and anecdotal observations show gulls are concentrated at colonies, landfills, and flight lines between the two, it would be valuable to conduct habitat enhancement actions for other waterbirds in areas away from these centers of gull concentration. When this is not possible, it would be prudent to attempt to enhance islands or other features in ways that favor other species and disfavor gulls. The level and type of enhancements needed generally will vary among species as described below.

Snowy Plover

Although plovers in the salt pond system of the South Bay have bred on levees around full evaporators and on levees and flats in partly dry evaporators, they currently are heavily concentrated in the Eden Landing/Baumberg area south of the east side of the

San Mateo Bridge. As an overall management strategy, it would be prudent to create or enhance habitat elsewhere so that the population is more widely spaced around the bay and, hence, less vulnerable. Given current priorities for restoration, it would be valuable to create additional plover habitat in the Ravenswood complex of ponds on the west side of the Dumbarton Bridge, where plovers have nested in higher numbers in the past. It would also be valuable to consider managing a suite of sites so that they all vary in their suitability for plovers from year to year. If plovers are concentrated at the same sites year after year predators may focus their attentions on these areas once they learn they are reliable sites to find plover nests and chicks. Regardless, ongoing predator management will likely be needed to maintain a sustainable population of plovers in the bay.

Scattering of oyster shells or other small debris on dry evaporator bottoms might benefit plovers. They often nest near surface irregularities, such that enough topographic relief or disruptive coloration (sand-pebble substrate) may provide some concealment of the eggs and in many cases the incubating bird (Henderson and Page 1981).

Black-necked Stilt and American Avocet

To reduce overall predation on these two species of shorebirds, it would be valuable to greatly increase island nesting habitat for them so they would much less reliant on nesting on levees or in marshes where, in addition to California Gulls, they are vulnerable to a suite of mammalian predators. If at all possible, it would be prudent to locate new nesting islands in ponds that are distant from large gull colonies, landfills, and flight lines between the two. Islands for these shorebirds should be designed with gradually sloping sides (Engilis and Reid 1997) and should lack or minimize features favored by California Gulls, particularly rough substrate. Although not aesthetically pleasing, an electric perimeter fence around a constructed wetland in the southern San Joaquin Valley reduced predation to <1% (Davis et al. 2008). Such fences may not be necessary, however, if shorebird nesting islands are isolated by stretches of water not easily crossed by large mammalian predators. Although fences or isolated islands will not deter aerial predators, reduction or elimination of mammalian predation may keep overall predation levels at a tolerable level.

Caspian Tern

Given the commitment of the U. S. Army Corps of Engineers and the U.S. Fish and Wildlife Service to create or enhance nesting habitat for Caspian Terns in San Francisco Bay (USFWS 2005, 2006), concerns for this species for the bay as a whole may be addressed adequately by these agencies without direct involvement of the South Bay Salt Pond Restoration Project. Still, it would be valuable for the restoration project to serve in an advisory role to ensure that management for Caspian Terns has the greatest chance for success. If any projects for these terns are contemplated for the South Bay, they should be designed with habitat preferences of the species in mind. For example, of experimental nest substrates in Ontario, terns preferred sand over pea-gravel and crushed stone and all of these over pre-existing hard packed ground (Quinn and Sirdevan 1998). Given California Gulls typically like rougher substrates, sand or gravel substrates on islands might ensure colonization solely by the terns.

Forster's Tern

In the South Bay, Forster's Terns nest on dredge spoil islands and levees. They prefer to nest in areas with low vegetation, particularly alkali heath (*Frankenia grandifolia*), and near moderately steep substrate (Dakin 2000). The latter may provide cover to the nest or restrict its visibility from above and give protection from wave-whipped, wind-blown froth. It would be valuable to create new nesting islands with such characteristics. Knowing that the species can nest in marsh vegetation, it would be valuable to experiment with nesting islands within restored tidal marsh if these can be built and maintained easily in this situation (Cheryl Strong pers. comm.). The installation of nest shelters at nesting colonies should be investigated, as these have been used successfully to reduce gull predation on Common Tern (*Sterna hirundo*) chicks (Burness and Morris 1992). If other options fail, managers should investigate the use of nesting rafts, which have been used to establish new nesting sites for Common Terns (Dunlop et al. 1991, Jarvie and Blokpoel 1996). Such rafts can be built or outfitted to contain suitable nesting substrate for terns, underwater habitat for fish, and decoys and recordings to attract nesting terns; they can be anchored in suitable locations and moved if necessary.

Knowing that Forster's Tern colonies are more persistent at unstable locations than at more stable sites (Strong et al. 2004), it would be prudent to vary water levels at ponds with suitable nesting habitat. Whenever possible, it would be desirable to construct new tern nesting islands in areas that are not on a direct path between gull colonies and landfills (Kakouros 2006). Because tern nests and chicks are most vulnerable when left unattended by adults, it is important to restrict prolonged human access to tern colonies; when such visits are necessary, measures should be taken to protect tern nests and young from attacking gulls.

California Least Tern

Reflecting this tern's status as state and federally endangered, all the key colonies in San Francisco Bay are currently heavily managed, and lethal control of California Gulls can be, and has been, used to protect these populations. With the California Gull population being concentrated in the South Bay, any additional habitat for Least Tern's should be created in the central or northern reaches of the bay. Given the ongoing intensive management of Least Tern colonies in the bay, there probably is little that the South Bay Salt Pond Restoration Project can do for these terns other than to work toward its overall goal of reducing numbers of nesting California Gulls in the region.

ATTRACTION AND ACCOMMODATION OF GULLS IN DESIRABLE LOCATIONS

To lessen impacts on other species, it might be valuable to eliminate some gull habitat and attract the displaced gulls to other areas where there would be fewer conflicts. There is very little information on this specific topic, as the voluminous literature on gull control focuses primarily on reducing gulls numbers or removing them from areas where they are undesirable. At Mono Lake, California, gulls returned to nest on a former nesting island after rising water levels restored the site to insular status and gull decoys were placed on the island (Shuford and Page 1985). The effectiveness of the decoys in attracting the gulls to the island was unclear, however, as the decoy plots were not monitored during nest establishment, and though some gulls nested near the decoys others nested far away. Decoys and taped playback of vocalizations have been widely used to attract breeding terns to reestablish colonies (e.g., Kress 1983), so it seems likely that similar methods could be used to attract gulls to nest in particular areas if other habitat conditions were suitable.

OVERALL RECOMMENDATIONS

Because of the difficulties, complexities, and uncertainties surrounding gull control, an overarching recommendation is to form a working group to develop a list of specific goals and actions, a timetable and cost estimate for their implementation, and a strategy to monitor the results of these actions on gulls and other waterbirds that allows for changes to management actions as new information becomes available. The goals and actions should be tiered to the first phase of restoration plans. On the basis of other information presented above, and knowing lethal control is not a possible broad-scale option, management efforts should focus on (1) reducing the suitability of gull habitat by altering its structure or eliminating it entirely where appropriate, (2) developing a multifaceted and coordinated program to restrict access of gulls to garbage at both the Newby Island and Tri-Cities landfills, (3) producing a comprehensive strategy for enhancing habitat for all vulnerable species of waterbirds, (4) developing an overall predator management plan to address the full suite of avian and mammalian predators that prey on waterbird nests and young, and (5) devising a monitoring plan to assess the effectiveness of both salt pond restoration and gull control actions. In concert with these management goals, it would be valuable to develop a prioritized list of research objectives that will enable managers to assess the outcome and success of their actions and to obtain new information about gulls or other species needed to refine management actions. Likewise, it may be necessary to also form an outreach and education strategy to enlist partners and engage stakeholders knowing that gull control will require cooperative actions and may prove controversial to some.

LITERATURE CITED

Ackerman, J. T., J. Y. Takekawa, C. Strong, N. Athearn, and A. Rex. 2006. California Gull distribution, abundance, and predation on waterbird eggs and chicks in south San Francisco Bay. Final report of U.S. Geological Survey, Western Ecological Research Center, Davis and Vallejo, CA.

Albertson, J. D., and J. G. Evens. 2000. California Clapper Rail (*Rallus longirostris obsoletus*), in Goals Project. Baylands ecosystem species and community profiles: Life histories and environmental requirements of key plants, fish, and wildlife (P. R. Olofson, ed.), pp. 332–340. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Amling, W. 1980. Exclusion of gulls from reservoirs in Orange County, California, in Proceedings of the 9th Vertebrate Pest Conference (J. P. Clark and R. E. Marsh, eds.), pp. 29–30. University of California, Davis.

Anderson, W. 1965. Waterfowl production in the vicinity of gull colonies. California Fish and Game 51:5–15.

Belant, J. L. 1997. Gulls in urban environments: Landscape-level management to reduce conflict. Landscape and Urban Planning 38:245–258.

Belant, J. L., and S. K. Ickes. 1996. Overhead wires reduce roof-nesting by Ring-billed Gulls and Herring Gulls, in Proceedings of the 17th Vertebrate Pest Conference (R. M. Timm and A. C. Crabb, eds.), pp. 108–112. University of California, Davis.

Bishop, J., H. McKay, D. Parrott, and J. Allan. 2003. Review of international research literature regarding the effectiveness of auditory bird scaring techniques and potential alternatives. Report of Central Sciences Laboratories to the Department for Environment, Food and Rural Affairs, London. Available from Defra Publications, Admail 6000, London, SW1A 2XX or at www.defra.gov.uk/ENVIRONMENT/noise/research/birdscaring/index.htm.

Blodget, B. G., and L. Henze. 1992. Use of DRC-1339 to eliminate gulls and re-establish a tern nesting colony in Buzzards Bay, Massachusetts, in Proceedings 5th Eastern Wildlife Damage Control Conference (P. D. Curtis, M. J. Fargione, and J. E. Caslick, eds.), pp. 211–215. Available at http://digitalcommons.unl.edu/ewdcc5/.

Blokpoel, H., and W. C. Scharf. 1991. The Ring-billed Gull in the Great Lakes of North America, in Proceedings of the 20th International Ornithological Congress, vol. 4 (B. D. Bell, R. O. Cossee, J. E. C. Flux, B. D. Heather, R. A. Hitchmough, C. J. R. Robertson, and M. J. Williams, eds.), pp. 2372–2377. New Zealand Ornithological Trust Board, Wellington.

Blokpoel, H., and J. Struger. 1988. Cherry depredation by Ring-billed Gulls, *Larus delawarensis*, in the Niagara Peninsula, Ontario. Canadian Field-Naturalist 102:430–433.

Blokpoel, H., and G. D. Tessier. 1983. Monofilament lines exclude Ring-billed Gulls from traditional nesting areas. Proceedings 9th Bird Control Seminar (W. B. Jackson and B. J. Dood, eds.), pp. 15–20.

Blokpoel, H., and G. D. Tessier. 1984. Overhead wires and monofilament lines exclude Ring-billed Gulls from public places. Wildlife Society Bulletin 12:55–58.

Blokpoel, H., and G. D. Tessier. 1986. The Ring-billed Gull in Ontario: A review of a new problem species. Canadian Wildlife Service Occasional Paper no. 57.

Blokpoel, H., and G. D. Tessier. 1987. Control of Ring-billed Gull colonies at urban and industrial sites in southern Ontario, Canada. Proceedings of the Third Eastern Wildlife Damage Control Conference (N. R. Holler and J. B. Christian, eds.), pp. 8–17. Available at http://digitalcommons.unl.edu/ewdcc3/.

Blokpoel, H., and G. D. Tessier. 1992. Control of Ring-billed Gulls and Herring Gulls nesting at urban and industrial sites in Ontario, 1987–1990, in Proceedings 5th Eastern Wildlife Damage Control Conference (P. D. Curtis, M. J. Fargione, and J. E. Caslick, eds.), pp. 51–57. Available at http://digitalcommons.unl.edu/ewdcc5/.

Bousman, W. G. 2007. Breeding avifaunal changes in the San Francisco Bay area 1927–2005. Western Birds 38:102–136.

Brough, T., and C. J. Bridgman. 1980. An evaluation of long grass as a bird deterrent on British airfields. Journal of Applied Ecology 17:243–253.

Brown, K. M., R. M. Erwin, M. E. Richmond, P. A. Buckley, J. T. Tanacredi, and D. Avrin. 2001. Managing birds and controlling aircraft in the Kennedy Airport–Jamaica Bay Wildlife Refuge Complex: The need for hard data and soft opinions. Environmental Management 28:207–224.

Buckley, P. A., and M. G. McCarthy. 1994. Insects, vegetation, and the control of Laughing Gulls (*Larus atricilla*) at Kennedy International Airport, New York City. Journal of Applied Ecology 31:291–302.

Burness, G. P., and R. D. Morris. 1992. Shelters decrease gull predation on chicks at a Common Tern colony. Journal of Field Ornithology 63:186–189.

Butterfield, J., J. C. Coulson, S. V. Kearsey, P. Monaghan, J. H. McCoy, and G. E. Spain. 1983. The Herring Gull *Larus argentatus* as a carrier of *Salmonella*. Journal of Hygiene 91:429–436.

Bystrak, D. 1981. The North American Breeding Bird Survey. Studies in Avian Biology 6:34–41.

California Integrated Waste Management Board (CIWMB). 2008. Solid Waste Information System (SWIS) Database (www.ciwmb.ca.gov/SWIS/default.htm).

Calladine, J. R., K. J. Park, K. Thompson, and C. V. Wernham. 2006. Review of urban gulls and their management in Scotland. A report to the Scottish Executive, St. Andrew's House, Edinburgh EH1 3DG, Scotland. Available at http://www.scotland.gov.uk/Publications/2006/05/18113519/0.

Chelton, D. B., P. A. Bernal, and J. A. McGowan. 1982. Large-scale interannual physical and biological interaction in the California Current. Journal of Marine Research 40:1095–1125.

Conover, M. R. 1983. Recent changes in the Ring-billed and California gull populations in the western United States. Wilson Bulletin 95:362–383.

Coulson, J. C. 1991. The population dynamics of culling Herring Gulls and Lesser Black-backed Gulls, in Bird Population Studies: Relevance to Conservation and Management (C. M. Perrins, J.-D. Lebreton, and G. J. M. Hirons, eds.), pp. 479–497. Oxford University Press, Oxford.

Coulson, J. C., J. Butterfield, and C. S. Thomas. 1983. The Herring Gull *Larus argentatus* as a likely transmitting agent of *Salmonella montevideo* to sheep and cattle. Journal of Hygiene 91:437–443.

Coulson J. C., N. Duncan, and C. Thomas. 1982. Changes in the breeding biology of the Herring Gull (*Larus argentatus*) induced by reduction in the size and density of the colony. Journal of Animal Ecology 51:739–756.

Dakin, R. E. 2000. Nest site selection by Forster's Terns (*Sterna forsteri*). M.A. thesis, San Jose State University, San Jose, CA.

Davis, D. E., C. H. Hanson, and R. B. Hansen. 2008. Constructed wetland habitat for American Avocet and Black-necked Stilt foraging and nesting. Journal of Wildlife Management 72:143–151.

Dierks, A. J. 1990. Parental care and diet of California Gull (*Larus californicus*) chicks at Alviso, California. M.S. thesis, Moss Landing Marine Labs, San Jose State University, San Jose, CA.

Dolbeer, R. A., S. C. Barras, and R. B. Chipman. 2000. Integrated management program to reduce bird strikes with aircraft at John F. Kennedy International Airport, 1991-

2000. Abstract only, available at www.icao.int/icao/en/ro/nacc/acilac/12_dolbeer_usda_jfk_management.pdf.

Dolbeer, R. A., J. L. Belant, and J. L. Sillings. 1993. Shooting gulls reduces strikes with aircraft at John F. Kennedy International Airport. Wildlife Society Bulletin 21:442–450.

Dolbeer, R. A., P. P. Woronecki, E. C. Cleary, and E. B. Butler. 1988. Site evaluation of gull exclusion device at Fresh Kill Landfill, Staten Island, New York. Bird Damage Research Report no. 411. Denver Wildlife Research Center, Ohio Field Station, Animal and Plant Health Inspection Service, U. S. Department of Agriculture, Sandusky, Ohio.

Dolbeer, R. A., S. E. Wright, and E. C. Cleary. 2000. Ranking the hazard level of wildlife species to aviation. Wildlife Society Bulletin 28:372–378.

Drury, W. H. 1973. Population changes in New England seabirds. Bird-Banding. 44:267–313.

Drury, W. H. 1974. Population changes in New England seabirds. Bird-Banding 45:1–15.

Drury, W. H., and J. A. Kadlec. 1974. The current status of the Herring Gull population in the United States. Bird-Banding 45:297–306.

Duncan, N. 1978. The effects of culling Herring Gulls (*Larus argentatus*) on recruitment and population dynamics. Journal of Applied Ecology 15:697–713.

Dunlop, C. L., H. Blokpoel, and S. Jarvie. 1991. Nesting rafts as a management tool for a declining Common Tern (*Sterna hirundo*) colony. Colonial Waterbirds 14:116-120.

Engilis, A., Jr., and F. A. Reid. 1997. Challenges in wetland restoration of the western Great Basin. International Wader Studies 9:71–79.

Ferns, P. N., and G. P. Mudge. 2000. Abundance, diet and Salmonella contamination of gulls feeding at sewage outfalls. Water Research 34:2653–2660.

Foerster, K. S., and J. E. Takekawa, 1991. San Francisco Bay National Wildlife Refuge predator management plan and final environmental assessment. U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge, P.O. Box 524, Newark, CA 94560.

Forsythe, D. M., and T.W. Austin. 1984. Effectiveness of an overhead wire barrier system in reducing gull use at the BFI Jedburg Sanitary Landfill, Berkeley and Dorchester counties South Carolina, in Proceedings Wildlife Hazards to Aircraft Conference and Training Workshop (M. J. Harrison, S. A. Gauthreaux Jr., and L. A. Abron-Robinson, eds.), pp. 253–263. U. S. Department of Transportation, Federal

Aviation Administration, Office of Airport Standards, Washington, DC. Available from the National Technical Information Service, Springfield, VA 22161.

Gill, R. E., and L. R. Mewaldt. 1983. Pacific Coast Caspian Terns: Dynamics of an expanding population. Auk 100:369–381.

Gorenzel, W. P., F. S. Conte, and T. P. Salmon. 1994. Bird damage at aquaculture facilities, in Prevention and Control of Wildlife Damage (S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds.), pp. 5–18. University of Nebraska, Lincoln.

Gosler, A. G., R. E. Kenward, and N. Horton. 1995. The effect of gull roost deterrence on roost occupancy, daily gull movements, and wintering wildfowl. Bird Study 42:144–157.

Grinnell, J., H. C. Bryant, and T. I. Storer. 1918. The game birds of California. University of California Press, Berkeley.

Grinnell, J., and A. H. Miller. 1944. The distribution of the birds of California. Pacific Coast Avifauna 27.

Guillemette, M., and P. Brousseau. 2001. Does culling predatory gulls enhance the productivity of breeding Common Terns? Journal of Applied Ecology 38:1–8.

Harding, E. K. 2000. Non-native predator: Red fox (*Vulpes vulpes regalis*), in Goals Project. Baylands ecosystem species and community profiles: Life histories and environmental requirements of key plants, fish, and wildlife (P. R. Olofson, ed.), pp. 251–252. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Harris, M. P., and S. Wanless. 1997. The effect of removing large numbers of gulls *Larus* spp. on an island population of oystercatchers *Haematopus ostralegus*: Implications for management. Biological Conservation 82:167–171.

Henderson, R. P., and G. W. Page. 1981. III: San Francisco Bay and the interior, in The breeding status of the Snowy Plover in California (G. W. Page and L. E. Stenzel, eds.), pp. 16–23. Western Birds 12:1–40.

Hite, J. M., P. H. Wrege, and D. W. Winkler. 2004. Seasonal and diurnal variation in the diets of California Gull nestlings at Mono Lake, California from 2000 to 2002. Unpublished report, Contribution No. 1018 of PRBO Conservation Science. Available from PRBO Conservation Science, 3820 Cypress Drive, # 11, Petaluma, CA 94954.

H. T. Harvey & Associates. 2005. South Bay Salt Pond Restoration Project. Biology and habitats existing conditions report. Submitted to California State Coastal Conservancy, U.S. Fish and Wildlife Service, and California Department of Fish and Game. Available at www.southbayrestoration.org/pdf_files/Biology_Habitats_Existing_Conditions.3.25.05.pdf

Horton N., T. Brough, and J. Rochard. 1983. The importance of refuse tips to gulls wintering in an inland area of southeast England. Journal of Applied Ecology 20:751–765.

Hudson, S., and D. Le Fer. 2008. California Gull surveys at landfills in the south San Francisco Bay, February – August 2007. Unpublished report from San Francisco Bay Bird Observatory, 524 Valley Way, Milpitas, CA 95035.

Ickes, S. K., J. L. Belant, and R. A. Dolbeer. 1998. Nest disturbance techniques to control nesting by gulls. Wildlife Society Bulletin 26:269–273.

Jarvie, S., and H. Blokpoel. 1996. Reefrafts for Common Terns and fish: guidelines for design, construction and operation. Published by authority of the Minister of Environment, © Minister of Public Works and Government Services Canada. ISBN: 0-662-24375-7.

Jehl, J. R., Jr. 1987. Geographic variation and evolution in the California Gull (*Larus californicus*). Auk 104:421–428.

Jones, P. A. 1986. Aspects of the reproductive biology of the California Gull in Alviso, California. M.A. thesis, San Francisco State University, San Francisco.

Kadlec, J. A. 1971. Effects of introducing foxes and raccoons on Herring Gull colonies. Journal of Wildlife Management 35:625–636.

Kadlec, J. A., and W. H. Drury. 1968. Structure of the New England Herring Gull population. Ecology 49:644–676.

Kakouros, A. O. 2006. Effects of California Gulls on nesting Forster's Tern behavior. Unpublished M.S. thesis, Department of Environmental Studies, San Jose State University, San Jose, CA.

Kress, S. W. 1983. The use of decoys, sound recordings, and gull control for re-establishing a tern colony in Maine. Colonial Waterbirds 6:185–196.

Marschalek, D. A. 2008. California Least Tern breeding survey, 2007 season. Nongame Wildlife Program Report 2008-01, Wildlife Branch, California Department of Fish and Game, Sacramento.

Maxson, S. J., S. A. Mortensen, D. L. Goodermote, and C. S. Lapp. 1996. Success and failure of Ring-billed Gull deterrents at Common Tern and Piping Plover colonies in Minnesota. Colonial Waterbirds 19:242–247.

McAtee, W. L., and S. E. Piper. 1936. Excluding birds from reservoirs and fishponds. Leaflet no. 120. U. S. Department of Agriculture, Washington, DC.

McLaren, M. A., R. E. Harris, and W. J. Richardson. 1984. Effectiveness of an overhead wire barrier in deterring gulls from feeding at a sanitary landfill, in Proceedings Wildlife Hazards to Aircraft Conference and Training Workshop (M. J. Harrison, S. A. Gauthreaux Jr., and L. A. Abron-Robinson, eds.), pp. 241–251. U. S. Department of Transportation, Federal Aviation Administration, Office of Airport Standards, Washington, DC. Available from the National Technical Information Service, Springfield, VA 22161.

McNicholl, M. K., P. E. Lowther, and J. A. Hall. 2001. Forster's Tern (*Sterna forsteri*), in the Birds of North America (A. Poole and F. Gill, eds.), no. 595. Birds North America, Philadelphia.

Meckstroth, A. M., and A. K. Miles. 2005. Predator removal and nesting waterbird success at San Francisco Bay, California. Waterbirds 28:250–255.

Molina, K. C. 2000. The recent nesting of California and Laughing gulls at the Salton Sea, California. Western Birds 31:106–111.

Molina, K. C. 2004. Breeding larids of the Salton Sea: Trends in population size and colony site occupation. Studies in Avian Biology 27:92–99.

Monaghan, P., C. B. Shedden, K. Ensor, C. R. Fricker, and R. W. A. Girdwood. 1985. Salmonella carriage by herring gulls in the Clyde area of Scotland in relation to their feeding condition. Journal of Applied Ecology 22:669–680.

Neuman, K. K., G. W. Page, L. E. Stenzel, J. C. Warriner, and J. S. Warriner. 2004. Effect of mammalian predator management on Snowy Plover breeding success. Waterbirds 27:257–263.

Olijnyk, C. G., and K. M. Brown. 1999. Results of a seven-year effort to reduce nesting by Herring and Great Black-backed gulls. Waterbirds 22:285–289.

Oro, D., and A. Martínez-Abraín. 2007. Deconstructing myths on large gulls and their impact on threatened sympatric waterbirds. Animal Conservation 10:117–126.

Owen, M., J. Kirby, and J. Holmes. 2001. Review of the effectiveness of gull-culling for nature conservation purposes. English Nature Report no. 438. Available from Natural England Publications, Communisis Print Management, Balliol Business Park West, Benton Lane, Newcastle upon Tyne, NE12 8EW, United Kingdom or natural.england@communisis.com.

Page, G. W., and L. E. Stenzel, eds. 1981. The breeding status of the Snowy Plover in California. Western Birds 12:1–40.

Page, G. W., L. E. Stenzel, W. D. Shuford, and C. R. Bruce. 1991. Distribution and abundance of the Snowy Plover on its western North American breeding grounds. Journal of Field Ornithology 62:245–255.

Page, G. W., L. E. Stenzel, D. W. Winkler, and C. W. Swarth. 1983. Spacing out at Mono Lake: Breeding success, nest density and predation in the Snowy Plover. Auk 100:13–24.

Page, G. W., J. S. Warriner, J. C. Warriner, and P. W. C. Patton. 1995. Snowy Plover (*Charadrius alexandrinus*), in The Birds of North America (A. Poole and F. Gill, eds.), no. 154. Academy of Natural Sciences, Philadelphia.

Paul, D. S., J. R. Jehl Jr., and P. K. Yochem. 1990. California Gull populations nesting at Great Salt Lake, Utah. Great Basin Naturalist 50:299–302.

Pochop, P. A., R. J. Johnson, D. A. Aguero, and K. M. Eskridge. 1990. The status of lines in bird damage control – a review, in Proceedings of the 14th Vertebrate Pest Conference (L. R. Davis and R. E. Marsh, eds.), pp. 317–324. University of California, Davis.

Quinn, J. S., and J. Sirdevan. 1998. Experimental measurement of nesting substrate preference in Caspian Terns, *Sterna caspia,* and the successful colonisation of human constructed islands. Biological Conservation 85:63–68.

Riensche, D. L. 2007. California Least Tern habitat enhancement and nesting in the East Bay Regional Park District, California. Transactions of the Western Section of the Wildlife Society 43:62–71.

Rintoul, C., N. Warnock, G. W. Page, and J. T. Hanson. 2003. Breeding status and habitat use of Black-necked Stilts and American Avocets in South San Francisco Bay. Western Birds 34:2–14.

Robbins, C. S., D. Bystrak, and P. H. Geissler. 1986. The Breeding Bird Survey: Its first fifteen years, 1965–1979. Resource Publication 157, U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Robinson, C., D. Le Fer, J. Albertson, and C. Strong. 2007. Western Snowy Plover numbers, nesting success, and avian predator surveys in the San Francisco Bay, 2007. Unpublished report of San Francisco Bay Bird Observatory, Milpitas, CA, and Don Edwards San Francisco Bay National Wildlife Refuge, Newark, CA.

Robinson, C., C. Strong, L. Tucci, and J. Albertson. 2006. Western Snowy Plover numbers, nesting success, and avian predator surveys in the San Francisco Bay,

2006. Unpublished report of San Francisco Bay Bird Observatory, Alviso, CA, and Don Edwards San Francisco Bay National Wildlife Refuge, Newark, CA.

Robinson, J. A., L. W. Oring, J. P. Skorupa, and R. Boettcher. 1997. American Avocet (*Recurvirostra americana*), in The Birds of North America (A. Poole and F. Gill, eds.), no. 275. Academy of Natural Sciences, Philadelphia.

Robinson, J. A., J. M. Reed, J. P. Skorupa, and L. W. Oring. 1999. Black-necked Stilt (*Himantopus mexicanus*), in The Birds of North America (A. Poole and F. Gill, eds.), no. 449. Birds of North America, Philadelphia.

Ryan, T. P. 2000a. Caspian Tern (*Sterna caspia*), in Goals Project. Baylands ecosystem species and community profiles: Life histories and environmental requirements of key plants, fish, and wildlife (P. R. Olofson, ed.), pp. 355–359. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Ryan, T. P. 2000b. Forster's Tern (*Sterna forsteri*), in Goals Project. Baylands ecosystem species and community profiles: Life histories and environmental requirements of key plants, fish, and wildlife (P. R. Olofson, ed.), pp. 351–355. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, results and analysis 1966–2007, version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD. Available at www.mbr-pwrc.usgs.gov/bbs/.

Seamans, T. W., and J. L. Belant. 1999. Comparison of DRC-1339 and alpha-chloralose to reduce Herring Gull populations. Wildlife Society Bulletin 27:729–733.

Shellhammer, H. S. 2000. Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*), in Goals Project. Baylands ecosystem species and community profiles: Life histories and environmental requirements of key plants, fish, and wildlife (P. R. Olofson, ed.), pp. 219–228. Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Shuford, W. D., and D. P. Craig. 2002. Status assessment and conservation recommendations for the Caspian Tern *(Sterna caspia)* in North America. U.S. Department of the Interior, Fish and Wildlife Service, Portland, OR.

Shuford, W. D., and G. W. Page. 1985. California Gull decoy placement on Negit Island, Mono Lake, California. Contribution No. 317 of Point Reyes Bird Observatory. Available from PRBO Conservation Science, 3820 Cypress Drive, # 11, Petaluma, CA 94954.

Shuford, W. D., G. W. Page, J. G. Evens, and L. E. Stenzel. 1989. Seasonal abundance of waterbirds at Point Reyes: A coastal California perspective. Western Birds 20:137–265.

Shuford, W. D., and T. P. Ryan. 2000. Nesting populations of California and Ring-billed gulls in California: Recent surveys and historical status. Western Birds 31:133–164.

Shuford, W. D., D. L. Thompson, D. M. Mauser, and J. Beckstrand. 2006. Abundance and distribution of nongame waterbirds in the Klamath Basin of Oregon and California from comprehensive surveys in 2003 to 2004. Final Report to U.S. Fish and Wildlife Service, Klamath Basin NWR Complex, 4009 Hill Rd., Tulelake, CA 96134. Contribution 1284 of PRBO Conservation Science, 3820 Cypress Dr., #11, Petaluma, CA 94954.

Sibley, C. G. 1952. The birds of the south San Francisco Bay region. Mimeo by the author, available at PRBO Conservation Science, 3820 Cypress Dr., #11, Petaluma, CA 94954.

Sibley, C. G. 1953. Forsters Terns breeding on San Francisco Bay, California. Condor 55:278–279.

Skira, I. J., and J. E. Wapstra. 1990. Control of Silver Gulls in Tasmania. Corella 14:124–129.

Smith, G. C., and N. Carlile. 1993. Methods for population control within a Silver Gull colony. Wildlife Research 20:219–226.

Sodhi, N. S. 2002. Competition in the air: Birds versus aircraft. Auk 119:587–595.

Southern, W. E. 1986. Histoplasmosis associated with a gull colony: Health concerns and precautions. Colonial Waterbirds 9:121–123.

Spaans, A. L., J. C. Coulson, P. Migot, P. Monaghan, J. Prüter, and G. Vauk. 1991. The Herring Gull in north-west Europe, in Proceedings of the 20th International Ornithological Congress, vol. 4 (B. D. Bell, R. O. Cossee, J. E. C. Flux, B. D. Heather, R. A. Hitchmough, C. J. R. Robertson, and M. J. Williams, eds.), pp. 2365–2371. New Zealand Ornithological Trust Board, Wellington.

Spear, L. B. 1993. Dynamics and effect of Western Gulls feeding in a colony of guillemots and Brandt's Cormorants. Journal of Animal Ecology 62:399–414.

Strong, C. M., L. B. Spear, T. P. Ryan, and R. E. Dakin. 2004. Forster's Tern, Caspian Tern, and California Gull colonies in San Francisco Bay: Habitat use, numbers and trends, 1982–2003. Waterbirds 27:411–423.

Suryan, R. M., D. P. Craig, D. D. Roby, N. D., Chelgren, K. Collis, W. D. Shuford, and D. E. Lyons. 2004. Redistribution and growth of the Caspian Tern population in the Pacific Coast region of North America, 1981–2000. Condor 106:777–790.

Thomas, G. J. 1972. A review of gull damage and management methods at nature reserves. Biological Conservation 4:117–127.

Tucci, L., C. Strong, and J. Albertson. 2006. Western Snowy Plover population, nesting success, and predator surveys in the San Francisco Bay – 2005 breeding season. Unpublished report of San Francisco Bay Bird Observatory, Alviso, CA, and Don Edwards San Francisco Bay National Wildlife Refuge, Newark, CA.

U.S. Fish and Wildlife Service (USFWS). 2005. Caspian Tern management to reduce predation of juvenile salmonids in the Columbia River estuary: Final Environmental Impact Statement. U.S. Fish and Wildlife Service, Migratory Birds and Habitat Programs, 911 NE 11th Ave., Portland, OR 97232 (http://migratorybirds.pacific.fws.gov/CATE_FEIS_document_pdf_files.htm).

U.S. Fish and Wildlife Service (USFWS). 2006. Record of Decision. Caspian Tern management in the Columbia River estuary: Final Environmental Impact Statement. U.S. Fish and Wildlife Service, Migratory Birds and Habitat Programs, 911 NE 11th Ave., Portland, OR 97232 (www.fws.gov/pacific/migratorybirds/Record%20of%20Decision%20Caspian%20EIS%20.pdf)

Vermeer, K., and D. B. Irons. 1991. The Glaucous-winged Gull on the Pacific coast of North America, in Proceedings of the 20th International Ornithological Congress, vol. 4 (B. D. Bell, R. O. Cossee, J. E. C. Flux, B. D. Heather, R. A. Hitchmough, C. J. R. Robertson, and M. J. Williams, eds.), pp. 2378–2383. New Zealand Ornithological Trust Board, Wellington.

Wanless, S., and D. R. Langslow. 1983. The effects of culling on the Abbeystead and Mallowdale gullery. Bird Study 30:17–23.

Winkler, D. W. 1996. California Gull *(Larus californicus),* in The Birds of North America (A. Poole and F. Gill, eds.), no. 259. Academy of Natural Sciences, Philadelphia.

Wires, L. R., and F. J. Cuthbert. 2000. Trends in Caspian Tern numbers and distribution in North America: A review. Waterbirds 23:388-404.

Wrege, P. H., W. D. Shuford, D. W. Winkler, and R. Jellison. 2006. Annual variation in numbers of breeding California Gulls at Mono Lake, California: The importance of natal philopatry and local and regional conditions. Condor 108:82–96.