California Gull population growth and ecological impacts in the San Francisco Bay estuary, 1980–2016

Catherine E. Burns[1,5], Joshua T. Ackerman[2], Natalie B. Washburn[1,6,*], Jill Bluso-Demers[3], Caitlin Robinson-Nilsen[1], and Cheryl Strong[4]

***Abstract*:** The breeding population of California Gulls (*Larus californicus*) in the San Francisco Bay estuary increased from 24 individuals in 1980 to a peak of over 53,000 in 2014, then declined to 38,040 in 2016. The expansion of the breeding population may be related to the availability of suitable nesting sites in close proximity to anthropogenic food subsidies at landfills. Telemetry data indicate that California Gull movements are largely dictated by the two primary landfills in South San Francisco Bay. The large population of California Gulls has had negative effects on locally breeding shorebirds and terns, especially the Forster's Tern (*Sterna forsteri*), American Avocet (*Recurvirostra americana*), and Western Snowy Plover (*Charadrius nivosus nivosus*). In South San Francisco Bay, California Gulls were responsible for 13% and 38% of egg predation events at nests of American Avocets and Snowy Plovers, respectively, and 55% and 54% of chick predation events of American Avocets and Forster's Terns, respectively. The forced relocation of the largest gull colony (~24,000) at Pond A6 in 2010 resulted in increased survival of Forster's Tern chicks at the adjacent colony at Pond A7 in 2011. The California Gull population and its effects on locally breeding shorebirds and terns are among the most pressing concerns for wetland managers within the San Francisco Bay estuary, especially for the South Bay Salt Pond Restoration Project. Further research is needed to evaluate the gull's reproductive rates, habitat use, and annual movements and so to clarify its demographics and to quantify its effects on other breeding birds.

***Keywords*:** colonization, *Larus californicus,* population monitoring, predator management, subsidized predators, urban ecology

Globally, wildlife populations are changing substantially in response to climate change, urbanization, changing agricultural practices, and a wide variety of other anthropogenic factors. In urban areas, communities of birds and other wildlife have changed rapidly (Grimm et al. 2008, Puth and Burns 2009). These changes stem largely from habitat loss and alteration, which negatively affect some species, and anthropogenic food subsidies, which enhance populations of others (Grimm et al. 2008). Understanding the causes and consequences of these rapid changes is a high priority for ecologists and conservation biologists and is essential for protecting functional ecosystems in these highly altered landscapes.

The area surrounding the San Francisco Bay estuary is now home to over 7 million people. It is one of the most highly altered estuaries in the United Sates, with most of the area's historic tidal marsh lost to development or conversion to salt-evaporation ponds and agricultural fields (Goals Project 1999, USFWS 2013). These changes have greatly affected avian communities, with some species benefiting from these anthropogenic changes (Nichols et al. 1986).

The California Gull (*Larus californicus*) is an example of a species likely benefiting from changes in San Francisco Bay, where its breeding population has increased rapidly since it first colonized the area in the early 1980s (Strong et al. 2004). These gulls commonly feed at landfills around the bay (Ackerman et al. 2009) and other places where

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[1]San Francisco Bay Bird Observatory, 524 Valley Way, Milpitas, California 95035, [2]U.S. Geological Survey, Western Ecological Research Center, Dixon Field Station, 800 Business Park Drive, Suite D, Dixon, California 95620, [3]Humboldt County Resource Conservation District, 5630 South Broadway, Eureka, California 95503, [4]U.S. Fish and Wildlife Service, Don Edwards San Francisco Bay National Wildlife Refuge, 1 Marshlands Road, Fremont, California 94555, [5]The Nature Conservancy, 201 Mission Street, 4th Floor, San Francisco, California 94105, [6]Ducks Unlimited, Inc., 1175 Nimitz Avenue, Suite 110, Vallejo, California 94592; corresponding author: nwashburn@ducks.org

human refuse is concentrated. California Gulls prey on the eggs and chicks of the bay's breeding shorebirds, including the Western Snowy Plover (*Charadrius nivosus nivosus*; Demers and Robinson-Nilsen 2012, Ackerman et al. 2014a, b), of which the Pacific coast population is designated as threatened by the U.S. Fish and Wildlife Service.

Large-scale restoration of wetlands has recently been undertaken in San Francisco Bay, and these habitat changes have the potential to affect nesting waterbirds. The South Bay Salt Pond (SBSP) Restoration Project (www.southbayrestoration.org) is the largest effort to restore tidal marsh on the Pacific coast of the United States. This 5665-ha project focuses on restoring tidal activity to a majority of the ponds in the southern portion of the bay (South Bay) that were previously managed for salt production. It is intended to increase the extent of tidal marshes in the South Bay thereby benefiting the wildlife dependent on them. However, converting managed ponds to tidal marsh may limit sites where locally breeding shorebirds and terns roost, feed, and nest and could favor predation by California Gulls.

Here, we address three primary questions related to the California Gull population in San Francisco Bay: (1) How quickly is the population growing? (2) What are the ecological implications of such a large gull population? (3) What management may be most effective in reducing the effects of gulls on other species? In doing so, we present new data on the gull's population in the bay and on its patterns of use at landfills in response to attempts at hazing. We supplement these data with the results of other recent studies of California Gull ecology in San Francisco Bay, patterns of movement of gulls displaced by the restoration of salt ponds, and the extensive literature on gull control and management worldwide. Finally, we discuss options for reducing the gull's effects on sensitive species in San Francisco Bay.

Study Area and Methods

San Francisco Bay Estuary

The San Francisco Bay estuary is the largest estuary on the west coast of the Americas (USFWS 2013). The current extent of tidal marsh in the

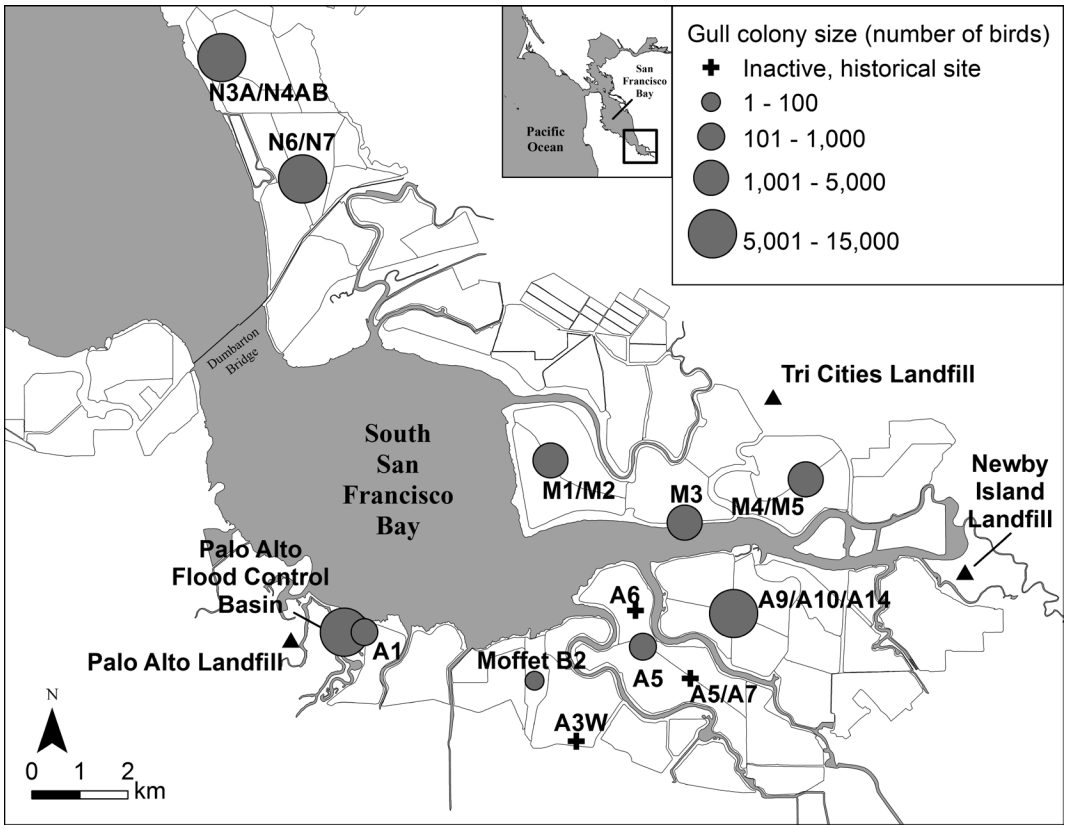

Figure 1. Location and relative size of California Gull colonies in South San Francisco Bay, California, in 2014.

estuary is 16,187 hectares, nearly 80% less than in the 1800s. In the mid-1850s, commercial salt production began in the South Bay and led to the conversion of 10,926 ha of land into shallow salt-evaporation ponds separated by levees (Ver Planck 1958). California Gull colonies in San Francisco Bay have been located on the dry salt flats or levees of these ponds, except for a few on islands in the Central Bay. Three landfills have been operating near the South Bay colonies: Tri-Cities Landfill in Fremont was active from 1994 until 2008, Palo Alto Landfill in Palo Alto was active from 2002 to 2011, and Newby Island Landfill in Milpitas opened in 1997 and will remain active until 2020 (Figure 1).

Gull Population Surveys

We estimated the growth of the California Gull population in San Francisco Bay from 1980 to 2016 on the basis of a yearly count of all known colonies. The colonies were censused in early to mid-May, late in the incubation period or early in hatching for the majority of the population. During censuses, teams of observers either counted the total number of adults in the colony (for small colonies) or systematically walked through the colony and visually tallied all nests (for large colonies). Empty nests and fully depredated nests were excluded from the total because they may not represent a breeding pair distinct from active nests (potential for renesting). Nest counts were multiplied by two birds per nest to yield a minimum estimate of the number of breeding adults. In 2004, several colonies were counted from the air rather than from the ground. Estimates of adults from aerial surveys were likely underestimates with respect to ground counts.

Gull Banding

Since 1983, over 11,000 California Gulls have been banded in the South Bay by the San Francisco Bay Bird Observatory (SFBBO) and the U.S. Geological Survey (USGS; USGS unpubl. data). From 2008 to 2010, over 1000 adults and chicks were banded with field-readable bands as part of a study to track gull movement and colony redistribution associated with the SBSP Restoration Project, particularly the restoration of pond A6 in December 2010 (Ackerman et al. 2013). Resightings of bands were recorded from 2011 to 2013 during the May colony counts or from observations submitted through the USGS's Bird Banding Laboratory.

Gull Hazing

From 2011 to 2016, several types of hazing were employed to prevent gulls from nesting at specific sites in the Don Edwards San Francisco Bay National Wildlife Refuge and SBSP Restoration Project wetlands. Potential locations for gull hazing were ranked into a three-tiered system on the basis of their proximity to and projected effect on sites of shorebird and tern breeding. The ranking of sites and hazing efforts applied were as follows: tier 1, high priority, sites where gulls should be prevented from nesting or roosting; tier 2, areas where the biologists preferred that gulls did not nest, and hazing was attempted within target areas (e.g., islands with nesting waterbirds) if time allowed; and tier 3, sites where gulls were allowed to nest without any deterrence (included previously established gull colonies). Hazing at tier-1 and tier-2 sites included human disturbance by walking, kayaking, or driving nearby, blowing a whistle or making other loud noises, and the use of hand-held lasers (class IIIb) at dawn and dusk. From 2011 to 2016, nesting material was also removed, empty nest bowls were destroyed, and gulls were prevented from roosting at all tier-1 sites for at least one hour a day until they ceased attempting to nest in that area.

Beginning in 2008, Newby Island Landfill—the largest operational landfill in the South Bay (Figure 1)—attempted to prevent gulls from roosting and foraging on the exposed refuse. Hazing included the use of pyrotechnics, lasers, falcons, dogs, whistles, a remote-controlled model eagle, and other deterrents. From 2007 to 2013, gull use of the landfill was monitored twice per month to determine baseline levels of foraging prior to the hazing and the subsequent effectiveness of the hazing. Full counts of all California Gulls on the ground began at sunrise and were repeated every 2 hours until a full 8-hour day was completed. We averaged the eight complete counts per month of all gulls on the exposed refuse of the landfill to represent monthly use of the landfill from 2007 to 2013.

Results

Gull Colony Locations

California Gulls have nested at 17 sites within the bay since 1980. Fourteen of these sites were in the South Bay and three were in the Central Bay (Alcatraz Island, Alameda Naval Air Station, and Brooks Island). In 2014, California Gulls nested at 10 locations within the South Bay (Figure 1).

Gull Population Growth

The number of breeding California Gulls in San Francisco Bay increased from an estimated 24 individuals in 1980 to a peak of 53,574 individuals in 2014, then declined to 38,040 in 2016 (Figure 2, Table 1; see also Strong et al. 2004, Ackerman et al. 2013). Until 2010, the largest California Gull colony was the Alviso A6 colony, which has contained an average of 76% of the breeding California Gulls in San Francisco Bay since 1980. The Alviso A6 gull colony reached a peak of 26,366 individuals in 2008, before the dry pond bed was flooded in December 2010 as part of the SBSP Restoration Project. After 2010, the largest California Gull colonies have been at the Alviso A9/A10/A14, Mowry M1/M2/M3/M4/M5, and Coyote Hills N3A/N4AB/N6/N7 levee systems, as well as the Palo Alto Flood Control Basin. In the breeding season following the tidal restoration of Alviso A6 (2011), the California Gull population in San Francisco Bay declined by 18% from 46,236 to 38,108, but then rebounded by 38% to 52,404 in 2012 (Table 1). Of 137 banded gulls resighted from 2011 to 2013, 70% were observed in the South Bay and 42% were observed at a gull colony adjacent to the former Alviso A6 colony at Alviso A9/10/11/14, indicating that many displaced gulls moved to this new colony adjacent to their former nesting site.

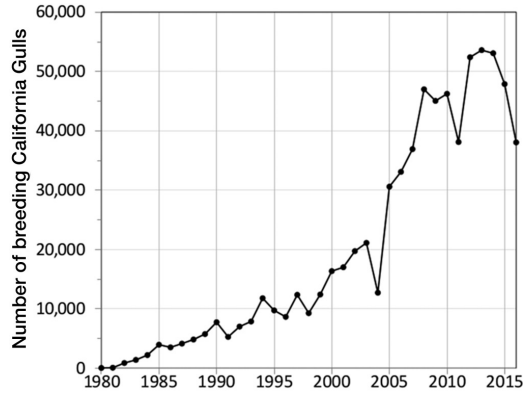

Figure 2. Estimated number of breeding California Gulls in San Francisco Bay, California, 1980–2016 (details by colony in Table 1). In 2004, numbers were estimated visually from an airplane and are likely an underestimate. The decline in numbers in 2011 likely reflects short-term dispersal caused by the December 2010 restoration of tidal action to pond A6, site of the largest California Gull colony in the South Bay up until that time.

Gull Hazing

Hazing was successful in preventing gulls from nesting in sites designated as tier 1 but was not always successful in preventing roosting at these sites. Hazing was employed at sites without a recent history of California Gull nesting, so its utility at historical nesting sites has not been evaluated, but presumably it would be more difficult. Monitoring of gull use of the Newby Island landfill in response to changing hazing practices has indicated that the most effective method is a multi-tactic approach in which all the techniques described in the methods were used throughout the day. When this multi-tactic approach was used, California Gull use of the landfill during the breeding season declined from an average of 977 to 37 individuals per survey (Figure 3). Newby Island Landfill continued implementing this gull hazing strategy through 2016.

Discussion

The rapid growth of the California Gull population in San Francisco Bay may have resulted from abundant suitable nesting sites in close proximity to anthropogenic food resources. The degree to which intrinsic population growth was augmented by immigration from other areas is unknown. Notably, no studies have examined the California Gull's reproductive rates (survival of nests and chicks) within San Francisco Bay or movements among colonies from outside San Francisco Bay. These data gaps impede our understanding of the gull's population dynamics and limit options for management.

A potential source of California Gulls immigrating to San Francisco Bay is the large population breeding at Mono Lake. Between 1983 and 2012, an average of 46,552 California Gulls bred at Mono Lake, and the population there has not changed significantly over the past 30 years (Nelson and Greiner 2013). Although movement of some nonbreeding individuals to the Farallon Islands was recorded from 2009 to 2013, only a few gulls banded at Mono Lake have been observed in San Francisco Bay.

Foraging at landfills has been shown to increase gulls' reproductive success and population size at some colonies, but not at others (Pierotti and Annett 1990, Pons 1992, Duhem et al. 2008, Weisler and Powell 2010). In San Francisco Bay, garbage accounted for 40% of the volume of chicks' diets at the Alviso A6 colony in 1987 and 1988 (Jones 1986, Dierks 1990) and from 19% to 81% of adult gulls' diet at several colonies (Peterson et al. 2017). Additionally,

Table 1. California Gull population growth in San Francisco Bay, 1980–2016, by colony. Estimates are derived from either nest counts multiplied by two birds per nest or from an estimate of all adults in the colony.[a]

Year	Alviso A6	Newark	Alviso A9/A10/A14	Mountain View A1	Mowry M4/M5	Mowry M1/M2	Mowry M3	Moffett B2	Alameda NAS	Brooks Island	Coyote Hills N3A/N4AB	Coyote Hills N6/N7	Palo Alto Flood Control Basin	Alcatraz Island	Alviso A5	Alviso A5/A7	A3W Boardwalk	Total
1980	24	—	—	0	—	—	—	0	0	0	0	—	—	—	—	—	—	**24**
1981	60	—	—	0	—	—	—	0	0	0	0	—	—	—	—	—	—	**60**
1982	412	—	434	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**846**
1983	1342	46	—	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**1388**
1984	2000	44	150	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**2194**
1985	3000	554	374	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**3928**
1986	3000	398	97	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**3495**
1987	4000	22	100	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**4122**
1988	4600	30	180	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**4810**
1989	5310	0	434	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**5744**
1990	7600	0	122	2	—	0	—	0	0	0	0	—	—	—	—	—	—	**7724**
1991	5250	0	0	0	—	0	—	0	0	0	0	—	—	—	—	—	—	**5250**
1992	5500	0	200	0	—	1294	—	0	0	0	0	—	—	—	—	—	—	**6994**
1993	6912	0	234	200	—	415	—	82	6	0	0	—	—	—	—	—	—	**7849**
1994	9000	0	300	350	—	1540	—	556	20	0	0	—	—	—	—	—	—	**11,766**
1995	7236	0	4	74	—	2009	—	300	100	0	0	—	—	—	—	—	—	**9723**
1996	6558	0	1410	0	—	174	—	282	200	0	0	—	—	0	—	—	—	**8624**
1997	6256	0	1722	164	—	3000	—	1000	200	0	0	—	—	0	—	—	—	**12,342**
1998	6562	0	1628	0	—	480	—	400	200	—	0	—	—	0	—	—	—	**9270**
1999	9380	0	2117	145	—	475	—	248	50	—	0	—	—	0	—	—	—	**12,415**
2000	11,482	0	1986	0	—	2526	—	254	80	10	0	—	—	0	—	—	—	**16,338**
2001	11,216	0	3056	278	—	1824	—	624	—	—	0	—	—	0	—	—	—	**16,998**
2002	11,302	0	3590	510	—	3120	—	712	—	486	0	—	—	0	—	—	—	**19,720**
2003	13,644	0	1010	862	—	4310	—	384	—	896	0	—	—	0	—	—	—	**21,106**
2004	8600[b]	0	1047[b]	321[b]	—	2233[b]	—	219[b]	0	270[b]	0	—	0	10	—	—	—	**12,700**
2005	18,418	—	426	1664	—	3044	—	830	—	800	5370	—	—	26	—	—	—	**30,578**
2006	19,456	0	234	380	—	5068	—	374	0	—	7442	—	—	42	84	—	—	**33,080**
2007	24,696	—	0	92	—	7384	—	—	105	—	4384	—	206	46	—	—	—	**36,913**
2008	26,366[c]	—	0	616	5934	8224	—	—	135	—	4952	—	690	42	30	—	—	**46,989**
2009	24,190	0	0	446	3640	8842	—	8	87	1577	4944	—	1164	22	110	—	—	**45,030**
2010	23,108	0	0	428	4780	6020	—	20	54	—	6594	2506	1704	132	174	716	—	**46,236**
2011	0	0	11,956	390	6068	4164	—	112	0	—	6394	4110	4478	278	156	0	2	**38,108**
2012	0	0	18,328	422	4414	1770	3700	122	—	—	7248	6738	9200	232	230	0	0	**52,404**
2013	0	—	15,900	270	3408	1260	5078	120	0	—	6256	6914	14,014	116	238	0	—	**53,574**
2014	—	—	14,414	404	3616	1314	4878	82	0	—	5914	7864	14,264	48	276	—	—	**53,074**
2015	0	—	13,204	404	4886	1786	3214	142	—	—	2150	8296	13,784	—	0	—	0	**47,866**
2016	—	—	10,086	344	3640	1382	2218	260	—	—	1472	5880	12,758	—	0	—	—	**38,040**

[a]Dashes denote no survey, in most cases indicating that the colony was not yet established.

[b]Count is from a visual estimate of adults from an aerial survey of the colony and is likely conservative.

[c]U.S. Geological Survey contributed supplemental information about this colony.

radio-marking and tracking of California Gulls in the South Bay found that the birds' movements were dictated largely by the location and timing of landfill operations (Ackerman et al. 2009). California Gulls generally arrived early in the morning and remained until evening when landfills were closed and refuse was covered. The recent implementation of gull-abatement programs at several of the area's landfills, however, appears to be reducing gulls' access to this food source. Continued hazing may affect gulls' movements and potentially their numbers over time. Altogether, these results suggest that anthropogenic food subsidies at landfills have played a role

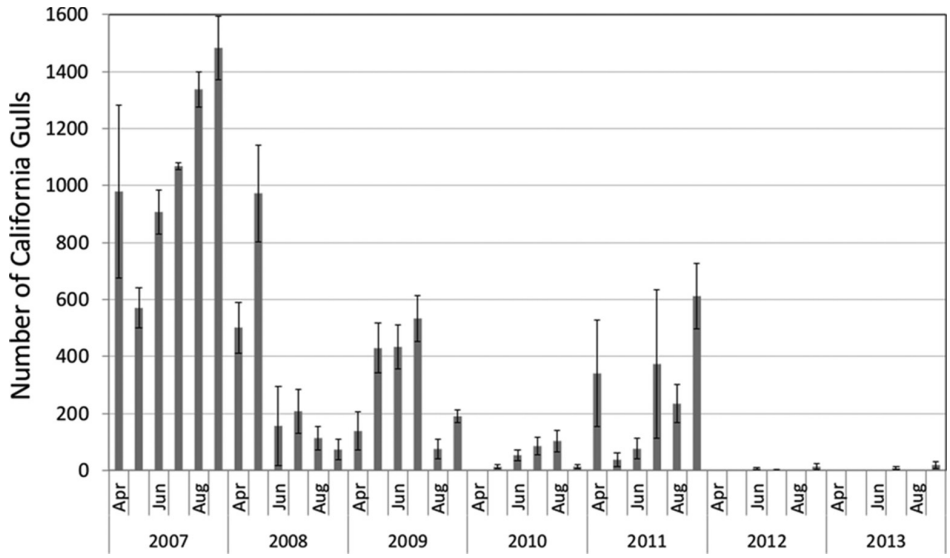

Figure 3. The average number (±1 standard error) of California Gulls observed on the ground at Newby Island Landfill, April to September 2007–2013. Hazing was initiated between September 2007 and April 2008, after which various efforts (e.g., falconry, pyrotechnics, multi-tactic) continued uninterrupted. The abatement was most successful (multiple tactics) June–September 2008, April–September 2012, and April–September 2013.

in the population growth of California Gulls in San Francisco Bay.

Gull Predation on Other Species

Land managers in the San Francisco Bay estuary, particularly those of the South Bay Salt Pond Restoration Project, are concerned about the ability of the area to support target populations of shorebirds and terns, as restoration projects may reduce the availability of nesting habitat and bring California Gulls into closer contact with other nesting species (Shuford 2008). Populations of the Western Snowy Plover, American Avocet (*Recurvirostra americana),* Black-necked Stilt (*Himantopus mexicanus)*, and Forster's Tern in the South Bay have recently declined (Strong et al. 2004, Shuford 2008, JTA unpubl. data). The California Gull is an important predator of shorebird and tern eggs (Herring et al. 2011, Demers and Robinson-Nilsen 2012) and chicks (Ackerman et al. 2014a, b). Moreover, California Gulls initiate nests before many other species and can exclude them from preferred nesting areas (Strong et al. 2004).

Several studies have documented that gulls reduce the reproductive output of other waterbird species, especially through predation of eggs and chicks (Thomas 1972, Spear 1993, Becker 1995, Bowman et al. 2004) and displacement from nesting sites (Kress 1983, Nisbet and Spendelow 1999). California Gulls' home ranges in the bay are large (50% utilization distributions averaged 6 km^2) and encompass nearly 60% of all waterbird nests monitored in the South Bay (Ackerman et al. 2009). In South San Francisco Bay, California Gulls were responsible for 13% and 38% of egg depredations in a sample of American Avocet (Herring et al. 2011) and Western Snowy Plover nests, respectively (Demers and Robinson-Nilsen 2012, Ackerman et al. 2013). Radio-telemetry studies also revealed that California Gulls caused 55% of deaths of American Avocet chicks (Ackerman et al. 2014b) and 54% of deaths of Forster's Tern chicks (Ackerman et al. 2014a), yet only 15% of deaths of Black-necked Stilt chicks (Ackerman et al. 2014b). In fact, many chicks were carried up to 11 km away and found depredated within California Gull colonies (Ackerman et al. 2014a, b). Ackerman et al. (2014a, b) found that in South San Francisco Bay survival of chicks from hatching to fledging was 6% for the American Avocet, 22% for the Forster's Tern, and 40% for the Black-necked Stilt. The greater success of the stilt appears to reflect its more frequent use of vegetated marshes for nesting, which provide greater concealment for chicks than the more open habitats in which avocets and terns nest. Ackerman et al. (2014b) reported that movements of recently hatched avocet chicks were nonrandom and that avocet chicks hatched on islands within managed ponds moved toward nearby thickly vegetated marshes. When restoration of Pond Alviso

A6 displaced the California Gull colony, survival of Forster's Tern chicks increased by 900% in a colony <1 km away but only by 14% at a more distant colony, >3.8 km away (Ackerman et al. 2014a). Furthermore, the fledging success of tern chicks was higher when nearby gull colonies were relatively small and when gull colonies were farther from the tern colony. The high rates of gull predation on eggs and chicks suggest this may ultimately cause declines of shorebirds and terns breeding around the bay.

Management Options

In response to evidence that the California Gull population in San Francisco Bay has affected other breeding species negatively through predation and displacement, land managers are attempting to reduce these effects. Primarily, this includes hazing gulls near sites of shorebird and tern nesting and at landfills. However, such hazing is costly, requiring dedicated staff to be successful, and may not reduce the population overall. Recent tracking by GPS shows that breeding California Gulls are now traveling to more distant landfills outside of San Francisco Bay (JTA unpubl. data).

Even if efforts at hazing gulls are successful, reduced gull numbers may not lead to reduced predation if a relatively small number of "problem" gulls focus their foraging on eggs and chicks (Guillemette and Brousseau 2001, Riensche et al. 2012, Ackerman et al. 2014a, b). Ackerman et al. (2014a) found multiple shorebird and tern bands at the same exact location within gull colonies. In one instance, they found 11 Forster's Tern chicks preyed upon at the same location, suggesting that an individual gull repeatedly specialized on eating tern chicks. This is consistent with studies elsewhere that have found a few specialist gulls responsible for most predation on chicks (Spear 1993, Hario 1994, Guillemette and Brousseau 2001, Oro et al. 2005). In contrast, removing specialist California Gulls and hazing led to increased success of California Least Terns (*Sternula antillarum browni*) at a small colony in San Francisco Bay (Riensche et al. 2012). Identifying specific problem gulls, however, is time-consuming, costly, and poses a significant challenge in an area the size of the entire South Bay.

Large-scale lethal control of gulls has been used in some locations where overabundance has caused negative ecological effects, including in New England and Europe (Thomas 1972, Owen et al. 2001, Calladine et al. 2006). These strategies include poison/narcotic bait, trapping/netting gulls, shooting, introduction of mammalian predators, destroying nests and eggs, and others (Thomas 1972, Shuford 2008). These practices must be continued for many years and are time-consuming, controversial, and costly. Furthermore, lethal control has often been ineffective over the long term, as emigration of individuals from other populations and successful reproduction of those individuals not culled have reconstituted the population (Thomas 1972). For example, a review of literature on the Yellow-legged Gull (*Larus michahellis*) suggested that large-scale gull-culling programs were not effective in reducing gull populations (Oro and Martinez-Abrain 2007).

The SBSP Restoration Project has played a large role in shaping the distribution and abundance of California Gulls in the South Bay. The SBSP Restoration Project, planned to extend over 50 years, is being implemented in phases, and the first phase included restoring the Alviso A6 site to tidal marsh. Breaching the levees caused water from the bay to flood the pond and forced the California Gulls to abandon the site. Additional phases may include removing the site where California Gulls nest at Pond A1. Continued efforts to restore tidal marsh may increase interactions of California Gulls with breeding shorebirds and terns as it reduces the number of sites where waterbirds can nest.

Nevertheless, the total amount of nesting substrate available to breeding gulls in the South Bay is not yet a limiting factor. Therefore, when one colony's location is removed for restoration, another colony is likely to grow in size, or a new colony is likely to appear elsewhere in the South Bay, unless additional measures are taken to prevent it. As a result, wetland restoration is likely to reduce gull numbers in San Francisco Bay only if it targets locations of multiple gull colonies simultaneously and if these gulls are aggressively prevented from resettling. In addition, wetland restoration is likely to have immediate negative effects on other nesting waterbirds if it constrains them to nesting closer to California Gulls, particularly where it eliminates managed ponds with islands that historically have hosted large populations of nesting shorebirds and terns.

Management and Research Considerations

Monitoring and management of California Gulls in the San Francisco Bay estuary from 1980 to 2016 indicate that continued management of gulls

will be necessary. Hazing has successfully reduced gull foraging on human refuse and minimized the presence of gulls near sites of shorebird and tern nesting. However, hazing on its own is unlikely to reduce the size of the gull population. In addition to the one South Bay landfill where hazing has been effective, many other landfills exist within and outside the estuary, and gulls can range widely during the day to reach anthropogenic sources of food. A collaborative and continued effort of hazing at all of these sites may reduce gulls' reliance on human refuse. In the future, additional hazing and adaptive management may be required if the goal is to limit the gull's depredation of sensitive species, but such work is time-intensive and can be costly. Large-scale lethal control of gulls is cost prohibitive and has ethical considerations, but targeting problem individuals for lethal control may be successful in reducing predation on chicks locally and could be enhanced by further research (Riensche et al. 2012, Ackerman et al. 2014a).

Restoration may also reduce the habitat available to breeding California Gulls, whether by flooding nest sites or by physically removing islands and levees where gulls nest. Restoration can have significant short-term consequences for the number of breeding gulls, and displaced gulls will likely settle within neighboring colonies. If restoration continues to displace large gull colonies, and if simultaneous hazing prevents those gulls from reestablishing colonies elsewhere, restoration might slow growth of the gull population. However, our findings indicate that if there is suitable habitat elsewhere in the South Bay, gulls will relocate unless hazing is intensive.

Research aimed at understanding the food resources of California Gulls using the bay is needed, including a comparison of the current importance of natural versus anthropogenic food items compared with patterns when the gull population size was much smaller (Jones 1986, Dierks 1990). Additionally, research on gull movements between colonies and landfills would help identify changes now that gull use of the largest and closest landfill has been reduced and the bay's largest colony, at Alviso A6, has been completely removed. To date, no study has examined the California Gull's reproductive rates in San Francisco Bay, but this information is critically important for managers to understand the degree to which population growth is intrinsic or driven by immigration. Our work indicates that the highest priority for future research is a detailed investigation of the California Gull's nest success and chick survival. Studies of the species' movements and habitat use, as well as immigration to and emigration from San Francisco Bay breeding sites, are needed to help inform land and resource managers.

Additionally, continued monitoring of the reproductive success of nesting shorebirds and terns, as well as investigation into techniques for enhancing these species' habitat, would guide conservation meant to benefit locally breeding birds.

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