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The Current Status and Distribution of the Least Tern Breeding in the Gulf of California, México

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Abstract.—The California Least Tern (*Sternula antillarum browni*) population is declining in California, U.S.A., but little is known about the Least Tern population breeding in the Gulf of California, México. Because of this decline in California, it is important to determine current distribution, population trends, and movements in the nearby Gulf of California. Emigration from coastal California to the Gulf of California is one possible reason for the decline. We analyzed Least Tern colony counts to provide an overview of its current breeding distribution, abundance trends, and connectivity in the Gulf of California. We documented 84 nesting sites, including 61 extant, 10 historic, and 13 sites of unknown status. We estimated the Gulf of California population to be 2,400–3,500 adults, breeding in the 61 extant colonies. Colonies here were small, averaging 49 adults/colony. Most colonies occurred in the Upper Gulf, Gulf Entrance, and on the southern end of the Baja California Peninsula. We estimated a significant negative trend for the population of the Gulf of California. We found no marked individuals in the Gulf of California nesting colonies banded in California or the Baja California peninsula, indicating no regular movement away from coastal California. *Received 2 Oct 2024, accepted 28 Jan 2025.*

Key words.—colonies, conservation, connectivity, decline, distribution, Gulf of California, Least Tern, nesting

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The Least Tern (*Sternula antillarum*) is a migratory seabird that nests in colonies along coastlines, river systems, and inland bodies of water in North America, Central America, the Hawaiian Islands, the Caribbean Islands, and South America (AOU 2020). In North America, five subspecies of Least Terns have been described (Patten and Erickson 1996). *S.a. antillarum* (Eastern) occurs along the Atlantic coast (Lesson 1847); *S.a. staebleri* in southern México (Brodkorb 1940); *S.a. browni* (California) along the coasts of the Californias (Mearns 1916); *S.a. mexicanus* along the coast of northern mainland México (van Rossem and Hachisuka 1937); and *S.a. athalassos* (Interior) in the Interior of the United States (Burleigh and Lowery 1942).

Taxonomic and ecological distinctions between the endangered California Least Terns that nest from California, U.S.A., to San Jose del Cabo, Baja California Sur, México (BCS) (Grinnell 1928; AOU 1957; Whittier *et al.* 2006) and those terns that nest within the Gulf of California are poorly defined. *S.a. mexicanus* breeds in the Gulf of California, from Sonora (SON) south through Colima, and may include those that breed along the Gulf coast of the Baja California Peninsula (Mellink and Palacios 1993; Patten and Erickson 1996). However, their subspecific status has been questioned, with recent reviews calling for further study (Gochfeld and Burger 1996; Palacios and Mellink 1996; Patten and Erickson 1996; Massey 1998; Draheim 2006; Whittier *et al.* 2006; Pyle 2008; Draheim *et al.* 2010; Thompson *et al.* 2020). All four subspecies of Least Terns that nest in México, including the California Least Tern, are listed as a Special Protected species [Sujeta a Protección Especial (Pr)] (NOM-059-SEMARNAT-2010) (DOF 2019).

The distribution of Least Terns in the Gulf of California before the 1980s is poorly known. Surveys here followed their Endangered status in the U.S.A., and the recovery plan called for additional information about their status in México (US Fish and Wildlife Service 1973, 1985). Regionwide surveys were conducted by Palacios and Mellink (1996, 2003). Palacios and Mellink (1996) collected observations from 29 nesting colonies from the Gulf of California in the states of Baja California (BC; 8 colonies), BCS (7 colonies), and SON (14 colonies). They estimated 400 breeding pairs (Palacios and Mellink 1996). However, extrapolating from Table 1 in Palacios and Mellink (1996), using only the years they visited most colonies, they found approximately 50–115 pairs in BC, 120–200 pairs in BCS, and 200–300 pairs in SON (Palacios and Mellink 1996). Surveys conducted in 2002–03 added six colonies in BCS, 12 in Sinaloa (SIN,) and 6 in Nayarit (NAY), and counted 228 pairs in La Paz, BCS (Region 6, Fig. 1), 102 pairs in Los Cabos, BCS (Region 4, Fig. 1), 456 pairs in northern SIN (Region 1, Fig. 1), and 665 pairs in southern SIN and NAY (Region 2, Fig. 1; Table 8 in and Mellink, 2003). Subsequently, Rosemartin and Van Riper (2011) intensively studied colonies in northern SON between Bahia San Jorge and Bahia Adair from 2006–2008 and estimated at least 141 (± 47) pairs, although the number of adults detected indicated that as many as 261 (± 204) pairs may be present. Fleishman and Blinick (2011) reported 55 nests in multiple sub-colonies at Estero Cardonal, SON in 2010. Leyva-García *et al.* (2023) reported 5 to 55 pairs at Estero Tobari, SON, between 2017 and 2022.

Overall, these surveys indicate 1,150 to 1,500 pairs in the Gulf of California in the 1990s and 2000s. Additional colonies that were likely active in these years have been located between the surveys, and since the latest surveys were completed, this is likely an underestimate. By comparison, the population estimate along California and Baja California's approximately 1200 km coast for the Endangered *S.a. browni* was an average of 8185 adults (4093 pairs) in 2023 (CDFW 2023). However, an average of 6843 adults (3421 pairs) (84%) nest in a 450 km coastline between Point Conception and the Tijuana River (CDFW 2023). Based on this information, there are fewer Least Terns in the Gulf of California than in the Endangered population in California. Palacios and Mellink (1996, 2003) described most nesting colonies along the Baja California Peninsula and Sonora as being small and widely dispersed, with a mean colony size of 23 pairs (SD = 36; Palacios and Mellink 1996) and 18 (SD = 35) nests (Rosemartin and Van Riper 2011). The mean colony size in SIN was larger, with 65 pairs per colony (Palacios and Mellink 2003). This is much smaller than nesting colonies of the Least Tern in California, with a mean colony size of 275 adults (SEM = 32.6, median = 108 adults), with < 30% of colonies less than 40 adults (CDFW 2023).

Since 2008, the Endangered California Least Terns population has declined by 56% (CDFW 2023). Given the proximity, known movements, and unclear subspecific status, it is now urgent that we understand if there is connectivity between these adjacent populations. We need to determine if the decline in the California Least Tern is due to a distribution shift

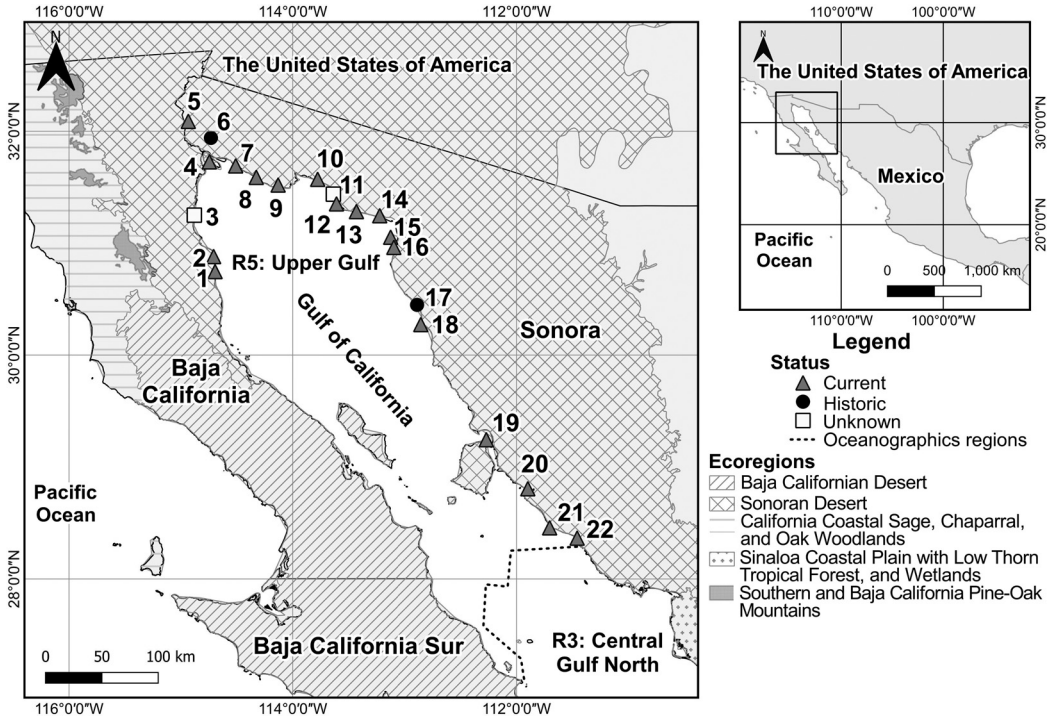

Figure 1. Map of the Upper Gulf of California showing the distribution and status (current, historic, unknown) of the Least Tern colonies, ecoregions, and oceanographic regions. Site numbers correspond to those in Table 1.

towards the Gulf of California. This possibility must be considered, given their proximity and known movement patterns. At their closest point, nesting colonies between the Pacific Coast and the Gulf of California are only 120 km apart. Ryan and Heyne (2020) documented that 10% of marked individuals move at least 90 km from their natal colonies. In 2022, a California Least Tern marked at Punta Azufre, San Quintin, BC, was observed 675 km north at Oceano Dunes State Vehicular Recreation Area (A. Clark *pers.comm.*), showing longer-distance movements are possible. Moreover, California Least Terns banded with alphanumeric tags and marked with Motus tags on the Pacific Coast have been detected in the Upper Gulf during migration (A. Hernández Alvarez and L. Ortiz *pers. obs.*). While there has not been a Least Tern from one region documented nesting in the other region, these recent observations indicate that the possibility exists and should be examined.

Our goals were to inventory all known Least Tern colonies on both coasts of the Gulf of California, provide a current breeding population estimate, and determine population trends for the Least Tern breeding in the Gulf of California. It is important to know the current conservation status and population trend of the Least Tern in the Gulf of California because the increasing threats of coastal development in México are similar to the changes in California before the population decline there. Additionally, studies of the individual movements and genetic variation between Pacific Coast and Gulf of California Least Tern populations are ongoing. Understanding both populations' distribution and population dynamics is important for conserving populations in both countries.

METHODS

Study Area

We compiled survey data for Least Terns breeding in the Gulf of California, México. The Gulf of California is located between the Baja California peninsula and the Mexican mainland. It covers a wide latitudinal range, from the Colorado River Delta, Sonora to Cabo Corrientes, Jalisco (JAL), from approximately 32°05′ N

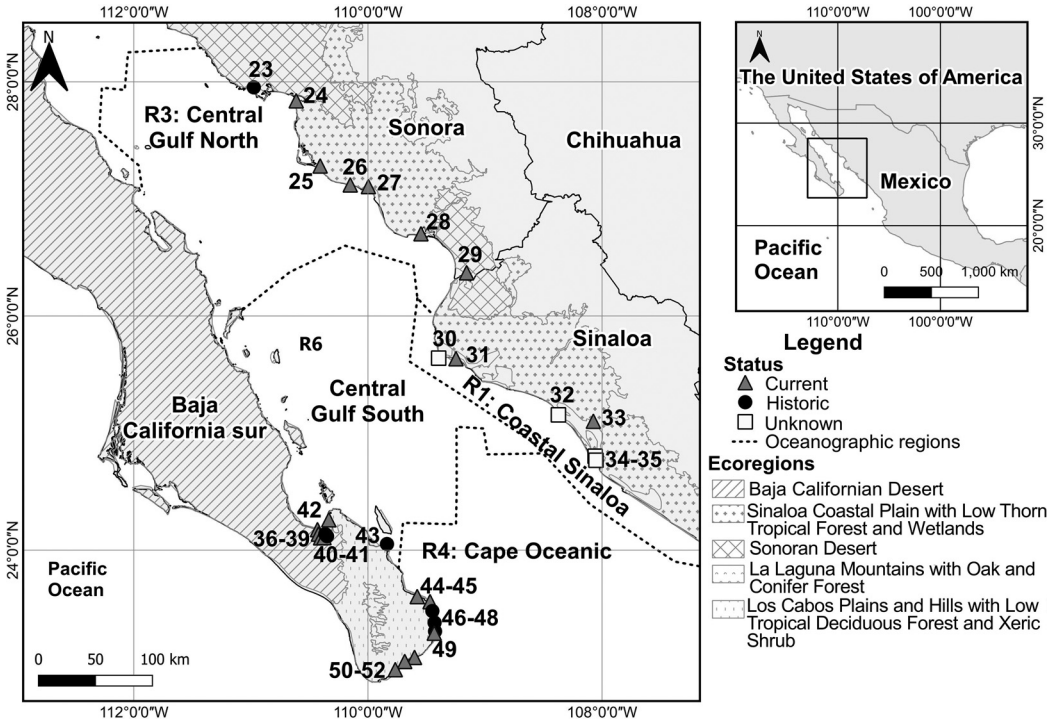

Figure 2. Map of the Central Gulf of California and the peninsula of Baja California showing the distribution and status (current, historic, unknown) of the Least Tern colonies, ecoregions, and oceanographic regions. Site numbers correspond to those in Table 1.

to 20°24′ N (Roden, 1958). It includes the coasts of the Mexican states of BC, BCS, SON, SIN, NAY and JAL (Figs. 1–3). The Gulf of California ranges from a temperate arid climate in the north to a sub-humid tropical climate in the south (Wilken *et al.* 2011). The currents, depth, winds, and river interaction vary with latitude. Least Terns in the region face various terrestrial and oceanographic conditions, which are both important to nest site selection and nest success (Wilken *et al.* 2011; López Martínez *et al.* 2023).

We subdivided the Gulf of California into six regions based on six oceanographic bioregions described by López-Martínez *et al.* (2023) and corresponding terrestrial ecoregions (Wilken *et al.* 2011; Figs. 1–3, Table 1). Each region's sea surface water characteristics can be found in López Martínez *et al.* (2023, Table 2). One exception occurred as we extended Region 1 north to include a small section of the coast of SIN from Bahia de Topolobampo to the north of the Fuerte River (Fig. 2) due to these colonies being on the east shore and in habitat similar to the other colonies in Region 1. We have modified the names but retained the regional numbering used by López Martínez *et al.* (2023, Fig. 3).

The *Upper Gulf of California* (Region 5) is surrounded by dry Sonoran Desert and few watercourses, particularly in the northern region (Fig. 1). Both water and air temperatures are cooler in winter and warmer in summer. The Colorado River Delta forms the northern boundary, though the river no longer reaches the Gulf. The Delta has expansive mudflats along the former river with estuaries fed by agricultural runoff and springs. Within the Delta, Isla Montague is a large, flat island formed at the end of the Colorado River and surrounded by tidal channels. There is a large tidal range in this region, which, combined with shallow depths and narrow channels between Isla Angel de la Guardia and Isla del Tiburon, the waters are highly productive, with tidal current-driven upwelling occurring year-round (López Martínez *et al.* 2023).

The *Central Gulf North* (Region 3) supports large, mangrove-lined coastal lagoons with barrier and internal islands. These are fed by large watercourses that contribute nutrients to the lagoons. This area has a winter-spring (December to April) upwelling bloom period driven by winter northwestern winds and a summer non-bloom period (July to October; López Martínez *et al.* 2023). All Least Tern nesting colonies in the Central Gulf North are on the east shore (Fig. 2).

The *Coastal Sinaloa* (Region 1) is similar to the Central Gulf South, with large estuary systems within chains of barrier islands dominated by mangroves and surrounded by agriculture and shrimp aquaculture (Figs. 2 and 3). The coastal waters support some of the Gulf's most intense seasonal winter upwelling. The waters are warmer but eutrophic with high seasonal Chlorophyll-a conditions (López Martínez *et al.* 2023).

The Gulf Entrance (Region 2) spans a large coastal area on the east shore of the Gulf and is heavily influenced by the large mangrove-dominated estuary system

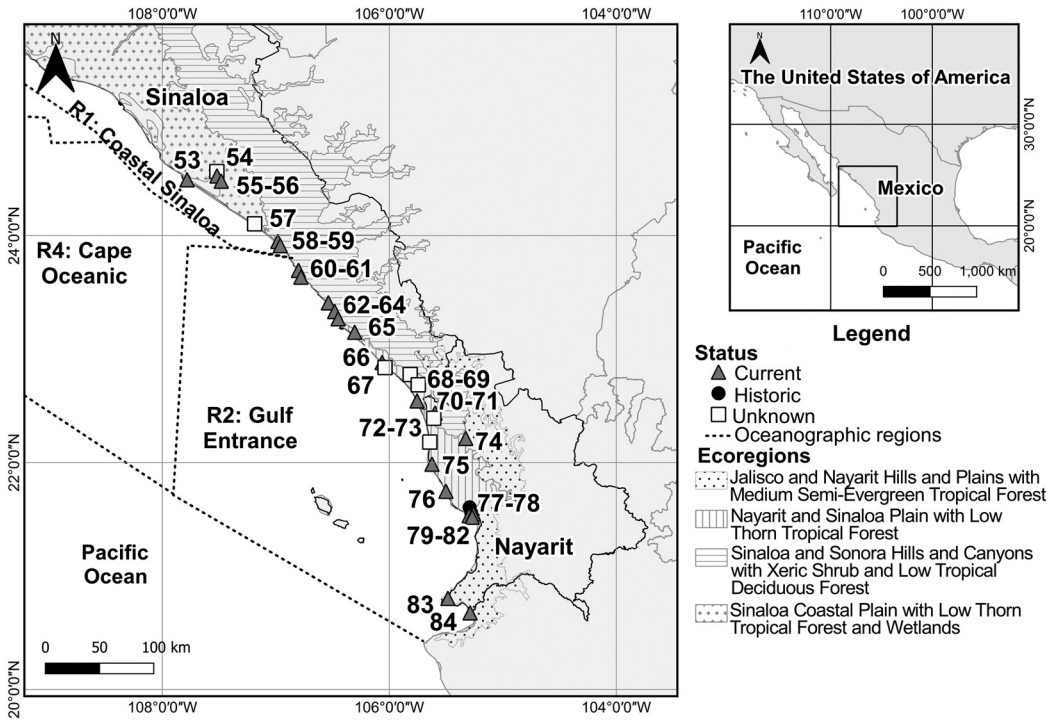

Figure 3. Map of the Lower Gulf of California showing the distribution and status (current, historic, unknown) of the Least Tern colonies, ecoregions, and oceanographic regions. Site numbers correspond to those in Table 1.

of the Marismas Nacionales and the mixing of currents at the mouth of the Gulf of California (Fig. 3). The Gulf Entrance has a mixing of warmer tropical surface water of the Mexican Coastal Current, with the Banderas eddies and the clockwise rotating eddies at the Gulf Entrance. This contributes to higher Chlorophyll-a concentrations further from the coast in this region (López Martínez *et al.* 2023). Along the coast are long, sandy beaches backed by dunes with large river mouths that connect the ocean with the flooded plains. Aquaculture, particularly shrimp ponds, encroach into the wetlands. Little is known about the Least Tern's breeding distribution here. This area is the northern wintering limit of Least Terns (Ryan and Kluza 1999).

The *Central Gulf South* (Region 6) is a rocky shoreline with numerous topographic features creating small sandy beaches, where ephemeral washes meet the shore and at peninsulas, bays, and protective offshore islands. Despite suitable sandy beaches, no known Least Tern colonies exist until the broad, shallow Magdalena Plains meet the Gulf of California at the Ensenada de La Paz (Fig. 2). The west side is cooler, foggier, and influenced by the California Current. The Gulf side has numerous intermittent streams and little permanent water besides small spring-fed ponds and streams. This area has a winter-spring (December to April) bloom period and a summer non-bloom period (July to October). However, on the west side of the Gulf, weak southern winds can generate mild upwellings, which are opposite the east side of the Gulf. Several eddies with both clockwise (downwelling) and counterclockwise (upwelling) rotations occur year-round on the southern boundary of this region adjacent to La Paz (López Martínez *et al.*, 2023).

The *Cape Oceanic Region* (Region 4) is at the southern end of the Baja California Peninsula, extending from the East Cape to the confluence with the Pacific Ocean in the Los Cabos region (Fig. 2). Heavy seasonal rainfall, tropical storms, and hurricanes heavily influence watercourses, creating large alluvial fans, some with associated dunes and estuaries. Like the Central Gulf South, weak southern winds can generate mild upwellings in summer. In late summer and early fall, the clockwise rotation of hurricanes can generate upwellings. However, typically, there are clockwise (downwelling) eddies offshore that contribute to the retention of higher Chlorophyll-a concentration in waters farther from the coast (López Martínez *et al.* 2023).

Field Surveys and Data Collection

Least Tern survey frequency differed among colonies. Some colonies were visited once a week or more, occasionally (two or more times per season), or once during the breeding season (April through July). For 25 colonies without regular monitoring, we used observations reported by known reliable observers in eBird (eBird 2024). We filtered eBird reports by month (April to July) and only used observations of more than ten Least Tern individuals. We feel this is justified as these colonies are remote and not regularly monitored, but

Table 1. The colonies of the Least Tern in the Gulf of California. Superscript numbers refer to location numbers on Figures 1-3. Status for the last five-year period, the last year when it was active, maximum adult count, the year of that count, and the average adult count is given for each colony. SE is the standard error of the mean; N [number of survey years]. * For *current* colonies, with one count, that count was used in place of the average.

Biological/Oceanographic Region	State	Colony	Status	Last Active	Max Adult Count	Year	Average* Adult Count 2019-23 *(SE, N [Years])*
Region 5 - Upper Gulf/ Sonoran Desert	Baja California	Isla Montague[4]	Current	2022	77	2022	77 (0.0, 1)
		Esteros La Bolsa[3]	Unknown	1992	22	1992	-
		Punta Estrella[2]	Current	2023	23	2023	23 (0.0, 1)
		Laguna Percebú[1]	Current	2023	74	1992	40 (0.0, 1)
	Sonora	Flor del Desierto[5]	Current	2021	32	2021	13 (7.8, 3)
		El Doctor[6]	Historic	1994	8	1994	-
		Golfo de Santa Clara[7]	Current	2021	70	2021	25 (10.9, 5)
		El Tornillal[8]	Current	2023	54	2022	31 (11.9, 3)
		San Judas[10]	Current	2019	7	2019	7 (0.0, 1)
		La Salina[9]	Current	2022	45	2022	25 (14.1, 2)
		Cerro Prieto[11]	Unknown	2007	18	2006	-
		La Cholla[12]	Current	2023	15	2023	8 (2.9, 3)
		Estero Morúa[13]	Current	2023	62	1996b	28 (6.7, 3)
		Estero La Pinta[14]	Current	2023	16	2023	16 (0.0, 1)
		Estero San Jorge-La Purinera[15]	Current	2023	550	1995	322 (51.17, 5)
		San Francisquito[16]	Current	2022	72	1992	8 (0.0, 1)
		Los Tanques[17]	Historic	2016	20	2016	-
		Punta Lobos[18]	Current	2023	50	2023	30 (13.8, 2)
		Punta Perla[19]	Current	2023	12	2023	12 (0.0, 1)
		Laguna La Cruz[20]	Current	2022	190	2022	57 (30.2, 5)
		Estero Cardonal[21]	Current	2023	210	2010	35 (11.1, 4)
		Estero Tastiota[22]	Current	2021	71	2014	15 (3.2, 2)
Region 3 - Central Gulf North/Sinaloa Coastal Plain	Sonora	Estero El Soldado[23]	Historic	1992	30	1992	-
		Barra Río Muerto[24]	Current	2022	48	2021	33 (10.6, 2)
		Salina de Lobos[25]	Current	2022	48	2021	43 (3.7, 3)
		Estero San Jose[26]	Current	2019	82	1994	10 (0.0, 1)
		Estero Tóbari[27]	Current	2023	204	1994	66 (24.2, 3)

Continued

Table 1.— Continued

Biological/Oceanographic Region	State	Colony	Status	Last Active	Max Adult Count	Year	Average* Adult Count 2019-23 *(SE, N [Years])*
		Bahia Yavaros[28]	Current	2022	10	2020	7 (1.1, 3)
		Bahia Agiabambo[29]	Current	2022	18	2022	18 (0.0, 1)
Region 1 - Coastal Sinaloa/ Tropical Dry Forest	Sinaloa	Punta de La Aguililla[30]	Unknown	2003	6	2003	-
		Isla Santa María, Topolobampo[31]	Current	2020	160	2020	160 (0.0, 1)
		Isla El Rancho, Bahía Santa María[32]	Unknown	2012	56	2012	-
		Granja Don Armando, La Reforma[33]	Current	2023	60	2023	45 (27.2, 2)
		El Molino, Bahía Santa María[34]	Current	2022	37	2022	33 (2.8, 2)
		Costa Azul/Isla Melendres[35]	Unknown	2011	96	2011	-
		Punta Yameto, Bahía Santa María[53]	Unknown	2002	196	2002	-
		La Pichihuila[54]	Unknown	2003	160	2003	-
		Estero Escopampa[55]	Current	2023	37	2023	25 (5.0, 3)
		Acuícola Chapeteato, Ensenada Pabellones[56]	Current	2023	40	2023	46 (4.2, 2)
		La Boquita (Cospita) [57]	Unknown	2003	57	2003	-
		Ensenada Pabellones[58]	Current	2023	80	2023	80 (0.0, 1)
		Salina de Playa Ceuta[59]	Current	2023	422	2011	94 (20.8, 5)
Region 2 - Gulf Entrance/ Tropical Wet Forest	Sinaloa	Boca del Río Piaxtla[60]	Current	2024	8	2024	6 (0.0, 1)
		Estero Tinajas/Meseta de Cacaztla[61]	Current	2023	84	2003	5 (1.1, 2)
		Estero Guayabal[62]	Current	2022	50	2022	50 (0.0, 1)
		Estero La Escopama[63]	Current	2023	12	2022	8 (1.7, 3)
		Marina EL Cid, Mazatlan[64]	Current	2021	160	2003	18 (2.3, 3)
		Granja Don Jorge, Mazatlán[65]	Current	2023	34	2023	25 (6.7, 2)
		Agua Verde - Caimanero[66]	Current	2022	7	2003	5 (0.0, 1)
		Boca de Mahaua[67]	Unknown	2003	160	2003	-
		Bahia Escuinapa-Teacapán[68]	Unknown	2003	4	2003	-
		Palmito del Verde[69]	Unknown	2003	2	2003	-
		Barra de Teacapán[70]	Current	2019	175	2003	12 (0.0, 1)
	Nayarit	Laguna Las Garzas/Pericos[71]	Current	2024	120	2019	63 (40.7, 2)
		Lago El Chumbeño[72]	Current	2024	90	2024	56 (17.0, 2)
		Santa Cruz de la Haciendas[73]	Current	2023	35	2023	18 (6.9, 3)

Continued

Table 1.— Continued

Biological/Oceanographic Region	State	Colony	Status	Last Active	Max Adult Count	Year	Average* Adult Count 2019-23 *(SE, N [Years])*
		Tecuala[74]	Unknown	2003	15	2003	-
		Boca de Camichín[75]	Current	2021	15	2003	11 (0.0, 1)
		San Blas - Chacalilla Shrimp Ponds[76]	Historic	2013	10	2013	-
		San Blas - Conchal Shrimp Ponds[77]	Historic	2015	5	2015	-
		San Blas - Playa del Rey[78]	Current	2024	55	2022	55 (0.0, 1)
		San Blas - Mirador[79]	Current	2024	50	2007	15 (0.0, 1)
		San Blas Paradero Marismas[80]	Current	2024	50	2023	50 (0.0, 1)
		San Blas - Punta Obsidiana[81]	Current	2020	100	2016	6 (0.0, 1)
		Boca de Cuautla[82]	Unknown	2003	40	2003	-
		Higuera Blanca[83]	Current	2022	10	2001	2 (0.0, 1)
		Boca de Tomates[84]	Current	2024	56	2021	48 (5.7, 2)
Region 6 - Central Gulf South/ Sonoran Desert	Baja California Sur	Playa Mogote – Zacatecas[36]	Current	2022	142	2002	13 (2.12, 2)
		El Comitán-CIBNOR[37]	Current	2023	6	2023	6 (0.0, 1)
		El Centenario[38]	Current	2023	50	2023	27 (11.4, 3)
		Chametla - Zacatal[39]	Current	2023	198	2002	25 (8.3, 4)
		Fidepaz[40]	Historic	2002	134	1989	-
		Islotes Afegua[41]	Historic	2017	326	1985	-
		San Juan Nepomuceno[42]	Current	2023	150	2023	64 (25.9, 4)
		Punta Arena de La Ventana[43]	Historic	2002	12	2002	-
Region 4 - Cape Oceanic Region/ Baja Californian Desert	Baja California Sur	La Ribera[44]	Current	2023	200	2020	106 (43.0, 4)
		Punta Arena del Faro[45]	Current	2022	99	2022	50 (23.3, 3)
		Las Barracas, Cabo Pulmo[46]	Historic	2003	40	2003	-
		Los Frailes, Cabo Pulmo[47]	Historic	2003	4	2002	-
		El Medano[48]	Current	2019	98	2019	32 (0.0, 3)
		Boca del Salado[49]	Current	2023	30	2023	30 (0.0, 1)
		La Laguna[50]	Current	2023	40	2019	31 (3.3, 5
		Estero San José[51]	Current	2023	180	2020	136 (30.5, 5)
		La Playa[52]	Current	2023	25	2019	18 (2.8, 5)

Table 2. Regional summaries of Least Tern nesting populations in the Gulf of California 2019-23. We provide the sum of the average adult count and maximum adult count for each region, the number of colonies in the region, the number of total counts made at colonies in the region, the number of counts per colony (2019-23), and the average and median colony sizes for each region.

Region	Sum of Average	Max Adult Count	No. of Colonies	Colony Counts	Count/Colony 2019-23	Average Colony Size	Median Colony Size
Region 5 - Upper Gulf	773	1235	22	46	2.09	59.4	24
Region 3 - Central Gulf North	178	244	7	13	1.86	34.2	18
Region 1 - Coastal Sinaloa	483	595	13	16	1.23	64.5	46
Region 2 - Gulf Entrance	452	576	25	29	1.16	25.4	12
Region 6 - Central Gulf South	135	271	8	14	1.75	33.6	24
Region 4 - Cape Oceanic	403	622	9	26	2.56	66.4	36
Gulf of California Totals	2424	3543	84	143	1.68	49.2	29

for which adult counts were available from these observers. Two observations from BC and BCS were confirmed with the observers. Most observations from SON and SIN were from biologists working on different waterbird monitoring projects in the region. For historical colony counts we used previously published records from Castillo-Guerrero *et al.* (2014), Cruz-Lopez *et al.* (2011), Del Viejo *et al.* (2004), eBird (2024), Fleishman and Blinick (2011), González-Medina *et al.* (2009), Mellink and Palacios Palacios (1993), Muñoz del Viejo and Vega (2002), Palacios and Mellink (1996 and 2003), Rosemartin and van Riper III (2011), and Zuria and Mellink (2002, 2005).

To determine if there was a movement of California Least Tern individuals from the Pacific coast into the Gulf of California, we searched for bands in the Least Tern colonies located in the Gulf of California. Biologists in California banded 63,353 California Least Tern chicks between 1988 and 2019 (BBL 2023). We estimate that 21,834 individuals fledged (Ryan and Heyne 2020). In addition, since 2012, we banded 1,202 Least Terns in California with white and green alphanumeric bands and 367 in BC and BCS with red alphanumeric bands. In 2022 and 2023, we visited colonies in SON and SIN and deployed small 5x5 cm video cameras at 236 nests. Cameras were placed approximately 25 cm from the nest cup and remained for 10 minutes or sooner if the adult returned. We then reviewed the video to determine the band status of each adult. Approximately 20% of adult Least Terns are observed in California colonies with bands (Ryan and Heyne 2020). We propose that if there were a large movement from California to the Gulf of California, these banded terns would be observed at nesting sites here.

Sites visited were reached by car, boat, and foot. Adult counts were made using binoculars and cameras by scanning and photographing flying and roosting flocks and counting adults in the air during flush events, and when multiple counts were made, we used the maximum count. Alternatively, if no adult count was available and a nest count was available, we conservatively estimated the number of adults present by multiplying the number of nests by two. We used adult counts instead of pairs or nests because colonies were often visited infrequently and often once per year. Nest counts are highly variable during the nesting season due to nest timing and nest loss due to predation and other causes.

We mapped nesting colonies using hand-held GPS at colonies visited or Google Earth aerial images and either the observer or someone familiar with the colony location to obtain exact coordinates. These were then mapped using ArcGIS. Polygons for the terrestrial bioregions were downloaded from (http://www.cec.org/north-american-environmental-atlas/terrestrial-ecoregions-level-iii/), and polygons for the oceanographic clusters were created on Google Earth from maps provided by López-Martínez *et al.* (2023). Distances between colonies were generated from the center point of the colony using ArcGIS.

Data Analysis

To obtain population estimates and ranges, we used the maximum adult count, the year recorded, the average adult count with the standard error of the mean (SEM), and the number of counts (N) at each colony (Table 1). We categorized colonies as being "Current" if adults and nests have been documented since 2019 (within five years), "Unknown" (UNK) if either the colony had been active with nests detected before 2019 but not surveyed since, or for colonies where only adults were observed, but no nests located, and "Historic" if the colony was visited in the past five years, and if it is no longer active or developed. This study combines multiple sub-colonies within the same estuary system into one colony. This differs somewhat from Palacios and Mellink (1996), who separated colonies in different regions of an estuary to compare the number of colonies active. We also report regional summaries that include the sum of the average and maximum adult count, the average colony size, and the median colony size (Table 2).

We used generalized linear mixed models (GLMM; Zuur *et al.* 2009) to estimate temporal trends in abundance. For all analyses, our sampling unit was the colony count for each survey year. For example, a given colony with six years of surveys was equal to six "colony-years." To analyze temporal trends in the Least Tern breeding population, we included a subset of 27 colonies with four or more surveys from 2000 to 2023 (Table 3), which produced a sample size of 158 colony-years. We estimated the

Table 3. Coefficient estimates (β) for year effects and estimated percent change per year (exp(β)− 1)*100) for Least Tern colonies in the Gulf of California and in the subareas of La Paz and Cape region, based on survey data during 2000–2023. Results are shown overall for the Gulf of California and by subarea. Trends that were significant according to 95% CIs are bold.

Subarea	No. of Colonies (colony/years)	Slope β (% change)	95 % CI (% change)
Gulf of California (Regions 1-6)	27 (158)	**−0.0310 (−3.1)**	**−0.0563, −0.0057 (−5.5, −0.6)**
Central Gulf South	4 (20)	**−0.040 (−3.9)**	**−0.0890, 0.0010 (−7.8, 0.1)**
Cape Oceanic	5 (24)	0.0160 (1.6)	−0.0741, 0.1060 (−7.1, 11.2)

Least Tern breeding abundance trend overall for the Gulf of California and the La Paz and Los Cabos regions by using survey year as a covariate and a random effect of the sampling unit (colony) in three separate models (Table 3). Other regions had insufficient counts to estimate regional population trends. We defined an ordinal year as the number of each survey year (i.e., year 1 = 2000, year 2 = 2001,., ., year 24 = 2023). Since the Least Tern abundance distribution was "overdispersed," we assumed a negative binomial distribution. We considered estimates of model parameters where the 95% confidence intervals (CI) did not overlap 0 to be significant. All analyses were performed in RStudio (R Development Core Team, 2020) using the programming language R version 4.0.0 (The R Foundation for R Development Core Team Computing 2020). Models were fitted using the maximum likelihood estimation via 'the glmmTMB' package, specifying the distribution family as "nbinom2" (Magnusson *et al.*, 2017).

RESULTS

We documented 84 nesting colonies across the Gulf of California from 1985 to 2023. Seventy-three percent (61 out of 84) were current Least Tern colonies occupied during the last five years, 12% (10 out of 84) were historical nesting sites (extirpated colonies), and 15% (13 out of 84) were unknown. Based on the sum of average counts and the maximum adult counts made at nesting colonies between 2019 and 2023, we estimated that the average annual population of Least Terns breeding in the Gulf of California to be 2,424–3,543 adults breeding (Table 2) in 61 current nesting colonies (Table 1). The average colony size in the Gulf of California was 49 adults, and the median colony size was 29 adults (Table 2). However, these estimates are based on various counting methods and varying survey frequency. The most frequent colony surveys were conducted at nesting colonies in the Upper Gulf (2.1 counts/5 years) and Cape Oceanographic Regions (2.6 counts/5 years) and the least frequent in Coastal SIN (1.2 counts/5 years) and the Gulf Entrance (1.2 counts/5 years; Table 2).

Distribution of Nesting Colonies

The highest densities of nesting colonies were concentrated at the Gulf Entrance (Figure 3) and the northernmost, mostly south-facing coast of the Upper Gulf (Fig. 1). Although they had smaller coastlines, colonies were clustered around the Ensenada de La Paz in the Central Gulf South and the Cape Regions (Fig. 2). There were relatively few colonies away from coastal lagoons in the southern part of the Upper Gulf and the Central Gulf North (Figs. 1 and 2). There were no known colonies along the west shore of the Gulf on the Baja California Peninsula from Laguna Percebú (Colony 1) to the Ensenada de La Paz (Colony 68; Figs. 1 and 2).

The Upper Gulf (Region 5) supported the largest population of Least Terns in the Gulf of California, with an average count of 772.7 adults (Max = 1,235) at 18 *current* colonies (Tables 1 and 2). The average colony size of 59 adults was larger than the median count of 24 adults (Table 2). The difference was mainly due to the largest colony in the Gulf at Bahía San Jorge/La Purinera, which averaged 323 adults, or 43% of the region total and 13% of the Gulf total. Large counts were recorded at Laguna La Cruz (190 adults) and Estero Cardonal (210 adults). Colonies at Punta Estrella and Laguna Percebu were considered current due to amateur observers' recent counts of large numbers of adults in suitable nesting habitats in nesting season. However, nesting here was not confirmed. Large areas of the Colorado River Delta, Bahia de Adair, and Cerro Prieto were not visited,

but suitable habitat was available, and there may be additional colonies.

The Central Gulf North (Region 3) supported an average of 178 adults (max = 244) at six *current* colonies. The average colony size was 34 adults, and the median was 18 (Tables 1 and 2). The largest nesting colony was at Estero Tobari, which averaged 67 adults (max = 204). This colony was a series of subcolonies on dredge spoil islands and the adjacent mainland. Estero Soldado was a colony that was heavily disturbed in the past but is currently within a protected area under restoration. Large areas in this region are poorly known, and additional colonies may occur in the extensive lagoons and associated barrier islands.

Coastal Sinaloa (Region 1) supported seven *current* colonies, with another six of unknown recent status. Based on little or no recent land development at the colonies, the six unknown colonies were likely *current* but have not been visited recently. We report an average of 483 adults (max = 595) in this region between 2019–2023 (Table 1). The average colony size was 65 adults, and the median was 46 (Table 1). The average and median difference was due to large colonies at Isla Santa Maria, Topolobampo, Ensenada Pabellones, and Salina de Playa Ceuta (Tables 1 and 2). However, colonies in this region were infrequently surveyed. Like the Central Gulf North, many parts of the large estuaries and barrier islands were rarely visited and may support additional unknown colonies. The Salina de Playa Ceuta was an exception, where researchers studied nesting Snowy Plovers and Least Terns.

The Gulf Entrance (Region 2) supported 18 *current* colonies, two *historic* ones, and an additional five of unknown status (Tables 1 and 2). The average count was 452 adults (max = 576) between 2019 and 2023. The average colony size was 25 adults, and the median was 12 (Tables 1 and 2). However, this was likely an underestimation because this area was infrequently surveyed and little known, particularly within the Marismas Nacionales between Teacapan, SIN, and San Blas, NAY. Known colonies were mostly near access roads and settlements with access by road, levee, and boat. There were vast areas that had not been assessed. Additionally, large colonies near both Mazatlán and Puerto Vallarta were threatened by development and recreation.

All known colonies in the Central Gulf South (Region 6) were on the west shore of the Baja California Peninsula near the Ensenada de La Paz (Figure 2). This region supported five *current* colonies and three historic ones. These colonies averaged 135 adults (max = 271). The average colony size was 34 adults, and the median was 24 (Tables 1 and 2). The terns in this region appeared to shift colonies regularly, with the largest colony shifting from Islotes Afegua to Playa Mogote and Chametla, and currently at San Juan Nepomuceno (Table 1).

Region 4 - Cape Oceanic. The Cape Region supported seven *current* colonies and two historic ones. This region averaged 403 adults (max = 622). The average colony size was 66 adults, and the median was 36 (Tables 1 and 2). The largest colonies were La Ribera and Estero San Jose. However, their nesting area at La Ribera has changed from an area that was developed as a heliport to a second constructed site that was elevated and leveled for housing. When this second area was developed, the terns abandoned the colony. Colonies in the Los Cabos region, including the Estero San Jose, are impacted by development and recreation, especially from off-road vehicles.

Population Trends

From 2000 to 2023, we analyzed 27 nesting colonies and 158 colony-years (Table 3). There was a −3.1% annual negative region-wide population trend in the Gulf of California's Least Tern breeding population. However, with the incomplete and sporadic counts, we recommend caution in this interpretation. The Central Gulf South (Ensenada de La Paz) also had a −3.9% annual negative trend, and the Cape Region was stable (Table 3). We suggest that more consistent surveys be conducted and trends be revisited once that is accomplished.

Connectivity

We deployed nest cameras at 236 nests at six colony sites in Sonora and Sinaloa in 2022 and 2023 (Table 4). Of these, we determined the

Table 4. Results of band-reading efforts at nesting colonies in Sonora and Sinaloa in 2022 and 2023. Did not return indicates that no adult returned while the camera was recording, AN = alphanumeric band, and UNK indicates that we were unable to determine band status from the video recording.

Colony	Did Not Return	No Band	USGS/Metal Band	AN Band	UNK	Total Observed
Estero Morua	4	17	0	0	2	23
Bahía San Jorge	12	79	0	0	2	93
Estero Cardonal	2	5	0	0	0	7
Salina Los Lobos	0	11	0	0	0	11
Estero Tobari	4	27	0	0	1	32
Salina de Playa Ceuta	21	49	0	0	0	70
Total	**43**	**188**	**0**	**0**	**5**	**236**

banding status for 188 adults definitively, five were not definitive (unknown banding status). We deployed cameras at an additional 43 nests where adults did not return while the camera was present (Table 4). We did not observe any USGS bands or alphanumeric bands using the camera surveys or any bands during casual observations.

DISCUSSION

In this paper, we provide an overview of the current breeding status of the Least Tern on both coasts of the Gulf of California. The estimated 2,424–3,543 breeding adult Least Terns were distributed at 61 nesting colonies along a stretch of approximately 4,500 km coastline (Tables 1 and 2). Most colonies were relatively small, consisting of an average of 49 adults or 24 pairs. Colony sizes in the Upper Gulf, Coastal Sinaloa, Gulf Entrance, near La Paz in the Central Gulf South, and Los Cabos in the Cape Region were larger than in other regions (Figs. 1–3). In contrast, an average of 8,185 adults (~4000 pairs) of the Endangered California Least Tern occur at 31 colonies along a 1,200-mile section of the California and BC coast between San Francisco and San Quintin. The mean colony size is 275 adults, with a median of 108 (CDFW 2023). However, these 31 colonies are surveyed annually with multiple visits, some biweekly (CDFW 2024). In contrast, most colonies in the Gulf of California are only visited occasionally, with few outside BC and BCS having regular monitoring surveys.

Our surveys show that nearly all colonies within the Gulf of California are smaller and more dispersed than the current distribution pattern in the California Least Tern. The Gulf of California tern density and population size are also smaller. There are notable exceptions, with large colonies that in some years reach nearly 200 to upwards of 550 individuals at Bahía San Jorge, Laguna La Cruz, Estero Cardonal, Estero Tobari, Punta Yameto, Salina de Playa Ceuta, Barra de Teacapan, Chametla, Islotes Afegua, La Ribera and Estero San Jose (Table 1). However, colony size at most sites fluctuates considerably; some sites are often below 100 adults, and some nesting colonies have not been used in some years.

Additionally, since 1985, most colonies in coastal California have been protected by barrier fences, active predator control, or both (CDFW 2024), thereby reducing predation. Nest predation pressure can be high for ground-nesting seabirds. Several studies have shown the positive effect of colony size against predation (Götmark and Anderson 1984; Wittenberger and Hunt 1985; Brunton 1999). Colonial nesting is an adaptation that reduces predation through mobbing and produces a superabundant and concentrated food source (Götmark and Anderson 1984; Wittenberger and Hunt 1985; Brunton 1999). Brunton (1999) demonstrated this to be the case against herons; however, they detected increased predation by gulls and corvids with larger colony sizes. The primary predators of Least Tern eggs and chicks in the Gulf of California detected during our surveys were coyotes (*Canis latrans*), feral dogs (*Canis lupus familiaris*), Common Raven (*Corvus corax*), American Kestrel (*Falco sparverius*), raccoons (*Procyon lotor*), white-nosed coatimundi (*Nasua narica*), striped skunks (*Mephitis mephisits*), domestic cat (*Felis catus*), and snakes.

Colony size may be a disadvantage because some nest predators are likely attracted by higher nest densities (more food) and are less deterred by mobbing adults. Additionally, the relatively small size of the Least Tern eggs may negate the effect of predators becoming satiated (Nisbet 1975), particularly one as large as a coyote or feral dog. Combined, these effects may explain the smaller colony sizes in the Gulf of California, where management to reduce nest predation is mostly nonexistent.

We found a significant negative trend in the breeding population of Least Tern in the Gulf of California and the Central Gulf South. In contrast, the Least Tern breeding population seems stable in the Cape Region (Table 3). Although smaller and more dispersed, the population of Least Terns in the Gulf of California shows a significant negative trend of −3.1% per year (Table 3). This is a smaller decline than the nearby California Least Tern population in northern BC and California of −5.4% annual decline (56% decline total) from 2008 to 2023 (CDFW 2023). California Least Terns are known to forage during the nesting season in the California Current and Southern California Countercurrent within the Pacific Ocean (Atwood and Minsky 1983; Baird *et al.* 1997). However, Pacific and Gulf of California populations share similar wintering areas (Morales Flores 2024), and based on separate observations of Least Tern marked with alphanumeric bands and MOTUS tags moving from coastal California and BC to the Upper Gulf, at least some likely share similar southerly migration routes. This indicates that the Least Tern is declining across multiple regional populations. With both populations declining, it is not likely that the observed declines can be attributed to dispersal because emigration from one area would show as a concomitant immigration-related population increase in the other area, nor is there anything to suggest that emigrants from both areas are dispersing farther south or to some unknown nesting region. However, it should be noted that no least tern chicks have been banded on the east coast of the Gulf of California, and chick banding on the Baja California Peninsula began in 2019. Therefore, it is currently unlikely that we can detect the movement of terns from the Gulf of California to coastal California.

Further, this study demonstrates conclusively that the Gulf of California region has not seen a population increase that would correspond to the size of the population decline documented in the nearby California Least Tern population. Surveys conducted in all regions (except Region 2) in 2021–23 found no Least Terns banded in California were detected at any nesting colonies in Regions 1, 3, 4, 5, or 6 in the Gulf of California. More locally in BCS, no Least Terns marked in the Cape Region were detected in the Central Gulf South, or those marked in the Central Gulf South were detected in the Cape Region. Ryan and Heyne's (2020) findings support this in that <10% of marked Least Terns move > 90 km from their natal colony. This indicates that there is no large-scale movement among these regions. Therefore, the declining populations in California cannot be attributed to a breeding distribution shift to the Gulf of California. Further, the lack of observations of banded Least Terns within nesting colonies in the Gulf further suggests that these two populations are reproductively isolated. Differences in the oceanographic conditions indicate that they are ecologically isolated as well. The combination of separate population trends and little connectivity supports the California Least Tern as a distinct population unit from the Gulf of California population. We encourage further study into the region's population and genetic connections among breeding colonies.

We conclude that Least Terns nesting in the Gulf of California are more dispersed than on the Pacific Coast of California, occur in smaller colonies, occur in a larger number of colonies, and those colonies are more ephemeral than those in California, which are restricted to fewer, highly protected colonies by extensive coastal development. However, both are experiencing declines. The California Least Tern, while better protected, are also confined to fewer, highly managed colonies, most near large urban areas. They are declining more rapidly. Both populations experience increased predation from human-associated mammalian and avian predators.

The California Least Tern may also be experiencing issues with prey availability based on observations of chick die-offs associated with localized warm-water events (G. Ibarguchi *pers. comm, unpubl. data*; T. Ryan *unpubl. data*).

We acknowledge significant gaps in our knowledge of the distribution and current status of populations in Regions 1 and 2 (Table 1, Figs. 2 and 3). Ten colonies here have not been visited in the past five years, and there is a strong likelihood of undocumented colonies in these regions, particularly in the Marismas Nacionales. Due to dedicated researchers and regional volunteers, colonies on the southern Baja California Peninsula in Regions 4 and 6 are regularly visited several times during the nesting season. However, with few exceptions at Golfo de Santa Clara, El Tornillal, Bahía San Jorge, Laguna La Cruz, Estero Cardonal, Salina de Lobos, and Estero Tobari, most colonies in Regions 3 and 5 are visited once annually or only occasionally during the nesting season. This reduces confidence in trend analysis due to variable effort and lack of surveys. We recommend regular, regionwide surveys of *current* and *unknown* colonies in future years to improve confidence in trends.

Threats to the existing nesting population in this region include coastal development and the associated off-road recreation near these cities. Within the broad coastal plains of northwest México lagoons and adjacent wetlands have been converted into agricultural lands, aquaculture, and salt evaporator ponds. We documented several colonies that are not occupied due to human development. With these developments comes an increase in the local native mesopredators, such as coyotes and common ravens, as well as feral dogs and cats, which can increase predation on eggs, chicks, and adults. Increased coastal flooding associated with sea level rise regularly floods nesting areas on sand bars and uplands adjacent to lagoons.

Local researchers and volunteers regularly monitor colonies at Golfo de Santa Clara, Estero Morua, Bahía San Jorge, Estero Tobari, Salina de Playa Ceuta, Boca de Tomates on the east shore, and colonies in the La Paz and Los Cabos municipalities on the west shore. Very few colonies have any signage, fencing, or indication that there is a nesting area. There is no regular predator control. Funding for these groups is not secure. The remaining colonies have no regular monitoring or any management whatsoever. Several colonies are within private lands including active aquaculture and salt evaporator roads, and they are afforded some protection by the limited activities here. Innovative partnerships organized by SyCOMA with some hotels in Los Cabos have also provided protection and opportunities for guests to view wildlife.

Conservation priorities should include increased monitoring and protection of the larger, more stable, and smaller colonies near existing community conservation groups that are accessible but most vulnerable to nearby development. Protections should be coordinated with local groups, including community outreach, signage, seasonal or permanent fencing, reduction and removal of waste, and removal/adoption of feral domestic animals, as well as impacts unique to the local colony. On the east shore, these include Isla Montague, Golfo de Santa Clara, El Tornillal, Estero Morua, Bahía San Jorge, Laguna La Cruz, Estero Cardonal, Estero Tobari, Ensenada Pabellones, Salina de Playa Ceuta, Marina el Cid, Laguna Las Garzas, Lago El Chumbeño, Punta Obsidiana, and Boca de Tomates. On the west shore, important colonies include Playa Mogotes, Chametla, San Juan Nepouceno, La Laguna, and Estero San Jose. Additionally, there are several *historic* colonies, but Least Terns have not been present in recent years. This includes colonies that have been developed, but there may be opportunities to provide alternate colonies nearby. These colonies include La Salina, Los Tanques, Estero El Soldado, Islotes Afegua, and La Ribera. Finally, there are large areas of suitable habitat in coastal southern SON, SIN, and NAY, where little or no information is currently available. We recommend that an effort to identify and survey potential nesting colonies, including suitable habitats near river mouths, openings between barrier islands, vegetation-free salt pannes, active and abandoned levees, levee roads, salt evaporator, and aquaculture ponds, and dredge spoil islands in this region. These

efforts may be coordinated with larger surveys of local shorebirds and waterfowl already occurring at some of these colonies.

Based on these findings, we recommend improved systematic monitoring of the population. Specifically, we suggest that due to the large geographic areas and costs involved, each region selects five colonies with regular attendance and attempts to visit them at least once monthly during the nesting period (April–July/August). We suggest El Tornillal, La Salina, Estero Morua, Bahía San Jorge, Estero Santa Cruz, Estero Cardonal, Salina de Lobos, Estero Tobari in SON; Isla Santa Maria, Isla Melendres, Punta Yameto, Ensenada Pabellones, Salina de Playa Ceuta, in SIN; and Barra de Teacapan, Laguna Las Garzas, San Blas, and Boca de Tomates in NAY. This would provide a more complete population index to better base regional trends.

We recommend a better understanding of the degree of clustering and movements among colonies in the Gulf. This could be accomplished through population-level genetic analysis and increased use of field-readable alphanumeric bands on fledglings. Resighting from the latter would also provide needed estimates of productivity, survival to first breeding, annual adult survival, and potentially migration and wintering areas.

Finally, we recommend that the Least Tern be considered for Endangered status within México. This is based on the relatively small population documented, less than half the population of the Endangered California Least Tern, and long-term, sustained negative population trends, current threats from increased coastal development, and a substantial likelihood of increasing development with increasing human population in the future.

The most effective way to accomplish these goals would be to work with groups established in SON, BC, and BCS, establishing new monitoring networks along the coast of SIN and in the Marismas Nacionales. We also recommend working with these groups to determine the best, long-term, and sustainable manner in which site-specific additional protections can be provided for these nesting colonies.

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