

RANGE-WIDE CONSERVATION AND SCIENCE OF THE ASHY STORM-PETREL *OCEANODROMA HOMOCHROA*

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SUMMARY

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In February 2015, a special paper session about the range-wide conservation and science of the Ashy Storm-Petrel *Oceanodroma homochroa* (ASSP) was held at the Pacific Seabird Group annual meeting. The main goal was to share information amassed during the past 20 years on this species, which breeds almost entirely in California, United States, for formulating future research and conservation actions. One key result is the six papers on ASSP and two on Leach's Storm-Petrels *O. leucorhoa* in this issue of *Marine Ornithology*. In this introduction, we augment contributed papers with a summary of historic and recent knowledge about the ASSP breeding range, key conservation issues and data gaps. The largest breeding concentration is at the South Farallon Islands in central California, but four other concentrations occur in southern California at the Channel Islands (Prince, Santa Barbara-Sutil, northwest Santa Cruz and northeast Santa Cruz). Over the past two centuries, many ASSP breeding colonies have been affected by introduced mammals and human-altered breeding habitats. Population decline due to heavy avian predation has been documented at the South Farallon Islands since 1972; decline due to eggshell thinning from organochlorine pollutants is suspected in the Channel Islands since the 1950s. Eradication of introduced mammals, reduction of pollution and social attraction (vocalization broadcasting and artificial nest sites) have helped to restore population size at certain colonies.

Key words: Ashy Storm-Petrel, *Oceanodroma homochroa*, California Current, introduced predator, Leach's Storm-Petrel, *Oceanodroma leucorhoa*, organochlorine pollution, population decline, seabird restoration

INTRODUCTION

The Ashy Storm-Petrel *Oceanodroma homochroa* (hereafter, ASSP) is endemic to the California Current System (CCS) and breeds among the limited number of islands and coastal rocks available along the coasts of California, United States, and northwestern Baja California, Mexico, between 41°N and 32°N (Ainley 1995, Carter *et al.* 2008a, 2015a, Howell 2012). The global breeding population is only roughly known, as is true with most crevice- and burrow-nesting seabird species, and is currently thought to be about 5000 pairs, concentrated at five main breeding areas in central and southern California (Fig. 1). This storm-petrel has received increased attention since 1970, with much effort focused on its breeding biology, status, distribution and conservation. The species is considered endangered and declining by the International Union for the Conservation of Nature (IUCN 2015), and in Mexico it has been listed at the federal level as threatened. In 2002, the US Fish and Wildlife Service (USFWS) listed it as a Bird of Conservation Concern (USFWS 2002). In 2009 and 2013, USFWS also completed status reviews to evaluate its potential listing under the US *Endangered Species Act* but decided against doing so (USFWS 2009, 2013). The State of California considers it a Species of Special Concern (Carter *et al.* 2008a) but has not considered it for possible listing as threatened under the *California Endangered Species Act*.

Little peer-reviewed literature about ASSP has been produced since 1995, when the *Birds of North America* account was published

(Ainley 1995). To share more recently acquired knowledge about status, natural history, conservation and restoration from different parts of the breeding range and to promote publication of recent findings, a special paper session, "Ashy Storm-Petrel range-wide conservation and science," was held at the annual meeting of the Pacific Seabird Group in San Jose, California, on 20 February 2015. Three of nine presentations in that paper session are published in this issue of *Marine Ornithology* (Adams 2016, Becker *et al.* 2016, McIver *et al.* 2016), and two have been published elsewhere (Carter *et al.* 2015a, Nur *et al.* in press). In addition, two other papers about ASSP not presented at the meeting (Harvey *et al.* 2016, Mills 2016) and two others about Leach's Storm-Petrels *O. leucorhoa* (LESP) in southern California (Adams *et al.* 2016, Carter *et al.* 2016) are included in this issue. This group of peer-reviewed papers on ASSP and LESP will (1) assist researchers, agencies and private groups to understand and manage these species throughout the CCS; (2) contribute to future status assessments by federal and state agencies; and (3) help to guide future conservation efforts. As background for these papers, we summarize historical and current knowledge of confirmed breeding colonies and key conservation issues related to these colonies. In addition, we clarify locations with reported but unconfirmed breeding, occurrences near potential breeding habitats that may indicate undetected breeding, and areas where additional colony surveys are needed. A separate effort is underway to collate and analyze at-sea data, which will be useful in examining at-sea conservation issues (D.G. Ainley, unpubl. data).

BREEDING DISTRIBUTION

In the 1970s and 1980s, most of the world population of ASSP was thought to breed at the South Farallon Islands (hereafter, “Farallones”) in the central CCS. The species description in 1864 was based on specimens from the Farallones (Coues 1864), and breeding was first documented there in 1885 (Ingersoll 1886). Dozens of naturalists subsequently described nesting in rock crevices and human-constructed rock walls and other structures; burrows are not excavated in soil as in many other storm-petrel

species (see summaries in Ainley & Lewis 1974, Ainley 1995, Carter *et al.* 2008a). Breeding biology and long-term monitoring of natural history patterns, avian predation and trends in colony size have been studied at the Farallones since 1971 (Ainley *et al.* 1974, 1990a, Sydeman *et al.* 1998, Nur *et al.* in press).

Ironically, breeding by this species was first documented in the California Channel Islands (CCI) in 1875 at San Miguel Island (most likely Prince Island), 11 years earlier than at the Farallones (Henshaw 1876; Carter *et al.* 2016). Breeding was documented (i.e.,

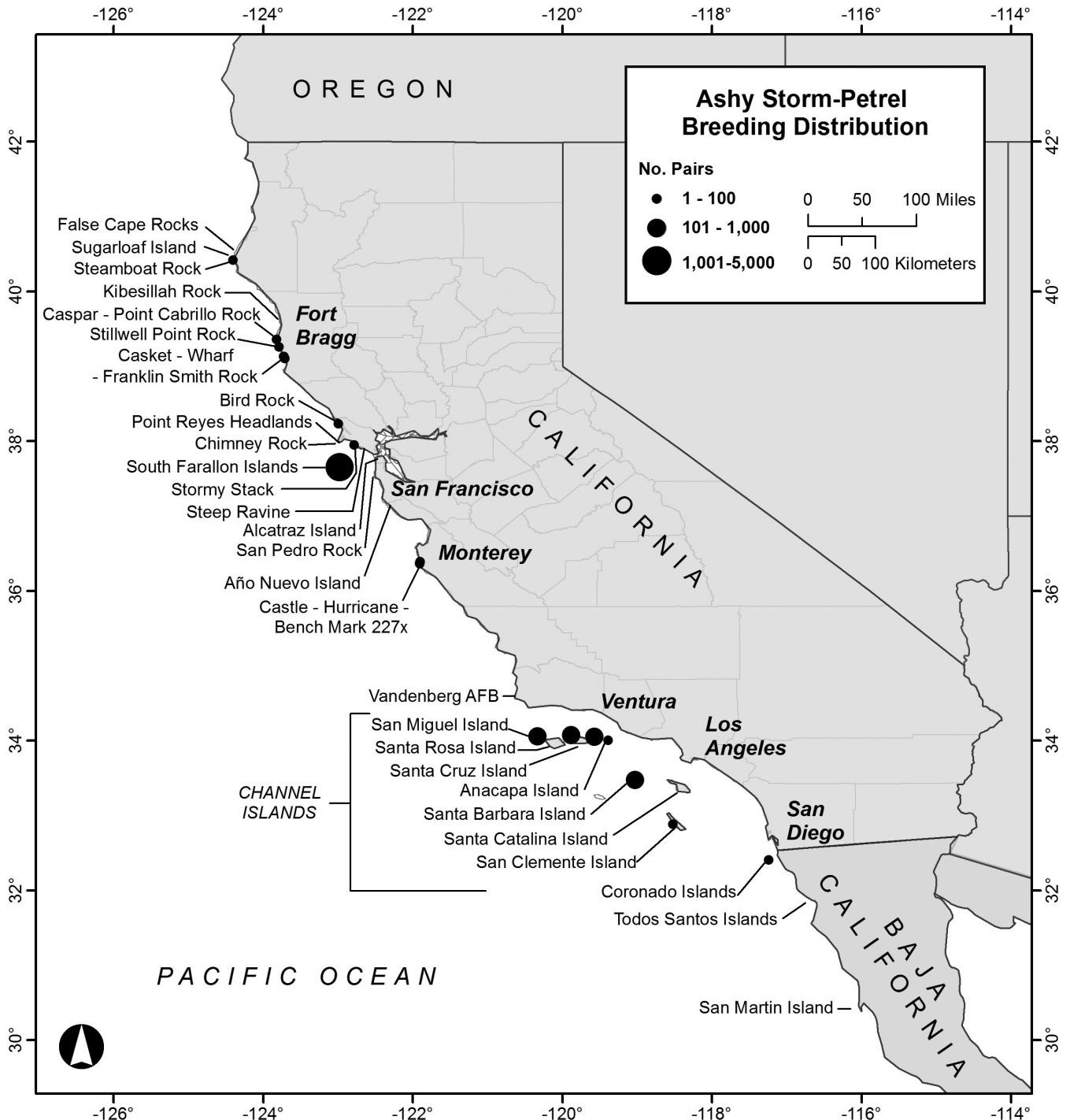


Fig. 1: Confirmed breeding locations (black dots) of the Ashy Storm-Petrel in California, United States, and Baja California, Mexico (updated from Carter *et al.* 1992, 2008a). Other locations mentioned in the text also are indicated.

eggs, chicks or incubating adults) at four CCI over a prolonged period: Santa Cruz Island — 1912 (Wright & Synder 1913); Santa Barbara Island (including Sutil Island) — 1976 (Hunt *et al.* 1979, 1980); San Clemente Island — 1996 (adult in incubating posture) and 2013 (adult incubating an egg; Carter *et al.* 2008a, 2009; Carter & Henderson 2015); and Anacapa Island — 2011 (Harvey *et al.* 2016). However, breeding was first suspected at Santa Barbara Island as early as 1904, when many ASSP came aboard the fishery research vessel *Albatross* anchored offshore (Miller 1936). At Santa Catalina Island, a historical ASSP breeding record (egg collected) exists for 1937 (Carter *et al.* 2008a), but was likely a nest of a misidentified dark-rumped LESP (Carter *et al.* 2016). ASSP also do not breed at San Nicolas Island. Among the CCI, long-term monitoring of natural history patterns, avian predation and trends in colony size have been in place at only five colonies at northwest and northeast Santa Cruz Island since 1995 (McIver 2002; McIver *et al.* 2009, 2016). At four of these colonies, ASSP nest within sea caves in rock crevices, in cavities beneath driftwood and in open sites (McIver 2002, McIver *et al.* 2016). At other CCI colonies, nests are in rock crevices on small rocks or islets or on steep slopes and cliffs on larger islands, and, to some degree, in empty Cassin's Auklet *Ptychoramphus aleuticus* burrows at Prince Island (Hunt *et al.* 1979; Carter *et al.* 1992, 2016).

CCI surveys in 1991 and 1994–1996 (Carter *et al.* 1992, H.R. Carter, unpubl. data) demonstrated that population size was higher than estimated in 1975–1977 (Hunt *et al.* 1979, 1980), although different techniques were used for population estimation at major colonies (see Adams *et al.* 2016). By contrast, the Farallones population was re-estimated in 1992 and thought to be smaller than in 1971–1972 (Sydeman *et al.* 1998), although, again, the re-estimate used a different technique than previously (Ainley & Lewis 1974). Since 1991 CCI surveys, about half of the world population has been considered to occur in the CCI, with concentrations at San Miguel (i.e., Prince Island and Castle Rock), Santa Barbara (mainly Sutil Island), northwest Santa Cruz (mainly Dry Sandy Beach Cave, Cave of the Birds' Eggs, and Orizaba Rock), and northeast Santa Cruz islands (mainly Bat Cave and Scorpion Rocks). Mist-netting methods and mark-recapture analyses for estimating breeding colony size have also differed between the Farallones (1971–1972, 1992 and 2010–2012; Ainley & Lewis 1974, Sydeman *et al.* 1998, Nur *et al.* in press) and the two largest CCI colonies (Prince and Santa Barbara islands, 1975–1977 and 1991; Hunt *et al.* 1979, 1980, Carter *et al.* 1992). At nearshore rocks in northern and central California and at most small CCI colonies, nest counts (some with rough adjustments for inaccessible but suitable habitats) in one or more years have been used most often for estimates, although mist-net data were used for estimating colony size at Bird Rock (Point Reyes National Seashore [PRNS]) in 1989 and Scorpion Rocks (Santa Cruz Island) in 1991 (Carter *et al.* 1992, 2015a, Becker *et al.* 2016, McIver *et al.* 2016). Greater standardization of future survey effort and methods for colony size estimation are desirable, but most focus should be placed on measuring trends in colony size indices.

Only very low numbers of ASSP are known to breed in northwestern Baja California, although this region has been poorly surveyed. The southernmost confirmed breeding colony is the Coronado Islands (32.4°N); on 19 August 1910, a downy ASSP chick (California Academy of Sciences #72730) was collected by H.W. Wright and, on 20 April 1916, an adult (San Diego Museum of Natural History #2566) and egg (Museum of Comparative Zoology #357926) were collected from a nest (Huey 1925). ASSP were not detected breeding

at the Coronado Islands in 1895–1902, when many nests of LESP and Black Storm-Petrels *O. melania* (BLSP) were first described (e.g., Anthony 1898, Grinnell & Daggett 1903). Between 1968 and 1991, low numbers of ASSP were captured in mist nets, and it was considered to be a rare breeder (Jehl 1977, Everett & Anderson 1991). Greater numbers were reported breeding in 2005 (Carter *et al.* 2006a, 2008a), but in retrospect it was difficult or impossible to distinguish many ASSP from dark-rumped LESP when viewed (often incompletely) inside crevices (Carter *et al.* 2016; H.R. Carter, unpubl. data). One storm-petrel nest found at Todos Santos Islands (31.8°N) on 7 May 2005 was initially thought to be ASSP (Carter *et al.* 2006b, 2008a), but in retrospect it too could well have been that of a dark-rumped LESP (Carter *et al.* 2016). More work is needed to document breeding and assess population sizes of ASSP, LESP and BLSP at the Coronado and Todos Santos islands.

There is only one verified specimen record of ASSP at a possible breeding colony south of Todos Santos Islands. On 13 April 1951, a specimen (Los Angeles County Museum #51880) was collected by W.V. Mayer at the anchorage at San Martin Island (30.5°N), after it flew aboard the fishery research vessel *Velero IV*, likely attracted by the vessel's lights. This anchorage is adjacent to suitable nesting habitat on the nearby cliffs; whether the bird was associated with this habitat is not known. However, ASSP often landed or were mist-netted on brightly lit boats anchored near breeding colonies in the CCI in 1994–1996; most or all of these birds were likely flying to or attending nearby nesting habitats (McIver *et al.* 2016; H.R. Carter, unpubl. data). On the other hand, storm-petrels also are attracted to brightly lit vessels at sea, far from land in the CCS (D. Ainley, pers. obs.), and it is equally possible that this individual was not attending a nearby colony.

At the San Benito Islands, Mexico, A.W. Anthony (unpubl. field notes housed at the Western Foundation of Vertebrate Zoology, Camarillo, CA) reported collecting 10 ASSP eggs on 23–26 July 1896, none of which are currently located in museum collections, and none are mentioned in the literature. Anthony (1896, 1898) did not note breeding ASSP at the San Benito Islands, although he did collect LESP, BLSP and Least Storm-Petrels *O. microsoma* (LTSP) there in 1896–1897. Anthony likely recognized that he had misidentified adults associated with these eggs and disposed of them. Subsequently, neither breeding nor occurrence of ASSP has been reported at the San Benito Islands, which has large populations of LESP, BLSP and LTSP. More work is needed to assess whether ASSP breed at San Martin, San Benito and other islands in central-west Baja California.

Low numbers of ASSP also breed on nearshore rocks along the coast north and east of the Farallones, although this region has also been poorly surveyed (Carter *et al.* 2008a, 2015a; Fig. 1). At PRNS, breeding was found at Bird Rock, Marin County, in 1969 and 1972, and then Stormy Stack in 2001 (Ainley & Osborne 1973; Carter *et al.* 2008a, 2015a; Becker *et al.* 2016). In 2012, breeding was verified as far north as Stillwell Point Rock, Mendocino County (39.3°N), although in 1926, breeding was documented slightly farther north at Caspar-Point Cabrillo Rock (39.4°N), and in 2012, storm-petrel smell was detected even farther north at crevices on Kibesillah Rock (39.6°N; Carter *et al.* 2015a). Just recently (fall 2015), the northernmost breeding record was added to online museum specimen databases: at Steamboat Rock, Humboldt County (40.4°N), F.J. Smith collected an ASSP egg in a crevice on 15 June 1914 (University of Arkansas Collections Facility

#0054-0022-0239). Subsequent surveys at Steamboat Rock and nearby Sugarloaf Island and False Cape Rocks, all large rocks with substantial potential breeding habitat, have not yet been conducted (Carter *et al.* 2015a).

From the Farallones south to the northern CCI, surveys of nearshore rocks have been conducted in only one small area in Monterey County (i.e., Castle Rocks and Mainland, Hurricane Point Rocks, and Bench Mark-227x) in 1996–1997, where breeding was confirmed (McChesney *et al.* 2000). Presence or storm-petrel odor has been noted at several locations with suitable breeding habitat, especially at PRNS (i.e., Chimney Rock and Point Reyes Headlands) and near the mouth of San Francisco Bay (i.e., Steep Ravine, Alcatraz Island, San Pedro Rock and Año Nuevo Island; Carter *et al.* 2008a, 2015b; Becker *et al.* 2016). At Vandenberg Air Force Base, north of Point Conception, presence has been noted far from any known colony through the capture of individuals in mist nets on the mainland (Brown *et al.* 2003). However, surveys of nearby areas, which have little or no suitable habitat, have not detected nests, although a few small nearshore rocks have yet to be checked (D. Robinette, pers. comm.). More work is needed at many of these locations to determine whether presence reflects undocumented small colonies or individuals that breed at other colonies. Museum collections hold several specimens found in cities in San Francisco Bay and along highly populated parts of the southern California coast, apparently associated with lighted structures, where suitable nesting habitat does not exist.

In the CCI, knowledge of the locations of breeding colonies also is incomplete; many areas with apparent suitable habitat, especially steep slopes and cliffs, have not been surveyed. In particular, mist-netting is needed along the north sides of Santa Cruz and Santa Rosa islands to assess possible breeding in extensive cliffs. The captures of ASSP in mist nets in areas lacking suitable nesting habitat but near known colonies also may provide clues to finding undetected colonies. At San Miguel Island, three ASSP were captured on the main island at Cuyler Harbor in 1976 (Hunt *et al.* 1979, 1980). This location is about 1.7 km from Prince Island but is adjacent to suitable breeding habitat between Harris Point and Cuyler Harbor; at the latter area, nests have not been found, but steep slopes and cliffs have prevented a thorough search. More work is needed to determine whether breeding occurs in this area, especially because Black Rats *Rattus rattus* have recently dispersed to this part of the main island (see below). At San Clemente Island, eight ASSP were captured in 1994 and one in 2013 at Knob Canyon, previously referred to as Mosquito Cove (Carter *et al.* 2008a, 2009; Carter & Henderson 2015). Breeding does not appear to occur there; steep cliffs occur nearby with nesting Scripps's Murrelets *Synthliboramphus scrippsi*, but Black Rats access these cliffs and eat murrelet eggs (Whitworth *et al.* 2015a). Occurrence at Knob Canyon was likely related to light attraction to boats anchored near shore and to vocalization broadcasting and head lamps during mist-netting (Carter & Henderson 2015).

AT-SEA SURVEYS AND HOTSPOTS

Coinciding with increased colony surveys and monitoring since the mid-1970s, a number of extensive at-sea surveys have been conducted in the CCS, both by aircraft and vessel. These have identified various ASSP at-sea “hotspots” (e.g., Briggs *et al.* 1987, Mason *et al.* 2007, Spear & Ainley 2007, Ainley & Hyrenbach 2010), including those where ASSP aggregate during the main period of

molt, primarily August through mid-October (P. Pyle, pers. comm.), although molt extends into January–February (Ainley *et al.* 1976). These hotspots are found between Cordell Bank (38°N) and the Santa Cruz Basin (33.5°N). One radio-telemetry study examined at-sea foraging areas of ASSP captured in mist nets on CCI colonies (Prince Island, Santa Barbara Island and Scorpion Rocks off Santa Cruz Island). Radio-marked ASSP frequented waters within ~180 km (i.e., continental slope off vicinity of Point Conception, western Santa Barbara Channel and Santa Cruz Basin); some birds foraged farther north off Monterey Bay (Adams & Takekawa 2008). Information about at-sea occurrence is also available from decades of “pelagic birding trips” originating from several California ports, mainly San Diego, San Pedro, Ventura, Monterey, San Francisco and Bodega Bay, but this information has been only broadly summarized (e.g., Stallcup 1976, Howell 2012). However, certain hotspots appear to have shifted during the past three decades. A large persistent hotspot in Monterey Bay (~36.5°N, south of the Farallones) in the 1970s apparently shifted to Cordell Bank (~38°N, north of the Farallones) by the 2000s (D. Shearwater, S. Howell & P. Pyle, unpubl. data). Much work is still needed to collate information on at-sea abundance and occurrence. This information would allow us to better examine global population size and trends, as well as to assess marine conservation issues, especially related to climate change, ocean acidification and vulnerability to pollution (e.g., oil, organochlorines and light).

CONSERVATION ISSUES

Historically, the numbers of ASSP at several breeding colonies were likely greater than today, but the degree to which colony sizes have changed is difficult to estimate. Decades before the ASSP was first described in 1864, changes in breeding habitats were occurring at the Farallones. In the early to mid-19th century, huge pinniped populations that covered the low- to middle-level portions of the islands were wiped out, perhaps allowing storm-petrel breeding in some additional areas. By the mid- to late 19th century, most crevice-nesting habitat (including upper-level portions) was greatly altered by human activities, likely leading to a decrease in storm-petrel habitat (Doughty 1971, Ainley & Lewis 1974, Ainley & Boekelheide 1990, White 1995, Carter 2001, Carter *et al.* 2008a). In 1807–1812, US sealers made several trips to the islands, and between 1812 and 1838, a sealing station was operated by the Russian-American Company, partly working with US sealers. Buildings were constructed from island rocks, and company activities included the harvesting of seabird feathers, meat and eggs, as well as sealing. In the 1850s, shortly after California statehood, the islands were further modified by the US Lighthouse Board and the Farallon Egg Company. Alien mammals, such as European rabbits *Oryctolagus cuniculus*, cats *Felis catus*, dogs *Canis familiaris*, chickens *Gallus gallus domesticus* and various other livestock, were brought to the islands. Many areas became trampled by livestock and eggers (mainly harvesting Common Murre *Uria aalge* eggs). Island rocks were cleared from many areas and used for construction of buildings, a lighthouse, a railway and major paths. Some ~1500 m of railway, built on a rock-wall foundation, partially encircled the main island, and a wagon path, also supported by large rock walls, zig-zagged to the lighthouse located atop the highest elevation. Certain buildings, the railway and most major paths did not contain cement or plaster to hold rock walls together; spaces occurred between certain rocks allowing access by ASSP for nesting. In 1885, ASSP were first reported breeding in natural cavities under rocks and in constructed rock

walls (Ingersoll 1886). By 1911, extensive use of rock walls was noted, and ASSP numbers were considered to have increased since the 1890s (Dawson 1911, Loomis 1918, Ainley & Lewis 1974, Carter *et al.* 2008a). This apparent increase might have reflected increased use of rock walls owing to loss of natural crevice habitats or increased availability of nesting cavities in expanded rock walls. At this time, many ASSP eggs were obtained by certain naturalists to sell to collectors. During World Wars I and II, military personnel were stationed on southeast Farallon Island, leading to new buildings and cement structures that covered more of the island but providing little access for ASSP nesting. Many unused buildings were demolished in 1959.

The negative effects of introduced mammals on nesting seabirds, especially smaller nocturnal species such as storm-petrels, became widely recognized in the 20th century (e.g., Croxall *et al.* 1984, Steadman 1995, McChesney & Tershy 1998). At southeast Farallon Island, European rabbits, which in some years seasonally numbered into the low hundreds, competed with cavity-nesting seabirds for nesting habitat. Upon rabbit removal in 1973, there was an abrupt increase in numbers of recently recolonizing Rhinoceros Auklets *Cerorhinca monocerata* and long-established Tufted Puffins *Fratercula cirrhata*, which took over many of the caves and cavities previously used by rabbits (Ainley & Lewis 1974, Ainley *et al.* 1990a, Warzybok *et al.* 2012). This was the third attempt to remove the rabbits, after an earlier shooting effort in 1922 by the US Navy (USN) personnel and a poisoning effort by the USFWS in 1959 (Pinney 1965, Doughty 1971, White 1995). The last house cats also were removed in 1974. Most of the time, cats appeared to have been pets of lighthouse keepers and were rarely mentioned in naturalist accounts; they may have periodically died out and never achieved a notable feral population size (P. White, pers. comm.). However, in the late 1960s, although associated with lighthouse personnel, cats were roaming freely, as noticed by biologists who were resident on the island. The degree to which ASSP were affected directly by rabbits and cats or their removal is not known, but we suspect that ASSP breeding conditions were improved and mortality reduced after removal. The House Mouse *Mus musculus* was not mentioned in various detailed descriptions of island wildlife between 1856 (Hutchings 1856) and 1964 (Thoreson 1964, Pinney 1965). However, mice were very much in evidence by the late 1960s (Point Blue Conservation Science, unpubl. data); it is not known when mice were introduced, but they remain to this day. The degree to which these mice have had a direct impact on ASSP remains a question; one chick in a monitored nest was considered eaten by a mouse either before or after death, possibly representing greater undocumented impact (Ainley *et al.* 1990b). However, mice are the primary prey for Burrowing Owls *Athene cucularia* on the Farallones; these birds also prey on ASSP, which has led to problems for the ASSP population (Mills 2016, Nur *et al.* in press; see below).

Alteration of nesting habitat has also been underway at the CCI for about two centuries, following the loss of the large populations of native peoples who resided on the islands for thousands of years. Between the early 19th and the mid- to late 20th centuries, major sheep or cattle ranching operations existed on the six largest islands (Santa Cruz, Santa Catalina, San Clemente, Santa Rosa, San Nicolas and San Miguel), with smaller operations on Santa Barbara and Anacapa islands (McChesney & Tershy 1998, Chiles 2015). At Santa Barbara Island, cats were introduced before 1863 (Whitney 1865), and at least 40–50 were reported in 1897 (Holder 1910).

Cat numbers were reduced in 1916–1922 by poisoning by ranchers raising European rabbits for pelts (Weinman 1978, Daily 1993). High numbers of cats were not reported subsequently. In 1939, only one cat was seen, although abundant scat was noted (Sumner & Bond 1939). In 1954–1957, cats were thought to be extirpated by shooting and poisoning during a rabbit eradication effort (Sumner 1958, Philbrick 1972), but in fact the last cat was not removed until 1978 (Murray *et al.* 1983). Cats may have preyed upon small numbers of storm-petrels nesting along the margins of the mesa on the main island, but suitable nesting habitat for ASSP is not found on the mesa top. For the most part, ASSP nesting is confined to offshore rocks (especially Sutil Island) or steep cliffs on the main island that is inaccessible or much less accessible to cats.

At Anacapa Island, Black Rats were probably introduced by the shipwreck of the *Winifred Scott* in 1863, although they may have arrived instead during later sheep ranching (Roberts 1983). Rabbits were also introduced in 1935, with more arriving during World War II; up to 1000 were recorded there in the 1940s, before they were removed (Doran 1980, Roberts 1983). In 1939, only four to five cats were noted: three on West Anacapa Islet (two as pets of a resident fisherman and one wild), and one to two on East Anacapa Islet (pets of the lighthouse keepers) (Sumner & Bond 1939). Cats had died out or been removed by the 1960s. ASSP probably were not affected greatly by cats and rabbits at Anacapa, as little or no suitable nesting habitat is found on the tops of the islets. However, rats are more able to access mesa edges and other portions of steep cliff habitats and likely restricted ASSP nesting to certain rat-inaccessible cliffs there (Harvey *et al.* 2016).

At San Miguel Island, Black Rats were probably introduced to the main island between 1905 and 1923, when four shipwrecks occurred on the west end (Roberts 1991). By 1989, rats were apparently restricted to the west and north sides of the island, likely owing to predation by the endemic island fox *Urocyon littoralis littoralis* (Collins 1979, Erickson & Halvorson 1990). However, in 2007, evidence of rats was first found on the east side of the main island (Carter *et al.* 2008b). There was a major decline of island foxes — from about 450 (1994) to 15 (1999) — before remaining foxes were taken into a captive breeding program. After later release, the population regrew to about 400 by 2011 (Coonan *et al.* 2014). During the period when foxes were greatly reduced or absent, rats expanded to the east side of San Miguel, where they were documented eating Scripps's Murrelet eggs in 2007 (Carter *et al.* 2008c), but little specific information is available about their numbers (C. Drost, pers. comm.). On the east side of the main island, ASSP have been captured in a mist net, but more work is needed to determine whether breeding occurs between Cuyler Harbor and Harris Point, where rats may be affecting ASSP nests (see above). However, relatively large numbers of ASSP breed at Prince Island, ~1.6 km off San Miguel's east side, which is now more susceptible to rat introduction from the main island than in the past.

ASSP conservation concerns for population concentrations at the Farallones and the CCI became more pressing in the early 1990s. Population size at the Farallones was found to be 44% lower in 1992 (Sydeman *et al.* 1998) than in 1971–1972 (Ainley & Lewis 1974, Ainley *et al.* 1974), based on a comparison of mist-net captures, albeit using differing methods of estimation. Decline was thought to have resulted from heavy predation by a large and growing population of Western Gulls *Larus occidentalis* (Ainley *et al.* 1974, Penniman *et al.* 1990, Sydeman *et al.* 1998) and by the longer

seasonal residency of Burrowing Owls. Autumn visitant owls were likely remaining through the winter because of the exploding population of mice resulting from rabbit removal and a subsequent increase in vegetation going to seed. Higher owl predation on ASSP then resulted, as over-wintering owls switched from foraging on mice to ASSP, following seasonal decreases in mice (Mills 2016; Nur *et al.* in press). At-sea numbers of ASSP in the central CCS also were 76% lower in 1997–2006 than in 1985–1994 (Ainley & Hyrenbach 2010), although the actual decline was likely less, owing to variation related to El Niño–Southern Oscillation. In fact, based on mist-net captures, the population rapidly increased between 2000 and 2006, before again rapidly declining between 2006 and 2012 during a period of heightened owl abundance and owl predation on ASSP (Nur *et al.* in press).

In the CCI, strong evidence of impacts to ASSP from chemical pollution emerged in the 1990s, leading to major concern. In 1992–1997, high levels of organochlorine pollutants (DDT and polychlorinated biphenyls [PCBs]) were found in ASSP eggs at Santa Cruz Island (Fry 1994, Carter *et al.* 2008a, c). These pollutants led to extensive eggshell thinning and possibly embryo mortality, resulting in relatively low mean hatching success (62%, range 54%–84%), as measured at Santa Cruz Island in 1995–1998 (Kiff 1994, McIver 2002, McIver *et al.* 2009). From the late 1940s to 1970, about 2000 tonnes of DDT and PCBs were dumped into the ocean through ocean outfalls off Los Angeles (especially White Point) and from barges in the San Pedro Basin (MSRP 2005). This activity was stopped to a great degree in 1970 through regulatory measures, and pollutant levels in the marine environment subsequently declined, although major impacts to reproduction and colony sizes of Brown Pelicans *Pelecanus occidentalis* and Double-crested Cormorants *Phalacrocorax auritus* were well documented from the 1960s to 1980s (Gress 1995). Impacts on ASSP hatching success in the CCI were likely greater during the period of highest pollution in the 1960s than in 1995–1998, but studies of ASSP reproductive success were not conducted in the CCI before 1995. By 2008, pollutant levels in ASSP eggs had dropped compared with 1992–1997 (Carter *et al.* 2008c), and mean hatching success at Santa Cruz Island in 2005–2007 was higher (McIver *et al.* 2009), similar to the mean seen at the Farallones in 1972–1983 (Ainley *et al.* 1990b). At Santa Cruz Island, colony size has rebounded since 1995 at Cave of the Birds' Eggs owing to reduced pollutants and lack of other major impacts. Colony size at Orizaba Rock has also recovered from light pollution impacts in 1995–1997, assisted by social attraction efforts since 2008. However, Bat Cave and Cavern Point Cove Caves colonies have had setbacks due to unusual predation events by island spotted skunks *Spilogale gracilis amphiala* (Carter *et al.* 2008a, McIver *et al.* 2009, 2016). Limited data are available for assessing trends at the largest colonies at Prince and Santa Barbara islands, and differences in mist-net methods complicate trend assessments (Hunt *et al.* 1979, 1980; Carter *et al.* 1992, Adams 2016, Adams *et al.* 2016). At the Farallones, moderate levels of organochlorine pollutants were found in ASSP eggs in 1969–1970, although ASSP hatching success did not appear to have been greatly affected (Coulter & Riseborough 1973, Ainley *et al.* 1990b).

A relatively new and emerging concern is rising sea levels and increasing storm surge due to climate change (National Research Council 2012), which will increase flooding of low-lying nesting habitat in sea caves and on offshore rocks during the ASSP breeding season. On Santa Cruz Island, high-water events in 2008, 2010

and 2011 at the Cave of the Birds' Eggs resulted in low adult and chick mortality, and in 2010 also caused loss of some cave floor crevice-nesting habitat that contained monitored nest sites (McIver *et al.* 2016). Continued monitoring at Santa Cruz Island is needed to determine to what degree these ASSP sea cave colonies are affected by high-water events over time and to develop mitigation projects. Efforts to relocate or establish nesting at higher elevation should be made before colonies are lost, to increase the likelihood of successful colony movements. Methods for such future efforts have been largely developed (see below).

Litigation following oil spills and organochlorine pollution has provided funding for restoration projects to benefit ASSP and other crevice-nesting seabirds, and the application of these projects appears to be generating positive results (Carter 2003, Helm *et al.* 2015). At Anacapa Island, Black Rats were eradicated in 2002 (ATTC 2001; Howald *et al.* 2009; Whitworth *et al.* 2013, 2015b). Nine years later, in 2011, the first ASSP nest was found and 20 birds were mist-netted (Harvey *et al.* 2016); however, a small remnant population likely persisted in rat-inaccessible habitats before eradication, as judged from the 50 birds captured in mist nets in 1994 (Carter & Whitworth 2013). At Orizaba Rock, artificial nest sites and vocalization broadcasting have been deployed annually since 2007 to restore colony size. This colony had declined by 74% between 1995 and 2004; by 2011, population size exceeded the 1996 peak level of 27 nests (MSRP 2005, McIver *et al.* 2016). At the Farallones, preservation of remaining rock walls has been important for conserving a portion of ASSP nesting habitat (R. Bradley, pers. comm.), and planning is underway for eradication of introduced mice there (LTC 2006, Nur *et al.* in press).

COLONY PROTECTION

All five major breeding concentrations and all smaller colonies of ASSP occur within protected conservation areas in the CCS. In 1909, the Farallon National Wildlife Refuge was established; it protected West End Island, Saddle Rock and the Islets, but not southeast Farallon Island, where most ASSP breed. In 1969, that island, too, was added to the refuge. USFWS manages the refuge, with monitoring and research conducted by Point Blue Conservation Science (previously known as Point Reyes Bird Observatory) since 1971 (see Ainley & Boekelheide 1990). San Miguel and San Clemente islands, managed by the USN, have been used for weapons testing and other activities since the 1930s, although San Miguel has not been used for target practice since about 1965. In 1938, Santa Barbara and Anacapa islands were designated as the Channel Islands National Monument, managed by the National Park Service (NPS). In 1980, five CCI (San Miguel, Santa Rosa, Santa Cruz, Anacapa and Santa Barbara) were included within the newly designated Channel Islands National Park. Some private properties within the park at Santa Rosa and eastern Santa Cruz have been subsequently obtained and are now managed by the NPS. San Miguel is now managed by both the USN and NPS. Various other small colonies in California also are protected within (1) the California Coastal National Monument (established in 2000), managed by the Bureau of Land Management, although most of the same islands and rocks had been protected through the California Islands Wildlife Sanctuary since 1983, then managed by the California Department of Fish and Wildlife; (2) Western Santa Cruz has been owned and managed by The Nature Conservancy since 1987; and (3) PRNS (established in 1964), managed by the NPS. Only small numbers of ASSP appear to breed at the Coronado

Islands in northwestern Baja California, and a few may breed at Todos Santos Islands. Both of these islands are managed by the Mexico Secretary of the Environment and Natural Resources and the Mexican Navy. Biosphere reserve status has been proposed for these islands.

LEACH'S STORM-PETRELS

While the focus of the Pacific Seabird Group special paper session was on ASSP, the two LESP papers in this issue (Adams *et al.* 2016, Carter *et al.* 2016) have helped to refine the location of a biogeographical boundary within the southern Channel Islands. This boundary apparently occurs between Santa Catalina Island, the northernmost colonies where LESP *O. leucorhoa chapmani* breed (Carter *et al.* 2016), and Santa Barbara and San Clemente islands where ASSP are most abundant and small numbers of LESP *O. leucorhoa leucorhoa* also apparently breed (at Santa Barbara Island, based on mist net captures; Carter & Henderson 2015, Adams *et al.* 2016). Another biogeographical boundary appears to occur at the north end of the ASSP breeding range near Cape Mendocino, California, with LESP *O. leucorhoa leucorhoa* and Fork-tailed Storm-Petrels *O. furcata* breeding northwards and mainly ASSP southwards, but more work is needed to examine the species and numbers of storm-petrels nesting on various rocks in this area (Carter *et al.* 2015a).

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