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AVIFAUNAL CHANGE ON CALIFORNIA'S COASTAL ISLANDS

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Abstract. I summarize the changes in status of breeding birds on California's Farallones and Channel Islands over the last 100 years. Several species have expanded their ranges, either colonizing from other islands or from the mainland. Other species, especially those with small populations, ceased to exist on certain islands. In many case these colonizations and losses seem due to normal species turnover. Several seabird species have declined due to human disturbance and are now increasing. Several raptor species have had significant losses. Several land bird populations have been lost, including endemic subspecies. Range expansions have come about naturally or as a result of protection and conservation efforts. Losses are almost all due to human influences, including direct disturbance and killing, DDT in the food chain, and predation and habitat destruction brought on by feral animals.

Key Words: California Channel Islands; extinction; range expansion; human influences; endemicity; conservation.

The breeding avifauna of the islands off California is unique. Hundreds of thousands of marine birds find resources just 20 or more miles from heavily populated metropolitan areas. Some resident land birds have evolved morphologically distinguishable populations, following, in a few cases, classic rules of island evolution (e.g., Johnson 1972, Power 1980a). Over the last 100 years there has been remarkable change. As with islands everywhere, there are natural processes at work. The numbers of bird species on islands are affected by plant species diversity and distances from sources of colonizing species [for the California Islands see Power (1972)]. Theoretically, immigration and extinction rates are also affected by island size and degree of isolation (MacArthur and Wilson 1967). Johnson (1972) describes several colonization scenarios specific to the Channel Islands.

In the shorter term, the balancing of extinction and immigration rates leads to a more-or-less constant number of species, but with the species composition subject to change, at least in theory (Diamond 1969). Diamond and Jones (1980), for example, record 56 species of land birds known to breed, or to have bred, on the eight Channel Islands, and found average annual turnover of island populations of 1–6% per year. For the avifauna of small Santa Barbara Island (1.0 sq. mi.), Hunt and Hunt (1974) calculated turnover rates of 120% for birds of prey and 42% for songbirds over the period 1900–1972. That works out to 1.7% and 0.6% per year, respectively. Hunt and Hunt also compared calculated turnover rates to island area for the nine California Islands from San Miguel in the north to Los Coronados in the south. Turnover was inversely proportional to island area for raptors, but not for songbirds. [Regarding overestimating turnover see Lynch and Johnson (1974).] Climatic variation is another cause of natural avifaunal change. For example, El Niños raise the sea temperature, changing the abundance and distribution of some prey species on which many nesting birds have come to specialize.

Over the last 100 years the impact of humans has far exceeded the effects of natural causes. Marine birds have been victims of egging, oil pollution, overfishing, gill nets, and DDT contamination in the food chain (e.g., Ainley and Lewis 1974, Risebrough et al. 1970). Raptors and other land birds were shot, poisoned, preyed on by introduced mammals, and had nesting habitat destroyed (e.g., Kiff 1980, Howell 1917). An idea of the habitat degradation that took place on one small island can be found in Philbrick's (1972) account of Santa Barbara Island. He discusses farming, introduction

of weeds and succulent plants, the spread of house cats, browsing by rabbits, and fire. Ainley and Lewis' (1974) account of the Farallones is as telling. Yet, if this paper had been written 20 years ago the situation would seem worse than today. Marine birds now are doing well, raptors may by reestablished soon, and habitat degradation has been reversed on many of the islands.

In this paper I review changes in the breeding populations of species that migrate to, or are resident on, the California Islands, from the Farallones in the north to San Clemente Island in the south (Fig. 1). I include only breeding species and populations that have changed. Space does not permit a review of nonbreeding birds or those populations that have been more-or-less stable over the last 100 years, nor am I treating changes in niche breadth or niche shifts (Yeaton 1974). I recognize four general categories: marine and shore birds, raptors, other land birds, and introduced birds. For a general overview of the state of our knowledge of the islands at three recent checkpoints, refer to the proceedings of symposia held in 1965, 1978, and 1987 (Philbrick 1967, Power 1980b, Hochberg 1993). There have been interesting changes on the Mexican islands off the Pacific Coast of Baja California as well, although they are not covered here. Among the useful papers to which readers can be referred are Abbott (1993), Dunlap (1988), Everett (1989), Everett and Anderson (1991), Friedmann et al. (1950), Jehl (1971, 1973, 1977a, b), Jehl and Everett (1985), and Kenyon (1947).

HISTORY OF BASELINE DATA

The first ornithological information on the Farallones dates to the 1850s and the U.S. Pacific Railroad Survey (Heermann 1859). H. R. Taylor (1887) reported on abundances of seabirds during a visit in 1886, and M. S. Ray (1904) and William Leon Dawson (1911) reported on longer stays. W. E. Bryant (1888) summarized information up to 1888 in a *Proceedings of the California Academy of Sciences* paper, and L. M. Loomis (1895) referenced the Farallones in his historical study on California water birds. The period 1887–1903 was covered by W. O. Emerson (1904). In a 1974 paper, David Ainley and T. James Lewis of the Point Reyes Bird Observatory summarized the entire history of Farallon Island marine birds.

For the Channel Islands off southern California, C. P. Streator (1888) provided notes on birds of some of the islands, and is important because of the early date, rather than the extent of the information. Joseph Grinnell (1897) reported on his findings on Santa Barbara, San Nicolas, and San Clemente islands during the spring of 1897, in the first publication of the Pasadena Academy of Sciences. Charles H. Townsend (1890) collected on the islands in 1888 and 1889 as part of the scientific exploration by the U.S. Fish Commission steamer *Albatross.* Taxonomic status and mensural data appeared in Robert Ridgway's series *The Birds of North and Middle America,* published from 1901 to 1914 (Bulletin of the U.S. National Museum 50, various parts). George Willett (1910, 1933) recorded distributional data in the early 1900s. The first major summary of the Channel Islands was produced by A. B. Howell (1917). Both Willett and Howell published in early volumes of *Pacific Coast Avifauna,* a publication of the Cooper Ornithological Society and the predecessor of *Studies in Avian Biology.* Joseph Grinnell and Alden Miller (1944) synthesized what was known at the time in their important *Pacific Coast Avifauna* volume on the birds of California. Alden Miller (1951) compared the avifaunas of Santa Cruz and Santa Rosa islands. Jared Diamond and H. Lee Jones provided the most complete baseline data in recent time through extensive surveys in the late 1960s and early 1970s (Diamond 1969, Jones 1975, Jones and Diamond 1976).

MARINE AND SHORE BIRDS

There were very few serious surveys of breeding populations of marine birds until

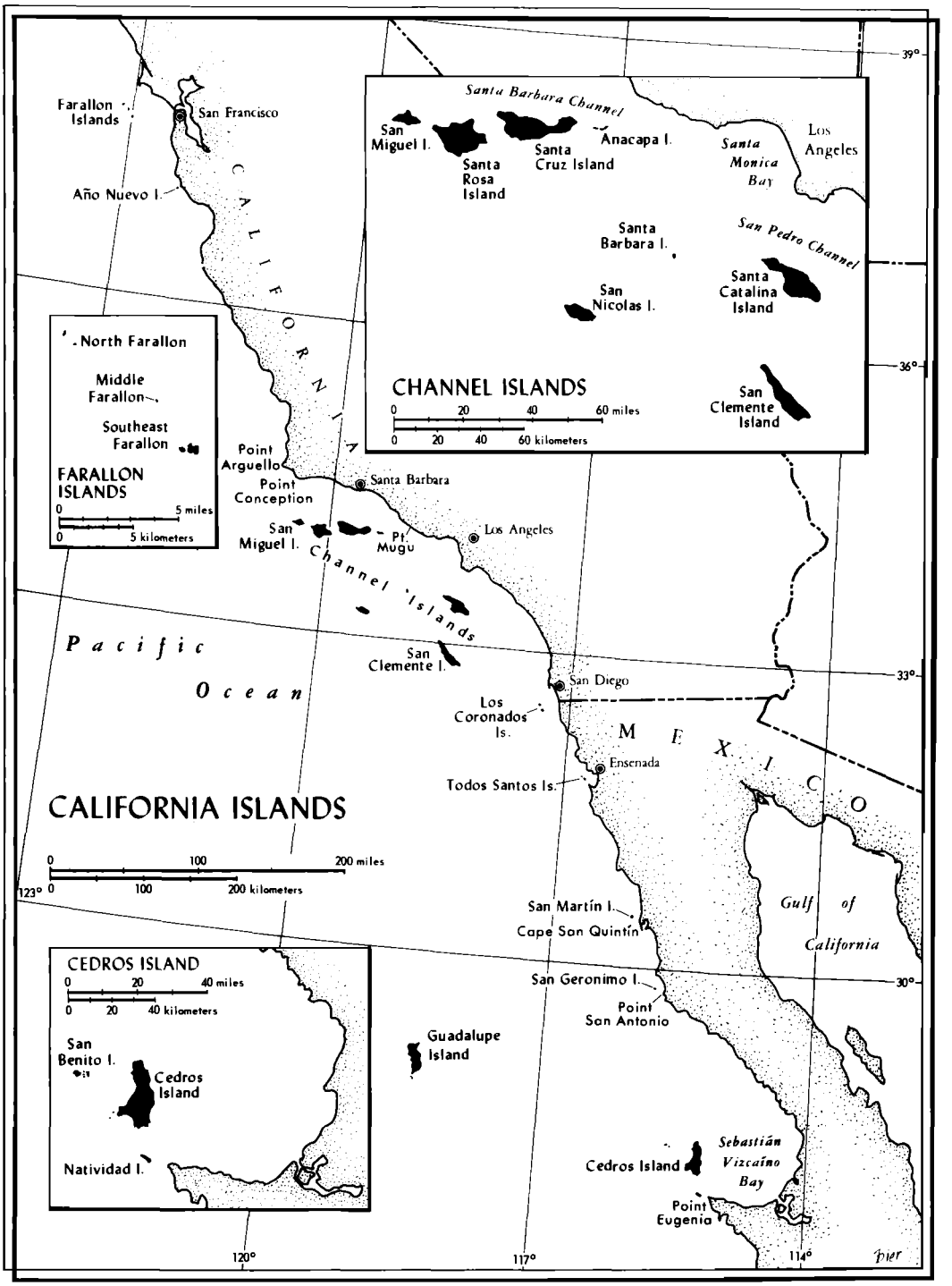

FIGURE 1. Map of the California Islands. The area covered by this study is from the Farallon Islands in the north to San Clemente Island in the south.

TABLE 1. TRENDS IN BREEDING POPULATIONS OF CALIFORNIA CHANNEL ISLANDS MARINE AND SHORE BIRDS OVER THE LAST 100 YEARS

A. Increases on all or some islands
Leach's Storm-Petrel (N)
Ashy Storm-Petrel (N)
Snowy Plover (N)
Western Plover (H)
B. Declines followed by increases on most islands
Brown Pelican (H)
Brandt's Cormorant (N) (H)
Pelagic Cormorant (N) (H)
Common Murre (H)
Pigeon Guillemot (H)
Xantus' Murrelet (H)
Rhinoceros Auklet (N)
C. Declines on all or some islands
Double-crested Cormorant (N) (H)
Tufted Puffin (N)
D. Increases followed by declines on most islands
Cassin's Auklet (N)

(N) Presumed natural causes. (H) Presumed human-induced causes.

the 1960s. Following the DDT-induced decline of Brown Pelicans (*Pelecanus occidentalis*) and other seabirds in the late 1960s and early 1970s, surveying became more intense as money became available from federal and state agencies (e.g., Ingram 1992). Several seabird species underwent declines in the late 1800s and early 1900s, and others in the middle of the 1960s and 1970s (Table 1). In many cases populations have recovered.

Leach's Storm-Petrel (*Oceanodroma leucorhoa*) has remained steady or possibly increased in the last 100 years. On the Farallon Islands it was first discovered in 1896, but it may have been present earlier (Ainley and Lewis 1974). Fifty to 100 pairs were reported in 1959 and about 700 pairs were reported in 1972 up to the present (Ainley and Lewis 1974, Carter et al. 1992). On the Channel Islands, a few pairs were reported in the early 1970s (Hunt et al. 1980) and about 160 pairs in the late 1970s (Carter et al. 1992).

The Ashy Storm-Petrel (*Oceanodroma homochroa*) may have increased. On the Farallones it was rare in the mid-1800s, increased to about 1500–2000 pairs in 1959, and stabilized at about 2000 pairs in 1972 up to the present (Ainley and Lewis 1974, Carter et al. 1992). On the other hand, Ainley et al. (1994) consider it less abundant on the Farallones than in the early 1970s. On the Channel Islands about 600 pairs of Ashy Storm-Petrels were reported throughout the 1970s, breeding on Castle Rock and Prince Island (islets near San Miguel Island), and on rocks and islets off Santa Cruz and Santa Barbara islands (Hunt et al. 1980, Carter et al. 1992). In 1991 about 1570 pairs were in the Channel Islands, with the greatest concentrations on Prince Island (about 580 pairs) and Santa Barbara Island (about 440 pairs) (Carter et al. 1992).

The episode of decline and recovery of the Brown Pelican on the California Islands is well known (e.g., Risebrough et al. 1970, 1971; Hom et al. 1974). The local subspecies *californicus* was classified as endangered under federal law in 1970 and under California law in 1971 (Carter et al. 1992). Brown Pelicans in the Southern California Bight raise more young when there is an abundance of northern anchovy (*Engraulis mordax*). Anderson et al. (1980) showed a relationship between northern anchovy biomass and pelican fledging rates at Anacapa and Los Coronados islands. Past pelican populations may have had a larger food base than they do today, feeding also on Pacific sardines (*Sardinops caerulea*) and Pacific mackerel (*Scomber japonicus*), species not now abundant. The pelican/anchovy relationship was disrupted by DDT residues in the Southern California Bight, contaminated anchovies being the major source of DDT for the pelicans (Anderson et al. 1980).

The pelican population in the California Current system had been declining since 1950 (Anderson and Anderson 1976). In historic times Anacapa Island had the largest breeding population in the region (Carter et al. 1992). Pelicans originally nested at both West and East Anacapa from 1884 to 1930 (Gress and Anderson 1983). By 1935 the entire colony existed only on West island. At Anacapa the estimated maximum

breeding population during the first half of the 20th century was about 2000 pairs. While there were fluctuations from year to year owing to sea temperature and anchovy biomass, the mean annual rate of decrease was about 4% per year from 1949 to 1974. In 1969, five young at most hatched from 1272 nesting attempts on Anacapa Island (Risebrough et al. 1970).

In 1975 through 1977, Briggs et al. (1981) estimated between 1800 and 5000 pelicans in the Southern California Bight could be attributed to local breeders and immatures. By the mid-1980s Briggs et al. (1987) believed that pelicans had substantially recovered from the decline of the 1960s and early 1970s. Subsequent increases are documented in Carter et al. (1992). In 1975–1980 there were 1258 breeding pairs on West Anacapa and another 87 on Santa Barbara Island. In 1989–1991 there were 5340 breeding pairs on West Anacapa and another 618 on Santa Barbara. The increase on Santa Barbara Island is especially encouraging: Brown Pelicans recolonized there in 1980, when 97 pairs were reported. The year of highest numbers on Santa Barbara was 1986, when 1441 nests were active. Clearly the population has recovered.

The Double-crested Cormorant (*Phalacrocorax auritus*) also has gone through declines and recoveries. On the Farallones, it was abundant, breeding in the thousands in the mid- to late 1800s (Ainley and Lewis 1974). Nesting plummeted (e.g., 20 nests in 1904) as a result of egging in the mid-1800s [mostly for Common Murre (*Uria aalge*) eggs] and other human disturbance. By 1972, numbers were still low: 40 pairs. By the late 1970s numbers began to increase to about 90 pairs and by 1991 the breeding population was up to 570 pairs (Carter 1992). Yet the population remains smaller than in pre-egging days. On the Channel Islands the Double-crested Cormorant has gone from being a very common breeder to one in which only remnant populations exist (Hunt et al. 1980). The decline was probably due to a combination of factors, including the disappearance of Pacific sardines owing to overfishing (Ainley and Lewis 1974) and increased human disturbance (Hunt et al. 1980). The most serious impact was reproductive failure due to eggshell thinning in the late 1960s (Gress et al. 1973). The largest breeding colonies were on Prince, Anacapa, and Santa Barbara islands. On West Anacapa in 1969, the year of greatest decline, there were only 76 nesting attempts and no young produced (Gress et al. 1973). In the mid-1970s population sizes began to increase, and in 1975 through 1977, the populations on Prince, West Anacapa, Santa Barbara, and Sutil (an islet near Santa Barbara Island) increased and adults fledged young in all colonies (Hunt et al. 1980). The total southern California island population was about 960 pairs in the late 1970s and about 1230 pairs in 1991 (Carter et al. 1992).

Brandt's Cormorant (*Phalacocorax penicillatus*) on the Farallones suffered the same consequences as the Double-crested Cormorant, with numbers declining from about 15,000 birds around 1860 to a few thousand in the early 1900s (Ainley and Lewis 1974). By the late 1970s the number of breeding pairs increased to an estimated 14,000 and today there are 8450 (Carter et al. 1992). In 1980 the total population (individuals) may have been 64,900 birds, then the largest nesting colony of Brandt's Cormorant in the world (Briggs et al. 1987, Carter et al. 1992). However, numbers dropped after the 1982/1983 El Niño and have not recovered (see Ainley et al. 1994).

Hunt et al. (1980) reported that in the late 1970s Brandt's Cormorant bred at major historical colony sites on seven of the eight Channel Islands, but at reduced numbers: more than 350 breeding pairs on Santa Barbara Island in 1912 and a maximum of only 166 pairs in 1975–1977. They estimated 4000 pairs on Prince Island and Castle Rock as late as 1968, decreasing to no more than 1823 in 1970–1975. These authors believe human disturbance precipitating gull predation was the principal cause of decline, but also cite some evidence for eggshell

thinning. More recently, Brandt's Cormorant has increased on the Channel Islands: the total breeding population in the late 1970s was about 3000 pairs and by 1990 was about 14,700 pairs (Carter et al. 1992). San Miguel had a total breeding population (all island and adjacent sites combined) of about 1850 pairs in the late 1970s and is up to 7850 now. Santa Rosa had 700 pairs in the late 1970s and has 2300 now. The Santa Cruz population jumped from 100 to 1570 pairs. Santa Barbara Island had about 130 pairs in the late 1970s and has 330 now. Finally, the San Nicolas population grew from about 200 to an estimated 2540 pairs in 1991. The species nests in small numbers on San Clemente Island (Jorgensen 1984).

The largest colony of the Pelagic Cormorant (*Phalacrocorax pelagicus*) in the study area is on South Farallon Island (Ainley and Lewis 1974). They reached their lowest numbers during the egging era, slowly increased until 1959, when 350–400 pairs were reported, and increased further to about 1000 pairs by 1972. Numbers seem to have held steady at 800–900 pairs in 1979, but then fell to only 400 pairs in 1987 (Carter et al. 1992). The decline occurred during the 1982/1983 El Niño. Ainley et al. (1994) show dramatic fluctuations in numbers between 1972 and 1992. On the Northern Channel Islands, both numbers of colonies and numbers of breeding birds have increased. Hunt et al. (1980) reported about 250 pairs throughout the Channel Islands in 1975–1977, and Carter et al. (1992) reported over 200 pairs in the same period. Breeding sites were San Miguel Island, Castle Rock, Prince, Santa Rosa, and Santa Cruz, and Santa Barbara and nearby Sutil islands. In 1991, Carter et al. (1992) reported about 1340 pairs at 46 active colonies (28 colonies were "newly discovered").

Spear (in Page and Stenzel 1981) summarized the status of the Snowy Plover (*Charadrius alexandrinus*) on the islands. On San Miguel it may have bred in the early 1900s, but breeding was only recently confirmed (35 pairs in 1979). On Santa Rosa, 21 pairs were recorded in 1980. On San Nicolas they have bred throughout the century (e.g., 74 pairs in 1978). Surveys in 1989 counted numbers of adults, and indicated smaller populations than in 1977–1980 on San Miguel and San Nicolas (36 vs. 84 and 90 vs. 133, respectively), and a larger population on Santa Rosa (91 vs. 43) (Page et al. 1991). The species was first recorded breeding on San Clemente in 1989 (Winchell 1990).

The Western Gull (*Larus occidentalis*) on the Farallon Islands fluctuated between 11,000 and 12,000 pairs from 1960 up to the 1982/1983 El Niño, when it declined slightly (Ainley et al. 1994). It then increased to about 14,000 pairs in 1986, dropped to less than 11,000 in 1987, and has declined gradually since then. On the Channel Islands the Western Gull has been ubiquitous throughout the century. It is one species that may have even benefited from human intrusion, feeding at dumps and taking offal from fishing vessels. Hunt et al. (1980) reported a maximum of about 5600 pairs in 1975–1977. Carter et al. (1992) counted over 13,800 pairs for the whole of the Channel Islands in 1991. Whether this represents a real increase or just more thorough censusing is not clear. On Santa Barbara Island, an excess of females and homosexual female pairing was reported (Wingfield, Martin et al. 1980). This behavior is not due to increased testosterone levels in females (Wingfield, Newman et al. 1980). Whether homosexual pairing is a recent phenomenon is not known.

The southernmost breeding point of the Common Murre is the Farallones (A.O.U. 1983). The population may have been as large as 200,000 pairs in the mid-1800s, but declined to only a few hundred to a few thousand in the early 1900s, after egging, human occupation of the islands, and oil spills (Ainley and Lewis 1974). It then grew to 3000–3500 pairs in 1959, and about 10,250 pairs by 1972 (Ainley and Lewis 1974). In the 1970s the population was estimated to be 55,770 pairs, but dropped to

34,000 pairs by the early 1990s, owing to a combination of gill net mortality, oil spills, and the 1982/1983 El Niño (Carter et al. 1992). In 1987, fishing regulation changes reduced mortality due to gill nets. The breeding population on the Farallones seems to be recovering at about 1–2% a year (Ainley et al. 1994). On the Channel Islands only one historic breeding site is known: about 11 pairs of Common Murres presumably bred on Prince Island between 1906 and 1912 (Garrett and Dunn 1981, Hunt et al. 1980).

Pigeon Guillemots (*Cepphus columba*) on the Farallones escaped egging because of their habit of nesting in crevices and burrows, but they did not escape the impact of oil pollution (Ainley and Lewis 1974). From 1900 into the 1940s oil tankers routinely flushed their tanks close to the island before entering San Francisco Harbor. The population was only about 100 pairs in 1911. After oil pollution lessened, the population reached about 500 pairs by 1959 and 1000 pairs by 1972, and it remains at about that number today (Carter et al. 1992). On the Channel Islands the Pigeon Guillemot breeds on San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara islands. Hunt et al. (1980) reported about 850 pairs in 1975–1977. Carter et al. (1992) reported 770 pairs in 1975–1978 and about 1600 pairs in 1989. Carter et al. believe the higher numbers reflect both better census techniques and a true increase.

The Xantus' Murrelet (*Synthliboramphus hypoleucus*) is restricted to the Channel and Pacific Baja California islands, from San Miguel south to Natividad and Guadalupe (A.O.U. 1983). Hunt et al. (1980) and Carter et al. (1992) add San Clemente and Santa Catalina, at least as historical sites. There is some evidence of recent breeding on San Clemente Island (Jorgensen 1984). Hunt et al. (1980) reported about 1670 pairs on the Channel Islands in 1975–1977, the vast majority (1590 pairs) being on Santa Barbara Island and adjacent Sutil and Shag Rock. Carter et al. (1992) reported about 860 pairs throughout the Channel Islands in 1991, with the majority (about 770 pairs) on Santa Barbara and adjacent islets. Carter et al. attributed the decline to differences in census techniques, loss of artificial habitat, loss of bush sites due to drought, and egg predation by deer mice (*Peromyscus maniculatus*). However, Carter et al. believed that in this century there has been a general increase in the population, which was presumed to be at a low in the early 1900s.

Cassin's Auklet (*Ptychoramphus aleuticus*) on the Farallones has increased tremendously over the last century (Ainley and Lewis 1974:438): "In the 1850s and 1860s they were rare and present only in the winter. . . . By the 1880s they were common and breeding, and by the 1890s they were abundant. In 1911 Dawson estimated 100,000–200,000 birds which includes the range of present estimates." Ainley and Lewis attribute the increase to a return of food-rich cold water following a warm-water period in the mid-1800s. Carter et al. (1992) estimate a breeding population of 67,500 pairs in the mid-1970s and about 19,140 in 1989. While Dawson's number may have been an overestimate, they attribute some real decline to the following possible factors: a decline in number of burrow sites, increased predation (especially by gulls), oil spills, and burrow collapses. (See also Ainley et al. 1994).

On the Channel Islands, Hunt et al. (1980) estimated at least 11,255 breeding pairs of Cassin's Auklets in 1975–1977, most from Prince Island and Castle Rock, both near San Miguel Island. Carter et al. (1992) reported 13,080 pairs in that period and a decrease to about 9150 pairs in 1991. They believe the decline was due to an overestimate of the Prince Island population in 1975–1977, but did not discount loss of burrow sites due to erosion and a die-back of vegetation. Cassin's Auklet bred within the last 100 years on Santa Barbara Island, but it is not there now and its loss is believed to be due to predation by feral house cats (Howell 1917).

TABLE 2. TRENDS IN BREEDING POPULATIONS OF CALIFORNIA CHANNEL ISLANDS RAPTORS OVER THE LAST 100 YEARS

A. Stable, increases, or turnover	
	American Kestrel (N)
	Barn Owl (N)
	Burrowing Owl (N)
	Long-eared Owl (N)
	Short-eared Owl (N)
	Northern Saw-whet Owl (N)
B. Declines and increases (mixed)	
	Red-tailed Hawk (N)
C. Declines or extirpations followed by increases	
	Bald Eagle (H)
	Peregrine Falcon (H)
D. Declines or extirpations	
	Osprey (H)

(N) Presumed natural causes. (H) Presumed human-induced causes.

The Rhinoceros Auklet (*Cerorhinca monocerata*) on the Farallones was present and breeding up to the mid-1860s and disappeared about that time (Ainley and Lewis 1974). It reestablished a breeding population in 1972 (Ainley et al. 1994). About 50 pairs were reported in the mid- to late 1970s. The population grew to 175 pairs by 1982, crashed during the 1982/1983 El Niño, and rebounded to about 260 pairs in 1989, where it remains today (Carter et al. 1992, Ainley et al. 1994). On Año Nuevo Island the population was estimated to have grown from zero in the mid-1970s to about 40 pairs in 1989 (Carter et al. 1992). On the Channel Islands the Rhinoceros Auklet was not known as a breeding bird until Carter et al. (1992) reported breeding behavior on Prince Island: 19 birds were observed. See Guthrie (1993) for fossil evidence of this species on San Miguel Island.

The Tufted Puffin (*Fratercula cirrhata*) on the Farallones did not decline during the egging years, but with the arrival of oil pollution their numbers dropped from an estimated several thousand in 1911 to 300 by 1933 (Ainley and Lewis 1974). In the early 1970s the numbers were apparently stable at 25–30 pairs. Numbers declined again owing to the 1982/1983 El Niño, but then recovered to about 35–50 pairs in 1985–1989 (Carter et al. 1992). On the Channel Islands moderate numbers of Tufted Puffins bred from 1886–1912, mainly on the Northern Channel Islands and on Santa Barbara Island (Hunt et al. 1980). Smaller numbers may have bred into the mid 1900s, but none were reported during surveys in 1965, 1968, and 1975–1977. Ainley and Lewis (1974) argued that the decline in both the Farallones and the Channel Islands was due to the demise of the Pacific sardine. In 1991 Carter et al. (1992) discovered that five pairs had recolonized Prince Island, and observed courtship behavior and a possible nesting crevice.

RAPTORS

Several of the principal raptor species on the Channel Islands have had a history unlike that of marine birds or other land birds (Table 2). Some marine-feeding species have felt the impact of DDT; others have been hunted. Also, being top-level predators, many normally occurred in low numbers.

In the last century and early 1900s, the Osprey (*Pandion haliaetus*) was a breeding resident on the southernmost islands: San Nicolas, Santa Catalina, and San Clemente (Howell 1917, Grinnell and Miller 1944, Kiff 1980). San Clemente Island seemed to have the largest historic population, with 20 nests being reported in 1907 (Kiff 1980). Its decline was noticed in the 1920s and by 1930 it was presumed extirpated from the islands. Kiff believes shooting by fisherman was the principal cause.

The Bald Eagle (*Haliaeetus leucocephalus*) once nested on all the Channel Islands (Grinnell and Miller 1944). In the late 1800s and early 1900s Santa Rosa supported at least three pairs and Santa Cruz at least five, and eagles could have been even more abundant on Santa Catalina (Kiff 1980). San Miguel had at least three active nests in a single year. Kiff estimated that the highest number of active Bald Eagle nests in one year for the Channel Islands was 24. The Channel Islands were one of the last strongholds for the Bald Eagle in California; however, it eventually succumbed to persecution there

as elsewhere (Kiff 1980). Declines were noted in the early 1900s. It was extirpated from Santa Barbara Island between 1927 and 1939, from San Miguel Island between 1939 and 1960, from San Nicolas between 1945 and 1959, and from Anacapa between 1959 and 1962. Kiff surmised that the eagle survived on Santa Catalina, Santa Cruz, and Santa Rosa until the late 1950s. Recorded causes of mortality include shooting, egg collecting, nest destruction and disturbance, trapping, and poisoning. Kiff (1980) believed that shooting, especially by sheepherders and visitors, was the most important factor leading to extirpation, but DDT likely contributed as well.

Attempts to reintroduce Bald Eagles to Santa Catalina began in 1980 (Garcelon et al. 1989, Garcelon and Roemer 1990), with introduction of eaglets. They were fed on carcasses of feral goats and pigs; later, as adults, they fed on their own, taking marine fish and birds. Hacking efforts ended in 1986, with 33 birds having been released. A pair of four-year-old birds built a nest in 1984 (D. Garcelon, pers. comm.). The first eggs were laid in 1987. Between 1987 and 1993, one to three pairs attempted nesting each year (three in 1992), but did not raise viable young until 1993 (one fledged), perhaps because DDT is too high for successful reproduction (D. Garcelon, pers. comm.). An attempt to reestablish the Bald Eagle on San Clemente Island was not successful (Jorgensen 1984).

The Red-tailed Hawk (*Buteo jamaicensis*) on the Channel Islands has not been subject to declines (Diamond and Jones 1980). It is present and breeds year round on Santa Rosa, Santa Cruz, and Santa Catalina islands, and has bred on more than one occasion, but not every year, on San Miguel, Anacapa, and San Clemente. Jones (pers. comm.) indicates that this species is probably relatively new to San Miguel Island: it was not recorded as a breeding bird before the late 1960s or early 1970s.

The American Kestrel (*Falco sparverius*) has been resident on Santa Rosa, Santa Cruz, Anacapa, Santa Catalina, and San Clemente, and the population on San Clemente seems to have increased (Jorgensen 1984). It has also bred, although not annually, on San Nicolas and Santa Barbara islands. Jones (pers. comm.) believes it did not breed on San Nicolas until 1976 and on Santa Barbara Island until after 1939, possibly as late as 1968 (see also Hunt and Hunt 1974). On San Miguel Island, the kestrel seems to have become an established breeder fairly recently (Diamond and Jones 1980). It was thought to be an occasional breeder or winter visitor in 1910, but presumed breeding was not documented there until 1968 (Jones, pers. comm.).

Peregrine Falcons (*Falco peregrinus*) were common residents on the islands into the first half of the 1900s (Kiff 1980). Throughout California, according to Herman et al. (1970), until the mid-1940s approximately 100 eyries were producing young annually, but in the two decades following 1945 there was a 95% decline of the total California population. Herman et al. believed the island populations were extirpated by 1955. Documented cases of mortality include shooting, collecting, and removal of young from nests for falconry. Reproductive failure associated with DDT was also important (Kiff 1980).

Peregrine Falcons now nest on the Channel Islands as a result of releases by the Predatory Bird Research Group, Santa Cruz, California (B. Walton, in litt.). The group began releases in Big Sur, in Los Padres National Forest, in the Santa Monica Mountains, and at two coastal locations in southern California. Because the birds wander they were likely visitors to the Channel Islands. The group also began releases on Santa Catalina Island in 1983 and on San Miguel Island in 1985. Today there is nesting on Anacapa, Santa Cruz, Santa Rosa, and San Miguel, and sightings are frequent on other islands. Along the California coast north of the Channel Islands, the density of Peregrine Falcons has returned to pre-DDT levels, but natural productivity is low, owing

TABLE 3. TRENDS IN BREEDING POPULATIONS OF CALIFORNIA CHANNEL ISLANDS LAND BIRDS OVER THE LAST 100 YEARS

A. Colonize new islands
Allen's Hummingbird (N)
Common Flicker (N)
Acorn Woodpecker (N)
Ash-throated Flycatcher (N)
Phainopepla (N)
Black-headed Grosbeak (N)
Rufous-crowned Sparrow (N)
Chipping Sparrow (N)
Western Meadowlark (N)
B. Declines and increases (mixed)
Orange-crowned Warbler (H) (N)
Dark-eyed Junco (H) (N)
C. Declines or one or more populations extirpated
Horned Lark (N)
Common Raven (H)
Bewick Wren
Loggerhead Shrike (H)
House Finch (H) (N)
Rufous-sided Towhee (H)*
Sage Sparrow (H)
Song Sparrow (H)*

(N) Presumed natural causes. (H) Presumed human-induced causes.
* Extinct subspecies.

to residual effects of DDT (Garcelon et al. 1989).

Barn, Burrowing, Long-eared, and Northern Saw-whet owls (*Tyto alba, Athene cunicularia, Asio otus,* and *Aegolius acadicus,* respectively) are residents or occasional breeders on one or more or the Channel Islands (Diamond and Jones 1980). However, we know little about their status. There is no evidence for decline, nor would this be expected in the absence of killing by humans and the fact that owls do not feed on DDT-contaminated marine food.

On Santa Barbara Island the Barn Owl was not recorded in early surveys (Howell 1917), but was present in 1968 and subsequently (Hunt and Hunt 1974). Jones (pers. comm.) states that the Burrowing Owl was not recorded before 1953 and may have colonized in this century. Also, on Santa Barbara Island, the Short-eared Owl (*Asio flammeus*) was present from 1980 through 1983, when numbers of deer mice (*Peromyscus maniculatus*) were high (Drost and Fellers 1991). Numbers of Barn Owls also track mouse population size (Drost and Fellers 1991).

OTHER LAND BIRDS

Surveys of most land bird species have not been consistent over the last 100 years, and I know of no studies where population counts have been done over enough years to provide hard data. However, by noting presence or absence and casual comments some general trends can be discerned (Table 3). Some species have colonized new islands, and others, especially certain endemic races, have been extirpated, usually due to habitat degradation by introduced rabbits, goats, and sheep.

Costa's Hummingbird (*Calypte costae*) was recorded on Santa Barbara Island in 1911, but not subsequently (Hunt and Hunt 1974; Jones, unpub.). However, there is no firm data that it actually nested there (P. Collins, pers. comm.).

Allen's Hummingbird (*Selasphorus sasin*) probably has been a breeding resident on Santa Rosa, Santa Cruz, Anacapa, Santa Catalina, and San Clemente islands throughout this century. More recently it became an established breeder on San Miguel; the first record was in 1968, when it was common and nesting (Diamond and Jones 1980, Jones, pers. comm.). On Santa Barbara Island Allen's Hummingbird has been recorded sporadically, and may be subject to turnover (Hunt and Hunt 1974).

The Common Flicker (*Colaptes auratus*) is a common resident on Santa Cruz and Santa Catalina islands, but the lack of evidence of breeding before 1906 on Catalina suggests it may have colonized that island in this century (Diamond and Jones 1980, Jones, pers. comm.).

The Acorn Woodpecker (*Melanerpes formicivorus*) has immigrated and become an established breeder on Santa Cruz (1928–1929) and on Santa Catalina (1955) (Diamond and Jones 1980; Jones, pers. comm.). Johnson (1972) discusses these colonizations in detail. Although the colonizations were natural, they may have been enhanced

by the presence of utility poles and trees planted by humans.

The Ash-throated Flycatcher (*Myiarchus cinerascens*) is an uncommon, summer resident on Santa Cruz Island (Diamond and Jones 1980), first recorded breeding there in 1968 (Jones, pers. comm.).

Horned Larks (*Eremophila alpestris*) are common residents on all of the Channel Islands, except Anacapa (Diamond and Jones 1980). It formerly bred on Anacapa but disappeared between 1941 and 1963 (Jones, pers. comm.). All Channel Island populations are considered a separate race, *E. a. insularis* [races of island land birds discussed here are given in A.O.U. (1957)]. On Santa Cruz cattle and feral sheep were taken off the island in the 1980s. In the absence of grazers, introduced sweet fennel (*Foeniculum vulgare*) is rapidly spreading through open grassland and may reduce habitat for larks.

The Common Raven (*Corvus corax*) is a common resident on the five largest Channel Islands. It was resident on San Miguel up to 1939, and may have been eliminated by poisoning or shooting by ranchers (Jones, pers. comm.). It is breeding again on San Miguel (B. Stewart, pers. comm.). Jones also reported that it may breed occasionally on Anacapa. It bred on Santa Barbara Island up to 1939, but in 1972 it was not recorded (Hunt and Hunt 1974).

The resident Bewick's Wren (*Thryomanes bewickii*) has differentiated sufficiently to have races identified for several island populations: *nesophilus* on Santa Rosa, Santa Cruz, and Anacapa; *catalinae* on Santa Catalina; and *leucophrys* was on San Clemente. *T. b. leucophrys* disappeared from San Clemente about 1941 (Diamond and Jones 1980; Jorgensen 1984; Jones, pers. comm.), probably owing to habitat destruction.

The Phainopepla (*Phainopepla nitens*) was known to breed only on Santa Catalina (Diamond and Jones 1980), until a pair was located on Santa Cruz in 1984 (Haemig 1986). Because Santa Cruz has been frequented by researchers for many years, this colonization is no doubt recent.

Two subspecies of Loggerhead Shrike (*Lanius ludovicianus*) occur on the Channel Islands, *anthonyi* on Santa Rosa, Santa Cruz, and Santa Catalina, and *mearnsi* on San Clemente. *L. l. mearnsi* was abundant in the early 1900s, but declined through the 1960s to 50 individuals in 1975 (U.S. Fish and Wildlife Service 1984), and ultimately to five pairs (Scott and Morrison 1990). The 1989 population estimate increased to 12–20 birds (Matthews 1990). The shrike seems to be affected in part by habitat degradation and resulting loss of prey. Predation by Common Ravens, feral cats, and island foxes (*Urocyon littoralis*) is also important, and mortality in young shrikes is higher than on the mainland (Scott and Morrison 1990).

The Orange-crowned Warbler (*Vermivora celata*) has long been a breeding resident on Santa Rosa, Santa Cruz, Anacapa, Santa Catalina and San Clemente islands (Diamond and Jones 1980). Island populations constitute a separate race, *V. c. sordida*. On San Miguel and San Nicolas it was not recorded as breeding until 1968 (Jones, pers. comm.). The population on Santa Barbara Island was absent for a time; Hunt and Hunt (1974) cite records for 1918, 1927, and 1939, but did not record it later, including during their 1972 survey. Hunt and Hunt surmise its loss may have been due to destruction of suitable nesting habitat by introduced rabbits and a fire in 1959. However, breeding has been recorded since 1972 (Jones, pers. comm.), so it has recovered on this island. Jones indicates variation in breeding from year to year.

The Black-headed Grosbeak (*Pheucticus melanocephalus*) occurs only on Santa Cruz Island, where the first confirmed breeding was in 1968 (Jones, pers. comm.).

The House Finch (*Carpodacus mexicanus*) occurred uninterruptedly on all eight of the Channel Islands until 20–25 years ago (Diamond and Jones 1980). On Santa Barbara Island, birds presumably of the island race *C. m. clementis* were last seen in 1968

TABLE 4. HUMAN-INDUCED INTRODUCTIONS TO THE BREEDING POPULATIONS OF THE CALIFORNIA CHANNEL ISLANDS OVER THE LAST 100 YEARS

A. Introductions followed by extirpation
Common Peafowl
B. Successful introductions
Chukar
Wild Turkey
Common [Ring-necked] Pheasant
Gambel's Quail
California Quail
Rock Dove
European Starling
House Sparrow

(Hunt and Hunt 1974), the loss being attributed to destruction of nesting habitat by introduced rabbits. House Finches of an unknown subspecies have recolonized Santa Barbara Island and were again breeding by 1977.

The Rufous-sided Towhee (*Pipilo erythrophthalmus*) has differentiated into two recognizable races on the Channel Islands: *megalonyx* (the mainland race) on Santa Cruz and *clementae* on Santa Rosa, Santa Catalina, and San Clemente (Johnson 1972). The population on San Clemente was nearly extinct in 1968 (an immature bird was seen in 1975) and is presumed gone (Diamond and Jones 1980; Jorgensen 1984; Jones, pers. comm.).

The island race of the Rufous-crowned Sparrow (*Aimophila ruficeps obscura*) is a breeding resident on Santa Cruz Island (Diamond and Jones 1980), and seems to have colonized Anacapa in recent times (Johnson 1972). It was first recorded in 1940 and was common by 1963 (Jones, pers. comm.)

The Chipping Sparrow (*Spizella passerina*) is present only during the breeding season and occurs on Santa Rosa, Santa Cruz, Santa Catalina, and San Clemente islands (Diamond and Jones 1980). It colonized Anacapa Island about 1940 (Jones, pers. comm.).

The endemic San Clemente Sage Sparrow (*Amphispiza belli clementeae*) was common earlier in this century (Howell 1917). Owing to habitat destruction by feral goats and sheep, and increased predation by island fox, it is now a federally "threatened" subspecies (Anon. 1980, Jorgensen 1984). Recent population estimates range from 20–30 breeding adults in 1974 (Stewart et al. 1974), to 90–110 adults in 1976 (Byers 1976, Sward 1977), and 250–400 individuals in 1982 (U.S. Fish and Wildlife Service 1984).

The Song Sparrow (*Melospiza melodia*) is now a breeding resident only on San Miguel (*micronyx*) and Santa Rosa, and Santa Cruz (*clementae*) (Diamond and Jones 1980). Island populations on Santa Barbara (*graminea*) and San Clemente (*clementae*) have become extinct in this century (Jorgensen 1984); the form on Santa Barbara Island was last seen in 1967 (Hunt and Hunt 1974).

Dark-eyed Juncos (*Junco hyemalis*), winter visitors to the Channel Islands, were first recorded breeding on Santa Catalina in 1986 (Collins 1987).

The Western Meadowlark (*Sturnella neglecta*) is a breeding resident on all Channel Islands (Diamond and Jones 1980). It colonized San Nicolas Island in this century, being first recorded from in 1945 (Jones, pers. comm.).

INTRODUCTIONS IN THE LAST 100 YEARS

The final category of avifaunal change is species introduced directly onto the islands, such as for hunting, or of species introduced elsewhere in North America that subsequently reached the islands on their own (Table 4).

The Chukar (*Alectoris graeca*) was established in 1975 on San Nicolas Island after repeated introductions by the California Department of Fish and Game (Jones, pers. comm.). There was also a successful introduction on Santa Rosa Island in 1985–1986 (P. Collins, pers. comm.). Releases on Santa Catalina (year unknown) and on San Clemente (1960) were not successful.

A pair of Common (Ring-necked) Pheasants (*Phasianus colchicus*) was unsuccessfully introduced on Santa Rosa Island in 1988 (P. Collins, pers. comm.). A small flock

of Common Peafowl (*Pavo cristatus*) occurs around the main ranch of Santa Cruz Island (pers. obs.); a release on Santa Catalina in the 1960s was not successful (Jones, pers. comm.). The Wild Turkey (*Meleagris gallopavo*) was introduced on Santa Cruz Island in 1877 but was never established; however, it was successfully reintroduced sometime before 1968 (Jones, pers. comm.). Jones also reports it was successfully introduced on Santa Catalina in 1969.

Gambel's Quail (*Callipepla gambelii*) was introduced on San Clemente Island about 1912 (Jorgensen 1984). The California Quail (*Callipepla californica*) on Santa Catalina Island (*catalinensis*) is larger and darker than its mainland counterpart (Johnson 1972), and may have been introduced by Native Americans, perhaps thousands of years ago. Quail from Santa Catalina were successfully introduced on Santa Rosa between 1935 and 1940, and on Santa Cruz in 1946 (Jones, pers. comm.). California Quail of an unknown race were introduced about 1890 on San Clemente, but eventually disappeared (Jorgensen 1984).

Rock Doves (*Columba livia*) are transient visitors to many of the Channel Islands (P. Collins, pers. comm.). They colonized the town of Avalon on Santa Catalina Island between 1917 and 1968 (Diamond 1969).

The European Starling (*Sturnus vulgaris*) was introduced in New York City in 1890 (A.O.U. 1983) and arrived in California about 1942 (Small 1974). The first record from the Channel Islands (Santa Cruz) came in 1964 (Jones, pers. comm.). It is now a common resident on all the Channel Islands.

The House Sparrow (*Passer domesticus*), introduced in New York City in 1850, with subsequent introductions elsewhere up to 1867 (A.O.U. 1983), was first seen on the Channel Islands (Santa Cruz) in 1915 (Jones, pers. comm.). In this century it became a breeding resident on Santa Rosa (first recorded in 1927), San Nicolas (colonized between 1945 and 1959), Santa Catalina (first recorded in 1928), and San Clemente (first mentioned in 1915; well established in 1968) (Jones, pers. comm.). Interestingly, a breeding population was never firmly established on Santa Cruz and it is now extirpated on Santa Rosa, both islands with extensive ranching operations, at least until recently (Jones, pers. comm.).

DISCUSSION

Tables 1–4 summarize changes in the avifauna over the last 100 years. Groupings are only an approximation and are not used to summarize general trends. Also, the designation of whether changes are "natural" or "human-induced" are based on published opinions; only in a few cases are they truly documented.

Over the last 100 years, four species of marine birds seem to have increased in range or numbers, seven species first declined and later increased or recovered over at least part of their range, two species declined or are declining, and one species seems to have increased and is now declining.

Six species of raptors have stayed constant or expanded their ranges to new islands, and another increased on some of the islands and declined on another. Two species of raptors were first extirpated and have been reintroduced (the Bald Eagle and Peregrine Falcon). The Osprey is extirpated.

Up to nine species of land birds may have colonized new islands. Two species have gained populations on new islands and seen declines or total losses on others. Eight species have suffered losses or had individual island populations lost, or presumed so. Two endemic races are extinct: San Clemente Bewick's Wren and Santa Barbara Island Song Sparrow. Populations of more widespread island races that are extirpated on at least one island include the San Clemente Rufous-sided Towhee and San Clemente and Santa Barbara islands' populations of the Song Sparrow. One endemic island population was extirpated and was replaced with an unknown race: the Santa Barbara Island population of the House Finch. The Sage Sparrow on San Clemente decreased signif-

icantly in the first 75 years of this century and is increasing again. The San Clemente Loggerhead Shrike was on the brink of extinction.

Eight species have been introduced, or, after having been introduced to North America, have made their way to the islands.

A few of the changes are natural, having been caused by variation in food supply or the result of turnover. However, most of the changes are not. Declines and extirpations resulted from egging in the 1800s, oil pollution, human disturbance, overfishing, shooting, DDT in the food chain, conscious introductions by humans, and habitat alteration following introduction of predators, grazers, and browsers. Recent trends are encouraging: several species once in danger now have well-established populations. In other cases, the jury is still out. A few, morphologically differentiated populations have been lost forever.

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