Historical Changes in Resident Populations of California Islands Raptors

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INTRODUCTION

The California Islands have been the scene of repeated avian extinctions (Jones and Diamond 1976), but no group of species has experienced more dramatic population changes in this century than the large birds of prey. The islands formerly supported resident populations of the Bald Eagle (*Haliaeetus leucocephalus*), Osprey (*Pandion haliaetus*), and Peregrine Falcon (*Falco peregrinus*), but all are now extinct.

This paper summarizes the existing data on historical changes in the status of these three raptors on the California Islands and evaluates the relative importance of known mortality factors in causing their disappearance as breeding residents. The raptor populations discussed here are those formerly resident on the California Channel Islands (San Clemente, Santa Catalina, Santa Barbara, San Nicolas, Anacapa, Santa Cruz, Santa Rosa, and San Miguel) and Los Coronados Islands, off the coast of northwestern Baja California about 40 km SW of San Diego, California.

METHODS

This study is an outgrowth of a larger project undertaken to establish an inventory of museum egg sets of all species collected on these islands. For the present report, I attempted to compile all available data for Bald Eagles, Ospreys, and Peregrine Falcons on the islands prior to 1965 from the following sources.

(1) Data accompanying museum egg sets. Forty-three of the principal egg collections in North America were examined personally, or for me by their staff members, for island egg sets of Bald Eagles, Ospreys, and Peregrine Falcons (Appendix 1). Specific set collection data will be presented elsewhere (Kiff in prep.). Although I have probably accounted for the great majority of egg sets collected on the California Islands by ornithologists and oologists, some sets, especially those taken as curiosities by casual visitors to the islands, have doubtless not come to my attention.

(2) Specimen labels on study skins and skeletons of the three raptors in the major California bird collections. No attempt was made to locate such specimens in other collections; I suspect that few others exist.

(3) The unpublished field notes or manuscripts of 40 persons, mostly collectors, who visited the California Islands prior to 1965 (Appendix 2).

(4) Interviews with long-time residents of the larger Channel Islands and with visitors to all of the islands.

(5) Published accounts of the birds of the California Islands. The principal sources of detailed information are Willett (1912, 1933), Howell (1917), Johnson (1972), Power (1972), Jones (1975), and Jehl (1977).

Because many of these data sources are anecdotal in nature, collectively they yield only a fragmentary picture of the extinct raptor populations, particularly of their former sizes and the causes of their disappearance.

RESULTS

Bald Eagle

Distribution and status

Bald Eagles nested at one time or another on all of the Channel Islands and on Los Coronados Islands. The resident population was apparently nonmigratory, but was augmented in some winters by an increment of birds from northern populations (Grinnell and Miller 1944).

Bald Eagles were reported from San Miguel Island as early as the spring of 1886 (Streator 1888), and a party led by George Willett (1910) found them to be common there during June. J. R. Pemberton and Dudley S. DeGroot visited the island on 31 March 1927 and saw three adult eagles and two inactive nests on the northwest side. On the following day, they took a set of eggs (WFVZ 2002) from a nest on the southwest side of the island (DeGroot field notes). Herbert Lester, then the caretaker of the island, told Lowell Sumner and Richard Bond in April, 1939 that two pairs of eagles nested regularly on San Miguel in addition to a pair on nearby Prince Island (Sumner unpubl. ms.).

The Pemberton-DeGroot party counted ten eagles and found three nests, two containing small young, during their visit to Santa Rosa Island between 2 and 4 April 1927 (Pemberton 1928). Because ornithological coverage of Santa Rosa was so meager during the years when eagles occurred there, it is likely that more than three pairs were usually resident on that large island. Most California Islands eagle nests were located on rocky cliffs and exposed pinnacles, but all of those seen on Santa Rosa Island by Pemberton were situated in trees in sheltered canyons (Pemberton 1928). He believed that the strong winds characteristic of Santa Rosa prevented the eagles from building their nests in more exposed sites. However, later visitors to Santa Rosa found some eagle nests on sea cliffs there (E. N. Harrison, pers. comm.; WFVZ 22562).

Santa Cruz Island regularly supported at least five resident pairs of Bald Eagles, and a steady procession of egg collectors and other visitors to the island frequently commented on the species' abundance there. Judging from the data slips accompanying egg sets, traditional nest sites were located at Pelican Bay, San Pedro Point, Blue Banks, Valley Anchorage, China Bay (Chinese Harbor), Potato Bay (Potato Harbor), and Middle Grounds, although not all were necessarily occupied by eagles every year. Almost all Santa Cruz Island eagle nests were in niches and potholes on exposed sea cliffs, but the Pelican Bay birds regularly nested in pine trees (Howell and van Rossem 1911, Canterbury field notes for 1919, Sheldon field notes for 1927-1928).

In some years, nearby Anacapa Island had three pairs of nesting eagles (Willett 1910, Burt 1911, DeGroot field notes for 1927), but two pairs were more usual in the 1930s (E. N. Harrison, pers. comm.). Sumner (unpubl. ms.) stated that on 16 April 1939 the species was "almost constantly in sight on Anacapa, two adults and four immatures having been seen over the highest peak at once." Burt (1911) thought the eagles nesting on Anacapa Island were required to transport their principal nesting materials, large sticks, from Santa Cruz Island because of the virtual lack of trees on Anacapa. However, later visitors to Anacapa (Sumner unpubl. ms., Quigley field notes for 1949) found an active eagle nest actually situated in a sizeable Island Oak (*Quercus tomentella*).

Howell (1917) thought it probable that Santa Barbara Island, because of its small size, supported only a single pair of Bald Eagles. Although an actual nest was never described, eagles were reported from Santa Barbara Island during the usual breeding season by Grinnell (1897), Willett (1912), Wright and Snyder (1913), and DeGroot (field notes for 1927).

Bald Eagles were evidently abundant on Santa Catalina Island in the nineteenth century. Cooper (1870), recounting a visit that he made to the island in the early 1860s, wrote that "I have seen more than thirty of these eagles in young plumage, soaring about the north end of

Catalina Island on the 9th of July, and their nests were numerous among the inaccessible cliffs of that island." At the turn of the century, several visitors to the island, including Zahn (1895), Grinnell (1898), Richardson (1908), and Snyder (1909), commented on seeing eagles and, usually, their nests on Santa Catalina. A. J. van Rossem (field notes) found four probably active eagle nests on 18 February 1921 while rowing along the shoreline from the town of Avalon. He concluded that the nests occurred at intervals of about two miles of coastline, indicating the apparent large size of the eagle population on the island at that time.

Few specific details are available concerning the status of Bald Eagles on San Nicolas Island, although Howell (1917) stated that eagles were reportedly abundant there, probably based on information supplied to him by C. B. Linton, one of the few early visitors to San Nicolas. Although Loye Miller (unpubl. ms.) did not encounter eagles on San Nicolas during his visit between 7 and 18 July 1938, Rett (1947) investigated a recently active eagle nest there on 23 September 1945.

Most visitors to San Clemente Island found eagles to be common there (Grinnell 1897, Linton 1908, Howell 1917), and a minimum of three nests were active in late February, 1923 (egg sets at WFVZ). Presumably, other nesting pairs existed in the more poorly investigated sections of the island.

Bald Eagles were surprisingly scarce on Los Coronados Islands. The only evidence suggesting that the species ever nested there at all was provided by Grinnell and Daggett (1903), who saw one on South Coronado Island on 6 and 7 August 1902 and wrote that "We were told that a pair had a nest there." Howell (1917) did not record the species during several visits to Los Coronados between 1910 and 1917. Stephens (1921) saw an immature over North Coronado Island on 5 March 1921, but it was evidently a transient. If the species had nested there at that time, this would surely have been known to the egg collectors, who visited the islands almost annually.

In summary, the highest numbers of active Bald Eagle nests reported (or inferred from the available data) during a single year for the various California Islands are as follows: San Miguel (including Prince Island), 3; Santa Rosa, 3; Santa Cruz, 5; Anacapa, 3; Santa Barbara, 1; Santa Catalina, 4; San Nicolas, 1; San Clemente, 3; Los Coronados, 1—for a total of 24 nests. Because of incomplete coverage by observers of the larger islands, including Santa Rosa, Santa Cruz, Santa Catalina, and San Clemente, these figures are undoubtedly low; the actual maximum number of Bald Eagles that nested concurrently on the California Islands within historical times was surely much higher.

Food habits

Of the three raptors discussed here, Bald Eagles were by far the most catholic in their food preferences. They reportedly fed on a variety of fish, birds, and mammals, including a high percentage of carrion.

Grinnell (1897) saw the species feeding on dead fish washed up on the beach at San Clemente Island, and he contended that the eagles there did not rob Ospreys of their food as frequently as had been popularly supposed. Burt (1911) found half-eaten fish in an Anacapa Island eagle nest that contained young two to three days old. Other than DeGroot's (field notes) observation of "some large sea bass" in a Santa Rosa Island eagle nest, there are no specific reports on the size and species of fish utilized by Bald Eagles on the California Islands.

The nest examined by DeGroot on Santa Rosa also contained a Surf Scoter (*Melanitta perspicillata*), a raven (*Corvus corax*), and the feet of several gulls (*Larus* sp.) (DeGroot field notes). Sumner (unpubl. ms.) looked into an eagle nest on Prince Island on 18 April 1939 that contained the remains of two young pelicans (*Pelecanus occidentalis*), a guillemot (*Cepphus* sp.), and the wing of a California Gull (*Larus californicus*). On San Nicolas Island, a resident told Rett (1947) that he had found the wing of a gull and some large black wings, possibly those

of a cormorant (*Phalacrocorax* sp.) or raven, in an eagle nest that he had visited in the summer of 1945.

Many writers mentioned that Bald Eagles ate sheep and lambs on the islands where these domestic animals had been introduced. Although there seems to have been a prevalent belief that eagles took living lambs (*e.g.*, Burt 1911, Dawson 1923, Sheldon field notes for 1927-1928), I have been unable to find a firsthand account of such predation on the California Islands. On the other hand, certain residents of the islands told visiting ornithologists that they thought that eagles ate only sheep and lambs that had died from other causes. The ranch foreman on San Clemente Island, Charles Howland, had lived there for 15 years when A. B. Howell, D. R. Dickey, and L. M. Huey visited in 1915. He stated that he had seen an eagle carrying a lamb only once during his tenure on the island, and that the animal had died of natural causes (Howell 1917). Sumner (unpubl. ms.) was told by Herbert Lester, the caretaker on San Miguel Island, that eagles did not take living sheep there, and the residents of Santa Cruz Island made similar statements to E. N. Harrison (pers. comm.) during his visits to that island in the 1930s.

Several egg collectors mentioned finding sheep carcasses in the immediate vicinity of eagle nests or actually incorporated into the substructure of nests (Linton 1908, Carpenter field notes for 1922, Bancroft field notes for 1923, Dawson 1923, Sheldon field notes for 1927-1928). A nest investigated by Bancroft on San Clemente Island on 24 February 1923 contained the carcasses of seven sheep (data slip for WFVZ 10084).

Bald Eagles probably also fed regularly on carcasses of the native Island Fox (*Urocyon littoralis*) on those islands where it occurs. Rett (1947) found the hind leg of a fox in a San Nicolas Island eagle nest, and D. R. Dickey discovered the entire desiccated carcass of a fox stuck in the wall of a nest on San Clemente Island in 1915 (Howell 1917).

Period of decline

Willett (1912) and Howell (1917) regarded the Bald Eagle as a common resident of the Channel Islands. By the early 1920s, Dawson (1923) felt that the species was still fairly common there, although he noted that the population had been greatly reduced by human persecution. He predicted, "Unless the Bald Eagle is actually protected, not alone from lawless marauders in motor boats, but from the vengeance of the sheepmen . . . its days are numbered." In a revision of his 1912 work, Willett (1933) amended his earlier assessment of the eagle's status on the islands to "fairly common." Nevertheless, Grinnell and Miller (1944) described the Channel Islands as being one of the two "breeding metropolises" of the Bald Eagles still remaining in California, the other being in the northeastern sector of the state. This was the last general reference on California birds in which the Bald Eagle was considered to be extant as a breeding form on the California Islands.

It is not possible to specify the year of the eagle's disappearance from most of the islands because of the paucity of recorded observations for several decades. The latest report of nesting eagles cannot be considered a meaningful estimate of when the species vanished. For example, an apparently active eagle nest examined on San Clemente Island on 26 March 1927 by the DeGroot-Pemberton party (DeGroot field notes) represents the latest record of the species that I have been able to locate for the island, but virtually no observations were reported for San Clemente birds between 1927 and recent years. Similarly, the latest record of nesting eagles for San Miguel Island was April, 1939, but no further bird observations were reported from there until the 1960s. By then, the Bald Eagle had vanished from the island.

Extinction of the Bald Eagle on Santa Barbara Island evidently occurred between 27 March 1927, when the species was noted there by the DeGroot-Pemberton party (DeGroot field notes), and 1939, when it was not found by L. Sumner and R. Bond in April (Sumner unpubl. ms.), or by a biological survey party from the Los Angeles County Museum of Natural History between 27 and 30 May (J. C. von Bloeker, Jr. *in litt.*). The island is so small that these visitors could

FIGURE 1. *Bald Eagle chick in 1949 Anacapa Island nest. Photo by Raymond J. Quigley.*

scarcely have missed eagles, had they been present.

At least one pair of eagles nested on San Nicolas Island in 1945 (Rett 1947), but a party from the University of California at Los Angeles did not record the species during field work between 9 and 13 January 1959 (Collias field notes). Townsend (1968) did not see any eagles during his long stay on San Nicolas Island between 2 May 1962 and 1 January 1964.

Bald Eagles nested on Anacapa Island as late as May, 1949 when Raymond Quigley, Telford Work, and Harold Hill investigated a nest containing a nestling three or four days old (Quigley field notes). The photographs made of the nest and chick (Fig. 1) may be the latest certain documentation of a Bald Eagle nesting attempt on the California Islands. When he visited Anacapa again on 27 May 1962, Quigley (field notes) did not see any Bald Eagles, and Banks (1966) found none during his visits to the island in 1963, 1964, and 1965.

On the remaining Channel Islands—Santa Catalina, Santa Cruz, and Santa Rosa—the Bald Eagle probably survived as a resident until the late 1950s, although a gradual decline in their

numbers had evidently been occurring prior to that time. Referring to the Santa Catalina Island population, Howell (1917) wrote, "A number are killed here annually by tourists and sheepherders, until they are now not quite so abundant," and van Rossem (field notes for 1921) noted that the Santa Catalina Island eagles were seeking more remote nesting sites as the popularity of the island increased. Nevertheless, A. Douglas Propst (pers. comm.) informed me that he noticed Bald Eagles on Santa Catalina for several years after he became a resident there in 1953, and he estimated that the resident eagle population vanished from the island completely in the late 1950s.

Similarly, long-time residents of Santa Cruz Island think that Bald Eagles were last seen there in about 1958 (Lyndal Laughrin, pers. comm.), although it is not known whether the birds were still attempting to nest then. Bill Wallace, ranch foreman on Santa Rosa Island, stated that the foreman who preceded him persecuted eagles in various ways on the island during the 1950s (pers. comm. to H. L. Jones). Wallace believes that these activities ceased in about 1958 when no more eagles could be found on the island.

With the extirpation of the Bald Eagle from these three large islands, the once thriving Channel Islands breeding population became totally extinct. Although some authors have stated that the extinction of Bald Eagles occurred at virtually the same time on the southern California mainland as on the Channel Islands (Diamond 1969, Lynch and Johnson 1974), the species essentially vanished as a breeding form on the adjacent mainland long before it disappeared from the islands.

Henshaw (1876) reported that Bald Eagles were abundant on the southern California mainland in the 1870s, but they barely persisted there past the turn of the century. I am aware of only seven southern California mainland nest localities used by Bald Eagles since 1900: (1) La Jolla Canyon, Ventura County (van Rossem field notes for 1922; egg set purportedly taken by O. W. Howard in 1921 not located by me); (2) Zuma Canyon, Los Angeles County (set of two eggs taken by W. L. Chambers on 13 March 1897, now WFVZ 65873; nesting continued until much later, according to E. N. Harrison, pers. comm.); (3) Malibu Canyon, Los Angeles County (Willett 1933; also set of two eggs taken by D. S. DeGroot on 21 March 1931, now WFVZ 58517); (4) Little Tecate Mountain (= "Lookout Mountain"), San Diego County (fresh egg taken by A. O. and Adan Treganza on 8 March 1936, now WFVZ 55005); (5) near the Sweetwater Reservoir, San Diego County, where a pair had a nest on top of a smokestack in an abandoned brick factory during the early part of the century (J. B. Dixon *in litt.*); (6) Rincon Creek, near Carpinteria, Santa Barbara County until the late 1930s (W. Abbott, pers. comm.); and (7) Dos Pueblos Ranch, Santa Barbara County. According to W. Abbott (pers. comm.), this nest was active until the early 1950s. It was photographed by L. T. Stevens on 8 February 1954 when it may still have been in use. No eggs are known to have been collected from Santa Barbara County mainland nest sites.

Causes of decline

Reported historical causes of Bald Eagle mortality on the California Islands include shooting, egg collecting, nest destruction, nest disturbance leading to desertion, removal of young from nests, trapping, and poisoning. Shooting, particularly by sheepherders but also by visitors to the islands, was probably the most important of these factors (Howell 1917, Dawson 1923). A single shooting incident could have accounted for the disappearance of eagles from the smaller islands (*e.g.*, Los Coronados and Santa Barbara), where only a single pair may have constituted the entire breeding population. On the larger islands, eagle populations seem to have been remarkably resilient, despite intensive persecution. On a visit to San Miguel Island between 27 and 29 December 1930, A. J. van Rossem (field notes) saw the wings of twenty or more Bald Eagles nailed to the wall of a barn by the caretaker of the island, who claimed that he had shot or poisoned all of the birds during the past year. Nevertheless, van Rossem reported that he saw

TABLE 1. Number of Bald Eagle egg sets collected on the Channel Islands and Los Coronados.

Island	Number of egg sets
San Clemente	15
San Nicolas	1*
Santa Catalina	10
Santa Barbara	0
Anacapa	15
Santa Cruz	35
Santa Rosa	5
San Miguel	2
Los Coronados	0
Total	82

* Not confirmed.

the "usual number" of live eagles on the island at the time of his visit. Some of the dead birds, as well as the living ones seen by van Rossem, could have been wintering individuals from northern populations. In April, 1939, L. Sumner and R. Bond encountered a more benevolent caretaker, Herbert Lester, and a healthy breeding population of Bald Eagles on San Miguel Island (Sumner unpubl. ms.).

George Breninger (1904) collected two sets of eggs (FMNH 481 and 15785) and at least two adult birds on San Clemente Island in February, 1903. His colorful account of eagle behavior at the nest, if true, indicates that the birds allowed close approach by Breninger and an assistant and may have engaged in actual nest defense. Such behavior, if typical, and the conspicuous nature of their nests would have contributed to the vulnerability of eagles to shooting.

Other birds were taken by museum collectors, but the number appears to be comparatively insignificant. My data sources yielded evidence of only six Bald Eagle study skins or skeletons from the California Islands, including those of Breninger, although a few others were no doubt collected.

At least 82 sets of Bald Eagle eggs were collected on the Channel Islands between 1875 and 1949. The total number of sets taken on each island is given in Table 1. In addition, at least one set was reportedly collected by C. B. Linton on San Nicolas Island (Willett 1912), but I could not locate it.

There appears to be no record of a replacement clutch being laid by a Bald Eagle on the California Islands after the loss of its eggs. Several veteran oologists with whom I have discussed this matter, as well as Dawson (1923), agreed that the former California Bald Eagles did not replace eggs that were collected, apparently differing in this respect from the Florida population (Bent 1937). Therefore, each set of eggs that was collected presumably cancelled the reproductive output of a given pair of eagles for an entire year.

Egg collecting probably had a negligible impact on eagle populations on most islands, since it occurred sporadically and usually involved only a single pair of birds in a given year. However, intense collecting pressure on Anacapa and Santa Cruz Islands between 1916 and 1922 may have temporarily reduced the resident eagle populations there, since at least 30 sets of eggs were taken from the two islands during that period. In his field notes covering a visit to Santa Cruz Island in 1920, van Rossem wrote, "All known nests on the island were robbed by a party of egg-hunters from Ventura (accounts of fishermen and islanders varied from seven to nine sets). These people are evidently making a yearly clean-up of eagles on all the northern group of islands, as I have reliable information of seven sets taken last year." That an actual

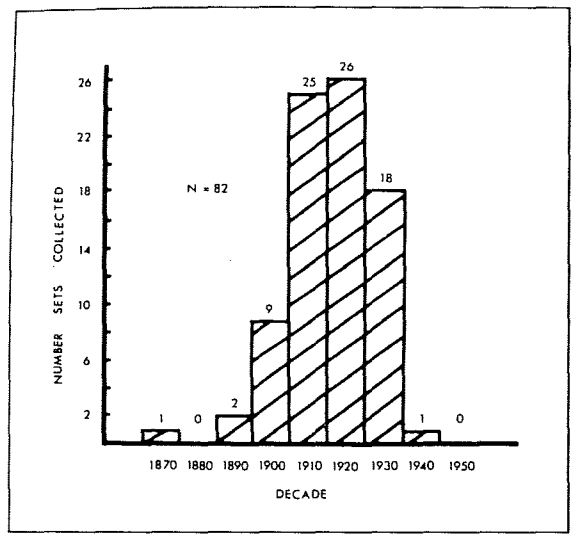

FIGURE 2. *Number of Bald Eagle egg sets collected on the California Islands per decade.*

decline in the eagle population occurred is suggested by Ross (1926), who reported, during a visit to Santa Cruz Island between 29 March and 1 April, being "impressed by the abundance of Ravens, and the scarcity of Bald Eagles."

Yet eagles were found nesting at nearly all of their traditional sites on Anacapa and Santa Cruz Islands in later years, according to the notes of collectors and others who visited the islands. During the 1930s, at least 14 more egg sets were taken (10 on Santa Cruz and 4 on Anacapa), but other nests successfully fledged young (E. N. Harrison, pers. comm., Sumner unpubl. ms.). Possibly, the eagle populations on Santa Cruz and Anacapa Islands were augmented by individuals hatched on other islands (*e.g.*, nearby Santa Rosa), where the birds were subjected to less harassment.

Collecting of Bald Eagle eggs on the Channel Islands was most intense between approximately 1915 and 1936 (Fig. 2); only a single set is known to have been taken after 1939. Although egg collecting probably contributed to short-term declines in eagle populations on some islands, it cannot account for the extirpation of the species from any island. Even where collectors were most active (*i.e.*, Anacapa and Santa Cruz Islands), nesting eagles were still present in significant numbers well after egg collecting had ceased.

Other forms of Bald Eagle mortality on the California Islands are more poorly documented, but some may have taken a considerable toll. Dawson (1923) reported that sheepherders destroyed nests on some islands, as well as routinely shot eagles. Even in the 1950s, the Santa Rosa Island population was still suffering from several forms of rancher-induced persecution, including destruction of nests and capturing of young, in addition to shooting (H. L. Jones, pers. comm.). A pair of eagles on San Clemente Island deserted their nest, which contained two eggs, after Donald Dickey left a camera set up beside it (Howell field notes for 1915).

Aside from Rett's (1947) report of an active eagle nest on San Nicolas Island in 1945, virtually nothing is known of Bald Eagles on the California Islands during the 1940s, a period when San Miguel, San Nicolas, and San Clemente Islands were under the jurisdiction of the United States Navy. The impact of wartime activities on eagles and other conspicuous animals on the islands is now a matter of conjecture, but it may have been severe. There are no post-war

records of Bald Eagles from any of these islands, but field work on each of them was too inadequate in the late 1940s and 1950s to confirm the disappearance of the species.

Poisoning programs were administered at one time or another on nearly all of the Channel Islands, mostly to control populations of introduced mammals. Such activities reportedly resulted in Bald Eagle deaths from primary or secondary poisoning on San Miguel Island (van Rossem field notes for 1930) and Santa Rosa and Santa Cruz Islands (E. N. Harrison, pers. comm.). However, the extent of these programs, the types of poisons used, and the actual incidence of eagle deaths from this source escaped documentation.

No environmental poison has had a more profound impact on avian populations than DDT. This pesticide was first used widely in the United States in 1947, and DDT-related residues were detected in the sediments of the Santa Barbara basin in about 1952 (Hom *et al.* 1974). Levels of DDT-type compounds have been unusually high in the southern California marine ecosystem, primarily as the result of the effluent from a DDT manufacturing company in Los Angeles (Burnett 1971). Numerous studies have shown that low dietary levels of p,p'DDE, the principal metabolite of DDT, are the primary, and perhaps sole, cause of eggshell thinning in populations of bird-eating and fish-eating wild birds (Cooke 1973, Stickel 1975, Peakall 1975).

At the time DDT was introduced in California, Bald Eagles still nested on at least Anacapa, Santa Cruz, Santa Rosa, and Santa Catalina Islands, although probably in lower numbers than previously because of the combined factors already discussed. For example, R. Quigley, H. Hill, and T. Work found only one active Bald Eagle nest on Anacapa Island in 1949 (Quigley field notes), whereas the island had traditionally supported two or three pairs of nesting eagles (Banks 1966). By 1960, resident Bald Eagles were completely extinct on all of the Channel Islands. A causal relationship between the disappearance of eagles and the introduction of DDT into the southern California marine ecosystem is suggested by the following points.

(1) Significant eggshell thinning has occurred in Bald Eagle eggs from most other parts of its range, and some eggs contained DDE residues of the same magnitude as those that produced shell thinning in experimental species (Anderson and Hickey 1972, Wiemeyer *et al.* 1972).

(2) Channel Islands populations of two piscivorous species, the Brown Pelican (*Pelecanus occidentalis*) and Double-crested Cormorant (*Phalacrocorax auritus*), have suffered severe eggshell thinning and population declines that were attributed to the effects of DDE (Risebrough *et al.* 1971, Gress *et al.* 1973, Anderson *et al.* 1975).

(3) Bald Eagles vanished at about the same time—in the late 1950s—from several of the larger islands, suggesting that a single factor was responsible.

(4) The timing of the extinction is compatible with the expected life span of this long-lived species. If DDE did affect eagle reproductive success on the Channel Islands by the early 1950s, adults may have occupied nesting sites for several years without reproducing successfully, leaving the sites vacant upon their deaths.

Osprey

Distribution and status

The Osprey occurred as a breeding resident only on the southernmost Channel Islands, specifically, San Clemente, Santa Catalina, and San Nicolas (Howell 1917). The nesting population was migratory (Howell 1917, Grinnell and Miller 1944) and occasional individuals seen in winter were probably transients from more northern populations.

Howell (1917) thought that it was doubtful that Ospreys nested on Los Coronados Islands, but an apparently authentic set of two eggs was taken there on 10 May 1897 by H. McConville for the noted oologist R. Magoon Barnes and is now in the collection of the American Museum of Natural History (AMNH 7074).

The largest nesting population of Ospreys off the California coast appears to have been

located on San Clemente Island. On visits to that island during the spring of 1897, Grinnell (1897) found Ospreys "quite abundant about the south end of the islands, and there was hardly a rocky promontory or pinnacle which was not used as a nesting site. The nests were either on pillars of rock standing directly in the surf, or on over-hanging ledges close above the water." During February, 1903, Breninger (1904) saw additional Osprey nests at the north end of the island, although he did not specify their number or status. C. B. Linton (1908) investigated 12 to 14 Osprey nests on the southeastern coast of San Clemente in early April, 1907, probably the same colony mentioned earlier by Grinnell. On a data slip accompanying a set of eggs (WFVZ 32401) he took on 4 April, Linton stated that he found a total of 20 Osprey nests on San Clemente Island in 1907, the largest number mentioned by an observer for any of the islands in a single year.

Ospreys were also common on Santa Catalina Island, although I have encountered no specific estimates of their former numbers there. Howell (1917) noted that on Santa Catalina "every detached rock of any height has its resident pair."

Ospreys were "tolerably common" and presumably nesting on San Nicolas Island in May, 1897 (Grinnell 1897). A single egg was taken from an Osprey nest on that island in 1901 by Blanche Trask (MVZ 4236). A statement by Howell (1917) that C. B. Linton found the species "plentiful" on San Nicolas Island is ambiguous, since the accompanying citation refers to the latter author's 1908 paper on the birds of San Clemente Island, which includes no mention of San Nicolas observations. However, at least three sets of Osprey eggs (MCZ 8695 and 8696, WFVZ 97065), including one set taken by Linton, were collected on San Nicolas Island in 1909.

Period of decline

Willett (1912) stated that the Osprey was common on the Channel Islands, but Howell (1917) categorized the species as a "fairly common breeder on some of the islands." By the early 1920s its status had been reduced to: "breeds sparingly upon the Santa Barbara Islands" (Dawson 1923). A decade later, Willett (1933) reported that the species occurred on San Clemente Island in much reduced numbers, was seldom seen on Santa Catalina Island, and that its status on San Nicolas Island was unknown to him. He presented no evidence that the Osprey still actually nested on the Channel Islands, and it is possible that the species ceased to breed there by 1930.

The last documented nesting of the Osprey on the Channel Islands was on 26 March 1927 when a party consisting of D. S. DeGroot, J. R. Pemberton, H. W. Carriger, and O. W. Howard collected two sets of eggs (WFVZ 59971; other set in collection of James B. Dixon, Escondido, California) from a colony of six nests located on rocky pinnacles off the south end of San Clemente Island. DeGroot (field notes) commented on the fact that few active nests were found there, compared with the colony's much larger size when Howard had collected eggs there in 1905.

As in the case of the Bald Eagle, Ospreys survived on the Channel Islands long after they had vanished as a breeding species on the adjacent southern California mainland. Cooper (1887) found the species "common along the coast of Ventura County in the early 1870s," but Willett (1912) concluded that the species had been nearly exterminated along the mainland since then.

The species appears never to have been common as a breeding resident on the mainland within recent time, and I am aware of only three specific Osprey nesting records for the southern California mainland. Cooper (1870) described the attempts of a pair to build a nest on the main-top platform of an old boat anchored in San Diego Bay. Despite efforts to discourage them, the birds persisted in carrying nesting material to the boat until its resident became exasperated and shot one of the pair, thus ending the nesting attempt. Willett (1912) cited an

Osprey nesting record of unknown outcome by E. Davis near Laguna Beach, Orange County on 5 March 1895. A "set" of four eggs was taken singly from a nest on top of a light beacon in San Diego Bay by a boat captain for A. M. Ingersoll on 11, 14, 18, and 21 April 1912 (WFVZ 71019). This was apparently the last known nesting attempt by Ospreys on the southern California mainland.

Farther south along the Pacific coast of Baja California, a similar decline in the populations of nesting Ospreys occurred on many islands and along the mainland coast between about 1910 and the mid-1940s (Kenyon 1947). Kenyon felt that the disappearance of Ospreys was more marked in the northernmost Baja California localities, and his data suggest that the most precipitous declines occurred there after the mid-1920s.

Causes of decline

Shooting of Ospreys was repeatedly mentioned by early writers as the most significant cause of mortality. In discussing the status of the species in southern California, Willett (1912) stated, "Many have been shot by gunners and most of those remaining have taken refuge on the islands." Howell (1917) noted that Ospreys were not as abundant as they had been formerly on Santa Catalina Island, "owing to the depredations of the tourists." DeGroot (field notes) speculated that the decline in the number of Ospreys noted by his party on San Clemente in 1927 might have been due to shooting of the birds by fishermen, who regarded them as competitors, or merely as attractive targets.

In attempting to find a cause for the apparent reduction of Ospreys along the coast of Baja California and its adjacent islands, Kenyon (1947) concluded that shooting by commercial fishermen, mostly Americans, was the most devastating form of human persecution suffered by the species there, although he also noted that Mexican fishermen occasionally ate both Osprey eggs and young.

On San Clemente and Santa Catalina Islands, as well as further south along the coast of Baja California, Ospreys built their large conspicuous nests on offshore pinnacles of rock that were easily approached by boats. As Kenyon (1947) pointed out, the birds were vulnerable to shooting and other harassment throughout their long incubation and nestling periods, which together amount to about 12 weeks.

I have records of 19 sets of Osprey eggs taken by collectors on the Channel Islands between 1893 and 1927 (12 on San Clemente, four on San Nicolas, and three on Santa Catalina). Although these activities were temporarily detrimental to the island Ospreys, egg collecting cannot account for their extinction. It affected relatively few pairs of birds and had essentially ceased before the period of precipitous decline in the Osprey populations. Only three sets of eggs are known to have been taken after 1909. Furthermore, although Ospreys raise only a single brood per season, they generally replace lost first clutches (Bent 1937). A factor that may have reduced the potential oological toll on Channel Islands Ospreys was the ready availability of their eggs from Eastern collectors who lived in areas where the species was more accessible and abundant.

While the combined effects of all forms of human persecution of Channel Islands Ospreys may have been sufficient to extirpate them, the concomitant decline in the Osprey population along the Pacific coast of Baja California (Kenyon 1947) suggests that some major environmental change may have affected the species throughout the region. Although there appear to be no available data concerning the food habits of Channel Islands Ospreys, the birds were presumably almost exclusively piscivorous there, like other North American Osprey populations (Bent 1937). It is possible that some deleterious change in the food supply of Pacific coast Ospreys occurred during the 1920s to 1930s that contributed to their extinction. Without specific data on the fish species eaten by Ospreys here, however, this is a matter of speculation.

Peregrine Falcon

Distribution and status

The Peregrine Falcon was a common permanent resident on the Channel Islands and Los Coronados Islands (Willett 1912, Howell 1917), although specific breeding records are lacking from some islands. Migrants and wintering birds from more northern populations also occurred on the islands (Grinnell and Miller 1944).

Compared with Bald Eagles and Ospreys, both peregrines and their nests are much less conspicuous to casual observers. From his studies of the Aleutian Islands population, White (1975) concluded that "unless specifically searching for Peregrines, the types of faunal studies that are generally carried out reveal only a minor percentage of the total Peregrines present." Thus, historical estimates of the number of peregrines on the California Islands were almost certainly too low, except on the smallest islands. Furthermore, the lack of reported observations of the species by island visitors is *not* conclusive evidence of its absence (see Hunt and Hunt 1974, Jones and Diamond 1976).

The Peregrine Falcon was most abundant on Los Coronados Islands, and the former density of breeding pairs there may have been the highest ever recorded for the race *Falco peregrinus anatum*. At least three pairs nested regularly on Los Coronados (Howell 1917), but in some, perhaps many, years the number was higher. Wright (1909) found three pairs on South and Middle Coronados Islands on 22 June 1908, and earlier in the same year Osburn (1909) saw apparently the same birds on South Island, plus an additional two pairs on North Island. L. M. Huey (*in* Howell field notes for 1913) saw 11 peregrines on North Island alone on 30 May 1913, despite the fact that this island is only "1 mile long, 0.12 miles wide, and 467 feet high" (Jehl 1977).

Banks (1969) was told by Lewis Wayne Walker that in about 1932 there were two or three pairs of peregrines on North Island, one on Middle Island, and four or five on South Island. Because these estimates are much higher than those of other observers for the same period, and because they were made over 30 years after Walker's visit to Los Coronados, they may be unrealistic. In about 1945, Walker reportedly thought that there were only four active peregrine sites on Los Coronados—two on North Island and two on South Island (Zuk unpubl. ms.).

Although an actual nest was never reported from San Clemente Island, peregrines were presumably resident there. The earliest report of the species from the island was that of Mearns (1907), who, with A. W. Anthony, recorded it there between 22 and 29 August 1894. Grinnell (1897) apparently did not find peregrines on two trips to San Clemente totaling 18 days in 1897. However, as previously pointed out, this does not rule out the presence of the species on San Clemente, considering the relatively large size of the island and the limitations of a single observer. Breninger (1904) saw a pair of peregrines on San Clemente in February, 1903 and collected the male. Linton (1908) found pairs at two different sites during his four visits to San Clemente Island in 1907. He stated that at least one pair bred on the island during that year, but gave no further details. Howell (1917) and his party saw a pair of peregrines repeatedly on San Clemente during late March and early April, 1915, but did not succeed in locating a suspected nest site.

On Santa Catalina Island, Willett (1912) took a set of four eggs (WFVZ 23185) at Long Point on 8 April 1904, and a set of three eggs (WFVZ 63151) was collected on 5 May 1905 from another site on the island by O. W. Howard. Howell (1917) stated that he had seen several peregrines on the northwest part of Santa Catalina, and the species was also reported during the breeding seasons of 1920 by A. J. van Rossem (field notes) and 1938 by R. Arnold (field notes).

Of all the California Islands, it is least certain that Peregrine Falcons nested on San Nicolas. Loye Miller (unpubl. ms.) found the bodies of a pair of peregrines discarded on the beach at San Nicolas Island on 7 July 1938. The birds appeared to have been shot some months earlier, and

their wings and feet had been cut off. Miller assumed that they had been nesting in the vicinity. Rett (1947) saw two Peregrine Falcons fly over the north shore of San Nicolas Island, heading southward, on 14 March 1945. I am aware of no other specific reports of peregrines from the island.

Cooper (1870) wrote that on Santa Barbara Island in May, 1863, a pair of peregrines "which probably were still feeding their young swept boldly around my head, when I must have been fully half a mile from the nest, and I shot the female, a very fine specimen." On 1 May 1908, Howell (1917) flushed a pair "from the cliff on the seaward side of Santa Barbara Island, where they undoubtedly had a nest of young." The DeGroot-Pemberton party visited the island on 27 March 1927 and "this species was seen by all members of the field party" (DeGroot field notes), although the number of birds involved was not mentioned.

Lowell Sumner and Richard Bond did not record peregrines during their short visit to Santa Barbara Island in April, 1939 (Sumner unpubl. ms.). However, a biological survey party from the Los Angeles County Museum of Natural History observed a pair of peregrines daily between 27 and 30 May of the same year as they flew about in the vicinity of Sutil Islet, a rocky pinnacle just off the main island (J. C. von Bloeker, Jr. *in litt.*). The birds appeared to be defending an active nest site. Since Hunt and Hunt (1974) concluded from Sumner's observations, or lack of them, that the Peregrine Falcon was extinct on Santa Barbara Island by 1939, this is a clear example of the difficulties involved in assessing the significance of "non-sightings" of peregrines.

Nesting peregrines were found on Anacapa Island by Willett (1910), Burt (1911), and probably by Wright and Snyder (1913) in 1912. The DeGroot-Pemberton party visited the island on 28 March 1927 and flushed peregrines from both the landward and seaward sides of the island (DeGroot field notes). R. Bond (*in* Thelander 1977) thought that three pairs of Peregrine Falcons nested on Anacapa in 1935 and that three sets of eggs were taken there that year. I have been unable to locate the egg sets, however. Bond also visited active peregrine nests on Anacapa in 1934 and 1939 (Sumner unpubl. ms.). From a boat off the west end of Anacapa Island on 18 March 1941, J. C. von Bloeker, Jr. (*in litt.*) watched a peregrine stoop repeatedly on a feral housecat that rose on its hind legs each time to meet the attack. Finally, the falcon struck the cat a blow on the head that knocked it off a cliff and into the sea many feet below. Presumably the peregrine was engaging in nest defense, rather than attempting to take the cat as prey.

Peregrine Falcons were common on Santa Cruz Island, although few actual nest sites were reported. O. W. Howard took a set of three eggs there on 5 April 1906 (Willett 1912), and Linton (1908) made observations on peregrines on various parts of the island in 1907. M. C. Badger (field notes) found an active nest on 4 March 1918, and he and R. Canterbury (field notes) independently recorded what seemed to be nesting birds in 1919. R. Bond (*in* Thelander 1977) located two peregrine nests with "fair accessibility" on Santa Cruz in 1935. Nests were also found during the 1930s by several egg collectors, including E. N. Harrison (pers. comm.), L. T. Stevens (field notes), and M. C. Badger (field notes), but no eggs were taken during this period, to my knowledge.

The DeGroot-Pemberton party located three pairs of Peregrine Falcons, two of them far inland in canyons, on Santa Rosa Island between 2 and 4 April 1927 (Pemberton 1928). Although their apparent nest sites were located, none contained eggs at that date. Pemberton and DeGroot returned to Santa Rosa Island on 22 April of the following year and collected a set of three eggs from one of the sites (WFVZ 58685).

The only definite nesting records of peregrines for San Miguel Island were those of the DeGroot-Pemberton party, which spent 31 March to 2 April 1927 on the island (DeGroot field notes). They did not find peregrines until their second day on the island, despite the fact that the

group consisted of four seasoned field ornithologists: DeGroot, Pemberton, Carriger, and Howard. On 1 April, Pemberton found a female on an apparent nest in a pothole on the northwest side of the island. The site proved to be inaccessible, even with a rope. Another nest was found later in the day on the southwest end of the island in a large pothole 300 feet down a huge cliff. Although the female sat tightly on the nest, DeGroot found that the scrape was empty when he climbed down to it; apparently eggs were about to be laid.

In summary, the highest numbers of Peregrine Falcon nests reported (or inferred from the available data) during a single year for the California Islands are as follows: Los Coronados, 5 (or up to 9 if the report of L. W. Walker *in* Banks 1969 is accepted); San Clemente, 1 (probably 2); Santa Catalina, 2; San Nicolas, 1?; Santa Barbara, 1; Anacapa, 3; Santa Cruz, 2; Santa Rosa, 3; and San Miguel, 2—for a total of at least 20 nests.

Food habits

Peregrines evidently fed exclusively on avian prey on the California Islands and there are reports of at least 22 species of birds being taken. Howell (1917) concluded that California Islands peregrines were most common in the vicinity of colonies of small pelagic birds, a view consistent with the data presented in the previous section. On Los Coronados Islands, such species included primarily Leach's Storm Petrels (*Oceanodroma leucorhoa*), Black Storm Petrels (*Oceanodroma melania*), Xantus' Murrelets (*Endomychura hypoleuca*), Cassin's Auklets (*Ptychoramphus aleuticus*), and even Rhinoceros Auklets (*Cerorhinca monocerata*) (Howell 1910, 1917). Grinnell and Daggett (1903) found the remains of gulls (probably *Larus occidentalis*) on Los Coronados for which they thought peregrines were accountable. Cassin's Auklets were also taken by peregrines on the Channel Islands, according to Breninger (1904) and Bond (1946). Bond also observed peregrines taking nestling Double-crested Cormorants (*Phalacrocorax auritus*), a Black Oystercatcher (*Haematopus bachmani*), and a Pigeon Guillemot (*Cepphus columba*) on the Channel Islands.

Peregrines must have had a considerable impact on both the resident and migratory birds occurring on the California Islands. Huey (field notes for 1924) made an informal examination of avian remains in a peregrine nest site on Los Coronados Islands that contained four well-developed young. He found evidence of the following species: Storm Petrels (probably both Leach's and Black), Mourning Dove (*Zenaida macroura*), Ash-throated Flycatcher (*Myiarchus cinerascens*), an *Empidonax* flycatcher, Swainson's Thrush (*Catharus ustulatus*), Hermit Thrush (*Catharus guttatus*), Orange-crowned Warbler (*Vermivora celata*), Western Tanager (*Piranga ludoviciana*), House Finch (*Carpodacus mexicanus*), and Fox Sparrow (*Passerella iliaca*). In addition, the nest contained at least 42 pairs of wings of Xantus' Murrelets. On a nearby trail, Huey's companion, A. J. van Rossem, found a Western Flycatcher (*Empidonax difficilis*) and a Black-throated Gray Warbler (*Dendroica nigrescens*) that had apparently been killed by the peregrines.

Elsewhere, DeGroot (field notes for 1927) saw peregrines feeding on Horned Larks (*Eremophila alpestris*) on Santa Rosa Island, and Linton (1908) observed them taking a Red Phalarope (*Phalaropus fulicarius*) and Black Turnstones (*Arenaria melanocephala*) on Santa Cruz Island.

Period of decline

Up until the 1940s, virtually all authorities considered the peregrine to be at least fairly common on the California Islands and on the adjacent mainland (Willett 1912, 1933, Howell 1917, Dawson 1923, Grinnell and Miller 1944). Based on data presented by Bond (1946), as well as on his unpublished notes, Herman *et al.* (1970) concluded that approximately 100 peregrine eyries were producing young annually during the mid-1940s in California, including the Channel Islands. There was no indication that a population decline was then in progress.

In the two decades following 1945, a catastrophic decline occurred in California peregrine populations (Herman *et al.* 1970). A survey of historical sites conducted in the breeding season of 1970 indicated that the mainland breeding population was reduced at least 95 per cent from the numbers that nested in California in the mid-1940s (Herman 1971). Furthermore, Herman *et al.* (1970) felt that nests along the southern California coast, including those on the offshore islands, suffered the earliest reduction. Although they had no on-site data, they suspected that the Channel Islands peregrine population was extirpated by 1955. The more detailed, albeit fragmentary, data that I have gathered support this conclusion. On an island-by-island basis, the last reliable report of probable resident peregrine occurrence, and the earliest subsequent survey on which the species was not recorded, are as follows.

Los Coronados.—E. N. Harrison (pers. comm.) located four active nests on these islands on 30 April 1940 (two on South Island, one on Big Middle Island, and one on North Island). He felt that other active nests may have been overlooked. D. Brimm (pers. comm.) found single nesting pairs of peregrines on South and North Islands in 1948. When T. Cade visited the islands in 1954, he found no peregrines present (Herman *et al.* 1970).

San Clemente.—No reports of peregrines subsequent to 27 March 1915 (Howell field notes) are known to me.

Santa Catalina.—The latest report was by R. Arnold, who saw peregrines chasing Bald Eagles and also being chased by ravens on 15 April 1938.

San Nicolas.—Rett (1947) saw two peregrines on 14 March 1945. A party from the University of California at Los Angeles did not find the species between 9 and 13 January 1959 (Collias field notes).

Santa Barbara.—Apparently, nesting peregrines were noted between 27 and 30 May 1939 (J. C. von Bloeker, Jr. *in litt.*), but none recorded during a rabbit destruction program administered on the island between 1953 and 1957 (Sumner unpubl. ms.).

Anacapa.—An adult that was probably nesting was seen on 21 May 1949, but none was found on 27 May 1962 by R. Quigley (pers. comm.), or by subsequent visitors (*e.g.*, Banks 1966). The latest certain nesting was documented by Sumner (unpubl. ms.) on 16 April 1939.

Santa Rosa.—No observations of peregrines were reported after 1927 (Pemberton 1928).

Santa Cruz.—R. Bond (*in* Thelander 1977) found two nests in April, 1935, and M. C. Badger and L. T. Stevens saw an apparently resident pair on 7 March 1937 (Badger field notes). Peregrines were not encountered by A. Miller (field notes) during March, 1950.

San Miguel.—The latest pre-1965 sighting was by L. Sumner (unpubl. ms.), who saw a single adult flying along the coast of the island in mid-April, 1939.

In summary, peregrines survived until at least 1937 on seven islands. There is no evidence that they were gone from any island prior to 1950. The last reported sighting of a probable breeding adult was on 21 May 1949 on Anacapa Island.

Causes of decline

Documented causes of peregrine mortality on the California Islands include shooting, skin collecting, egg collecting, and removal of young from nests. Additional possible causes of the peregrine's disappearance from the islands include the effects of DDE and changes in the food supply.

Probably few peregrines were shot on the California Islands, at least compared with the destruction of the larger, more conspicuous, and slower-flying Bald Eagles and Ospreys. There is only one actual report of wantonly shot peregrines, the pair found by L. Miller on San Nicolas Island on 7 July 1938 (Miller unpubl. ms.).

At least 14 museum specimens (all study skins) of peregrines were collected on the islands: 11 from Los Coronados, and one each from San Clemente, Santa Barbara, and Santa Catalina. The

latest of these were taken in 1924. Eight of the Los Coronados Islands birds were juveniles of less than a year, seven of them collected by L. Huey from two nests in May, 1917 and May, 1924.

As with study skins, most egg sets of peregrines from the California Islands were collected on Los Coronados. At least 14 egg sets were taken there between 1898 and 1940. I know of only four sets definitely collected on the Channel Islands: two on Santa Catalina, one on Santa Rosa, and one on Santa Cruz. Bond (*in* Thelander 1977) believed that three sets of eggs were collected on Anacapa Island in 1935 by an unnamed collector, but I have been unable to locate these sets in any collection.

Based on my conversations with several old-time egg collectors, I have concluded that sets of peregrine eggs were taken on the California Islands in such limited numbers for the following reasons: (1) peregrine eggs, unlike those of Bald Eagles, could be readily obtained from mainland nest sites; (2) with the exception of Los Coronados Islands (Howell 1917), peregrine eyries on the California Islands were usually very difficult to reach, and probably few collectors had either the equipment or the persistence to gain access to them; and (3) most oologists visited the islands specifically to collect eggs of waterbirds, Bald Eagles, and/or endemic passerines.

Peregrines usually replace lost clutches on the California mainland (Thelander 1977) and, presumably, also did so on the California Islands. Two sets of eggs were taken on Los Coronados Islands in 1920, 1921, and 1931, and in each instance the second set was believed by the collectors to be a replacement clutch. Most of the other sets taken by egg collectors were probably actually replaced by the birds, with net productivity being little affected by the collecting activities.

Although removal of young peregrines from nests for falconry purposes has posed a significant threat to the depleted mainland California peregrine populations in recent years (Herman *et al.* 1970), it is unlikely that many birds were lost for such reasons from the former California Islands population. Thelander (pers. comm.) informed me that young were taken from an Anacapa Island peregrine nest by falconers in the 1940s, and another juvenile from a Santa Rosa Island nest in 1942, but no other instances of this kind have come to my attention. Perhaps some of the same factors that minimized the effects that egg collecting had on California Islands peregrines also operated to reduce the toll by falconers.

In summary, the available data indicate that neither the chronology nor magnitude of shooting, skin collecting, egg collecting, or removal of young from nests can be considered factors of any significance in the disappearance of the Peregrine Falcon from the California Islands.

The events suggesting a causal relationship between the appearance of DDT in the southern California marine ecosystem and the extirpation of the Bald Eagle from the California Islands serve equally well, or better, to explain the disappearance of the Peregrine Falcon from the same islands. In fact, it was the precipitous decline of the peregrine in England that led to the discovery of the deleterious effect of DDT on populations of bird-eating and fish-eating birds (Ratcliffe 1967); DDE-induced eggshell thinning in peregrines now appears to be a nearly universal phenomenon (Peakall and Kiff 1979).

Hickey and Anderson (1968) showed that all California mainland peregrine eggshells collected after 1947 were significantly thinner than those taken before World War II. Peakall (1974) demonstrated the presence of DDE in California peregrine eggs as early as 1948 in concentrations sufficient to account for the observed shell thinning. Reproductive failures of the type that have come to be known as the "DDT syndrome," including egg breakage, reduced clutch size, and behavioral abnormalities, are known to have occurred in the late 1940s or early 1950s at most peregrine nest sites on the portion of the mainland nearest the California Islands (Thelander *et al.* in prep.). The pattern of decline observed in peregrine populations on

the California mainland is apparently related to worldwide patterns of DDE contamination of prey species; peregrines in marine environments, where DDE levels are highest, are the quickest to disappear and the slowest to recover (Herman *et al.* 1970, Thelander 1977). In short, the effects of DDE on peregrine reproduction are almost certainly the primary and, perhaps, the only factor responsible for the extirpation of the species on the California Islands.

Peregrines, like most higher trophic level species, are particularly vulnerable to changes in their food supply. In addition to causing reproductive failure, DDT and other environmental contaminants can cause a reduction in the bird populations upon which peregrines subsist. Although historical data are largely unsatisfactory for making rigorous quantitative estimates of changes in seabird populations on the California mainland, there has clearly been an overall reduction in their size and diversity since the turn of the century (Hunt *et al.* 1980). Nelson and Myres (1976) related a decline in the resident peregrine population on Langara Island, British Columbia to nest failures caused by DDE in their usual prey item, Ancient Murrelets (*Synthliboramphus antiquus*). They stated that, in a year, a family of peregrines (two adults and four young) will kill about 1,000 murrelets. Although California Islands peregrines had a more varied diet, it is doubtful that the southern California marine ecosystem now provides a sufficient food base to support the number of peregrines that occurred there historically, especially on Los Coronados Islands.

DISCUSSION

Since the publication of Diamond's (1969) paper on avian turnover rates, there has been much interest in the interaction of immigrations and extinctions on the Channel Islands. The three species of raptors treated here have figured prominently in these discussions since they account for a large proportion of the extinctions recognized by Diamond (*op. cit.*). Lynch and Johnson (1974) pointed out that since most or all of these extinctions were probably caused by human activities, their inclusion in the calculation of island turnover rates yields artificially high figures. Jones and Diamond (1976) argued that the net effect of the elimination of the large raptors from the islands and the southern California mainland pool was to reduce actual turnover rates in the long run since these species turn over more rapidly than most other groups in the island avifauna.

Whatever the case, the Channel Islands appear to be a rather poor arena for examining turnover characteristics of the large raptors. From the data presented earlier, it seems highly probable that man was directly responsible for the extirpation of the Bald Eagle and Peregrine Falcon from the California Islands. This may also have been the case with the Osprey, but the available data are too nebulous to be certain. It is difficult to see the relevance to natural turnover rates of calculations based, in large part, upon man-induced extinctions.

Various authors, including Hunt and Hunt (1974) and Jones and Diamond (1976), have stated that predatory birds tend to experience more rapid turnover on islands than species at lower trophic levels, primarily because of their relatively lower population sizes. If so, this contrasts sharply with mainland raptor populations, which are remarkable among birds for their stability over long periods of time in environments free from human interference. Newton (1976) cited numerous examples of such stability based on long-term studies of populations of fourteen falconiforms, and he listed seven such studies of peregrine populations. For example, Ratcliffe (1972) noted that out of 49 peregrine eyries known to falconers in England between the 16th and 19th centuries, 42 were still occupied by 1930. Bald Eagles are also notorious for their long-term occupancy of nest sites, and several egg collectors, including D. R. Dickey, M. C. Badger, and Sidney Peyton, commented in their field notes or on egg data slips about the extreme age of some of the nests from which they collected eggs.

Jones and Diamond (1976) stated that the extirpation of the Bald Eagle and Osprey on the

southern California mainland had the effect of lowering expected turnover rates, since it eliminated the most important potential source of immigrants for the recolonization of the islands following extinctions. While this is true, the islands themselves served as a potential source of colonizers for the unsaturated mainland during much of this century, yet there is little or no evidence that such immigration took place.

If the adverse effects of DDE were the ultimate cause of the extirpation of the peregrine and Bald Eagle from the California Islands, then it is possible that the reduction of residue levels in the local marine environment that has occurred since 1972 (Anderson *et al.* 1975) will permit the re-establishment of these species on the islands. Recolonization of the peregrine may occur without human intervention, since the nearby mainland population appears to be slowly recovering (Thelander 1977, D. Harlow, pers. comm.). The nearest breeding population of Bald Eagles, however, is presently in northeastern California, and it is probable that man will have to aid their reintroduction to the islands. The successful re-establishment and maintenance of populations of these two species on the Channel Islands would provide still further evidence implicating DDE in their local extinctions.

SUMMARY

The California Channel Islands and Los Coronados Islands formerly supported resident populations of Bald Eagles, Ospreys, and Peregrine Falcons. Data on the former status of these species on the islands were obtained from museum egg and study skin collections, field notes and unpublished manuscripts of visitors to the islands, interviews with island residents and visitors, and the published literature.

Bald Eagles once nested on all the islands. They became gradually more scarce from man-induced factors, including shooting, nest disturbance, and poisoning, finally becoming extinct in the late 1950s, possibly from the effects of DDE. The islands supported a minimum of 24 pairs of Bald Eagles within the present century, a decrease from the 1800s. Both Bald Eagles and Ospreys were essentially extirpated on the adjacent mainland by the turn of the century.

Ospreys, which nested only on the southernmost Channel Islands, vanished by about 1930 from unknown causes. A similar decline occurred about the same time along the coast of northern Baja California. Ospreys were most common on San Clemente Island, where at least one colony contained over 20 pairs.

Peregrine Falcons were apparently resident on all the islands. The population became extinct between the mid-1940s and early 1950s, and a severe decline in the California mainland population occurred during the same period. Evidence suggesting that DDE caused the extirpation of the peregrine and the Bald Eagle on the California Islands includes the correlation between the extinctions and the introduction of DDT, the simultaneous nature of the extinctions on all the islands, DDE-caused breeding failures in both species elsewhere in their ranges, unusually high local DDE residue levels, and well-documented DDE-caused breeding failures in certain seabirds resident on the islands. No other significant mortality factor is known for the island peregrines. At least 20 pairs of peregrines may have been resident on the California Islands.

The California Islands are ill-suited for examining turnover rates of large raptors because of man's persistent interference with the birds and their environment. Elsewhere, however, raptors are distinguished by the extreme constancy of their populations in stable environments; a natural extinction on the islands of any of the three species treated here has not been convincingly documented. If formerly high DDE residue levels in local food chains resulted in the extirpation of the peregrine and the Bald Eagles on the California Islands, then the southern California marine ecosystem may now be "clean" enough to permit the re-establishment of resident populations of these species.

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Appendix 1

The following collections were examined for egg sets of Bald Eagles, Ospreys, and Peregrine Falcons from the California Islands (abbreviations are those used in the text):

Western Foundation of Vertebrate Zoology, Los Angeles, Calif. (WFVZ)
Museum of Vertebrate Zoology, University of California, Berkeley, Calif. (MVZ)
California Academy of Sciences, San Francisco, Calif. (CAS)
Field Museum of Natural History, Chicago, Ill. (FMNH)
American Museum of Natural History, New York, N.Y. (AMNH)
Museum of Comparative Zoology, Harvard University, Cambridge, Mass. (MCZ)
Santa Barbara Museum of Natural History, Santa Barbara, Calif.
San Bernardino County Museum of Natural History, Redlands, Calif.
San Diego Natural History Museum, San Diego, Calif.
Denver Museum of Natural History, Denver, Colo.
Puget Sound Museum of Natural History, University of Puget Sound, Tacoma, Wash.
Royal Ontario Museum, Toronto, Ontario, Canada
Carnegie Museum of Natural History, Pittsburgh, Penn.
Peabody Museum of Natural History, Yale University, New Haven, Conn.
Los Angeles County Museum of Natural History, Los Angeles, Calif.
United States National Museum, Washington, D.C.
Museum of Zoology, University of Michigan, Ann Arbor, Mich.
Florida State Museum, University of Florida, Gainesville, Fla.
Delaware Museum of Natural History, Greenville, Del.
British Museum (Natural History), Tring, Hertfordshire, England
James B. Dixon private collection, Escondido, Calif.
Nelson D. Hoy private collection, Media, Penn.
Zoology Museum, Clemson University, Clemson, South Carolina
Rob and Bessie Welder Wildlife Foundation, Sinton, Texas
Life Sciences Museum, Brigham Young University, Provo, Utah
Museum of Zoology, Louisiana State University, Baton Rouge, La.
Cleveland Museum of Natural History, Cleveland, Ohio
Chicago Academy of Sciences, Chicago, Ill.
Thomas Burke Memorial Washington State Museum, University of Washington, Seattle, Wash.
Reading Public Museum and Art Gallery, Reading, Penn.
University of Arkansas, Fayetteville, Ark.
Strecker Museum, Baylor University, Waco, Texas
Charleston Museum, Charleston, South Carolina
University of Massachusetts, Amherst, Mass.
Milwaukee Public Museum, Milwaukee, Wisc.
Ohio State University, Columbus, Ohio
National Museum of Canada, Ottawa, Ontario, Canada
Philadelphia Academy of Natural Sciences, Philadelphia, Penn.
Putnam Museum, Davenport, Iowa
Buffalo Museum of Science, Buffalo, N.Y.
Cowan Vertebrate Museum, University of British Columbia, Vancouver, B.C., Canada
El Paso Centennial Museum, University of Texas at El Paso, El Paso, Texas
State Museum, University of Nebraska, Lincoln, Neb.

Appendix 2

Unpublished field notes or manuscripts of the following visitors to the California Islands were examined for data on Bald Eagles, Ospreys, and Peregrine Falcons (all are housed in the archives of the Western Foundation of Vertebrate Zoology): A. W. Anthony, J. S. Appleton, R. Arnold, M. C. Badger, G. Bancroft, Sr., R. Canterbury, B. P. Carpenter, N. K. Carpenter, H. W. Carriger, W. L. Chambers, D. S. DeGroot, D. R. Dickey, H. A. Edwards, C. L. Field, P. H. Field, E. N. Harrison, O. W. Howard, A. B. Howell, L. R. Howsley, L. M. Huey, A. Jay, L. Miller, E. Paquette, J. R. Pemberton, L. G. Peyton, S. B. Peyton, W. M. Pierce, R. J. Quigley, C. O. Reis, J. S. Rowley, W. J. Sheffler, L. T. Stevens, F. Truesdale, A. J. van Rossem, G. Willett, and L. Zuk.

In addition, Dr. H. L. Jones allowed me to examine copies of unpublished field notes of J. B. Dixon, N. C. Collias, A. H. Miller, and H. H. Sheldon, as well as two unpublished manuscripts by E. L. Sumner, Jr.