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PHOTOGRAPHIC CENSUSING OF THE 1982-1983 CALIFORNIA CONDOR POPULATION

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ABSTRACT.—An intensive census of the remnant California Condor (*Gymnogyps californianus*) population based on photographic identification of individuals revealed a minimum of 21 and a probable maximum of about 24 condors in late summer 1982. Corresponding figures for 1983 were 19 and 22 condors. Two condors are known to have died in the wild since the 1983 census. These data, when compared with earlier population estimates, indicate a continuing catastrophic decline of the species. In the absence of intensive conservation measures, extinction of the wild population can be expected within 10 to 20 years.

Beginning with the early studies of Koford (1953), a number of researchers have estimated the size of the California Condor (*Gymnogyps californianus*) population (Fig. 1). The estimates offered have varied considerably, presumably owing in part to actual changes in the population size and in part to errors in methods of estimation. Although a continuing decline in condor numbers has been unmistakable, the absolute population sizes and rates of decline during various periods have been uncertain.

Koford (1953) believed that the wild population consisted of about 60 condors in the late 1930s through mid-1940s. Ostensibly, this total was based on fall estimates of 30 nonbreeding adults, 10 breeding adults, and 20 other birds (mainly immatures). Koford provided no clear justification, however, for his estimates of the numbers of birds in these categories. In part, his population estimate may have been derived from a few large flock counts that he extrapolated to total numbers of birds on the basis of an unstated assumption that the largest flocks included most birds in the population. Koford was impressed that the largest totals he could assemble from simultaneous or near-simultaneous counts in various parts of the range were no greater than the numbers seen in the largest single flocks. Unfortunately, Koford did not fully explain the basis for his population estimate, and there is no way to know exactly how it was made and how much error it contained.

The population estimate of 40 birds by Miller et al. (1965) was based primarily on comparisons of flock sizes seen in the late 1950s and early 1960s with those reported earlier by Koford. Thus, the accuracy of their estimate depends largely on the validity of Koford's estimate.

An annual October survey of condors was begun in 1965 (Mallette and Borneman 1966). This survey involved simultaneous observations from many prominent lookouts in the best-known areas of condor concentration and usually ran for a two-day period. The October survey was repeated every year through 1981, except 1979, but has now been abandoned because the results have been difficult to interpret. Variations in weather, number and experience of observers, number of observation stations, and movements of birds, coupled with difficulties in differentiating birds seen at various observation stations at different times, have led to highly variable counts with unknown relationships to actual population sizes. The totals and some of the difficulties in interpretation of the survey have been discussed by Sibley et al. (1968), Verner (1978), and Wilbur (1980). Despite the weaknesses of the October surveys, the results strongly suggest a

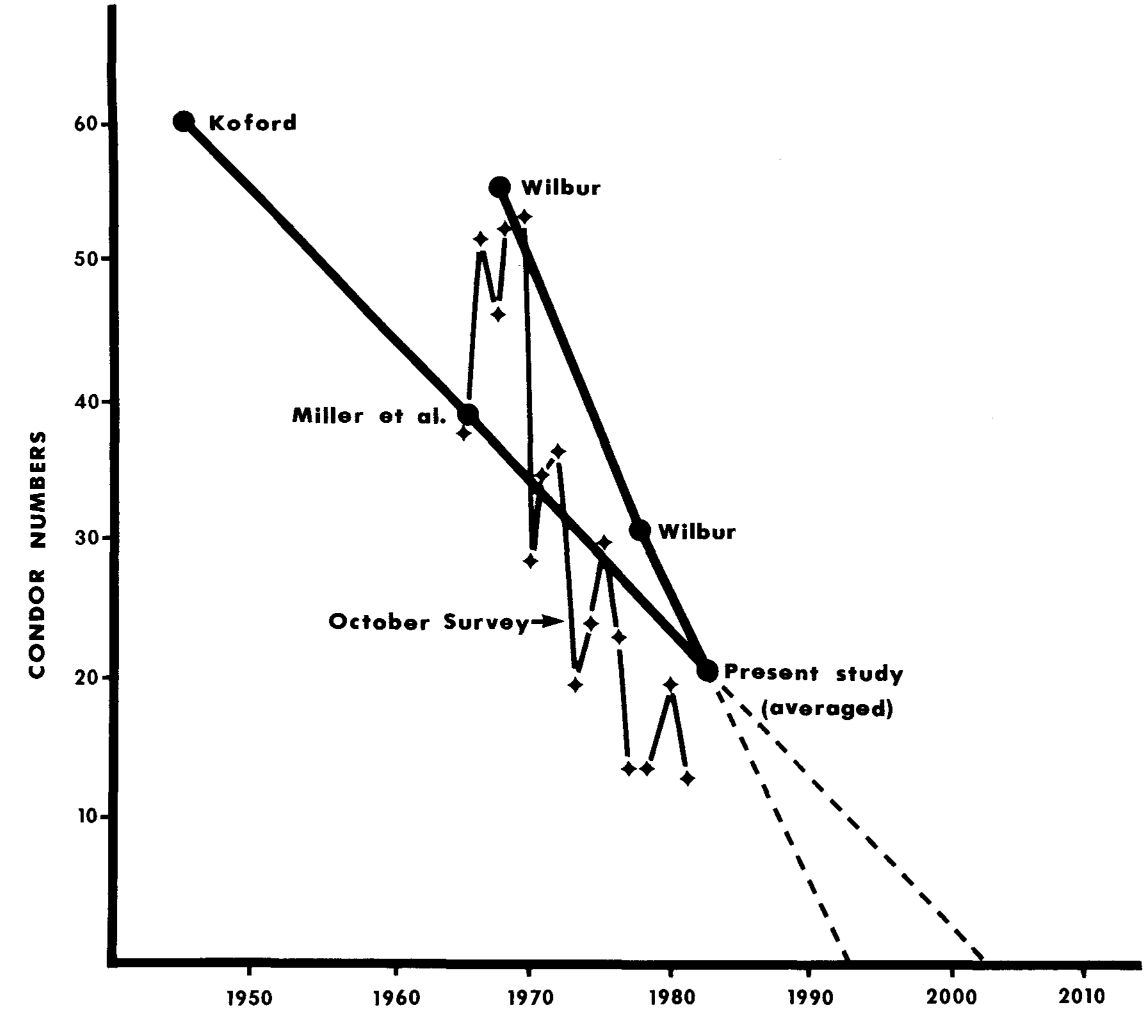


FIGURE 1. Estimates of the size of the California Condor population from Koford (1953) to the present. Dotted lines represent extrapolations into the future.

continuing decline of the wild population and a minimum population size of 50–60 birds in the mid-1960s.

Wilbur (1980) analyzed trends in numbers of sightings, flock size, and sightings of immatures, together with a number of simultaneous and near-simultaneous counts, to arrive at estimates of 50–60 birds for 1968 and 25–35 birds for 1978. Although his estimates appear reasonable, judging from comparisons of numbers of birds seen in various areas over the years, the extent of error cannot be rigorously specified.

In 1981, we began efforts to improve censusing by basing estimates on individual identifications of birds as determined by peculiarities in feather patterns. The potential value of feather pattern analysis was discussed by Wilbur (1975), and the method was used to a limited extent by Koford (1953) to differentiate members of pairs, and by Mallette and Borneman (1966) to differentiate birds seen during October surveys. Nevertheless, the usefulness of feather analysis had never been comprehensively tested on a population-wide basis before 1981. During the summer of that year, one of us (EVJ) led efforts to monitor condor activity from an important overlook of commonly used foraging country in the foothills surrounding the southern San Joaquin Valley (Johnson et al. 1983). Drawings were made of the patterns of molt and damage in secondary feathers for all birds seen. Analysis of these patterns in the late summer revealed a surprisingly large number of apparently different birds. However, because of problems with observer error in recording individual patterns and because of rapidly changing patterns of secondary feather gaps in individual birds, it appeared that identifications based on such data entailed considerable risks of overestimating the number of birds under observation.

In the fall of 1981, efforts (primarily by NFRS) were begun to determine whether uncertainties and errors in recognition of individual condors could be eliminated by switching emphasis to photographic documentation of primary feather patterns. Our initial results with the photographic method were sufficiently promising that we continued with full-scale testing in 1982. With the understanding gained in that year of how to avoid certain pitfalls in interpretation, the method has now been refined into an apparently reliable means of identifying and counting condors. In this paper, we describe the details of the photographic method and the results of the 1982 and 1983 censuses. We also comment briefly on other applications of the photographic data and the significance of the recent census results with respect to condor conservation efforts.

MATERIALS AND METHODS

During 1982 and 1983, a major effort to photograph all condors seen in flight was made by personnel of the Condor Research Center in Ventura, California; E. V. Johnson and his students at California Polytechnic State University, San Luis Obispo; J. Hamber and her associates at the Santa Barbara Museum of Natural History; and various other individuals. Observers used a variety of 35 mm cameras and telephoto lenses ranging in focal length from 300 to 1,000 mm. With such equipment, it was sometimes possible to record details of flight feathers from as far away as 1 km. Photographs were taken predominantly on Kodachrome and Ektachrome films, were later enlarged and copied on Panatomic-X film, and were printed as 10 × 12.5 cm monochrome enlargements for analysis. The use of monochrome internegatives from color originals did not cause any significant loss of feather detail in final prints and offered substantial advantages in sorting, filing, and analyses of the photographs. Color originals were essential for determinations of head color (hence age determinations) of the birds.

Efforts were made to photograph the birds in full wing-spread position in order to yield the most informative feather detail, and, whenever possible, multiple photographs were taken of each bird to resolve potential problems with overlapping or hidden feathers. Breeding birds of known identity were photographed repeatedly near nest sites through the year, and efforts were made to monitor known foraging and roosting areas throughout the range. Photographs were taken from 17 stations in 1982 and 18 stations in 1983 (Fig. 2). At one important foraging area in the southern San Joaquin Valley foothills (station 9), coverage was maintained daily from 12 July through 19 September 1982, and from 11 July through 30 October 1983. Records were kept of the age-status of all birds photographed, locations, dates, times, and the presence of associated birds.

The process of analyzing the photographs to determine minimum numbers of condors involved evaluation of molt sequences and feather damage patterns. In addition, we had to resolve various technical difficulties that were due primarily to poor photographic definition and unfavorable angular perspective in some photographs. One of these difficulties was the occasional spurious "disappearance" of primary 10. This feather is sometimes viewed edge-on because of its rotation in the airstream and sometimes, especially in photographs from afar, fails to be recorded on film (Fig. 3). Problems in detecting primary 10 were usually revealed by examining multiple photographs of each bird. In cases where multiple photographs were not available, we never assumed that an apparently missing primary 10 was necessarily missing in a photograph of marginal quality.

We also sometimes encountered difficulties with overlap of primary feathers when birds were photographed at too shallow an angle (Fig. 4). Such problems were usually obvious from inspection of the photographic angle. They were handled by analysis of multiple photographs and by assuming that some undetected overlap of feathers might occur in any shallow-angle photograph.

Gaps and distinctive patterns in tail feathers and secondaries, and idiosyncrasies in the shape of the white underwing triangles were also useful in confirming the identity of birds, but proved risky as the main means of identification because they sometimes changed quickly and unpredictably. Because of the variable degree of overlap in secondaries and rectrices, conspicuous gaps, especially ones that appeared long and slit-like, sometimes appeared, disappeared, and reappeared without feathers being lost, often within a few minutes or hours (Fig. 5). Although some gaps in secondaries and rectrices proved to be relatively stable through time, it was often difficult to predict which ones would persist.

In contrast, it was difficult to misconstrue the presence, absence, or state of growth of primaries 3 through 10, as long as photographic resolution and angle were adequate. These primaries extend as minimally overlapping "fingers" from the ends of the wings and cover one another only when wings are held in flexed or folded position. However, gaps produced by primary loss were sometimes filled in by positional adjustment of adjacent primaries, and, for some birds that had recently molted primaries, we were unable to judge which pri-

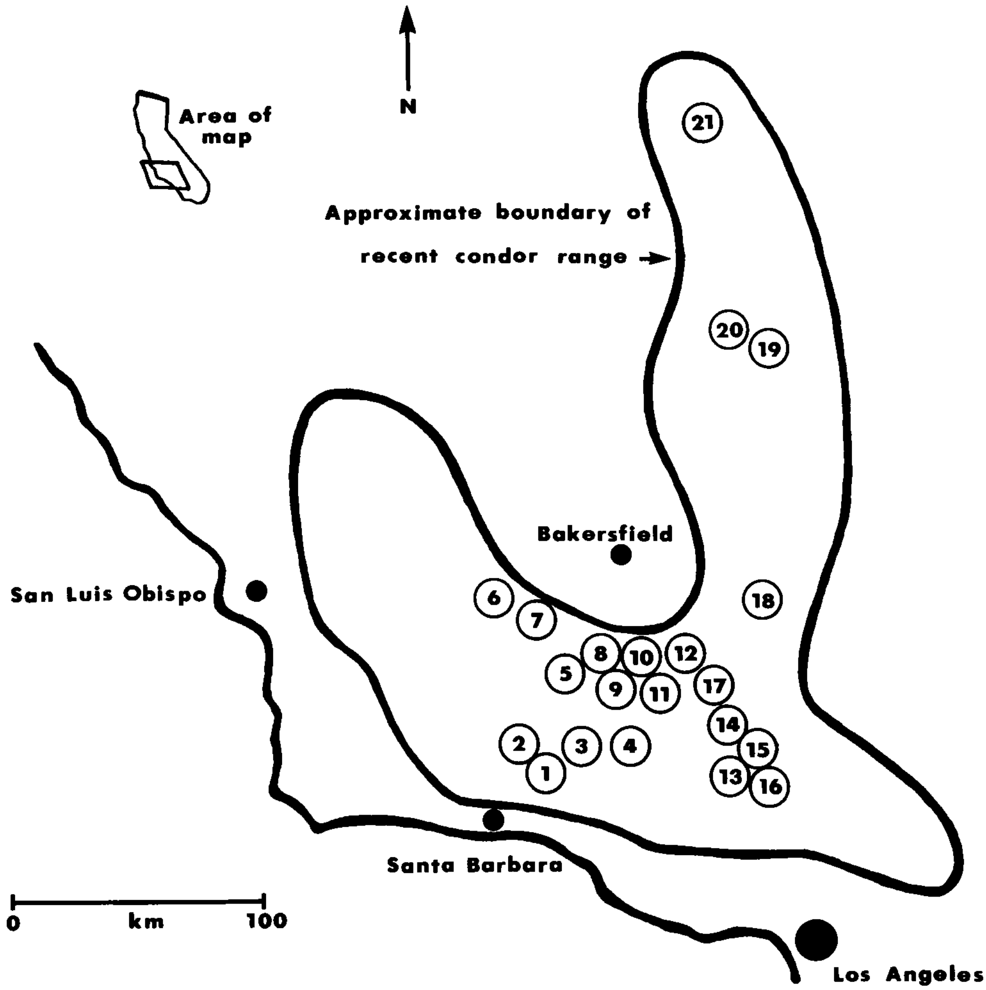
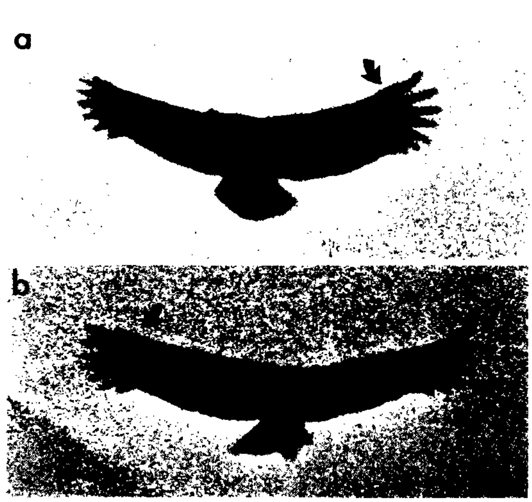


FIGURE 2. Approximate boundaries of the recent range of the California Condor and approximate locations of the observation stations from which condor photographs were taken in 1982 and 1983. See Table 1 for details regarding photographs taken at the various stations.



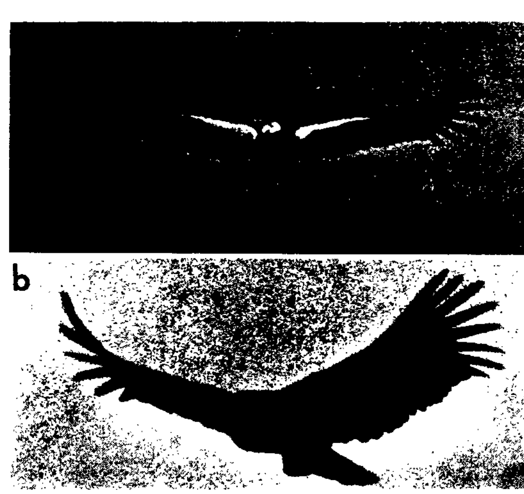


FIGURE 3. Successive photographs of a distant condor, illustrating inconsistent photographic detection of primary 10 on each wing (see arrows).

FIGURE 4. Successive photographs of an adult condor, illustrating the disappearance of primaries on the right wing resulting from shallow photographic angle.

FIGURE 5. Successive photographs of an adult condor, illustrating rapid change in the appearance of a secondary gap on the left wing.

maries were missing (Fig. 6). With birds followed photographically through time, these problems were usually resolved conclusively as replacement primaries appeared.

Some individuals had damaged flight feathers—most often ones with broken tips or missing sections of the vane (Fig. 7). These damage patterns were unique and obvious, and allowed quick and reliable identifications of individuals as long as the damaged feathers were not molted.

Important to the process of recognizing birds through time was an understanding of the growth rates of primary feathers. Growth rates were studied through repeat photographs of nesting adults and other birds of known identity taken throughout the molting season. First, the sequence of loss and regrowth of primaries

FIGURE 6. Adult condor missing one primary on each wing, illustrating difficulties sometimes encountered in determining just which primaries have been molted—a problem resulting from a tendency of adjacent primaries to fill in gaps.

FIGURE 7. A dark-headed condor with broken primaries on each wing. The broken feathers made this individual easily recognizable for over a year.

was established with each bird. Then the timing of loss, first photographic appearance of new feathers, and completed growth of feathers was documented as closely as possible. For the longer primaries (3 through 10) total time from feather loss to full regrowth of a replacement primary generally ranged from 14 to 18 weeks. Time from feather loss to first appearance of a new feather in the photographs usually ranged from 5 to 8 weeks, and time from first appearance of a new feather to its full growth usually ranged from 8 to 11 weeks. Details of the molt studies will be presented separately (Snyder et al., unpubl.).

With an understanding of how fast primary growth can be expected to progress, we were able to match photographs of the same individuals and to separate photographs of different individuals even when they had been taken on different dates. The existence of a partially grown primary implied that the feather had been missing some weeks earlier and would become progressively longer at a definable rate in subsequent weeks. Thus, during the molting season, it was generally possible to photograph a bird on a given date and decide quite rigorously whether the bird could have been the same individual as one photographed a month earlier or a month later at some other location.

The most useful period for identifications based on feather patterns was the mid- to late molting season from July through November. Some individuals photographed in the winter nonmolting season were in sufficiently perfect plumage as to be indistinguishable, and, during the early molting season in spring, it was sometimes difficult to distinguish individuals because of problems in determining just which primaries were missing (Fig. 6). However, even in winter and spring, it was often possible to recognize many individuals by damaged or missing feathers. For example, one easily recognized adult (PCA) finished its annual molt in the fall of 1981 with primary 6 still missing on each wing, and it did not replace these primaries until the following summer.

RESULTS

NUMBERS OF BIRDS

Several thousand condor flight photographs with adequate to excellent primary feather detail were taken during 1982. Once duplicates were eliminated, this total reduced to 403 different bird-location-dates (note: multiple photographs of a single bird at two different observation stations on a single day would represent two bird-location-dates, as would single photographs of one bird at the same location on two different days). By a process of systematic comparison of all photographs, we were able to reduce these 403 bird-location-dates further to a total of just 20 individuals known to be alive within the survey area in August–September 1982 (Fig. 8 and Table 1).

Increased coverage resulted in the accumulation of 522 different bird-location-dates in 1983. However, the minimum number of individuals identified in August–September 1983 was only 19. A comparison of identifications of individuals between the two years indicated that one of the adults documented in 1983 (UN3) had been missed in the late summer photographs of 1982, so the adjusted late-summer minimum for 1982 should be 21 individuals. In addition, two individuals photographed a number of times in the spring of 1982 (SMA and UN2) disappeared before the late summer census period and thus may have been birds additional to the 21 known individuals. These two birds were clearly different from any of the 20 birds documented in late summer 1982, although it is possible that one of them may have been the same as UN3 of 1983. It is equally possible that both SMA and UN2 perished in the late spring of 1982. Two other individuals identified in 1982 and 1983 (BOS and ICI) were found dead subsequent to August–September 1983, so by April 1984 the presumed minimum number of wild condors within the survey area had dropped to 17 individuals.

Several adults photographed in the spring and winter of 1982 and 1983 could not be clearly matched with or differentiated from birds identified in late summer, primarily because they possessed few feather peculiarities and because too much time had elapsed between the dates when they were photographed and the dates when potentially synonymous individuals among the known birds in late summer were photographed. Thus, the 21 birds of 1982 and the 19 birds of 1983 represent late summer minima, but not necessarily the actual numbers of birds in existence within the survey area. While we suspect that most of the unclassifiable individuals were in fact the same as known birds, we cannot rule out the possibility that they included some different individuals.

The distributions of locations where known individuals were photographed support a conclusion that few individuals were missed (Table 1). Almost every individual recorded in the two years was photographed at a number of observation stations. In fact, many individuals were using nearly the entire known foraging range for the species. Conversely, essentially all birds in the population were documented using certain feeding areas (stations 8 through 10) regardless of the locations of their primary roosting or nesting areas. Thus, it appears to be improbable that there could be many individuals within the range who might be so constricted in their movements that they might never appear at any of the observation stations. Moreover, it appears likely that virtually all individuals in the population can be documented if just stations 8 through 10 can be manned thoroughly enough. The only cases of birds being photographed at only one observation station were: (1) a recent fledgling (BOS) who was still confined to its parental nesting area through 1982 (this same bird ranged widely among observation stations in 1983), (2) an adult (SMA) who disappeared from its nesting area (and may have perished) in March 1982, leaving its mate in attendance as a single bird through the rest of the year, and (3) several birds photographed too early or too late in the year to have distinctive enough feathers that they could be conclusively matched with or differentiated from the known individuals.

Our coverage of stations in the northeastern part of the range, however, was relatively light in 1982, and we suspected that if there were birds with relatively restricted ranges in this region we could have missed them. During that year, we photographed only one adult and two immatures at the most northeasterly station (station 21), and only one adult and three immatures at the two stations just to the south of this station in the Sierra Nevada foothills (stations 19 and 20). All these birds were individuals whom we also photographed repeatedly at stations 8 through 10.

Aside from the northeastern part of the range, there is only one other substantial portion of the known range where photographic stations appear sparse in Figure 2—the northwestern

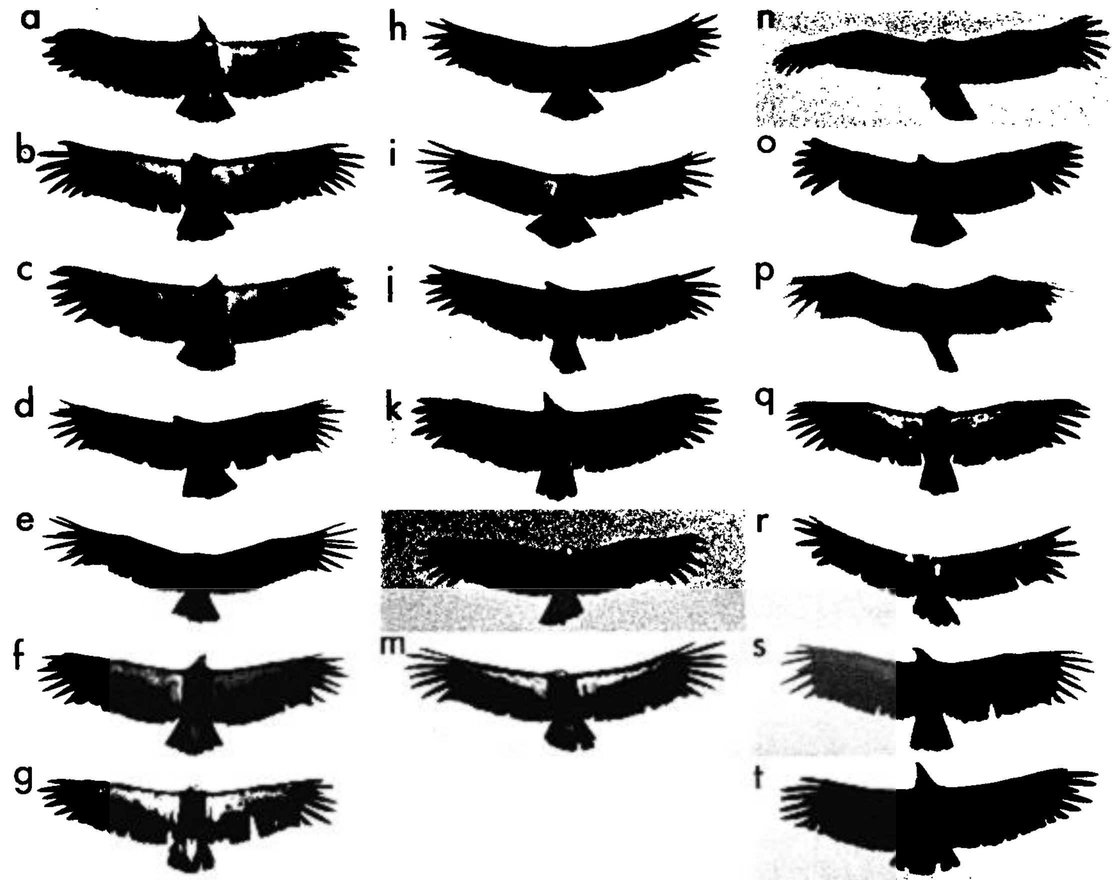


FIGURE 8. The 20 condors documented in late summer 1982, including 13 orange-headed birds (a through m) and seven dark-headed or ring-necked birds (n through t). Expanded coverage in 1983 led to the discovery of only one additional adult. Dates of the photographs were: a (1 Sept.), b (1 Sept.), c (1 Sept.), d (1 Sept.), e (26 Aug.), f (2 Sept.), g (22 Aug.), h (1 Sept.), i (1 Sept.), j (1 Sept.), k (20 Aug.), l (14 Sept.), m (2 Sept.), n (28 Sept.), o (17 Aug.), p (7 Aug.), q (22 Aug.), r (4 Sept.), s (1 Sept.), t (11 Aug.).

region. This area was intensively searched in the summers of 1980 and 1981 and spring of 1982, and has been searched more irregularly since then, but no condors have been seen or photographed during these efforts. Thus, the fact that no stations are illustrated in this portion of the figure is not due to an absence of coverage. While condors are still occasionally reported from northwestern parts of the range, and both of the condors radioed in 1982 (SBM and ICI) were occasionally tracked into this region in 1983 (Ogden et al., unpubl.), no recent nesting activity has been documented here, and present use of the region is likely limited to infrequent wandering of birds that more commonly use the southern San Joaquin Valley foothills for foraging.

The only other area of the known range where we have not obtained any photographs is the southeastern corner, where reliable sightings of a resident pair were made in 1979 and 1980. Very occasional reports of single condors have come from this general region in subsequent years, but despite considerable searching, we have not seen any birds there in these years. It is unclear if the birds infrequently reported from this region since 1980 represent anything other than occasional wanderers from the main part of the range.

In 1983, coverage of the northeastern portions of the range was greatly increased, with continuous monitoring of the most northeasterly observation station from 6 June to 9 October and substantially intensified coverage of the next observation stations to the south throughout the year. In addition, coverage was generally intensified throughout the southern portion of the range. The expanded efforts increased the number of bird-location-dates ninefold for the three northeastern stations. Overall bird-location-dates increased by about a third. Despite these increases, only one adult was documented additional to the adults documented in 1982. This relatively minor improvement suggests that coverage of observation stations throughout the range may now

TABLE 1. Number of bird-location-dates at various observation stations for all birds photographed 1982–1983.

Bird	Probable age (yrs)	Paired with	Year	Photographic station number[a] 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
BOS[b]	0	—	1982	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	1	—	1983	1	—	—	—	1	—	3	5	25	—	—	—	—	—	—	—	—	—	—	2	—
PAX[c]	1	—	1982	—	—	—	2	—	—	—	7	4	5	—	—	—	—	—	—	—	—	—	—	—
WGI[d]	1	—	1982	—	—	—	—	—	—	—	1	1	—	1	—	2	—	—	—	—	—	—	—	—
REC[e]	2	—	1982	—	—	—	—	—	—	—	3	6	3	—	—	—	—	—	1	—	—	1	—	—
	3	—	1983	—	—	—	—	—	—	—	1	9	2	—	—	—	—	—	—	—	—	—	9	1
HIW[f]	2	—	1982	—	—	—	—	—	—	—	1	6	4	—	—	—	—	—	—	—	2	1	—	2
	3	—	1983	—	—	—	—	—	—	4	—	6	—	—	—	—	—	—	—	—	—	—	10	3
ICI[g]	3	—	1982	—	—	—	—	—	—	—	2	2	2	—	—	—	—	—	—	—	3	—	—	—
	4	—	1983	—	—	—	—	—	—	4	2	4	—	—	1	1	—	—	—	—	—	—	5	2
BFE[h]	4	—	1982	—	—	—	—	—	—	—	3	6	1	2	—	—	—	—	—	—	—	—	1	2
	5	—	1983	—	—	—	—	—	—	—	3	12	2	—	—	—	—	—	—	—	—	—	10	3
CCM	adult	CCF	1982	—	—	—	—	—	—	—	1	2	2	—	—	—	—	—	13	—	4	—	—	—
			1983	—	—	—	—	—	—	2	—	—	—	—	—	—	—	1	16	—	—	—	1	2
CCF	adult	CCM	1982	—	—	—	—	—	—	—	1	1	1	—	—	—	1	—	13	—	3	—	—	—
			1983	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	14	—	—	—	1	—
SSM	adult	SSF	1982	—	—	—	—	—	—	—	4	2	2	—	—	13	—	—	—	—	—	—	—	—
			1983	—	—	—	—	—	—	—	4	5	2	—	—	22	—	—	—	—	—	—	1	—
SSF	adult	SSM	1982	—	—	—	—	—	—	—	3	2	—	—	—	12	—	—	—	—	1	—	—	—
			1983	—	—	—	—	—	—	—	8	4	—	—	—	19	—	—	—	—	—	1	2	—
CVM	adult	CVF	1982	—	—	—	2	—	—	—	12	3	7	—	—	—	—	—	—	—	—	—	—	—
			1983	—	—	—	11	—	—	—	5	12	2	—	—	—	—	—	—	—	—	—	—	—
CVF	adult	CVM	1982	—	—	—	1	—	—	—	8	3	5	—	—	—	—	—	—	—	—	—	—	—
			1983	—	—	—	9	—	1	1	3	13	2	—	—	—	—	—	—	—	—	—	1	—
SBM[i]	adult	SBF	1982	—	2	13	—	1	—	—	14	13	6	—	—	—	—	—	—	—	—	—	—	—
			1983	4	—	1	—	—	2	5	5	24	2	—	—	—	—	—	—	—	—	—	—	—

TABLE 1. Continued.

Bird	Probable age (yrs)	Paired with	Year	Photographic station number[a] 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
SBF	adult	SBM	1982	—	—	7	—	—	—	—	9	7	4	—	—	—	—	—	—	—	—	—	—	—
			1983	4	—	—	—	—	2	3	10	16	2	—	—	—	—	—	—	—	—	—	—	—
SMM[j]	adult	SMA	1982	—	—	—	—	—	—	—	3	4	1	1	—	—	—	9	—	—	5	1	—	—
		PPF	1983	—	—	—	—	—	—	—	2	8	1	—	—	1	—	1	2	—	—	—	8	4
SMA[k]	adult	SMM	1982	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—
PPF[l]	adult	—	1982	—	—	—	—	—	—	—	7	7	3	—	—	—	—	—	—	—	1	—	—	3
		SMM	1983	—	—	—	—	—	—	1	5	5	2	—	—	—	—	—	—	—	—	—	7	10
PCA	adult	PCB	1982	—	—	—	—	—	—	—	4	5	1	—	—	—	15	—	—	1	—	—	—	—
			1983	—	—	—	—	—	—	1	1	5	1	—	—	—	15	2	—	—	—	—	1	—
PCB[m]	adult	PCA	1982	—	—	—	—	—	—	—	3	4	1	1	—	—	15	—	—	—	—	—	—	—
			1983	—	—	—	—	—	—	1	3	10	—	1	—	—	11	1	—	—	—	—	—	—
UN1[l]	adult	—	1982	—	—	—	—	—	—	—	13	2	7	—	—	—	—	—	—	—	1	—	—	—
			1983	—	—	—	—	—	—	—	4	12	1	—	—	—	—	—	—	—	—	—	8	1
UN2[n]	adult	—	1982	—	2	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	—	—	—	—
UN3	adult	—	1983	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1	—
Unclassified adults[o]			1982	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Unclassified adults[o]			1983	—	—	—	—	—	—	—	2	1	—	—	—	—	—	—	—	—	—	—	3	—

[a] Stations 1–4, 13–16 are nesting regions; 5–10, 12, 17–18, 20 are foraging regions; 11, 19, 21 are roosting areas. See Figure 2 for locations of observation stations.
[b] Progeny of SBM and SBF fledging in September 1982; died of apparent cyanide poisoning in November 1983.
[c] Progeny of CVM and CVF fledging in 1981; trapped for captive breeding program in December 1982.
[d] Progeny of SSM and SSF fledging in September 1981; last seen in August 1982, now presumed dead.
[e] Presumed progeny of CCM and CCF fledging in November 1980.
[f] Bird of unknown parentage, presumably fledging in 1980.
[g] Bird of unknown parentage presumably fledging in 1979; radio-telemetered in October 1982; died of lead poisoning in March 1984.
[h] Bird of unknown parentage, probably fledging in 1978; not safely distinguishable from an adult by end of 1983.
[i] Bird radio-telemetered in November 1982.
[j] Adult bird with streaked underwing triangles; lost mate in March 1982; judging from molt studies, formed new pair with PPF in 1983.
[k] Adult disappeared from nesting area in March 1982; not subsequently seen or photographed, now possibly dead.
[l] Identification of individual from 1982 to 1983 based on molt studies.
[m] Adult abandoned mate, PCA, in May 1983 but still apparently alive, judging from molt studies.
[n] Adult observed in pair-flights with members of three different pairs between February and April 1982; not subsequently seen or photographed, now possibly dead.
[o] Birds photographed in winter or spring that could not be safely distinguished from or matched to known adults in late summer.

be thorough enough to ensure documentation of every or almost every bird in the population. We emphasize, however, that the one new bird documented in the extensive coverage of 1983 was photographed at only two of the observation stations, and only once at each. Thus, it would be unwise to assume that the photographs taken necessarily included all individuals.

In summary, we believe that the extensive geographic coverage achieved by the photographic efforts within the known range of the species, the almost complete absence of recent reliable condor sightings from outside this range, the generally widespread locations at which individuals have been documented, and the numbers of repeat photographs of individuals, all lead to a conclusion that the current photographic efforts are documenting essentially the entire condor population. We suggest that appropriate estimates of the size of the late summer (August–September) condor population are 21 to 24 individuals for 1982 and 19 to 22 individuals for 1983.

AGE STRUCTURE AND MOLT

The 21 individuals known for late summer of 1982 included seven dark-headed or ring-necked immatures and 14 orange-headed adults or subadults. Two of the dark-headed birds, judging from behavior and molt, were individuals that fledged in 1981. Both molted in the region of primaries 1 through 5 during the year—the pattern exhibited by Topatopa, the captive adult at the Los Angeles Zoo, during his first year after fledging (Todd and Gale 1970). Both also associated intermittently with adult pairs presumed to be their parents. Two other dark-headed birds molted mainly in the vicinity of primaries 6 through 10 (similar to the pattern exhibited by Topatopa during his second year after fledging) and were probably two-year-olds. Still two other birds exhibited the light neck coloration of "ring-necks" during the summer and fall of 1982 and thus were probably three- or four-year-olds (Topatopa became a ring-neck late in his third year). Neither of these birds molted primaries according to a clear pattern of 1 through 5 or 6 through 10. The last of the dark-headed birds was a condor that fledged from an active nest in September 1982, exhibiting perfect primary and secondary remiges.

The 14 orange-headed birds known in late 1982 included five pairs that were photographed repeatedly around nesting areas as well as on the foraging grounds. One bird (SMM) was single at this time. Pairing status of three adults in late 1982 (PPF, UN1, and UN3) was unknown. In May 1982, however, PPF was observed associating with an apparent mate whom we were not able to photograph.

Only one of the orange-headed birds of 1982 (SMM) had any subadult characteristics—some dark streaking in the white underwing triangles. The streaking, however, does not appear greatly changed today (1984) from the time we first began studying and photographing this bird (1980), so it is likely that the bird was actually fully adult in 1982. From late 1980 through early 1982, SMM was paired with SMA, but they did not produce an egg either in 1981 or 1982. Both birds exhibited male behavior patterns and they may have been a same-sex pair.

By late summer 1983, the number of immature-plumage birds in the wild had dropped from seven to five, with the disappearance and presumed demise of one of the yearlings (WGI) and the trapping for captive breeding of the other yearling (PAX). In addition, by the end of 1983, one of the ring-necked birds of 1982 (BFE) had achieved essentially adult feather and head coloration characteristics. Subsequent to the census of August–September 1983, two immature birds were found dead: the fledgling of 1982 (BOS) and one of the ring-necks of 1982 (ICI). Thus, by April 1984, only two immature-plumaged birds (HIW and REC) were still known in the wild population; both were ring-necked by this time. One of the two wild nestlings known in 1982 and both wild nestlings known in 1983 were taken into captivity.

Each of the adults of 1982 and 1983 underwent a unique pattern of primary molt, and none showed the pattern of molting primaries 1 through 5 and 6 through 10 in alternate years that was observed in Topatopa as a young bird. Judging from the data on closely-studied pairs and immatures, however, there was a strong, but not completely rigid, tendency for birds of all ages to molt primaries in one year that they had not molted in the previous year. This tendency, coupled with general nesting area fidelity and mate fidelity of breeding birds, allowed us to match birds from 1982 with those of 1983 with considerable confidence (Table 1). The dovetailing of molt patterns from one year to the next has also given strong evidence that SMM, after the disappearance of his mate, SMA, formed a new pair bond with PPF in 1983. This pair bred in 1984 at a location 150 km from SMM's original nesting location with SMA and in an entirely different sort of nesting site (a natural cavity in a *Sequoiadendron giganteum* rather than a pothole in a cliff).

The 1982 minimum population of seven dark-headed and ring-necked individuals and 14 orange-headed individuals provides a reasonably close match to the ratios of dark-headed to orange-headed birds reported by Koford (1953) and Miller et al. (1965) for large flocks seen during their studies. If anything, the proportion of immatures was somewhat higher in 1982 than in the earlier studies, but it is unclear whether actual age ratios in the population were estimated adequately by early flock counts. Most of these counts were of flocks seen in nesting areas. In our observations, free-flying immature birds spent most of their time in the foraging areas once they reached their second summers. This tendency could significantly affect ratios of immatures to adults that are documented in nesting regions. Age ratios in the wild in 1983 were strongly modified by the taking of nestlings and young birds into captivity.

MOVEMENTS AND POPULATION STRUCTURE

In addition to providing information on condor numbers, molt, and age ratios, the photographs allow some generalizations about condor movements and population structure. The most mobile individuals were the older immatures, who were repeatedly documented moving from one end of the known foraging range to the other. With the exception of the yearlings and recent fledglings, however, immatures were only rarely photographed in the mountainous nesting regions, and then mainly during the spring months. Adults, in contrast, primarily commuted between nesting areas and the nearest foraging areas in the San Joaquin Valley foothills, although they also undertook more extensive movements throughout the foothills region. Nesting adults were not commonly photographed in nesting regions other than their home nesting areas. One pair (SMM-SMA) was photographed, however, nest-prospecting in the nesting area of a closely-adjacent pair (CCM-CCF) in October 1981. Reciprocally, the latter pair was seen and photographed in the territory of the former on a number of occasions. Limited territorial overlap was also seen between one of the above pairs (SMM-SMA) and another closely-adjacent pair (PCA-PCB) in 1981. One distinctive, unpaired adult (UN2) was photographed in four different nesting regions in the spring of 1982. In three of these regions, this bird engaged in pair-flights with members of known pairs, so it may have been actively seeking a mate.

As all the birds appeared to mix quite freely on the foraging grounds, the photographs do not support a postulated division of the condor population into distinct subpopulations (Wilbur 1978). It is likely that most, if not all individuals in the wild population interact with each other at least a number of times each year.

DISCUSSION

Our overall experience in working with the methodology of photographic identifications of individuals has led to a conclusion that feather pattern identifications can be impressively reliable for condors. During the July–November period it appears to be extremely unlikely, at least with the present low population size, that any two condors will ever appear identical in all feather characteristics. At this time of year, there are usually many peculiarities in the plumage of each bird, and the chances of incorrectly matching photographs of two individuals or incorrectly interpreting multiple photographs of a single bird to represent more than one individual appear to be slight, as long as numerous photographs are available through time for most birds and the proper precautions are taken in their analysis. The extensive series of photographs obtained with birds of known identity around nest sites have given a convincing check on how reliable feather patterns can be in individual recognition. All changes in feather patterns documented in these birds have been consistent with the principles of identification that we develop in this paper.

In the areas studied most intensively over the years, the numbers of birds seen today are only about 10 to 20% as large as those documented by Koford in the 1930s and 1940s. For example, Koford and other observers recorded several sightings of more than 30 condors (maximum of 42) in the Hopper Canyon area during the early 1940s. In this same area, the staff of the Condor Research Center have seen a maximum of four condors in hundreds of observation days since 1980. Similarly, although as many as 32 condors were seen at one time in the Sisquoc-Big Pine region in the late 1930s, a maximum of only five birds have been seen there during hundreds of observation days in recent years. Coupled with the estimates we develop in this paper for the 1982–1983 condor population size (21–24 and 19–22 birds), these comparisons suggest that Koford greatly underestimated the size of the condor population, possibly by as much as a factor of two or three. Furthermore, since the estimate of 40 birds given by Miller et al. (1965) was based primarily on comparisons of flock sizes seen in the late 1950s and early 1960s with those seen by Koford, a similar error factor should probably be applied to the data of these authors as well.

Regardless of whose population estimates one prefers, the California Condor appears to be heading rapidly toward extinction. The estimates of Koford (1953) and Miller et al.

(1965), in conjunction with our recent estimates, yield a linear extrapolation to extinction in about 20 years. The more reasonable estimates of Wilbur (1980), coupled with our recent estimates, extrapolate to extinction in roughly 10 years. Effective extinction, however, may occur long before actual extinction because of random fluctuations in sex ratio and the deleterious effects of inbreeding.

The most defensible estimates of former population size of the condor (those of Wilbur 1980), coupled with our estimates of 1982 and 1983, suggest an overall decline of approximately two birds annually (Fig. 1). Yet, data from observations of recent nesting pairs and from the photographs indicate a recent production of about two fledglings per year. Taken together, these figures suggest a probable recent loss of about four birds each year. With a recent population size of about 25 individuals, losses of this magnitude suggest an overall annual mortality rate exceeding 15% in the population. Verner (1978) calculated that a species with the demographic characteristics of the condor could not sustain itself with adult mortality much over 5% annually and mortality of immature birds much over 15% annually. Mortality of immatures has been especially heavy in the year and a half since the 1982 census, with the loss of three out of six birds (excluding one young bird brought into captivity). In addition, two of the adults documented since the start of the photographic efforts (SMA and UN2) may now be gone. Thus, regardless of whether or not current reproduction is everything it ought to be, recent mortality (at least immature mortality) appears to have been excessive.

Unfortunately, the sources of mortality in the wild population are still known only imperfectly, and the acquisition of effective control over mortality factors is likely to be a slow process in the conservation program. Perhaps the most effective means of reversing the decline in the near term are not to be found in the reduction of mortality factors but in the reproductive increases that can be produced by multiple-clutching and annual-nesting of the wild pairs (Snyder and Hamber, unpubl.) and by captive breeding and release of captives to the wild (Carpenter 1982, Temple and Wallace 1983).

Continued efforts to document the size and age structure of the wild California Condor population by photographic means are planned for the years ahead. Anyone with photographic skills can contribute to this program. We encourage the submission of originals or copies of good flight photographs to the Condor Research Center, 2291A Portola Road, Ventura, California 93003, provided the dates, photographers, and locations can be accurately specified. If the current level of photography can be sustained or improved, it should be possible to track future changes in the population with a minimum of error.

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U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Condor Research Center, 2291A Portola Road, Ventura, California 93003. Address of second author: Biological Sciences Department, California Polytechnic State University, San Luis Obispo, California 93407. Received 6 January 1984. Final acceptance 14 September 1984.

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RECENT PUBLICATIONS

Current ornithology, Volume 1.—Edited by Richard F. Johnston. 1983. Plenum Press, New York. 425 p. $39.50. This volume inaugurates a projected series, the scope of which is "all of the biology of birds . . . . The aim of the work, to be realized over several volumes, is to present reviews or position statements concerning the active fields of ornithological research. The reviews will be relatively short, and often will be done from the viewpoint of a readily identified group or school." The contents of the first volume are: Comparative avian demography (by R. E. Ricklefs), Determination of clutch size in precocial birds (D. W. Winkler and J. R. Walters), Structure and function of avian eggs (C. Carey), Origin of birds and of avian flight (L. D. Martin), The Great Plains hybrid zones (J. D. Rising), Species concepts and speciation analysis (J. Cracraft), Bird chromosomes (G. F. Shields), Genetic structure and avian systematics (K. W. Corbin), Phylogeny and classification of birds based on the data of DNA-DNA hybridization (C. G. Sibley and J. E. Ahlquist), Experimental analysis of avian limb morphogenesis (J. R. Hinchcliffe and M. Gumpel-Pinot), Variation in mate fidelity in monogamous birds (N. L. Ford), and Evolution of differential bird migration (E. D. Ketterson and V. Nolan, Jr.). Articles such as these seldom appear in journals, yet they are invaluable to both students and experienced workers who want to keep up to date. The editor deserves commendation for having conceived and established this publication, for seeking such a diversity of timely subjects, and for persuading such expert authors to write for him. Illustrations, lists of references, indices.

The birds of China.—Rodolphe Meyer de Schauensee. 1984. Smithsonian Institution Press, Washington, DC. 602 p. $45.00 cloth, $29.95 paper. Here, for the first time, is a single volume that describes all of the birds found in China. It is further distinguished from the two-volume work by Etchécopar and Hüe (1978, 1982) by being in English and readily available. The work has been planned as a descriptive catalogue rather than as a typical field guide. Its Introduction usefully sketches the geography of China and the history of ornithology there. The accounts then treat all of the country's 1,195 species (an avifauna smaller than that of Venezuela, covered in the author's 1978 book!). They each provide a concise yet full description "with emphasis in the *form of italics,* on easily distinguishable markings that should aid field identification." The differentiating characteristics of subspecies are included in cases where they can be seen in the field. Also given are the known geographic range within and outside China, plus the habitat and altitudinal range. Almost nothing is said about voice or habits. Approximately half of the species are illustrated in 38 color plates by John Henry Dick, John A. Gwynne, Jr., and H. Wayne Trimm, as well as 39 wash drawings by Michel Kleinbaum. The plates are grouped together after the Introduction while the drawings are placed near their respective accounts. Bibliography, list of variant names, checklist, indices. Clearly, this reference book will be indispensable for English-speaking students of Chinese birds, both in the field and in museum collections. One hopes that it will be translated into Chinese so that it can be read by the people who have most use for it.

Voices of the New World jays, crows, & their allies/ Family Corvidae.—Compiled, edited, narrated, and produced by John William Hardy. 1984. 33⅓ rpm monaural phonograph record, ARA 9, ARA Records and the Bioacoustic Laboratory and Archive, Florida State Museum. No price given. Source: ARA Records, 1615 N.W. 14th Ave., Gainesville, FL 32611. This phonodisc offers sound recordings of 48 species of New World corvids, lacking only one species which has not been caught on tape, *Cyanocorax heilprini.* Hardy has diligently compiled and edited material from his own recordings and those of 27 other recordists. Many of the species are represented by two or more cuts, giving different calls or geographic variants. While the entries for most of the species are of generous length, they do not adequately convey the large vocal repertoires characteristic of corvids. Each cut is introduced by only the spoken name of the species or example, details of the recordings and Hardy's comments being wisely relegated to the album and an insert booklet. There seems to be some problem in the production of this disc: although the review copy did not appear to be warped, the innermost bands broke up and would not play properly unless the tracking force of the tone arm was increased considerably above normal. The record may serve as an aid to field identification of voices yet it will probably be more useful as a source of acoustic data for behavioral and taxonomic research.