

Molt and Sequence of Plumages of Golden Eagles and a Technique for In-Hand Ageing

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ABSTRACT

We describe the molt and characteristics of flight and tail feathers of wild caught Golden Eagles. We verify that adult plumage is attained after four or five annual molts and present a technique for classifying most Golden Eagles in hand into one of five age classes: juvenile, Basic I-III, and adult. Age characters are presented separately for primaries, secondaries, and tail feathers and serve for ageing eagles throughout the year including periods of active molt, when characters change gradually from one age class to the next. Known-age eagles recaptured in this study provided verification of our ageing technique.

INTRODUCTION

Current knowledge of molt in the Golden Eagle (*Aquila chrysaetos*) in North America is based almost entirely on detailed observations from one eagle reared in captivity and notes on a second eagle from Colorado by Jollie (1947). Ginn and Melville (1983), Watson (1997), and Forsman (1999) present some information on molt of Golden Eagles in Europe. However, to our knowledge, Golden Eagle molt has not been described in detail from eagles captured in the wild.

We describe the molt and characteristics of flight and tail feathers of wild Golden Eagles captured in California, including the range of variability in the number of flight and tail feathers molted annually. We find, as did Jollie (1947), that adult plumage is attained after four (sometimes five) annual molts. We present a technique for classifying Golden Eagles in hand into one of five age classes based

upon the molt sequence of primaries and secondaries (remiges) and tail feathers (rectrices), and on the premise that two to three different age classes (generations) of flight and tail feathers can be recognized by examination of their shape, fading, wear, pattern, and coloration. Edelstam (1984) based a similar but less detailed ageing technique for White-tailed Sea Eagles (*Haliaeetus albicilla*) solely on examination of museum specimens.

Age characters are presented separately for primaries, secondaries, and tail feathers and serve for ageing eagles throughout the year, including periods of active molt, when characters change gradually from one age class to the next. The ageing characters were developed based on identification of molt centers and sequences of feather replacement by Jollie (1947), as supported by Edelstam (1984) and Miller (1941). These characters were refined with data from this study, the literature, numerous museum specimens, confiscated dead eagles in the possession of the U.S. Fish and Wildlife Service (USFWS), and observations of eagles captured from other studies. Known-age eagles recaptured in this study provided verification of the ageing technique. For immediate reference in determining age, we have included eye color in paragraphs describing plumage.

METHODS

During 1984 to 1987, 178 Golden Eagles were captured in pit traps and cannon nets as part of a study examining the prevalence of lead toxicosis in the range of the California Condor (*Gymnogyps californianus*) (Bloom 1987, Bloom et al. 1989,

Pattee et al. 1990). Twenty-two of these banded eagles were later recaptured, and three were captured a third time. Additionally, 200 nestlings were banded, of which one was recaptured and another was found electrocuted; both were retrieved as adults. All eagles were captured in southern California and presumably included individuals of both resident and migratory populations (Bloom, unpubl. data). Photographs were taken of the undersides and uppersides of wings and tails or data were recorded on the molt of flight and tail feathers or both, for all eagles in Basic I - III. Eagles captured just prior to night, during inclement weather, or at the same time as a California Condor, were released quickly and a full complement of data and photographs was not taken.

The ageing technique was developed largely on the premises both that juvenile flight and tail feathers differ from replacement flight and tail feathers, and that their molt begins at molt centers and proceeds as described in Jollie (1947), Edelstam (1984), and Miller (1941). Eagles banded as nestlings, or initially captured as juveniles or during their first prebasic molt, were aged easily. These were "known-age" individuals.

We tested the ageing technique by examining photographs of Golden Eagles captured in winter by T. and E. Craig and year-round by G. Hunt, D. Driscoll, R. Jackman, and B. Latta. Eagles recaptured that were in subsequent plumages, both from this study and the study by T. and E. Craig, provided verification of the molt sequences and ageing technique. Further, Bloom and Clark together examined over 50 Golden Eagle carcasses in the possession of the USFWS and were able to assign age classes to all, including several known-age eagles.

We used the Humphrey-Parkes molt terminology (Humphrey and Parkes 1959, Wilds 1989), except we substituted "adult" for "Definitive Basic." The age class terminology of the Bird Banding Laboratory (BBL) is compared with the Humphrey-Parkes terminology and with each eagle's actual age (Fig. 1). An estimate of the age in months (Fig. 1) was determined by assuming a hatching date of approximately 15 Mar based upon eagles fledged in California (Bloom unpub.). The term

"generation," as used on the figures, refers to the number of times an individual feather has been replaced, not the number of annual molts.

Flight feathers are referred to by primary (P) or secondary (S) number. Primaries are numbered from the innermost outward and secondaries from the outermost inward, with P1 being the inner and P10 the outer primary, and S1 the outer and S14 the inner secondary (S15-17 are tertiaries). Tail feathers are numbered in pairs, with T1 being the central pair and T6 the outer pair; they are further distinguished as left or right.

All eagles were assigned a BBL age class of Hatching Year (HY), Second Year (SY), Third Year (TY), Fourth Year (FY or 4Y), After Fourth Year (AFY or A4Y), or After Fifth Year (AFFY or A5Y). (NB Before reporting, banders should verify currently acceptable codes with BBL. Eds.)

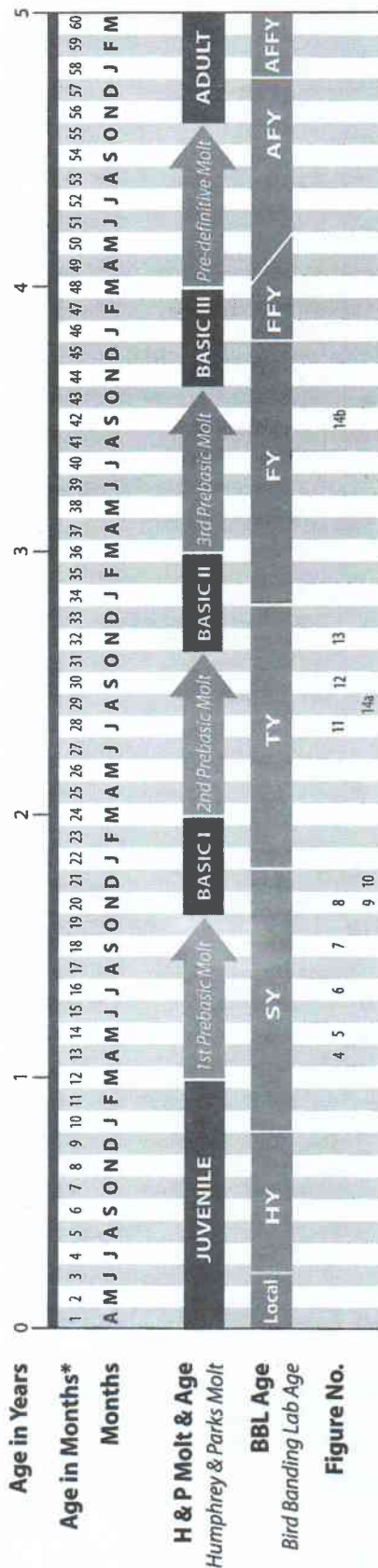
RESULTS

Molt Sequences

Primaries. Primaries are molted in sequence from P1 to P10. In the first prebasic molt, primary molt always begins with P1 and proceeds outward. Rarely a primary is molted randomly or adventitiously replaced. When molt is resumed the following spring, the first primary to be replaced is usually the next in sequence; however, P1 is replaced anew (Jollie 1947, Stresemann and Stresemann 1966, Edelstam 1984, Prout-Jones and Milstein 1986, this study) which starts a new wave of molt. The primary molt thereafter proceeds in two or three places.

Secondaries. Secondaries are replaced in the first prebasic molt beginning at three molt centers, S1, S14, and S5, usually, but not always, in that order (Miller 1941, Jollie 1947, Edelstam 1984, Prout-Jones and Milstein 1986, this study). Molt proceeds inward from S1 and S5, and inward and outward from S14. Occasionally S4 is replaced before S5, or S15 before S14, and rarely a secondary is replaced randomly or adventitiously. Molt proceeds in the following year at the next secondaries in sequence, until all juvenile secondaries are replaced. S1 is sometimes replaced a second time before all juvenile secondaries (e.g., S9) are replaced.

Figure 1 | GOLDEN EAGLE AGE AND MOLT CHRONOLOGY (Figures 4-14b)



* Assumes a hatch date of 15 March

Tail feathers. Rectrices are usually replaced in a set order, but with considerable variation. Usually the T1 pair is replaced first in the first prebasic molt, followed by the T6 pair and then by T2. Tail molt is often not symmetrical and becomes less symmetrical as eagles increase in age. Twenty-nine (63%) of 46 eagles molting from Juvenile into Basic I plumage were symmetrical, whereas, only 17% of 30 eagles advancing from Basic I to Basic II were symmetrical.

Timing of Molt

Molt is usually suspended in late autumn. However, a few eagles molt actively during the winter months (Fig. 2) and for these, few feathers are being replaced (Fig. 3). Only 37% of 52 non-juvenile eagles had growing flight or tail feathers during the months of November through February, compared to 98% of 64 non-juvenile eagles captured between May and October (Fig. 3). In December and January, only three (13%) of 23 eagles captured were molting from one to four feathers each. Watson (1997) reports similar results for Scottish Golden Eagles.

Primaries. The greatest number of growing primaries per eagle was counted in July, with an average of 4.1 (range 3-6) feathers in active molt per eagle (n = 7, Fig. 3). All 16 non-juvenile eagles captured from May through August were molting primaries, compared to only seven (14%) of 49 eagles caught from November through February, and these usually had molted only one primary on one wing. From 20-26 months are required to replace all of the juvenile primaries.

Secondaries. The greatest number of growing secondaries per eagle was counted in May and June, with an average of 6.5 (range 4-9) feathers per molting eagle (n = 4, Fig. 3). June through September were the most active months for eagles molting secondaries, with 39 (98%) of 40 eagles exhibiting secondary molt. Winter, from November through March, was the most inactive molt interval, with only 12 (21%) of 57 eagles showing secondary growth, usually with only one feather growing.

Tail Feathers. Peak tail feather molt occurred from May through July, when a mean of 3.9 feathers per non-juvenile eagle were growing (n = 12, Fig. 3).

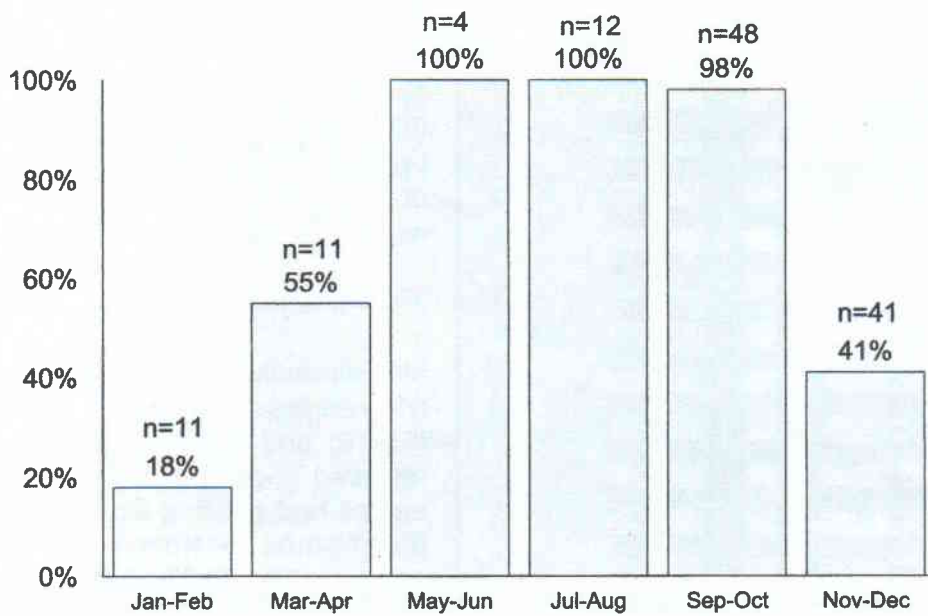


Figure 2. Percentage of molting non-juvenile Golden Eagles.

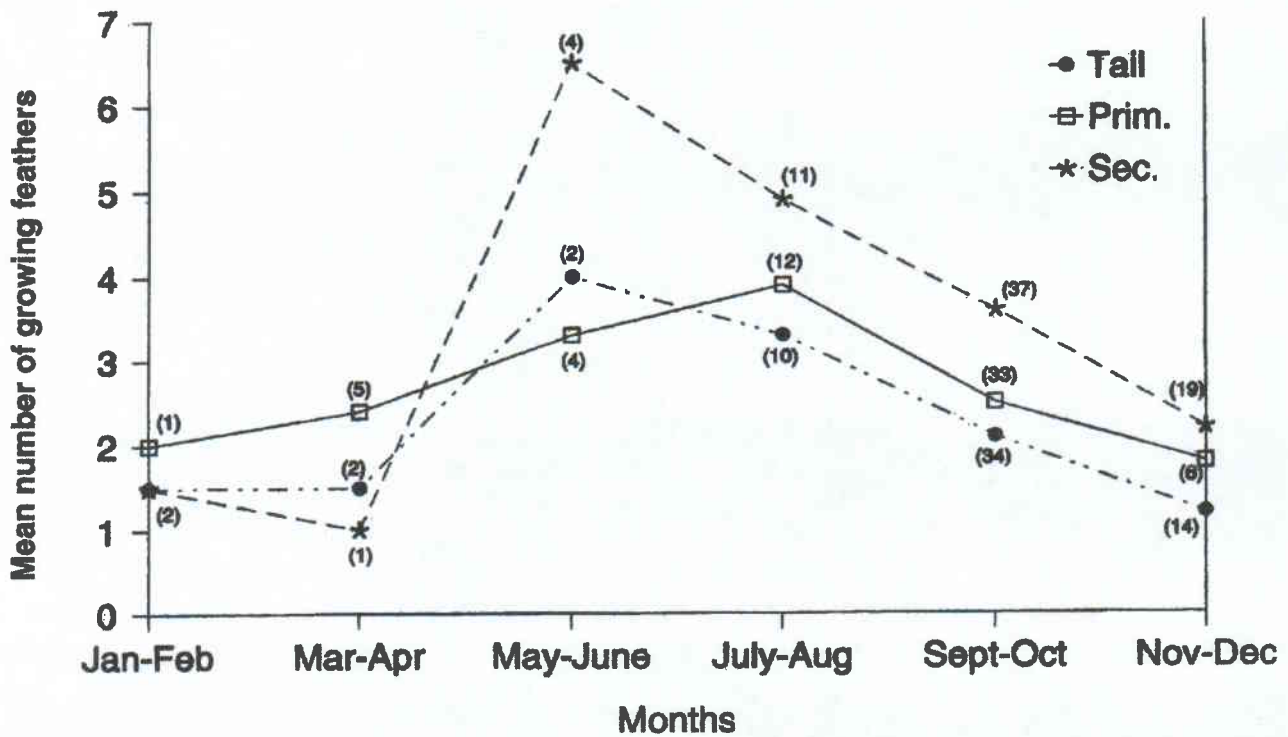


Figure 3. Mean number of growing flight feathers for molting Golden Eagles greater than one year old (sample size is shown in parentheses).

The interval when the greatest number of eagles were molting tail feathers was from July to October, with 71%, 100%, 81%, and 63% respectively, for 58 captured eagles in active molt.

Plumages and Molts

Juvenal Plumage (Photos 1-2: see also plates GE06-07 in Wheeler and Clark 1995). The first plumage is acquired in the nest and is characterized by the lack of molt (that is, all feathers are the same age and appear uniform in color and shape) as well as by the patterns of the secondaries and the tail (Fig. 4). Juveniles have dark brown eyes. Young eagles in the first six months after fledging tend to be overall blackish-brown but appear a paler dark brown the following spring as they near the first prebasic molt. Secondaries have rather pointed tips and are uniformly dark in color (except for white bases, if present) and lack grayish marbling and a dark tip (Photo 1). Many juveniles show a substantial amount of white on the base of flight feathers; the white is more extensive on the underwings. However, four (15%) of 26 juvenile eagles captured, for which presence or absence of white was recorded, lacked white on the bases of the flight feathers. The tail is bicolored: base white and tip dark brown (Photo 2); with a more or less well-defined line of contrast between them. There is no grayish marbling in the dark area, but there may be some dark spotting or flecking in the white area, which is somewhat irregular, but at approximately the same place on each feather.

Juveniles show no molt of the flight or tail feathers (Fig. 4, Photos 1-2). One or two adventitious exceptions may occur, but neither symmetrically nor at molt centers. All feathers of each group (primaries, secondaries, and tail feathers) are the same shape and age (Photo 1). All feathers of the body plumage are the same color, dark brown, and can appear black on recently fledged eagles. In addition, juveniles lack tawny coloration on median secondary upperwing coverts shown by all other plumages.

In Banding Lab terminology, juveniles are aged as Local (L) in the nest, as Hatching Year (HY) from fledging in late spring and summer until 31

Dec, and as Second Year (SY) after 1 Jan until the beginning of the first prebasic molt (Fig. 1).

First Prebasic (Post Juvenile) Molt. Juvenile Golden Eagles begin molt into Basic I plumage in their second calendar year at about 12 months of age, or between 9 to 11 months after fledging, usually beginning molt in March to May (Figs. 1, 5) and usually cease active molt by November (Figs. 1, 8). One juvenile, 609-19457 (Fig. 5), captured on 9 May, showed active primary molt but no molt of secondaries or tail; its new P1 was fully grown on both wings, and P2 and P3 were growing. Based on Jollie's (1947) observations, this eagle most likely had dropped P1 in late March or early April, the earliest evidence for initiation of the first prebasic molt. On the other hand, a juvenile captured on 21 Apr had not initiated molt of flight or tail feathers.

The first feathers molted are the inner primaries: P1 first, followed then by P2, and so on (Fig. 5, Photo 3) and usually the central tail feathers (T1 first) (Figs. 6, 8-9, Photo 4). No wild eagles replaced more than six primaries per wing annually. Jollie's (1947) captive eagle replaced seven on the right wing, so this could happen in the wild; however, results of molt studies of birds in captivity should be treated with caution (Palmer 1972).

When primary molt is well underway, secondary molt begins, with S1 usually being replaced first. Typically, S14 or S15 and S5 are then replaced (Figs. 7-10, Photos 3, 5). Molt proceeds inward from the S1 and S5 molt centers and both ways from the S14 center. A few individuals had replaced one or two secondaries out of sequence. For example, one eagle had molted S1, S4, S11, S13, and S14 on one wing and S1, S4, S12 on the other wing. Only one eagle had replaced no secondaries during this molt.

Typically, only one to six secondaries are replaced on each wing during this molt, resulting in a mix of old, faded, longer pointed juvenile secondaries and new, wider, shorter replacement feathers (Photo 4). New secondaries have grayish mottling except for the wide dark tips and are easily differentiated from the juvenile secondaries (Photo 4).

Tail feather molt usually begins with the central pair, T1, followed by either T2 or T6, with some variation in order (Figs. 6, 8, Photo 4). T3 and T4 are usually replaced during the next annual molt but can be retained and replaced in the third annual molt. Feather replacement is more often symmetrical during the first prebasic molt with 29 (63%) of 46 eagles having symmetric tail molt.

Of 23 Basic I eagles, one had replaced P1 through P3, five had replaced P1 through P4, seven up to P5, and nine up to P6. One eagle had anomalously molted P1 to P5 on both wings and skipped P6 on one wing and molted P7 and P8, for a total of seven new primaries for that wing. All eagles this age had replaced at least three primaries. Eagles replaced a maximum of six primaries (60%), six secondaries (34%), and nine tail feathers (66%) in the first prebasic molt. Golden Eagles during their first prebasic molt are aged in BBL terminology as SY (Fig. 1). Howell and Corben (2000) make a good point that this molt should be called the second prebasic molt.

Basic I Plumage (Photos 3-4). Basic I eagles have from three (Fig. 9) to six (Fig. 8) new inner primaries. This is the only age-class to show just two ages of primaries (Photo 3), new (dark and fresh) inner ones and old (faded and worn) outer ones (Figs. 8-10, Photo 3). Their eyes are brown. New secondaries are obvious, as they are shorter, wider, with less pointed tips and have grayish marbling and dark tips. New secondaries are found at S1, S5, and S14 (Fig. 8, Photo 3), but a few eagles have molted no secondaries.

New tail feathers usually include the pairs of T1, T2, and T6 (Figs 8, 10, Photo 4), occasionally others. Between one and nine juvenile tail feathers had been replaced on 31 Basic I eagles. Occasionally, eagles have replaced only a single tail feather, e.g., on 15 Jan, one Basic I (TY) eagle had only replaced a single juvenile T1. New Basic I tail feathers differ from juvenile tail feathers by having grayish marbling in the dark tip and a more irregular and less well-defined border between the dark tip and white base (Photo 4). Compared to juvenile tail feathers, there is more variation in pattern among individual replacement feathers.

Body feathers at this age and older show a mottled mix of faded brown feathers and darker new feathers, giving them a somewhat mottled

appearance compared to the more uniform coloration of juveniles. According to Jollie (1947), as much as 75% of body feathers can be replaced annually. New median secondary upperwing coverts show tawny mottling. This character is present on all subsequent plumages but not on juvenal plumage.

Several Basic I eagles had replaced the minimum number of flight (P1-P3, S14) and tail feathers (T1) and appeared overall very juvenile-like, except for the new flight and tail feathers and new body and coverts. Basic I Golden Eagles are aged in BBL terms as SY until 31 Dec and as TY after 1 Jan until the beginning of the second prebasic molt (Fig. 1).

Second Prebasic Molt. The second annual molt begins in March or April and resumes where the first prebasic molt ended in replacing flight feathers (Figs. 11-13). Primary molt begins with the first feather outward from the last molted previously, continuing the wave. Then a new wave molt begins again at P1 (Figs. 11-13). Secondary molt also continues in each of the three molt areas with the next feather in sequence. In addition, S1 is often replaced again during this molt (Figs. 11-13).

The pattern of tail molt is now rather irregular, including some asymmetry (Figs. 11-13). Of 23 eagles in their second molt, only three (13%) were replacing feathers symmetrically. As many as three juvenile primaries, five secondaries, and seven tail feathers can still be present at the end of the second prebasic molt. Golden Eagles undergoing their second prebasic molt are aged in BBL terms as TY (Fig. 1).

Basic II Plumage (Photos 5-6; see also plate GE05 in Wheeler and Clark 1995). This plumage is distinguished by the presence of three ages of primary feathers, almost always with at least one of the outer primaries (P10) being old and worn (Figs. 13, 14a, Photo 5) and by two ages of non-juvenile tail feathers; both ages have white basal areas and grayish marbling in the dark areas (Photo 6). Ages of primaries are determined by color and wear. New feathers are dark and unworn; old feathers are faded and worn. Those grown in between are intermediate in character (Photos 7-8). Primary molt appears as waves, with feathers becoming progressively newer and fresher outward