PRIMARY MOLT IN JUVENILE CARDINALS

By Charles H. Blake

In the attempt to find out something about the postjuvenal primary molt in the Cardinal (*Richmondena cardinalis*), I have kept a record of the primaries in molt at each capture of juveniles for several years at Hillsborough, North Carolina. Quite aside from the information actually obtained about the Cardinal, I offer a discussion of the analysis of such data.

The period of time included is from 1 June to 30 November. Each month is divided into three parts denoted by superscripts 1, 2, 3, being days 1-10, 11-20, and 21-30 or 31 respectively. The stage of molt is denoted by the number of the outermost primary then in molt and by *No* or *Complete.*

TEMPORAL DISTRIBUTION OF JUVENILES

The number of juvenile Cardinals banded varies with date of banding in a characteristic way. Practically none are banded before 21 May and a peak is reached in July, August, or September and then declines. The actual peak month varies from year to year. The decline after September may be more apparent than real, simply reflecting the difficulty of ascertaining the juveniles. This variation is, doubtless, correlated with the intensity of nesting which must reach its peak in June or early July. This is validated by the fact that the stage of molt at banding is closely correlated with the date of banding from mid-July on. Those birds banded before 21 June are, at the most, just barely fully fledged.

The second type of temporal distribution concerns the distribution of repeats. This is illustrated in Fig. 1. The repeats of birds banded in May and June are few and scattered, as compared with repeats of the ones banded in July and later. This is apparently not a question of differential mortality since quite a number of the early banded birds reappear for the first time in the following spring, actually January to April. I suggest the following behavior sequence. Young birds stay in the vicinity of the nest while still managed by the parents. This may be for three or four weeks. They then move further away, perhaps in no fixed direction, for two or three weeks, and finally more or less settle down. The straight line distance from the nest may not be great. If so, some might join the group wintering near the banding station which would account for their reappearance seven months or more after banding.

THE POSTJUVENAL MOLT

The postjuvenal molt begins in the pectoral region just about the time that the juvenal primaries are completely formed. This may be before the last sheathing at the base of the primaries has disappeared. At about the same time molt of the lesser coverts begins. My best estimate is that the primary molt begins about one month

Banded

Recaptured	May 3	June 1	June 2	June 3	July 1	July 2	July 3
June 1	2						
June 2	3	3					
June 3	3	2	4				
July 1	1	1	3	4			
July 2	1		2	2	5		
July 3			1		4	3	
Aug. 1	1		1	2	4	2	4
Aug. 2				1	3	2	6
Aug. 3				1	2		2
Sept. 1		1		2	2		5
Sept. 2			1			3	2
Sept. 3		2	1		1	1	5
Oct. 1		1	2		1	1	
Oct. 2				1	1	2	3
Oct. 3		1		2	1		
Nov. 1					4	3	
Nov. 2					3	4	2
Nov. 3		1	1		3	1	2
Dec. 1			2		2	3	6
Dec. 2			2		2	5	1
Dec. 3				1	2	3	5

Figure 1. Recaptures of birds banded in the periods stated in top line. Data of seasons 1967-1970.

after body molt begins. Primary molt is about half finished when secondary molt begins and tail molt begins still later. These remarks are made to bring out the point that postjuvenal quill molt is delayed in its inception as compared with the usual passerine postnuptial (prealternate) molt. The slow primary molt is still in process long after the completion of body molt.

THE PRIMARY MOLT

Because the number of observations available is so variable from one part of a month to another, the way to secure comparable figures is to tabulate for each stage of primary molt the percentage of the observations of that stage relative to the whole number of observations for the given 10 (or 11) day period. This is shown in Fig. 2.

It is possible that a very few birds leaving the nest in May[1] begin primary molt in June[3] but this has not been seen yet. Fig. 2 suggests, on this supposition, that few birds leave the nest after the end of July.

Stage of primary molt

Observation periods	No	1	2	3	4	5	6	7	8	9	Com.
June 1	100										
2	100										
3	100										
July 1	95	5									
2	87		13								
3	71	2	19	5	2						
Aug 1	58	5	12	12	14						
2	25	2	29	15	15	12		2			
3	13		18	32	18	11	5	3			
Sept. 1	2	2	3	20	17	20	10	12	3	2	
2		2	4	19	17	21	15	10	2	10	
3					3	31	11	14	8	33	
Oct. 1					3	10	19	3	3	61	
2							9	6	11	57	17
3										71	29
Nov. 1										46	54
2										27	73
3										13	87
Dec 1											100

Figure 2. Percentages of total numbers of birds in each period related to each stage of primary molt. "No" means no primary molt; "Com" means primary molt completed.

The peak percentages in the columns of Fig. 2 suggest that, with two exceptions, the primaries are dropped about 10 days apart.

The present data comprizes 295 observations of birds actually in the process of primary molt. Only seven of these are of birds in which molt was restricted to the first primary. This indicates that the second primary is dropped very soon after the first. A gap left by two dropped primaries at the proximal end of the series should have little effect on flight. The result could be to shorten the total time required for primary molt by about a week.

The data on primaries 6-8 is much more limited than that on primaries 2-5. This suggests that the former three grow more rapidly than the latter four. If this be true it is consonant with the significance for flight of primaries 6-8. These three are quite similar in length and form the tip of the wing. Lift is importantly dependent on the length of the leading edge of the wing. It would, therefore, be advantageous to have at least one of these three primaries nearly full-grown at all times.

The ninth primary is short and relatively unimportant in flight. The present data indicate that it is dropped soon after primary 8 and that its growth is slow. During the early part of its growth primary 8 could well substitute for primary 9. The passerine birds must have a very long history as flying birds and it should not be surprising if their primary replacement is particularly adapted to their aerodynamic requirements.

Three siblings banded in the nest on 6 May will illustrate the progress of part of the molt and also the difficulties caused by long gaps in the record.

Molt in Three Siblings

Dates	# 917	# 918	# 919
6 May	banded	banded	banded
18 May			no molt
24 May	very early body molt		
28 May			almost fully fledged, early body molt
2 June	not quite fully fledged	wings fully fledged	
4 June			wings fully fledged
6 June	wings fully fledged		
24 Aug.	moly: primaries 5-6		
12 Sept.		molt: primaries 7-9	
22 Sept.	molt: primaries 7-9		
27 Sept.	molt: primaries 8-9		
6 Nov.		molt: complete	

Referring again to Fig. 2, we may conclude the time spans shown are fairly representative of the whole reproductive season. It suggests also that, for practical purposes, nesting ceases at the end of July.

Two questions merit further investigation. First, do birds hatched toward the middle or end of the breeding season begin piimary molt when younger than those hatched early in the breeding season? Second, why is postjuvenal (or postnuptial) molt more frequently observed in those species in which it is a lengthy process? Is this because the birds are more active during the process or only because such species are more readily captured by existing methods?

ANALYTICAL COMMENTS

It is obvious that the first step in any analysis is to arrange the data in some logical fashion. Since we are here interested in the stage of molt versus time of year, this was done as a preliminary to Fig. 2, that is, the actual number of observations was inserted in each rectangle. It may not always be recognized that such a diagram is three-dimensional. The two coordinates in the plane of the paper are obvious. Each number represents a height vertical to the plane of the paper. It is not uncommon to convert such a diagram into a model or a perspective drawing in which the numbers de-

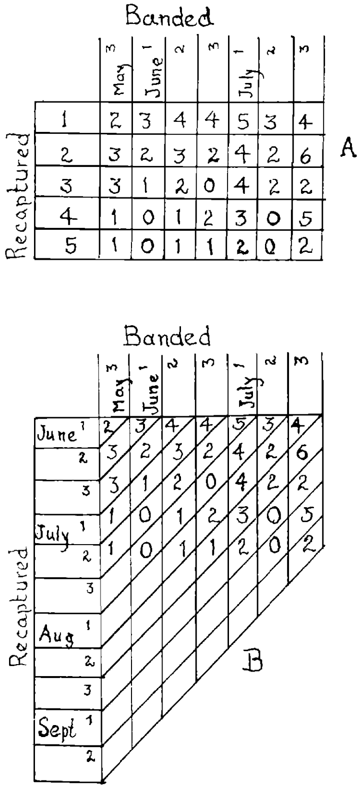

Figure 3. Rearrangement of the first five possible entries in each column of Fig. 1. A. By periods after banding without regard to actual periods of recapture. B. Fig. 3A arranged to show actual periods of recapture.

termine the elevation of a surface above a base plane.

It is usually possible to arrange data in more than one way. Fig. 3 shows two other ways to display the five upper entries of each column of Fig. 1. In Fig. 3A the elapsed number of intervals after banding is shown but the actual dates of the intervals are ignored. Fig. 3B is actually the same as Fig. 1 except that what were horizontal coordinates in Fig. 1 are now slanted upward toward the right at 45°.

The second step is to decide whether the arranged data can be analyzed by the available statistical methods or should be subjected to a transformation. In the present case time seemed more important as a measure of the progress of molt than absolute numbers. This is especially true when it is recognized that the number of birds recorded in a given period and stage of molt is not necessarily a fixed proportion of the number so specified in the whole population. The latter situation might be nearly true if all birds repeated at fairly regular intervals and we had several thousand rather than 523 observations. Hence, a transformation was indicated. The simplest one was to percentages. This has a great advantage in that it does not distort the statistical distribution of the array to which it is applied. The only useful transformation is to convert the raw data in the rows into percentages. Fig. 2 is the result.

Is anything to be derived from statistical treatment? If we consider the columns in Fig. 2 and take means then it is obvious that the means of the first and last columns have no real significance. The first column merely shows when primary molt begins and when it has been initiated in all birds. We could average only the entries less than 100 and take that result as showing the mean date of beginning of primary molt. A similar figure for the last column could be interpreted as the mean date of completion of primary molt. The overriding difficulty in using means, at all, is that they imply a false premise, namely that the observations represent precise stages of molt. For example, of the birds represented by the figure 58 for August[1], one bird might drop the first primaries later on 1 August and another bird might not drop them until 11 September. The same reasoning applies to any other entry shown in Fig. 2.

It will be noted that there is an indication of bimodality in the distributions for primaries 2 and 6. If this were of any real significance we would expect it to occur for primaries 3-5. Breeding certainly occurs over a period of time but chiefly in May and June. There is also evidence of rebreeding by some individuals. Two discrete periods of breeding would be expected to show a truly bimodal distribution, in time, of molt stages. From the data available to me, I conclude the interval between identical stages of two successive, complete broods for the same female would be 35 to 40 days. Evidently the two peaks in the distribution of primaries 2 and 6 are too close together.

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