COMPARATIVE GROWTH AND PLUMAGE DEVELOPMENT IN *COTURNIX* AND BOBWHITE

DAVID L. LYON

SEVERAL releases of Japanese Quail (*Coturnix coturnix japonica*) have been made in the United States since 1956. This attempted stocking appears to have been unsuccessful, as were releases of this form and *C. c. coturnix* made more than fifty years ago (Phillips, 1928). However, recent interest in the bird has pointed up its qualities as an experimental animal. As Padgett and Ivey (1959) pointed out, *Coturnix* is easy to handle, hardy, has short breeding cycles, and great egg-laying ability.

Objectives of the present study were to provide detailed information on eggs, growth, and plumage development of *C. c. japonica*, and to find accurate criteria for determining age in this bird. Bobwhites (*Colinus virginianus*) reared under the same conditions as the Japanese Quail furnished a standard for comparison of growth rates and plumage development.

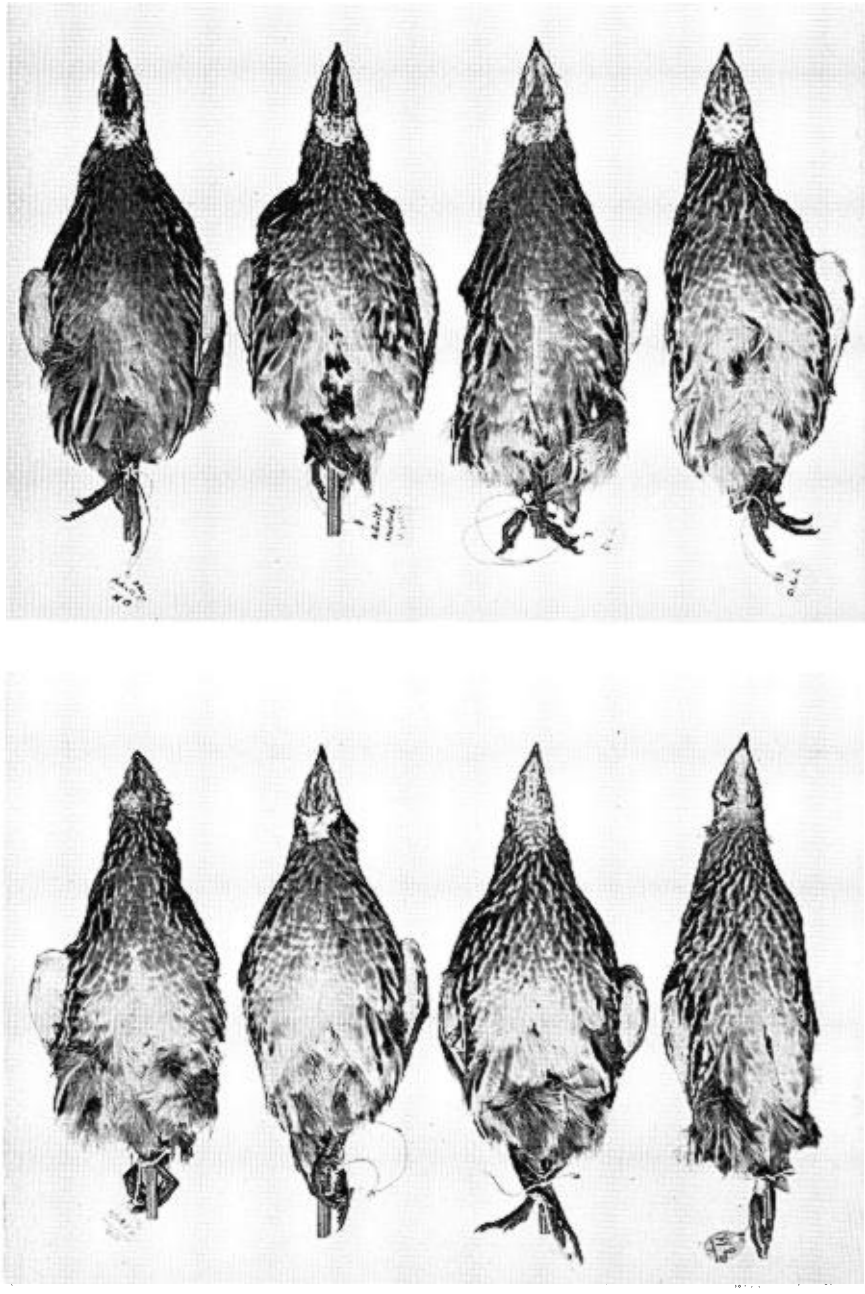
MATERIALS AND PROCEDURES

Coturnix c. japonica and Bobwhite eggs were obtained from Lowrance Quail Farm, Joplin, Missouri. Upon hatching, all chicks were taken to an electrically heated outdoor brooder, and later removed to smaller rearing pens. Chicks were fed a commercial game starter until six weeks of age and then were fed either growing mash, laying mash, or chicken scratch.

During 1957, some data were obtained from 120 Japanese Quail, but a complete history of growth was obtained for only 37 of these birds. In 1958, data were gathered from 20 *Coturnix*. Bobwhite measurements were obtained from 20 birds in 1958. Data on molting were collected from all these groups as well as three additional groups: 15 *Coturnix* in 1957, another 15 in 1958, and 20 Bobwhites in 1958. Measurements included length of culmen, tarsus, fifth primary, and body weight.

EGGS

Coloration and shape.—The *Coturnix* egg is similar in shape to the Bobwhite egg but tends to be less conical and more variable in shape. The coloration of *Coturnix* eggs is extremely variable (Taka-Tsukasa, 1935). The usual background coloration is light tan to brown with dark brown or purplish blotches, freckles, or spots scattered over the entire egg. In the present study some eggs were almost completely white and were difficult to distinguish from those of the Bobwhite; Taka-Tsukasa did not describe eggs of this type.



Variation in winter plumage of *Coturnix* (upper, male; lower, female).

Egg weights.—In this study two groups of unincubated eggs were weighed; 60 *Coturnix* and 30 Bobwhite eggs layed in the first week of March, and 25 *Coturnix* and 25 Bobwhite eggs produced in the first week of August. The average weight for the early set of eggs was 10.6 grams for *Coturnix* and 9.3 grams for Bobwhite; in the later sets the average weight of *Coturnix* eggs was 10.2 grams, and for Bobwhite, 9.8 grams.

Stanford (1957) also found *Coturnix* eggs to be heavier than those of Bobwhites. He reported an average weight of 10.6 grams for *Coturnix* eggs, and 9.3 grams for Bobwhite eggs laid in the hatchery. Both Stanford's Bobwhite eggs and mine were heavier, on the average, than those weighed by Stoddard (1931). He found that 845 eggs of wild Bobwhites collected during a three-year period averaged 8.6 grams.

In the present study, only the Bobwhite eggs showed increased weights as the breeding season progressed. An increase could be expected not only within a breeding season, but also with increasing age of the females (Stoddard, op. cit.; Romanoff and Romanoff, (1949). The latter relationship was not examined in this study, and the weights reported were from *Coturnix* and Bobwhite eggs laid by females of mixed ages.

Measurements.—Although *Coturnix* eggs weigh somewhat more than those of Bobwhite, the eggs of the two species are very similar in length and width. Several published measurements of *Coturnix* and Bobwhite eggs are compared in Table 1 with those of the present study.

Eggs of both Bobwhite and *Coturnix* in the present study are larger than most in other series reported. In hatchery-reared game birds as in domestic fowl, increased egg size may result from a number of causes: selective breeding for a larger egg (Olsen and Knox, 1940), selective breeding for a larger bird and subsequent increase in egg size, and better nutrient balance through improved game feeds (Romanoff and Romanoff, 1949).

The latter authors pointed out that species under domestication for the longest periods produce the largest eggs in comparison with their wild counterparts. Taka-Tsukasa (1935) asserted that *Coturnix* has been a favored cage bird in Japan since ancient times, and that the egg has increased "from one-third to twice its size." Possibly the disparity in size between eggs of wild *Coturnix* and those obtained in the present study indicates an admixture of "domestic" blood in the Missouri birds.

GROWTH OF CHICKS

Weight.—Growth in weight of *Coturnix* chicks varied in the 1957 and 1958 groups. In 1958, growth in weight was less erratic and more rapid. At eight to ten weeks, however, average weights of the 1957 birds equaled or exceeded those of the 1958 birds (Fig. 1). In 1957, the birds were somewhat more

TABLE 1
MEASUREMENTS OF *COTURNIX* AND BOBWHITE EGGS

Form	Measurements (mm)	Source and sample size	Authority
Colinus virginianus	Avg 30.0/25.0	Wild New England birds; sample size unknown	Minot, 1877
" "	Max 33.8/25.0 Min 32.5/24.8	Unknown	Maynard, 1890
" "	Avg 30.0/24.8	Minnesota birds; sample size unknown	Roberts, 1932
" "	Avg 30.0/24.0 Max 32.5/26.0 Min 26.0/22.5	55 eggs from U. S. National Museum	Bent, 1932
" "	Avg 31.4/24.6 Max 33.7/26.0 Min 29.1/23.3	50 eggs of hatchery birds	Present study
Coturnix c. japonica	Max 32.6/22.4 Min 26.2/20.5	Wild birds in Japan; sample size unknown	Taka-Tsukasa, 1935
" "	Max 32.6/20.4 Min 26.2/21.5	Eggs of hatchery birds; sample size unknown	Stanford, 1957
" "	Avg 31.0/24.7 Max 34.3/26.1 Min 28.7/23.0	100 eggs of hatchery birds	Present study
Coturnix c. coturnix	Avg 30.4/22.8 Max 32.7/24.9 Min 27.9/21.2	Wild British birds; 26 eggs	Witherby, 1941
" "	Avg 29.6/22.9 Max 31.5/26.1 Min 26.1/23.2	Wild Danish birds; sample size unknown	Westerskov, 1947
Coturnix pectoralis	Max 32.0/23.0 Min 29.5/21.5	Wild birds in Australia; sample size unknown	Lucas and LeSouef, 1911

crowded, mortality was greater, and there was harrassment of the birds by raccoons (*Procyon lotor*). The 1958 weight curve is thought to be more typical of this hatchery strain.

In 1958, growth rate of *Coturnix* exceeded that of Bobwhite from the second to the fifth week of age. After five weeks, weight increased steadily in Bobwhite, but began to level off in *Coturnix* and a plateau was reached at approximately eight weeks.

Growth curves for *Coturnix* obtained during 1958 agreed closely with those presented by Stanford (1957), but the growth rate of Bobwhite was greater

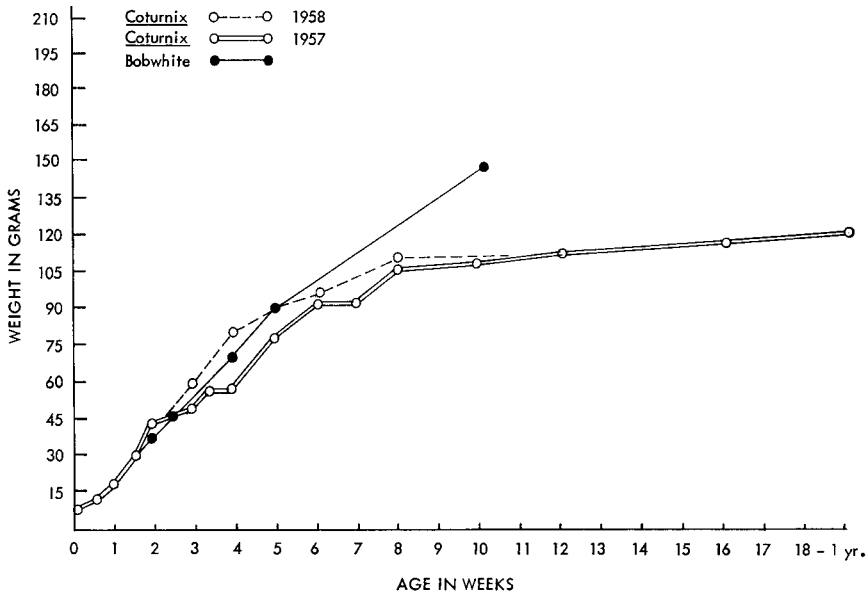


FIG. 1. Post-embryonic growth in weight of *Coturnix* and Bobwhite.

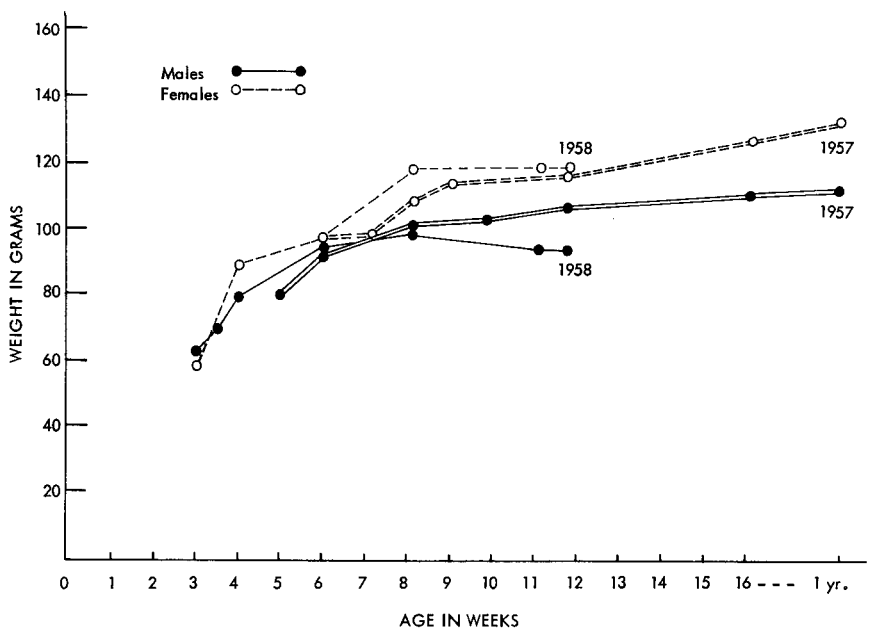


FIG. 2. Post-embryonic growth in weight of *Coturnix* according to sex.

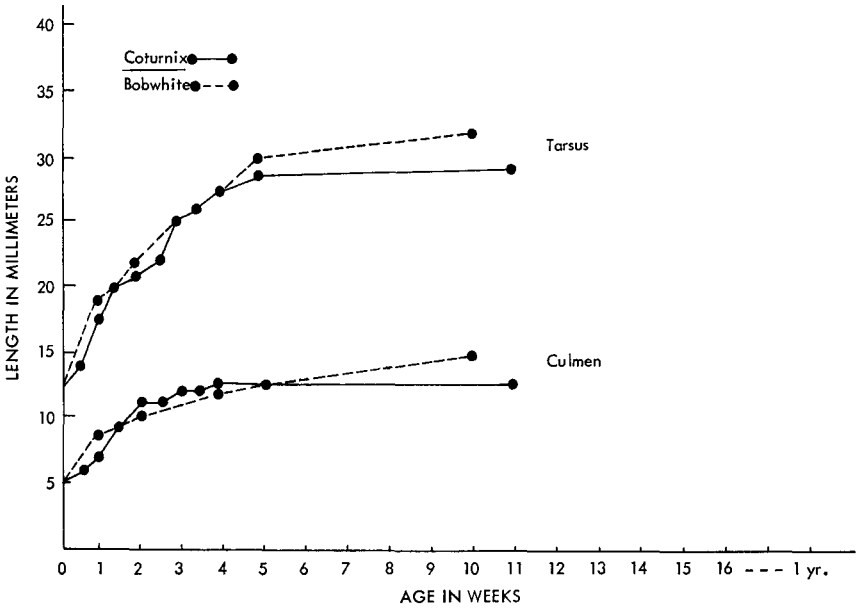


FIG. 3. Post-embryonic growth of tarsus and culmen of *Coturnix* and Bobwhite.

than those reported in most previous studies: Stoddard (1931), Reeves (1954), Hamilton (1957), and Stanford (1957).

Sexual dimorphism in size of *Coturnix*, as judged by body weight, was apparent between six and eight weeks of age (Fig. 2). A slight increase in weight of both sexes continued into the second year. Under hatchery conditions, Stanford (1957) also found a difference in weights of males and females and a slight weight increase extending into the second year. This difference between weights of males and females may result from confinement. Wyatt (1870) reported no difference in weights of males and females in the wild (*C. c. coturnix*) but found that under confinement, females consistently outweighed the males.

Culmen and tarsus.—Although weight increments of *Coturnix* differed considerably in 1957 and 1958, measurements of culmen and tarsus in the two years were so similar for both sexes of *Coturnix* that the results were combined (Fig. 3). Tarsus and culmen measurements of Bobwhite exceeded those of *Coturnix* chicks after about five weeks.

Of the three measurements taken, weight was the most variable, and for determining ages of *Coturnix* chicks, tarsus measurements are the most reliable, because of relative lack of variability in tarsus growth and the fact that

TABLE 2
SEQUENCE OF APPEARANCE OF JUVENAL PLUMAGE FEATHERS

Feather tract	Age In Days	
	Coturnix	Bobwhite
Alar	1–2	2–3
Ventral	3–4	4–5
Humeral	3–4	4–5
Femoral	3–4	4–5
Spinal	4–6	6–8
Caudal	4–6	6–8
Crural	7–8	8–9
Inferior	8–9	9–10
Capital	9–11	11–13

the tarsus requires a longer period to reach maximum size than does the culmen.

DEVELOPMENT OF PLUMAGE

Because there has been some confusion about the sequence of plumages in *Coturnix*, each plumage of *C. c. japonica* subsequent to the natal plumage is described in detail below, using Palmer and Reilly's (1956) color standard.

Natal plumage.—In both *Coturnix* and Bobwhite embryos, feathers first appear on the back as a double row of quills extending along opposite sides of the spinal column. These feathers are visible in the *Coturnix* embryo on the eighth day of incubation but are not apparent in the Bobwhite embryo until the eleventh day. The belly is the last area to develop feathering; in *Coturnix* belly feathers appear on the twelfth day of incubation, in Bobwhite on the sixteenth day.

Upon hatching, chicks of the two species are similar in general appearance, but there are differences in coloration. In *Coturnix*, black and yellow predominate (Taka-Tsukasa, 1935), while black and brown are the dominant colors in newly hatched Bobwhites (Dwight, 1900; Stoddard, 1931; and others).

First juvenal plumage of *Coturnix*: Bill light brownish olive; head, neck, and back grayish buffy brown. Feathers of the neck and back with a thin, pale cream shaft streak; throat and breast white to pale grayish cream. Breast of both sexes with blackish brown spots, but in addition, upper breast and lower throat of male tinged with light rufous; feet pale olive chestnut.

In *Coturnix* chicks, the black quills of Primaries 1–7 and Secondaries 2–11 are visible at the end of the first day and are apparent in all birds by the end

TABLE 3
PROGRESSION OF FEATHERING ON VARIOUS TRACTS IN *COTURNIX* AND BOBWHITE

Feather tracts	Origin and progression of feathering
Alar	Begins along trailing edge of wing (primaries and secondaries) and spreads anteriorly to leading edge of wing; underside of wing is last to acquire feathers.
Ventral	Begins in center of tract and spreads posteriorly to abdomen, laterally to sides, and anteriorly into throat region.
Humeral	Begins in any part of tract.
Femoral	Begins in center of tract and spreads largely posteriorly and anteriorly to cover flanks.
Spinal	Begins anywhere along mid-dorsal line as a double row of quills and develops anteriorly or posteriorly before spreading laterally to cover the back.
Caudal	Begins throughout tract with simultaneous appearance of all rectrices.
Crural	May begin anywhere in tract but usually begins on forward edge of leg before spreading to cover rest of leg.
Inferior	Begins as a double row of quills at cloacal lip and spreads anteriorly and laterally to cover abdomen.
Capital	Begins as a thin stripe on crown extending from forehead to nape. Spreads laterally to cover rest of crown, nape, auriculars, cheeks, malar region, and chin.

of the second day (Table 2). Unsheathing of these feathers does not begin until the fifth to eighth day.

At three to four days of age, feathers appear simultaneously on the ventral, humeral (scapulars), and femoral tracts and begin pushing out the natal down, but unless the young birds are examined closely these feathers are not visible. Origin and progression of feathering in various tracts are shown in Table 3.

In the four-to six-day-old *Coturnix* the quills of the spinal and tail feathers begin to emerge. All rectrices (usually 10 in number) appear together, but numbers five and six are already longer than the others one day after their appearance. Unsheathing of the first seven primaries begins.

At one week of age juvenal plumage feathers show clearly, but natal down still predominates (Fig. 4). The first seven primaries are largely unsheathed and primary and secondary coverts are growing rapidly. The fifth primary is 17 to 25 mm long (half grown). The head, legs, and abdomen, and most of the breast, back, and rump remain in natal down.

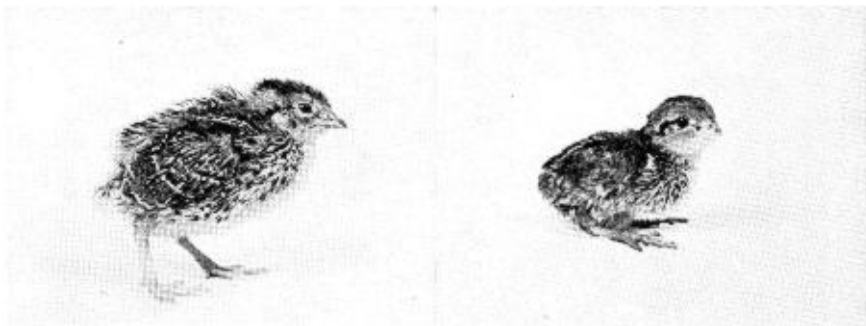


FIG. 4. *Coturnix* (left) and Bobwhite (right) at one week of age.

In the seven-to eight-day-old *Coturnix* the crural tract begins to feather, quills first appearing on the forward edge of the leg. By the eighth to ninth day of age feathers appear on the inferior tract. Two parallel rows of quills originate at the cloacal lip and extend over the abdomen. All seven primaries are unsheathed to the edge of overlapping coverts, and length of the fifth primary ranges from 23 to 36 mm.

The capital is the last tract to develop. A single row of quills appears on the head at nine to eleven days of age and extends from the forehead to the edge of the nape. At 11 to 12 days of age juvenal primaries eight and nine become visible and on the twelfth to thirteenth day the tenth primary appears.

Except for the head, the upperparts of the juvenile *Coturnix* are largely feathered at two weeks of age. The characteristic white striping of the feathers on the back and rump is now apparent. Juvenal feathers on the head form a "V" starting at the base of the bill and extending over the crown, but the rest of the head remains in natal down. The upper breast, except for a small area below the throat, is well feathered, but the underparts are mainly downy. All ten primaries are visible and growing rapidly; Primaries 1–7 are almost completely unsheathed, but Primaries 8–10 have not yet begun to unsheath. The fifth primary ranges from 43 to 54 mm in length, the eighth, 10 to 25 mm, and the tenth, 5 to 10 mm.

Feather development is most rapid between the second and third weeks. At three weeks of age the juvenile *Coturnix* is almost completely feathered, but natal down still predomiates on the head. The crown and nape are partially feathered, but down persists on the outer edges of these areas as well as on the lores, chin, and upper throat. Juvenal Primaries 1–7 are hardened and almost full grown. This is in agreement with Heinroth and Heinroth (1928) who also reported hardening of the proximal primaries at three weeks. Primaries 8–10 are beginning to unsheath. The fifth primary measures 52 to 58 mm; Primary 8 is 45 to 50 mm long, Primary 10 is 20 to 36 mm long.

By four weeks of age the first juvenal plumage is complete except for a small area immediately surrounding the eye and restricted areas on the abdomen and legs where natal down persists. Down disappears entirely on these areas at four and one-half to five weeks of age. The first seven primaries are full grown, and the fifth primary measures 61 to 62 mm. Primaries 8–10 are growing rapidly, but they will not be completely unsheathed and hardened until five to five and one-half weeks of age.

Development of the juvenal plumage in Bobwhite has been described by Dwight (1900), but the age at which feathering first appeared on the different body areas was not discussed. In the present study it was found that the development of the juvenal plumage in Bobwhite is very similar to that of *Coturnix*. Although the appearance of feathers on the different tracts occurs only slightly later in the Bobwhite (Table 3), the rate of feather development is considerably slower. In *Coturnix* the juvenal plumage is complete at four and one-half to five and one-half weeks of age, but Bobwhites do not attain full juvenal plumage until six to seven weeks of age. Stoddard (1931) and Stanford (1957) reported the juvenal plumage in Bobwhite complete at approximately seven weeks of age.

Second juvenal plumage of *Coturnix*: Bill dark brownish olive to black; forehead, nape, and crown dark buffy brown except for light cream median and supercilliary lines; neck tawny and back tawny to very deep buffy brown. Feathers of both regions with a broad, cream shaft streak; wing coverts medium buffy brown to light grayish buffy brown. Primaries grayish buffy brown with tawny spots or blotches on outer web. Secondaries similar but blotches larger and broader; abdomen white and tinged with very pale tawny. Feathers on sides dark tawny with a white shaft streak near the tip of the feather; throat of male solid cinnamon to chestnut and breast pale to light tawny. Throat of female pale grayish cream with black malar line descending onto edge of throat. Breast pale grayish cream with black or blackish brown spots; feet pale olive chestnut.

The sequence of plumages in young *Coturnix* is unlike that found in the young of most gallinaceous species. Whereas most juvenile gallinaceous birds have two body molts prior to the acquisition of the first winter plumage (post-natal and post-juvenal molts), *Coturnix* has three body molts (post-natal, first post-juvenal, and second post-juvenal). Apparently Heinroth and Heinroth (1928) had observed the third molt, because they mentioned that young *Coturnix* molt differently from other gallinaceous birds, and they remarked that a body molt accompanies the shedding of the juvenal primaries. In describing molting in juvenile *Coturnix* (both *C. c. Coturnix* and *C. c. japonica*) Dementiev and Gladkov (1952) noted only a post-natal and post-juvenal molt, but the description of molts strongly suggests the existence of an extra molt.

In the present study it was found that the first and second juvenal plumages of *Coturnix* are acquired in rapid succession. Unless birds are inspected fre-

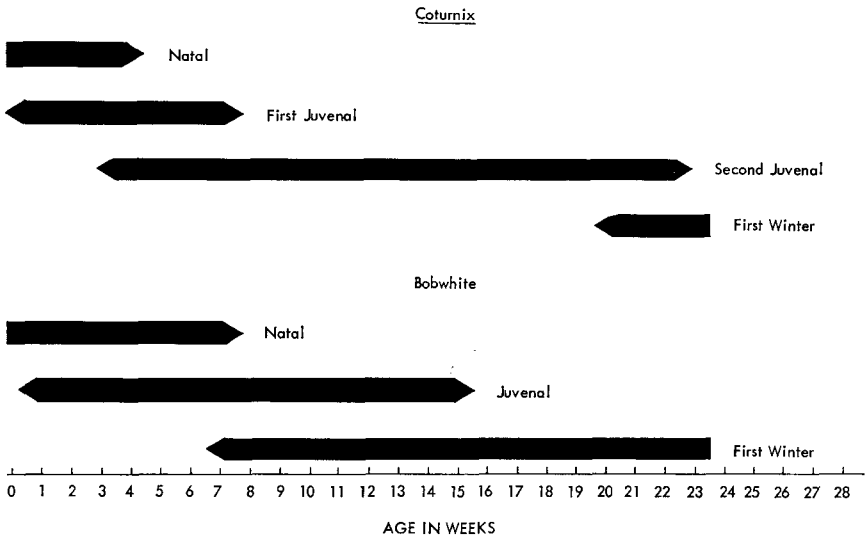


FIG. 5. Duration of plumages in *Coturnix* and Bobwhite.

quently the second juvenal plumage may be mistaken for the later stages of the first, and the two plumages may incorrectly be identified as one.

The pattern of feather development of the second juvenal plumage is similar to that of the first juvenal plumage; however, unlike the first juvenal plumage which is acquired by a complete post-natal molt, the first post-juvenal molt preceding the second juvenal plumage is only a partial molt. During this molt feathers on the ventral, humeral, femoral, spinal, caudal, and alar tracts are shed, but feathers on the crural, inferior, and capital tracts are retained until the following second post-juvenal molt.

The first feathers of the second juvenal plumage make their appearance well before the first juvenal plumage is completed. At two and one-half to three weeks, new feathers appear on the ventral, humeral, and femoral tracts, but natal down still predominates on the head and abdomen, and at approximately the same time the first juvenal primary is dropped. Shortly after, new feathers appear on the back, the juvenal rectrices are molted beginning from the outer edge and proceeding inward, and the plumage is complete at approximately seven to eigth weeks of age.

Juvenile Bobwhites, like the young of most other gallinaceous birds, have only two plumages prior to the acquisition of the first winter plumage (Dwight, 1900). Young *Coturnix* have three plumages in approximately the same period (Fig. 5).

In *Coturnix*, the post-juvenal wing molt coincides with the onset of the first post-juvenal molt. The first juvenal primary is dropped at two and one-half weeks to three weeks of age at which time the first feathers of the second juvenal plumage are noticeable on the breast. In young Bobwhites the wing molt is considered part of the post-juvenal molt and begins well in advance of the body molt (Dwight, 1900).

First winter plumage of *Coturnix*: Similar to second juvenal plumage except for coloration of throat and breast. Throat of male usually white with black anchor or streak. Breast pale to medium tawny. Throat and breast of female usually similar to second juvenal plumage, but sometimes will be identical to throat and breast coloration of the male.

In *Coturnix* the beginning of the second post-juvenal molt apparently is influenced by the time of hatching during the season as well as by the age of the bird. Birds hatched later in the season began the second post-juvenal molt at an earlier age than those hatched earlier. Stanford (1957) reported that the molt prior to the first winter plumage began on 7 October, or at approximately 20 to 22 weeks. His birds were hatched the second week in May. However, in the present study, four groups of birds hatched at different intervals during the spring and summer began the second post-juvenal molt at different ages (Fig. 6). The second post-juvenal molt is the only one thus affected. Birds of all groups began and completed the post-natal and first post-juvenal molts (or first juvenal and second juvenal plumages) at the same ages.

Apparently the duration of this molt is also affected by the hatching date. Birds hatched earlier required a longer period of time to complete the molt than did those hatched later in the season. Birds in a group hatched on 1 April began the second post-juvenal molt in the third and fourth weeks of September and completed it in seven weeks. Those of another group hatched on 18 August began the molt on 15 October and only five weeks were required for its completion.

The post-juvenal wing molt seemed also to be affected by the hatching date. However, this molt appears to be very erratic. In the present study the progress of the wing molt was recorded in the groups hatched on 1 April and 21 July. Unfortunately, most of the birds in the groups hatched 1 April were lost at 12 weeks of age, and it was possible to record only part of this molt. In birds of both groups the dropping of the first three primaries occurred at approximately the same age, but thereafter molting of subsequent primaries occurred at a greater age in the 1 April group and extended over a longer period.

Apparently, *Coturnix* is not the only gallinaceous species in which the date of hatching affects the progress of the post-juvenal primary molt. Although Buss (1946) found no difference in the wing molt of several groups of young Ring-necked Pheasants (*Phasianus colchicas*), more recent evidence

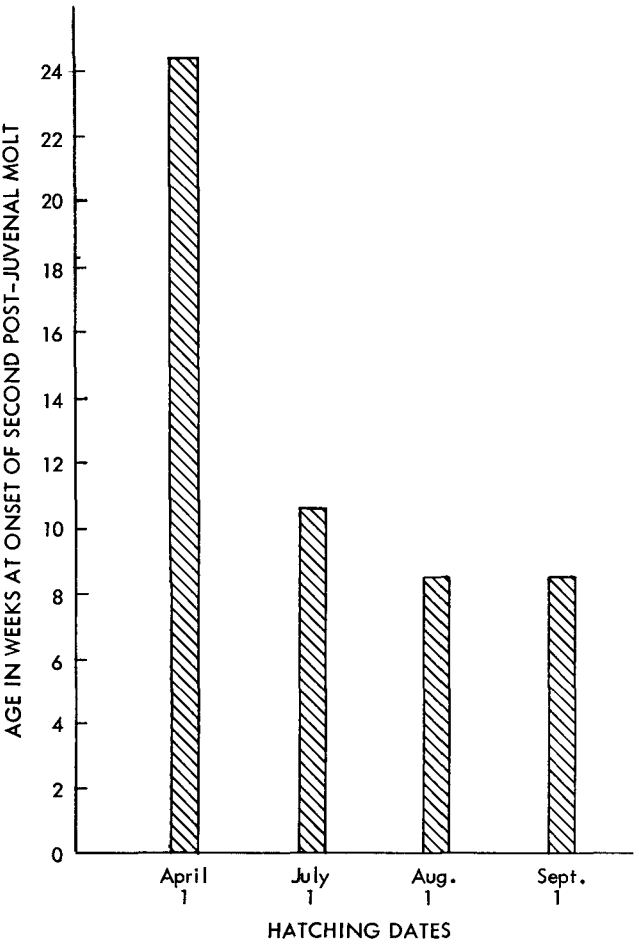


FIG. 6. Age of *Coturnix* at onset of second post-juvenal molt in relation to hatching date.

(Woehler, 1953) indicates a more rapid molt in late-hatched birds of this species. The post-juvenal wing molt in a group of young cocks hatched on 17 June was found to be five to eight days in advance of the molt in another group hatched on 20 May. All birds were chosen from the same breeding stock, were fed the same rations, and penned under identical conditions. These phenomena may be related to day length; Lesher and Kendeigh (1941) showed experimentally that short days may protract the post-nuptial molt in Bobwhites, White-throated Sparrows (*Zonotrichia albicollis*), and House Sparrows (*Passer domesticus*). In mid-winter, Host (1942) was able to in-

duce the post-nuptial molt in a male Willow Ptarmigan (*Lagopus lagopus*) by artificially decreasing day length. Kobayashi (1957) showed that short days accelerated molting in Canaries (*Serinus canarius*), and he further demonstrated that short days hastened the termination of the post-nuptial molting period. Kobayashi and Okubo (1955) had shown earlier that long days may prolong the post-nuptial molt in this same species.

In Bobwhites, the hatching date apparently does not affect the age at which the post-juvenal body molt begins, nor does it seem to influence the age of inception of the post-juvenal wing molt. In the present study, birds from a group hatched on 1 May and those from a group hatched on 25 August were observed to display no differences in the timing of this molt. Birds in both groups began the body molt at seven weeks of age and the wing molt at four weeks of age.

DISTINGUISHING THE SEXES IN *COTURNIX*

Coloration of the throat and breast feathers is the best criterion of sex. Sexes may be distinguished as early as the thirteenth day. At this age birds of both sexes have spotted breasts, but in males light rufous feathers of the first juvenal plumage begin to appear along the inner edges of the ventral tract, and as the post-juvenal molt progresses the rufous coloration spreads to the throat. In females the entire breast is spotted; the rufous feathers do not appear.

In the second juvenal plumage the sexes are more easily distinguished. The throat and chin of the male are a solid cinnamon to chestnut and the breast is light to pale tawny throughout. In contrast, the throat and chin of the female are pale grayish cream and the breast is spotted with black or blackish brown.

Sex determination in the first winter plumage is quite often difficult because in both sexes the coloration of the throat and breast is variable. In males the throat is usually white and flecked or striped with light tawny, but occasionally it may be a light tawny to light cinnamon throughout. In addition, considerable variation may occur in the throat markings. Below is a list of the variations observed in male birds reared during this study.

1. "Anchor" on throat.
2. Collar encircling upper throat.
3. Single stripe running from lower mandible to mid-point of throat.
4. Stripe plus incomplete collar.
5. Incomplete collar.
6. Solidly colored triangle on throat.
7. No markings on throat.

Markings are usually black but may vary in color from blackish brown to

light tawny. A thin, blackish brown to chestnut collar usually edges the lower throat but this is not present in all birds. The middle of the breast is light to dark tawny and the sides are deep tawny to chestnut. Occasionally the upper breast may be heavily streaked or flecked with chestnut.

In the female the coloration of the throat and breast is usually similar to that of the second juvenal plumage, but variation also occurs. The throat is usually a pale grayish cream without markings but gradations between this and typical male patterns are frequent. The breast is usually a very pale tawny and streaked or spotted with black, deep tawny, or chestnut, but occasional birds may present a breast coloration identical with that of the male (Front.). Taka-Tsukasa (1935) described this variation as well as several others.

Accurate determination of sex during the winter period can usually be made by a careful examination of the coloration and markings of the throat and breast. Errors in sex determination are most likely to occur in the examination of females. Although the hen occasionally resembles the male in every respect, males apparently never acquire a plumage similar to the typical winter plumage of the female.

As mentioned above, sex determination of birds in the second juvenal plumage (and subsequent nuptial plumages) is not difficult, but occasional birds are encountered in which it is difficult to distinguish the sexes. In this case another method may be used. In breeding males the cloacal region becomes enlarged and protrudes (Coil and Wetherbee, 1959), and when the bird is held tightly in the hand a frothy fluid is exuded from a gland above the dorsal lip of the cloaca. The female *Coturnix* does not show the protuberance.

AGE DETERMINATION IN *COTURNIX*

Aging of young by replacement of juvenal primaries.—Several investigators have described the molt of the juvenal primaries of *Coturnix*. Heinroth and Heinroth (1928) observed the post-juvenal primary molt in three young birds of *C. c. coturnix* and found that molting does not proceed rapidly up to the eighth primary as it does in other gallinaceous birds. At seven weeks the first five primaries in the females and the first four primaries in the male had been renewed, but Primary 6 in the females and Primary 5 in the male had not been shed. Juvenal Primaries 5-10 were full-grown so that the wing was completely feathered and ready for flight. Since young wild birds were often only two months old at the beginning of migration, Heinroth and Heinroth suggested that the interrupted wing molt was an adaptation which best suited the young birds for migration.

TABLE 4

AGE IN DAYS OF *COTURNIX* AT TIME OF SHEDDING OF JUVENAL PRIMARIES

Authority	Primary number								Sample size
	1	2	3	4	5	6	7	8	
Stanford, 1957	21	21	28	35	42	56	63	–	Unknown
Edwards (letter)	21–23	22–26	27–32	33–36	39–65	42–?	–	–	Unknown
This study (I)	18–32	21–36	28–44	32–70	35–78	42–84	49–103	57–?	120–37
This study (II)	20–27	23–29	24–32	32–?	48–?	–	–	–	25–19

The findings of Dementiev and Gladkov (1952) are similar to those of the Heinroths. In young birds (*C. c. coturnix*) at seven to eight weeks the first seven adult primaries in males and the first six primaries in females were full-grown. At this stage of wing molt the birds began migration.

Edwards (in litt.) found that in general the replacement of the juvenal primaries stopped when birds (*C. c. japonica*) were 32 to 42 days of age. In most instances this followed the replacement of the fourth primary, but one bird had shed only the first primary and several others had molted the fifth and sixth primaries. Detailed information about shedding of juvenal primaries as recorded by Edwards and by Stanford (1957) is shown in Table 4.

In the present study the progression of the post-juvenal primary molt was recorded in two groups of *C. c. japonica*. In the first group (sample size was 120 birds at the beginning of the study but only 37 remained at its completion) the time at which each specific primary was shed was variable (Table 4). The eighth primary was shed by one bird as early as 57 days, but at 147 days (mid-December) only 74 per cent of the birds had shed this feather. A few birds shed the ninth primary at 70 days. At 147 days no birds had shed the tenth primary.

In the second group (sample size was 25 birds at the beginning of the study but only 19 remained at its completion) the molting of the first three primaries was less variable than in the first group (Table 4). However, molting of the fourth and fifth primaries was more variable than in the first group.

Molting of the first three primaries in the second group was similar to that reported by Edwards (in litt.). If this is the typical molting pattern then birds may be accurately aged up to four weeks. However, other plumage characteristics and tarsus measurements may be more helpful in aging young birds (Table 5). After the six weeks no reliable criteria of age were found.

In Bobwhite the replacement of the juvenal primaries is a reliable aging method. Petrides and Nestler (1943) found that the first primary was dropped at four weeks of age, the second at five weeks, the third at six weeks,

TABLE 5
CRITERIA FOR AGING YOUNG *COTURNIX C. JAPONICA*

End of first week	Juvenal Primaries 1–7 are present and beginning to break their sheaths. Primaries 8–10 absent. Fifth primary shaft 22–23 mm; tarsus 11–18 mm.
End of second week	Juvenal Primaries 8–10 just appearing. In males, light tawny feathers are beginning to appear on breast. Fifth primary shaft 42–54 mm; tarsus 19–23 mm.
End of third week	Feathers of second juvenal plumage just beginning to appear on breast, shoulder, and flanks. Fifth primary shaft 52–56 mm; tarsus 23–27 mm.
End of fourth week	Natal down confined to small area around eye. Down disappears at four and one-half to five and one-half weeks.

the fourth at seven weeks, the fifth at eight weeks, and the eighth at fourteen and one-half weeks. Thompson and Kabat (1950) further refined this aging method; the length of the developing adult primaries was found to be a more accurate indication of age.

In the present study, the primary molt of young Bobwhites was recorded up to the fifth primary. Replacement in these pen-reared birds was very similar to that recorded by Petrides and Nestler (1943).

Means of distinguishing young-of-the-year from adults.—In Bobwhites and other North American quail, methods of distinguishing young from adults have been thoroughly investigated. Stoddard (1931) noticed that the ninth and tenth primaries of juvenal Bobwhites were pointed at the tip while those of adults were not. Van Rossem (1925) apparently was the first investigator to discover that juvenal primary coverts are retained in native quail until the second fall molt, and that they differed in color from the primary coverts of adult birds. A. S. Leopold (1943) demonstrated the greater reliability of the color of the juvenal primary coverts as compared with the shape of the outer primaries as an aging index in native quail. He found that in Bobwhites the juvenal primary coverts are tipped with buff while those of adults are solid gray.

Apparently no aging technique has been developed for *Coturnix* to distinguish young-of-the-year from adult birds. Although Witherby (1941) stated that the ninth and tenth juvenal primaries are retained until the year following hatching, Stanford (1957) found that these feathers were attenuated at the tip of both young and year-old birds and that they appeared to be of no value in determining age. Stanford's results were confirmed in the present study.

Petrides (1945) reported that unlike North American quail, all European quail shed the juvenal primary coverts during the post-juvenal molt. This was

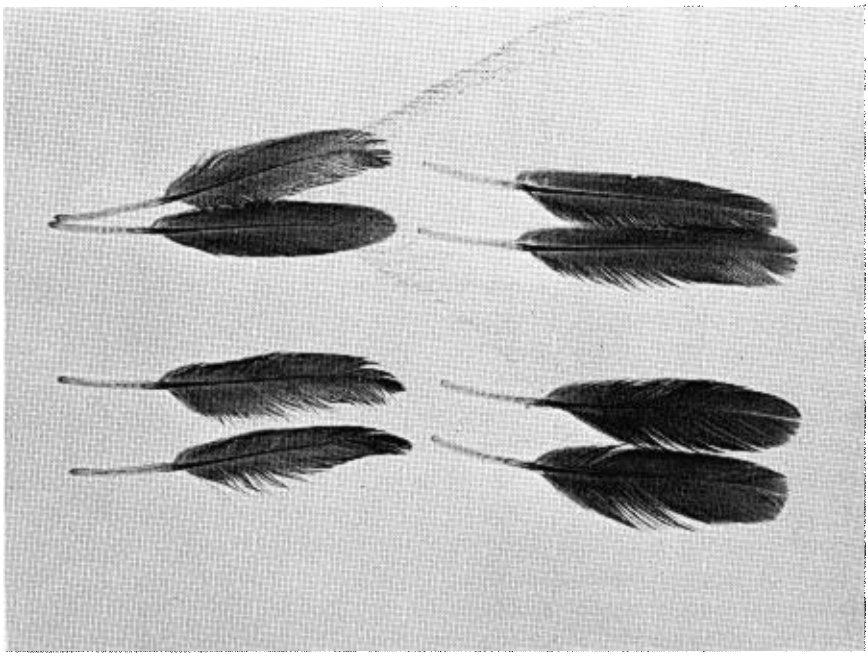


FIG. 7. Primary coverts of *Coturnix* (young, left; adult, right).

found to be true in *Coturnix*; juvenal primary coverts were shed at approximately the same time as the juvenal primaries. Nevertheless, the second set of primary coverts in the young-of-the-year are different in some respects from those of adults. In the young the coverts are usually plain grayish to dark brown, but in adults the outer portions of the rachises of these feathers, especially the coverts of the outer four or five primaries, are usually light tawny to white. There are exceptions; the coverts of adults seldom lack the white rachis, but those of young birds occasionally have the white rachis. Of 65 adult birds and 75 young birds examined, only five adults (8 per cent) lacked coverts with white rachises, but 19 young birds (25 per cent) had primary coverts colored like those of most adults.

The shape and texture of the coverts differed in young and adult birds. In young birds the tips of the coverts are rounded or pointed but in adults the tips of these are blunt (Fig. 7). In addition, the covert tips of the young are slightly frayed while those of adults are not, a condition apparently similar to that described for juvenal Bobwhites (Haugen, 1957). This appears to be the best method for age determination. Of the 140 young and adult birds examined for the shape and texture of the primary coverts, all fitted the categories as described above. However, a group of wings from banded *Coturnix*

shot during the hunting season in Nebraska were much more difficult to classify correctly. Thus, this method of age determination needs further checking under a variety of conditions.

RELATIONSHIP OF *COTURNIX* MOLTS AND PLUMAGES TO THOSE OF OTHER GALLINACEOUS BIRDS

Throughout this paper molts and plumages of *Coturnix* have been designated according to their correspondence in timing with those of Bobwhites and most other gallinaceous birds. Because *Coturnix* completed two plumages in the period in which Bobwhites completed the juvenal plumage, the two were called the first and second juvenal plumages. The last plumage to appear was termed the first winter plumage because its appearance coincided approximately with that of the first winter plumage of Bobwhites. However, the actual correspondence of plumages of young *Coturnix* and Bobwhites is not clear. The designation of avian molts and plumages proposed recently by Humphrey and Parkes (1959), is helpful in analyzing this correspondence. These authors suggest a system of nomenclature for molts and plumages which is independent of the reproductive, seasonal, and developmental phenomena upon which previous nomenclatures have been based.

In species having only one plumage per cycle as adults, this plumage is usually replaced by a complete molt. Humphrey and Parkes used the term *basic* for this plumage. The molt renewing it is called the *prebasic molt.* In birds which as adults have two plumages and two molts per cycle, one molt (the prebasic) is a complete molt. The other is usually partial, affecting only the body feathers and is followed by a plumage which is thus a composite of old basic feathers and the new incoming feathers. The authors designated this plumage as the *alternate plumage* and the molt preceding it as the *prealternate molt.* In addition, numerical prefixes may be affixed to the plumage stage if the age classes are recognizable by plumage characteristics beyond the first year class.

Two possible systems of correspondence between Bobwhite and *Coturnix* plumages are shown in Fig. 8. One, expressed in Dwight's (1900) terminology (bottom line, Fig. 8), is the one employed throughout this paper. The other (third line, Fig. 8), expressed in the Humphrey and Parkes (1959) terminology actually seems the more reasonable.

There are several lines of evidence for the latter system of correspondence. The first nuptial (first alternate) plumage in most North American gallinaceous birds is the plumage in which the birds first breed, and it is identical in coloration to all subsequent breeding plumages (Dwight, 1900). Juvenile *Coturnix* breed (in their first summer) in the second juvenal plumage, and it is identical with the breeding (alternate) plumage of adults.

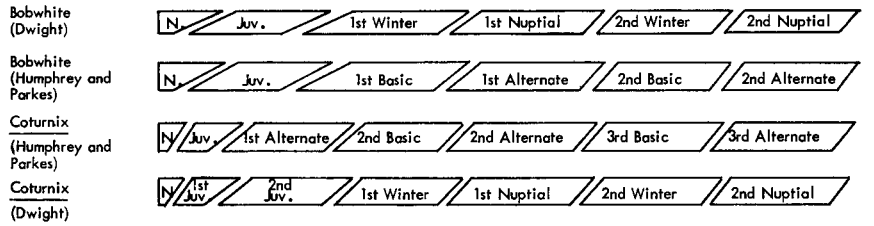


FIG. 8. Correspondence of plumages of Bobwhite and *Coturnix* according to two systems of nomenclature.

Thus the second juvenal plumage in *Coturnix* seems to be equivalent to the first nuptial (first alternate) of the Bobwhite and other North American species. Moreover, in many North American gallinaceous species the juvenal plumage of both sexes resembles that of the nuptial plumage of the female (if sexes differ). The first juvenal plumage of *Coturnix* satisfies this requirement, because in both sexes it resembles the second juvenal plumage and all other breeding plumages of the females. Apparently then, young *Coturnix* differ from the Bobwhite and, most other birds, by lacking the first basic plumage rather than having an additional juvenal plumage. In this respect the sequence of molts and plumages in young *Coturnix* may approximate that of some species of sunbirds (Nectariniidae) in which the first basic plumage appears also to be suppressed (Mackworth-Praed and Grant, 1945), and of ducks in which the first basic plumage apparently is greatly protracted (Humphrey and Parkes, 1959).

A molting sequence somewhat similar to that in young *Coturnix* has been recorded in the young of a few other gallinaceous birds. Salomonsen (1939) recorded an extensive fourth molt in the Rock Ptarmigan (*Lagopus mutus*), and A. S. Leopold (1943) found that young Turkeys (*Meleagris gallopavo*) undergo a partial first winter molt in which the body feathers, lesser and middle wing coverts, tail coverts, and the central rectrices are replaced. In ptarmigan the additional molt results in a white plumage which may be an adaptation to the arctic environment. Salomonsen (1939) regarded it as a mechanism for thermoregulation, resulting in conservation of body heat. In Turkeys the additional molt was thought by A. S. Leopold to be related to the great increase in the size of young birds during the first year. He suggested that since the first winter plumage began when the juvenal was only five to six weeks old it would be impossible for so small a bird to produce a plumage adequate to cover a full-grown bird during the first winter.

Neither of these reasons, however, seems to apply to *Coturnix*. It is believed that the exceptional pattern in the young of this species is related to the rapid maturation of young birds. Inasmuch as young *Coturnix* may be sexually

mature at eight to nine weeks of age they may begin the "adult" molting pattern for the year of hatching, thus rapidly acquiring a plumage that seems to be the first alternate.

Like Bobwhites, adult *Coturnix* have two plumages and two molts per cycle; a complete molt in the late summer or fall and a partial molt of the head and throat in the spring (Stanford, 1957).

Of additional interest in *Coturnix* is the relation of the post-juvenal wing molt to the post-juvenal body molt. In North American gallinaceous birds the wing molt begins before the body molt, but both reach completion at approximately the same time (Dwight, 1900). In Bobwhites, for example, the wing molt begins at four weeks of age and is completed at fourteen and one-half weeks of age when the eighth primary is shed (Petrides and Nestler, 1943). The ninth and tenth primaries are not shed until the post-nuptial molt of the next year. The body molt begins at seven to eight weeks and is completed at approximately 15 to 16 weeks (Stoddard, 1931). However, in *Coturnix* the relation between the wing and body molt is somewhat different. Both wing and body molt begin at approximately the same time, but the body molt is complete at eight to nine weeks while the wing molt may continue until the twenty-fifth week, and in many cases may still be in progress when the second post-juvenal (second prebasic) molt begins. This suggests that in *Coturnix* at least, the post-juvenal wing molt should be regarded as a separate molt and that it may not be controlled in the same fashion as is the post-juvenal body molt.

SUMMARY

Growth and plumage development of pen-reared migratory Japanese Quail are described and compared with Bobwhites reared under the same conditions.

In young *Coturnix* an extra molt and plumage were noted and termed the first post-juvenal molt and the second juvenal plumage, respectively. The molt begins on the ventral, humeral, and femoral tracts at approximately three weeks of age and coincides with the post-juvenal wing molt. The molt is complete with the exception of the primaries, and the birds are in full second juvenal plumage at approximately eight to nine weeks of age.

The age at which the next, or *second* post-juvenal molt, begins apparently is influenced by the date of hatching. Birds hatched late in the season begin to molt at a younger age than do early hatched birds. Early hatched birds required a longer period to complete this molt.

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997 PAMMEL COURT, IOWA STATE UNIVERSITY, AMES, IOWA, 31 DECEMBER 1960

NEW LIFE MEMBER

Phyllis L. Hurlock, of Coatesville, Pennsylvania, is a new Life Member of the WOS, having joined as an active member in 1959. She is also a member of the West Chester Bird Club, the Cooper Ornithological Society, and the Wilderness Society, and is a life member of the AOU and the National Audubon Society. Miss Hurlock is a graduate student at Drexel Institute and serves as Librarian at the Downingtown Joint Junior High School. Her principal interests in ornithology include studies of bird populations, especially their composition and trends.