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## BREEDING BEHAVIOR OF THE BELL VIREO IN SOUTHERN INDIANA

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In late May of 1958, Bell Vireos (*Vireo bellii*) were discovered nesting at Bloomington, Indiana. Since these birds were some 40 miles southeast of Brazil and 50 miles south of Indianapolis, the previously known outposts at the eastern edge of the breeding range, it seemed desirable to obtain information about them (Brooks, 1942). No intensive investigation was made in that year, but of the three pairs known to have been present, two pairs and their eight young were color-banded and observed for a few minutes a day until mid-July. Three of the banded adults returned in 1959, and the three pairs of 1959 and their ten fledglings were caught. Those not marked in the previous year were banded. A seventh adult, a male that apparently was not mated while under observation, was not captured. Home ranges were visited briefly and irregularly until mid-September, and much of the history of one male is known from the day of his probable arrival until possibly the day he departed. The accumulation of fragments of information on breeding biology and behavior and postnesting activities has prompted this paper, since published data based on banded birds seem to be lacking for the Bell Vireo and are scanty for all vireos.

### LOCALITY AND HABITAT

The four fields in which the vireos were found are scattered over a strip about three-quarters of a mile long and one-quarter of a mile wide just north of Bloomington. A previously published account of the topography, land use, and vegetation of an adjoining tract (Nolan, 1955) suffices as a general description of the vireos' area, except as qualified in the present paper. A good deal of such habitat exists around Bloomington, much of it familiar to me for 20 years and to many other naturalists at Indiana University since at least 1883 (McAtee, 1905). So far as I know, the only record of the Bell Vireo from this section of Indiana, other than those reported herein, is my observation of a singing male on September 7, 1953, two miles east of the place where the species now nests. Unfortunately, the home ranges of the birds which Raymond Schneider and I discovered breeding on May 28, 1958, had not actually been visited by me in 1957. However, I had worked regularly in an immediately adjacent tract and had often been within earshot of these fields without ever hearing the familiar song of this species. For these reasons, and because Mumford's (1952) summary of the status of the Bell Vireo in Indiana lists no reports for the state prior to 1943, I believe that the species has only recently established itself at Bloomington.

The habitat of the Bell Vireo was indicated by Ridgway (1873) as being thickets shared with the White-eyed Vireo (*V. griseus*). Bent (1950:254, 259) also records the two vireos occurring together and in his life histories of the Bell Vireo and other brush-dwelling members of the family mentions instances of the Bell Vireo associating closely with its congeners. Hamilton (1958:308, 313), on the other hand, reports that "co-occupancy of the same habitat is almost unknown" among vireos. "[S]ympatric species of *Vireo* show *habitat separation* . . . occurring during the breeding season in different or separate habitats or in different, stratal subdivisions of a habitat . . ."; even the latter type of overlap is avoided by species belonging to the same subgenus. Hamilton's gen-

eralization describes the relations of *bellii* and of the common *griseus* at Bloomington, where the two species keep to separate types of scrub. The essential distinction in habitat seems to lie in the physiognomy of the vegetation, namely, in the amount of medium high, dense cover present. An illustration of the difference is that Blue-gray Gnatcatchers (*Poliophtila caerulea*) often nest at Bloomington in the same habitat as do White-eyed Vireos, whereas the Eastern Meadowlark (*Sturnella magna*) is common in two fields where the Bell Vireo is found (compare Sauer, 1952, and Brewer, 1955). Thus the White-eyed Vireo probably never ventures far from the shelter and shade of relatively close-growing stands of 8- to 25-foot trees, whether saplings or mature plants of low, round habit, such as *Crataegus* spp. In the more open, sunny, dry, grassy, and often more extensive areas are Prairie Warblers (*Dendroica discolor*), Yellow-throats (*Geothlypis trichas*) and Yellow-breasted Chats (*Icteria virens*), among the insectivorous birds, and it is in these fields that *bellii* nests; Indigo Buntings (*Passerina cyanea*) and Field Sparrows (*Spizella pusilla*) are also commonly associated species. The only high cover typically consists of a thicket at the base of one or two large trees growing near a sink hole, and/or a row of sassafras (*Sassafras albidum*) or osage-orange (*Maclura pomifera*) along a fence, and perhaps also scattered clumps of one or more scrubby trees from three to 20 feet high. Such fields also contain low tangles of blackberries (*Rubus* spp.) and prairie rose (*Rosa setigera*), in which the Bell Vireo does much of its foraging and sometimes nests. Habitat descriptions by Pitelka and Koestner (1942:97-98), Hensley (1950), and Mumford (1952:226-227) list similar or only slightly less open growth, but Bent's collection of reports indicates that the Bell Vireo will nest in fairly dense scrub. In view of this apparent tolerance of a rather wide range of differences in cover, it may be suggested that an important element in the selection of open habitat at Bloomington is that association with the White-eye is thereby avoided. Some support for this point may be drawn from the fact that pairs of Bell Vireos, during most of the season at least, also avoided intraspecific contacts except those within the family unit. This subject is discussed further in the following section.

#### LOCALIZATION

"Localization" is used here not to suggest the process by which Bell Vireos form an attachment to a particular place (Scott, 1958), but to introduce data concerning manifestations of that attachment. Also included is the related subject of dispersion over the breeding habitat. Pairs are designated by letters which will be used throughout the paper.

*Spacing of pairs.*—In no case did two pairs breed in the same field, although, as will be shown, the home ranges of five of the six males studied lay in fields large enough to accommodate more than one range. The closest approach to adjoining occupancy occurred in 1958, when males A and B used fields which, although separate, touched at one corner of each. However, this point was near the top of a long hill, so that the two ranges lay on different slopes and were divided to some extent by this topography as well as by a mowed field lying in the right angle between them. Members of the two pairs were never known to meet, but each male sang once, on different dates, at the common corner; one had travelled about 175 yards from his nest, the other about 130. The maximum distance that could have separated nests built in the two fields would have been about 450 yards; the actual distance between nests was about 250 yards in a straight line across the mowed area. Never as I stood on one home range did I hear both these males singing at the same time.

During the nesting season in 1959, the ranges of the four males lay in a rough north-south line, each in a field bounded on all sides by tracts of wholly unsuitable habitat

for the Bell Vireo. The widths of the unsuitable tracts between the home ranges, that is, the distances by which each male was isolated from the next, were 500, 250, and 400 yards. In late summer Male C from the north and unbanded Male D from the south (the latter identification is assumed) crossed the barriers and settled in Male A's field next to his home range.

The dispersion just described suggests that pairs of Bell Vireos shun contacts with other pairs during nesting. It may be significant that the two males that shifted in late summer had brought off no young. The effect of their moves to points within earshot of another male was perhaps to break what otherwise might have been late summer isolation from members of their species. If there is a breakdown of territory lines at the end of nesting in the Red-eyed Vireo, *Vireo olivaceus* (Southern, 1958:188), this may be a related phenomenon.

*Territory.*—As already indicated, encounters with other vireos, which might have stimulated defense behavior, were never witnessed. That such behavior is evoked under conditions of population density is shown by Grinnell (1914:189–190), who studied the distribution of the Bell Vireo along a narrow strip of willow association between the Colorado River and the desert. "A singing male occupied each segment of about 200 yards in this belt. . . . Each pair of vireos was closely delimited in its forage beat by that of its neighbor. Each pair in its own area actively resented encroachment by others of its own species."

*Home range.*—Except for occasional short excursions, pairs confined themselves to a utilized home range of two to three acres, until the young flew readily. The family thereafter occupied an area at least as restricted, but not necessarily identical with that used earlier. After the young disappeared, probably both adults remained on the late summer range of about one acre. I have only one late August record of a female, but this may be because females are silent and hard to discover. Males, on the other hand, could usually be found day after day in the same thicket. Faithfulness to a home range carried over to the following year in the male, and the one female that returned remated with her last year's partner.

The boundaries of the ranges used during breeding became stabilized after the first nest was begun and were probably determined by its location. Sometimes the nest was at the edge of the field in a fence row, but where it was in mid-field it was roughly the geographical center of activity. Occasionally birds were seen as much as 200 yards from the nest; these moves beyond the usual radius of 100 to 125 yards were made along fence rows or strips of cover. Postbreeding home ranges centered around a favored thicket.

The data to support the foregoing summary follow. References are to utilized and not maximum home range (Odum and Kuenzler, 1955). *Pair A, 1958:* This pair used about three acres of a ten-acre field; eight more acres of habitat lay immediately across a little-travelled road. Contact with Pair A was lost in late July when their field, except for the fence rows, was mowed in preparation for a subdivision. *Pair A, 1959:* The adults paired again but moved into the unmolested eight acres just across the road, the habitat nearest their now unsuitable home range of 1958. The two nests of 1959 were 12 yards apart and 180 yards from that of 1958. During nesting there were only two sightings of Pair A outside a two-acre circle with the nest roughly in the center; on both occasions the pair had followed a fence row back to the home range of the preceding year. When fledglings of a second brood could move about, the family went some 100 yards south and seemed to stay very largely within about one acre, much of it covered by a thicket around a sink hole. Just before becoming independent the young enlarged their sphere of activity to include an area of about two acres. Male A could almost

always be found at or near the sink hole until he left. *Pair B, 1958*: This pair probably seldom ventured beyond a line encompassing 2.5 acres in a seven-acre field of uniformly suitable habitat. Two nests were 50 yards apart. I quit visiting the field in late July, when all but about three acres around the nest were cut over. *Pair B, 1959*: Male B returned to the same home range, acquired a new mate, and used approximately two acres of the uncut part of the field. Two nests were 34 yards apart; the first of these was 23 yards from the second nest of 1958. From late July until I last saw them about the middle of August, the adults and young kept to denser cover of fence rows and tree clumps in about one acre of their range. *Pair C, 1959*: These birds were not visited often but during nesting were never seen outside an area of about 2.5 acres around the nest, which was in a corner of the field. The next adjoining acre of their six-acre tract had been eroded or stripped down to bare clay, a sort of barrier which may have confined them somewhat. A nest failed in mid-June, after which I lost the pair, but Male C was found nearly daily in the three weeks before mid-September. He had moved 400 yards from his nesting range, and he rarely left a 15×55-yard strip (about 0.17 acres) of fence row and blackberries. *Male D, 1959*: Male D occupied a field containing about six or seven acres of habitat. His home range covered an area of 2.5 acres, but he made more frequent sorties from it than did the other males, possibly because he had no mate. Some days he could not be found, and in late June he disappeared; an unbanded male that turned up at the end of July 350 yards north of the range of this male was thought to be Male D. During molt he moved again, another 250 yards north across the range of Pair A, where he remained until last seen in late August.

[In 1960 all six banded adults of the preceding year returned to their home ranges, except Male B. Pair A remated, as did Pair C, but the latter pair disappeared after about a week. Female B was present for only two or three days. There were also an unbanded pair and three, unbanded, unmated males.]

Other authors have found single pairs of *bellii* using a three-acre tract (Pitelka and Koestner, 1942:97) and having a home range of 3.1 acres (Hensley, 1950), but in the latter case it is impossible to tell whether more extensive habitat was available and whether other pairs were present. Territory size of *olivaceus* has been reported as averaging 1.4 and 2.1 acres (Lawrence, 1953:51-52) and 1.2 acres (Southern, 1958:109). Brewer (1955) describes a home range of 0.33 acres for one pair of *griseus*, but my own unpublished observations of color-banded birds of that species suggest a larger area.

#### ARRIVAL AND PAIR FORMATION

Male A first sang in 1959 on May 6, after several warm days and nights, and since male Bell Vireos are in full song even while migrating through Central America (Dickey and van Rossem, 1938) it is probable that Male A had just arrived. Loud songs at a rate of 15 per minute were uttered from middle heights in 10- and 15-foot trees. Most movement was over about two acres immediately south of what was to become the home range; once he covered 200 yards and sang from that future center of activity. Frequent song, uttered from the clumps of trees, continued next day. At 6:30 a.m. (all times herein are central standard) on May 8 an unbanded bird, assumed to have been a female, was present. I became aware of this when Male A quit singing and flew about 20 yards on stiff, horizontal, scarcely beating wings. Suddenly the female flew out of blackberries near him and for 10 or 15 seconds there ensued a rapid twisting pursuit, the male from one to four feet behind the female and both ranging in height from one to eight feet. The chase was interrupted when the two landed in a bush and pecked or pulled with their bills at each other for two seconds before darting another 30 yards out of sight in

the brush. Male A then flew to a tree near me and for 1.5 minutes sang every few seconds until the female suddenly reappeared, in the berries ten yards from him. She was immediately pursued as before, again with the interruption for pecking at each other. At the end of the flight the birds lit five feet apart in a bush, where both flicked their wings and flirted their tails laterally in rapid movements closely resembling those made in dew-bathing. (These wing and tail movements occur frequently between mated Bell Vireos and are often given when the two are close together, continuing at least until young leave the nest.) In a few seconds one bird spread its tail slightly and hopped toward the other, which retreated; both then moved into the brush and were out of sight for 20 minutes.

When rediscovered the vireos were some 60 yards beyond, and their behavior seemed to have entered a second stage. The female now moved slowly through the thickets, about 20 yards at a time, the male following, landing some ten yards from her, singing once or twice, and then in silence rapidly flicking wings and tail until the next move. In ten minutes or more, during which 250 yards were covered, there was only one variation in this: then the male approached to within two feet of the female, she raised and spread her tail, and he hopped away. Two hours later the birds were back where I had first seen them, still moving along together in the manner just described.

During the next two days Male A sang about 15 times per minute from 10- to 15-foot perches. This constant singing and my inability to find the unbanded female made it clear that she had gone. On May 17, the banded mate of the previous year was present. Nest building had already begun on this date, and that fact and the scarcity of songs by Male A from May 11 through May 17 suggests that the pair had been formed on May 11 or very shortly thereafter. Red-eyed Vireos fall silent temporarily immediately after pair formation (Lawrence, 1953:52).

One other episode, on June 6, between unmated Male D and a second bird so closely parallels the observations just described that it seems probable that it involved courtship and not agonistic behavior. There was the same close rapid pursuit (covering 40 yards, reaching 25 feet in height, with faint notes audible from a few yards distance), the same wing and tail quivering as the two birds perched, the same temporary disappearance of the newcomer during which the male sang loudly, and finally a series of short flights together through the brush. In this case, too, no pair was formed, for the second bird left after I had watched for about 15 minutes. For the next 20 minutes Male D sang steadily from the highest perches on and around his usual range, most of them 30 feet or more high; about two minutes were spent on each perch. On subsequent days he sang the loud, regular song that seems especially characteristic of unmated males. He never scolded me as mated males do when one is near the nest.

It is possible that one or both of the foregoing episodes involved two males, but because of similarity with the courtship of other vireos I think this is not likely. I have seen following and wing-quivering in the pair formation of color-banded White-eyed Vireos known to be male and female, and Lawrence (1953:53) reports comparable behavior in Red-eyed Vireos. Lawrence also describes a first meeting between male and female Red-eyed Vireos characterized by a fast twisting pursuit to the ground, and Southern (1958:114) records much the same thing in the courtship of Red-eyed Vireos, as does Lewis (1921:28) in that of Philadelphia Vireos (*Vireo philadelphicus*).

Grinnell, Dixon, and Linsdale (1930:364) write of two Bell Vireos on April 23: "One, probably the male, was singing and keeping within one meter of the other, both moving through the low branches, feeding. The singing bird kept its tail spread and frequently gave it a twitch, spreading the feathers still more. Also at intervals the tail was pushed downward to a nearly vertical position."

## NEST BUILDING

The interval between pair formation and building by Pair A, which had been mated before, can have been no greater than five days. Five to six days is the length of the same period in the Red-eyed Vireo (Lawrence, 1953:54), whereas about two months elapse between the arrival of males and nest building in the tropical Yellow-green Vireo, *Vireo flavoviridis* (Skutch, 1960:14, 25).

Twice when predators destroyed nests, one containing eggs and the other young, replacement nests were found immediately; building had evidently begun no later than the day after the first nests failed. Nice (1929:16) and Pitelka and Koestner (1942:98-99) report equally prompt renesting.

There was no systematic observation of building, but both sexes were seen with material, the male sometimes singing with it in his bill. Once Male B was noted carrying plant fibers at a time when the first nest had probably not yet been begun. During building the male usually accompanied the female very closely as she ranged as much as 85 yards from the nest. In my own brief experiences he sang little, for example, on one occasion 15 times in 15 minutes, but Mrs. Nice (1929:16-17) and Hensley (1950) found males very vocal at this stage.

Duration of building is known relatively precisely only for the two replacement nests, which were constructed in a maximum of four days each. The only first nest found in the building stage must have required considerably more time, for insertion of the thin, grassy lining alone took three days. Four to five days is the period reported by Mrs. Nice (1929:16), Pitelka and Koestner (1942:99), and Hensley (1950). Calculation of duration of building and of the interval before laying is complicated because the birds often come to the nest even after it is functionally complete and at times add material to it. Male B once affixed a spider's egg case after Female B had laid her first egg. This habit of prolonged building is found in *Vireo philadelphicus* (Lewis, 1921:31), and in *Vireo olivaceus* it persists until after the eggs hatch (Lawrence, 1953:56; Southern, 1958:126). Skutch (1960:17) saw one instance of nest reinforcement by an incubating Yellow-green Vireo.

## NEST TREES AND NESTS

Eight nests were built in the course of the study, two in white elms (*Ulmus americana*), two in sassafras (*Sassafras albidum*), two in blackberries (*Rubus* sp.), one in sugar maple (*Acer saccharum*), and one in osage-orange (*Maclura pomifera*). All trees but the last ranged in height between four and seven feet; the osage-orange was 12 feet high. The blackberries grew among patches along fence rows, whereas the trees either stood alone or were at the edges of little clumps of saplings measuring six feet or so across. Ground and field cover around the nest trees and bushes consisted of grasses such as *Poa compressa* and *P. pratensis*, *Triodia flava*, and *Aristida* sp. and such forbs as *Daucus carota*, *Asclepias* sp., *Plantago* sp., *Solidago* sp., *Erigeron* sp., *Achillaea millefolium*, *Cirsium* spp., and *Chrysanthemum leucanthemum*. Some of these, as well as blackberries, reached as high as the branches in which the nests were placed.

All eight nests were suspended from and fixed tightly in lateral forks ranging in angle from 45° to 85°, and one was fastened also to a second lateral twig which thus provided support on a third side. The minimum height was 23 inches, the maximum 34, and the average about 28. Except for the blackberry nests, all were placed between six inches and one foot from the end of a branch at a point where it was nearly horizontal. The osage-orange nest was five feet out from the trunk; the others were between one and two feet out. Supporting twigs were from about two to five millimeters in diameter, and terminal leaf clusters of the nest limb and sometimes of limbs above it provided

shade and some concealment. Nests built in blackberry bushes were in lateral forks of horizontal or slightly diagonal canes growing from a main leader; there were numerous new leafy shoots nearby.

Most nests were slightly oval-shaped cups, with the long axis of the oval bisecting the angle of the suspending fork. Rims were slightly constricted, and the apertures of nests in acutely angled forks were wedged-shaped segments of circles. Except for one dimension, depth, it is unnecessary to record in detail the measurements of four nests, since they closely approximate those reported by Mumford (1952) for seven Indiana nests. Depths of the cups of four nests were 47, 46, 45, and 44 mm., averaging 45.5 mm.; Mumford's maximum inner depth was 38 mm., and his average was 34 mm. Outside depth measurements of the same four nests were, respectively, 58, 68, 55, and 64 mm., averaging 61 mm. Average outside diameters were 68×60 mm., and average inside diameters were 51×44 mm. Weights, in grams, of dry nests were 5.6, 5.5, 5.2, and 5.0.

Nests have two parts, a relatively thick outer cup and a thin lining. Externally they are a general smoke gray (Palmer and Reilly, 1956), deriving their color from the weathered bast fibers and leaf fragments which are the major components of the cup. The lining is composed of three- to five-inch culms and axes of inflorescences of grasses (*Aristida* sp. and others) and is between buffy brown and dark smoke gray in color. The many cottony, 3- to 12-inch fibers (most of them probably from *Asclepias* sp.) of the cup are somewhat matted and stiffened by rain and dew into a tight, hard, resilient structure. Spider webs seem to form an important ingredient only near the rim, sometimes lending a whitish color to that part, from which they may spill down one-half inch or so on both inside and outside. Egg cases of spiders are also used in small quantities on the outside of the cup. Pieces of leaves no larger than about one inch square are a conspicuous element in the nest, especially toward the bottom, their proportion varying from a few fragments on the outside to a sometimes almost solid pad added just before the grassy lining. One nest had several bits of newsprint, another some papery outer bark probably from a young sumac (*Rhus* sp.), while a more interesting leaf substitute was 50 or so pieces of the thin bright orange outer bark of an osage-orange root exposed 25 yards from a nest. It is probable, judging from the texture of the cup, that the fibers are placed in random directions across the nest rim after a shell has been formed and are pressed into position by the body and limbs; loose ends presumably are fastened in place by the bill. The texture of the grassy lining indicates a similar random placement; incomplete nests in the lining stage sometimes have many pieces of grass in a loose mass in the cavity. In one nest the total weight of the long fibers was 2.3 gm., of the leaves and osage-orange root bark 2.1 gm., and of the grass lining 0.6 gm.

#### EGG LAYING AND EGGS

The period between completion of the nest and the laying of egg 1 was, in two first nests of the year, one and two days. In two replacement nests there were a one-day interval and no interval. Mrs. Nice (1929:16) noted a time lapse of one or two days until laying, Pitelka and Koestner (1942:99) none or one day, and Hensley (1950) none. On most occasions when I have seen the pair at this stage they have been together, the male relatively silent, although twice the male was singing at or near the nest.

Female A's first egg in 1959 was laid on May 22, which was 16 days after the arrival of Male A and about 11 days after Pair A was formed. Of the other seven nests studied, dates for the laying of egg 1 are known or can be calculated for four nests discovered before or in the course of laying. These dates are, for two first nests, May 25 and May 26, and for two replacement nests, June 10 and June 16 or 17. In two nests found with

young, the beginning of laying can be fixed within one or two days as May 16 and July 1, the latter involving a second brood.

Clutch size in seven nests was four, but for three nests this figure is based on the fact that they contained that number of eggs or young when found; a fifth egg or nestling might already have disappeared. The eighth nest was the only one parasitized by the Brown-headed Cowbird (*Molothrus ater*), and it held two cowbird eggs; the three vireo eggs cannot safely be assumed to have been a complete clutch.

Eggs were marked in nests discovered during the early stages of laying. It was found that the eggs were laid on consecutive days. The hour of laying was probably at or just after dawn, because the egg was invariably deposited after my visit in the late evening and before my next visit between 5:30 and 6:00 a.m. the following day. Once a male was found perched beside the nest at 5:15 a.m., with the female on a newly laid egg, her third. Southern (1958:121) and Lewis (1921:32-33) record similar hours of laying for other vireos, but Mrs. Lawrence (1953:57) noted exceptions in a pair of Red-eyed Vireos.

Measurements of Female A's first clutch in 1959, in the order in which the set was laid, are 17.7×13.2, 17.9×13.4, 18.1×13.4, and 18.3×13.5 mm. Female B's two sets in 1959 were measured in the order laid, except that egg 2 in the first set disappeared before it could be measured. Also, the second nest when discovered held only a cowbird egg, so that the first vireo egg found may have been in fact the second vireo egg laid. With dashes to indicate these gaps, egg sizes were: 17.7×13.0, —, 17.0×12.8, 16.9×12.8 mm. in the first set; and —?, 17.1×13.0, 18.0×13.0, 18.4×13.0 mm. in the second set.

#### INCUBATION AND HATCHING

*Roles of the sexes.*—Both male and female Bell Vireos sit on the eggs, and the species is uniformly placed on the list of those vireos in which the male incubates. However, in the Bell Vireo, as in all (Bailey, 1952:134) or most (Skutch, 1957:77-78) passerines, males have no incubation patch. This was true, at least, of Males A, B, and C, all of which were examined during the stage of feeding nestlings. Male A was examined in both 1958 and 1959. Lacking a patch, males cannot warm the eggs efficiently (Kendeigh, 1952:168, 274-278; Bailey, 1952:128; Skutch, 1957:77); and it seems probable that their attentive periods at the nest serve other functions than incubation in the strict sense, although Skutch (1957:78) suggests that this is not necessarily true. Among these functions may be included keeping track of the general situation and requirements of the family, such as discovering the presence of nestlings as soon as they hatch (Skutch, 1953; 1960:18-20), and standing guard. Mrs. Nice (1929:15) saw a male Bell Vireo drive away a Brown Thrasher (*Toxostoma rufum*), and Mumford (1952:230) observed the repulsing of a female cowbird; but in neither of these instances had the male been covering the eggs at the moment of intrusion. Such guarding is not confined to the females' periods of inattentiveness, for males often sing in the nest tree (Nice, 1929:15), and by the time the eggs have hatched there is usually a great patch of droppings on the leaves below a favorite perch. The male Solitary Vireo (*Vireo solitarius*) is a silent watcher near his nest (Bent, 1950:311).

Conservation of heat supplied the eggs by the female, shelter from direct exposure to sun and rain, and reduction of losses from wind and storms (as in an instance described by Southern, 1958:124, for the Red-eyed Vireo) are other possible or probable results of the male's covering the eggs. In evaluating the relative importance of the possibilities suggested, it may be noted that, unlike the female, the male Bell Vireo often leaves the nest to sing at and scold the observer the minute his approach is noticed.



Thus, I seldom saw a male sitting on the eggs but only detected him when he was slipping away from the nest. Bennett (1917:288-289) describes a "characteristic" incubation habit of "sitting absolutely motionless at the edge of the nest . . . at more or less regular intervals," sometimes of 10 or 20 minutes. He ascribes this behavior to both sexes, but he worked with unmarked birds and I wonder if the habit he saw was not primarily the male's.

If it is true that the male does not warm the eggs, data on the relative attentiveness of the sexes are of special interest. My observations are scanty. Nests were inspected 59 times from the day the last egg was laid through the day on which hatching began, and females were found sitting 35 times (59 per cent) while males were present 22 times (37 per cent). These percentages compare closely with those determined by Hensley (1950) by prolonged observation of one pair; a female spent 56 per cent of 206 minutes on a nest and her mate spent 43 per cent. While this degree of female attentiveness is below that of most passerine species in which the male does not incubate (Nice, 1943: 221-222, 227), the comparison of greatest interest is with figures for other vireos in which the females alone cover the eggs. In the Red-eyed Vireo, Southern (1958:128) reports extremes of attentiveness for eight females as being 52 and 82 per cent; the range for five females watched by Mrs. Lawrence (1953:60) was between 71 and 83 per cent. Four female Yellow-green Vireos incubated for periods varying from 62 to 77 per cent of the observation time (Skutch, 1960:16, 27), and a Gray-headed Greenlet (*Hylophilus decurtatus*) spent 52 per cent of the time on her eggs (*ibid.*:31, 34).

Returning to the Bell Vireo, my records of the distribution throughout the day of the time spent on the nest by the male and female alter the picture presented by mere percentages of attentiveness. In 37 nest inspections before 9 a.m., I found the male present 21 times, the female 14. On 22 inspections after 9 a.m., the male was at the nest once, the female 21 times. Thus the ratio of attentiveness of the male and the female in the early morning was 3:2, and 95.5 per cent of the male's time at the nest and 40 per cent of the female's time were attributable to the early hours of the day. There was no noticeable change in proportion or hourly distribution correlated with time advance of incubation. I would conclude that these facts, incomplete though they are, indicate the need for much further investigation of incubation patterns and egg temperatures before we shall understand the roles of the sexes in those vireos in which both male and female sit on the nest.

A full sequence of nest relief was watched only once. The male approached the nest apparently with caution but sang a few yards from it, and he sang again ten yards from it when relieved by the female 15 minutes later. Possibly the songs were directed at me, but since the male Bell Vireo, like many other vireos, sings on the nest (Bennett, 1917:289; Nice, 1929:15), this was not necessarily true.

*Beginning of incubation and sequence of hatching.*—In three of five nests found on or before the day the first eggs were laid, females were seen sitting before the clutch was complete. That some warming occurred at these times is indicated by the sequences of hatching: In four marked or partly marked clutches, the last egg laid was the last to hatch, in two the third egg laid was next-to-last to hatch, and in one the first egg laid was the first to be piped. In no instance was an egg known to hatch in a sequence differing from that of laying.

A measure of the amount of early incubation is to be found in the times elapsing between the hatching of eggs in a clutch. The most precise figure available is for one interval between the hatching of eggs 3 and 4; it was  $26 \pm 2$  hours. Another such interval was more than ten hours. The period between hatching of the first and next to last eggs was known in one instance (unmarked eggs) to be about seven hours, and in another

instance it could be fairly guessed to be at least 12 hours. At the latter nest a newly hatched bird from egg 3 at 6 a.m. weighed 1 gm. while its largest nest mate had already attained 1.8 gm., which is only 0.2 gm. less than a nestling has been found to weigh at 25 hours of age. Variable though weights are, the difference of 0.8 gm. shortly after dawn suggests that the largest bird hatched the preceding day. If so, then the interval between the first and last hatchings in this set was 36 hours or more, and hatching extended over three days. Lewis (1921:40-41) reports a similar instance for a set of eggs of the Philadelphia Vireo.

All the foregoing data are from situations in which there must have been substantial incubation before the clutch was complete, in one instance beginning probably with the laying of egg 2. The opposite is indicated for the nest in which only three eggs were found, namely, the nest parasitized by the cowbird. I removed the two cowbird eggs when the vireo's laying was complete, and on four visits to the nest during laying never found an adult on the nest. The first of the three vireo eggs failed to develop; the last two laid piped nearly simultaneously and two nestlings of the same size were present on my next visit. Incubation therefore began probably shortly, if at all, before the last egg was laid, a fact which may be related to molestation by the cowbird or to the possibility that the complete clutch consisted of three rather than the usual four eggs. Mrs. Lawrence (1953:59) reports beginning of incubation in Red-eyed Vireos after the laying of egg 3, whether the full set consists of three or four eggs.

The variability in the start of incubation in the Bell Vireo is reflected in the reports of others: Mrs. Nice (1929:13) found it beginning with egg 3, Pitelka and Koestner (1942:99) with egg 1, and Hensley (1950) with egg 2. Southern (1958:122) noted similar irregularity in *Vireo olivaceus*.

*Duration of incubation and hour of hatching.*—On the assumption that eggs were laid between 5 and 6 a.m., the period of incubation for three marked fourth eggs was 13 days,  $16 \pm 10$  hours; 13 days,  $20 \pm 6$  hours; and 14 days,  $2 \pm 2$  hours. In an unmarked set the last egg to hatch did so 13 days,  $18 \pm 6$  hours after egg 4 was laid. In a nest in which the hatching time of egg 4 is unknown, egg 3 hatched exactly 14 days after it was laid. All other investigations report a like incubation period of 14 days.

Fine cracks and one or more tiny convex irregularities become visible toward the large end of the egg about 24 hours before the egg hatches. The bumps may enlarge as time passes, but often no further change is noticeable until a true hole is cut. In one instance the hole appeared about two hours before the two shell halves were forced apart. Southern (1958:127) records five hours and ten minutes from the first sign of hatching to the emergence of a young *olivaceus*.

The hour of hatching is known fairly closely for only five eggs; three hatched between 4:30 a.m. and 8 a.m., one at 12 noon, and one between 2 p.m. and 5 p.m. Three more hatched between dusk and my inspection next morning at 5 or 6 a.m. Southern (1958:127) learned that the majority of eggs of the Red-eyed Vireo hatch during mid-morning.

#### NESTLING PERIOD

*Parental behavior.*—Disposition of the eggshell was seen once. When the female flushed from a nest at 5 a.m., it was found to contain newly hatched young and half a shell. The female returned to brood but quickly left when the male brought food. He then took the shell and flew out of sight.

The foregoing incident shows that males begin to feed the young promptly. Other data are sufficient only to reveal that both adults participate in nestling care, that brooding by the female is probably more frequent than covering by the male, and that after

the oldest nestlings are about seven days old the parents normally spend little time at the nest during the day. Mrs. Nice's (1929:17) data support these general impressions, as do Hensley's (1950).

Males are quick to scold at a person approaching the nest; I found their songs less frequent after hatching. Females too sometimes scold intruders, but more frequently they simply disappear into the brush.

#### FLEDGING

The hour of departure from the nest was usually before the middle of the morning. One bird is known to have left between 6:30 and 9:15 a.m., one before 7:45, two before 11, and one before 8:45. One brood left sometime after 8:30 a.m. There was no known case of afternoon nest-leaving, but for several young that possibility cannot be excluded.

In three of the five nests producing fledglings, the members of the brood left on the same day. In a fourth, one bird left on June 17, two on June 18, and the last on June 19. In the fifth nest, there was a similar three-day fledging period.

Ages of young of two broods in which all nestlings of the brood left the nest on the same day can be determined to the nearest 12 hours (half-day); two left at age 10.5 days, one at 11.5 days, and three at 12 days. In the two nests in which fledging was prolonged over three days, the assumption is made that departure took place in the same order as hatching, that is, the oldest bird first and the youngest last; two young left at age 10.5 days, four at 11 days, and two at 11.5 days. Two of those leaving at age 10.5 days belonged to the same two-young brood; all others were in broods of four nestlings. The maximum error in these calculations of age is about 12 hours; if error is present, it affects only the figures within the extremes of 10.5 and 12 days without altering the extremes themselves.

Pitelka and Koestner (1942:99-100) found that the two nestlings which hatched in a nest parasitized by a cowbird fledged on the same day, after 11 days of nestling life. Hensley (1950) reports a nestling life of 12 days for four young, but he does not say whether they left on the same day and he seems not to have established the dates of hatching.

#### DEVELOPMENT OF NESTLINGS

*Weights and measurements.*—At hatching one nestling weighed 1 gm.; its two nest mates, the larger of which was probably 12 hours or more old, weighed 1.8 gm. and 1.2 gm.; one egg was still unhatched. Table 1 presents weights and measurements of nestlings at other ages.

Table 1

Weights and Measurements of Nestling Bell Vireos

	About 12 hours	25 hours <sup>1</sup>	About 60 hours <sup>1</sup>	144-168 hours <sup>2</sup>	144-168 hours <sup>2</sup>	144-168 hours <sup>2</sup>	144-168 hours <sup>2</sup>
Weight	1.8 gm.	2.0 gm.	3.3 gm.	6.8 gm.	8.0 gm.	8.2 gm.	8.3 gm.
Culmen, from base	3.6 mm.	5.6 mm.	6.8 mm.	7.8 mm.	8.3 mm.	8.1 mm.	8.4 mm
Gape	7.3	8.7	10.0	11.0	11.0	11.4	11.0
Tarsus	6.5	7.6	10.4	16.5	17.0	18.4	18.0
Hand	6.0	7.0	10.5				
Forearm	5.2	5.8	8.0				
Folded wing				23.1	27.0	29.7	27.5
Closed eye	5×5.5	5×6	6×6.5				
Eye slit	2.0	3.2	3.3				
Open eye				3×1.7	3×2	3×3	3×2

<sup>1</sup> Youngest and oldest members of brood of four.

<sup>2</sup> Members of same brood.

*Plumage.*—Young are naked at hatching. The body color is between flesh and rufous (Palmer and Reilly, 1956) except where folds of the straw yellow skin obscure the underlying colors. The bill and tarsi are buffy yellow, the latter with flesh undertones; the closed eye is dark gray; the gape was not compared with a color chart but is a shade of yellow. Twenty-four hours later darkening humeral and spinal tracts are becoming visible and hair-like projections about 0.4 and 0.1 mm. long, respectively, have emerged at the locations of the papillae of the primaries and rectrices. My notes fail to record that the alar tracts are marked by darkening papillae, but I think that they are. At age 60 hours the capital, spinal, and humeral tracts appear as rows of dark dots beneath the skin; the femoral and ventral pterylae are visible as light-colored dots; the crural tract papillae show, but my notes neglect to state their color. The quills of the remiges project 1 to 2 mm. through the skin, and the alar tracts are dark.

There is a gap in my notes until age six to seven days when quills have emerged in all pterylae. Feathers are appearing at the tips of the sheaths of rectrices and remiges and in spinal and ventral tracts. The ventral feathers project about 1 mm.; the primary feathers extend about 5 mm. beyond the distal ends of the sheaths, which measure as much as 14 mm.; the sheaths of the rectrices are 2.5 mm. at the maximum.

After seven days of age there is a marked change in appearance as feathers rapidly emerge on all tracts; the dorsal apteria appear to be covered as the young sit in the nest. The young birds cannot be handled beyond this age without risk of disrupting nest life. At the time they leave the nest they are typical tailless passerine fledglings. I took no detailed notes on appearance at this stage but saw nothing at variance with Forbush's (1929:195) general description.

*Behavior.*—Newly hatched birds attempt to right themselves, using the head and moving the limbs in this effort. At 12 hours the head is lifted for about four seconds in order to gape; this response could not be elicited by squeaking or by probing the body or tapping the surface on which it rested. At 24 hours pulling of the muscles of the eyelid can be seen; my notes do not show when the eye opens.

Banding is best accomplished when the young are six to seven days old. The young now sit with bills at a 45° angle. Crouching in the nest was once noted when I appeared, or perhaps when I or a parent bird was heard, and removal of a nestling from the nest invariably causes the brood to give loud nasal cries somewhat resembling the sounds made by steady blowing on small toy tin horns. This greatly excites the adults, whose scolding notes, however, elicit no evident responses in the young. Like other nestling vireos, young Bell Vireos hold tight to the lining of the nest with their feet when one tries to handle them. However, once out of the nest, birds gape, eyes open, apparently orienting toward their handler; sometimes the eyes soon close as though the effort to keep them open is too great. At six days slight and steady progress over the ground is accomplished by kicking, the wings being extended at times, evidently both as props and for balance. At seven days movement on the ground is better coordinated. At this age the bird can sit upright with its tarsi flat along the surface, and simultaneous kicks of both legs project it forward in jumps of two or three inches.

Although an attempt to remove a nestling from a nest of young aged eight to nine days will cause some of the brood to jump out, they can be returned and induced to remain for two days or more if the cupped hand is held over the nest briefly. Birds at this age are still poorly equipped for survival in the open; their movement through grass is ineffective. They cannot escape from an ordinary glass jar six inches deep and about 3½ inches in diameter with an open top 2½ inches across. Nasal crying continues, and once two young in darkness between my cupped hands uttered faint *peeps* reminiscent of chicks.

Calling from the nest in a long series of loud single nasal cries was heard from a nestling about 10.5 days old left alone by its mates and possibly temporarily neglected by its parents. The calls continued despite the scolding addressed to me by the adults.

At the age of nest-leaving the fledgling moves through brushy field cover perhaps as much as 30 yards in several hours, but the extent to which this is accomplished by flight was not learned. A young Red-eyed Vireo aged 10 or 11 days could travel 12 feet through the air (Lawrence, 1953:68), and a 13-day old fledgling Philadelphia Vireo covered 60 feet in a descending flight (Lewis, 1921:192). A Yellow-green Vireo flew at least six feet just after leaving the nest, and a Gray-headed Greenlet managed 25 feet in a downward course (Skutch, 1960:25, 33).

#### SECOND BROODS

Mumford and I on August 21, 1958, found four unbanded young about 40 to 45 days old, and although they could not have been produced by pairs A or B, the date suggested that they were a second brood. There are also items in my notes for July, 1958, on Pair A that in retrospect lead me to think that a second brood was attempted before the habitat was destroyed. In 1959, on July 26, Schneider and I discovered Pair A near a nest of four eight-day old young 12 yards from that pair's first nest. To clinch the question of ownership we put up a mist net and caught Pair A at the nest, holding them until it was clear that no other adults were in attendance. Although statements are numerous that various vireos, including the Bell Vireo (Scott, 1888:33), may or do have more than one brood, I find no other verification by banding. Morse (in Bent, 1950:256), however, described a double nest, one with young and the other with eggs, presumably attended by the same pair of Bell Vireos; and Solitary Vireos have been seen building a nest while fledgling young begged for food (McLaughlin, in Bent, 1950:308).

The second brood of Pair A was discovered too late to answer a number of interesting questions, for example, whether the male sits on the eggs or leaves the nest unguarded in order to be able to feed the earlier fledglings. Young of the first brood were 49 days old and had left the home range when the second nest was discovered. A timetable for Pair A shows the first brood leaving the nest in the period from June 17 to 19 (they remained within about 75 yards of it for several weeks) and the second brood leaving on July 28. Assuming that the various stages of the second nesting were of normal length, egg 1 of that brood must have been laid on or about July 1 and nest construction begun on about June 26, about seven days after the last fledgling left the earlier nest. Care of the young of the second brood occupied Pair A, or at least Male A, until his molt appeared to be virtually complete, and the last juveniles were found on the home range on September 2, at age 46 or 47 days.

#### DEVELOPMENT OF FLEDGLINGS

My appearance on the home ranges evoked such excitement in the parents, especially the males, during the two weeks after the young left nests that I learned nothing about the fledglings except that they apparently dispersed within a radius of about 30 to 60 yards from the nest and there remained hidden in thickets while both parents fed them. The male sang daily, usually in little bursts of three or four songs a minute, followed by irregular intervals of silence. Hensley (1950) found young 30 feet from the nest the day after leaving and 300 feet from it five days later.

At age 25 days a juvenile uttered high, tinny, adult-like notes when fed; it was four feet from the ground. Three days later, ten feet high in a dense growth and 35 yards from its nest, it called a series of one and two nasal notes, not so vigorous as an adult's; these seemed to be location calls to maintain contact with the parent. At this age the bill was

still slightly thickened in the rictal region but the remiges, rectrices, and feathers of the back resembled those of an adult. The head and neck were scrawny and ragged, with bare skin visible. The inverted V of the incoming feathers of the ventral tract extended half-way back on the belly and appeared light buffy yellow in contrast with the grayish white of the juvenal plumage being replaced.

Two broods were observed when they were 35 days old. By this time only the head appeared to be molting, although close examination would have revealed body molt. Traces of raggedness on the head were not noticed beyond age 41 days, after which it would be difficult to age a bird on the basis of its appearance in the field.

By age 35 days the young had become very gregarious, trooping about freely and seldom separating by more than 20 yards. Often the entire brood followed the first to fly and perched in the same bush, where individuals might be as close as a foot or two apart. Occasionally, two or more birds engaged in a short chase. A nasal call indistinguishable from that of an adult seemed to serve both to signal location to siblings and to scold the human intruder. Association with fellows was not constant, however, for a 37-day old bird was found approximately 100 yards from the others. At that distance it sang steadily for about five minutes, giving long, rambling sub-songs.

In addition to the vocalizations already described, I heard single adult-like songs, some *otto voce*, by unbanded young in a group of four on August 21, 1958. Mumford and I collected one of these, a female; the ragged plumage of her head indicated an age of about 40 to 45 days, as did the behavior and extreme gregariousness of her presumable siblings. Young Red-eyed Vireos and Warbling Vireos (*Vireo gilvus*) sing adult-like songs in late summer (Sutton, 1949:16, 26).

The age at which a bird was last seen being fed was about 30 days, but some feeding almost surely occurs thereafter, probably for about ten more days. A 41-day old juvenile followed one to three feet behind the male parent and fluttered its slightly extended wings as it begged, but I lost sight of the birds after a minute or two. At this age the young could feed themselves without help, even executing such complex maneuvers as swooping to recover dropped food before it touched the ground. Mrs. Lawrence (1953:68) saw 35-day old Red-eyed Vireos being fed, but 42-day old young were disregarded when they begged. Tyler (in Bent, 1950:338) noted a similar long period of dependence in the same species. Sutton (1949:27) refers to full-grown Warbling Vireo broods begging from the adults.

As to whether the brood splits and leaves the home range separately or moves off together, there is evidence pointing to both alternatives: A careful search of the field of Pair A when the second brood was about 47 days old turned up only two young, which were not associating. On the other hand, the four 40- to 45-day old birds found by Mumford and me remained very close together for at least two days and were in a field in which they had not been seen before. Their parents' home range was unknown, but the nearest possible field, that which was used by Pair C in 1959, was 350 yards away. Sutton (1949:15) believes that broods of Yellow-throated Vireos (*Vireo flavifrons*) stay together until they go south, but this opinion is not based on marked birds. Mrs. Lawrence (1953:68, 70, 74), who made a day-by-day study of a family of Red-eyed Vireos, apparently unbanded, reports that the brood stayed on the adults' home range until 42 days old, when the entire family started to migrate. Southern (1958:188) disagrees with Mrs. Lawrence and states that broods split up shortly after leaving the nest, but he may not have given sufficient weight to the possibility that they reassemble, as do Bell Vireos, when they achieve the stage of easy flight.

In the 40- to 45-day-old unbanded female collected on August 21, 1958, close examination revealed a complete body molt still in progress. This bird weighed 10.4 gm. at

6 a.m. and had an incompletely ossified skull and an ovary about  $1 \times 1.5$  mm. in size; there was no fat. Without a chart for comparison, the gape was judged to be flesh color and the tarsi bluish gray. The arc of the wing measured 56 mm., the tail 46 mm.

#### ADULTS IN LATE SUMMER

*Behavior.*—Several important aspects of late summer behavior have been mentioned earlier in other contexts, namely, that birds may be tending young until the end of August, throughout most of the molt; that home range shrinks in size and may shift and that males spend much time in a single thicket; and that only once has a female been seen. Singing continues in the male, usually diminished to brief series of five to ten songs at a time but not terminated during molt. One male seemed to skulk after molt, singing only occasionally from a berry thicket where he was almost impossible to find, but others at the end of August sang at heights of 35 to 40 feet from conspicuous perches, as males do at times during breeding. Bennett (1917:285) speaks of the species' "retiring habits in late summer."

*Molt.*—Both males A and B showed signs of molt before their mates did. The date of onset can be roughly fixed because the members of Pair B, when banded on July 2, 1958, were not molting, but Male B on July 20, 1959, and Male A on July 26, 1959, were molting heavily. Male B, watched on July 20, had lost many feathers on the anterior half of the body and some skin showed about the ear; when he preened an extended wing a short inner primary was visible and some of the coverts were missing. Male A, caught on July 26, was in the middle of molt involving all tracts, with sheathed feathers numerous on the head and chin, back, breast, and both wing and tail coverts. One of the central pair of rectrices was lacking from the old tail. The first primary was about 20 mm. long, about half-sheathed, and the second primary was 12 mm. long and half-sheathed; all the other old remiges seemed present. No good opportunity to study Male A in the field came again until August 24, when the outer pair of rectrices was one-half inch short of full length and the next pair one-fourth inch short. From below, a bare area on the belly was visible. The same traces of molt were seen on August 27, but thereafter the new plumage looked complete. Male C appeared to have finished his molt by August 27, 1959, when he was rediscovered. The unbanded male thought to be Male D was molting and lacked a tail on August 2, but on August 29 it showed only a slightly ragged throat.

Female A, examined on the same day as Male A, July 26, 1959, showed no molt; later sightings of her were too brief to permit observation of plumage. Female B on July 30, 1959, had lost many feathers from the head, neck, and breast but was otherwise still in old plumage. When she was last found, feeding young on August 6, her tail had lost two or three pairs of rectrices and her head was very ragged.

*Departure.*—Male A was seen and heard nearly daily from late August through September 11, 1959, and Male C was seen through September 15. These dates correspond with those given in Bent (1950:262) for the fall migration, and with Bennett's latest record in Iowa (1917:285). Mrs. Lawrence (1953:70, 74) stated that Red-eyed Vireos remain on territory until going south; from context she was referring to both sexes.

#### VOICE

Some reference to song frequency throughout the summer appears in the foregoing sections. Bent (1950:259–260) and many others have described the normal song, and the following notes are limited to vocal behavior not found discussed elsewhere. No female was known to sing, but Pitelka and Koestner (1942:103) recorded female song, perhaps connected with nest relief.

*Adult "run-on" song.*—On three occasions, two of them in the course of this study, I heard an unusual, rambling song, single performances of which lasted ten seconds or more. Adjectives in my notes attempting to describe it are "twanging," "Bobolink-like," "bubbling," "jerky," "squeaky." The volume was at times faint. Twice there seemed to be a complex recurring pattern faintly reminiscent of the typical song of the species, so that in this respect there was a resemblance to rehearsed song in certain young birds. What may have been an intermediate between run-on and typical singing was a performance by Male C on August 28, 1959. The normal song suddenly became hushed and twanging and by the introduction of many new notes achieved a sort of double, improvised, *bel canto* effect.

The first true run-on song I heard near Indianapolis on June 1, 1946, from a male closely accompanying a female, apparently in an early stage of nesting (see Mumford, 1952:230). During the present study, Male D sang as described on the morning of May 26. This was the day I discovered him, and although searches made in the next few days indicated that he was then unmated, he may have had a female on the date the song was heard. Male B sang several run-ons in the early morning on June 16 during the laying period of his replacement nest; he was perched first in the nest tree and then 20 yards from it, ten feet off the ground, and gave the impression of being excited.

It may be this same song which Du Bois (in Bent, 1950:260) describes as "entirely different . . . with loud, harsh squeaks," and Mrs. Nice (1929:16) heard "a squeaky, scolding series something on the order of the song . . ." White-eyed Vireos often sing protracted, rambling, sometimes faint, catbird-like songs, into which more typical phrases of the species may be introduced. That a comparable vocalization is widespread in the genus, possibly connected with courtship, is suggested by a number of reports (Lawrence, 1953:72; Bent, 1950: *solitarius* 299, *flavifrons* 285, *olivaceus* 335).

*Unusual occasions for song.*—Male A on July 17, 1958, sang frequently, once arching his back and uttering a normal song in flight. The occasion for this was undiscovered; 36-day old young were probably somewhere near. Male B when caught on July 2, 1959, was wild with excitement and gave a loud mixture of scolding notes and song; when released he sang immediately. Song by the male on the nest, as in many other vireos, has already been referred to; I heard it only once.

*Song by young birds.*—The sub-song of a juvenile 37 days old has been mentioned. In its length and rambling, twanging character it resembled the adult run-on song, but no pattern was discernible and the singer's species was only faintly suggested by his voice. The single songs of birds about 40 to 45 days old have been described.

*Calls.*—Both adults give a loud *chee chee* or *cheev cheev* call when alarmed. The rate for continuous calling is 25 per five seconds, but more commonly there are slight pauses so that the number ranges between 12 and 20. A call that I find indistinguishable except in its slow, irregular rate serves apparently to maintain contact within the family. Young give the *cheev* call, but at a higher pitch and less vigorously than do adults until they are about 35 days old.

The long, crying notes of disturbed nestlings have been discussed, as have the chicken-like *peeps*.

Faint calls heard from a male and female in a courtship chase were unlike any mentioned herein, but I cannot describe them.

#### ENEMIES

The rate of cowbird parasitization, two eggs in one nest of the eight studied, is much below that which one would expect in the light of heavy molestation of the Prairie Warbler here (Nolan, MS) and of the Bell Vireo elsewhere (Pitelka and Koestner, 1942:



100-102; Bent, 1950:260-261; Mumford, 1952:231-232). The vireos did not desert the nest, and I then immediately removed the parasite eggs in order to obtain other data. Egg 2 disappeared from another nest during laying and perhaps was taken by a cowbird.

The predators to which the occupants of three nests succumbed are unknown, but the undisturbed condition of the nests themselves suggests the pilot black snake (*Elaphe obsoleta*) and the black racer (*Coluber constrictor*). These are perhaps the commonest nest predators in scrub habitat here.

The four nests of pairs A and B in 1959 were heavily infested with the mite *Ornithonyssus sylviarum*. Bites of *Ornithonyssus* may have accounted for numerous small, brown, scab-like growths on the tarsi of the nestlings in July; these lesions were about 0.5 mm. in diameter. One nestling when banded had fresh blood at the base of the hind toe. The softer skin of the bodies of the nestlings showed no conspicuous scabs, but I did not think to make a close examination for them. I am indebted to Nixon Wilson for identification of the mites. Pitelka and Koestner (1942:103-104) found nests of two pairs of Bell Vireos infested by this species; in one a nestling died.

#### REPRODUCTIVE SUCCESS

In summarizing reproduction, the nest parasitized by the cowbird is treated separately. For nests found after laying but containing four eggs or young, clutch size is assumed to have been four. Twenty-eight eggs were laid in seven nests, and 23 eggs (82 per cent) hatched. One clutch of four failed when three eggs disappeared, and in another nest one egg disappeared in the laying period. Of the 23 eggs that hatched in six nests, 16 produced fledglings; that is, 57 per cent of the eggs laid, or 69.5 per cent of those hatched, survived to the stage of nest-leaving. One brood of four nestlings and another of three disappeared. Each of the four successful nests yielded four fledglings.

The nest parasitized by the cowbird was found with one cowbird egg in it; next day it held one vireo and two cowbird eggs, and ultimately it held two more vireo eggs. The cowbird eggs were removed, one vireo egg failed to develop, but two vireo eggs hatched and produced fledglings. The young in this brood of two and those in a brood of four were followed to ages of 35 and 40 days and all survived.

#### MISCELLANEOUS

*Adult weights.*—All the following weights are of adults feeding nestlings. Males weighed 9.1, 9.5, 9.5, and 9.9 gm.; these were recorded, respectively, at 8 a.m., June 18; 11 a.m., July 26; 4:45 a.m., June 7; and 7 p.m., July 2. The first two weights are of Male A in the two successive years. Females weighed 9.6, 9.6, 10.5, and 11.0 gm. on the following dates, respectively: 7 p.m., July 2; 4:45 a.m., June 7; 9 a.m., June 18; and 6:30 p.m., July 5.

*Measurements.*—Wings (chord) of two males were 56.8 and 57.0 mm. long, of two females, 54.0 and 55.2 mm.

*Head scratching.*—The foot was extended over the wing in one observation of head scratching by a male.

*Bill wiping.*—A male was seen wiping his bill by scraping it from base to tip on a branch.

*Bathing.*—The only water on the home ranges was from dew and rainfall. Male B on a dewy morning in July bathed by rubbing against leaves until he was very wet. I have seen *Vireo griseus* do much the same thing; this has also been recorded by Southern (1958:201) in *olivaceus*.

*Unusual feeding behavior.*—Male B twice caught large black flies or Hymenoptera,

carried them to a branch, and put his foot on them while he hammered them with his bill and picked out soft matter. He then worked on the bodies with his bill and ate them. I once saw a White-eyed Vireo put his foot on a tough spider egg case, and Herrick (1935:229) saw a Red-eyed Vireo hold a caterpillar in this way while battering it with the bill. Skutch (in Bent, 1950:297) reports use of the foot by the Solitary Vireo, but says that the habit "appears to be very imperfectly developed among the vireos." In connection with the presence of the behavior in the Bell Vireo, Chapin (1925) found this species to take a greater quantity of such bulky insects as grasshoppers and the like than any other vireonid whose food items are known. Use of the foot would seem to be correlated with the eating of large, hard insects.

The Bell Vireo occasionally took food from a leaf as it flew past with scarcely a pause. Seizing food in flight has been noted in many vireos and seems especially conspicuous in the Philadelphia Vireo (Lewis, 1921:200).

*Wing flicking and tail flicking.*—Wing flicking and lateral tail movements associated with courtship and performed by both adults, especially the male, have already been described. Indistinguishable movements were seen in both adults and in juveniles nearing 40 days of age, when nervousness at my intrusion or possibly the excitement of mutual association seemed to be dominating the behavior of the moment. Under these circumstances either the wings or the tail or both were flirted, the tip of the tail traversing an arc of as much as  $2\frac{1}{2}$  inches.

#### SUMMARY

During 1958 and 1959, five pairs of Bell Vireos and an unmated male were studied at Bloomington, Indiana, where the species has probably only recently become established. Members of pairs were color-banded, and two males and one female were present in both years. The habitat was dry open scrub, which may have been selected because in it contact with the White-eyed Vireo was avoided. Breeding pairs were isolated one to a field, although fields were large enough to accommodate more than a single pair. Home ranges, which measured two to three acres, were reclaimed by two males in successive years, and a female rejoined her mate of the previous season.

The birds arrived in early May. A male sang often until he had acquired a mate, after which he became relatively silent for a time. Rapid chases and following were conspicuous during pair formation. A nest was begun no more than five days after a pair was formed. All nests were two to three feet above ground; both sexes built. Construction of first nests seemed to take more than the four or five days required to replace a nest lost to predators. When the nest was finished, the female sometimes began to lay on the next day and once she waited as long as two days before laying; she laid an egg a day for three or four days, probably always in the early morning. The beginning of incubation was irregular but it usually occurred at least one day before the last egg was laid. Males were found to lack incubation patches, so that in their intervals on the nest they sheltered and guarded but probably could not have supplied much warmth to the eggs. Eggs hatched after about 14 days of incubation.

The nestlings, which were naked and one of which weighed about 1 gm. at hatching, were covered and fed by both adults. They left the nest at age 10.5 to 12 days; all members of the brood sometimes left on the same day, but on occasion the departure of an entire brood required 48 hours. Until they became adept at flight the young remained on the home range and were probably separated from each other. At the age of 35 days, when only small traces of the postjuvinal molt remained evident, the broods were gregarious although individuals might perch alone and utter sub-song. Parents still were followed and were begged for food, and the broods remained intact until the

fledglings were 40 days of age or a little older. The young then disappeared. At this stage they were capable of song resembling the adult's.

Second broods were raised; one new nest was begun about seven days after the first brood left its nest. Care of the young in this case occupied the parents through August, by which time the postnuptial molt was virtually complete. This molt began in mid-July in two males, which was earlier than in their mates. In late summer males tended to spend much time in a single thicket, either on the breeding range or as much as 400 yards from it. Song continued until departure in mid-September.

The mite *Ornithonyssus sylviarum* was an abundant ectoparasite in 1959.

Seven of eight nests held clutches of four; the eighth, which held three, was the only one parasitized by a cowbird. Of 28 eggs laid in the seven nests, 23, or 82 per cent, hatched and 16 young, or 57 per cent, left the nest.

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