BREEDING BIOLOGY OF THE AMERICAN GOLDFINCH IN OHIO

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The American Goldfinch (*Spinus tristis*) has been rather thoroughly investigated in the Midwest. However, much can be learned by using comparative methods that examine temporal and spatial patterns of variation within the species and between goldfinches and other species. The present investigation is a contribution toward this objective.

PROCEDURES

The study area of 50 acres was inside the city limits of Toledo, Ohio and consisted mainly of wet prairie and deciduous scrub forest habitat. Man-made ditches carry off excess water and although several fields were used to raise wheat and soybeans, the majority had not been tilled for 10 to 20 years. This decline in agriculture gave the goldfinches a good habitat, since fields that had been tilled perhaps two or three years previously had a growth of numerous forbs and thistles. Brushy hedgerows separated the old fields, and these, together with the second-growth vegetation in the fields and ditch banks, supplied numerous nesting sites.

The area was studied for three years in the summers of 1963, 1964, and 1965. Daily visits were made in the field from the spring to fall of each year except in 1963, when observations began in late June, and in 1965 when they were terminated in late August.

Nest dimensions were measured to the nearest one-half centimeter directly after completion and excluded strings of material other than the primary structure. The lesser and greater depth of the nest bowl were obtained. Some nests were measured again after nestlings had fledged to determine the expansion of the nest bowl and its possible effect on nestling survival.

Eggs were marked with finger-nail polish in the sequence of laying in 1964 and 1965, and the dimensions of the lesser and greater diameter were measured with calipers to the nearest one-half millimeter. Eggs from all three years were weighed to the nearest one-tenth gram on the day following the laying of the last egg. The egg shape index (Beer, 1965) was calculated for the eggs in sequence of laying and for the total number of eggs. The index is in terms of percent and indicates ratio of length to width.

$$\frac{\text{lesser diameter x 100}}{\text{greater diameter}}$$

The time of day when eggs were laid was determined by visiting some nests two or three times. Brown-headed Cowbird (*Molothrus ater*) parasitism was also recorded.

The weights and sizes of eggs and of the egg clutches were compared for different months to find if there was a decline in clutch

TABLE 1. CLIMATOLOGICAL DATA FOR THREE NESTING SEASONS IN TOLEDO, OHIO

1963	Degrees F. Mean Temperature	Total Rainfall (Inches)
May	55.3	2.63
June	67.9	4.31
July	72.7	1.98
August	67.4	2.22
1964		
May	62.6	.96
June	68.8	1.89
July	73.8	1.58
August	67.8	3.80
1965		
May	63.5	3.80
June	66.9	2.57
July	68.5	2.03
August	67.2	8.47

size or egg weight in renesting attempts or late nests. Individual birds were not banded and, therefore, I could not distinguish those birds that were renesting from those that were late nesters. On a few occasions, I had reason to suspect that a bird was renesting near her old nest site.

Climatological data were obtained from the Toledo Weather Bureau to compare differences in annual weather schemes with the breeding biology of the Goldfinch.

Statistical data are given in terms of a sample mean. The standard error and range were included to aid in interpreting population sample trends. A two-sided Student's t-test at the 0.05 level was used to determine whether the mean clutch sizes were significantly different in the three years and whether dimensions and indices of eggs of known laying sequence were different.

RESULTS AND DISCUSSION

Nest Building

In the three years of study, 120 nests were started, 102 were completed and 71 had full clutches of eggs laid.

Pertinent climatological data obtained from the Toledo Weather Bureau for the years in which studies were conducted are summarized in Table 1. The mean dates for the beginning of nest building of the first ten nests in 1963, 1964 and 1965 were 17 July, 18 July and 8 July, respectively. The mean dates of laying the first egg for these nests were 26 July, 29 July and 19 July for the three years.

The most apparent differences in these mean dates is the starting of nest building and time when the first eggs were laid. Goldfinches constructed nests and laid eggs earlier in 1963 and 1965 than in 1964. The mean temperatures for June, July, and August were lower in 1963 and 1965 than in 1964 but the total rainfall was greater in the months preceding nesting in 1963 and 1965.

Rainfall seems to be an important factor. The years 1963 and 1964 were very dry years with a total of only 22.05 and 24.28 inches of precipitation, respectively. The normal annual rainfall for Toledo is 30.50 inches. 1965 was a wet year with a total of 40.85 inches of rainfall. Although 1963 was relatively dry, there was plentiful rainfall in May and June. These are the critical months for growth of vegetation used for food and nest sites by goldfinches.

Vegetation, such as bull thistles and Canadian thistles, grew very slowly in 1964 and were not ready as soon for a source of food and nest material. Thus, goldfinches used milkweed down instead of thistle down for lining early nests. Batts (1948) found that when thistle down was not available for early nests, goldfinches used pappus of other composites for lining nests.

Farner and Follett (1966), in an extensive review of factors affecting avian reproduction, report that control schemes from the hypothalamic level to the gonads are similar in most species. The adaptive significance is in use of sources of information which are most reliable for initiating reproduction when reproduction will be most successful. Photoperiodic responses have been studied in several species and for those nesting in the middle and higher latitudes; day length has the most reliable predictive quality for onset of reproductive activity.

Miller (1958) reviewed the subject of adaptation of breeding schedule to latitude. He suggested that increased rigor of requirements of photoperiod at progressively higher latitudes masks or minimizes other ecologic factors which affect breeding schedule. Seasonality other than to photoperiod was chiefly due to rainfall, the hypothesis being that perhaps the birds physiologically were ready for breeding and could reproduce quickly if sufficient rainfall provided ample food.

Tordoff and Dawson (1965) subjected the Red Crossbill (*Loxia curvirostra*) to different light regimes for 12 months. There was a failure of any of the birds to complete gonadal development. The ability of even the birds on short photoperiods (8 hours of light, 16 hours of dark) to undergo partial enlargement of testes suggested that the Red Crossbill can reach a partial state of readiness for reproduction on any naturally occurring photoperiod. The investigators suggested that the final maturation of gonads is dependent in the wild on availability of suitable food.

Kendeigh (1964) found that onset of laying in the House Wren (*Troglodytes aëdon*) was regulated to the general time of year by the development of the gonads under stimulus of changing photoperiods, to the time of month by their return to the breeding grounds from spring migration, and to the precise day by temperature.

Nice (1937) found that Song Sparrows (*Melospiza melodia*) began nesting depending on the temperature. However, Song Sparrows utilize different food sources than goldfinches. Stokes (1950) reported that goldfinches probably wait until July to nest because the composites which they feed upon do not produce adequate food until that time. I have observed the diets of nestlings by viewing the contents of crops through the translucent membranes. They contained mainly seeds of thistles, a few small caterpillars and occasionally insects.

Baker (1938 a; b) recognized two distinct roles of periodic environmental factors. The "ultimate selecting role" exerts selection pressure by favoring the survival of populations that produce young during the optimal season of the year for survival. The "proximate informational role" provides the internal control system of the individual with necessary information for initiating the periodic functioning of the reproductive system at a time when young will be produced in an optimum season for survival.

Goldfinches do not begin nesting until after the maximum day length in June. To my knowledge no one has reported on gonad activity of this species throughout the year. I would like to suggest that an ultimate factor, such as production of adequate quantities of composite seeds in July and August, has affected the evolution of the breeding season of the goldfinch. Stokes *op. cit.* also suggested this. The internal mechanisms of reproduction may be stimulated by a proximate factor, such as long length of day in June and July, and then the occurrence of an adequate food source to support adults in reproductive condition, and to feed young birds, initiates nesting. Therefore, perhaps another of the proximate factors governing the start of breeding in goldfinches is rainfall which promotes faster growth and production of seeds in composites.

Duration of Time Needed to Build Nest

It took less time to complete all stages of nest building in August nests than July nests (Table 2).

Walkinshaw (1938) reported that the time required for nest building was about the same for early and late nests found in southern Michigan. Stokes (*op. cit.*) reported less time for nest building as the season progressed; 13 days (July 1-15), 10.8 days (July 16-31), 5.8 days (August 1-15) and 5.6 days (August 16-31). Batts (1948) reported that Margaret Drum found nest building took an average of nine days with a range of six to 17 days. She attributed the delay to heavy rains. Sutton (1959) reported a five-day time delay between nest completion and egg laying in one goldfinch nest. Walkinshaw (1938) found that this period was between one and 27 days. His average was a little over two days for most nests.

Nest Materials and Support

Table 3 shows the frequency of use of 16 different plants as nest supports for the different years. The panicled dogwood (*Cornus racemosa*) and hawthorn (*Crataegus spp.*) were the preferred nesting

TABLE 2. MEAN TIME INTERVALS REQUIRED FOR STAGES IN NEST BUILDING AND EGG LAYING (DAYS)

		Nest to Start Platform Stage	Platform to Nest Bowl Complete	Nest Bowl Completion to Nest Complete	Nest Complete To First Egg Laid
	N	14	17	25	38
	$\bar{X}$	3.3±1.0	1.9±.4	3.4±.3	3.4±.5
July	Range	1–15	0–7	1–8	0–15
	N	4	3	6	11
	$\bar{X}$	1.3	1.00	1.8	1.3±.4
August	Range	1–2	....	1–3	1–5

TABLE 7. MEAN WEIGHT AND SIZE OF GOLDFINCH EGG CLUTCHES IN JULY AND AUGUST—SEPTEMBER (GRAMS)

	July			August-September			Combined Data		
Clutch Size	No. of Clutches Weighed	Mean Clutch Weight	Mean Egg Weight	No. of Clutches Weighed	Mean Clutch Weight	Mean Egg Weight	No. of Clutches Weighed	Mean Clutch Weight	Mean Egg Weight
3	....	....	....	1	4.70	1.57	1	4.70	1.57
4	4	4.80	1.20	3	4.50	1.13	7	4.67	1.17
5	24	6.66	1.33	9	6.32	1.26	33	6.57	1.31
6	6	8.28	1.38	5	7.44	1.24	10	7.86	1.31

TABLE 3. PRIMARY NESTING SUBSTRATE USED BY NESTING GOLDFINCHES—FREQUENCY OF USE

	1963	1964	1965	Combined Data
Cornus racemosa	17	12	11	40
Crataegus spp.	12	17	17	46
Cirsium vulgare	9	..	2	11
Ulmus americana	4	2	2	8
Populus tremuloides	2	1	..	3
Quercus macrocarpa	1	..	2	3
Acer negundo	1	1	1	3
Prunus virginiana	1	..	1	2
Acer saccharum	..	1	1	2
Salix purpurea	..	1	1	2
Gleditsia triachanthos	1	..	..	1
Solidago spp.	1	..	..	1
Malus spp.	1	..	..	1
Rhus typhina	..	1	..	1
Populus grandidentata	..	1	..	1
Cornus stolonifera	..	1	..	1

sites in this area. The lack of thistles in 1964 is responsible for their absence as nest sites.

The outer lining of most nests was composed of fiber strips of dry milkweed, or other large annual plants. Down from Canadian thistles was the substance used most often for lining nests. In the relative absence of thistles in 1964, some milkweed seed down was utilized. Other substances used were rabbit hair, cottonwood catkins, fine grasses and feathers.

Some nests built in late August were completely filled with thistle down and then deserted; no eggs were laid. When rains occurred while nests were being lined, the females often relined the nest with another layer after the nest had dried. One nest had four inner layers. In one instance on 30 July 1965, a first egg was laid while down was still being added. The female manipulated the egg enough to keep it above the down.

I will not elaborate on all of the different plants in which goldfinches have been reported to nest. They apparently nest in whatever is acceptable in their geographic region. Stokes (*op. cit.*) found that 68 percent of the goldfinches he studied were nesting in elderberry (*Sambucus canadensis*), and that they used these more often because they were very numerous. Walkinshaw (1938) found the largest percent of nests in dogwoods, (*Cornus amomum* and *Cornus stolonifera*). His nesting area was in a swampy habitat where these

TABLE 4. MONTHLY AND YEARLY DIFFERENCES IN MEAN HEIGHTS OF GOLDFINCH NESTS

		1963	1964	1965	Combined Data 3 Years
	N	26	13	17	56
July	X̄	53.0	60.7	59.8	56.9
	Range	30.0–82.0	42.0–79.0	33.0–92.0	30.5–92.0
	N	18	12	9	39
August	X̄	48.6	60.0	56.5	53.9
	Range	27.0–92.0	23.5–79.0	33.5–115.0	23.5–115.0
	N	3	4	....	7
Sept.	X̄	36.0	47.0	....	42.6
	Range	33.0–40.0	31.5–62.0	....	31.5–62.0
Combined	N	47	29	26	102
Yearly	X̄	50.3*	58.6	58.6	54.8
	Range	27–92	23.5–79.0	33.0–115.0	23.5–115.0

*This mean value of 1963 nests is lower because of the use of many bull thistles as nesting sites

species probably were abundant. Nickell (1951) found the largest percent of nests in panicled dogwood and the second largest number in hawthorn.

Height of Nest and Effect on Nest Success

Table 4 shows the mean height of nests in July, August and September and the mean height for each year. The nests for 1963 had a lower mean height because of frequent use of thistles (Table 3). There is no significant difference between the mean height of July and August nests. Table 5 shows there is better nesting success in those nests that are built at greater heights.

Holcomb and Twiest (1968) and Meanley and Webb (1963) reported that when Red-winged Blackbird (*Agelaius phoeniceus*) nests were built at higher elevations, the nesting success was much better. This is probably due to keeping ground predators away from the nest. The mean height of goldfinch nests varies depending on the plant community with which they are associated. Nickell (*op. cit.*) reported a mean height of 6.1 feet for 211 nests. Stokes (*op. cit.*) found an average height of about five feet and Walkinshaw (1938) found 111 nests averaging about 4.3 feet up. My average for 102 completed nests was 54.8 inches or about 4.6 feet.

Holcomb and Twiest (1968) found that Red-winged Blackbird nests do not increase in height with progression of the breeding season. Nice (1937) found that Song Sparrow nests did increase in height as the season progressed. Walkinshaw (1944, 1939 a) re-

TABLE 5. GOLDFINCH NEST SUCCESS BASED ON HEIGHT OF NEST - 3 YEARS

	Nests Between 24 and 48 inches	Nests Above 48 inches	Combined
Nests	33	40	73
Eggs Laid	153	190	343
Young Fledged	51	82	133
Percent Eggs Producing Fledglings	33.3	43.2	38.8
Mean Height of Nests –Inches–	40.0	66.3	51.6

corded an increase in nest height of the Chipping Sparrow (*Spizella passerina*) and of the Field Sparrow (*Spizella pusilla*) as the season progressed. Horvath (1964) and Taylor (1965) reported an increase in height of nests as the season progressed for the Rufous Hummingbird (*Selasphorous rufus*) and the Mockingbird (*Mimus polyglottos*) and Brown Thrasher (*Toxostoma rufum*), respectively. The goldfinch nests appear to be lower in September but my sample size was too small for a good comparison.

Nest Dimensions

Nest dimensions of 29 nests constructed in July (inner width, 4.7 cm; outer width, 7.8 cm; inner depth 3.3 cm; outer depth, 7.4 cm) were not different from 20 August and September nests (inner width, 4.8 cm; outer width, 7.5 cm; inner depth, 3.4 cm; outer depth 6.8 cm). Nest dimensions of 19 nests constructed below 48 inches (inner width, 4.7 cm; outer width, 7.7 cm; inner depth, 3.3 cm; outer depth, 7.3 cm) were not different from 30 nests constructed above 48 inches (inner width, 4.8 cm; outer width, 7.7 cm; inner depth, 3.4 cm; outer depth, 7.1 cm). The mean height of those below and above 48 inches was 40.3 and 69.3 inches respectively.

Walkinshaw (1938) reported the average dimensions of unused goldfinch nests as 50.25, 83.2, 35.1 and 70.6 mm for the inner diameter, outer diameter, inner depth and outer depth, respectively. Nickell (*op. cit.*) reported these same dimensions as 2.0 inches (5.0 cm), 2.9 inches (7.3 cm), 1.6 inches (4.0 cm) and 2.8 inches (7.0 cm). Neither of the above investigators mentioned a difference in the size of nests depending on height or when they were built.

Holcomb and Twiest (1968) found that Red-winged Blackbird nests have a greater mean inner depth when built at higher elevations. They were not different when constructed early or late in the nesting season.

Success of Nests as a Function of Nest Dimension Size Change

Thirteen nests were measured before incubation started and after the young had fledged to determine the change in nest bowl size and its effect on success of the nest. These nests were measured only if nestlings had left or were taken by predators when they were at least 10 days of age. The inner depth changed very little (in 10 nests there was no change) and the mean net change was 2 mm (range, -5 to $+ 10$). The mean outer depth net change was 8 mm (range, -20 to $+ 10$). The mean inner depth positive change was $+ 1$ mm and the mean outer depth positive change was -3 mm showing that the mean inner depth stayed nearly the same but that the whole nest structure was pressed down by the use of nestlings and adults. The mean inner diameter had a positive change of 15 mm (range, 5 to 25) and the mean outer diameter had a positive change of 12 mm (range, 0 to 30). This shows that inner nest expansion as the nestlings grow is due in part to expansion and flexibility of the nest structure and also to compressing of the nest wall.

Nests fledging more nestlings were stretched to a greater degree than those fledging fewer nestlings. Those producing four or five fledglings stretched 15 to 20 mm but two nestlings were crowded out and died and one was tossed from the nest by heavy wind. One nest producing six fledglings stretched 25 mm. The nest dimensions should determine to some extent the nesting success, for crowding becomes a problem when nestlings grow larger, (Young, 1963, Holcomb and Twiest, 1968). A robin nest would be a good example of one which would be inflexible, and in which crowding could become critical. The goldfinch builds a more flexible nest and usually lays four to six eggs. As these nestlings grow, they crowd one another a great deal and trample younger birds or shove them out of the nest. Although the nests expanded, in some instances nestlings were crowded out. Nickell (*op. cit.*) reported an increase in dimensions of used nests. The adaptation to construction of a nest that can expand, the clinging habits of the nestlings mentioned by Sutton (1959) and the early grasping abilities of goldfinch nestlings reported by Holcomb (1966) probably all play a very important role in the success of nests.

Egg Laying

In 1963, 1964, and 1965 the first nest construction began on 7 July, 2 July and 5 July, respectively. The first egg was laid on 21 July, 14 July and 16 July, respectively. The date for last eggs laid is not known for 1965, but for 1963 and 1964 the dates were 23 August and 7 September, respectively. Fully completed nests were sometimes deserted when rainfall prohibited normal egg-laying for several days. One female laid only one egg on 2 August, 1965 after a long delay in building (started on 4 July) and waiting period after completion. The nest was deserted and was still intact on 20 August.

Batts (*op. cit.*) quoted Margaret Drum in saying that goldfinches were seldom found around the nest for three days after nest completion. I found a delay of from zero to 15 days in July with a mean of $3.4 \pm .5$ days for 38 nests and from one to five days with a mean of $1.3 \pm .4$ days for 11 August nests. The eggs are probably laid quicker in August because of the urgency promoted by the development of follicles. I found that the time required in every stage of nest building was about one-half as long in August as in July nests. When birds first begin to build nests in July, the hormones governing nesting are probably being secreted at a slow rate. There are also many inexperienced young females building for the first time. In August the hormone level has perhaps become sufficient to hasten nest building or birds are renesting after an unsuccessful attempt or are building a second nest.

In 1963, one female either laid two eggs in one day or two females laid eggs in the nest. I visited the nest after sunset one evening and there were two eggs present. On the following day there were four eggs in that nest at 1900 and a fifth egg was present the next day.

Usually, if all the eggs are taken by a predator the female abandons the nest or pulls it apart to rebuild in another location. In 1965, the first two eggs of one nest were taken by a predator and the female did not lay the following day. However, on the next day she began laying again and laid a total of four additional eggs.

Time of Day When Eggs Were Laid

Goldfinches laid their eggs early in the morning. This was checked closely only in 1965. Of 92 eggs, all were laid before 1000 hours and most of them were laid well before that time. The earliest egg was laid before 0610. Eggs were laid early in the morning in both early and late nesting birds. In nest 12, egg six was laid between 0614 and 0635 and in nest 18, egg three was laid between 0607 and 0640. In nest 24, egg one was laid between 0630 and 0650 and egg five between 0637 and 0710. Walkinshaw (1938) found a third egg laid before 0530. Most eggs were laid between 0600 and 0830.

Cowbird Parasitism

In the three years of studies only one of 102 goldfinch nests contained a cowbird egg. This nest was found on 30 July and all four goldfinch eggs hatched by 8 August. The cowbird egg remained in the nest unhatched on 22 August after the goldfinch young had fledged.

Walkinshaw (1938) found no cowbird parasitism in 111 nests. Sutton (*op. cit.*) found only one nest of 61 parasitized and Stokes (*op. cit.*) found only one of 230 nests parasitized. Nickell (*op. cit.*) mentions one of his nests containing three dead cowbird young. Berger (1948) reported on two goldfinch nests that were parasitized by cowbirds. Undoubtedly, the late nesting season of the goldfinch and the earlier laying of the Cowbird in Ohio is responsible for the low parasitism rate. Friedmann (1963) reports a total of 53 instances of parasitism on goldfinches.

TABLE 6. MEAN NUMBER OF EGGS PER CLUTCH IN GOLDFINCHES

	1963	1964	1965	Combined Data
No. of Nests	32	23	16	71
Mean Eggs Per Nest	5.13 ± .12	4.70 ± .17	5.31 ± .12	5.03 ± .09
Range	4–6	3–6	5–6	3–6

Clutch Size and Egg Weights

Tables 6 through 9 show the summaries of data on egg clutch sizes and weights. Table 6 shows only 4.70 ± .17 eggs per clutch in 1964 compared to higher values of 1963 and 1965. The mean clutch size in 1964 was significantly different ($P < .05$) from those for 1963 and 1965. The smaller number of eggs per clutch in 1964 may be due to a scarcity of food because of low rainfall that year. Lack (1966) develops at length theories concerning the effect of environmental conditions and food supply on clutch sizes. There was no significant difference between mean clutch size for 1963 and 1965. There is little difference between clutch sizes for July (5.1 ± .1; 43 nests) and August (5.0 ± .2; 25 nests). September nests have fewer eggs (4.0 eggs per clutch in three nests).

Table 7 indicates that a three-egg clutch has larger individual egg weights. The four-egg clutches measured had exceptionally small eggs. Five-and six-egg clutches had individual eggs exhibiting the same mean weight. There was a decrease in the weight of clutches of the same size from July to August and September.

Table 8 shows the mean egg weight of eggs laid in known sequence. Egg two weighs less than egg one. There is a gradual increase in

TABLE 8. GOLDFINCH MEAN EGG WEIGHTS - GRAMS -

	N	1964	N	1965	N	Combined Data
Egg 1	16	1.34 ± .03	12	1.30 ± .05	28	1.33 ± .03
Egg 2	17	1.30 ± .03	13	1.28 ± .05	30	1.29 ± .03
Egg 3	16	1.33 ± .04	13	1.31 ± .05	29	1.32 ± .03
Egg 4	16	1.35 ± .03	13	1.35 ± .06	29	1.35 ± .03
Egg 5	12	1.39 ± .05	14	1.39 ± .07	26	1.39 ± .04
Egg 6	3	1.40 ± .08	4	1.50 ± .06	7	1.46 ± .05
All Eggs	86	1.33 ± .02	82	1.36 ± .02	321*	1.30 ± .01

*Includes 1963

weight of eggs from eggs three through six. The range of weights was from .8 to 1.8 g. Two hundred eighteen July eggs had a mean weight of 1.32 ± .01 g and 103 August and September eggs had a mean weight of 1.25 ± .02 g.

Kendeigh *et al.* (1956) develop a hypothesis that cooler weather early in the breeding season of the House Wren stimulates maximum feeding and a high level of productive energy which, in turn, permits not only heavier eggs but more of them per clutch than are present in later clutches laid in warmer weather.

Since there was a significant difference between clutch sizes in the three years of study, it is appropriate to direct attention to Table 1. The average clutch size for 1964 was significantly smaller than in 1963 and 1965. Table 1 shows that in each year the mean temperature was lower for August than July although the clutch sizes for these months were nearly identical and the mean clutch weights and mean individual egg weights were less for the later clutches. From these data, I could conclude that temperature has very little, if any, effect on clutch size or egg weight in the goldfinch.

Stokes (*op. cit.*) found a mean of 4.6 eggs per clutch in 150 nests with a range of two to seven. He found a mean clutch size in July of 5.3 eggs but by late August the clutches averaged only 3.7 eggs. For 10 females where first and second clutches were known, Stokes found that the first clutch averaged 4.8 and the second, 3.8 eggs, respectively. Walkinshaw (1938) found an average of 4.56 eggs for 62 clutches. He divided the breeding season into three periods and found an average of 4.74, 4.31 and 3.0 eggs per clutch laid before 10 August, between 11 and 31 August and after 1 September, respectively. Sutton (*op. cit.*) found a mean of 4.5 for the clutch size in 22 nests. I found a mean of 5.03 ± .09 eggs for 71 nests with a range of three to six. Walkinshaw (1944), Nice (1937), Meanley and Webb (*op. cit.*), Smith (1943) and Holcomb and Twiest (unpub.) discussed reduction in size of clutch as the season progresses for the Chipping Sparrow, Song Sparrow and Red-winged Blackbird. Walkinshaw (1938) also noticed that there was a higher mean number of eggs per clutch in the 11-31 August interval for a wetter year. Holcomb and Twiest (unpub.) found that mean weight of individual Red-winged Blackbird eggs decreased from 4.35 to 4.26, 4.14 and 3.83 g for two-, three-, four- and five-egg clutches, respectively. Nice (1937) found that eggs in four-egg sets were larger than those in five-egg sets in the Song Sparrow. Holcomb and Twiest (unpub.) found a significant difference between the mean size of May and June clutch size in Red-winged Blackbirds with fewer laid in June clutches. However, the eggs in June clutches weighed significantly more than May eggs. Allen (1914) also reported that redwing eggs became larger as the season progressed.

Successive eggs in clutches of the domestic fowl decrease in size and weight (Atwood and Weakley, 1917: Bennion and Warren, 1933). Nice (1937) found that in the Song Sparrow, the last egg was heaviest in 41 percent, the first egg in 29 percent and an intermediate egg in 29 percent of the cases, respectively.

TABLE 9. MEAN DIMENSIONS OF GOLDFINCH EGGS (mm) AND INDICES

	N	Lesser Diameter	Greater Diameter	Egg Index
Egg 1	30	12.8 ± .1	16.7 ± .1	76.4 ± .5
Egg 2	29	12.7 ± .1	16.7 ± .1	76.2 ± .6
Egg 3	30	12.7 ± .1	16.7 ± .1	76.4 ± .6
Egg 4	31	12.9 ± .1	16.9 ± .1	76.1 ± .5
Egg 5	27	13.0 ± .1	17.1 ± .2	75.9 ± .5
Egg 6	7	12.9 ± .1	17.7 ± .3	72.7 ± 4.1
All Eggs	161	12.8	16.9 ± .1	76.0 ± .2

Kendeigh *et al.* (*op. cit.*) reported a strong tendency for the last egg of the clutch in House Wrens to be the longest, widest and heaviest. In many clutches which I examined there was more than one egg that was of the same weight or dimension. Therefore, a comparison was made of eggs only when one egg of the clutch was heavier, longer, or wider than any others in the clutch. On weight basis, 57 percent of last eggs were heaviest and 35 percent were first eggs. When comparing length, 92 percent were last eggs and 8 percent, first eggs; on width, 44 percent were last eggs, and 22 percent were second from last eggs and 22 percent first eggs. This indicates that in the American Goldfinch the first or last egg has a tendency to be heaviest and the last egg has a tendency to be longer and wider than the others.

Holcomb and Twiest (unpub.) found that in the redwing, the first egg weighed more than the second; then an increase in weight occurred. The third and fourth eggs were nearly the same in weight and if a fifth egg was laid, it was usually smaller than the others. Table 8 shows that egg two weighs less than the first and then a steady increase in weight is evident through egg six. Walkinshaw (1938) found a mean weight of 1.41 g for 87 fresh eggs with a range of 1.1 to 1.7 g. I found a mean of 1.30 ± .01 g for 321 fresh eggs with a range of .8 to 1.8 g.

Egg Dimensions and Indices

Table 9 indicates the variation in the lesser and great diameter of eggs in known sequence of laying. There is a general trend for eggs to become narrower compared to the length, from the first to last eggs but no significant differences were found. This is also shown in Table 9 where mean indices range from 76.4 for egg one to 72.7 for egg six but no significant difference was found.

Walkinshaw (1938) reported mean measurements of 93 goldfinch eggs at 16.53 x 12.4 mm. When the index is calculated for these 93 eggs it comes to 75.02. This is very close to the value of 76.0 ± .2 which I obtained for 164 eggs.

TABLE 10. TIME INTERVAL FROM LAYING UNTIL HATCHING

	Egg 1	Egg 2	Egg 3	Egg 4	Egg 5	Egg 6	All Last Eggs
N	34	33	31	28	25	3	32
$\bar{X}$	14.1	13.1	12.4	11.8	11.6	11.0	12.2
Range	13–22	12–14	11–14	11–13	*10–13	....	11–13

Last of clutch—All intervals were from the day the egg was laid until it hatched.

*See discussion in text.

Kendeigh *et al.* (*op. cit.*) reported the two last eggs of clutches in the House Wren are longer, broader, have a greater calculated volume and are heavier than the first ones laid. They found no significant differences in average length, breadth, shape or calculated volumes between eggs in different size clutches, but larger clutches contained heavier eggs. There was less variation among different eggs laid by the same bird than among average egg characteristics of different birds.

Incubation Period

Female goldfinches were quite tame and often would sit on the nest while I weighed eggs or nestlings. They often refused to leave the nest until I touched them. One female pecked my fingers each day before she was pushed off the nest.

The four last eggs of clutches hatched in July had a mean incubation period of 12 days and for 28 last eggs of clutches hatched in August the mean incubation period was 12.2 days. As more eggs were laid in a clutch, there was a decline in the percent hatching. Of 35 first eggs in nests where others hatched, only one failed to hatch (3 percent). However, one of 34 second eggs (3 per cent), three of 34 third eggs (9 per cent), five of 33 fourth eggs (15 per cent), three of 28 fifth eggs (11 per cent), and four of seven sixth eggs (57 percent) did not hatch. The third through the sixth eggs of a clutch had improper development of the embryo more often or fertilization did not take place as frequently.

There was a range of 10 to 22 days between laying and hatching of eggs. This shows the degree of variability of time when birds began incubation and also reflects the variation in constancy of incubation. The 10 day and 22 day intervals were extreme cases and the usual extremes were from 11 to 15 days, (Table 10).

Walkinshaw (1938) reported an incubation period of 12 to 14 days averaging 12 days - 21 hours for 33 marked eggs. When applying the formula for incubation constancy recommended by Skutch (1962) to the data on the goldfinch presented by Kendeigh (1952), the incubation constancy of the goldfinch is 94 percent.

TABLE 11. GOLDFINCH NESTING SUCCESS

	1963	No. Nests	1964	No. Nests	1965	No. Nests
Total Eggs Laid	184	38	115	28	103	22
Total Eggs (Complete Clutches)	175	34	108	23	85	16
Deserted Eggs	3	1	....	..	1	1
Infertile Eggs	17	11	4	3	....	..
Embryo Dead In Egg	....	..	3	3	2	1
Loss - Eggs Due to	....	..	....	..	4	1
Wind - Nestlings	....	..	....	..	1	1
Loss due to Wind - Eggs and Rain	....	..	7	2	....	..
Human Eggs	2	2	....	..	....	..
Predation - Nestlings	....	..	1	1	....	..
Animal Eggs	38	11	37	12	26	7
Predation - Nestlings	22	6	11	3	18	4
Eggs Hatched	123	28	64	16	54	12
Starved and Trampled Nestlings	9	7	1	1	....	..
Diseased Young	....	..	3	1	....	..
Nestlings Crowded from Nest	....	..	2	2	....	..
No. Fledged	91	24	46	12	23	5
Per Cent Eggs Producing Fledglings	49	..	40	..	*30	..

*Incomplete results were known on 27 eggs and nestlings, leaving 76 eggs on which the fate was known.

Wetherbee (1961) and Wetherbee and Wetherbee (1961) reported on the incubation times of bird eggs incubated at constant temperature and humidity. I obtained a variation of between 11 and 13 days incubation time for 32 last eggs with a mean of 12.2. From the data presented on incubation one might say that in most cases, incubation begins with the laying of the third or fourth egg. Walkinshaw (1938) checked some nests at night to find when incubation began and found in nests of four eggs it started the day the second egg was laid, as a rule, and at nests of five eggs, about the day the third egg was laid. The large amount of variation in incubation time may be due to difference in constancy of incubation between individuals. The 10 and 22 day periods between laying and hatching are certainly the extremes and the 10 day period does not represent 10-24 hour periods and is probably closer to 11 days. Constant incubation of goldfinch eggs in an incubator has not been reported in the literature.

Nesting Success

Goldfinch nesting success was determined by dividing the number of eggs laid into the number of fledglings leaving the nest.

Ten factors are listed in Table 11 as agents affecting goldfinch nesting success adversely. These are egg desertion, infertile eggs, dead embryos, high winds and heavy rains, human predation animal predation, nestling starvation, diseases of young, and nestlings crowded from the nest. Each year, the birds were studied more intensely and perhaps the increase in my visits to each nest was one reason for a decline in the breeding success.

Nice (1957) reports the fledging success of 29 studies involving 21,951 eggs as varying from 22 to 70 percent with an average of 46. In a study of 14 species in a deciduous scrub habitat, Nolan (1963) reported that 17.6 percent of 598 eggs produced fledglings. Of these, 30.6 percent of 108 goldfinch eggs produced fledglings. Stokes (*op. cit.*) found 49 percent of goldfinch eggs producing fleldglings over a three-year period. He mentioned that Lewis (unpub.) had found 80.3 percent success in 608 nests located in thistle at St. Paul, Minnesota. Stokes listed storms as the only known cause for nest failure but implicated deer mice, garter snakes (*Thamnophis sirtalis*) and death of the female as probable factors. Walkinshow (1939 b) found of 248 eggs laid, 176 hatched and 145 or 58.46 percent fledged. He listed predation and drowning as reasons for young not leaving the nest. Sutton (*op. cit.*) mentioned as possible predators mice, red squirrel (*Tamiasciurus hudsonicus*), Blue Jay (*Cyanocitta cristata*), and garter snake. Walkinshaw (1943) reported the eating of a young goldfinch by a blue racer (*Coluber constrictor flaviventris*).

Very few eggs were deserted and few had dead embryos. There were 24 eggs that were not fertilized. Most of these eggs were the fourth through the sixth eggs of clutches. It would be interesting to know if goldfinch pairs copulate every day throughout egg-laying.

Most of the eggs and nestlings were lost due to predation. I found a garter snake with its head in a goldfinch nest where eggs had been disappearing (one each day) for three days. Half-grown nestlings have been found which were partially eaten or which had the scalps eaten away. This was probably the work of other birds or small rodents.

One nest had young that appeared diseased. They never grew to any extent, reaching only 2.6 g on day four, although the female and male were in attendance.

Often nestlings grew very slowly when hatched one or two days after the others. They were sometimes either trampled by the others or starved and often it was a combination of the two. An adequate food supply appeared to be available but the nests were often very crowded and adult birds usually feed the bird whose mouth opens and reaches the highest. This prevents the younger and smaller individual from receiving enough food.

There were many more goldfinches breeding in 1963 than in the other two years. Because of more rainfall in 1963 and 1965, food may have been more plentiful and, therefore, more eggs were laid per clutch. In 1963, many young were starved and trampled by other nestlings. Perhaps there was more competition for food. In 1964, the clutch size was reduced, perhaps because of less food availability. There was no observed mortality from starvation in this year. Ricklefs (1965) discussed brood reduction and suspected that it was more widespread among altricial birds than had been recognized and that it is a significant factor in determining the clutch size in some species. Lack (*op. cit.*) also discussed the reasons for clutch size variations and starvation of nestlings.

SUMMARY

The American Goldfinch (*Spinus tristis*) was studied for three summers (1963-1965) in Toledo, Ohio. Heavier rainfall in 1963 and 1965 than in 1964 probably accounted for earlier construction because of more food available from composites.

Four stages of nest building and egg laying were found. Each of these stages required less time in August nests than in July nests. Nesting substrate, height of nests, linings of nests and nest dimensions are discussed. Mean nest dimensions were the same for low and high nests and early or late nests. Nest dimensions change with nestling growth, depending on numbers of nestlings. Nesting success was 33 and 43 percent in nests between 24 and 48 and above 48 inches, respectively.

All eggs were laid before the 1000 hour. Seventy-one full clutches of eggs averaged $5.03 \pm .09$ eggs. Clutches were significantly larger ($P < .05$) in 1963 and 1965 than in 1964. There was a mean of 5.1, 5.0, and 4.0 eggs in July, August, and September nests, respectively. Eggs were smaller in larger clutches. Mean egg weight decreased from number one to number two egg. There was a steady increase in mean weight from egg two through egg six. Two hundred and eighteen July eggs had a greater mean weight than 103 August and September eggs but the difference was very little. One hundred sixty four eggs had a mean lesser diameter of 12.8 and a greater diameter of 16.9 mm. The mean egg shape index was 76.0. There is a tendency for last eggs of a clutch to be as large or larger than the others.

Mean incubation for 32 last eggs was 12.2 days with a range of 11 to 13 days. Time interval from laying until hatching was 14.1 (egg one), 13.1 (egg two), 12.4 (egg three), 11.8 (egg four), 11.6 (egg five) and 11.0 (egg six).

Nesting success was 49, 40, and 30 percent respectively, for the three years. Eggs failed to produce fledglings because of deserted eggs, infertile eggs, dead embryos, loss of eggs and nestlings due to heavy rains and wind, human and animal predation, starvation, diseases and nestlings crowded out of the nest prematurely. The possibility of brood reduction is discussed.

A suggestion is made that adequate quantities of composites which produce food for adults and nestlings may be the ultimate factor affecting breeding time of the goldfinch. Photoperiod may be a proximate factor causing gonad development and then adequate food supply may stimulate actual nest building. The food supply is dependent on amount of rainfall.

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