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BREEDING BIOLOGY OF CASSIN'S FINCH,
CARPODACUS CASSINII

A Thesis
Presented to
the Graduate Faculty
Central Washington State College

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
F. John Erickson, Jr.
June, 1969

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INTRODUCTION

In Central Washington the breeding habitat of Cassin's finch (Carpodacus cassinii) extends from the semi-arid bitterbrush (Artemisia tridentata) ponderosa pine (Pinus ponderosa) transition to the moist, cool timberline of the eastern slope of the Cascade Mountains. It breeds from interior British Columbia south to southwestern California, southern Nevada, northern Arizona and northern New Mexico on the eastern and western slopes of the Rocky Mountains. In winter it is found south to the mountains of Mexico.

A summary of known information on Cassin's finch comes from Bent (1968), but a review of this work reveals that detailed information on the species' life history is lacking. The present study was undertaken in an effort to increase our understanding of this species' life history, with special reference to the functional significance of delayed plumage development in males. Field studies were conducted throughout the breeding season, and efforts were made to determine whether or not sub-adult males were successful in acquiring mates. In conjunction with consideration of the function of delayed plumage development in males of this species, a general review of this phenomenon has been undertaken in the order Passeriformes.

In the following discussion, males with red plumage are referred to as adult males, and males in female-like plumage are referred to as sub-adult males.

STUDY AREA

Work was concentrated in the mountainous regions of Kittitas

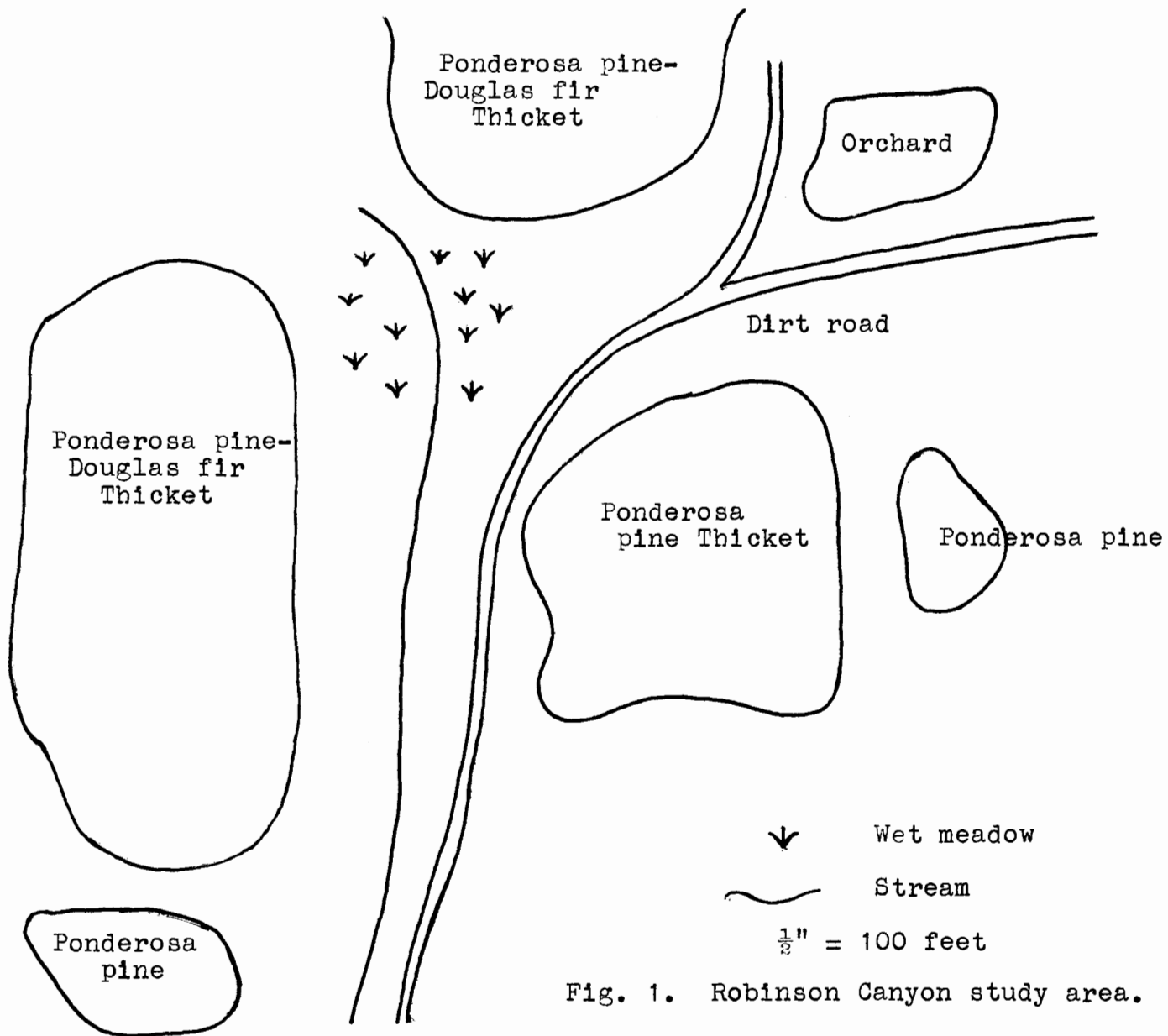


Fig. 1. Robinson Canyon study area.

County, Washington, with the primary study area located in the Robinson Canyon, approximately ten miles west of Ellensburg. The Robinson Canyon study area was mapped (Fig. 1) by locating points on a measured baseline and triangulating from those points to prominent features throughout the remainder of the area. A number of features were added by interpolation from known points. Supplemental data were gathered in the vicinity of Watt Canyon (15 miles west of Ellensburg), Quartz Mountain (25 mi. W.), Red Top Mountain (22 mi. N. E.), Colockum Pass (18 mi. N. E.), Naneum Lookout (20 mi. N.), Wilson Creek (10 mi. N.), and Perkins Creek (15 mi. E.).

The Robinson Canyon population was observed from 19 March through 25 May, 1967, and from 15 March through 10 July, 1968.

The vegetation of the study area was characterized by extensive thickets of ponderosa pine and Douglas fir (Pseudotsuga menziesii), with quaking aspen (Populus tremuloides) found along stream courses. Non-timbered areas supported bitterbrush, buckbrush (Ceanothus vetulinus), ocean spray (Holodiscus discolor) and snowberry (Symphoricarpos albus). Areas in which supplementary data were collected varied in their vegetational composition, some being similar to the Robinson Canyon site, others supporting forests of western larch (Larix occidentalis), silver fir (Abies amabilis), or subalpine fir (Abies lasiocarpa).

The main study area, at an elevation of 3000 feet, included a large basin of about 20 acres, containing a six-acre ponderosa pine and Douglas fir thicket near the center. The ridges surrounding the basin rise to an elevation less than one hundred feet higher than the valley floor and are covered with park-like stands of ponderosa pine

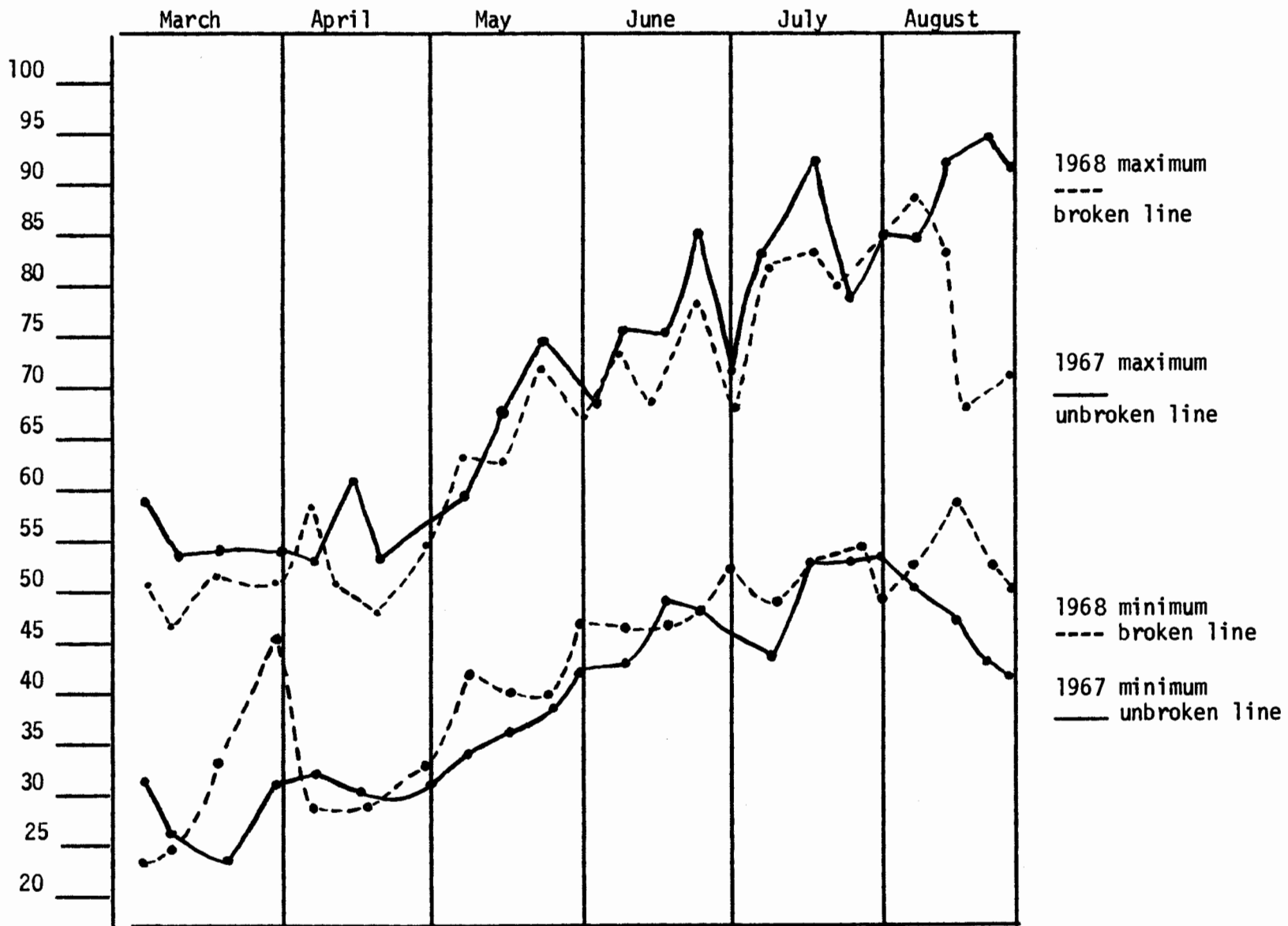
and Douglas fir. The basin is drained by an intermittent stream, bordered along part of its course by a large stand of quaking aspen.

During the early weeks of the 1967 study period, temperatures were relatively cool as compared to 1968. Temperatures dropped near or below freezing at night throughout the months of April and May. Warming trends occurred through June and July, with afternoon temperatures in mid-July reaching the nineties. Precipitation was relatively light. On 21 April, 1968, one inch of snow was recorded. A trace of rain was recorded on four separate days during the 1968 study. High winds were an almost daily occurrence during the months of May and June, velocities normally ranging between ten and fifteen miles per hour. Figure 2 graphs temperatures for the months of April through July, 1967 and 1968, for Ellensburg. The study area is approximately 1300 feet higher than Ellensburg, so the temperatures reported here are probably generally high but should at least be indicative of weekly trends.

METHODS

It was essential for future understanding and work on delayed plumage development to band as many birds as possible. Throughout the course of this study several attempts were made to band adults, using a number of methods. Seed was placed in known foraging areas in an attempt to lure birds into traps, dummies accompanied by playbacks of Cassin's finch songs, and placing nets across nest approaches were among the methods used, but these were not successful. Male 68-1 was captured near the nest when a fledged young was placed on the ground in front of a mist net. When the bird approached the fledgling he was

Figure 2, 1967 and 1968 weekly means of maximum and minimum temperatures, Ellensburg, Washington



flushed into the net. This was the only adult bird banded. Thirteen nestlings were banded, using numbered aluminum bands, with various colored band combinations. Young birds were not banded until at least six days old. Before banding, the young were distinguished by variously marking the feet with red paint.

Observations during the early season were confined to work on the ground. Feeding habits, foraging areas, and general distribution and behavior of birds during the early portion of the season were observed. As nesting activity began and nest sites were located, the nest structures were checked twice daily until egg laying. It was thought that in two cases over-observing caused abandonment of the nest. This occurred once during construction and once during incubation. After egg laying, observation was made from a nearby tree, or if the nest tree were large enough and the nest ideally placed, it was observed from a point in the same tree well above the nest. Nests were located by close observation of females as they gathered materials for construction or by the location of distinct begging calls made by nesting females when they were fed by males.

Eggs were marked with soft lead pencil with a number corresponding to their order of laying. Young finches were weighed daily until they became very restless when approached, usually after about ten days. Descriptions of plumage development were made daily.

Food habits were studied by direct observation of foraging birds and subsequent collection and identification of plants utilized. Periodic collecting of adult birds was carried out in supplemental areas, and stomach contents and testes were preserved for future analysis. Several specimens were prepared as study skins and deposited

in the Central Washington State College museum. Eleven sub-adult males and ten adult males were collected for comparative gonadal analysis.

All nests were collected at the end of the breeding season, weighed, and carefully dismantled to determine construction materials. Measurements were made of nests shortly before or during egg laying.

RESULTS

Spring arrival and pair formation

In 1968, the main study area was visited twice weekly in late March and daily during April. The arrival of Cassin's finches during the 1968 season occurred on 12 April, two weeks later than the previous year. One male was singing on the morning of 12 April. On the morning of 13 April an adult male and a female were observed together. These birds appeared to be paired, staying very close together as they foraged about the area. At 6:00 a. m., 16 April, four adult males were heard singing in the study area. On subsequent days it was common to observe as many as thirty individuals in this area. Paired individuals were observed early, 13 April and 17 April, which leads me to believe that pair formation may, at least in some cases, occur before arrival on the breeding grounds. If conspicuous pair formation behavior occurs in the species, it was not observed in this study.

Only on one occasion were two males observed in a dispute over a female. An adult male and a female were feeding on the ground in a bitterbrush clearing about mid-day. A second adult male arrived and immediately performed a display before the female. This display consisted of fanning the tail, fluttering the wings, and tipping the head back, while the male walked a short path back and forth in front

of the female. At the height of this display, the female flew, pursued by the intruding male, who was immediately chased and driven from the scene by the apparently paired male.

On another occasion, a mounted specimen of an adult male was placed in a tree twenty feet from the base of a tree containing a nest under construction 35 feet from the ground. A speaker was placed beneath the dummy, and recorded songs of an adult male Cassin's finch were broadcast over the speaker for a period of about ten minutes. The female that was building the nest flew and perched within a foot of the dummy. Her mate landed on a nearby branch and displayed as described above, in front of the female. No aggressive display was made toward the dummy by either sex. Before playback of the songs ceased both birds left the area of the stuffed bird and were not observed near the mount during periodic checks the remainder of the day, even though further playbacks were carried out.

Territoriality

Cassin's finches tend to stay in flocks throughout the spring, fall, and winter, and it is not uncommon to find them in foraging flocks of five to fifteen individuals throughout the breeding season. In most cases in which flocks were observed, the birds were either feeding or migrating through the study area. In some instances, very early in the spring, groups of males were noted singing from the same tree. In one such example, four adult males were seen in a ponderosa pine snag, all singing. They were joined by a fifth adult male that had been singing for twelve minutes in a nearby Douglas fir.

It is apparent from some of the above examples that territoriality is not a strongly enforced phenomenon in Cassin's finch males.

It was difficult to determine whether or not males recognized explicit territorial boundaries, for they were very flighty when observed on song perch. They would commonly sing at one location for periods of up to ten minutes, then make very long flights across the area, sometimes up to several hundred yards in length, occasionally passing between two major song perches of other males. Males were commonly observed to venture near nest locations of other males with no apparent reaction toward one another. It was common, while I checked a nest site, to have three to five neighboring finches, including males, attracted by the distress calls of the nesting pair, and no attempt was made by the nest-owners to drive the other finches away.

Adult males were observed singing while in flight many times daily during the first weeks of the breeding season. This display was characterized by wings held at high angles above the body and tail widely fanned, while the bird floated through the air singing. Sub-adult males were not noted in this type of display. Flight song was observed daily through mid-June but not often after that. These flights often passed through the apparent territory of other adult males, as determined by observation of song perches.

Nest building

The nesting season for Cassin's finch begins in May, rather early for an inhabitant of montane regions, and extends into July (Orr, 1968.) In Robinson Canyon the first nesting activity was observed on 4 May, 1968. Nests constructed during July probably represented replacement clutches for nests destroyed during the early part of the season. The height of the breeding season occurred in late

May, when egg laying began, and early June when most nests had young in them. There were apparently no cases of double-broodedness.

In Robinson Canyon nest construction was observed only during the 1968 season. Nine nests were found through the course of the 1968 season. Of the total of twelve nests found in the study area over the two seasons, ten were in ponderosa pine and two in Douglas fir. Measured nest heights ranged from 25 feet, 3 inches to 63 feet, 8 inches, the mean being 38 feet, 8 inches. Nests observed in Colockum Pass were placed in western larch and were estimated to be sixty to eighty feet from the ground, on horizontal branches. Nests located in other areas ranged within the limits of those found in Robinson Canyon. Nests were placed, in all cases, in densely foliated portions of branches and were not readily distinguishable from the ground.

The actual construction of nests was observed in five cases. On 4 May 1968, a female was noted carrying nest material to nest 68-1 at 8:30 a. m. Examination of the ponderosa pine in which the bird left the material revealed a small platform of dead twigs. The structure was located 33 feet above the ground in the dense top of the tree. The nest required seven days for construction, being built of twigs, rootlets, grasses, and lichens, sparsely interwoven with horse hairs. The lining of the structure was composed of deer, elk, cattle, and horse hairs.

At nest 68-3, a female was observed carrying small twigs to the top of a Douglas fir on 15 May. The male of this pair was a sub-adult bird who sang in a nearby snag as the female gathered materials. This nest was located about two days after construction began, and the lining was completed five days after its discovery. The nest probably required seven days for construction.

Nest 68-4 was also found during the construction period. A female carrying lichens in her beak was followed to the nest site, the top of a ponderosa pine, 25 feet, 4 inches above the ground. The nest was probably in its second day of construction when located at 6:30 a. m. on 21 May 1968. The structure was completed on 24 May, thus requiring about five days for construction. The male also was a sub-adult.

On 18 June nest 68-8 was located, apparently in its second day of construction, in a ponderosa pine 38 feet above the ground near the bushy top of the tree. It consisted of a layer of dead twigs with a layer of lichens placed on top. When checked on the fourth day of construction it was found that all of the material had been removed, possibly as a direct result of my repeated intrusions.

A rather novel observation was made during the construction of nest 68-6, found on 24 May in a large ponderosa pine, 49 feet, 8 inches from the ground. The nest was at the tip of a horizontal branch about ten feet from the trunk of the tree. Approximately ten feet from this nest, about five feet higher, a western tanager (Piranga ludoviciana) female was busy constructing a nest. When the tanager left its nest site, the female finch removed twigs from the structure and placed them in her own nest. On 24 May the female finch was seen taking material from the tanager nest three times. This nest was completed on 26 May.

In all cases observed the female was solely responsible for the construction of the nest. Materials were gathered away from the nest area in most cases. Many materials were gathered in the fir-pine thickets where twigs and lichens were removed from the dead limbs below the forest canopy. Twigs of oceanspray and snowberry were gathered in non-timbered areas. Rootlets were gathered from exposed dirt banks

Table 1. Weights (in grams) of materials in five nests of the 1968 breeding season.

Materials	Nests				Perkins Cr.	total	%
	68-3	68-4	68-5	68-7			
Lining	2.72	1.93	.71	2.54	1.64	9.54	16.6
Twigs: oceanspray	.62	.91	2.65	1.23	3.70	9.11	15.7
Douglas fir	2.50	.80	2.03	-	-	5.33	9.2
Lichens:	3.15	3.85	4.63	4.79	4.81	11.23	34.9
Herbaceous stems	.74	1.80	1.06	1.66	-	5.26	9.1
Rootlets	-	.12	.41	.79	2.37	3.69	6.4
Leaves: ponderosa pine	.58	-	-	-	-	.58	1.0
Debris and dirt	.95	.65	.43	.52	.76	3.15	6.0
Total	11.26	11.06	11.92	11.37	13.28	57.89	99.4

along roadways in the area. Lining materials were gathered on the ground throughout the study area. Nest construction occurred throughout the day at scattered intervals, with increased time spent in nest construction during the early morning hours.

Egg laying

Egg laying occurred during the early morning hours. Time of laying was determined for fourteen eggs at three nests. The eggs in these nests were laid between 5:00 and 6:00 a. m., PST.

Orr (1968) states that the number of eggs laid by Cassin's finch ranges from three to six, with four or five generally comprising a clutch. In this study, nine nests were believed to contain complete clutches, ranging from three to five, with an average of 4.2 eggs per clutch.

The eggs are ovate. The ground color is bluish-green and small olive brown spots are found, usually toward the larger end of the egg but sometimes scattered evenly over the surface. One egg found in the Perkins Creek area lacked spots.

The measurements of fifty eggs averaged 20.3 by 14.7 millimeters; the eggs showing the four extremes measured 23.9 by 16.3, 18.5 by 14.8, and 19.2 by 13.4 millimeters (Orr, 1968.)

Incubation

Incubation was the sole responsibility of the female. Only when feeding the incubating female did males show any interest in the nest site. Males approached the nest site at intervals ranging from fifteen minutes to one hour and landed in a nearby tree; the female then left the nest and landed near the male. A begging posture was

then assumed by the female: head cocked back, tail fanned, and wings fluttered rapidly and persistently, similar to the earlier described display of the male. During this display, the female made loud cheeping vocalizations. The location of these vocalizations aided in the discovery of nest sites during the incubation period.

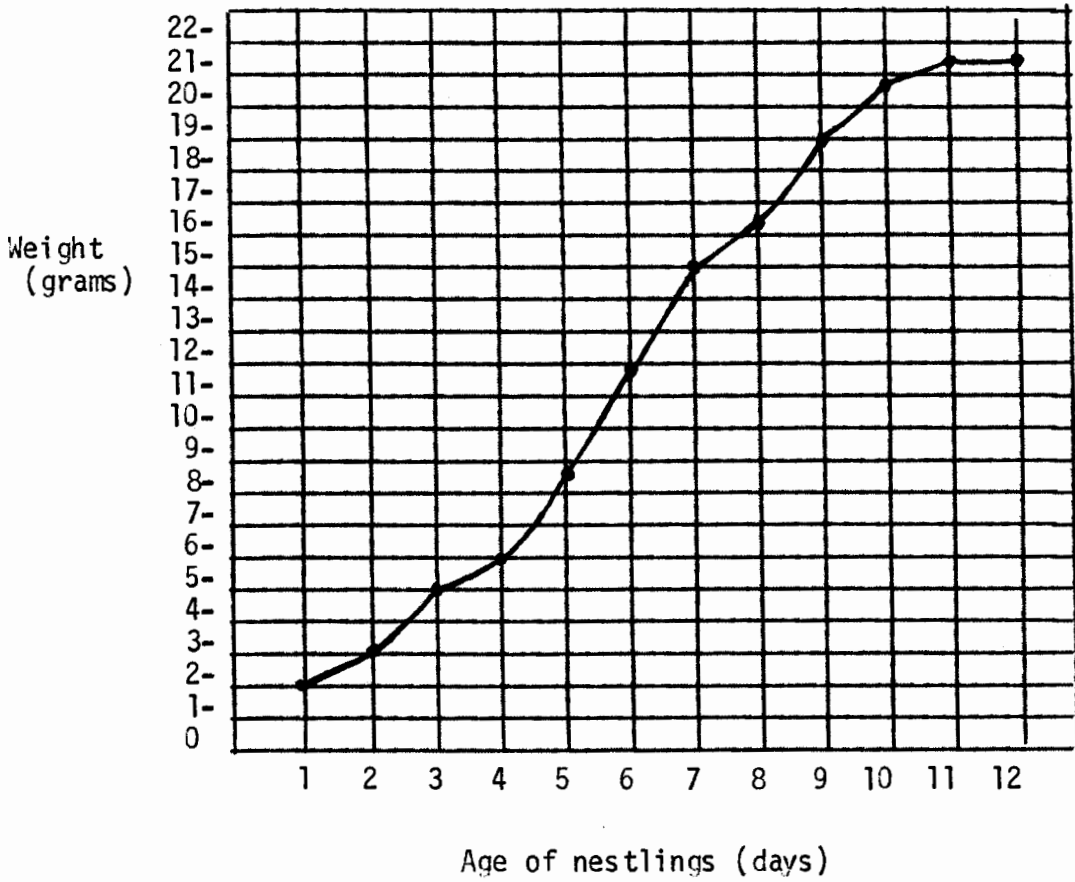
The incubation period, i. e. the time interval from laying of the last egg to hatching of the last egg was determined to be twelve days at five nests and thirteen days at a sixth nest. In all instances but one, incubation was begun with the laying of the final egg in the clutch, as determined by observations of the presence of the female at the nest. The one exception was at nest 68-6, where incubation apparently began with the laying of the first egg. Hatching period, i. e. the time interval between hatching of the first and last eggs, showed great variation among nests. In nests 68-1 and 68-7 the hatching period was almost twenty-four hours. At nests 68-3 and 68-4 all young hatched within a period of two hours. At 68-6 the period of hatching was eight hours.

Nestling period

In most cases the placement of nests required lowering of young to the ground for weighing. To avoid injury to young, records of weights were kept only at nest 68-6 (see Table 2.) The nest tree and the placement of the nest in this case afforded a site at which a platform could be constructed to hold a triple-beam balance.

A protective covering was placed around the balance to eliminate interference from wind. A spring balance could not be used because of wind conditions. Young were removed from the nest individually, weighed, their plumage examined, and returned to the nest.

Table 2. Mean daily weight gain of five nestlings in next 68-6.



The female stayed very near the nest during all observations.

At hatching the young were naked except for sparse patches of medium-gray down above the eyes and on the top of the head. The spinal, humeral, and ventral tracts were sparsely clothed with down; the remainder of the body was naked, the skin being flesh-colored. The eyes of the young were not open at that time.

The young birds gaped when a squeaking noise was made near the nest. The inside of the mouth was bright reddish-pink, and the edge was creamy yellow in color. Audible peeping noises were made by the young shortly after they hatched.

The following description is an average for the five young of nest 68-6, supplemented by observations from nests 68-1, 68-3, 68-7 and 68-9.

One day old. There was little, if any, change in the plumage. The remiges and rectrices were visible as dark lines along the wings and tail. Dark lines appeared on the wings and on the tail along covert tracts; dark lines also appeared on the ventral tracts. The abdomen was naked and protruding.

Two days old. Feathers of the ventral tracts were beginning to break through skin. Feather growth was also noted on the capital tract. Eye slits were open partially. Down appeared slightly longer and more dense.

Three days old. Ventral feather tract sheaths were broken through the skin completely. Down had not increased in length, about 10mm.

Four days old. Primary and secondary sheaths had broken through the skin. Dorsal feather tract became visible as feather

sheaths started to break the skin.

Five days old. Young had their eyes completely open. Primary and secondary feather sheaths were completely exposed, feathers were breaking their sheaths slightly. Dorsal tract feathers were beginning to break through the skin.

Six days old. Ventral feather tracts were becoming more dense and formed two feathered strips on the underside of the bird. The young were now very alert and beginning to show an awareness of the observer. When removed for weighing, they emitted a squeaking distress call which brought the parents very near.

Seven days old. Contour feather tracts were beginning to fill out. Dorsal tract feathers covered the body well. The flanks were bare, and the thighs were sparsely feathered; the down on the head was slight and down on the back was becoming less apparent. The humeral tracts were evident when the wing was extended. The young were beginning to appear well feathered, but the midline and abdomen were still bare. The capital tract was slightly feathered, but bare spots still remained on the head.

Eight days old. The young were large enough for banding. Rectrices were well out of their sheaths and measured five millimeters in length.

Nine days old. Primary feathers were out of their sheaths seven millimeters. Down still remained on the body and above the eyes. Naked spots appeared on the flanks, abdomen, and around the bases of the wings; the apterium in the mid-ventral line was still visible.

Ten days old. The primaries were about fifteen millimeters long. Feathers on the abdomen were beginning to take the streaked

appearance of the adult female. The young were beginning to show a great fear of being handled.

Eleven days old. Only four young were weighed in this sample, the fifth having fallen out of the nest during the night. Measurements were not made from this point because the young were too likely to leave the nest prematurely when disturbed.

The nestling period lasted 16 days at nest 68-6 and 14 days at nest 68-7.

A fledgling captured on 20 June 1968 was measured and held in captivity for five days before it died. When collected, this young was judged to be about five days out of the nest. Measurements of feathers exposed from their sheaths were as follows: primary feathers 45-50 mm; secondary wing feathers, 30-48 mm; rectrices, 25-30 mm; spinal tract, 17 mm; ventral tract, 20 mm; crural tract, scantily covered with feathers 5 mm in length; femoral tract, 15 mm; humeral tract, 9 mm; capital tract, 7 mm. The young bird appeared similar to the female in plumage. Breast streaks were not as distinct as in the adult. Yellow was present at the corners of the mouth. The fledgling lacked the distinct white background beneath the streaking, and the plumage appeared to be very ragged.

Food for nestlings was gathered almost entirely by the female in the instances observed. In one case, male 68-6 was observed feeding regurgitated material to the brooding female, who then proceeded to feed the young. This was the only recorded observation of a male participating in the care of young. Females were noted to gather food in the immediate vicinity of the nest as well as in areas some distance from the nest site. At nests 68-1 and 68-4, located in the central pine-fir

thicket, and nests 68-5 and 68-9 on the south border of the meadow (Fig. 1), food was gathered away from the nest area in most cases, often in the thickets on the opposite side of the meadow. At all other nests in the study area, where the raising of young was observed, a great deal of food was collected in the general vicinity of the nest. Those areas were characterized by large ponderosa pine or Douglas fir of sixty to one hundred feet in height. The other nests were located in areas of forest height ranging from ten to forty feet. I was not able to draw any direct correlation between the character of the nesting habitat and the amount of time the birds fed in the vicinity of the nest.

Observation of female 68-6 revealed that she rarely traveled over one hundred yards from the nest site to feed. This nest was located on the edge of a burned area where bitterbrush and ocean spray were the dominant plant species.

Superficial observation of feeding revealed that a great deal of plant matter, in the form of seeds, was fed to the young, in addition to large quantities of insect matter. The transparent nature of the skin on the neck of nestlings made a general examination of esophageal contents possible. A more comprehensive analysis of materials follows in the section entitled Food Habits.

Fecal sacs were removed from the nest by the female during the first three to four days. During the remainder of the nestling period excrement was deposited in a layer on the rim of the nest, in some cases falling from the nest, but in most instances simply fouling the nest.

Fledgling Period

The first flight of nestling number 101-108301, nest 68-1, covered a distance of 120 feet across a clearing to an aspen thicket. The remaining young left the nest and stayed in the immediate vicinity during the remainder of the day. They were not seen again after that day.

When the young fledged from nests 68-6 and 68-7, they were observed perching in the high branches of the nest trees and other trees surrounding the nest trees. A check on the day after fledging revealed that young and adults had left the area of nest 68-6, but at 68-7 young were seen in the vicinity two days after they left the nest. Four days after fledging, young number 101-108304 was observed being fed by the female, about 120 feet from the nest from which it had fledged.

The previously-mentioned fledgling, captured on 20 June 1968, was observed perched in a small ponderosa pine about five feet from the ground. This young was being fed by a female with an adult male nearby. The male was not seen attending the young bird. (No male was ever observed to feed a fledgling, although very few observations were obtained on the care of fledglings.)

The fledglings had a feeding call similar to that described for the incubating female when she was fed by the male. When not being fed, the young birds sat quietly on the dead branches of a large pine or on the bare branches, near the trunk, of smaller pines or firs.

As the month of July progressed, fewer finches were noted in the study area. Males were heard occasionally, but it was clear that

a substantial percentage of the population had left the area. Small flocks of birds were more frequently observed than at the height of the nesting season. On 10 July 1968 a flock of eight to ten finches - males, females, and young - was observed about one mile east of the study area, at an elevation of about 2500 feet, in an area known not to contain a breeding population. A female was seen feeding a well-developed young there.

Enemies

Direct observation of predation was not made during the course of the study, but the results of attack by predators were seen in several instances. A nest found on 26 May 1968, in the Perkins Creek area, was checked one week later and found to contain three broken eggs. The predator in this case was not known.

In the Robinson Canyon the Steller's jay (Cyanocitta stelleri), known for destroying the eggs of smaller birds (Jewett, 1953), was a common resident. Black-billed magpies (Pica pica) were also observed in the area. This corvid is another common predator of bird eggs and young (Jewett, 1953.) On one occasion, when I was checking nest 68-6, the scolding of the female brought a Steller's jay to the vicinity of the nest. On another occasion a Steller's jay was noted harrassing a fledgling as it was fed by a female. The jay left as I approached.

During the construction of nest 68-4 a yellow pine chipmunk (Eutamias amoenus) was flushed from the nest on two separate mornings. On two other occasions a chipmunk was seen in the tree near the nest. On the tenth day of incubation the eggs in this nest were destroyed by an unknown predator. On many occasions chipmunks were chased from

the nest trees by nesting finches. At nest number 68-6 chipmunks were harrassed and forced to leave the nest tree by the female finch on two separate occasions. At nest number 68-5 a chipmunk was chased from the nest tree by the male and the female. This pair also was noticed harrassing a pair of chipping sparrows (Spizella passerina) which landed in the nest tree. The chipping sparrows were chased from the area near the nest.

The alarm cry of a Cassin's finch female once lead the observer to a long-eared owl (Asio otus) crouching in a Douglas fir thicket. The finch sat about 20 feet from the owl and produced a loud distress call. The owl flushed and was immediately followed about one hundred yards to another point in the thicket, where the female finch continued to voice the presence of the intruder. The major portion of the diet of this owl does not include small birds (Jewett, 1953.)

Nest 68-3 was destroyed during the nestling period when the young were one day old. In this instance it was not determined whether the nest was destroyed by a predator or by wind conditions. The location of the nest, near the top of a 70-foot Douglas fir, may have subjected the structure to great stress by windy conditions. The nest was broken apart and one young was missing when the nest was examined. Two young remained in the nest and were consumed by ants (Formicidae).

Brown-headed cowbird (Molothrus ater) parasitism of Cassin's finches was not recorded in the study area, although parasitism did occur in a western tanager nest located about ten feet from nest 68-6. Another western tanager nest, containing one cowbird egg and two tanager eggs was found on the north edge of the study area. The brown-headed cowbird was a common species in the study area.

Food Habits

During the early part of the breeding season, finches were observed feeding only on the ground, where they concentrated their efforts on seeds of two common annuals, Phlox gracilis and Collinsia parviflora. These seeds were gathered in open areas and in park-like timbered areas. Seeds of ponderosa pine and Douglas fir were taken in some cases. As the season progressed and a third annual (Montia linearis) matured, it became a third major component of the diet. As early as 4 May 1968 a male was observed taking insect larvae from the branches of Douglas fir. On one occasion a male took insect larvae and flew to within six inches of his mate, where the larvae were consumed by the male. The female showed aggression toward the male after this, chasing him about the immediate area for about fifteen seconds. The progression of the breeding season brought a shift of feeding into shrubs and tree branches where insects comprised a greater portion of the diet than earlier. Seeds were still collected on the ground, but not as frequently as before. A total of 25 stomachs was collected from 17 April to 22 June, 1968. Eight of these, five females and three males, all collected at the height of the breeding season, contained insect material. The majority of insect matter consisted of Lepidopteran larvae of the families Tortricidae and Syrphidae, with smaller amounts of aphids. (Aphidae), and three species of ants (Formicidae.)

On 28 May, a pair of finches was observed feeding on aphids in the branches of ocean spray. On 1 July, a female was observed feeding on larval insects in bitterbrush.

Table 3. Percentage of individuals in which representative food types were present.

Food	April (N=4)	May (N=14)	June (N=7)
Plant material			
<u>Pinus ponderosa</u> seeds	33%	17%	
<u>Phlox gracilis</u> seeds	100%	64%	40%
<u>Colinsia parviflora</u> seeds	100%	29%	
<u>Pseudotsuga menzeisii</u> seeds		17%	
Montia linearis seeds		50%	40%
Composite seeds		21%	
Insect material (family)			
Formicidae		17%	14%
Tortricidae			30%
Syrphidae			30%
Aphidae			30%
Unidentifiable		29%	71%

Hawking for insects was observed on one occasion, 18 June 1968, when a female took flying moths three separate times in the manner of a flycatcher; sitting on a branch, flying out a few yards and returning with the prey. These insects were shortly afterwards fed to the fledgling.

It is evident from the data that as the breeding season progresses and nestlings begin to appear there is a change in dietary preference from seeds to insects.

Plumages

Jewett (1953) describes the adult plumages of Carpodacus cassinii venifer as follows: "Adult male, top of head with squarish patch of bright crimson, rump dull rose pink; back and scapulars dull pinkish brown, sharply streaked with dark brown; underparts pale pink fading to unstreaked white on belly; lower tail coverts usually conspicuously streaked with dusky; wing feathers edged with reddish; tail much shorter than wing, deeply emarginate. Adult female: whole body sharply streaked with dusky; ground color of upperparts olive gray; underparts white. Young: similar to female, but streaks of lower parts narrower and wing edgings more ochraceous."

A description of sub-adult males is not available in the literature. A comparison of five adult females and four sub-adult males in the Central Washington State College collection reveals that there are no substantial criteria which can be satisfactorily used for distinguishing the plumages of these birds.

Data are lacking in this study on the development of plumages. Birds in juvenal plumage were observed as early as 10 July during the 1968 season, but after this time it became difficult to locate birds

in the study area. Finches were observed during mid-August at elevations of five to six thousand feet. These birds were seen in flocks of varying size, up to twenty individuals. Apparently there is a period of migration within the breeding habitat before southward migration. On 19 October 1967, approximately 25 finches, apparently a migratory flock, were seen in the sagebrush areas fifteen miles east of Ellensburg.

DISCUSSION

The most interesting problem emerging from the present study relates to the evolutionary implications of successful breeding among sub-adult males. Meager though the data are, they do confirm the fact that sub-adult males acquire mates and rear young. It is essential to the understanding of delayed plumage development in this species to know if sub-adult males are equally successful in attracting mates as are adult males. Unfortunately the data are not adequate in the present study, and to obtain them would require the color-banding of large numbers of Cassin's finches for a period of several years.

To obtain a broader perspective of the general pattern of delayed plumage development among males of sexually dimorphic species, a review of this phenomenon in 103 sexually dichromatic Passerine species was undertaken in the literature.

Of these 103 sexually dichromatic species, males of 36 are reported to commonly require more than one year to acquire full adult plumage. Of that number, males of 13 normally resemble the breeding female in their first year, and males of five of these species reportedly breed in their first year. In the other 23 species, males

Table 4. Review of the presence or absence of delayed male plumage development in sexually dichromatic, North American Passerine birds. List of dichromatic species from Verner and Wilson (in press); data on plumage development from Bent (1942, 1947, 1948, 1949, 1950, 1953, 1958, 1968 a, b, c.)

Common name	Scientific name	Reported delay	Reportedly no delay	No data
Rose-throated becard	<u>Platypsaris aglaiae</u>			X
Vermilion flycatcher	<u>Pyrocephalus rubinus</u>			X
Purple martin	<u>Progne subis</u>	X		
Black-eared bushtit	<u>Psaltriparus melanotis</u>			X
Varied thrush	<u>Ixoreus naevius</u>			X
Eastern bluebird	<u>Sialia sialis</u>		X	
Western bluebird	<u>Sialia mexicana</u>		X	
Mountain bluebird	<u>Sialia currucoides</u>		X	
Wheatear	<u>Oenanthe oenanthe</u>			X
Bluethroat	<u>Luscinia svecica</u>			X
Blue-gray gnatcatcher	<u>Polioptila caerulea</u>			X
Black-tailed gnatcatcher	<u>Polioptila melanura</u>			X
Golden-crowned kinglet	<u>Regulus satrapa</u>		X	
Ruby-crowned kinglet	<u>Regulus calendula</u>	X		
Black-capped vireo	<u>Vireo atricapilla</u>			X
Black-and white warbler	<u>Mniotilta varia</u>		X	
Prothonotary warbler	<u>Prothonotaria citrea</u>			X
Golden-winged warbler	<u>Vermivora chrysoptera</u>			X
Blue-winged warbler	<u>Vermivora pinus</u>		X	
Bachman's warbler	<u>Vermivora bachmanii</u>	X		
Nashville warbler	<u>Vermivora ruficapilla</u>			X
Parula warbler		X		
Olive-backed warbler	<u>Parula pitiayumi</u>			X
Olive warbler	<u>Peucedramus taeniatus</u>	X		
Yellow warbler	<u>Dendroica petechia</u>		X	
Cape May warbler	<u>Dendroica tigrina</u>		X	
Black-throated Blue warbler	<u>Dendroica coerulescens</u>			X

Common name	Scientific name	Reported delay	No delay	No data
Myrtle warbler	<i>Dendroica coronata</i>		X	
Audubon's warbler	<i>Dendroica auduboni</i>		X	
Black-throated Gray warbler	<i>Dendroica nigrescens</i>	X		
Townsend's warbler	<i>Dendroica townsendi</i>		X	
Black-throated Green warbler	<i>Dendroica virens</i>		X	
Golden-cheeked warbler	<i>Dendroica chrysoparia</i>		X	
Hermit warbler	<i>Dendroica occidentalis</i>			X
Cerulean warbler			X	
Blackburnian warbler	<i>Dendroica fusca</i>		X	
Bay-breasted warbler	<i>Dendroica castanea</i>		X	
Blackpoll warbler	<i>Dendroica striata</i>		X	
Pine warbler	<i>Dendroica pinus</i>		X	
Kirtland's warbler	<i>Dendroica Kirtlandii</i>	X		
Prairie warbler	<i>Dendroica discolor</i>		X	
Kentucky warbler	<i>Oporornis formosus</i>		X	
Connecticut warbler	<i>Oporornis agilis</i>	X		
Mourning warbler	<i>Oporornis philadelphia</i>			X
MacGillivray's warbler	<i>Oporornis tolmiei</i>	X		
Yellowthroat	<i>Geothlypis trichas</i>		X	
Ground-chat	<i>Chamaethlypis poliocephala</i>		X	
Hooded warbler	<i>Wilsonia citrina</i>		X	
Wilson's warbler	<i>Wilsonia pusilla</i>		X	
Canada warbler	<i>Wilsonia canadensis</i>		X	
American redstart	<i>Setophaga ruticilla</i>	X		
Bobolink	<i>Dolichonyx oryzivorus</i>			X
Yellow-headed blackbird	<i>Xanthocephalus xanthocephalus</i>	X		
Red-winged blackbird	<i>Agelaius phoeniceus</i>	X		
Tri-colored blackbird	<i>Agelaius tricolor</i>	X		
Orchard oriole	<i>Icterus spurius</i>	X		
Black-headed oriole	<i>Icterus graduacauda</i>	X		
Hooded oriole	<i>Icterus cucullatus</i>	X		
Scott's oriole	<i>Icterus gularis</i>	X		

Common name	Scientific name	Reported delay	No delay	No data
Baltimore oriole	<u>Icterus galbula</u>		X	
Bullock's oriole	<u>Icterus bullockii</u>	X		
Rusty blackbird	<u>Euphagus carolinus</u>			X
Brewer's blackbird	<u>Euphagus cyanocephalus</u>			X
Boat-tailed grackle	<u>Cassidix mexicanus</u>			X
Great-tailed grackle	<u>Cassidix palustris</u>			X
Common grackle	<u>Quiscalus quiscula</u>			X
Western tanager	<u>Piranga ludoviciana</u>	X		
Scarlet tanager	<u>Piranga olivacea</u>	X		
Hepatic tanager	<u>Piranga flava</u>	X		
Summer tanager	<u>Piranga rubra</u>	X		
Cardinal	<u>Richmondia cardinalis</u>		X	
Pyrrhuloxia	<u>Pyrrhuloxia sinuata</u>		X	
Rose-breasted grosbeak	<u>Pheucticus ludovicianus</u>	X		
Black-headed grosbeak	<u>Pheucticus melanocephalus</u>	X		
Blue grosbeak	<u>Guiraca caerulea</u>	X		
Indigo bunting	<u>Passerina cyanea</u>	X		
Lazuli bunting	<u>Passerina amoena</u>	X		
Varied bunting	<u>Passerina versicolor</u>	X		
Painted bunting	<u>Passerina ciris</u>	X		
Dickcissel	<u>Spiza americana</u>			X
Evening grosbeak	<u>Hesperiphona vespertina</u>		X	
Purple finch	<u>Carpodacus purpureus</u>	X		
Cassin's finch	<u>Carpodacus cassinii</u>	X		
House finch	<u>Carpodacus mexicanus</u>		X	
White-collared seedeater	<u>Sporophila torqueola</u>	X		
Pine grosbeak	<u>Pinicola enucleator</u>		X	
Black Rosy finch	<u>Leucosticte atrata</u>		X	
Hoary redpoll	<u>Acanthis hornemanni</u>		X	
Common redpoll	<u>Acanthis flammea</u>	X		
American goldfinch	<u>Spinus pinus</u>		X	
Lawrence's goldfinch	<u>Spinus lawrencei</u>			X

Common name	Scientific name	Reported delay	No delay	No data
Lesser goldfinch	<u>Spinus psaltria</u>			X
White-winged crossbill	<u>Loxia leucoptera</u>	X		
Red crossbill	<u>Loxia curvirostra</u>		X	
Rufous-sided towhee	<u>Pipilo erythrophthalmus</u>		X	
Lark bunting	<u>Calamospiza melanocorys</u>	X		
Black-chinned sparrow	<u>Spizella atrogularis</u>			X
McCown's longspur	<u>Rhynchophanes mccownii</u>			X
Lapland longspur	<u>Calcarius lapponicus</u>	X		
Smith's longspur	<u>Calcarius pictus</u>			X
Chestnut-collared longspur	<u>Calcarius ornatus</u>			X
Snow bunting	<u>Plectrophenax nivalis</u>		X	
Mckay's bunting	<u>Plectrophenax hyperboreus</u>			X

are intermediate in their plumage characters between adult females and males in full breeding plumage. Of the remaining 67 species, males of 37 reportedly acquire full adult male plumage within one year, and insufficient data are available on the remaining 30 species to permit a decision on the rate of plumage development in males.

In order to make this analysis complete one would need to know how many individuals of each species exhibit first-year delays and how many do not.

While the adaptive significance of delayed plumage development in males of sexually dichromatic species remains obscure, particularly in view of the fact that, at least in some species, males in female-like plumage reproduce successfully, the following model is offered as a possibility. The acquisition of brightly colored plumage probably enhances the courtship display of the males and hence their ability to attract mates. At the same time, the sacrifice of crypticity increases the male's vulnerability to predation. If acquisition of full adult plumage in males is delayed one year, the birds have an opportunity to learn predator avoidance while being minimally conspicuous to predators. Later acquisition of conspicuous plumage characteristics would thus not endanger the individual as much as acquiring the same coloration at an earlier age.

If this were the only factor involved, one would predict that sexual dichromatism would not have evolved in these species. However, selection should favor those females pairing with older males, since such males have already demonstrated their capacity to survive, and it would be to each female's advantage to have this survival potential transmitted to her offspring. Consequently sexual selection should

favor the development of sexual dichromatism, and fully adult males would then represent a compromise between selection for conspicuous coloration and its attendant advantages in attracting mates, and selection for cryptic coloration, an advantage for predator avoidance. The present model depends upon the proposition that the balance in this compromise is shifted toward conspicuous coloration as a result of the experience acquired by the male during its first year or so of life. It follows from the model that, on the average, males in fully adult plumage should be more successful in acquiring mates than males in female-like plumage. If this were true, and if some males failed to acquire mates, a significantly higher percentage of sub-adult males should be without mates. If, on the other hand, all males acquire mates, then the date of initial pairing among sub-adult males should be significantly later than that among fully adult males. This was not true in the present study, at least as judged by the initiation of egg-laying in the various nests involved; however, the sample size is insufficient to attach any significance to these results. Moreover, limited data suggest that pair formation may occur in winter flocks, thus precluding the possibility of having established a time of initial pairing among the birds in the present study.

In a further attempt to understand the evolutionary significance of delayed plumage development, a color analysis was made in the 73 species of Passerine birds which are known either to exhibit delays or not to exhibit delays. Table 5 shows the number of species in which each of the colors listed occurs. From this table it is seen that the colors red and yellow show a definite variation in the numbers of times they occur between the delay group and the non-delay group; red appears

14 times in the delay group but only 7 times in the non-delay group, while yellow occurs 10 times in the delay group and 18 times in the non-delay group.

If we assume that species exhibiting delays are equally likely to show red and yellow in their plumage, the probability of a 14 : 10 distribution in the occurrence of these two colors is 0.117.* Thus there is no significant deviation from expectation in these colors in the delay group. In the non-delay group, however, the probability of a 7 : 18 distribution is only 0.001*, indicating that red occurs significantly less frequently among the non-delay group than does yellow. Similarly, red is significantly (P of 14 : 7 distribution = 0.005*) more likely to occur in the delay group than in the non-delay group. Additionally the chi square test indicates that the occurrence of red and yellow in the plumage of delay and non-delay species deviates significantly from random ($\chi^2 = 9.37$; 0.01 P 0.001).

These results can be explained within the framework of the model if it can be shown that red is more conspicuous to birds, especially to birds of prey, than is yellow. The relative infrequency of red colors in the vegetation of most habitats, in contrast to the commonness of yellow colors, may be sufficient to result in red being more conspicuous than yellow.

$\frac{N!}{n!(N-n)!} (P)^n (q)^{N-n}$ *Probability calculated directly according to the formula where N=the total number of observations, n=the number of observations in one category, N-n=the number of observations in the other category, p=the probability of n and q=the probability of N-n.

Table 5. Number of sexually dichromatic species in which various colors occur in the plumage of males.

Color	Species with delayed male plumage development	Species without delayed male plumage development
red	14	7
yellow	10	18
white	12	13
black	17	18
blue	9	6
green	4	6
brown	4	4
orange	3	3
purple	2	0
gray	0	1

The 73 species were then divided, roughly, into size categories (1=warbler-sized, 2=finch-sized, and 3=robin-sized birds). Among the delay group there were 10 size 1 species, 11 size 2, and 16 size 3 ($X=2.16$); among the non-delay group there were 21 size 1 species, 9 size 2, and 6 size 3 ($X=.58$). Student's t test indicates that the difference between these means is not significant ($t=0.362$; $0.40 P$ 0.35). To properly test this possibility, however, one would need to examine the difference between mean weights (assuming weight to be a reliable index to size) of the delay and non-delay groups. It seems reasonable, on the basis of the model, that the non-delay group should have the smaller size, on the average, since (1) smaller birds are less conspicuous to predators than larger birds, (2) smaller birds may be less frequently preyed upon because their small bodies provide less energy to predators and, hence, make them less efficient prey organisms and, (3) small birds may be less frequently preyed upon because their size gives them an advantage in maneuverability, so they are more difficult to capture than are larger species. An examination of mean prey size in the diet of Cooper's hawk (Accipiter cooperi) and the sharp-shinned hawk (Accipiter striatus) would be of value here.

Certainly a variety of factors can be involved in the total picture of delayed plumage development among males of various species of Passerine birds. The model proposed above to explain the adaptive significance of such delays leads to certain conclusions that can be tested for their validity. Hence, the model itself would seem to be testable and, therefore, worthy of further consideration.

SUMMARY

The breeding biology of the Cassin's finch (Carpodacus cassinii) was studied in 1967 and 1968 in the Robinson Canyon, 10 miles west of Ellensburg, Kittitas Co., Washington.

The birds arrived in the study area during mid-April, a few adult males preceding the main population by a few days. Observation of the birds did not reveal any conspicuous pair formation activities, at least some pair bonds appearing to have been formed before arrival on the breeding grounds. Male finches do not show territorial defense to the degree that many species do, as far as was observed in this study. It was common to see three or four adult males on song perches in the same tree during the early weeks of the breeding season.

Twelve nests were located during this study. Nest building began in early May and lasted until July, latest nests probably representing replacement clutches. Nest heights ranged from about 25 feet to about 65 feet. Nests were constructed of lichens, herbaceous twigs, and Douglas fir twigs, and were lined with deer or elk hair. The female was solely responsible for nest building, males spending a great deal of time on song perch but occasionally accompanying females as they gathered nest material.

Egg laying occurred during early morning hours, and the mean of 9 clutches was 4.2 (range 3 - 5).

Females were solely responsible for incubation, and the incubation period was 12.1 days for six nests (range 12 - 13). Young left the nest after about fifteen days and did not stay in the vicinity

of the nest more than one or two days after fledging.

Predation on Cassin's finches was not observed during the study, although the presence of predators of small birds in the study area was noted, especially those which prey upon eggs and young - Steller's jay - (Cyanocitta stelleri) and black-billed magpies (Pica pica). Cowbird parasitism was not observed.

Food habits of finches varied throughout the course of the breeding season. Early in the season plant material comprised the largest percentage of the diet. After the young hatched, however, insects comprised the majority of the diet.

During the course of this study it was found that sub-adult males, which are identical to females in plumage coloration, successfully acquired mates and produced young. This fact raised several questions regarding delay in acquisition of full adult plumage by males.

It is hypothesized that the bright color of males of sexually dichromatic species increases their conspicuousness to predators but also enhances their mate attracting displays. The evolution of bright colors is thus subjected to conflicting selection pressures, and it is proposed that the balance shifts in favor of bright colors after the male has had a year or so to learn more effectively how to locate and escape predators. A review of 103 sexually dichromatic Passerine species revealed that red occurs in the plumage of those in which males exhibit delayed plumage development significantly more commonly than in those without delays. There is also a difference in size, the delay group being larger than the non-delay group, although the difference cannot be confirmed to be significant by the crude size categories used here. These results are consistent with the model if it can be

shown (1) that red is especially conspicuous to predators and (2) that smaller species are less likely to be preyed upon than are larger species.

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