

Technical Report No. 47

THE NESTING BIOLOGY OF THE HOUSE FINCH, CARPODACUS
MEXICANUS FRONTALIS (SAY), IN HONOLULU, HAWAII

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PREFACE

This report gives the results of a second graduate student project concerned with the breeding biology of exotic bird species in Hawaii. Technical Report No. 29 dealt with the Japanese White-eye (Zosterops j. japonica), which is now presumed to be the most abundant land bird species in Hawaii. The present study describes the breeding biology of the House Finch, which already has proven to be a serious pest on experimental plantings of sorghum on Kauai and Hawaii. Such baseline studies are essential to further research on the effects of exotic birds on man and his activities as well as on the endemic forest birds. The report was prepared as partial fulfillment of the requirements for a Master of Science degree in Zoology, and was conducted under the direction of Andrew J. Berger. The study was supported, in part, by NSF Grant No. GB 23230 of the Island Ecosystems IRP under the US/International Biological Program.

ABSTRACT

A study of the House Finch, Carpodacus mexicanus frontalis (Say), was conducted on the University of Hawaii Manoa campus, from January 1972 through July 1974. From 25 to 50 pairs were found nesting in the study area from February through August. Nest construction takes approximately 12 days, the incubation period 13 days, the nestling period 17 or 18 days, and the fledgling period probably lasts from two to three weeks. A pair most likely has two successful broods per nesting season. Clutch size averaged four eggs.

Nestlings exhibit the standard type of avian growth curve, increasing in weight from less than two grams at hatching to 17 grams, 13 days later. Nestlings of the same brood that hatched earlier weighed more than those that hatched later, and this difference may reflect sibling competition for food. The behavior of the adults during the various stages of the nesting period and the development of the nestlings are discussed.

Nest faunas from three 1972 nests were extracted and identified. Although the blood-sucking parasitic mite (Mesostigmata:Dermanyssidae) was found, it is felt that this mite did not cause the deaths of a significant number of nestlings. A number of other mortality factors are discussed as to the reason for such a low nesting success in Hawaii (17% in each of 1972 and 1974, 30% in 1973).

Some characteristics of the Hawaiian House Finch are different from reported populations in other parts of the United States. Significant differences exist in egg weight, possibly in the length of the nestling period, rate of nestling growth, nesting success, and male coloration. In Hawaii, the House Finch has a much longer nesting season, and this may be explained by the highly developed photoperiodic mechanism that controls the timing of reproduction in this species.

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INTRODUCTION

The House Finch, Carpodacus mexicanus frontalis (Say), is a small seed-eating passerine found throughout western North America. In the hundred years since its introduction to Hawaii, there have been only fragmentary and generalized accounts of this bird. This field study began in January 1972, on the University of Hawaii Manoa campus, to provide additional information on the nesting biology of this species. Findings are discussed in relation to what is known about House Finch populations in other parts of the United States.

The House Finch on the Mainland

Although this species has been given many common names (a list is given by Grinnell and Miller 1944), I will use in this paper either "House Finch," the name given in the AOU 1957 Check-List, or "Linnet," with due respect to the objections raised by Henderson (1916).

The House Finch is about 14 cm long, has a rambling, canary-like song. The male is gray-brown, with parts of the head, breast, and rump red or reddish and the belly light colored and somewhat streaked. The female is gray-brown, faintly streaked above, and light colored and more distinctly streaked below.

The House Finch belongs to the Carduelinae, a subfamily comprised of over 100 species (112 species by Austin 1967, about 122 species by Storer 1971), presumed to have an Asiatic origin, and has since obtained, except for Australiasia, worldwide distribution (Austin 1967, Moore 1939). Many species of this subfamily do not remove the fecal sacs of the young from the nest, a behavioral trait unusual for passerine birds (Austin 1967, Berger 1972). Recently this group has been placed in the family Ploceidae by some authors (Austin 1967,

Berger 1972, Storer 1960, Tordoff 1954, Van Tyne and Berger 1971), whereas others (Storer 1971, Sutton 1967) have kept the carduelines in the family Fringillidae. The limits of the genera and the relationships among the species in this subfamily are also uncertain and subject to different interpretations (Paynter, in Peters 1968).

The Linnnet is a western bird, breeding and largely resident from southwestern and south-central British Columbia, central western and southern Idaho, central northern and southeastern Wyoming, western Nebraska, south through California, central Baja California, central Sonora, including a number of off-shore islands, northwestern Chihuahua, and western and south-central Texas (AOU 1957, Peters 1968). It also occurs in New Mexico, Utah, Colorado, Oklahoma, and probably western Montana and Kansas (Bailey and Niedrach 1965, Hand 1970, Sutton 1967). Booth (1971) mentions, however, that it is not a resident in western British Columbia or western Washington. It is an introduction to Hawaii and southeastern New York (Fig. 1).

Probably with man's assistance through introductions and changes in the environment, the House Finch is increasing its distribution and numbers (Bent 1968). It has moved into Washington since 1900, and into British Columbia since 1935 (Edwards and Stirling 1961). Since its release on Long Island, New York, probably in 1940 (Elliott and Arbib 1953), the Linnnet has spread west to New Jersey, north to Massachusetts, and as far south, in the winters at least, as South Carolina (Peters 1968).

A great deal has been written about the House Finch, primarily as short field notes or in lists of birds of specific geographic areas. Most longer papers done before World War II were field-related studies, whereas studies since the war have dealt largely with



Fig. 1. The breeding range of the House Finch.

physiological and photoperiodic problems that were better answered by laboratory and experimental approaches. Both approaches tend to complement each other, substantiating and clarifying various aspects of Linnet biology.

The House Finch in Hawaii

The House Finch was introduced to Hawaii probably from San Francisco as an escaped cagebird, sometime prior to 1870 (Grinnell 1911). It is not listed for Kauai or Niihau in Bryan's 1901 list of Hawaiian birds, although it was reported on Kauai by 1903 (Grinnell 1911). It is reported to have established itself on Niihau from the population on Kauai, some 40 km (25 miles) away (Fisher 1951). Today the Linnet is commonly found on all the main islands, in urban and rural areas, and in the high ranch and forest lands on Maui and Hawaii, although it is not common in the near virgin rain forests. It is also abundant in the mamani-naio forest (Sophora chrysophylla—Myoporum sandwicense) on Mauna Kea and in the partly cutover and mixed ohia-koa forests (Metrosideros collina—Acacia koa) (Berger 1972).

Because of its fondness for overripe papaya, the Linnet is also known as the papaya bird. Munro (1960) gives it an Hawaiian name, Ai-nikana (papaya eater).

Based largely on a difference in male coloration, Grinnell (1912a, 1912b) proposed (later supported by Moore 1939) that the Hawaiian Linnet be called "Carpodacus mutans." The House Finch in Hawaii is still listed, however, in the 1957 AOU Check-List under C. mexicanus frontalis.

Work on the nesting biology of this species in Hawaii is largely fragmentary and generalized. Active Linnet nests were found on Kauai in early May (Eddinger, in Berger 1972) and in late June (Richardson and Bowles 1964); on Oahu from early March to July (Berger 1972); on Maui in late April (Berger 1972) and on Molokai in late March (McGregor 1902); and on Hawaii at Volcanoes National Park, Kilauea-Mauna Loa section, from April to June (Baldwin 1941) and on Mauna Kea from the first half of April until mid-July (Berger 1972). Nests that were presumed active were found on Niihau in mid-August (Fisher 1951) and on Oahu between late January and early March (W.A. Bryan 1905). Egg-clutch sizes range from three to five, with five-egg clutches not uncommon on the island of Hawaii (Berger 1972). E.H. Bryan, Jr., (1937) reports that the Linnet raises two or three broods a year, with the eggs measuring 14.0 x 20.3 mm (0.55 x 0.8 inch). Charles van Riper, III, (in press) has studied the nesting of the House Finch on the Big Island, especially on Mauna Kea.

Berger (1972) concludes, from what little is known about the length of the breeding season of the Linnet in the state of Hawaii, that probably most nesting occurs between March and the first part of August, as in southwestern California.

THE STUDY SITE, MATERIALS AND METHODS

The Study Site

This field study of the nesting biology of the House Finch extended from 5 January 1972 through July 1974. The study site was confined mainly to the University of Hawaii Manoa campus, but some observations were made on the Big Island from 21 to 28 December 1973, and casually and infrequently at various Oahu locales offcampus.

The campus is located in Manoa Valley, a residential area close to Honolulu. The entire campus embraces about 1.5 km² (380 acres) and has over 500 different kinds of trees and plants from all over the world. The main campus, in which my efforts and time were concentrated, contains about 0.4 km² (90 acres) (Fig. 2).

Materials and Methods

Most of the study consisted of field observations, with almost daily checks of nests. Because of my class and working schedules, most of the checks were made in the afternoon, usually after 1500. During the nesting seasons, I covered the campus at least once a week looking for new nests.

Measurements were made using a caliper, ruler, or tape measure. Weights were obtained using Pesola scales. Observations were usually aided with the use of a 7x50 binoculars. To facilitate future identification, eggs were marked with a black-colored "Sharpie" pen; nestlings were marked in 1972 with red nail polish but in 1973 with a red-colored "Sharpie" pen, which proved more satisfactory. A 3.7-meter long (12 foot) aluminium ladder was used to reach the nests.

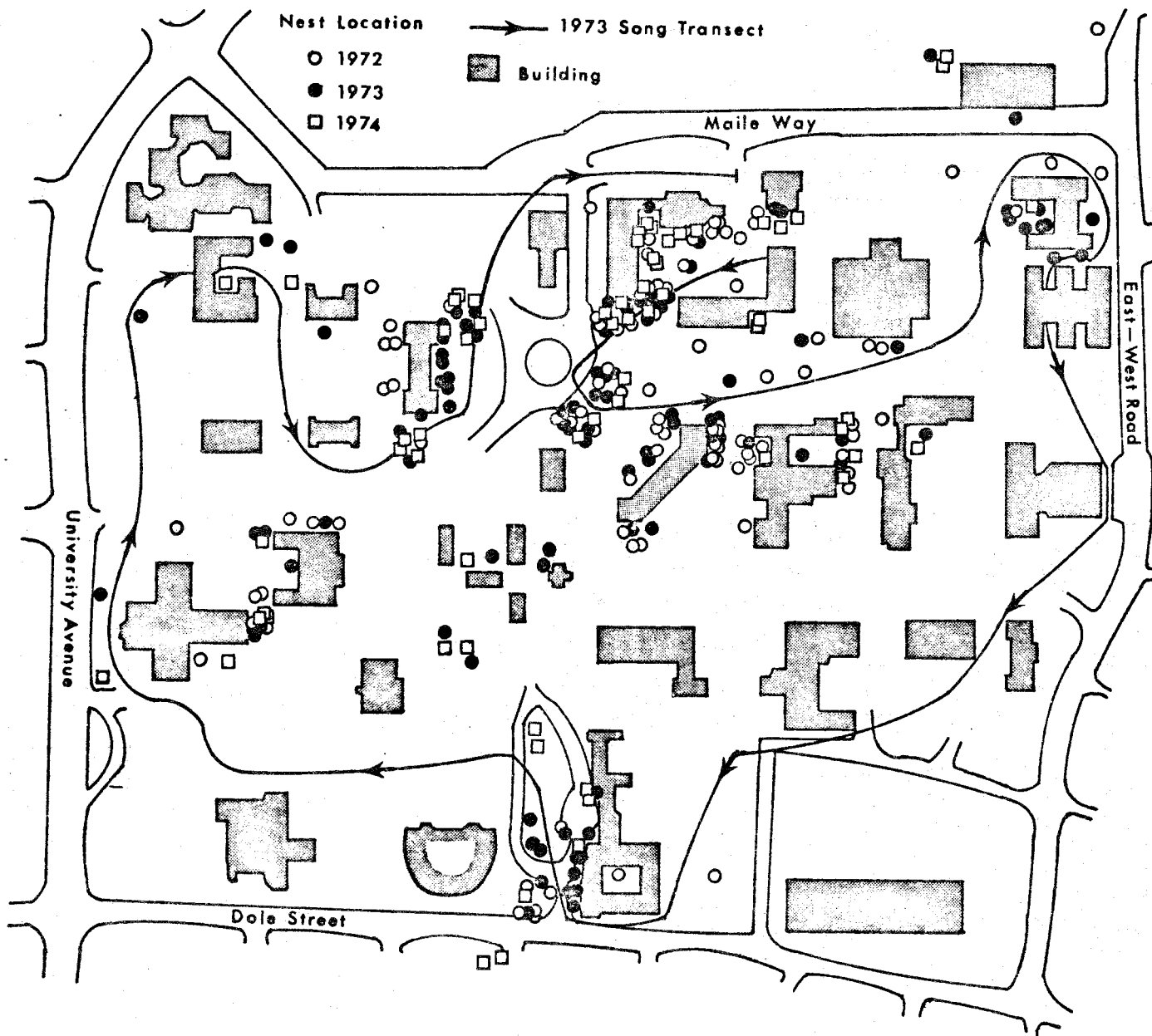


Fig. 2. The study site on the University of Hawaii Manoa campus.

Birds were banded with a U.S. Fish and Wildlife metal band and one or two plastic bands in different color combinations, to facilitate later recognition of the birds. Nestlings were banded usually when they were 10 to 14 days old. Banding and handling older young often led to them jumping from the nests when replaced. This premature leaving of the nest, before the young could fly, reduced their chances of survival. With the help of H. Eddie Smith and Sandra J. Guest, I trapped and banded a number of adult birds during 1973. I noted body weights, colorations of the males, and the general conditions of the birds at the time of banding.

Two nestlings, a male and a female, from the 1972 nesting season, were raised and kept in an indoor aviary. The young had been disturbed from their nests and could not be replaced. A male from the Big Island was added to the aviary in 1974.

Throughout 1973 I walked a transect on the campus seven times a day on 10 different days, recording all Linnet songs heard, to evaluate any daily and seasonal differences in singing by House Finches (Fig. 2). The transect passed by Linnet nesting locations and covered a distance of 2.4 km (1.5 miles), taking about 40 minutes to walk. The seven walks in a day were divided into two successive ones at sunrise, one between sunrise and midday, one at midday, one between midday and sunset, and two successive ones before sunset.

Daily, or almost daily, observations of 60-minute durations were done at selected nests for the 1972 and the 1973 breeding seasons to note Linnet behavior during the nest-building, incubation, and nestling stages. The times of the observations were arranged to fit my schedule.

On certain days **for** the incubation and the nestling stages for 1973, I did two observational sessions per day, each 60 minutes long, once in the morning (sunrise to 1200) and again in the afternoon (1200 to sunset), to evaluate any Linnet behavioral changes on a daily basis. The days chosen were incubation day 4 and early (before the oldest bird was over seven days old) and late (about seven days after the first early nestling observation) nestling days. In connection with these observations, I weighed each nestling before and after it was fed by the parents.

Faunas from eight nests from 1972 and 1973 were collected by running each nest through a Tullgren funnel for at least three days. The animals collected from the 1972 nests were identified by Darwin S. Yoshioka, graduate student in entomology.

Unless otherwise indicated calculations are in the form mean \pm one standard deviation. The 0.05 value is considered the level of rejection.

RESULTS AND DISCUSSION

The House Finch Population

The House Finch is one of 12 introduced bird species on or near the University campus. The only native bird found on campus is the migratory and nonnesting American Golden Plover (Pluvialis dominica). There are at least 25 nesting pairs of House Finches, and possibly as many as 50, on the main campus at any one time. An exact count is difficult because the birds tend to move about in flocks the year round and do not defend large, discrete territories.

During the nonbreeding season House Finches form mixed flocks of males and females, usually numbering over 10, and in certain situations, especially at feeding sites, aggregations of 25 to 50 were observed. In the more open country, as on the Big Island, large flocks of over 100 individuals can be observed. Linnets still flock during the breeding season, but the flocks tend to be small, less than 10, and composed mainly of males feeding in trees or on the ground.

In flocks, Linnets displace one another from the perches, with an increase in agonistic encounters as the nesting season approaches. Very few interspecific interactions were observed. A female House Sparrow (Passer domesticus) and a juvenile Red-crested, or Brazilian, Cardinal (Paroaria cucullata) were attacked by female Linnets when the two birds perched 0.3 and two meters, respectively, from the House Finches' nests. In a third case, a male Linnet displayed before a male House Sparrow perched nearby. The Linnet assumed a horizontal posture, with legs flexed, neck stretched forward along the main axis of the body, and wings partially extended and rotating

slowly. He then flew at the House Sparrow, displacing the bird from its perch. No nests were observed nearby. This display is the most extreme form of the head-forward display, an aggressive behavior of House Finches (Thompson 1960a). A lesser form of this head-forward display by House Finches, without the wing rotation, was observed in the aviary and on campus directed toward White-eyes (Zosterops japonica japonica) (Sandra J. Guest, pers. com.). Most other interspecific encounters involved displacement, or supplantation, when a bird flies toward or next to another that is perched. I have observed House Finches being displaced from perches by Mynahs (Acridotheres tristis tristis), a Mockingbird (Mimus polyglottos), Red-vented Bulbuls (Pycnonotus cafer), and House Sparrows. House Finches, in turn, supplant House Sparrows.

House Finches are "skittish" birds and tend to perch on roofs of buildings, telephone wires, or in trees, rather than near or on the ground. They shy away from humans and for this reason are not as conspicuous as some other species, such as House Sparrows and Barred Doves (Geopelia striata striata). While perched, especially in the evening just before roosting, House Finches preen themselves, ruffle their feathers, stretch their wings, legs, and tail, and yawn. They also scratch their heads indirectly, bringing their feet up and over the lowered wing (Pettingill 1970).

In the aviary and on campus, Linnets take water and sun baths. Water bathing occurs in shallow puddles or other standing water. The bird hops into the water, stands there, and periodically tips its throat and breast into the water, flaps its wings, and splashes water over its body. After it is sufficiently wet, the Linnet flies

to a nearby perch and preens, ruffles, and shakes the water from its feathers. In sunning, the Linnet perches with its back to the sun, ruffles up the feathers of the rump, back, neck, and head, spreads open the wing feathers nearer the sun, fans out the tail, turns the head so that one side faces the sun, may open the mouth slightly and may have the eye facing the sun closed. Sunning may last several minutes, interspersed with periods of preening and head scratching. I observed the aviary birds, when they were less than two months old, taking water baths in a container filled with honey water and sun bathing under a lamp.

Sandra J. Guest (pers. com.) observed the aviary Linnets taking dust baths in a pan of dirt placed on the cage floor. I have never seen this behavior in wild birds.

Diet

Linnets, on campus, feed from trees and the ground on a variety of plant seeds and fruits. I have never seen House Finches use their feet as aids in feeding. While I have not analyzed the stomach contents of any campus Linnets, Beal (1907) examined the stomach contents of over 1,000 House Finches in California, finding that about 97% of the food eaten by the Linnets were weed seeds or fruits, the remaining 3% insects, possibly ingested accidentally along with the vegetable matter. Roessler (1936) calculated that a House Finch eats 1,000 seeds daily.

Table 1 gives a list of plants on campus that I have observed the Linnet feeding upon. Also a partial list, compiled by others in Hawaii, is included. In December 1973, H.E. Smith and S.J. Guest

Table 1

Food Plants Eaten by the House Finch in Hawaii

I. This paper (1972-1974)

Seeds

- Ironwood (Casuarina equisetifolia)
- Formosa koa (Acacia confusa)
- Pink tecoma (Tabebuia pentaphylla)
- Lau-kahi, or broad-leaved plantain (Plantago major)
- Beggar tick (Bidens sp.)

Fruits

- Port Jackson fig (Ficus rubiginosa)
- Banyan, probably Chinese (Ficus retusa)
- Guava (Brassaia actinophylla)
- Octopus (Brassaia actinophylla)

Nectar

- African tulip (Spathodea campanulata)

II. Previous authors

Seeds

- Beggar tick (Bidens sp.) (Baldwin 1953, Hawaii)
- Pua kala, or spear thistle (Cirsium vulgare) (Berger 1972, Hawaii)

Fruits

- Tangerine (Citrus nobilis) (Guest 1973, Manoa campus)
- Rose apple (Eugenia sp.) (Richardson and Bowles 1964, Kauai)

Nectar

- Ohia (Metrosideros collina) (Baldwin 1953, Hawaii)

observed House Finches drinking what seems water-diluted nectar from African tulip blossoms (Spathodea campanulata). Since then I have observed similar behavior on campus, except that the Linnets do not drink from the open ends of the flowers, but instead, approach the blossoms from below and slit with their beaks the bases of the corollas to obtain the nectar. Today the House Finch is not generally considered an economic pest, although this may change if a greater effort is made to establish a sorghum industry in Hawaii.

Male Coloration

Male Linnets in Hawaii show considerable variation in coloration, with the red often being replaced by either yellow or orange. Based on the literature and my observations on Oahu and on the Big Island, the dominating color morph (either yellow-orange or red) seen on the various major islands are:

Kauai and Niihau--yellow-orange (Fisher 1951),
Oahu--yellow-orange (Grinnell 1911, personal observations),
Maui--yellow-orange (Grinnell 1911, McGregor 1902, Dunmire 1961),
Hawaii--red (Baldwin 1941, Dunmire 1961, personal observations).

During the 1973 breeding season, I determined the color of males at 93 nests. While the colors ranged from a dull, pale yellow to a bright red hue, with no sharp and clearcut separations, I placed a male into one of three color-morph categories, yellow, orange, or red. There are males that are yellow-orange or orange-red in colorations. In a case of overlap, I placed a male in the category which I felt was the dominant color for the bird. Yellow-colored males accounted for 51 (54.8%) of the total, orange-colored males for 37 (39.8%), and red-colored ones for 5 (5.4%).

For a three-year period, at Pasadena, California, Michener and Michener (1931) trapped 1,226 males, 1,001 (81.6% of the total) were red and the remaining 225 (18.4%) were yellow, orange, or orange-pink. By combining into one category the yellow and orange males that I noted, the proportion of color morphs seen in Hawaii and in California is significantly different ($2 \times 2 \chi^2_{adj.} = 273.56$, d.f. = 1, $P < 0.005$).

The cause for this difference in coloration is unknown but there are a number of possible explanations. Michener and Michener (1931, 1940) feel that House Finches with pale or duller coloration (yellow) represent the first adult plumage and/or late molting individuals. Dunmire (1961) believes that the cause is dietary differences between the populations on the mainland-Big Island and Maui (and probably Oahu and Kauai). Grinnell (1911) strongly implies that the difference is genetic and physiologically based, brought about by the close inbreeding of the small original stock introduced to the islands (a possible case of founder effect, Mayr 1965).

It seems unlikely that the age of the bird and the time of molting could be responsible for the observed differences in color variation. House Finches are known to change from red to yellow in captivity (Bent 1968), and research into diet as a possible factor is presently underway in California. Yet, observations that there are some red-colored males on Oahu and some yellow-colored ones on the Big Island (H. Eddie Smith and C. Van Riper, III, pers. com.) and that these birds feed in flocks would seem to cast doubts on diet as the major factor in determining male coloration. Also, there is the question of what is the difference(s) in diet on Kauai, Oahu, and Maui as compared to the mainland and the Big Island. Although

Michener and Michener (1931) trapped males which turned from yellow to red, a small number (2% of the birds trapped) failed to acquire the red coloration after several years. Instead the males retained an orange shade. If the paler coloration is genetic in nature, then it is possible that small populations of Linnets, with restricted and different genetic makeups, could have been introduced to the various islands, resulting in the color-morph compositions seen today. This founder-effect explanation seems reasonable.

Molt

The House Finch has only one molt, in Hawaii the population starts molting by August and it is completed by the end of October. Through May 1973, 15 adults were trapped, with 10 being caught on 31 May. None were molting. A female trapped on 21 July 1973, also was not molting. From 3 to 5 August 1972, H. Eddie Smith trapped six Linnets on the western slopes of Diamond Head, about 4 km (2.5 miles) from the campus. Only one of the House Finches, a juvenile male, was molting. On 20 August and 3 September 1973, I observed several Linnets with tail feathers molting. In September 1973, I trapped 13 adults, 10 were in various stages of molting. On 2 October 1973 and 22 October 1972, I observed Linnets with tail feathers molting. From 1 to 6 November 1973, 12 adults were trapped and none were molting. Although I have no trappings for June and only one in July, I do not feel that birds molt in June or early July because many of the birds are still nesting. Molting probably occurs to some extent in late July.

I did not determine the length of time that it takes an individual bird to molt completely, but Michener and Michener (1940) found that it takes an average of 105 days, ranging from 90 to 120 days, for the House Finches at Pasadena, California. Thompson's (1960a) findings indicate a molting time of 75 days, at the most, for the Linnets in the Berkeley, California area.

The Nesting Season

The nesting season, when active nests are found, extends from February through August for the House Finch in Hawaii.

In 1972, nest building was first observed on 21 February and egg laying started on 28 February. The last young fledged on campus on 6 August. The last active nest, containing eggs, was abandoned about 17 August. I did find a nest, containing two young about ready to fledge, at Leahi Hospital, Kaimuki, about 3.2 km (two miles) from the University, on 18 August. By 21 August the nest was empty. The final observation of a fledgling being fed by an adult was on 7 September.

In 1973, nest building was first observed on 10 February and egg laying started on 24 February. The last young that probably fledged did so on 10 August. The last active nest, containing young, terminated about 13 August. A bird, with a short tail and possibly a fledgling, was sighted on 8 September.

In 1974, nest building was first observed on 19 February and egg laying started by 26 February. By the end of July nesting was nearly over.

During the 1972 breeding season 91 nests were found in various

stages, under construction, with eggs or young. In 1973, 103 nests, and in 1974, through July, 63 nests were found (Fig. 2). Only nests that were active and were verified as being used by House Finches were counted.

Calls and Songs

The House Finch has a number of vocal sounds for different situations. The classification of the sounds is from Van Tyne and Berger (1971) and display terms from Thompson (1960a, 1960b).

Call notes

- 1) Location notes--cheep or chip, a commonly heard call by both sexes when perched and in flight. The purpose seems communicatory. Also given occasionally by perched fledglings, waiting to be fed.
- 2) Agonistic notes--chit, also commonly heard, especially in flocks, and usually given in series during supplanting attack or during actual combat, when two birds hover in mid-air, loudly and rapidly calling, pecking and grappling at each other.
- 3) Alarm notes--meow, fright call given when the bird is disturbed. Usually there is a series of calls and the House Finch assumes a stiff-legged and erect posture.
- 4) Feeding notes--chee, given in series, rapidly, and high pitched by the nestling being fed by the parent and clearly heard in the latter half of the nestling stage. Also given by the fledgling or nesting female, begging and being fed.
- 5) Whisper call--a soft, barely heard chee, given continuously with some variation in strength by the female on the nest

during the egg-laying stage and usually in the morning hours. This call may serve as a communicatory device between the female and her mate (Thompson 1960a).

Songs

- 1) Female song--almost indistinguishable from the male primary song. Heard rarely and the purpose is unknown. Reported also by Thompson (1960a) and Bergtold (1913).
- 2) Male primary song--a canary-like warble, ending at times with a final, rising tzeep. The song is from two to four seconds long and is repeated continuously with slight pauses. I have heard a male singing continuously for at least 20 minutes. It is usually sung as the male is perched, but occasionally while he is flying overhead or from one perch to another nearby. A spectrogram is given in Thompson (1960a) and a phonetic breakdown in Bent (1968).

During actual nesting the male sings from an elevated and prominent position near the nest, often from the same post throughout the egg-laying and the incubation periods. Usually the post is located in a tree, at the topmost exposed branch. Table 2 gives the distance between the singing post and the nest and the heights of the post and the nest.

I agree with Thompson (1960a, 1960b) that the male primary song has little connection with territoriality. Like Thompson, I have observed two or three males singing in the same tree or within 30 meters of each other and have seen a singing male attract both females and other males to its tree. The song seems to function primarily for advertising and attracting a mate. Thompson also feels that

Table 2

The Singing Post of the House Finch

	<u>Distance From the Nest (meters)</u>	<u>Height of the Post (meters)</u>	<u>Height of the Nest (meters)</u>
range	11.0-27.4	3.7-11.0	2.3-4.6
mean	17.6	7.0	3.4
standard deviation	4.9	2.6	0.8
sample size	14	14	14

singing by the male when its mate is incubating is an attempt to attract other females. I feel male singing at this time serves more to help maintain the pair bond.

The song, with the sharp rising tzeep, is part of the male courtship display before the female. The male stretches his neck up and slightly back, tilts his head slightly upwards, seems to sleek his body feathers, droops his wings slightly, raises his tail vertically and somewhat spread, flexes his legs and is thus in a horizontal position, hops before the female, pivoting from side-to-side, and singing very loudly, often emphasising the tzeep ending. The male hops out of the reach of the female, moving farther from her when she makes a peck-intent movement toward him.

Thompson (1960a) feels that the male courtship display serves less in pair formation and more in inducing a second nesting, because the display usually occurs in California near the end of the first nestling period and not early in the season. The display probably aids in bringing about a second nesting by the female, but I feel that it serves more importantly in establishing the pair bond. Contrary to Thompson, I have observed male courtship display mostly in the early part of the breeding season, before nest building had started, and when there still seem to be birds that are unpaired.

The song is considered partially learned (Baptista 1972, Miller 1929, but see Miller 1952, for a possible physiological aside). A male, hand raised from two weeks of age, has not learned the characteristic song after two years in the aviary, although its call notes and behavior seem normal.

Figures 3 and 4 give the average number of songs heard monthly and daily, respectively, based on observations made walking the campus transect during 1973. Although the amount of singing that was heard could be attributed to Linnet movements on and off the campus or to weather conditions, I feel that the results reflect behavioral differences and thus seasonal and daily singing cycles.

A seasonal cycle is evident in Figure 3, with greater singing during the nesting months January through June and less during the nonnesting months July through December (one-factor anova, $F= 5.65$, $m/n= 9/60$, $P < 0.01$). Singing is nearly absent in September, although some songs are heard infrequently, usually early in the morning.

There is also a daily singing cycle (Fig. 4). House Finches start singing by sunrise, usually before the sun is directly striking the campus but when the area is lighted, and end just before sunset, when the sky is still somewhat light. The greatest amount of singing occurs at sunrise and the early morning hours and decreases until the early evening-afternoon hours, with an increase one or two hours before sunset (one-factor anova, $F= 3.52$, $m/n= 6/63$, $P < 0.01$).

During the nesting period, the male sings when accompanying the female during nest construction, when he is near the nest during the incubation period, rarely, if at all, during the first two-thirds but noticeably more during the last one-third of the nestling stage.

Pair Formation

Because I did not have a banded pair, I cannot make any definitive statements about pair formation and stability in the House Finch. Some Linnets do seem paired at least for the entire nesting season and I have observed what seemed like pairs in the nonnesting season

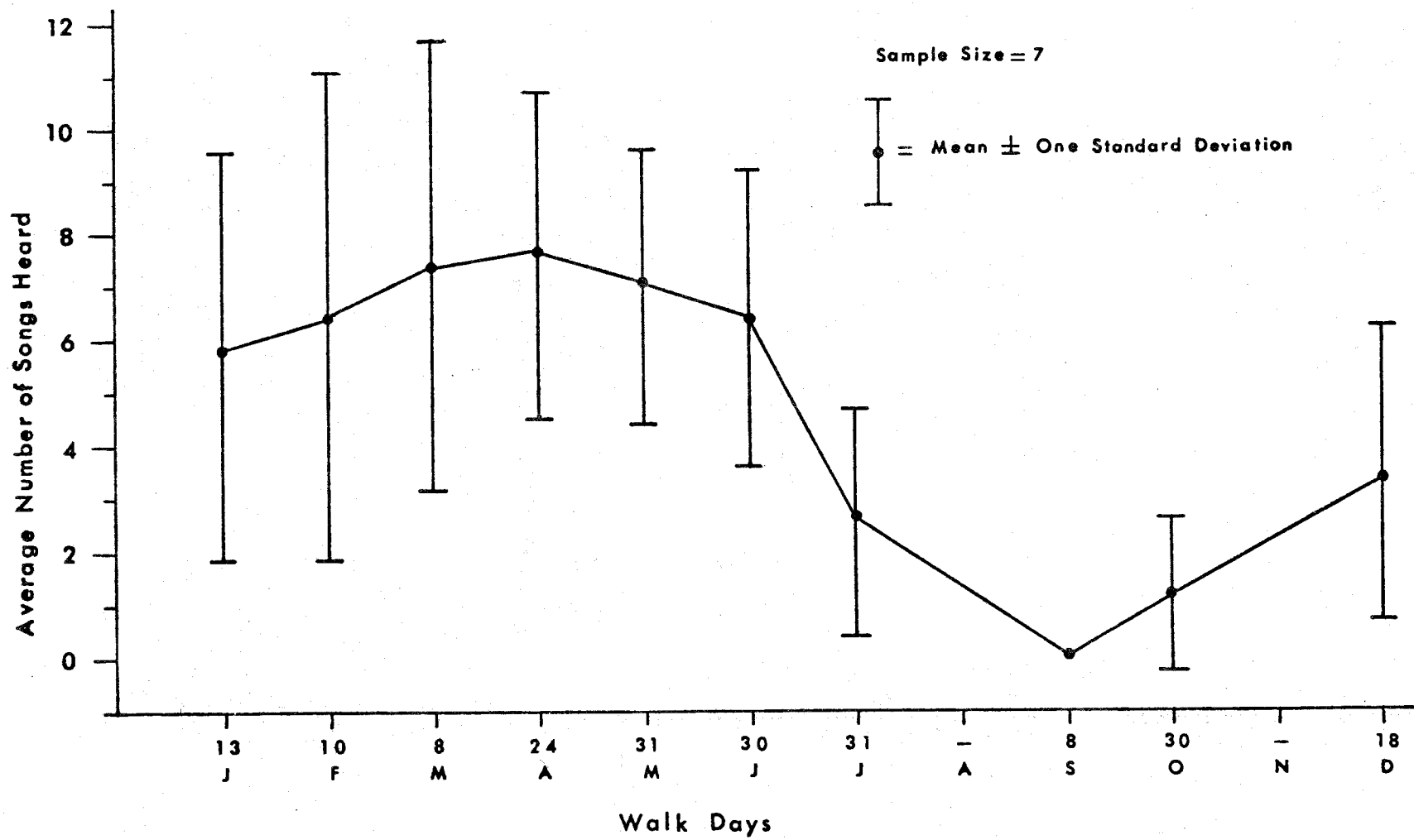


Fig. 3. Seasonal song cycle of the House Finch in Hawaii.

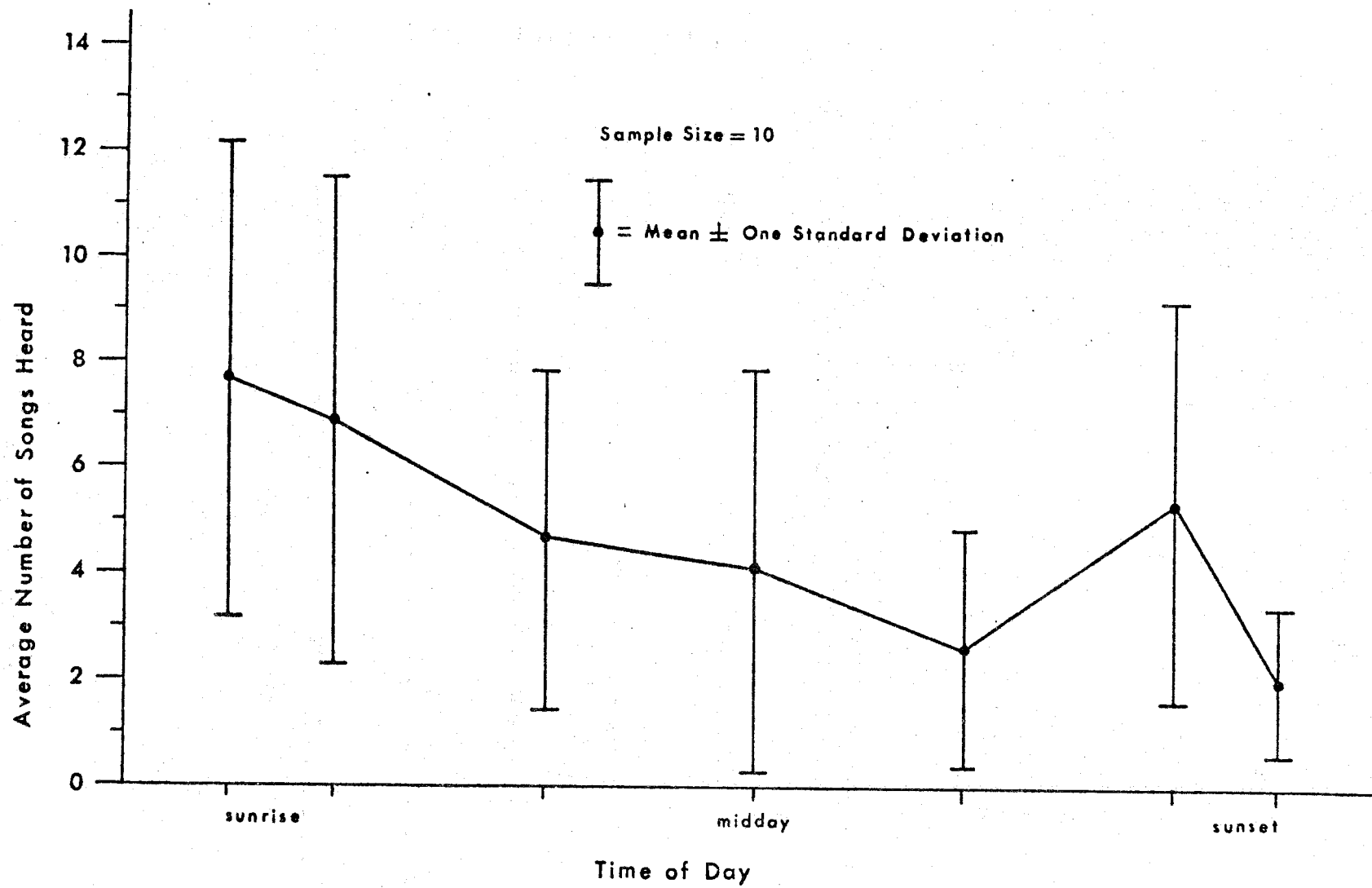


Fig. 4. Daily song cycle of the House Finch in Hawaii.

as well. A limited banding study at New York, by Gill and Lanyon (1965), indicates that House Finches can maintain the pair bond for the entire year.

House Finches seem to follow a common pattern in achieving and maintaining the pair bond. The male courtship display seems to initiate the establishment of the pair bond. After an unknown length of time, a pair bond is established and maintained, at first by billing, a mandibulating activity where the male approaches the perched female and both, rather erect, briefly peck or rub closed beaks. Billing is considered a form of incipient courtship feeding (Van Tyne and Berger 1971). Billing is followed, as the nesting season approaches, by the male pecking at the female's slightly opened beak. Both birds lean toward each other, and are not erect, during this mock feeding. Finally true courtship feeding occurs, where the female begs for food from the male and the male responds by feeding her regurgitated seeds. When begging, the female crouches before the male, gives loud, rapidly repeated calls, has the tail flicking vertically, flutters or vibrates her wings, points her head upwards toward the male, and gapes. The male then feeds her. This behavior is seen only during actual nesting and is reminiscent of a fledgling begging to be fed.

In courtship feeding, the male may feed the female at or away from the nest. Out of a total of 108 records of courtship feedings done before the eggs had hatched, only 12 (11.1% of the total) feedings were done at the nest. There were no cases where all, or even a majority, of the courtship feedings for a nest were done at the site. The display of the female is the same at or away from the nest.

During a 60-minute observational session, the male may courtship feed the female up to two times, averaging from egg-laying day 1 through incubation day 11 (or nestling day 0) 0.8 ± 0.2 feedings per session (Fig. 10). After the young start to hatch, courtship feeding declines quickly and is very rarely seen after nestling day 4.

Courtship feeding starts soon after sunrise and ends a half hour, at the latest, before sunset. Observations, one session in the morning and a second in the afternoon, on incubating day 4 at 13 1973 nests, reveal no significant difference in the number of courtship feedings per session as the day progresses (two-tailed paired t-test, $t = -0.433$, d.f. = 12, $P = 0.7-0.6$).

Male courtship displays are underway by January, about one and a half months before the start of nesting. In the middle of January billing is noticeable and by February mock feeding is evident. The male courtship display and actual courtship feeding were usually observed in single pairs. Billing and mock feeding were observed occurring, as well, between individuals in flocks.

Nest-site Searching Behavior

The male, with calls or actual songs, may lead the female to a number of prospective sites, or may follow the female as she hops from site to site. At sites, the female seems to inspect them, perches or sits in them. The final choice of the nest site appears to be made by the female. Nest-site searching behavior is usually seen most frequently in the morning hours, and I have seen searching behavior and females with bits of grasses or other material in their beaks by early January of each year. These materials are carried briefly and then dropped. At times I have observed House Finch pairs

very agonistic toward each other, supplanting, chasing, even attacking each other at sites that later contained nests.

The Nest

All Linnets nests were in vegetation. The 257 nests from 1972, 1973, and 1974 were in 26 different types of plants (considering as single groups the different species of pandanus and palms) (Table 3). Pandanus and palms were the most common nesting trees, with 41.2% and 28.0% of the total number of nests, respectively. Monkeypod (Samanea saman) with 7.4% and fiddlewood (Citharexylum spinosum) with 6.6% were other frequently used trees.

Nests were usually constructed on sites providing cover and shade, and not in the more open, interior portions, as reported in Bent (1968). Nests were built in clusters of pandanus leaves, on the stems or axes of palm leaves, near or some distance out from the trunks, and in the outer portions of the foliage of monkeypod and fiddlewood trees.

The height of a nest was measured from the bottom of the nest to the ground below, using a tape measure if the nest was not higher than 4.6 meters or estimated as closely as possible if higher. Heights were variable, ranging from 1.8 to 15.0 m, with an average in 1972 of 4.3 ± 1.5 m (based on 91 nests), in 1973 of 5.0 ± 2.4 m (based on 103 nests), and in 1974 of 4.6 ± 1.6 m (based on 63 nests).

The height at which a nest is constructed is positively correlated to the height of the tree (Fig. 5). The taller the tree the higher up is the nest. (Nests built on palms were not included in Figure 5, because the only possible nest sites are on the stems or leaves, which are found at or near the top).

Table 3

Location of House Finch Nests--1972, 1973, 1974

<u>Name of Plant</u>	<u>No. of Nests Built</u>			<u>Total</u>	<u>% of Total</u>
	<u>1972</u>	<u>1973</u>	<u>1974</u>		
Cypress (<u>Cupressus sempervirens</u>)		1	2	3	1.2
Pandanus (<u>Pandanus</u> sp.)	39	41	26	106	41.2
Palmae	27	27	18	72	28.0
Fishtail (<u>Caryota mitis</u>)			1	1	0.4
Golden-fruited (<u>Chrysalidocarpus lutescens</u>)	12	4	4	20	7.8
MacArthur (<u>Ptychosperma macarthurii</u>)	14	23	11	48	18.7
Betel-nut (<u>Areca catechu</u>)	1		2	3	1.2
Yucca (<u>Yucca elephantipes</u>)	2	3		5	1.9
Ti (<u>Cordyline terminalis</u>)		1	1	2	0.8
Money tree (<u>Dracaena marginata</u>)		1		1	0.4
Dracaena (<u>Pleomele</u> sp.)	1			1	0.4
Breadfruit (<u>Artocarpus communis</u>)		1	1	2	0.8
Fig (<u>Ficus</u> sp.)		1		1	0.4
Banyan, probably Chinese (<u>Ficus retusa</u>)	3		2	5	1.9
(<u>Stenocarpus</u> sp.)	1	1		2	0.8
Sea grape (<u>Coccoloba uvifera</u>)		1	1	2	0.8
Custard-apple (<u>Polyalthia suberosa</u>)			1	1	0.4
Monkeypod (<u>Samanea saman</u>)	7	7	5	19	7.4
Shower (<u>Cassia</u> sp.)		1		1	0.4
Mock orange (<u>Murraya paniculata</u>)	1		1	2	0.8
Kukui (<u>Aleurites moluccana</u>)	1	1		2	0.8
Sandbox (<u>Hura crepitans</u>)	1			1	0.4

Table 3 (cont.)

Location of House Finch Nests--1972, 1973, 1974

<u>Name of Plant</u>	<u>No. of Nests Built</u>			<u>Total</u>	<u>% of Total</u>
	<u>1972</u>	<u>1973</u>	<u>1974</u>		
Fern tree (<u>Filicium decipiens</u>)		1		1	0.4
Hibiscus, or Maga (<u>Montezuma speciosissima</u>)	1			1	0.4
Flame (<u>Brachychiton acerifolium</u>)	1	1		2	0.8
Brisbane box (<u>Tristania conferta</u>)	2			2	0.8
Paper bark (<u>Melaleuca leucadendra</u>)	1			1	0.4
Panax (<u>Polyscias</u> sp.)		3	1	4	1.6
Fiddlewood (<u>Citharexylum spinosum</u>)	3	10	4	17	6.6
Teak (<u>Tectona grandis</u>)		1		1	0.4
total number of nests	91	103	63	257	
total number of plants used	15	18	12	26	

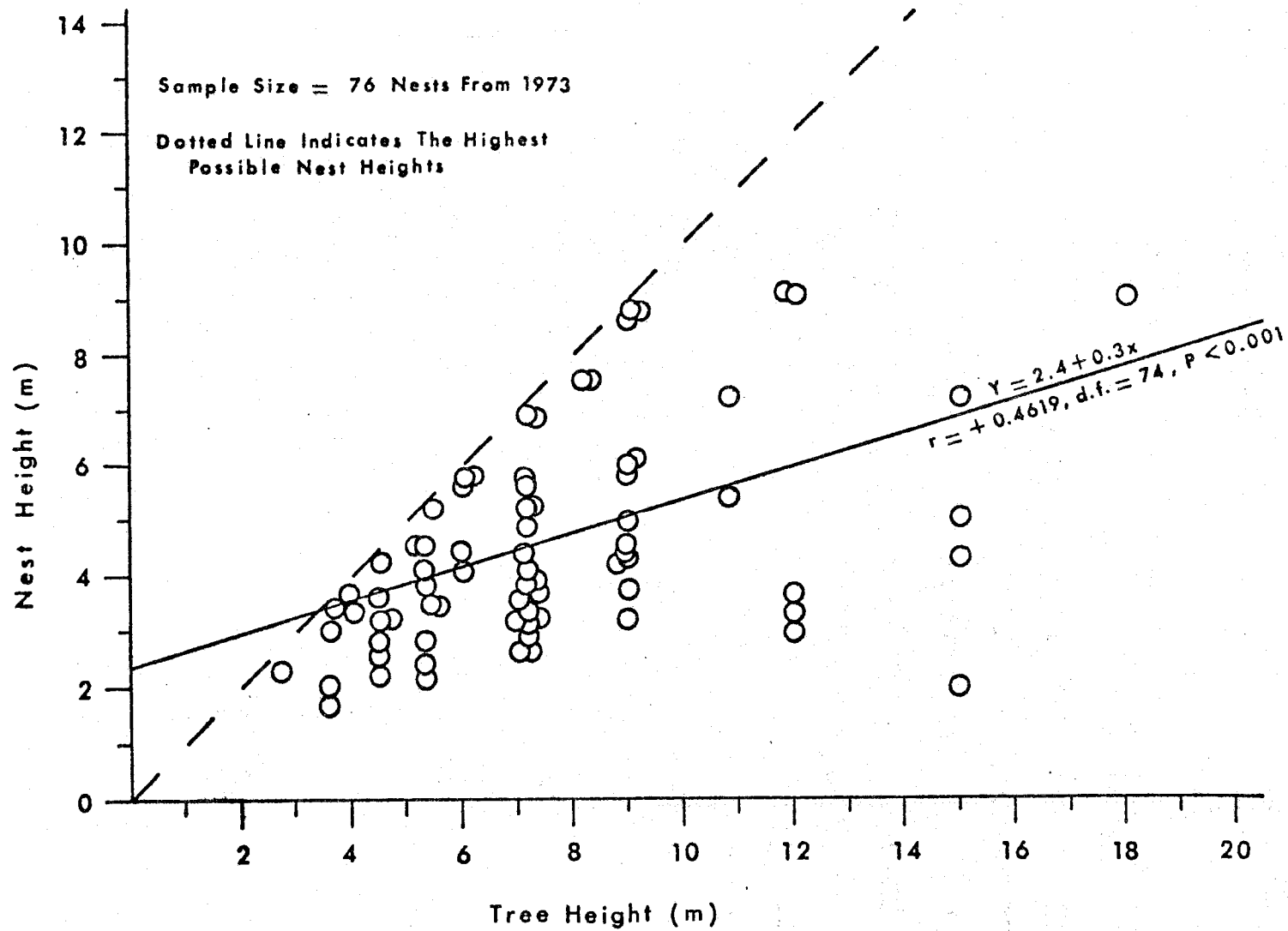


Fig. 5. Heights of House Finch nests in relation to heights of the nesting trees.

The House Finch nest varies from a rather loose to a very compact structure and may be classified as an open statant cupped nest, with the rim standing firmly upright and supported mainly from below by branches or leaves (Pettingill 1970). Nest measurements of 25 nests from 1973 are summarized in Table 4.

A variety of material is used in nest building. The foundation and outer portions of the nest are composed of larger sized material; the cup is constructed of finer ones. Frequently used material for the foundation include old inflorescences of fiddlewood, fibrous strips of coconut (Cocos nucifera) and pandanus, fresh and dried grasses (Bermuda, Cynodon dactylon; Finger, Chloris species; and Hilo, Paspalum conjugatum), composites (Flora's paint brush, Emilia sonchifolia), legumes (Acua, Desmanthus virgatus), fresh and dried leaves from trees near the nest site, string, paper strips, and feathers. The inner cup is constructed of fine and soft plant material (fine coconut fibers), hair, and frayed cigarette filters and nylon string.

The Nest-building Period

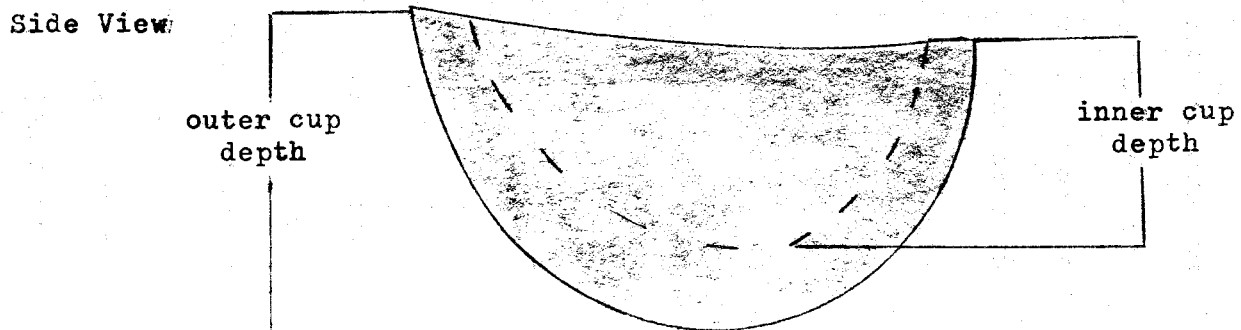
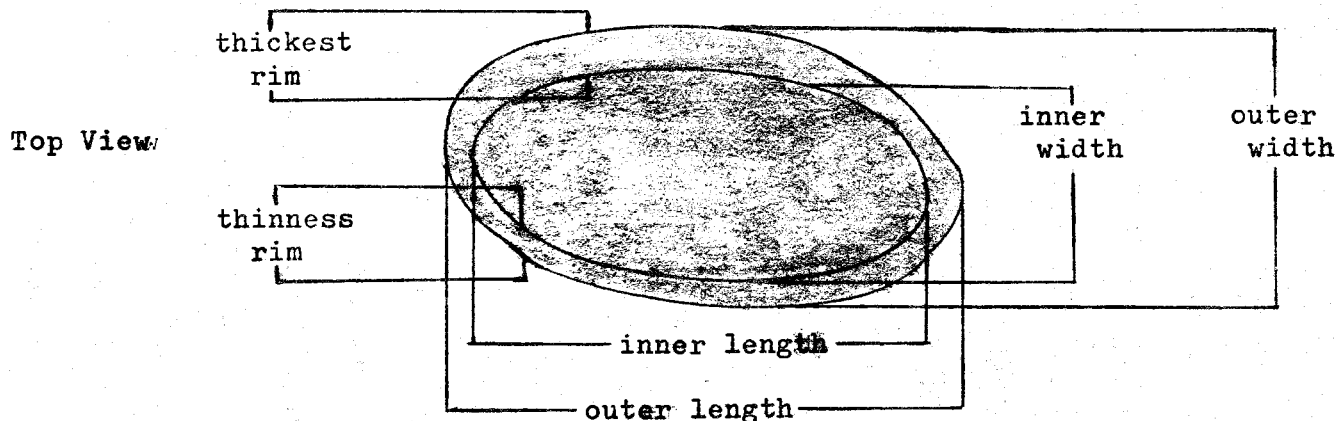
Only nests that were found before nest building started or were in the very early stages were included in calculating the length of time it takes in constructing a nest. Nest construction takes from six to 22 days, averaging 11.8 ± 4.7 days, based on 15 nests from the three years. (There is no significant difference in the lengths of time for nest construction for the three nesting seasons, one-factor anova, $F = 0.59$, $m/n = 2/12$, $P > 0.2$). My data are insufficient to reveal any seasonal differences in the length of time for nest construction.

Table 4

Measurements of 25 1973 House Finch Nests (cm)

	<u>Nest Dimensions (Width x Length)</u>				<u>Cup Depth</u>		<u>Rim Thickness</u>	
	<u>outer</u>		<u>inner</u>		<u>outer</u>	<u>inner</u>	<u>thin</u>	<u>thick</u>
mean	9.5 x 12.0		5.5 x 6.2		7.3	4.2	1.0	4.8
standard deviation	1.3	3.3	0.6	0.6	1.7	0.8	0.6	2.8

Definitions of nest measurements:



Nest building is done almost exclusively by the female. Only material brought to the nest by the female is used, and the male aids the female in molding the nest only in the first half of the nest-building period. Thereafter only the female works on the nest, the male accompanying the female to and from the site, singing frequently. Pettingill (1970) lists three stages in the process of nest building, 1) preparing the site, 2) constructing the floor and the sides, and 3) lining the nest cup.

House Finches take about one or two days to enlarge the site, and the rest of the time for laying down the foundation and lining the cup. In constructing the nest, the female House Finch sits in the center of the nest and pulls, drops, or pecks a piece of material into the cup and presses it into place using her chin, breast, abdomen, and partly opened wings, turning frequently from side-to-side in the cup.

From 13 to 24 February 1973, I observed the construction by a pair of unbanded House Finches of a nest about three meters up in a MacArthur palm (Ptychosperma macarthurii). A daily account of the nest construction and the general behavior of the pair is shown in Figure 6 and Appendix 1.

The number of trips made by the female to the nest seem to increase during the middle of the nest-building period when most of the foundation and cup lining is added to the nest; they decrease near the completion of nest building (Fig. 6). The average number of trips by the female to the nest per hour, for the 11 observational days, is 11.5 ± 6.0 trips per hour. Although the data are insufficient, there seems to be a daily cycle in nest building, with more of the

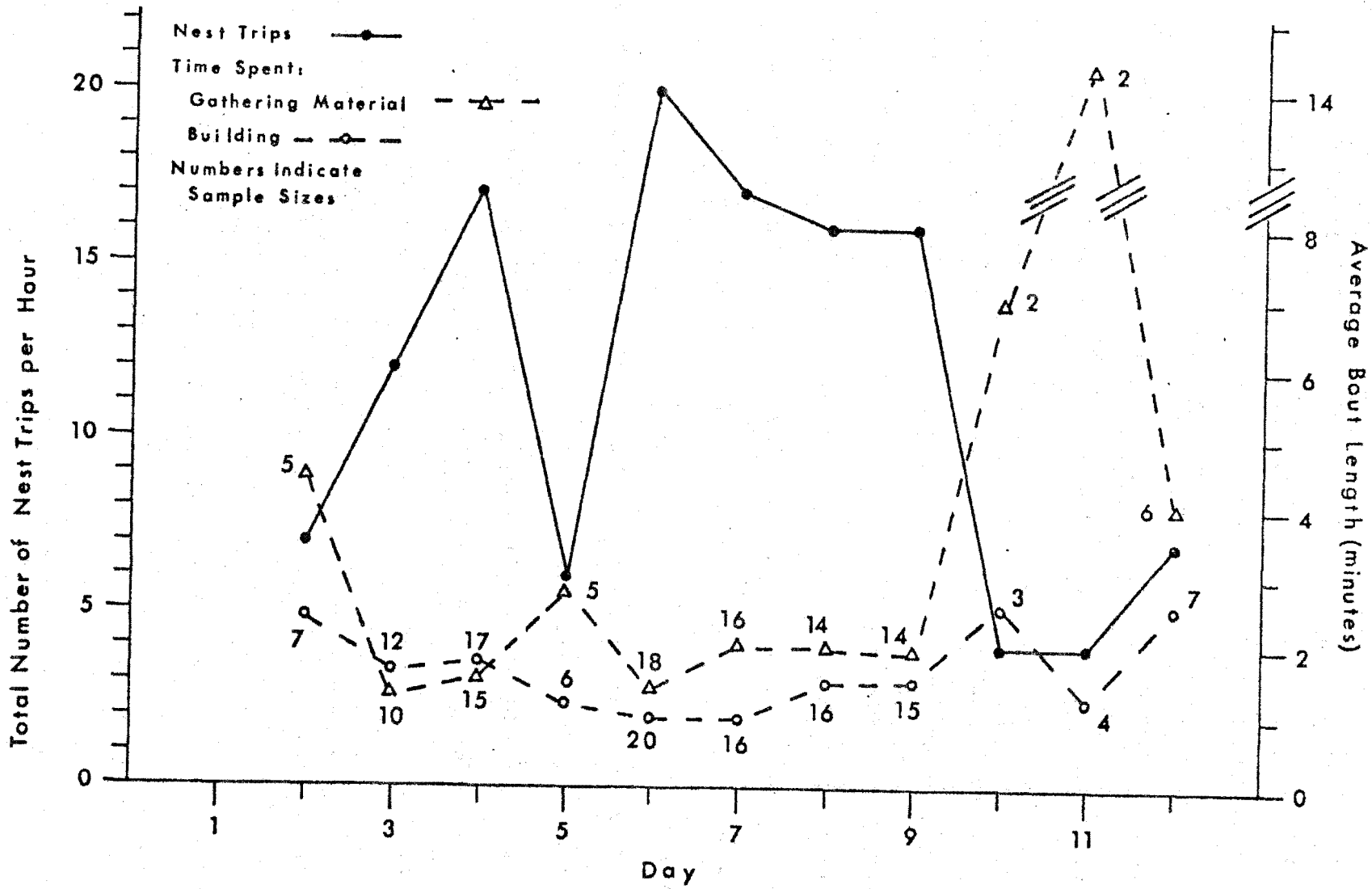


Fig. 6. Behavior of the female House Finch during nest construction.

work being done in the morning than in the afternoon, with activities starting soon after sunrise and ending one or two hours before sunset. The intensity of nest construction seems to be more influenced by the stage of nest building and the time of day than by weather conditions.

Spurts of fairly intense nest building alternate with longer periods when the birds are not seen in the area and are presumed to be resting or feeding (Anderson and Anderson 1944, Thompson 1960a). These "feeding" periods ranged from 4.2 to 27.0 minutes in duration per one-hour session, averaging 14.8 ± 8.4 minutes.

During the periods of intense nest building, the female spends 1.7 ± 0.8 minutes at the site. There are significant differences in the average lengths of time the female spends at the site on the different days of nest construction (one-factor anova, $F= 3.06$, $m/n= 10/112$, $P= 0.05-0.02$), and it is felt that this probably reflects whether the female is just placing the material on the site and flying off or taking the time to enlarge the site or mold the nest into shape. The material-gathering forages of the female seem to be done in the near vicinity, being reflected by the short time spent away from the nest by the female, 3.9 ± 3.9 minutes (the data do not include the longest intervals from the nest, the "feeding" period, for each observational session). Material is gathered from the ground, trees, or even, in one case, taken from a deserted Linnet nest.

Nests do not usually persist from one year to the next, or even through one nesting season, and House Finches usually build new nests for each nesting effort. However, I had two nests from 1972 that were reused in 1973. Although no nests from 1973 were reused in

1974, I had two cases where nesting occurred near or at the sites where nests were the previous year. At one site, a MacArthur palm, the banded female that nested there near the end of the 1973 nesting season renested at the same site at the beginning of the 1974 season. Although the males were not banded, the color was different and may indicate that the female had different mates. Later in the 1974 breeding season the same female nested again about 100 meters away; the site was used for nesting two more times by other females. Four nests during each of the 1973 and the 1974 nesting seasons were reused, one 1973 nest being reused three times. In reusing a nest, the Linnets at least relined the old cup with new material, once in 1974 covering over an egg left from the previous nesting. Because the birds usually were not banded, I could not determine in most cases if the same or different birds reused the nests.

In two cases, an inactive White-eye nest was used by Linnets, both of which added new material to the nests. Neither nest was successful in fledging young, both nests falling from their supports. The 1972 nest terminated when it contained young a few days old, and the 1973 nest during the nest-building stage.

Barred Doves (one case) and House Sparrows (two cases) used old Linnet nests. Guest (1973) reports that White-eyes sometimes take material from active Linnet nests. I have seen a male House Sparrow steal nesting material from an active Linnet nest.

Territoriality

A territory is defined as any defended area. House Finches do not have very large territories. They have a type C territory, where only a small area around the actual nest is defended (Van Tyne and Berger 1971, type D in Pettingill 1970). I have found a number of active nests in close proximity to each other. In one case in 1972, I had four active nests located along a 31-meter line. Two nests were six meters apart in a pandanus tree, the third, in a hibiscus tree, nine meters from the closer nest in the pandanus, and the fourth, located in a fiddlewood tree, 16 meters from the nest in the hibiscus. The two nests in the pandanus and the one in the fiddlewood were started about a week before the one in the hibiscus. All four reached at least the egg-laying stage. It is not uncommon to find at least two active nests in the same pandanus tree, at the most nine meters apart. Nests located close to each other are built in such a manner in the clusters of leaves or foliage that they face away and are not apparent to each other.

Interspecific spacing of nests can also be very small. I have seen Linnet nests in the same trees 8.1 meters from a White-eye's nest, 1.8 meters from an American Cardinal's (Cardinalis cardinalis) nest, 1.8 meters from a Barred Dove's nest, and within 10 meters of nests of House Sparrows, Red-crested Cardinals, Mynahs, and Ricebirds (Lonchura punctulata).

Copulation

Copulation occurs at the invitation of the female. I have never seen male courtship display lead immediately to a copulatory attempt. In eliciting copulation from the male, the female crouches on a perch, raises her tail to a rather vertical position, may droop and vibrate her wings, retracts her neck slightly and tilts her head back so that the beak points upward. The male flies to the female, hops on her back, flapping his wings to maintain balance, leans back, pressing his tail against the female's body. Copulation lasts only a few seconds (usually less than 15), and typically occurs only once. I did not hear any calls between the pair but I may have been too far away. I have never seen the post-copulatory display, reminiscent of food begging, that Thompson (1960a) says occurs, especially after successful copulation.

Egg Laying and Eggs

Egg laying usually starts the day after nest building ends, although I did observe a female adding soft material to a 1974 nest that contained at least three eggs. Although I do not have conclusive proof, it seems that the female arrives at the nest in the early morning hours to lay the first egg of the clutch and does not stay at the nest from the night before. The first egg, and most probably the entire clutch, is laid in the early morning hours. Nests checked before 0800 have contained newly laid eggs. Usually the female lays one egg per day until the clutch is completed. Out of a total of 44 nests (22 in each of 1972 and 1973), only five (three in 1972 and two in 1973) had a day or more skipped in the laying of the clutch. These nests seem to occur randomly during the nesting season.

Bergtold (1913) and Evenden (1957) had similar interruptions, feeling that the causes were extremely cold weather or early morning interruptions by cats, House Sparrows, or the observer. I am uncertain what caused the interruptions on campus.

Eggs vary in shape and weight, even in the same clutch. They may range in shape from almost spherical to elliptical, but usually are oval (somewhat rounded at one end and bluntly pointed at the other). Egg measurements, from 1972, 1973, and 1974, were taken only from nests that were found on or before the day the first eggs were laid and where the clutches were completed. Eggs were measured and weighed the day they were laid. Maximum dimensions of the eggs from the three nesting seasons are shown in Table 5. The 1974 eggs are significantly narrower in width than the 1972 and the 1973 eggs (one-factor anova, $F = 69.4$, $m/n = 2/194$, $P < 0.005$). I found an extremely small egg in a 1972 nest, in which the clutch was completed when found. The egg measured 10.7×13.4 mm and weighed 0.85 g; the two other eggs in the clutch measured 12.9×17.2 mm and 13.1×18.3 mm and weighed 1.55 g and 1.60 g, respectively. The eggs and incubating female later were lost to a predator.

Eggs from the 1972 and 1973 nesting seasons do not show differences in weight if they were laid first, second, third, fourth, or fifth in a clutch, in small or large clutches, or early or late in the nesting season (one-factor anovas, $P > 0.05$).

Bergtold (1913) gave measurements of House Finch eggs from Denver, Colorado, that averaged 13.7×19.6 mm, somewhat larger than my measurements. The larger eggs from Denver also are heavier in weight. Based on two clutches containing four and five eggs,

Table 5

Egg Measurements of the House Finch

	<u>Greatest Width (mm)</u>	<u>Length (mm)</u>	<u>Weight (g)</u>	<u>Clutch Size</u>
1972 eggs				
range	12.3-14.5	17.5-23.0	1.60-2.55	2-5
mean	13.6	19.1	1.90	4.0
standard deviation	0.4	0.9	0.18	0.7
sample size	87	87	87	22
1973 eggs				
range	12.9-14.5	17.3-20.8	1.70-2.20	3-5
mean	13.6	19.0	1.89	4.2
standard deviation	0.4	0.8	0.12	0.5
sample size	84	84	84	20
1974 eggs				
range	11.8-14.3	17.8-21.3	1.55-2.05	4-5
mean	13.2	19.2	1.82	4.3
standard deviation	0.6	0.9	0.13	0.5
sample size	26	26	26	6

Bergtold found that the weight of an egg averaged 2.25 ± 0.08 g. There is a significant difference in the weights of the eggs from Denver and Hawaii (two-tailed t-test, $t = 7.030$, d.f. = 204, $P < 0.001$). (Bergtold recorded his weights in grains and I converted them to grams. It is also unclear if he weighed his eggs on the day they were laid or when the clutch was completed. From the paper it seems that he waited until the clutch was completed).

Although I do not know what was the availability of food in Hawaii for the past three years and in Denver during the early 1900s, a possible cause for this difference in egg weights could be the food supply of the breeding females. Perrins (1970) feels that the amount of food that a female can get prior to egg laying may influence the weight of an egg. Birds that cannot get adequate food lay smaller eggs; birds that get more food lay larger eggs. King (1973), however, feels that an inadequate food supply causes the breeding female to lay fewer eggs in the clutch and not smaller eggs.

The color of the egg yolk of the House Finch is a bright yellow, resembling that of a chicken's.

Clutch Size

Clutch size is the total number of eggs laid by one female for a single nesting (Van Tyne and Berger 1971). Although the females were usually not banded, I am fairly certain that the clutches found represent the laying efforts of only one female. I did find, however, one 1973 nest that had three eggs in it on 6 March, four on 7 March, and hatching started on 10 March. The last egg laid did not hatch. Because the incubation period is usually about

13 days, this nest may represent either a late egg addition by the incubating female or, more likely, an addition by another female. Cases of more than one female laying in a nest have been reported (Bent 1968).

From the three years I had two nests with 2-egg clutches, seven nests with 3-egg clutches, 87 nests with 4-egg clutches, and 31 nests with 5-egg clutches. The 127 nests have an average of about four eggs per clutch (Table 6). Clutch sizes for the three years revealed no significant differences (one-factor anova, $F = 0.72$, $m/n = 2/124$, $P > 0.2$). I do not know if females that reneest have smaller or larger clutches. There was no difference, though, in clutch sizes when the nesting seasons for 1972, 1973, and 1974 were each divided into first and second halves (two-tailed t-tests, $P > 0.05$).

In other parts of the country clutch sizes vary from two to seven, with four or five the more frequently found clutches (Bailey and Niedrach 1965, Bent 1968, Bergtold 1913, Gill and Lanyon 1965, Keeler 1890, Thompson 1960a). Table 6 gives the clutch sizes from papers that have information amenable for comparison. There is no difference in clutch sizes when comparing the ones I found and those from Arizona and California (two-tailed t-tests, $P > 0.05$). (Hensley's data were slightly modified so that I could use it for statistical testing. I used a $N = 11$, instead of his $N = 12$, because one of the clutch sizes was not given and could not be figured out from his paper. Also Grinnell and Linsdale caution that the four nests which they found with 3-egg clutches may have been incomplete.)

Table 6

Clutch Sizes for House Finches

locale	<u>Arizona</u>	<u>California</u>	<u>California</u>	<u>Hawaii</u>
work cited	<u>Hensley</u> <u>(1959)</u>	<u>Grinnell and</u> <u>Linsdale (1936)</u>	<u>Evenden</u> <u>(1957)</u>	<u>This Study</u>
range	3-5	3-6	4-6	2-5
mean	4.0	4.3	4.4	4.2
standard deviation	0.4	0.9	0.3	0.6
no. of nests	11	18	25	127

The Incubation Period

Incubation is the application of heat to the eggs, but, as a working definition, the incubation period is the length of time between the laying of the last egg in the clutch until that egg hatches when all the eggs hatch (Van Tyne and Berger 1971).

Birds trapped during the nesting season and examined confirm Bailey's (1952) finding that only the female House Finch develops a mid-ventral arterial incubation patch. No males showed signs of a patch. Although the presence or absence of an incubation patch may not indicate whether a bird incubates (Bailey 1952, Van Tyne and Berger 1971), this evidence plus nest observations seem to confirm that the female House Finch is the only one of the pair that truly incubates and broods.

Many birds begin to incubate after the penultimate or the last egg of the clutch is laid (Van Tyne and Berger 1971). From the day the first egg is laid, the female is attentive at the nest, to some degree during the daylight hours and always at night. In two cases, I disturbed females at night from nests in which the first eggs had been laid that day. At sunset I have seen females at their nests during the other days of the egg-laying period. Except in one case, the males were not observed at the nests during these late hours, and it may be that the males roost together, away from the nest sites during the nesting period, as reported by Evenden (1957).

While on the nest during the egg-laying and the incubation periods, the female intermittently stands up in the nest cup and moves and turns the eggs with her bill, changes sitting positions, rises and settles, may preen her feathers, even wing stretch and

head scratch. Loud noises will make her look about while on the nest; sudden gusts of wind will cause the female to crouch lower into the cup.

Incubation presumably starts before the entire clutch is completed and probably after the first or second egg is laid. In 1973, I took temperature readings at two nests, which had 4-egg clutches, to establish when incubation begins. A temperature probe was placed in the cup for the nest temperature and a second one placed nearby, but outside the nest, for the air temperature. Table 7 gives the readings I obtained when the female was at the nest during the egg-laying period. In the two nests it is possible that incubation started by the night the first egg was laid and almost certainly by the second night. Hatching in nest 1 was missed, although it seems, from the weights of the young, that two nestlings hatched the first day and one each the next two days. The eggs in nest 2 were destroyed later in the incubation period.

The incubation period in 29 nests was about 13 days (12.8 ± 0.6 days), ranging from 11.5-13.5 days. There was no difference in the length of the incubation period among the three nesting seasons (one-factor anova, $F = 0.196$, $m/n = 2/26$, $P > 0.2$), nor with the incubation period of 13.8 ± 1.1 days (based on 11 nests) determined by Evenden (1957) at Sacramento, California (two-tailed t-test, $t = 1.887$, $d.f. = 38$, $P = 0.1-0.05$). Clutch sizes of the nests used to calculate the incubation period ranged from two to five, but did not affect the length of the incubation period (one-factor anova, $F = 3.37$, $m/n = 3/25$, $P = 0.1-0.5$).

Table 7

Nest Temperatures ($^{\circ}\text{C}$) During Egg Laying¹

<u>Nest</u>	<u>Date</u>	<u>No. of Eggs</u>	<u>Time of Recording</u>	<u>Nest Temp Female in Nest</u>	<u>Air Temp Female in Nest</u>	<u>No. of Readings</u>
1	25 Feb.	one	1117-1142	21.6 \pm 0.5	22.8 \pm 0.5	4
			1840-1900	23.5 \pm 2.6	19.1 \pm 0.4	5
	26 Feb.	two	0715-0815	24.0 \pm 0.7	20.9 \pm 1.7	6
			1855-1905	29.5 \pm 0.1	20.1 \pm 0.1	3
	27 Feb.	three	1655-1755	30.9 \pm 1.0	22.6 \pm 0.4	6
			1840-1850	31.1 \pm 0.4	21.2 \pm 0.1	3
	28 Feb.	four	0750-0850	31.9 \pm 1.2	24.1 \pm 1.6	7
	1 Mar.	four	1338-1438	32.7 \pm 0.7	23.8 \pm 1.3	7
	2 Mar.	four	0910-1010	30.8 \pm 0.5	26.0 \pm 2.2	7
	2	8 May	one	2145	29.5	22.0
9 May		two	1945	32.0	24.9	2
10 May		three	1945	33.0	23.5	2
11 May		four	1900	33.0	25.0	2
12 May		four	1705	33.2	24.6	2
13 May		four	1940	31.0	23.2	2

¹Temperature readings were taken with a YSI Model 43 Single Channel Tele-Thermometer, using YSI general purpose and small vinyl probes, with YSI soft extension leads.

Weight Loss in Eggs

House Finch eggs lose weight after being laid as water evaporates. In 1972 and 1973, I weighed eggs from the day of laying until the day before the young hatched. Because the scale I used was not sensitive enough to detect daily changes in the weights of the eggs, however, I could obtain with certainty only the weights at the time of laying and the day before the young hatched. Based on 58 eggs from 22 nests, an egg loses about 16% (15.9 ± 6.1 %) of its original weight before hatching. This is similar to the 18% weight loss calculated by Rahn and Ar (1974) (based on 46 species studied by Drent).

Hatching

The first evidence of hatching is pipping--having a star-shaped crack in the shell (Pettingill 1970). This occurs, at the earliest, less than 24 hours before the young hatches. In rare instances one young may hatch each day until all the young have emerged. Usually two or three young hatch on one day and the remaining eggs then hatch out one per day. I have never observed all the eggs of a clutch hatching on the same day. Although I have had two or three young hatch on the first, second, or third day of the hatching period, a greater number of young hatch on the first day than the other days: two young on the first as compared to one for the other hatching days (Table 8) (one-factor anova, $F= 7.10$, $m/n= 3/50$, $P < 0.01$).

Hatching may occur at any hour of the day. I have found young in the process of hatching and young with the down still wet, in the morning, at midday, and during the late evening hours. At a nest in 1972, one young hatched between 1800 and 1900, after

Table 8

Average Number of House Finch Young Hatching per Day

	<u>Day of Hatching</u>			
	<u>First</u>	<u>Second</u>	<u>Third</u>	<u>Fourth</u>
mean	1.8	1.2	1.1	1.0
standard deviation	0.7	0.5	0.3	0.0
no. of nests	19	19	14	2

Based on nests where all the eggs of the clutch hatched and the egg-laying sequence was known.

the sun had set and it was dark. I have found pipped eggs in the afternoon; by the next morning the eggs had hatched and the young had dry, fluffy down, indicating that the chicks were more than a few hours old. In other nests, eggs that were not pipped in the afternoon, had hatched by the following morning (by 1000) and the young still had wet down. Hence, young hatch during the night as well as during the daytime.

Eggs hatch in the order that they were laid. In six cases where only one young hatched on the first day of hatching and where the entire clutch eventually hatched, the first egg laid was the one that hatched first. In nine other cases, where more than one young hatched on the first day, the remaining eggs in the clutches hatched in the order in which they were laid.

During actual hatching I have seen a female flying off twice from the nest to a royal poinciana (Delonix regia), 17.6 m from the nest, where she dropped egg pieces, which I presume came from one of the eggs that had just hatched. Another female remained on the nest and ate the egg pieces.

The Nestling Period

A young bird while still in the nest is called a nestling. One that has left the nest but is still dependent on the adults for food is a fledgling (Van Tyne and Berger 1971). Collectively the young of a nest are called a brood.

Because the young may fledge over a number of days and I could not check the nest closely during the latter part of the nestling stage without frightening the nestlings from the nest, I could determine with accuracy the lengths of the nestling periods for

only a limited number of young and mostly from those nests where all the nestlings fledged on the same day. The nestling periods varied from 14 to 19 days (Table 9). I did not obtain nestling periods for 1974. The nestling periods for 1972 and 1973 differ significantly (two-tailed t-test, $t = 4.551$, $d.f. = 34$, $P < 0.001$). The problems encountered in obtaining nestling periods may partially explain this difference.

Bergtold (1913) found that the nestling period at Denver, Colorado, averaged about 14.5 days (based on two nests with four young each; it is unknown if one of the young fledged) (Table 9). The differences in nestling periods between Bergtold's and the ones I found for 1972 and 1973 are significant (two-tailed t-tests, $P < 0.05$).

Young that are fed less may develop at a slower rate (Ricklefs 1968, Van Tyne and Berger 1971). Nestlings from Denver and Hawaii, however, weighed about the same by nestling day 13, suggesting that the young from Denver did not fledge earlier than those from Hawaii because they were fed better and could develop faster. Bergtold weighed his nestlings up to the time of fledging, and this prolonged handling of the young may have caused them to fledge prematurely, resulting in the much shorter nestling periods.

At the time of hatching, a House Finch is altricial, helpless, blind, and has some fluffy whitish down on the head and the body. Appendix 2 summarizes the daily development of the nestlings.

I do not know when temperature control is fully attained. Pettingill (1970) states that temperature control is attained early, soon after the mid-point on the nestling period (which for the House Finch would be nestling day 8 or 9). Lanyon and Lanyon (1969),

Table 9

Length of the House Finch Nestling Period (in days)

locale	<u>Hawaii (1972)</u>	<u>Hawaii (1973)</u>	<u>Colorado (Bergtold 1913)</u>
range	15-19	14-19	14-16
mean	16.8	18.5	14.6
standard deviation	1.1	1.0	0.7
no. of young	12	24	7
no. of nests	6	8	2

who reared young House Finches, from the egg to fledging, say that nestlings achieve some capacity for thermoregulation about the time the eyes open and the feathers begin to emerge from the sheathes (for the House Finch this would be nestling days 5 to 7).

The fear response in a nestling, when it crouches down in the cup and does not gape when the nest is approached, is first noticed when the young is between eight and 12 days old, averaging 10.3 ± 1.1 days (based on 15 nests from 1973).

Nestling Weight Increase

Nestlings are fed by regurgitation, presumably seeds. Beal (1907) examined the stomach contents of 46 nestlings from California, and found that vegetable matter, entirely weed seeds, comprised about 98% of the nestling's food. The animal matter may have been ingested accidentally by the adults along with the plant food. I did not analyze any nestling stomachs, but I did watch adults feeding nestlings, and later noticed what seemed like weed seeds about the beaks of the young. I brought some of the seeds back to the office and attempted to grow them; they did not grow.

Nestlings from a total of 43 nests (15 nests in 1972 and 28 nests in 1973) were weighed daily or almost daily. Figure 7 shows the mean weight \pm two standard deviations of a nestling from day 0 (the day the young hatches) until day 13. There is no difference between 1972 and 1973 in the weights for the respective days (two tailed t-tests, $P > 0.05$). There is a steady increase in body weight of a nestling from less than two grams on the day of hatching to about 17 grams, 13 days later. Although I could not get weights beyond day 13 without frightening the young prematurely from the

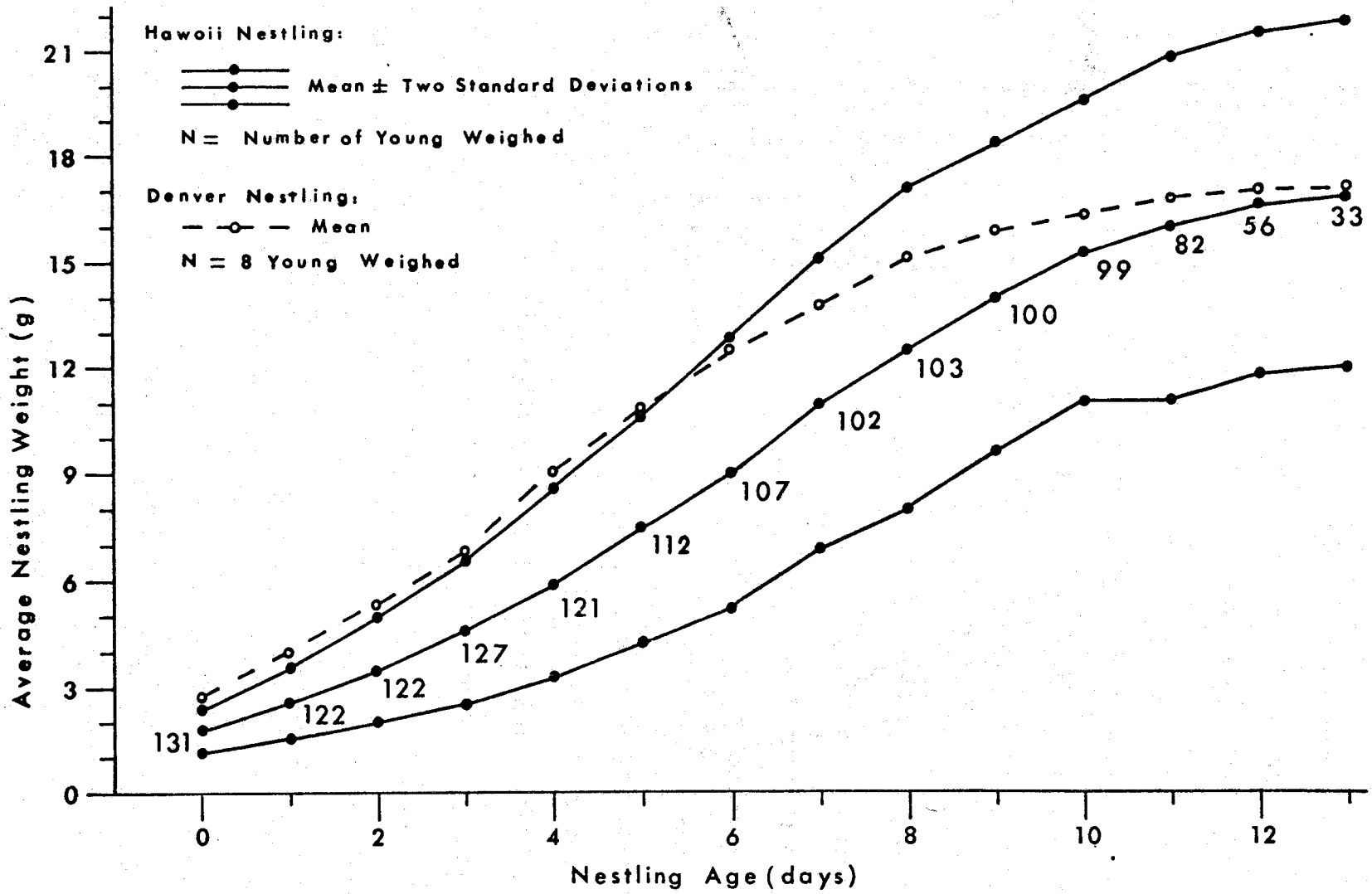


Fig. 7. Average Weight of a House Finch nestling.

nest, in two cases in 1973, a just-fledged young, 19 days old, and a chick, 18 days old and a day away from fledging, both weighed 19.0 grams. This suggests that a House Finch young probably shows the standard type of avian growth curve (Ricklefs 1968), where nestling weight increases to approximately that of the adult (for the Linnet about 19.5 grams) during the nestling period.

Figure 8 shows the average daily weight increase of a nestling for the first 13 days of life. Nestling weights were obtained from 42 nests (15 nests in 1972 and 27 nests in 1973) and represent the weight change that I found between two successive checks, not more than a day apart. Based on the first 13 days of life, the average weight increase of a nestling is 1.2 ± 0.4 g per day, although this rate is not uniform over the 13 days but shows greater weight gains from the day of hatching, peaking on nestling day 7, and then showing lesser gains for the remaining days (one-factor anova, $F= 20.96$, $m/n= 12/1152$, $P < 0.01$). This trend partly reflects energy being used more for growth than maintenance during the first half of the nestling period, but more energy being needed for maintenance as the young becomes larger, leaving less for growth (Ricklefs 1968). The especially greater weight gain between days 6 and 7 seems to reflect the increased total feeding rate during the middle third of the nestling period.

There are no significant differences when comparing the average growth gains per day during the first 13 days of the nestling periods between the first and the second halves of the nesting seasons (one-factor anova, $F= 0.12$, $m/n= 3/48$, $P > 0.2$).

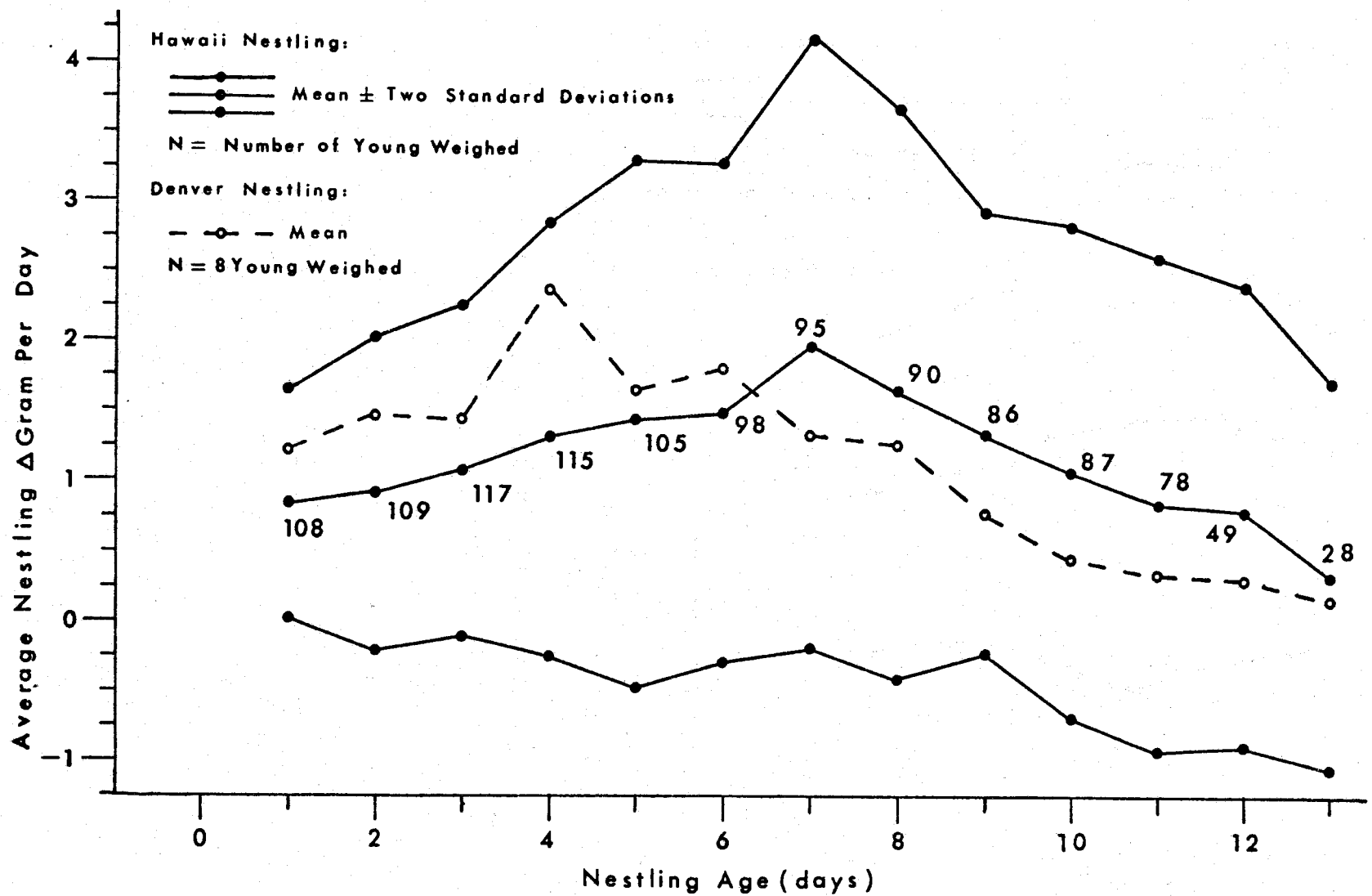


Fig. 8. Average weight increase of a House Finch nestling.

At Denver, Colorado, Bergtold (1913) weighed eight young from two nests during the nestling period. At one nest four young hatched on the same day; at the other nest two nestlings hatched on the first day, one each on the second and the third days. Seven nestlings took from 14 to 16 days to fledge, and it is unknown if the eighth young fledged. Figures 7 and 8 show the average weight and the average weight increase, respectively, for the Denver nestlings.

The average daily weight increase for the nestlings for the first 13 days after hatching is 1.1 ± 0.7 g per day, and does not differ from the rate for the campus young (two-tailed t-test, $t = 0.045$, d.f. = 24, $P > 0.9$). The development of the Colorado nestlings does differ, though, from the Hawaiian ones on a day-to-day basis. The Colorado young weigh significantly more at hatching and through day 9, but from day 10 to 13 there is no difference in the weights of the young from either localities (two-tailed t-tests, $P = 0.05$ level used).

Ricklefs (1968) found as much as 20% variation in growth parameters in populations of a species at different geographic localities, but does not believe that this variation is directly related to nutrition. The fact that the nestlings from Denver and from Honolulu weighed the same by nestling day 13 would seem to indicate that the different growth curves were not affected by the food supply for the nestlings. The Denver nestlings hatched from eggs that were heavier than those from Hawaii, and it may be that the manner of growth of a nestling is affected by the weight of the egg.

Schifferli (1973) had similar weight developments in the growth of Great Tit (Parus major) nestlings hatched from heavier eggs and those hatched from lighter eggs, and concludes that egg weight affects growth.

Nestlings hatch out over a period of days and show differences in weights, with older young usually weighing significantly more than the younger nestlings on days 2, 3, 9, 10, and 11 (Fig. 9) (one-factor anovas, $P < 0.05$). The reason for the weight differences seems to be sibling competition for food brought by the adults (Ricklefs 1968), although the adults try to feed an equal portion to each nestling of the brood. Early in the nestling period, the eyes of the older young open first, giving them an advantage over the sightless and younger nestlings. The older young are able to direct their gapes toward the feeding adult and may be able to get more food. Later in the nestling period, the older and larger young are able to gape much more vigorously and forcibly before the feeding adult. Asynchronous hatching, even in species where the age spread in the young is less than a day, could be considered an evolutionary mechanism for brood reduction, whereby only the largest young survive in poor food years but all may in years of adequate food (Cody 1971). Although the later hatching Linnet nestlings weighed less than their older siblings, they usually survived to fledge. Only in broods containing five young did the last nestling to hatch (usually on the fourth day) fail to survive. It may be that in Hawaii the food supply is not adequate for brood sizes of five. More research is needed to verify this point.

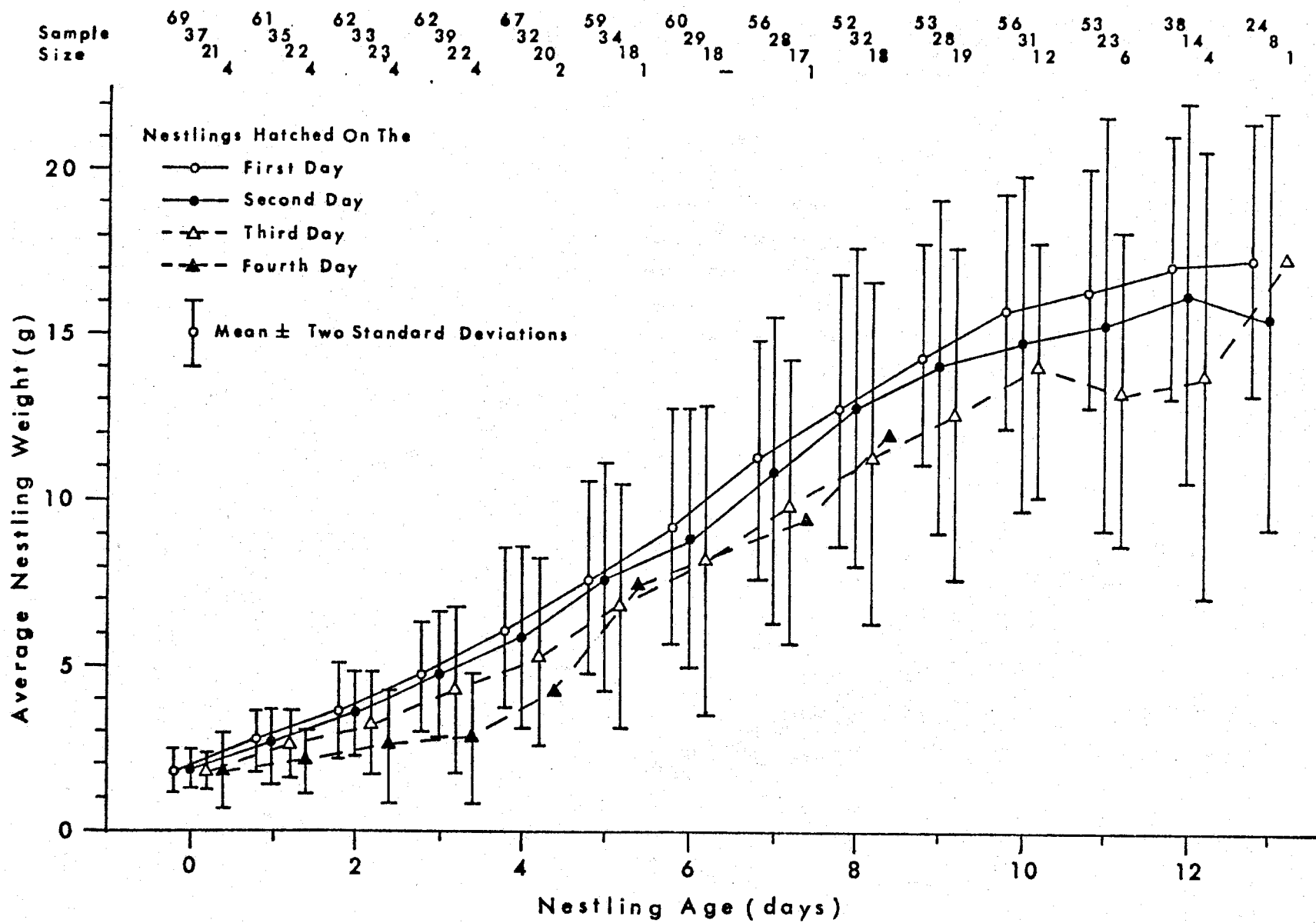


Fig. 9. Average weights of House Finch nestlings hatched on different days.

In 1973, during the early and the late nestling periods, I weighed young before and after they were fed by the adults. Based on a total of 38 readings from 18 nests, the weight gain of a brood after a feeding ranged from 0.00 to 2.30 grams per feeding, averaging 0.63 ± 0.55 g per feeding. The weight gain of a brood did not differ significantly whether the nestlings were fed early or late in the nestling period, by the male or the female (two-tailed t-tests, $P > 0.05$). The weight increase of a brood did not differ significantly whether the size of the brood ranged from two to five (one-factor anova, $F = 2.12$, $m/n = 3/33$, $P > 0.2$). After a feeding, regardless of brood size, each nestling showed a similar weight gain, suggesting that an adult tries to feed every young an equal amount (one-factor anova, $F = 0.05$, $m/n = 3/127$, $P > 0.2$).

Nest Attentiveness

At the nest an adult bird incubates eggs and broods nestlings. An adult may incubate and brood at the same time if the eggs of a clutch takes several days to hatch. The time a bird spends at the nest is referred to as attentiveness; the time spent off the nest is called inattentiveness. This alternation of periods is spoken of as the incubation rhythm, when eggs are in the nest, and the brooding rhythm, when young are in the nest. The brooding rhythm is considered fundamentally a continuation of incubation behavior (Pettingill 1970, Van Tyne and Berger 1971).

The female House Finch not only incubates and broods, but at two nests, when the situation arose and the nests received direct sunlight, each female perched on the rim with her back to the sun, wings held out, and shielded the young from the intense radiation.

Frequently the female had her beak slightly opened and seemed to be panting. At one nest the female sun-shaded the young, about five days old, almost the entire observational session (58 out of 60 minutes), interrupting her activity only to have the nestlings fed. The only case of male attentiveness occurred at a 1973 nest, where the male, after feeding recently-hatched young, stood in the cup and shielded the nestlings from a sudden downpour. The rain ceased two minutes later and the male flew off.

Figure 10 gives information on female attentiveness at the nest during the daylight hours for the nesting period. Information is based on 60-minute observational sessions from 1972 and 1973. When more than one session for a nest was held on the same day the mean is used. In the egg-laying period, days 1 to 4 do not include the day the last egg of the clutch was laid, because this day is also the start of incubation and is thus under incubation day 0. The incubation period is defined slightly differently than previously, being from the day the last egg of the clutch is laid (day 0) until all the eggs that will hatch do. The egg-laying period is based on observations at nine nests, with one nest containing a 3-egg clutch, six nests with 4-egg clutches, and two nests with 5-egg clutches. The incubation period is based on observations at 23 nests; the nestling period on 25 nests. See, also, Figure 11, the feeding-rate graph.

Total female attentiveness increases significantly from 53.0% on the day the first egg of the clutch is laid to 94.0% on the day the last egg of the clutch is laid (31.8 ± 19.8 to 56.4 ± 2.8 minutes per session) (two-tailed t-test, $t = 3.555$, d.f. = 11, $P = 0.01-0.001$).

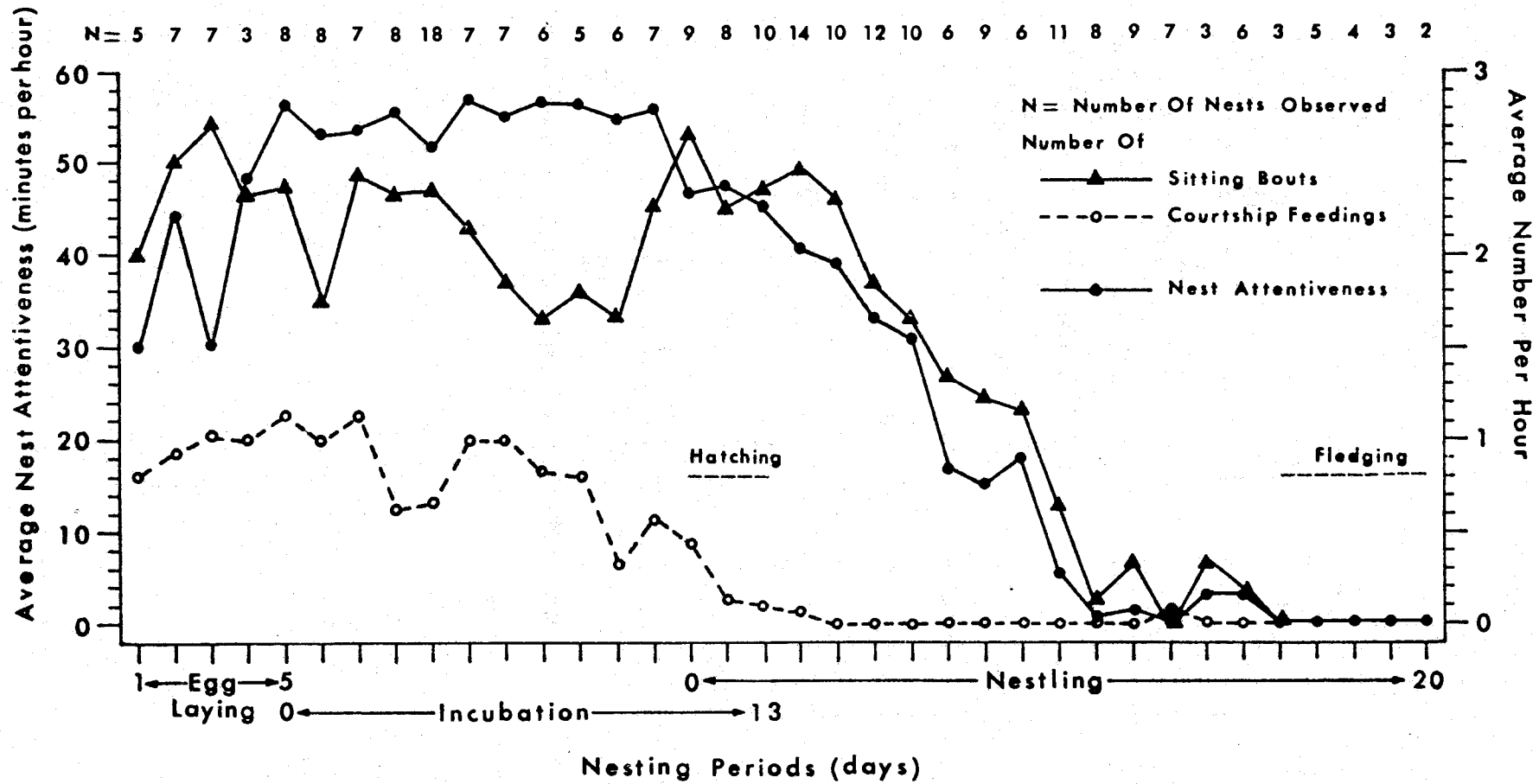


Fig. 10. Female nest attentiveness and related House Finch behavior.

During the incubation period the female is on the nest 89.2% of the time (53.5 ± 4.1 minutes per session), but she is more attentive during the nonhatching days 0 to 10 than during the hatching ones 11 to 13 (55.4 ± 1.6 vs. 46.5 ± 0.9 minutes per session) (two-tailed t-test, $t = 9.107$, d.f. = 12, $P < 0.001$).

Skutch (1962) found that in those species in which only one adult incubates, the eggs are kept covered about 60 to 80% of the time. Attentiveness above 80% is shown by species where the incubating adult is well nourished on the nest by attendants or by those which enjoy exceptional advantages in finding food during the recesses.

During the incubation period, the male House Finch courtship feeds the female about once every hour (Fig. 10). Courtship feeding for the House Finch could possibly provide the food which allows the female to incubate for as long as she does. As Royama (1966a) suggests, the food value of courtship feeding may be as important, if not more, than the symbolic function.

For the first seven days after the young start to hatch (nestling days 0 to 6), the female spends 67.4% of the time at the nest (40.4 ± 6.6 minutes per session). After day 6, female attentiveness declines until about day 10, from which point onward daytime brooding is infrequently observed. Night brooding ends after days 12 to 14. The decline in brooding attentiveness may be due to the young developing better body-temperature control (Pettingill 1970, Royama 1966b).

Comparisons of two one-hour observations, one done in the morning and the other in the afternoon, at 13 1973 nests on incubation day 4 and 18 1973 nests during the first part of the nestling period, reveal no significant differences in female attentiveness as the day progresses (two-tailed paired t-tests, $P > 0.05$).

Although I have observed females on the nest, especially during the incubation period, for the entire 60-minute session, attentiveness is usually broken into bouts, with recesses away from the nest when the female is fed by the male, forages for food for herself or the nestlings, or preens, water baths, or defecates. Time spent away from the nest is fairly short during the incubation period, increasing during the nestling period as the young are fed more and brooded less. From egg-laying day 1 to nestling day 6, during which period the female spends a great deal of her time on the nest, the average number of sitting bouts per session is 2.2 ± 0.3 . From nestling day 6 onward, the number of bouts per session declines, as does attentiveness (Fig. 10).

Feeding Rates

Feeding has been grouped into four categories, 1) male courtship feeding of the female, observed mainly in the egg-laying and the incubation periods, but seen occasionally during the nestling stage (Fig. 10), 2) male courtship feeding of the female, who in turn feeds the newly hatched young (hereafter referred to as male-female feeding), seen only during the early part of the nestling period, and 3) the male and 4) the female, each individually, feeding the nestlings, observed throughout the nestling stage (Fig. 11, Table 10).

The total number of feedings of the nestlings per 60-minute session for the entire nestling period is about two feedings per session (Fig. 11, Table 10). It is rare when no feedings occur during a 60-minute period, and I have noted as many as four feeding trips. The total feeding rate increases significantly from the first to the middle third of the nestling period (one-factor anova, $F = 20.4$,

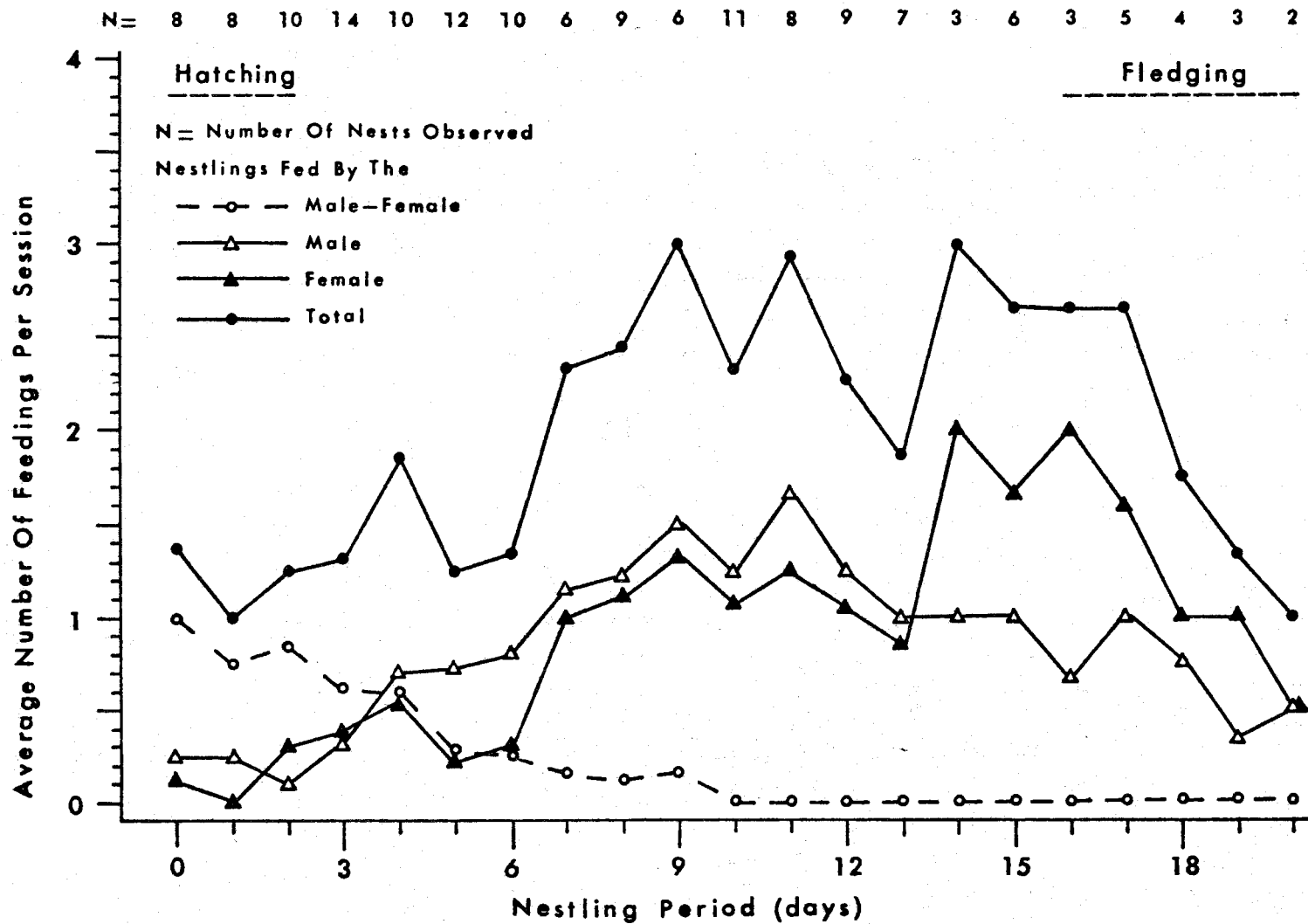


Fig. 11. House Finch feeding rates.

Table 10

House Finch Feeding Rates per 60-minute Session

<u>Feeding by</u>	<u>Nestling Period</u>			
	<u>first third</u> <u>(days 0-6)</u>	<u>middle third</u> <u>(days 7-15)</u>	<u>last third</u> <u>(days 16-20)</u>	<u>overall</u> ¹
Male-Female				
mean	0.6			0.5
standard deviation	0.4			0.3
sample size	72			10
Male				
mean	0.5	1.2	0.7	0.8
standard deviation	0.5	0.7	0.8	0.4
sample size	72	65	17	21
Female				
mean	0.3	1.2	1.3	0.9
standard deviation	0.5	0.7	1.2	0.6
sample size	72	65	17	21
Total				
mean	1.3	2.5	2.0	2.0
standard deviation	0.9	1.1	1.4	0.7
sample size	72	65	17	21

¹ The overall feeding rate for the male-female feeding is from days 0 to 9; the other overall feeding rates are from days 0 to 20.

m/n= 2/151, $P < 0.01$), and is due to both the male and the female increasing their number of feeding trips.

In the male-female feeding of the young, the male courtship feeds the female at the nest and the female, in turn, feeds the newly hatched nestlings. Normally the female feeds the young immediately after being fed herself, but I have seen attentive females intermittently feeding the nestlings until the next courtship feeding, suggesting that the recently hatched young are fed small amounts of food over a span of time and not one large amount at one feeding. Although the male-female courtship feeding method is absent during the last two-thirds of the nestling period, it constitutes a significant portion of the feeding rate in the first third of the nestling period and may have evolved as a means by which the female is able to brood longer the recently hatched young.

Over the course of a day there are no significant differences in the total number of feedings per session during the nestling period (two-tailed paired t-tests, $P > 0.05$).

When both adults feed the young, the usual pattern is for the male and the female to alternate in feeding, first one parent arrives, feeds the young, and flies off, and some time later the second parent comes in to feed the nestlings. At 13 1973 nests, where the young were more than seven days old, the intervals between feedings and which parent did the feedings were noted during 60-minute sessions. Out of 30 consecutive feedings, only four (13.3% of the total) were by the same adult; only three feedings (10.0% of the total) were within one minute of each other. The times between feedings ranged from one to 38 minutes, averaging 16.7 ± 12.0 minutes apart.

Bergtold (1913), at Denver, Colorado, mentions feedings done at intervals of 15 to 25 minutes. Bailey (1953), also in Colorado, gives feeding rates for a nest with four young about five or six days old as once every hour for the female and once every two hours for the male. Thompson (1960a), at Berkeley, California, had feedings at intervals of about 25 minutes, with the parents alternating feedings. The literature does not mention the male-female courtship feeding method. Keeler (1890) at San Francisco, California, mentions that the male does not appear to aid in the caring of the young, although whether he was referring to only brooding or also feeding is not clear.

Nest Sanitation

The fecal sacs of House Finch nestlings accumulate on the nest rim. Especially when three of four young fledge, the nest rim may be covered with fecal matter, although the cup itself is often clean, partly because the older nestlings raise their cloacal regions over the rim when passing fecal sacs. For the early part of the nestling period no fecal sacs are evident on the nest, because both the male and the female remove the sacs, usually by eating them. In one case a male carried them away. The first sacs on the rim appear from four to nine days after the young first start hatching, averaging 6.1 ± 1.3 days (based on 29 nests from 1972 and 1973).

Dead nestlings are removed within the day that they died. In only a few cases have I found dead nestlings in the nest cup from one check to the next. Newly hatched young are easily removed when

they die but older young are often found just outside the cup proper, dangling on the nest rim. In one instance a young over 14 days old was found dead on the cup bottom after its two fellow nestlings had fledged.

Adult Nest Defense

When a nest is approached the Linnet usually gives alarm calls from a nearby high perch or from the nest tree. When the disturbance has passed the bird quietly returns to the site and resumes the disrupted activity (incubation, brooding, or feeding). I have seen a lizard (possibly Anolis) scare a female from a nest, which contained eggs and recently hatched young. The female flew about near the nest, perched on higher branches, and gave alarm calls. She did not attack the lizard, and, when the reptile left a few minutes later, the female Linnet returned to the nest. The lizard did not harm the eggs or young. Some nesting females, though, are not so easily scared off and do not leave the nest until one is actually looking into the nest and about to touch the bird.

At a 1973 nest, the young were handled when they were too old and jumped from the nest. While I was retrieving one of the nestlings, the male gave alarm calls, flew very slowly about me, within 1.5 m (five feet) of the ground, gliding with occasional flappings of the wings. This is the only observation of what I consider to be a form of distraction display.

Fledgling Period

My information on the fledgling stage is scanty. The young fly well at fledging. Nestlings that I have frightened into fledging prematurely were capable of flights of more than 15 m. The young

of a brood may fledge all in one day or over a number of days and seem to fledge in the morning hours. Because the young, especially at the time of fledging, can be frightened prematurely, I could not determine the exact number of young that fledged daily when it occurred over a period of days, nor whether the oldest young fledged first and the youngest last.

It seems that the young move out of the nesting area soon after fledging. Charles van Riper, III, says that for the first few days after leaving the nest the fledglings perch quietly and inconspicuously in the nest vicinity, and then move farther from the area with the adults in small family groups.

The fledglings are fed by the adults for at least two weeks and probably are independent after three weeks. On four occasions a total of five banded fledglings were fed by adults (presumably the parents), in two cases up to 14 days after the young had fledged. Usually the male was the only one that fed but in one instance, when the young had been fledged five days, the female also fed. In 1973 I saw a banded young, 21 days after fledging, following a pair (unbanded adults but presumed to be the parents) that was actively nest building. I did not see either parents feed the young, although it begged. The next day the adults were still building but the young was not seen from then on. Two other young, 24 days after fledging, were seen unaccompanied by adults. The birds that were hand-raised in the aviary could feed themselves when they were about 25 days old, although they still begged for a month more. Given a nestling time of 17 days, the young were able to feed eight days after what might be called "fledging."

In the first few days after fledging, I have observed a male feed a fledgling twice in 60 minutes, a female feeding one of three fledglings once in 95 minutes, and a male feeding one of two fledglings once in 60 minutes on two different days and three times in 60 minutes on a third day.

The remains of a young, that fledged probably on 6 June 1972, was found about 270 meters from the nest in a drainage ditch on 28 June. The dead fledgling was rather badly decomposed and had been dead at least a few days.

Of the 83 banded nestlings that fledged in 1972 and 1973, only three were sighted on campus in the next nesting season.

Renesting

Because I did not band many adults, my information on renesting is inadequate. A banded male in 1973 helped raise to fledging young at two nests. The young at the first nest fledged on 6 June and the second nest, with one egg, was found on 12 June, some 270 meters from the first nest. Unfortunately the females in neither cases were banded and I do not know if they were the same at both nests. On 1 May 1973, I sighted a banded young accompanying and food begging to two unbanded adults as they were constructing a nest in a monkeypod tree. The nest was in a very preliminary stage, with little material on the site. The young had fledged from a nest in a yucca (Yucca elephantipes) 275 meters from the second nest by 10 April. On 6 April 1974, I discovered in a pandanus tree a nest with two young over 14 days old. The nest female was banded. Both nestlings had their heads bloody and battered and by the next day were dead. On 29 April

I found a nest built by the same female, 18 meters away in another pandanus; the first egg was laid on 3 May and young subsequently fledged. The interval between the loss of the first nest and the start of the second is about 2.5 weeks, assuming that the nest was under construction about five days when it was discovered.

Even with the extended nesting season in Hawaii, most likely only two broods are raised successfully in one season by a pair because of the long nesting period (about two months, including 20 days before renesting) and the low nesting success.

In other parts of the country, two broods in one season seem to be normal for the House Finch (Bent 1968, Evenden 1957, Gill and Lanyon 1965, Hensley 1954, Keeler 1890), although Bailey and Niedrach (1965) had Linnets at Denver nesting three times (but it is not clear if the third nesting was successful) and Thompson (1960a) found that only one brood was raised successfully, and rarely a second attempted, in the Berkeley area. In all the above, except for Gill and Lanyon and possibly Evenden, conclusions about the number of broods that are raised in one season by a pair probably are not based on banded birds.

Banding Records

In 1972, 55 nestlings from 23 nests were banded, and 38 nestlings from 17 nests fledged. In 1973, 68 nestlings from 20 nests were banded, and 45 young from 14 nests fledged. There were few later sightings or recoveries, indicating that the young either suffer a very high mortality rate after fledging or, more likely, they move off the campus within a few days.

In 1972 one adult female was banded, in 1973 42 adults were banded during and after the nesting season. As with the fledglings, very few banded adults were seen after they were released, possibly suggesting that there is a large population on or near the campus and/or a considerable turnover in individuals from one nesting season to the next.

Five trapped adults lacked one or more toes or had the toes and legs greatly swollen and bleeding. One female, trapped by H. Eddie Smith on Diamond Head on 23 May 1973, had swollen legs and a deformed beak. Charles van Riper, III, (pers. com.) also reported a female with a missing upper mandible, on Mauna Kea. A nestling on campus also lost its upper mandible but was able to fledge.

I did not trap enough birds to determine if there is any seasonal change in House Finch body weights. Based on weights from the 1973 trappings, 23 males and 20 females, House Finches may weigh from 16.9 to 23.8 grams, averaging 19.5 ± 1.6 g. There is no difference in male and female body weights (two-tailed t-test, $t = 1.575$, d.f. = 41, $P = 0.4-0.3$).

House Finch Nest Fauna

Nest faunas from three nests in 1972 and five in 1973 were extracted using the Tullgren-funnel method. With the kind assistance of Darwin S. Yoshioka, entomology graduate student, the animals from the 1972 nests were identified, usually to family but in some cases only to order. Identification of the nest faunas from the 1973 nests is pending. The three nests revealed a combined total of 17 different types of animals. Table 11 lists the animals found,

numbers extracted, and probable reason(s) for finding the animal at the nests. Unless otherwise indicated all individuals found in the group were adults.

The most interesting species found is the blood-sucking mite (Mesostigmata:Dermanyssidae). It was present at every nest I found, ranging from being scarcely noticeable to literally covering the nest and the nestlings. Young, even at those nests where the mite populations were in the thousands, gained weight and fledged. Bergtold (1913) collected a similar mite.

Nesting Success

Nesting success may be defined in a number of ways. In this paper the following are defined as

- 1) nesting success--the proportion of the number of young that fledge in relation to the number of eggs that are laid,
- 2) hatching success--the proportion of the number of young that hatch in relation to the number of eggs that are laid, and
- 3) nestling success--the proportion of the number of young that fledge in relation to the number of young that hatch.

No nests were considered in computing nesting success where even one egg or young was lost, or believed lost, by my actions or by others. For a more accurate picture of nesting success, only nests that were found before hatching began are included.

Of the 141 nests found during the nest-building period, 82.3% (116 nests) were completed and had at least one egg laid in it.

There are no significant differences in the proportions of nests that were completed from the three years ($2 \times 2 \chi^2$ tests, $P > 0.05$).

Table 11

House Finch Nest Fauna

<u>Animal</u>	<u>Numbers Extracted</u>	<u>Probable Reason(s) Found at the Nest</u>
Jumping spider (<u>Araneida:Salticidae</u>)	0-1	A predator on the other nest fauna, especially springtail (Zimmerman 1948).
Mite (<u>Cryptostigmata</u>)	0-10	Feeds on nest fungi and organic detritus (Yoshioka, pers. com.).
Mite (<u>Mesostigmata:Dermanyssidae</u>)	0-thousands	Nest-inhabiting parasitic mite, emerging from the shelter of the nest material or adjacent sites for brief periods of attachment to the host when blood is taken. Various stages in the life cycle found (Pettingill 1970, Tomich 1967).
Springtail (<u>Collembola:Entomobryidae</u>)	0-23	Feeds on nest fungi and organic detritus (Tomich 1967, Zimmerman 1948).
Earwigs (<u>Dermaptera</u>)	0-16	Omnivorous or carnivorous insect, at the nest because of its moist conditions. Various sizes found (Zimmerman 1948).
Psocids, or book lice (<u>Psocoptera</u>)	37-145	Feeds on nest fungi and organic detritus. Various life stages found (Pettingill 1970, Tomich 1967, Zimmerman 1948).
Louse (<u>Mallophaga</u>)	0-1	Wandered off the host bird and then found in the nest (Rothschild and Clay 1952). The Hawaiian Linnet has at least two lice species externally attached (Alicata 1964).
True bugs, or flower bugs (<u>Hemiptera:Anthocoridae?</u>)	0-2	The family <u>Anthocoridae</u> is a predator on other nest fauna, especially thrips and mites (Rothschild and Clay 1952, Zimmerman 1948).

Table 11.

House Finch Nest Fauna

<u>Animal</u>	<u>Numbers Extracted</u>	<u>Probable Reason(s) Found at the Nest</u>
Thrips (<u>Thysanoptera</u>)	0-7	Scavenger or fungivores. Various stages in the life cycle found (Zimmerman 1948).
Beetles (<u>Coleoptera:Staphylinidae</u>)	0-1	<u>Staphylinidae</u> could be a predator on other
: <u>Tenebrionidae</u>)	0-1	insects; <u>Tenebrionidae</u> feeds on decomposing
:unknown)	0-1	organic matter (Fullaway and Krauss 1945).
Moth or butterfly (<u>Lepidoptera</u>)	0-9	Only larval forms found and probably wandered onto the nest as they were feeding (Swezey 1954).
Gnats or flies (<u>Diptera:Sciaridae</u>)	0-7	<u>Sciaridae</u> feeding habits in Hawaii unknown
: <u>Sarcophogidae</u> or	0-2	but associated with decomposing matter and
<u>Calliphoridae</u>)		humus material (Zimmerman 1960).
: <u>Muscidae</u> , genus <u>Fannia</u>)	0-1	<u>Sarcophogidae</u> or <u>Calliphoridae</u> feeds on
		decomposing organic matter; only larval
		forms (Fullaway and Krauss 1945). <u>Muscidae</u>
		feeds on nest refuse and decaying plant
		material; larval forms only (Fullaway and
		Krauss 1945).
Ant (<u>Hymenoptera:Formicidae</u>)	0-4	A predator on other nest fauna, especially springtails and psocids (Tomich 1967, Zimmerman 1948).

Table 12 lists the number of nests where at least one young fledged, based for 1972 and 1973 on 46 nests each and for 1974 on 43 nests. The number of nests where a portion of the clutch eventually fledged is significantly greater in 1973 than in the other two nesting seasons ($2 \times 2 \chi^2$ tests, $P < 0.05$).

This greater number of young that fledged in 1973 is reflected in the nesting success of 1973 being significantly higher than in 1972 and 1974 (Table 13) ($2 \times 2 \chi^2$ tests, $P < 0.05$). The 1974 breeding season showed a significantly higher nestling success than 1972 and a higher hatching success than 1974. The higher success in 1973 is partly the result of a better hatching success in the second half of the breeding season than in the first; in the other two years nesting success did not differ significantly in the two halves. Higher nesting success was not observed in the second half of 1972 because of a lower nestling success, resulting from a higher number of nestlings dying in the second than in the first half. It was not uncommon in the second half of 1972 for a young to die daily until the entire brood was lost. Higher nesting success was not observed in the second half of 1974 because of a lower hatching success, resulting from a greater number of eggs not hatching in the second than in the first half. During the second half of 1974, not only did one or two eggs of a clutch not hatch, but at a number of nests the entire clutch failed to hatch.

I do not know what caused the higher nestling death rate or hatching failure rate for the second halves of 1972 and 1974, respectively. Because the weight developments of nestlings from

Table 12

House Finch Nest Success

<u>Year</u>	<u>Number of Nests Where</u>		
	<u>One Young Fledged</u>	<u>Portion of the Clutch Fledged (more than one but less than all)</u>	<u>All Fledged</u>
1972	1	5	5
1973	1	15	2
1974	1	5	3

Table 13

Nesting Success of the House Finch in Hawaii

<u>Time</u>	<u>Number of</u>				<u>% Success</u>		
	<u>Nests</u>	<u>Eggs Laid</u>	<u>Eggs Hatched</u>	<u>Nestlings Fledged</u>	<u>Hatching</u>	<u>Nestling</u>	<u>Nesting</u>
1972							
first half	26	93	44	21	47.3	47.7	22.6
second half	20	77	44	8	57.1	18.2	10.4
overall	46	170	88	29	51.8	33.0	17.1
1973							
first half	31	119	65	30	54.6	46.2	25.2
second half	15	62	46	25	74.2	54.3	40.3
overall	46	181	111	55	61.3	49.5	30.4
1974							
first half	30	114	61	21	53.5	34.4	18.4
second half	13	50	18	7	36.0	38.9	14.0
overall	43	164	79	28	48.2	35.4	17.1

1972 and 1973 are the same, I do not believe more young starved to death in 1972 than in 1973. Disease or parasites could be the cause (but see a following discussion on the Dermanyssidae mite), but I did not examine nestlings that died. The 1974 nesting season was unusually rainy and windy and may have influenced egg-hatching success.

Although the data from the three years do not really indicate any pattern, weather differences between the first and the second halves of the breeding season could be influencing the nesting success of the House Finch in some undetermined way. The nesting season was divided into halves at mid-late May. In Hawaii, the first half of the nesting season is in the "winter" part of the year, a time when the weather is cooler and the trade winds are more frequently interrupted by other winds and by periods of widespread cloud cover and rainfall, while the second half is in the "summer" part of the year, when the weather is warmer and drier and the trade winds are more persistent (Price 1973).

Nice (1957) calculated that the nesting success of temperate altricial species was 46%. In all three years of this study the nesting success of the House Finch was far lower. In fact, the nesting success of the Hawaiian Linnet is closer to the 30% found by Skutch (1966) for Central American species that build open or roofed nests. Although the nesting success of the House Finch is very low, it is a fairly abundant bird, suggesting that there may be high survival during the fledgling and/or the adult stages. It could also be that the seemingly low numbers that "make it" each year is still sufficient to maintain the House Finch population at its present level.

Table 14 lists nesting success for House Finch populations in various locations in the country, primarily urban and suburban environments. A number of the studies were done for more than one year, but for ease of computation a combined nesting success is given for each locale. Nesting success in Hawaii for the three nesting seasons is 21.7% and compares similarly with the finding of West (1972) in New Mexico, but is significantly lower than the success from Bergtold's (1913) Denver population, Evenden's (1957) Sacramento Linnets, and Hensley's (1954) Arizona House Finches ($2 \times 2 \chi^2$ tests, $P = 0.05$ level used). The higher nesting success of Evenden's and Hensley's Linnet populations is contributable to both higher hatching and nestling successes. The House Finch in Hawaii has a much lower nesting success than most Linnet populations in other parts of the country.

Various factors cause the loss of eggs and young; the losses were: in 1972, 141 eggs or young; in 1973, 126 eggs or young; and in 1974, 136 eggs or young.

1) Strong winds knock eggs and nestlings from the nest, often toppling the nest from its site. In 1972 winds accounted for 36.2% of the mortality, in 1973 for 37.3%, and in 1974 for 30.9%.

2) Predation; the remains of eggs and young have been found in nests. In two instances in 1972, three in 1973, and one in 1974, the nesting female was also felt to have been killed, because of the large number of feathers found in the nest. I have not actually observed predation, but it seems that the agent is a rat species. Once in 1974 I found a rat (species unknown) in an inactive House Finch nest that was located in the leaf midrib of a golden-fruited

Table 14

Nesting Success of the House Finch

<u>Locale</u>	<u>Literature Cited</u>	<u>Number of</u>					<u>% Success</u>		
		<u>Years</u>	<u>Nests</u>	<u>Eggs Laid</u>	<u>Eggs Hatched</u>	<u>Nestlings Fledged</u>	<u>Hatching</u>	<u>Nestling</u>	<u>Nesting</u>
southeast New Mexico	West (1972)	1	8	28	16	8	57.1	50.0	28.6
Denver, Colorado	Bergtold (1913)	5	about 68	283		166			58.7
southern Arizona	Hensley (1954)	2	10	41	33	33	80.5	100	80.5
Sacramento, California	Evenden (1957)	5	37	117	80	57	68.4	71.2	48.7
Honolulu, Hawaii	This study	3	135	515	278	112	54.0	40.3	21.7

palm (Chrysalidocarpus lutescens), 0.6 meter from the trunk and 3.7 meters above the ground. The mongoose (Herpestes mungo) is present on campus and has been reported (La Rivers 1948) to possibly prey occasionally on the Linnet on Oahu. If it climbs pandanus trees, the mongoose could be a major predator on House Finches. Predation accounted for 23.4% of the losses in 1972, 31.7% in 1973, and 27.9% in 1974.

3) In some nests the entire clutch did not hatch and it is presumed that the nests probably were deserted, possibly because of very bad weather conditions (storms), disturbance, or, especially near the end of the nesting season, physiological changes that bring about the termination of nesting behavior. In other nests an egg would be found cracked in the cup while the rest of the clutch would be intact, this probably caused when the nesting female moves about in the nest. In still other nests, some of the eggs would hatch and others would not. I did not examine all such unhatched eggs, but those that I did usually showed some signs of a dead embryo. Failure of eggs to hatch accounted for 17.0% of the mortality in 1972, 11.1% in 1973, and 23.5% in 1974. Egg loss in 1974 is significantly higher than in 1973 ($2 \times 2 \chi^2$ test, $\chi^2 = 6.97$, d.f. = 1, $P = 0.01-0.005$).

4) Nestlings die from a number of causes besides predation and inclement weather. Nestling deaths were divided into a) those that died before they were seven days old and b) those that died after they were seven days old. The age-cutoff point is used because adult behavior, such as nest attentiveness and feeding rates, change about seven days after hatching starts and may indicate that mortality factors also change. Nestlings that died in the early part of the

nestling period accounted for 14.9% of the mortality in 1972, 15.1% in 1973, and 14.7% in 1974. Those that died in the later part accounted for 8.5% of the mortality in 1972, 4.8% in 1973, and 2.9% in 1974.

Especially during the first few days after hatching, nestlings may die because they are inadequately brooded or inherently weak. The blood-sucking mite (Dermanyssidae) may also cause nestling loss. However, I do not feel that this mite is a direct cause of nestling mortality. Arthropod parasitism is probably a significant factor mainly during the early nestling period when the young are poorly feathered and incapable of grooming themselves (Ricklefs 1969). Although a nest may be literally covered by mites, the population is greatest near the end of the nestling period, with few, if any, mites seen at the beginning. As suggested by H. Eddie Smith, mites may not cause the direct death of a nestling, but could so weaken the young that its chances of survival is greatly reduced after fledging, when favorable conditions change and the food supply becomes less abundant than previously. Michener and Michener (1936), however, feel that heavy mite infestation can cause nest mortalities.

Starvation varies in importance in different species of birds, and seems especially important during the latter part of the nestling stage (Ricklefs 1969). In the House Finch, there appears to be sibling competition for food brought by the adults during the early and the later stages of the nestling period. Younger nestlings of a brood, especially those from broods containing five chicks, may starve as the older and better developed young get most of the food. Losses seem to be greater in the earlier than in the later stages.

Some nestlings, close to fledging, become so entangled in the nest material, particularly in the hair used to line the cup, that they cannot free themselves and die. Nestlings have been found dangling over the nest rim edge, nearly dead, unable to free themselves of hair strands that have become securely wrapped around one or both legs. I even freed an incubating female that had gotten hair strands about her body. She could not free herself in the one hour that I observed.

When a comparison is made between nesting success of 60 nests (containing 241 eggs) built in pandanus trees, the most frequently used nest-site vegetation, and 75 nests (containing 274 eggs) built in other types of plants and trees, nests in pandanus show significantly higher success (29.9% vs. 14.6%) (2×2 χ^2 test, $\chi^2 = 21.0$, d.f. = 1, $P < 0.005$). Although there is a greater loss of eggs and young from nests built in pandanus than other vegetation by predation (49.7% vs. 11.5%), this loss is more than offset by a significant reduction to loss by high winds (5.9% vs. 55.6%) (2×2 χ^2 tests, $P < 0.05$). Pandanus trees by their very nature, with thick trunks and branches, and leaves that originate from clusters, do not sway greatly and afford sheltered nest sites from even the strongest winds. There is no difference in losses in nests located in pandanus or other vegetation due to nestling deaths in the early (16.0% vs. 14.1%) or in the later (4.7% vs. 6.0%) nestling period. There seems to be a greater loss by eggs not hatching in nests in pandanus than other types of trees (23.7% vs. 12.8%), but this may be the misleading result of placing such egg losses under losses by strong winds for nests from non-pandanus trees.

Nesting interference by the House Sparrow is reported from other parts of the country (Bent 1968, Bergtold 1913, Evenden 1957). To an unknown extent there is also interference in Hawaii. I have seen a male House Sparrow steal nesting material from an active Linnet nest. The nest was completed, though, and fledged young. An active House Finch nest in 1973 was incorporated into a House Sparrow's nest. On 2 May I observed a pair of House Finches nest building in a monkeypod. At one point in the observation a male House Sparrow arrived and perched within 0.3 meter of the nest site. No agonistic interactions occurred between the Linnets and the Sparrow. The Sparrow, in a few minutes, flew off. On 3 May the pair was still nest building, but by 6 May the pair was not seen, a pair of House Sparrows was now nest building on the site.

On 6 April 1974, I found one nestling dead on the ground 4.6 meters from its nest and a second young dying in the nest. Both had their heads bloody and battered. Although I did not see House Sparrows about the nest, it could be that they were the cause of the nestlings' deaths. Guest (1973) reports that House Sparrows pecked to death White-eye young on the campus.

A great deal has been written about clutch size and breeding success (Cody 1966, Lack 1954, 1966). Table 15 lists the nesting success in relation to the clutch size. There are no significant differences in nesting success among the nests with different clutch sizes for the combined 1972 through 1974 data, but nests of clutch sizes four and five show significantly higher success in the good nesting year 1974 than in the poor ones 1972 and 1973 ($2 \times 2 \chi^2$ tests, $P = 0.05$ level used).

from mid-May to mid-November. Thompson (1960a) found that the molt period for the population in the Berkeley area is from September through early November. The termination dates of molting of the House Finch in all three locales are similar.

Table 16 indicates that nesting of the House Finch in various parts of the country usually occurs from April to July, to some degree in March and August, but rarely in February. In Hawaii nesting occurs from February through August. Why the longer nesting season in Hawaii? I agree with Lofts and Murton (1968) that extended breeding seasons of birds introduced into new environments "are all explicable in terms of the natural physiological cycle and in most cases there is no need to assume any sort of genetic selection." One must look at proximate factors and not ultimate ones.

By a series of experiments, Hamner (1968) showed that the annual gonadal cycle and thus the annual reproductive cycle of the House Finch is primarily controlled by a photoperiodic response, with an underlying circadian rhythm. To explain nesting in California from April through July, Hamner hypothesized that the start of the reproductive season is brought about by the response of the House Finch to increasing daylengths and its termination by an absolute photorefractory period, a time at the cessation of the breeding season when the gonads show rapid regression and when artificially long daily photoperiods fail to induce gonadal growth. This absolute period lasts for about 45 days and is followed by a relative refractory period during which the birds will not respond to day lengths equal to or shorter than those to which they have been previously exposed. Only with the increasing day lengths of spring is the House Finch brought again into a reproductive

Table 16

The Nesting Span of the House Finch

<u>Location</u>	<u>Cited Work</u>	<u>J</u>	<u>F</u>	<u>M</u>	<u>A</u>	<u>M</u>	<u>J</u>	<u>J</u>	<u>A</u>	<u>S</u>	<u>O</u>	<u>N</u>	<u>D</u>
Arizona													
	Bent 1968			x	x	x	x	x					
southern	Hensley 1959			x	x	x	x						
British Columbia													
	Bent 1968				x	x	x	x					
California ¹													
	Bent 1968	x	x	x	x	x	x	x	x				
Sacramento	Evenden 1957				x	x	x	x	x				
Butte County	Davis 1933				x	x							
Berkeley	Thompson 1960a				x	x	x	x					
San Francisco	Keeler 1890				x	x	x	x	x				
Colorado													
	Bent 1968				x	x	x	x					
	Bailey and Niedrach 1965				x	x	x	x					
Denver	Bergtold 1913	x	x	x	x	x	x	x	x				
New Mexico													
	Bent 1968				x	x	x	x					
Santa Fe	Jensen 1923				x	x	x	x	x				
Oklahoma													
Mesa County	Sutton 1967					x	x	x					
Oregon													
	Bent 1968				x	x	x	x	x				
Williamette	Guillion 1951				x	x	x	x					

Table 16 (cont.)

The Nesting Span of the House Finch

<u>Location</u>	<u>Cited Work</u>	<u>J</u>	<u>F</u>	<u>M</u>	<u>A</u>	<u>M</u>	<u>J</u>	<u>J</u>	<u>A</u>	<u>S</u>	<u>O</u>	<u>N</u>	<u>D</u>
Texas													
	Bent 1968				x	x	x	x					
Utah													
	Bent 1968				x	x	x	x					
Washington													
	Bent 1968				x	x	x	x					
New York													
Huntington, Long Island	Gill and Lanyon 1965				x	x	x	x	x				
Hawaii													
Honolulu	This Study	x	x	x	x	x	x	x	x				

x= nesting reported at this time

¹Smith (1930) and Howell and Burns (1955) each found an active Linnet nest, containing eggs, late in the year. Smith's nest was located on 24 November 1929, at Walnut Creek, Contra Costa County. Howell and Burns found their nest on 23 December 1954, on the UCLA campus. Neither nest went to completion.

state. Hamner's hypothesis is similar to Lofts and Murton's (1968) type B photoperiodic-controlled model, and both interpretations imply that the refractory period occurs after the summer solstice, when day length starts to decrease. Hamner experimented principally with male House Finches, but Farner and Lewis (1971) feel that the natural photoperiodic environment serves the same predictive function in timing the cycle of the female as it does the male, although the induced gonadal growth in the female may not be as dramatic as in the male. To Farner and Lewis (1971), some aspects of Hamner's hypothesis are not entirely clear (e.g., there is no explanation for an absolute or a relative refractory period), but the hypothesis, possibly with slight modifications, is attractive.

In Hawaii the longest and the shortest days are about 13.5 and 11 hours in lengths, respectively, and the sun is directly overhead toward the end of May, as it travels northward, and again in late July, as it returns southward (Price 1973). From late July, when the daylengths start to decrease, nesting for the House Finch ceases, molt starts, and presumably the Linnets enter the absolute refractory period, which lasts until late September. The relative refractory period then keeps the Linnets in a nonreproductive state until late December when the days start to increase. Maximum gonadal growth and the reproductive state are reached in about two months (Hamner 1968), and in Hawaii this coincides with late February, the times when I first observed nesting. Modifying and supplementary factors (food availability, pair interactions) determine the day when nesting actually starts (Farner and Lewis 1971). Although there are reports of unusually

late nesting by the House Finch in California, the fact that the nesting of this bird probably shows a periodicity in Hawaii, where there is only a 2.5-hour variation in yearly daylength, speaks highly of the level of development in the House Finch of the photoperiodic mechanism that controls the time of reproduction.

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APPENDIX 1

Daily Account of House Finch Nest Construction

Day 1--Site enlargement. Nest site on palm stem, near trunk. Only a strand of grass at the site and one of the leaflets is frayed, possibly to make room for the nest or the entrance for the birds. No observations, only a sighting at 1418, of the male singing at the palm and going to the nest site.

Day 2--Site enlargement. Some fresh and dried plant material placed on the site. 0705-0805 session. By sunrise pair nest building, both male and female taking turns entering the site and enlarging it by nibbling off bits of the surrounding leaflets. The male helps to enlarge the site but only the female brings material to the site. Agonistic encounters between the nest pair and other Linnets in the area. The nest pair chased other Linnets from the nest palm and also from a palm about 10 meters away. A White-eye momentarily at the nest palm was not chased off.

Day 3--Laying down of the foundation. Much more material, mostly dried and larger in size. 0750-0850 session. The male accompanies the female as she makes trips for nesting material. Only the material gathered by the female is used, although both birds construct the nest. Soft calls are heard between the pair and the male sings occasionally.

Day 4--Laying down of the foundation. More material packed down at the site. 0725-0825 session. The male accompanies the female on material-gathering trips and does some nest construction but also perches nearby and sings while she builds. Mock feeding between the pair observed, as well as the pair chasing off other Linnets from the nest palm.

Day 5--Laying down of the foundation. Material taking on vague nest shape. 1610-1710 session. The male accompanies the female and perches and sings at the top of a tulipwood tree (Harpullia pendula), about 18 meters away. The male was not observed aiding in nest construction.

Day 6--Laying down of the foundation. Nest cup formed. 1138-1238 session. The male is noticed with a piece of grass in its beak but did not add it to the nest. The male accompanies the female and sings on the nearby perch tree or at the palm when the female is building. The male occasionally enters the site and helps in nest construction, although the majority of the work is done by the female. The male supplanted a White-eye from the nest palm.

Day 7--Cup lining. Nest has a cupped shape and frayed cigarette filters evident in the cup. 1535-1635 session. The male accompanies the female and sings, perched nearby, while she builds.

Day 8--Cup lining. No nest check.
0830-0930 session. Male accompanies the female and sings while she builds. Observed for the first time the male attempting copulation with the female. Pair back and the female landed and crouched on a palm leaf. The male landed on her and copulation was attempted for about two to three seconds. Then the male hopped next to the female and both remained perched quietly for about five to 10 seconds before the female entered the nest site and resumed building and the male began to call and sing. In about two minutes the pair flew off to gather nesting material.

Day 9--Cup lining. Soft material added.
0800-0900 session. The male accompanies the female and sings while she builds. Calls between the pair.

Day 10--Cup lining. Much frayed cigarette filters added to the nest cup.
1120-1220 session. The male accompanies the female. Only the female builds and gathers material.

Day 11--Cup lining. Much frayed cigarette filters added to the nest.
0704-0804 session. I was present at the nest from 0600, when it was still dark. Birds, other than House Finches, were seen or heard by 0645, but the pair was first observed at the nest at 0705. Male accompanies the female and sings infrequently. Only the female builds. Agonistic encounters between the nest pair and a second pair which was at the nest palm. The second pair was driven from the tree. The male attempted copulation with the female.

Day 12--Cup lining. More soft material added.
1010-1110 session. The female is nest building and while on the nest gives the whisper call, softly. Noticed billing between the pair. The male sings nearby and accompanies the female on material-gathering trips. The next day the first egg was laid in the nest.

APPENDIX 2

Daily Development of a House Finch Nestling

Following is a generalized pattern of development of a House Finch nestling, based on examinations of young from 16 nests in 1972 and five nests in 1973. Terms, especially those concerned with pterylosis, are from Van Tyne and Berger (1971) and Pettingill (1970). The day that the young hatches is considered nestling day 0.

Day 0. Development. Eyes are closed. The young has fluffy white-gray down on the rump, head, wings, back, eyelids, and legs. The body is a pinkish color. No feather tracts (pterylae) are evident, except that there may be a faint black line in the alar region. The legs are soft looking, not scaly, and show simple grasping actions. The beak is flesh colored, with the corners (rictal flanges) pale white or yellowish. A very small and insignificant egg tooth is at the tip of the upper mandible. The gape is colored dull orange-red, with a very pale yellow outline. Two darker spots on the corners of the inside of the upper mandible are present.
Behavior. The young is weak and lies inactive on the cup bottom.

Day 1. Development. Eyes are still closed. The feather tracts are not evident, except for the faint development of the alar tract. The beak is turning yellow, especially at the corners of the mouth.
Behavior. The young is still weak, but it may gape weakly when the nest is tapped.

Day 2. Development. Eyeslits are visible but the eyes probably are still unable to open. The young still has much of its down. The alar tract is developing and the humeral is starting (black line). The gape is becoming bright orange-red, with a yellow outline.
Behavior. The young is still weak but gapes readily when the nest is tapped. The young voids a fecal sac when handled.

Day 3. Development. The eyes are able to open although they are usually closed. The feather tracts are developing. The alar tract has pin feathers, less than 1 mm in length; the other tracts, except for the crural and the capital, are faintly evident.
Behavior. The young is able to gape more vigorously, able to hold its head up higher and longer.

Day 4. Development. The eyes can open but are usually closed. Feather tracts, except for the crural and the capital, are evident. The alar pin feathers are about 1 mm in length. The crop, filled with food, is very evident on the right side of the neck.
Behavior. The young is able to elevate its cloacal region up to the nest rim when defecating. The fecal sac is then deposited on the rim and not in the cup.

Day 5. Development. Eyes are usually opened. The alar feathers are about 2 mm long, the rectrices about 1 mm. Other feather tracts are at least evident. The legs are changing from a soft to a scaly and hard appearance. The beak is yellow in coloration, especially at the corners of the mouth, which are quite swollen. The gape is red or bright orange with a yellow outline. Evident in the gape on the upper mandible are two dark spots at the corners and a dark centrally located line leading down into the throat. These mouth markings presumably serve as directive marks in aiding in coordinating the gaping of the young with the feeding response of the adults (Van Tyne and Berger 1971).

Behavior. The young gapes readily and voids a fecal sac when handled.

Day 6. Development. The alar pin feathers are about 8 mm long and the rectrices about 2 mm. Still down on the head and rump but lost in most other regions.

Behavior. Young more active in the nest, sits up, gapes toward the feeding adult.

Day 7. Development. Legs are scaly in appearance. The pin feathers in the pterylae, except for those at the crural and capital tracts, are starting to unsheathe. The alar feathers are about 12 mm in length and the rectrices about 4 mm. The beak is still yellow but showing faint signs of turning grayish in color.

Behavior. Young is active, alert, able to preen feathers. It gapes vigorously, and, by now, food calls, when being fed, are clear. When removed from the nest, the young may grasp the cup bottom and utter some calls.

Day 8. Development. Alar feathers are about 15 mm long, rectrices about 5 mm.

Behavior. The nestling is increasingly active.

Day 9. Development. Feather tracts continue to develop. The alar feathers are about 20 mm long and the rectrices about 9 mm in length. Much of the body still is not covered by feathers.

Day 10. Development. The alar feathers are about 24 mm long, rectrices about 13 mm. The beak is turning a grayish color, but there still is some yellow, especially at the corners.

Behavior. The young is very active. Some difficulty in replacing the nestling into the nest, and it exhibits fear reaction.

Day 11. Development. The alar feathers are 25 mm long and the rectrices 19 mm. Some parts of the body, especially the abdominal region, lack feather cover. The down is concentrated mainly on the head and rump.

Behavior. The young gapes vigorously to the feeding parent, gives very audible food calls, moves about in the nest, and preens itself. The nestling shows a fear response and is difficult to replace in the nest.

Day 12. Development. Most of the body is covered with feathers, except for the areas under the wing and the lower abdomen-cloaca. Alar feathers are about 30 mm long, rectrices about 19 mm. Down is mainly evident on the head, adhering to the feathers. The legs are scaly and hard in appearance. The beak is grayish colored, with the swollen and yellowish corners prominent. Behavior. The young preens itself, stretches its wings, scratches its head indirectly. When handled, will not stay in the nest and may jump from it when replaced, even though it cannot fly.

Day 13 until fledging. The young was not examined closely because of the tendency to jump from the nest. By the time of fledging, the nestling is almost fully feathered, with a short, stubby tail, a few strands of down adhering to the head feathers, and distinctive and swollen beak corners. Behavior. The young is active in the nest, preening, head scratching indirectly, and wing stretching. As the time for fledging approaches, the nestling flaps its wings vigorously more and more frequently. The young often perches on the nest rim, as well as sits in the nest cup. The jump response becomes very strong, so that just looking into the nest may cause the young to jump or take flight.

LITERATURE CITED

- Alicata, J.E. 1964. Parasitic infections of man and animals in Hawaii. Hawaii Agr. Exp. Sta. Tech. Bull. 61. 138 p.
- American Ornithologists' Union. 1957. Check-List of North American Birds. Port City Press, Baltimore, Maryland. xiii + 691 p.
- Anderson, A.H., and A. Anderson. 1944. 'Courtship feeding' by the House Finch. Auk, 61: 477-478.
- Austin, O.L., Jr. 1967. Song Birds of the World. Golden Press, New York. 319 p.
- Bailey, A.M., and R.J. Niedrach. 1965. Birds of Colorado, Vol. II. Denver Museum of Natural History, Denver. x + 455 + 895 p.
- Bailey, P. 1953. Home life of the House Finches. Nature Mag., 46: 262-264.
- Bailey, R.E. 1952. The incubation patch of passerine birds. Condor, 54: 121-136.
- Baldwin, P.H. 1941. Checklist of the birds of the Hawaii National Park, Kilauea-Mauna Loa section, with remarks on their present status and a field key for their identification. Natur. Hist. Bull. 7. 38 p.
- Baldwin, P.H. 1953. Annual cycle, environment and evolution in the Hawaiian Honeycreepers (Aves:Drepaniidae). Univ. Calif. Publ. Zool., 52: 285-398.
- Baptista, L.F. 1972. Wild House Finch sings White-crowned Sparrow song. Z. Tierpsychol., 30: 266-270.
- Beal, F.E.L. 1907. Birds of California in relation to the fruit industry, pt. 1. U.S. Dep. Agr. Biol. Surv. Bull. 30. 100 p.
- Bent, A.C. 1968. Life Histories of North American Cardinals, Grosbeaks, Buntings, Towhees, Finches, Sparrows, and Allies. Part One. Dover, New York. xxx + 602 p.

- Berger, A.J. 1972. Hawaiian Birdlife. University Press of Hawaii, Honolulu. xiii + 270 p.
- Bergtold, W.H. 1913. A study of the House Finch. *Auk*, 30: 40-73.
- Booth, E.S. 1971. Birds of the West. College Press, Keene, Texas. 379 p.
- Bryan, E.H., Jr. 1937. Birds of Oahu. *Paradise of the Pacific*, 49: 24-25.
- Bryan, W.A. 1901. A Key to the Birds of the Hawaiian Group. Bishop Museum Press, Honolulu. 76 p. + 15 plates.
- Bryan, W.A. 1905. Notes on the birds of the Waianae Mountains. *Occ. Pap. Bernice P. Bishop Mus.*, 2: 229-241.
- Cody, M.L. 1966. A general theory of clutch size. *Evolution*, 20:174-184.
- Cody, M.L. 1971. Ecological aspects of reproduction, p. 461-512. In D.S. Farner and J.R. King, Avian Biology, Vol. I. Academic Press, New York.
- Davis, W.B. 1933. The span of the nesting season of birds in Butte County, California, in relation to their food. *Condor*, 35: 151-154.
- Dunmire, W.W. 1961. Birds of the National Parks in Hawaii. Hawaii Natural History Association, Hawaii. 36 p.
- Edwards, R.Y., and D. Stirling. 1961. Range expansion of the House Finch into British Columbia. *Murrelet*, 42: 38-42.
- Elliot, J.J., and R.S. Arbib, Jr. 1953. Origin and status of the House Finch in the eastern United States. *Auk*, 70: 31-37.
- Evenden, F.G. 1957. Observations on nesting behavior of the House Finch. *Condor*, 59: 112-117.
- Farner, D.S., and R.A. Lewis. 1971. Photoperiodism and reproductive cycles in birds, p. 325-370. In A.C. Giese, Photophysiology: Current Topics in Photobiology and Photochemistry, Vol. VI. Academic Press, New York.

- Fisher, H.I. 1951. The avifauna of Niihau Island, Hawaiian Archipelago.
Condor, 53: 31-42.
- Fullaway, D.T., and N.L.H. Krauss. 1945. Common Insects of Hawaii.
Tongg, Honolulu. 228 p.
- Gill, D.E., and W.E. Lanyon. 1965. Establishment, growth, and behavior
of an extralimital population of House Finches at Huntington, New
York. Bird-Banding, 36: 1-14.
- Grinnell, J. 1911. The Linnet of the Hawaiian Islands: a problem in
speciation. Univ. Calif. Publ. Zool., 7: 179-195.
- Grinnell, J. 1912a. A name for the Hawaiian Linnet. Auk, 29: 24-25.
- Grinnell, J. 1912b. Concerning the Hawaiian Linnet. Auk, 29: 543.
- Grinnell, J., and J.M. Linsdale. 1936. Vertebrate animals of Point Lobos
Reserve, 1934-1935. Carneige Inst. Washington Publ. 481. vi + 159 p.
- Grinnell, J., and A.H. Miller. 1944. The distribution of the birds of
California. Pacific Coast Avifauna 27. 608 p.
- Guest, S.J. 1973. A reproductive biology and natural history of the
Japanese White-eye (Zosterops japonica japonica) in urban Oahu.
Hawaii Tech. Report 29. vi + 95 p.
- Guillion, G.W. 1951. Birds of the southern Willamette Valley, Oregon.
Condor, 53: 129-149.
- Hamner, W.M. 1968. The photorefractory period of the House Finch. Ecology,
49: 211-227.
- Hand, R.L. 1970. House Finches (Carpodacus mexicanus) in Montana.
Condor, 72: 115-116.
- Henderson, J. 1905. Colorado notes. Auk, 22: 421-422.
- Henderson, J. 1916. House Finch or Linnet? Condor, 18: 30.

- Hensley, M.M. 1954. Ecological relations of the breeding bird population of the desert biome of Arizona. *Ecol. Monogr.*, 24: 185-207.
- Hensley, M.M. 1959. Notes on the nesting of selected species of birds of the Sonoran Desert. *Wilson Bull.*, 71: 86-92.
- Howell, T.R., and R.D. Burns. 1955. Mid-winter nesting of the House Finch at Los Angeles, California. *Condor*, 57: 246.
- Jensen, J.K. 1923. Notes on the nesting birds of northern Santa Fe County, New Mexico. *Auk*, 40: 452-469.
- Keeler, C.A. 1890. Observations on the life history of the House Finch (*Carpodacus mexicanus frontalis*). *Zoe*, 1: 172-176.
- King, J.S. 1973. Energetics of reproduction in birds, p. 78-107. In D.S. Farner, Breeding Biology of Birds. National Academy of Sciences, Washington, D.C.
- Lack, D. 1954. The Natural Regulation of Animal Numbers. Clarendon Press, Oxford. viii + 343 p.
- Lack, D. 1966. Population Studies of Birds. Clarendon Press, Oxford. v + 341 p.
- Lanyon, W.E., and V.H. Lanyon. 1969. A technique for rearing passerine birds from the egg. *Living Bird*, 8: 81-93.
- La Rivers, I. 1948. Some Hawaiian ecological notes. *Wasmann Collector*, 7: 85-110.
- Lofts, B., and R.K. Murton. 1968. Photoperiodic and physiological adaptations regulating avian breeding cycles and their ecological significance. *J. Zool.*, 155: 327-394.
- Mayr, E. 1965. Animal Species and Evolution. Belknap Press, Mass. xiv + 797 p.

- McGregor, R.C. 1902. Notes on a small collection of birds from the island of Maui, Hawaii. *Condor*, 4: 59-62.
- Michener, H., and J.R. Michener. 1931. Variation in color of male House Finches. *Condor*, 33: 12-19.
- Michener, H., and J.R. Michener. 1936. Abnormalities in birds. *Condor*, 38: 102-109.
- Michener, H., and J.R. Michener. 1940. The molt of House Finches of the Pasadena region, California. *Condor*, 42: 140-153.
- Miller, L. 1929. The song of cage-bred Linnets. *Condor*, 31: 221.
- Miller, L. 1952. Song in hand-reared birds. *Condor*, 54:173.
- Moore, R.T. 1939. A review of the House Finches of the subgenus Burricea. *Condor*, 41: 177-205.
- Munro, G.C. 1960. Birds of Hawaii. Charles E. Tuttle, Japan. 192 p.
- Nice, M.M. 1957. Nesting success in altricial birds. *Auk*, 74: 305-321.
- Payne, R.B. 1972. Mechanisms and control of molt, p. 103-155. In D.S. Farner and J.R. King, Avian Biology, Vol. II. Academic Press, New York.
- Perrins, C.M. 1970. The timing of birds' breeding seasons. *Ibis*, 112: 242-255.
- Peters, J.L. 1968. Check-List of Birds of the World, Vol. XIV. Heffernan Press, Mass. x + 433 p.
- Pettingill, O.S., Jr. 1970. Ornithology in Laboratory and Field. Burgess, Minn. xvii + 524 p.
- Price, S. 1973. Climate, p. 53-60. In R.W. Armstrong, Atlas of Hawaii. University Press of Hawaii, Honolulu.
- Rahn, H., and A. Ar. 1974. The avian egg: incubation time and water loss. *Condor*, 76: 147-152.

- Richardson, F., and J. Bowles. 1964. A survey of the birds of Kauai, Hawaii. Bernice P. Bishop Mus. Bull. 27. 51 p.
- Ricklefs, R.E. 1968. Patterns of growth in birds. Ibis, 110: 419-451.
- Ricklefs, R.E. 1969. An analysis of nesting mortality in birds. Smithsonian. Contrib. Zool., 9: 1-48.
- Roessler, E.S. 1936. Viability of weed seeds after ingestion by California Linnets. Condor, 38: 62-65.
- Rothschild, M., and T. Clay. 1952. Fleas, Flukes, and Cuckoos. Philosophical Library, New York. xiv + 304 p.
- Royama, T. 1966a. A re-interpretation of courtship feeding. Bird Study, 13: 116-129.
- Royama, T. 1966b. Factors governing feeding rate, food requirement and brood size of nestling great tits Parus major. Ibis, 108: 313-347.
- Schifferli, L. 1973. The effect of egg weight on the subsequent growth of nestling great tits Parus major. Ibis, 115: 549-558.
- Skutch, A.F. 1962. The constancy of incubation. Wilson Bull., 74: 115-152.
- Skutch, A.F. 1966. A breeding bird census and nesting success in Central America. Ibis, 108: 1-16.
- Smith, P. 1930. Winter nesting of the California Linnet. Condor, 32: 121.
- Storer, R.W. 1960. The classification of birds, p. 57-93. In A.J. Marshall, Biology and Comparative Physiology of Birds, Vol. I. Academic Press, New York.
- Storer, R.W. 1971. Classification of birds, p. 1-18. In D.S. Farner and J.R. King, Avian Biology, Vol. I. Academic Press, New York.
- Sutton, G.M. 1967. Oklahoma Birds. University of Oklahoma Press, Norman, Oklahoma. xlv + 674 p.

- Swezey, O.H. 1954. Forest entomology in Hawaii. Bernice P. Bishop Mus. Spec. Publ. 44. 266 p.
- Thompson, W.L. 1960a. Agonistic behavior in the House Finch. Part I: Annual cycle and display patterns. Condor, 62: 245-271.
- Thompson, W.L. 1960b. Agonistic behavior in the House Finch. Part II: Factors in aggressiveness and sociality. Condor, 62: 378-402.
- Tomich, P.Q. 1967. Arthropoda associated with a nest of the Hawaiian Crow. Hawaii Entomol. Soc. Proc., 19: 431-432.
- Tordoff, H.B. 1954. Relationships in the new world nine-primaried Oscines. Auk, 71: 273-284.
- Van Tyne, J., and A.J. Berger. 1971. Fundamentals of Ornithology. Dover, New York. xi + 624 p.
- West, S. 1972. House Finch nesting in New Mexico. Elepaio, 33: 52-53.
- Zimmerman, E.C. 1948. Insects of Hawaii, Vol. 2. University of Hawaii Press, Honolulu. viii + 475 p.
- Zimmerman, E.C. 1960. Insects of Hawaii, Vol. 10. University of Hawaii Press, Honolulu. ix + 368 p.

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