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# LINNET BREEDING BIOLOGY ON HAWAII

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ABSTRACT

A study of the Linnet (Carpodacus mexicanus frontalis) was conducted on the island of Hawaii from 1969 through 1973. Pair bond formation commences in early spring with a characteristic male courting behavior. Both native and introduced trees are utilized as nesting sites and there appears to be a direct correlation between nest height and total height of the tree. Favored areas of placement were found to be in the lower inside region of the tree, with a possible shift occurring to the outer forks. Nest construction--primarily by the female--takes from six to 11 days. The measurements of a number of nests are given with the types of materials utilized.

Clutch size was found to be 3.9 ± 0.7 eggs and the mean weight of the eggs was 1.5 ± 0.2 grams. Incubation period was 13 to 14 days and the nestling period varied from 14 to 17 days. The breeding season of the Linnet in Hawaii extends from early March through late July.

It appears that in the past 100 years the breeding biology of the Linnet in Hawaii has changed little from that of the birds in western North America.

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## LITERATURE REVIEW

Bent (1968) summarizes information available on the breeding biology of the Linnet. Although studied quite extensively in its North American home range, this bird has been paid little attention in Hawaii. Grinnell (1911) reported on different color patterns of the Linnet in Hawaii. Richardson and Bowles (1964) mention that on 23 June 1960 they found a nestling that had fallen from its nest on Kauai. The only other reference to the breeding aspects of the Linnet in Hawaii is that of Berger (1972). On Mauna Kea he found nests with eggs as early as 6 April (1968) and as late as 17 July (1967). Eleven of his nests were built on horizontal branches of mamane (Sophora chrysophylla), and two nests in naio (Myoporum sandwicense) trees. Complete clutches of three eggs were found in two nests, four eggs in five nests, and five eggs in one nest. Insofar as I have been able to determine, there are no other references to the breeding biology of the Linnet in Hawaii.

According to Caum (1933), the Linnet was introduced to Hawaii prior to 1870, probably as an escapee from captivity. Over the last 100 years this bird has successfully established itself on all of the main Hawaiian islands. Berger (1972) writes: "The Linnet is common in cities and towns, in both wet and dry rural areas, and in the high ranch and forest lands on Maui and Hawaii. It is uncommon in the depths of the near-virgin rain forests, but it is abundant in the mamane-naio [sic] forests on Mauna Kea, as well as in partly cutover mixed ohia-koa forests."

## STUDY AREAS AND METHODS

I conducted field work on the island of Hawaii during the years 1970, 1971, and 1972; additional observations were made in the summers of 1969 and 1973. All of the major forested regions on Hawaii were visited, that is, the Kohala Mountains, Mauna Kea, Mauna Loa, and Hualalai (FIG. 1). The majority of my observations were made in area 2 on the northwestern slope of Mauna Kea. This region, hereafter referred to as Puu Laau, is the last remaining major mamane-naio forest in Hawaii (FIG. 2).

The stippled areas of FIG. 1 represent a broad spectrum of the forest types on the island of Hawaii; included are native, introduced, and mixed stands of vegetation. Areas 2, 3, and 5 are dry forest regions with annual rainfall of 760 mm or less, whereas 1, 4, and 6 are forests with approximately 2500 mm or more rainfall

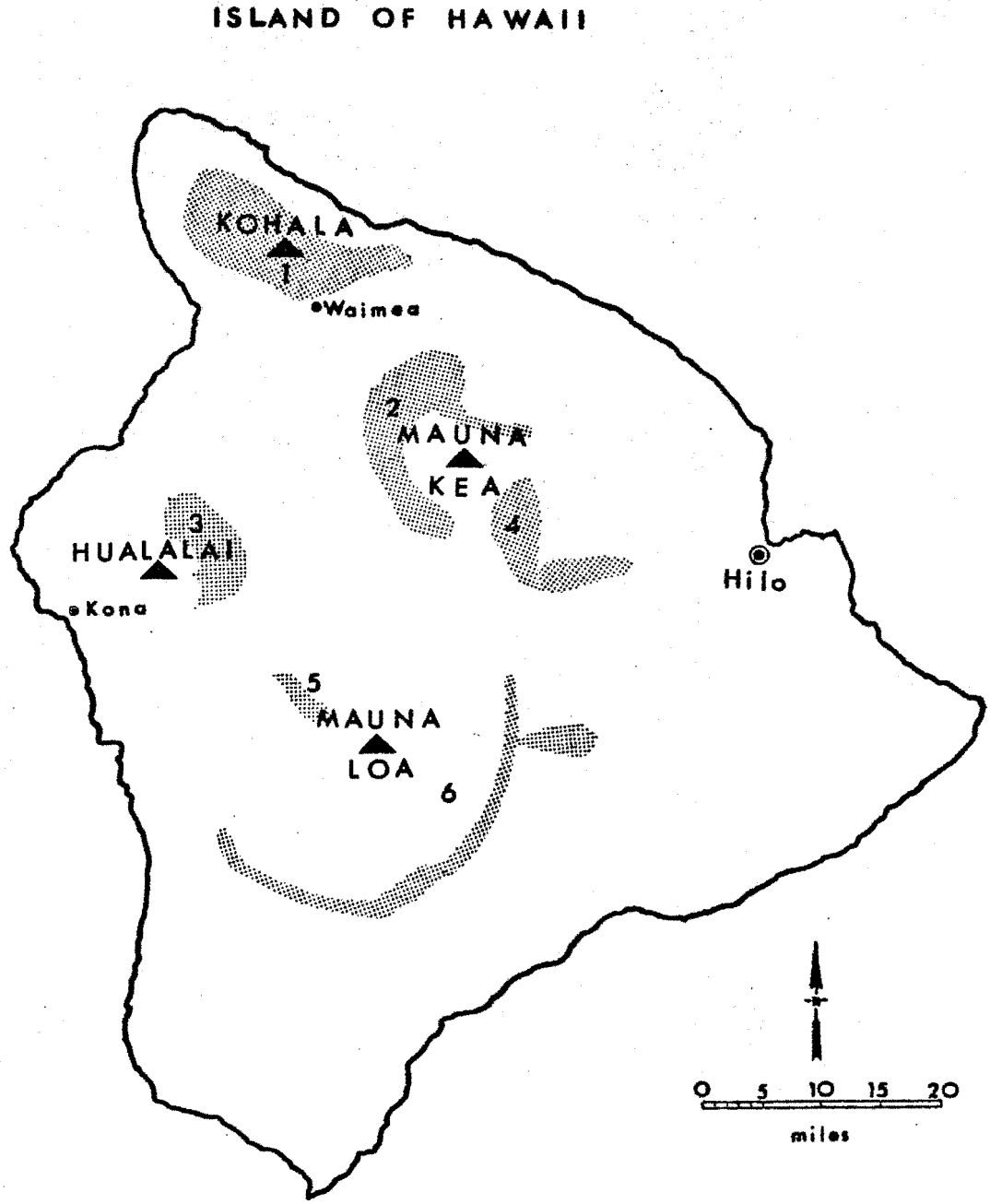


FIG. 1. The island of Hawaii with the stippled areas representing study sites.

FIG. 2. Puu Laau on the slopes of Mauna Kea at an elevation of 7,300 ± feet.

per year (TABLE 1).

Birds were mist-netted, color banded, and then released from 1971 through 1973. Nest- and tree-heights were taken with a clinometer when it was impractical to use a tape measure. Nest and egg measurements were made with calipers, and the weights of both on a sensitive spring balance.

## COURTSHIP

During early spring the large Linnet flocks on Hawaii disband, although not totally, and pairing of the birds ensues. I have often noted the male courting the female at this time of the year and this continues until mid-summer. At 1800 hours on 28 May 1973 at Puu Laau, a pair of birds flew into the uppermost dead branches of a mamane tree. The birds landed approximately one meter apart with the female higher up on an ascending horizontal branch. The female turned and faced away from the male; he then started walking up the limb with his tail erect and fully spread, wings lowered at his side, and breast outward, thus making the head and neck assume a ramrod position. As he walked he intermittently bowed and gave short, high pitched chirps. Spaced at intervals between chirps were low trills. When he approached to within 20 cm of the female, she turned and chased him down the branch. This sequence was repeated two times until, on the third approach, the female did not chase but remained facing away from the male. After an interval of less than one minute both birds flew into a grove of pines, presumably to roost for the night.

Courtship-feeding of the female by the male occurs frequently during incubation, but I have observed only two cases of it prior to egg laying. In the Kohala Mountains, during the third day of nest construction, I observed an unbanded male courtship-feed a banded female. The second instance of this happened on Mauna Kea (area 4) when a male fed a female prior to (or on the first day of) nest construction.

## NESTS

The Linnet uses almost any available species of tree for a nesting site. In the forests on Hawaii a fork or an upright limb, in the more open interior part of the tree, is the preferred nesting location. All of the nests I have found were situated in the branches of trees except for one on Hualalai, which was in a hole of

TABLE 1. Annual rainfall for selected areas on the island of Hawaii.

| Corresponding number in FIG. 1 | Area in Hawaii | Approximate mean annual rainfall (mm) |
|---|---|---|
| 1 | Kohala Mtn. complex | 2285 |
| 2 | Puu Laau | 500 |
| 3 | Puu Waawaa | 635 |
| 4 | Puu Oo | 4825 |
| 5 | Puu Lehua | 760 |
| 6 | Kulani-Mauna Loa complex | 3175 |

an ohia (Metrosideros collina subsp. polymorpha) trunk,and one nest that was wedged in the bark of a dead mamane tree at Puu Laau (van Riper 1974).

Mamane and naio make up over 95 percent of the trees in the Puu Laau area, and nest selection by the Linnet is influenced accordingly. Mamane, found in a 2:1 ratio over naio, is the preferred nesting tree (TABLE 2). Mamane also offers the bird a more dense canopy. Four nests were found in akoko (Euphorbia olowaluana), and one nest in an aalii (Dodonaea viscosa) shrub. I have found six nests in introduced pine trees at Puu Laau.

On Hualalai the Linnet utilizes mamane, pukiawe (Styphelia tameiameiae) shrubs, ohia, and kolea (Myrsine sp.) trees. On Mauna Loa (area 5) the sandalwood tree (Santalum sp.) is a frequent nesting location; in area 6 the koa (Acacia koa) is sometimes used.

In the Kohala Mountains I have found 24 nests in the introduced pine trees [mainly Norfolk Island pine (Araucaria excelsa)] and Ironwood (Casuarina equisetifolia), along the edge of the forest. The birds prefer these trees presumably because pasture land of the Parker Ranch surrounds the forest and contains a multitude of food types. Mr. L. Omura (pers. com.) found 18 nests in this area during the 1973 breeding season and all but one were in pine trees. The Linnet is not common in the deep forest of the Kohala Mountains. I found only eight nests, none more than 450 m from the forest edge; all were built in ohia trees.

Nest site locations were divided into three groups with terminal forks classed as the branches forming the most distant group of stems from the trunk in the topmost 20 percent of the canopy surface area. This category comprised over 35 percent of the potential nesting locations. Lateral forks were defined as the end cluster of branches in the remaining canopy. Branches were defined as any horizontal or vertical limb within the canopy cover. The Linnet prefers the open interior portions of the tree for nesting. Over 75 percent of the nests found in mamane and over 80 percent of those found in naio were placed either inside the canopy or in lateral forks (TABLE 3). Nest height appears to be influenced by the height of the nest tree, for as the height of the selected nest tree increased, the birds tended to build their nests at a correspondingly greater distance from the ground (FIG. 3). The considerable variance in nest height shows a utilization of many areas within the tree.

It is interesting to note that the three most aberrant points in FIG. 3 were all unusual nesting situations for the Linnet. Nest b was the immense nest,

TABLE 2. Heights of nests, nest-trees, and randomly selected trees of mamane and naio at Puu Laau, Hawaii.

| | Number Observed | Mean Length ± Stand. Dev. (meters) | Range (meters) |
|---|---|---|---|
| MAMANE | | | |
| Random Tree Height | 91 | 6.5 ± 2.6 | 2.7 - 11.9 |
| Nest Tree Height | 36 | 6.0 ± 1.9 | 3.4 - 10.7 |
| Nest Height | 43 | 4.7 ± 1.6 | 2.3 - 9.1 |
| NAIO | | | |
| Random Tree Height | 56 | 5.9 ± 2.2 | 2.8 - 11.6 |
| Nest Tree Height | 12 | 7.0 ± 2.0 | 3.7 - 10.1 |
| Nest Height | 12 | 5.0 ± 2.2 | 1.5 - 9.0 |

TABLE 3. Location of nest placement in trees at Puu Laau, Hawaii.

| Species | Number in Terminal forks | Number in Lateral forks | Number on Branches |
|---|---|---|---|
| Mamane | 10 | 17 | 15 |
| Naio | 2 | 6 | 4 |
| Akoko | 0 | 4 | 0 |

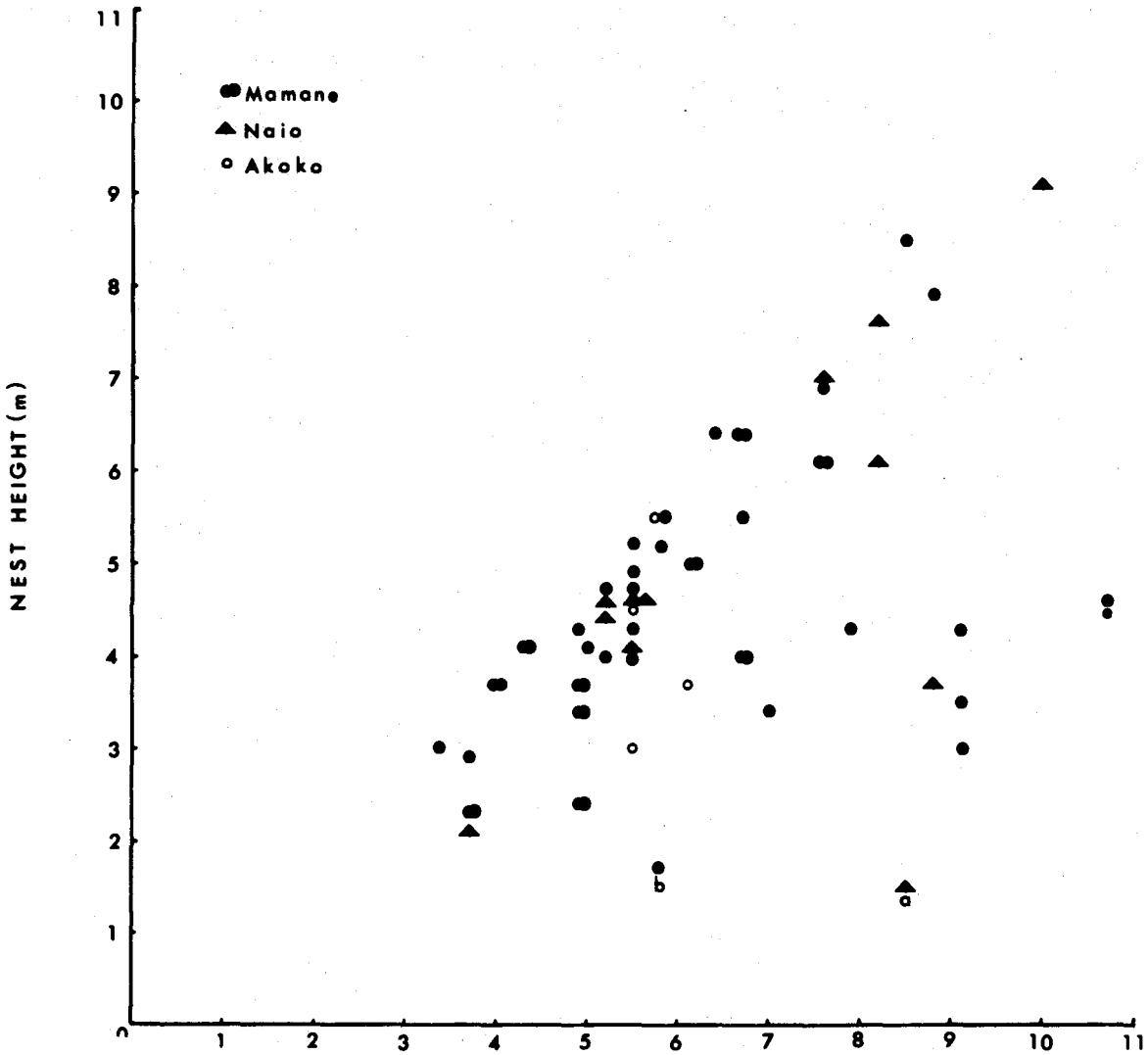


FIG. 3. The relationship between nest height and tree height at Puu Laau, Hawaii.

discussed earlier, that had been built between the sloughing bark and trunk of a dead mamane. Nests a and e were the only instances of two species nesting in the same tree; a was situated below an Amakihi (Loxops virens) nest and e was across from and lower than an active Elepaio (Chasiempis sandwichensis) nest.

The nest is constructed almost entirely by the female. On only two separate occasions have I observed males bringing material to the nest, but in neither case was it incorporated into the nest proper. The male does accompany the female, however, and often aids in molding the nest. Nest construction lasted from six to 11 days before the laying of the first egg.

Eight Linnet nests from the Puu Laau area were randomly chosen, and the materials used in the construction of each were identified by Dr. Darrel Herbst (APPENDIX). Grasses constituted the greatest part of the examined nests; it is probable that species other than the four listed were employed in nest construction, but only those with inflorescences were able to be identified with any certainty. Grass roots were interwoven into the nests and were the most commonly used material for lining the nest. These roots were probably obtained from plants that had been pulled out by rooting pigs or grazing sheep.

There are numerous reports of the Linnet using the same nest for a second brood in a year. On only one occasion in over 100 have I observed this in the forests on Hawaii. On 16 May 1971 I found a nest at about 7,000 feet elevation at Puu Laau which contained two nestlings and two eggs; subsequently all four young fledged. I returned to collect the nest on 11 June and found four new eggs in the nest.

The size and shape of Linnet nests on Hawaii are fairly uniform throughout the population (TABLE 4). The outer nest depth and weight of nest b, which was not built on a branch, were omitted from this table. I assumed a normal distribution of nest sizes and weights, and the probability of getting a value which deviated from the mean by 14.2 cm (outer nest depth of nest b) or greater, was about 0.04. This suggested that I was justified in eliminating this nest from the sample. The weight of the nest was 91.5 g, which is significantly different at the 0.001 level from the mean weight of the other nests; therefore, I have also eliminated this measurement from the table.

## EGGS AND YOUNG

The eggs of the Linnet usually are laid at 24 hour intervals. In one nest I

TABLE 4. Measurements of Linnet nests on Mauna Kea, Hawaii.

| | Number of Nests Measured | Mean Dimension ± Stand. Deviat. (cm) | Range (cm) |
|---|---|---|---|
| Outer nest depth | 21 | 7.1 ± 1.9 | 2.5 - 10.9 |
| Total width | 25 | 11.7 ± 1.9 | 8.1 - 17.0 |
| Inside bowl diameter | 22 | 5.6 ± 1.3 | 3.3 - 7.6 |
| Bowl depth | 14 | 3.6 ± 0.6 | 2.5 - 4.6 |
| Rim thickness | 26 | 2.5 ± 1.3 | 0.5 - 4.6 |
| Weight of nest | 12 | 19.5 ± 3.3 g | 13.7 - 25.2 g |

did observe a skipped day between egg number three and four in a four-egg clutch. I have recorded 93 Linnet clutches on Hawaii. At Puu Laau the average clutch of 14 completed nests was 3.9 ± 0.7 eggs. In each of the 14 nests, I observed and recorded the laying of each egg and was therefore almost certain that the clutch belonged to one bird. Sixteen eggs were measured and the mean length was found to be 18.3 ± 0.13 mm and the width was 13.2 ± 0.09 mm. The weight of the eggs was taken in the field with a hand spring scale and the mean was found to be 1.5 ± 0.2 grams.

I have recorded incubation periods of both 13 and 14 days with 13 being the most common. Only the female incubates; after hatching she continues to brood for about a week. Nestling periods varied from 14 to 17 days with two birds taking 20 days to leave one nest. In all but six cases the young of a clutch fledged at different times. I have never observed a banded young return after departure from the nest. When the young fledge they are fully feathered and are able to fly from the nest. The young and parents remain in the vicinity of the nest for about a week before starting to move around in a family group.

## BREEDING SEASON

The breeding season of the Linnet in Hawaii extends from early March until late July (FIG. 4). The earliest nest with eggs was found on 13 March (1971) and the latest was found on 14 July (1972). The heaviest concentration of nesting usually occurs in April, May, and June. The timing of the 18 nests Omura found in the Kohala Mountain area was three for April, nine for May, and six for June. In mid-July flocks become more apparent, and I have observed birds in large groups throughout the winter until the early spring breakup. The larger flocks of birds leave the Puu Laau region during the winter months and apparently move to lower elevations.

## DISCUSSION

Most sources give the breeding season of the Linnet in North America to be between March and the early part of August. I have found nests from early March through late July (FIG. 4), thus revealing little if any change in the length of the breeding season in Hawaii. Baldwin (1953), Eddinger (1970), and others have

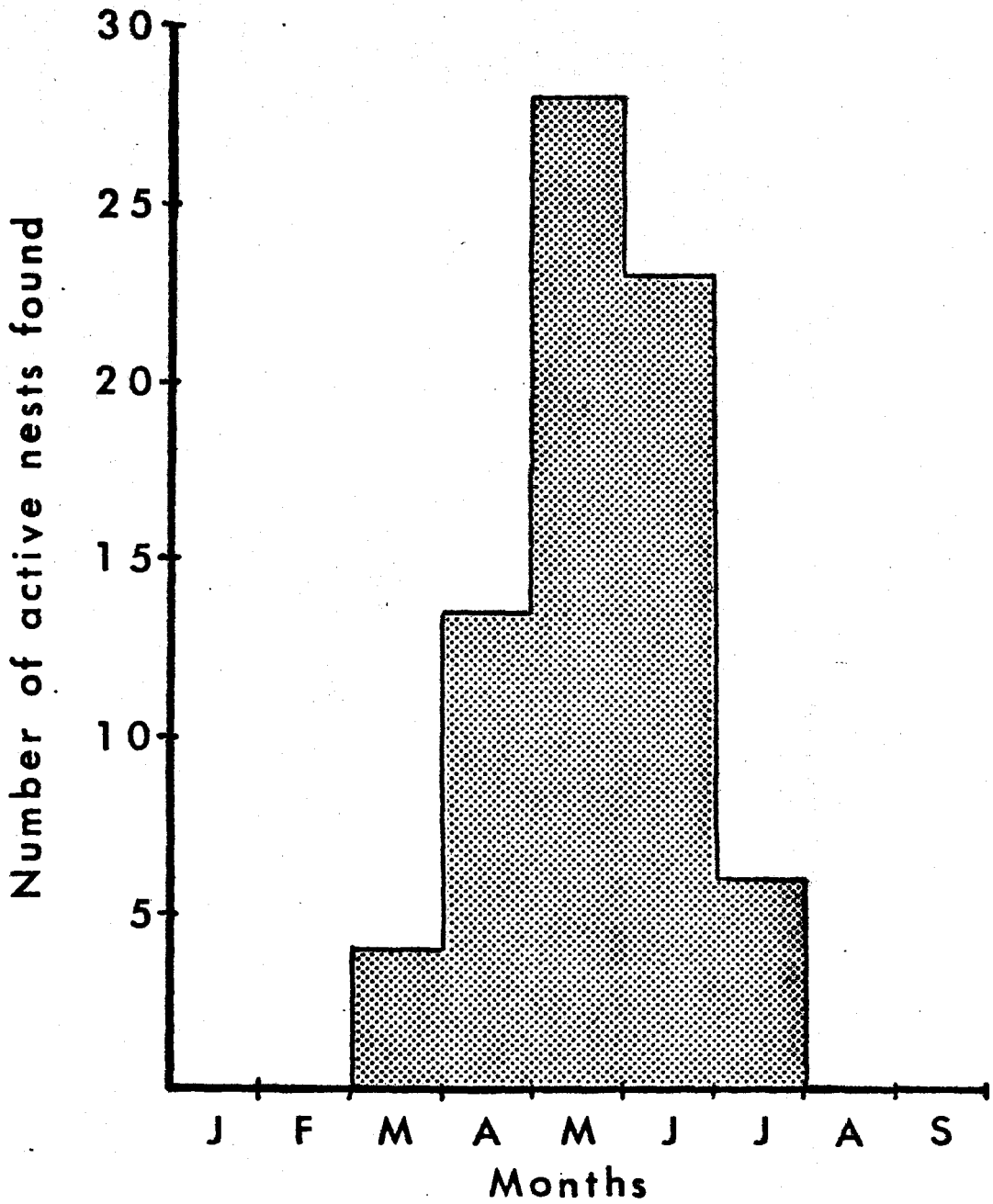


FIG. 4. The number of active Linnet nests found on Mauna Kea from 1970 through 1973.

found that the native birds of Hawaii breed in late winter and early spring. As none of the native avifauna has the same diet requirements as the Linnet, and they also nest at different times of the year, superficially there appears to be no competition and little reason for the bird to change its nesting time.

Bent (1968) gives clutch size as two to six with four or five eggs comprising the usual set. The measurements of 50 eggs averaged 18.8 x 13.6 mm. The mean clutch size in my study was 3.9 eggs and the mean egg size was 18.3 x 13.2 mm--approximately the same as the data of Bent. Bent suggested that the incubation period of from 12 to 14 days may be shortened in warmer climates; my observed incubation periods of 13 and 14 days does not bear this out. If it were true, with the temperature remaining fairly constant throughout the entire year in Hawaii, one would surely expect a shortened incubation period. Evenden (1957) lists the nestling period of the House Finch as varying from 11 to 19 days. Except for the two birds that took 20 days to leave the nest, all nestling periods were well within the extremes found in North America.

In Hawaii nest construction takes from six to 11 days with the female doing most of the work. This same time period has been reported by authors from California. These authors also mention that the female Linnet does the majority of the construction. The materials used vary with the locality, but there are some interesting differences as well as similarities between nest materials used in Hawaii and western North America. One of the most striking things is the number of introduced plants used in construction of the nest (APPENDIX). Of the 15 species that were identified, only four are native. Inasmuch as the Puu Laau area still has a reasonably high percentage of native plants, it seems peculiar that the Linnet would choose introduced plants for its nest.

Lichens have been reported in Linnet nests from California by Grinnell and Linsdale (1936), and at Puu Laau this was a favorite nesting material. In certain areas of New Mexico sheep wool is used by the Linnet (Bailey, 1928; cited by Bent, 1968). Of all the species of birds at Puu Laau, the Linnet probably uses sheep wool the least. Some species, such as the Elepaio, have nests made almost entirely of wool. It seems strange that the Linnet does not utilize this nesting material more as it appears to prefer it in certain areas of North America.

Bent (1968) lists nest height from five to seven feet (1.6-2.3 m) but does not give tree height. I found a mean nest height of five meters. This might suggest that the birds are tending to nest higher in Hawaii and that there is a trend to

build more nests in the external forks rather than in the interior of the tree. The nest measurements appear to bear this out. Bent gives the mean width of nests as five inches (12.7 cm); my data shows four and one-half inches (11.4 cm). His total nest outer depth is three (7.6 cm), whereas mine is three and one-half inches (8.9 cm). This shows an increase in total height but a decrease in the total width, thus suggesting more nests being fit into forks rather than spread out as they are when placed on internal branches of the tree.

Several authors in the western states report on a marked tendency of the Linnet to return to the same nesting location in subsequent years. I have marked over 100 nest sites in the last four years on Hawaii, and in not one case have I observed a location being used in two consecutive years.

There is a long list of other birds whose nests North American Linnets will use after the original owners leave. On Hawaii I have not found the Linnet to use the nests of other birds. I think one reason for this may be the rapid decomposition of nests due to climatic factors; 23 of 35 marked nests remained less than one month in the tree after the young fledged. Swift breakup of the nest may also inhibit use of the nest for a second brood. Two and three broods for the same nest are commonly reported from California, but on Hawaii I have only observed this once.

The abundance of the Linnet on Hawaii appears to have been enhanced by two factors. First, with no seed-eating native birds, this niche was open for the Linnet. The second major factor appears to be the spread of man in Hawaii. He has placed water troughs for his cattle over the entire island and the Linnets depend heavily upon these. I have observed flocks of 100 and more Linnets at watering places in the drier areas. I am sure that without the supplies of water, the Linnet could not live in these dry regions.

## ACKNOWLEDGEMENTS

I would like to dedicate this paper to Unoyo Kojima, who for years has helped give direction to the Hawaii Audubon Society. Research was supported in part by the International Council for Bird Preservation, the McInerny Foundation, the Hawaii Audubon Society and the ISLAND ECOSYSTEMS Integrated Research Program of the US/IBP. I would like to acknowledge the help of Dr. Darrel Herbst for identification of nest materials, also Dr. Andrew Berger, Dr. John Stimson, and Dr. Alison Kay for their criticisms of the manuscript, and lastly, to Mr. and Mrs. James Quinn Casey who have given their support throughout the work.

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# APPENDIX

A checklist of the plants used in construction of Linnet nests on Puu Laau, Hawaii. The family, scientific, and common Hawaiian names are given for each; frequency of use along with the parts of the plants used is also included. Species native to Hawaii are denoted by an asterisk.

## ASCOLICHENES

*Usnea sp. "Lichen"
Entire plant. Common.

## MONOCOTYLEDONAE

### GRAMINEAE - grass family

Bromus rigidus Roth "ripgut grass"
Leaves, culms and inflorescences. Common.

Dactylis glomerata L. "orchard grass," "cocksfoot"
Leaves, culms and inflorescences. Rare.

Holcus lanatus L. "velvet grass," "Yorkshire fog"
Leaves, culms and inflorescences. Abundant.

Poa pratensis L. "Kentucky bluegrass"
Leaves, culms and inflorescences. Common.

## DICOTYLEDONAE

### CARYOPHYLLACEAE - pink family

Stems with included leaves and dehisced fruits of some exotic member of this family were found in one nest.

### COMPOSITAE - sunflower family

Conyza bonariensis (L.) Crong. "horseweed"
Pieces of the inflorescence with one or more capitula. Occasionally achenes with included pappus were used in nest lining. Common.

Gnaphalium purpureum L. "purple cudweed"
Stems with included leaves and flowers. Abundant.

*Gnaphalium sandwicensium var. kilaueanum Deg. and Sherff "'ena'ena"
Stems with included leaves and flowers. In one instance an entire plant, with short pieces of roots, was noted. Abundant.

Sonchus oleraceus L. "sow thistle," "pua-lele"
Incomplete capitula consisting of the peduncle, receptacle and involucral bracts. Rare.

### CRUCIFERAE - mustard family

Lepidium virginicum L. "wild pepper-grass"
Flower stalks with included capsules. Rare.

EUPHORBIACEAE - spurge family

*Euphorbia olowaluana Sherff "akoko"
Leaves only used. Found primarily in lining, but occasionally in bulk of nest. Uncommon.

LEGUMINOSAE - pea family

*Sophora chrysophylla (Salisb.) Seem. "mamane"
Flowers, usually lacking petals. Uncommon.

LYTHRACEAE - loosestrife family

Lythrum maritimum HBK "pukamole"
Stems with included leaves and fruits. Rare.

SCROPHULARIACEAE - snapdragon family

Veronica plebeia R.Br. "common speedwell"
Stems with included fruits and leaves. Occasional.

## COMPOSITION OF NESTS EXAMINED

Nest no. 1

Leaves and culms of several species of grasses are the most common constituents of this nest. An inflorescence of a single species, Dactylis glomerata, was found, making it the only taxon which could be identified with any certainty. Gnaphalium and an unidentified carophyllaceous plant are the second most common constituents, Conyza, Lythrum and Sonchus are present also.

The nest is lined primarily with grass roots. Gnaphalium is a distant second, while culms and leaves of at least two species of grasses complete the lining.

Nest no. 2

Culms, leaves and inflorescences of Holcus lanatus form the bulk of the nest; Gnaphalium is a distant second; Veronica, grass roots, Sophora flowers and some animal fiber (wool of wild sheep?) are rare.

The lining consists of animal fibers and Sophora leaves.

Nest no. 3

The nest is composed almost entirely of grasses; Holcus lanatus and Bromus rigidus are identifiable.

The lining consists of these two grasses, at least, and Sophora leaves.

Nest no. 4

Usnea is the most common component; Conyza the second; also present are leaves, culms and inflorescences of Poa and Holcus, Sophora leaves, Lepidium inflorescences and various parts of Gnaphalium.

The lining consists primarily of Gnaphalium and Sophora with Holcus, Conyza and a few grass roots.

Nest no. 5

The nest consists chiefly of Holcus with some Conyza, Gnaphalium, Lepidium and grass roots intermixed.

The lining consists of Conyza pappus, a few grass roots and Sophora leaves, Gnaphalium and two Sophora flowers.

Nest no. 6

Leaves, culms and inflorescences of Holcus are the most common components of this nest. Gnaphalium stems, leaves and inflorescences are a close second. Also included are leaves, culms and inflorescences of Poa; entire plants of Usnea; leaves of Euphorbia; inflorescences of Conyza; and a few grass roots.

The lining consists primarily of grass roots and Euphorbia leaves.

Nest no. 7

Gnaphalium is the most common species of plant used in the construction of the nest. All parts including small complete plants with short, broken roots are present. Holcus is the (distant) second most common species: both culms and leaves were used. Also noted: a few grass roots; inflorescences of Bromus; culms and inflorescences of Poa; leaves of Sophora; a 2" twig of Veronica; a few flowers of Sophora; and two incomplete capitula of Sonchus.

Nest no. 8

Gnaphalium is the most common component; Holcus is second. Sophora leaves, Veronica fruits, Usnea, Sophora flower, Lythrum twigs, grass roots and animal fibers also present.

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