

LIGHT REQUIREMENTS OF THE WEAVER FINCH<sup>1</sup>

## 1. LIGHT PERIOD AND INTENSITY

BY MARIE ROLLO AND L. V. DOMM

In previous experiments (Brown and Rollo, 1940) it was shown that certain equatorial whydahs and weavers in eclipse plumage responded to increased daily light periods by assuming nuptial plumage. *Steganura paradisea*, *Pyromelana franciscana* and *Vidua principalis* assumed nuptial plumage out of season on daily light periods that were gradually increased from ten to sixteen hours. However, the plumage change did not come about until several months after the sixteen-hour period had been reached, which brought up the question as to whether the assumption of nuptial plumage was due to the gradually increasing daily light period or to the effect of the sixteen-hour period as such. The length of the daily light period as well as the intensity used in the above experiments were more or less arbitrarily chosen. Therefore the following experiments were undertaken to see:

- I. At which day-lengths *Pyromelana* would assume nuptial plumage.
- II. If there was an optimum day-length for producing nuptial plumage.
- III. The relative effects of gradually increasing periods and of a constant optimum period, if any, throughout the experiment.
- IV. The relationship between light intensity and daily light period in bringing about the molt.

## MATERIAL AND METHODS

Thirty-nine male *Pyromelana franciscana*, in eclipse plumage, were used in the experiments. Thirty-two of them were purchased in California and were said to be mature birds that had been in nuptial plumage once before. The other seven birds were three and five years old and had been previously used in the experiments by Brown and Rollo (1940) mentioned above, in which the birds, their origin, and general care were described.

A wooden rack, divided into compartments, 14 x 24 x 20 inches high, was built with a light socket attached to the center of the ceiling and a dark green roller shade on the front or open side of each compartment. A one and one-half inch frame extended over the shades on all four sides and prevented any leakage of light. Lights were turned on and off by individual time switches. The birds were examined weekly

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for the first appearance of nuptial plumage. The bright orange nuptial feathers appear first at the vent and can be distinguished from the drab of the eclipse plumage, even before they emerge from the sheath. At the completion of the molt, the last drab feathers that remain are at the sides of the abdomen and when these drop off the bird is in full color or nuptial plumage. The progress of the molt in *Pyromelana* is very regular and definite, making these birds particularly good material for a study of this kind.

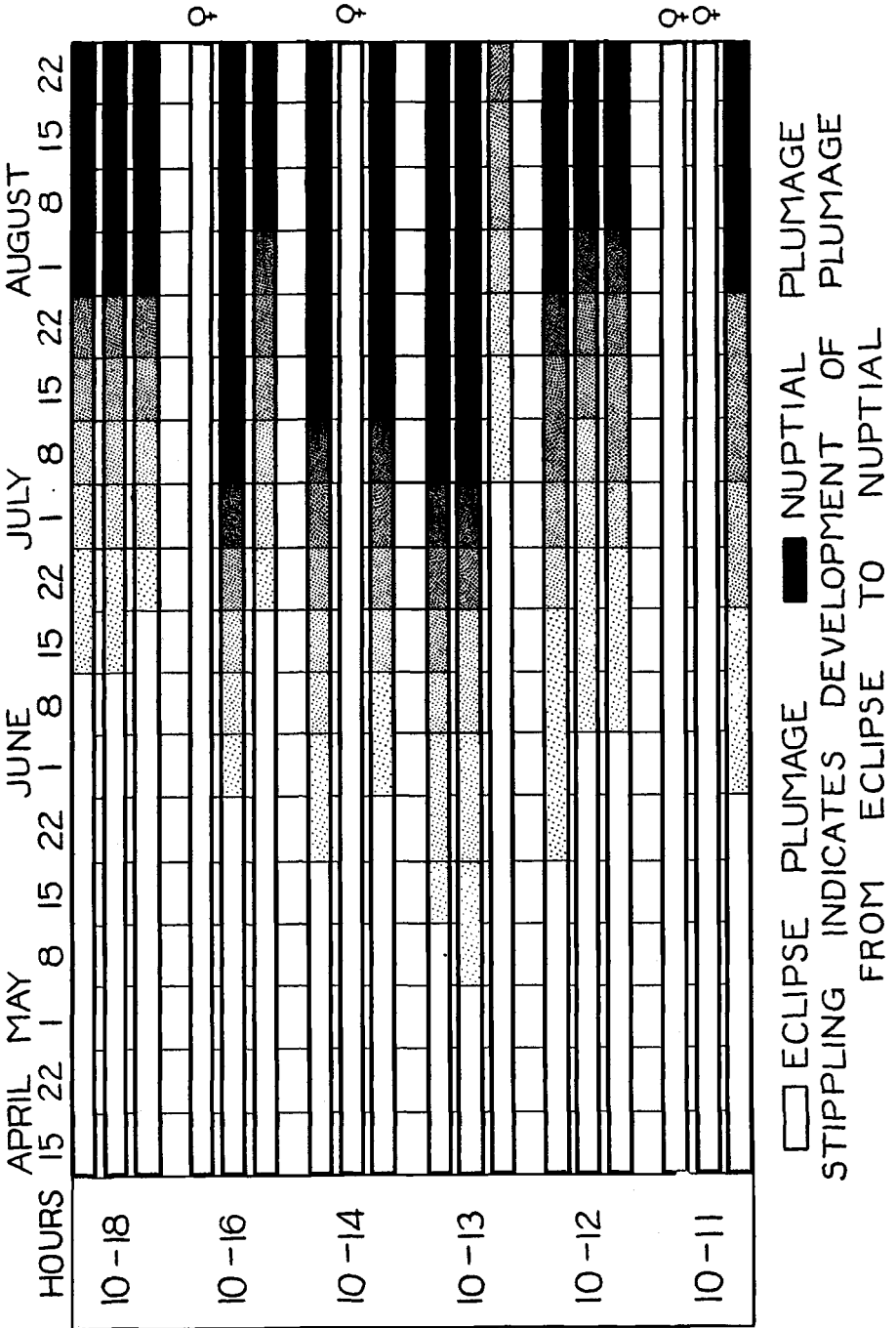
## RESULTS

### I. EXPERIMENTS ON LIGHT PERIOD

The experiments on light period were done in a room with west exposure. There were four west windows and the rack was placed against the north wall. All shades were raised at 7:30 A. M. and the birds received daylight from then until 5:30 when the artificial lights were turned on as needed. The shades were drawn when the desired light period had been obtained and the birds were then in total darkness until 7:30 the next morning. One-hundred-watt bulbs were used for the artificial lights.

*Experiment 1.*—On February 20, 1939, three birds were put into each of six cages and started on a ten-hour daily light period. This was increased ten minutes a day until one of the following periods was reached in each of the six cages—eleven, twelve, thirteen, fourteen, sixteen, and eighteen hours. They were then kept at that light period until the close of the experiment at the end of August. Due to the difficulty in sexing the birds when they are in eclipse plumage, four turned out to be females. The males on all periods came into nuptial plumage. However, those on the thirteen-hour period were first to start the molt and first to complete it. The first indications of a response in this group were noticed on May 8 and the birds were in full color by July 8. Longer and shorter periods retarded the appearance of nuptial plumage, an eighteen-hour period producing essentially the same results as an eleven-hour period. Thirteen hours, therefore, seemed to be the optimum period for producing this change. The results of this experiment are diagrammatically shown in Text-fig. 1.

*Experiment 2.*—This experiment was started at the same time as the above. Two birds were put into each of seven cages and given constant light periods of ten, eleven, twelve, thirteen, fourteen, sixteen, and eighteen hours from the start of the experiment. All of them assumed nuptial plumage. Although the response in these birds was



TEXT-FIGURE 1. Graph showing the assumption of nuptial plumage in birds receiving increasing daily light periods.

a little less regular than in those of Experiment 1, the constant light periods were equally effective as, if not more effective than, the increasing ones.

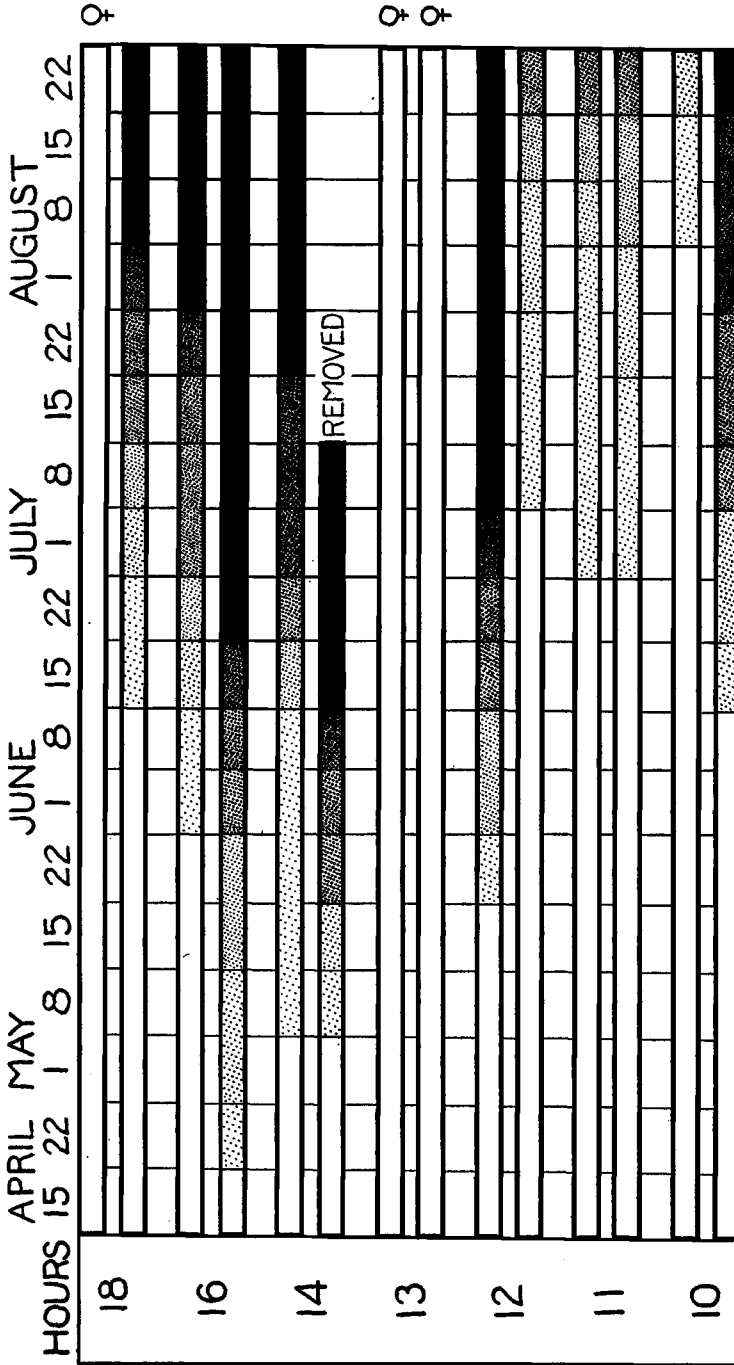
Unfortunately, the two birds on the thirteen-hour period, which proved to be the optimum in Experiment 1, turned out to be females. Of the remaining periods, the fourteen-hour period was the most effective and the birds on it showed the first indication of a response on May 7 and were in full color by June 15. The longer periods as well as the shorter ones retarded the appearance of nuptial plumage as was observed to be the case in Experiment 1, one bird in the eighteen-hour cage responding the same week as one in the ten-hour cage. It is evident that the plumage responds to the length of the daily light period as such and not to the gradual daily increase or decrease (see Text-fig. 2).

*Experiment 3.*—Seven older birds used in previous experiments (Brown and Rollo, 1940) and thus having varying light histories, were put into the same cages with the birds in Experiment 2 and therefore received identical treatment. They responded irregularly, but all but one on the ten-hour period came into nuptial plumage by July 15. The one in the ten-hour cage remained in eclipse plumage. No correlation was found between their response and their previous light history (see Text-fig. 3).

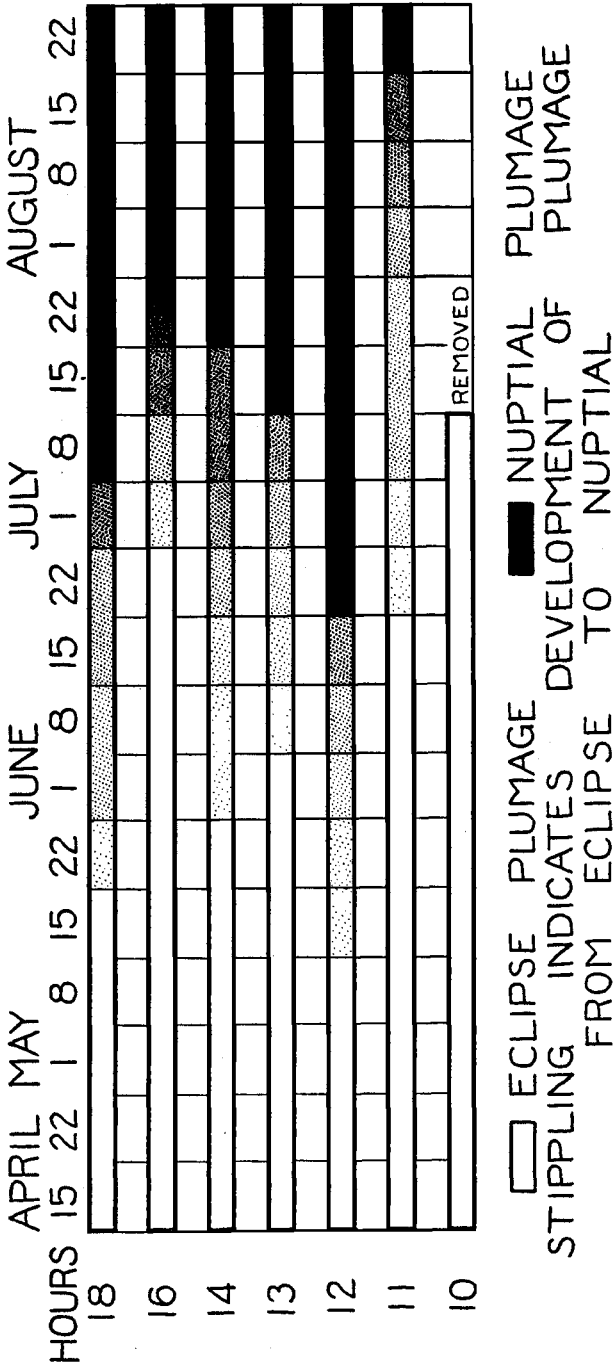
*Experiment 4.*—The bird in the ten-hour cage in Experiment 3, in eclipse plumage, and one from the fourteen-hour cage in Experiment 2, in nuptial plumage, were killed and dissected on July 15. The former had gonads about the size of a pin-head; the latter, almost one centimeter in diameter. No histological examinations were made.

The remaining birds were put into an aviary and kept on a fourteen-hour light period until February 18, 1940. On that date they were still in nuptial plumage and twenty-six of them were put into a cage and given a period of nine hours of daylight indoors.<sup>1</sup> The remaining eleven were kept on a fourteen-hour period. The light periods during the last part of the experiment were rather irregular, the birds sometimes receiving a slightly longer period than was intended. However, by July 6 the birds in the nine-hour cage were in eclipse plumage, while those in the fourteen-hour cage were still in nuptial plumage.

<sup>1</sup>On April 14, the food was removed from the nine-hour cage about noon. This was not discovered until 6:00 P. M. by which time five birds were dead and many others were in convulsions. Those that were able to eat were fed, and those that were not were put on a heating pad and fed warm milk with a pipette. There were no further losses and those that survived seemed to have suffered no harm.



TEXT-FIGURE 2. Graph showing the assumption of nuptial plumage in birds receiving various daily light periods, not increasing in length.



TEXT-FIGURE 3. The assumption of nuptial plumage in birds with varying previous light histories.

## II. EXPERIMENT ON LIGHT INTENSITY

For this experiment the rack was placed in a darkened room where the birds received fourteen hours of artificial light and no daylight. Seven compartments were used with  $7\frac{1}{2}$ , 15, 25, 40, 60, 100, and 150-watt bulbs, respectively. The intensity was measured in foot-candles in the three places where the birds spent most of their time, the center of the floor and the center of each of the two perches. These three figures were averaged to give the approximate number of foot-candles of light that the birds received.

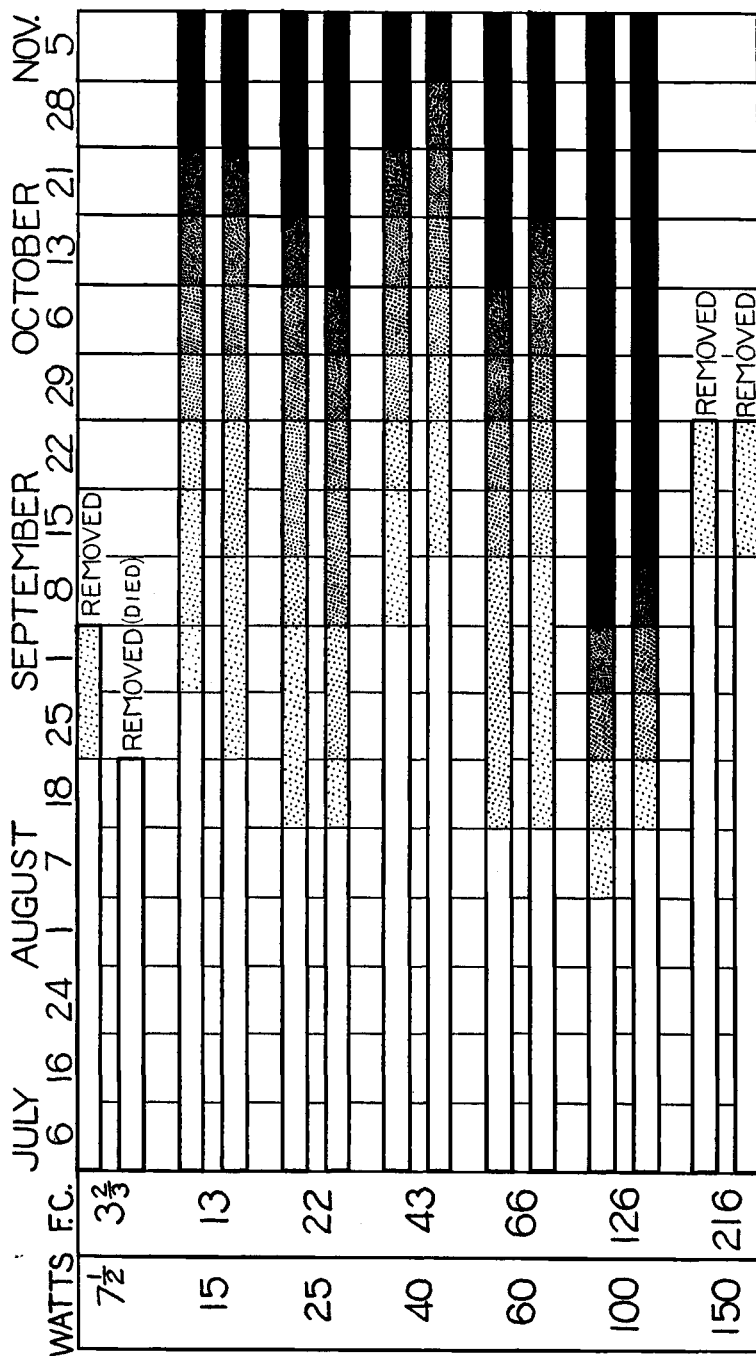
The birds in nuptial plumage showed no change and were therefore not recorded in the text-figure. They were removed from the experiment at the end of four weeks. The plumage changes of the birds in eclipse plumage at the start of the experiment are recorded below (Text-fig. 4).

We found that any intensity within the limits necessary for survival of the bird seemed to produce the nuptial plumage. Three and two-thirds foot-candles ( $7\frac{1}{2}$ -watt cage) retarded the appearance of nuptial plumage and produced convulsions. One bird died on August 25 and the other went into convulsions on September 8, but was revived with higher intensities of light. On the other hand, 216 foot-candles (150-watt cage) retarded the appearance of nuptial plumage and produced tremors by September 29. At the low and high intensities both the appearance and rate of growth of the feathers were retarded but no eclipse feathers were regenerated. The birds remained bare in spots. Approximately 126 foot-candles seems to be the optimum intensity, as birds on this intensity were first to start the molt into nuptial plumage and completed the molt five and six weeks before those on other intensities. With optimum period and optimum intensity these birds can be brought from eclipse into nuptial plumage in ten weeks.

## DISCUSSION

It was shown by Witschi (1936) that the henny plumage represented the neutral basic plumage in the weaver finch, *Pyromelana franciscana*. He found that the cock's plumage was induced by gonadotropic hormones and that its expression in the female was inhibited by ovarian hormones.

By manipulating the light period and light intensity, weaver finches can be brought into nuptial or eclipse plumage, at will, at any time of the year. Daily periods from eleven to eighteen hours, consisting of ten hours of normal daylight indoors supplemented by artificial lights at about 126 foot-candles, produced nuptial plumage. Birds



ECLIPSE PLUMAGE   
  NUPTIAL PLUMAGE  
 STIPPLING INDICATES DEVELOPMENT OF PLUMAGE  
 FROM ECLIPSE TO NUPTIAL

TEXT-FIGURE 4. The effect of intensity in producing nuptial plumage.



receiving thirteen or fourteen hours daily responded first and the others in direct proportion to the number of hours that the period was above or below the optimum.

In another experiment birds receiving a fourteen-hour period, at intensities ranging from  $7\frac{1}{2}$  to 126 foot-candles, also assumed nuptial plumage, with the optimum, judging by the fact that it produced nuptial plumage in the shortest time, at about 126 foot-candles. The lower and higher intensities,  $3\frac{1}{2}$  foot-candles and 216 foot-candles, did not facilitate survival of the birds and after prolonged treatment caused tremors and convulsions followed by death.

From time to time, birds in various stages of the molt were dissected. The gonads of those in full nuptial plumage were always between seven and ten millimeters in diameter while those of birds in eclipse plumage were from one to two millimeters in diameter. Birds in intermediate plumage sometimes had two gonads of intermediate size and at other times one fully developed gonad and one much smaller.

Light period and light intensity are two separate factors and one cannot be substituted for the other. Burger (1939) demonstrated that light intensity can only modify spermatogenesis in the male starling, but cannot be substituted for proper daily length of exposure. In other experiments, not recorded in this paper, weaver finches went into eclipse plumage on a nine-hour period in spite of an intensity of 350 foot-candles. Burger also found that increases beyond a certain period did not progressively produce a further acceleration of spermatogenesis. In our experiments, any light period longer than fourteen hours not only did not accelerate, but actually retarded, the appearance of nuptial plumage. This also held true for intensity.

Bissonnette (1937) states that regression and prolonged refractory periods invariably follow maximal activity, with or without environmental stimulation. In our experiments, weaver finches, on optimum period, did not show regression or refractoriness if we can assume that there is always a correlation between plumage and the state of the gonads. Several have been kept in perfect nuptial plumage for eighteen months and, in one case, for four years. However, on a period above the optimum, as well as on one below, they show what may be signs of regression; they develop shabby rectrices and remiges and become bare in spots and some actually molt and regenerate a few primaries. It is interesting to note that feathers which are the same color in both nuptial and eclipse plumages, such as remiges and rectrices, are replaced when molted as the result of too long a

light period while those that are different in color, orange in the nuptial and drab in the eclipse plumage, such as tail coverts, ruff and short body feathers, are not so readily replaced. This is the reason the birds become bare in spots.

If these can be called signs of regression, it may explain the fact that starlings normally show signs of regression of the gonads before the fifteenth of June, when the days are still increasing. Birds apparently inherit the ability to respond to a certain light period and a certain intensity. This period probably corresponds with the length of the daily light period at the latitude in which the birds originated.

Our domestic fowl originated at about the same latitude as the weaver finch (Rice and Botsford, 1940) and responds to the same light period. This is shown by the fact that poultrymen, in order to obtain increased egg production, add enough artificial light to produce a thirteen or fourteen-hour day when the days are short. However, they do not shorten the period when it is above the optimum in nature at this latitude and it is during this time that certain perplexing problems, such as "early molt," cannibalism, and drop in egg production, are encountered by the poultryman. A weaver finch on too long a light period, with its bare back, shabby, broken feathers, and sporadically regenerating primaries, is a miniature picture of a hen in an "early molt." The summer drop in egg production which is usually attributed to high temperatures also occurs at this time and may be related to this fact. It is therefore possible that the normal light period above the optimum is responsible for some of these difficulties in poultry and experiments are under way to see if such a relationship actually exists.

#### SUMMARY

Thirteen to fourteen hours is the optimum daily light period necessary for producing nuptial plumage in *Pyromelana franciscana*.

Longer as well as shorter daily periods were found to retard the appearance of nuptial plumage.

On optimum light period and optimum intensity these birds can be brought into nuptial plumage in ten weeks at any time of the year, or kept in nuptial plumage year after year.

On a nine or ten-hour period, birds in eclipse plumage do not assume nuptial plumage and birds in nuptial plumage molt into eclipse plumage.

On an excessively long light period, birds in nuptial plumage sometimes go into a partial molt.

There is a correlation between the size of the gonads and plumage changes.

Given enough time, any intensity sufficient for the survival of the birds will produce nuptial plumage provided that they have the optimum period.

The optimum light intensity is about 126 foot-candles.

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## NEST LIFE OF THE EASTERN YELLOW WARBLER

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### INTRODUCTION

THE data on which this paper is based were obtained from a careful study of forty-one nests of the Eastern Yellow Warbler (*Dendroica aestiva aestiva*), carried out during the summers of 1938 and 1939 at the Iowa Lakeside Laboratory, on West Okoboji Lake. The labora-