ABSTRACT

THE EFFECTS OF THE ENVIRONMENT ON GROWTH, DEVELOPMENT, AND TEMPERATURE REGULATION IN NESTLING EASTERN PHOEBES

by Harold D. Mahan

Between 1958 and 1962 nestlings and the nesting environments of the Eastern Phoebe, Sayornis phoebe, were studied in Isabella County, Michigan, to determine if there was any correlation between growth and development of temperature regulation in the nestlings and the environmental factors present in the foraging areas of the adults.

Daily growth measurements were obtained of 25 first-brood young, 1 to 12 days old and 21 first-brood young, 12 to 14 days old. Thirteen second-brood young, 1 to 12 days old and 10 second-brood young, 12 to 14 days old were also measured. Growth measurements indicated significant growth differences in first- and second-brood young but no difference in their fledging sizes. Although no significant difference in fledging success for either brood group was discovered, there was an average fledging time difference of 2.1 days, with the first-brood young fledging earliest at 14.8 days. Measurements of ectoparasite (mite) populations on the young showed a very significant difference in the numbers recorded on the two brood groups. The second-brood nestlings were heavily parasitized (20 or more mites/young) throughout their nestling lives whereas the

first-brood nestlings were heavily parasitized only after nine days of age.

From the same nestling population, 15 (1-14 day old) first-brood and 10 (1-14 day old) second-brood young were subjected to controlled temperature chambers for two hours (10°C. and 40°C.) in the laboratory. Body temperature records, breathing movement counts, and general observations of the behavioral responses of the young indicated that there was a significant difference between the ability of first- and second-brood young to control their body temperatures. All evidence indicated, however, that effective body temperature control was established in this species by 10 days of age. Prior to this age the young exhibited the poikilothermic condition.

One-half hour controlled temperature environment exposures (10°C., 25°C., 40°C.) in the laboratory of 12 first- and 17 second-brood one to six day old young showed no significant difference in the gaping response ability between either brood group. There was, however, a significant difference in the number of gaping responses among each brood group at each of the three environmental temperatures investigated, indicating that air temperature directly affects the gaping response ability of the young.

The growth measurements and laboratory investigation of body temperature control indicated, therefore, that there was a significant difference in the growth and development of temperature regulation in the first- and second-broods in this species, possibly caused by increased ectoparasite populations on the second-brood young. This difference was not reflected, however, in the ability of the young between one and six days of age to respond by gaping to mechanical stimulation after short periods of controlled temperature exposure. Apparently, however, the ability of all young to gape was affected by extreme air temperatures in that the greatest number of gaping responses was recorded after exposure to the 25°C. environments.

Environmental data were collected at three first-brood and three second-brood nests during the first 12 days of nestling life. One first-brood nest contained four young. The number of young was reduced to two in all other nests.

The size and nature of the adults' foraging areas were analyzed at all nests. The size of all foraging areas averaged 4,727 square meters. The most pronounced changes in foraging area size were recorded during adverse weather conditions (high winds and/or heavy rain).

Daily weather conditions (air temperature, wind speed, sky cover, rainfall, relative humidity) were continuously recorded in the foraging areas, as were the density and weight of aerial arthropods present (presumably available for feeding the young).

Although there were seasonal fluctuations in the number and species of aerial arthropods present, the majority belonged to seven arthropod groups. The arthropods collected indicated strong correlations between their number and weight and the existing weather conditions. The feeding activities (number of trips to the nests presumably with food) and brooding behavior of the adult phoebes likewise indicated strong correlations with the existing weather conditions.

Correlation coefficients of the daily weight gain of the young and weather conditions indicated little relationship between these factors, however. Similarly there were slight negative correlations between the daily weight gain of the young and the number of available arthropods in the foraging areas of the adults as well as the number of trips that the adults made to the nest. The slight negative character of these correlations, in fact, suggested that an increase in the number of arthropods present and an increase in the number of trips to the nest by the adults were reflected in a decrease in the weight gain in the young. Possibly this indicates that the changing nature of the arthropods present during adverse weather conditions together with a changing foraging pattern by the adults resulted in fewer but possibly larger arthropods being captured, and therefore of greater weight-gain value to the young. This also would result in fewer trips to the nest during such weather. Possibly, also, the poikilothermic condition of the young aided in less weight loss during adverse weather periods due to lowered activity. Probably, too, there were other factors operating. In any case, no environmental factor appeared to be so detrimental to the young in this species as to inhibit successful fledging. Otherwise, the Eastern Phoebe would not be as successful as it is in the areas where it now nests.

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INTRODUCTION

During the past 25 years considerable attention has been given to the relationships between the energy exchanges of organisms and their enviornments. Although relatively little attention has been paid to the higher vertebrate groups, a number of ornithologists (notably Koskimies, 1950; Lack, 1952; and Udvardy, 1953 in Europe; and, in this country, Baldwin and Kendeigh, 1932; Barthelomew, and Dawson, 1958; Dawson, 1954; Dawson and Evans, 1957, 1960; Farner, 1956, 1958; Kendeigh, 1952; and Scholander, 1955) have attempted to determine the bioenergetic relationships of birds. Although most of these studies have shown the physiological adjustments that birds can make, few studies have attempted to relate these adjustments to the total nesting situation of the species. Although the great mobility of birds prohibits a complete investigation, there are certain periods in their lives when energy-exchange relationships may be studied fairly easily.

With altricial birds, the period when the young are still confined to the nest is an excellent time to determine these relationships. At this stage the young bird's ecosystem has definite limits (i.e., the area in and around the nest, including the feeding area of the adults).

To relate the adjustments that occur between the young and the ecosystem, one can choose a single factor that represents the growth of the young and relate the development of this factor to the elements in the environment that are affecting it. With altricial birds, one such factor is internal temperature regulation, and because of its great importance in the growth of young birds, it was chosen as a focal point for this investigation.

In general, altricial birds hatch in a very underdeveloped state, and consequently have little ability to maintain a constant body temperature in extreme ambient temperatures. As these young are fed they increase in mass, grow an insulating covering of feathers, and develop internally in such a way as to become increasingly homoiothermic. Their ability to regulate internal temperatures, then, is related to their development and must also be related to environmental factors controlling growth. The major factor in the environment that controls their growth is the abundance and availability of food.

In the case of birds that feed on flying insects, food supply is controlled primarily by the physical factors in the environment. The studies of Glick (1939) and Palmen (1944) have shown that the density and activity of flying insects is primarily controlled by the weather. If this is true, it seems logical to assume that there is a relationship between the growth of the young of aerial-feeding birds and the weather, and perhaps other ecological factors that are affecting their food supply. Furthermore, it should follow that if the development of body temperature control is dependent upon growth, that both this and the factors controlling availability of food are likewise related. To date, no study has shown the degree to which these factors are related for any passerine species, and it is the purpose of this investigation to do so.

During the spring of 1958 a study was begun in Isabella County, Michigan, to determine the relationship between the environment and the development of growth and temperature regulation in the young of the Eastern Phoebe, *Sayornis phoebe* Latham. At the beginning of this investigation an attempt was made to study the growth of the young and to correlate this with the development of their thermoregulatory ability. Subsequently, the environment of the young of this species was analyzed to determine (1) the amount of potential food available to the adults for feeding the young, (2) the factors in the environment controlling the availability of this food, (3) the amount of food actually fed the young, and (4) other factors in the environment that were affecting the growth and development of the young.

The Eastern Phoebe was chosen for this investigation for several reasons: it is a common summer resident in Isabella County, Michigan (Cuthbert, 1962); it is a species which feeds exclusively on arthropods during the nesting season (Merry, 1941); and its nesting situation easily lends itself to field and laboratory investigations. In addition, it also has been studied extensively with regards to growth and development of the young (Stoner, 1939; Merry, op. cit.; Wetherbee, 1957), feeding frequency of the young (Kendeigh, 1952), and development of temperature control in the young (Stoner, op. cit.). Another interesting consideration is that this species, unlike many perching birds, commonly raises two broods of young in the same nest during a single nesting season. This second brood of young is very often heavily infested with ectoparasites (primarily mites), and this environmental influence is of extreme interest in connection with the development, growth, and the development of temperature regulation in the young. Finally, of great significance, is the long nesting period, which in the study area extends from April until August and provides a wide variety of weather and environmental conditions under which this species can be studied.

MATERIALS AND METHODS

In general it was necessary to make three separate approaches simultaneously in this investigation. The first involved determining the general growth and development of the young; the second, the determination of the thermoregulatory abilities of the young; the third, the ecological factors controlling the growth of the young.

Growth rates were determined by obtaining daily weights and various linear measurements in the field. These were obtained each evening at 7:00 p.m. (± 30 minutes).

Daily weight measurements were obtained with an Ohaus triplebeam balance, accurate to 0.1 grams. This instrument was securely attached to the bottom of a wooden box. The cover of this was designed so as to serve as a windbreak. Two levels were mounted on the box so that the balance could be maintained in a level position. Very young nestlings were weighed on the open pan. Due to increased movements, however, it was necessary to place young older than nine days in an open plastic container before weighing (Plate 1).

Measurements of length were obtained with steel calipers in conjunction with a steel millimeter-graduated rule. The following measurements were made:

(1) total body length, from the tip of the bill to the posterior end of the coccyx.

(2) length of the right third down feather from the posterior end of the dorsal tract,

(3) length of the right third down feather from the posterior end of the ventral tract,

(4) length of the innermost down feather on the inner wing feathers,

(5) length of the innermost down feather on the outer wing feathers,

(6) length of the innermost tail feather down,

(7) length of quill and barb on the right third feather from the posterior end of the dorsal tract,

(8) length of quill and barb on the right third feather from the posterior end on the ventral tract,

(9) length of quill and barb on the right third innermost secondary feather,

(10) length of quill and barb on the right third innermost greater secondary covert feather,

(11) length of quill and barb on the right third innermost primary feather,

(12) length of quill and barb on the right third innermost greater primary covert feather, and,

(13) length of quill and barb on the right innermost tail feather.

All other feathered areas were measured but their growth are only briefly summarized in this investigation.

Early in the study it appeared that the rapidly increasing numbers of ectoparasites were adversely affecting the young in the second broods. Beginning in 1959 an attempt was made to determine the effects of ectoparasites on the young in the first- and second-brood nests. During 1959 and 1960 five young of each day of age in first and second broods were randomly selected from the nestling population that was being studied. Ectoparasites were removed from these young with a fairly stiff camel's hair brush. The young were held over a flexible plastic grid sheet and brushed vigorously along their dorsal, ventral, alar, and caudal tracts. After the ectoparasites were identified and counted, the plastic sheet was rolled into the shape of a funnel and the ectoparasites were dumped back on the young.

Although social parasitism by the Brown-headed Cowbird (Molothrus ater) occurred in several nests, all cowbird eggs were removed as soon as they were discovered in order to eliminate this factor in the study.

All young phoebes were individually marked in a coded fashion with a plastic lacquer so that they could be recognized on each visit. When five days of age this marking system was replaced with serially numbered government bird bands.

A field tabulation form (Plate 2) was used so as to standardize the growth measurements obtained each day.

Investigations of the thermoregulatory abilities of the young were made in the laboratory. This was accomplished by removing one or two young from each nest each evening and transporting them, in most cases, a distance of less than three miles. Evening was chosen for these experiments so that the young would not be deprived of a full day of feeding. In the laboratory the birds were placed in an empty nest for a period of one-half hour. During this time they were also weighed, fed with a mixture of dog food and mealworms (using the method of Dawson and Evans, 1957:316), and allowed to adjust to room temperature (25°C. - 28°C.). At this time they were placed in either a controlled high- or low-temperature environmental chamber.

The temperature controlled chambers were constructed from unpainted one-gallon cans which had brass fittings for incoming and outgoing air lines mounted on the lids. The intake air line extended through the lid to three centimeters above a phoebe nest placed on the bottom of the can. The exhaust air line began at the very top of the can. This arrangement assured efficient circulation of air pumped through the chamber.

Each container was placed either in a high-temperature (10°C. $\pm$ .5°C.) refrigerator or a low-temperature

($40^{o}C. \pm .5^{o}C.$) incubator so that constant temperatures within each container could be maintained. Air was pumped from a double-piston Marco air pump through a manometer (at a rate of 150-300 cc./min., depending upon the age of the bird) into each chamber. Using this arrangement (see Figure 1) it was possible to expose the nestlings to constant high or low temperature environments for any time period desired.

During the 1959 and 1960 experiments the young phoebes were confined in the darkened chambers for a period of two hours. As Dawson and Evans (1957) showed with a similar technique with the Field Sparrow, Spizella pusilla, and the Chipping Sparrow, Spizella passerina, a two-hour period is sufficient to allow young of passerine species to reach a post-absorptive resting state and to adjust as best they can to the environmental temperature.

After removal from the controlled environments, the body temperatures of the young were measured immediately with a fast registering small animal thermometer inserted in the cloaca to a depth of eight millimeters. Following this, the breathing movements were counted and recorded. In very young nestlings exposed to cool environments the breathing movements were so slight that they could be detected only by observing the birds under a dissecting microscope.

In order to compare the temperature regulation ability of the young with adults of this species, five adults were captured at nests outside the study area and subjected to 10°C. and 40°C. controlled environments using a technique similar to that used with the young.

During 1960 and 1961 five young for each day of age between one and six days from both first- and second-brood nests (two from first-brood nests; three from second-brood nests) were randomly selected from the nesting population and subjected to controlled temperature environments of 10°C., 25°C., and 40°C. under conditions identical to the above but for only one-half hour periods. At the end of each of the one-half hour exposure periods in the controlled temperature environments the lids to the containers were quietly removed and the nests in the containers were than jarred to determine the effects of the shorter temperature exposure period on the gaping response and general behavior of the young.

In no case were the same birds used on two successive nights in the controlled temperature experiments. After each experimental period the birds were allowed to adjust to room temperatures, were fed again, and then returned to their nests, approximately three hours after removal. In nearly 300 experiments only four young died, and there was no noticeable difference between the growth of the experimental birds and those left in the nest.

All laboratory measurements and observations were recorded on a standardized tabulation form (Plate 3A).

Various techniques were used to measure the biological and physical factors in the nesting environments studied. Methods were developed to investigate insect densities, feeding rates of the young, amount of food fed to the young, nest temperatures, temperatures of the young in the nest, and the weather conditions in the nesting territory.

Early in the investigation an attempt was made to determine the densities of arthropods in the feeding territory of the adults. Although many attempts have been made to determine the densities of aerial arthropods in various environments (Phillips, 1931; Gray and Treloar, 1933; Beall, 1935; Johnson, 1951; Craig, 1953), the techniques first developed by Peterson (1934) and later modified by Taylor (1960) seemed most suitable for the present study. This technique involves using a vertical board coated with a sticky substance mounted on a revolving base. In this investigation a wind vane was attached to the back of the boards so that the coated surfaces would always face the wind (if the wind speed was three miles an hour or greater). The front of these "sticky board" traps consisted of 18" X 18" X 1/8th inch white tempered masonite boards attached with metal clips to 1/8th inch aluminum sheets. Each board was mounted on top of a five foot metal pole (Plate 4A). At the beginning of each daily recording period (within 15 minutes of the first actual feeding flight to the nest), the masonite boards, coated on one side with "tree tanglefoot" (a commercial insect trap compound), were attached to the masonite boards clipped to the aluminum sheets (Plate 4B). At the end of each recording day (within 15 minutes of the last feeding flight to the nest) the masonite boards were removed to the laboratory in a carrying case (Plate 4C) and the arthropods were removed with a pithing needle, placed in xylene for five minutes to remove the trap compount, air-dried on blotter paper, counted, and identified to order. Immediately afterwards they were weighed on a chain balance, accurate to .0001 grams.

Each arthropod sampling device was placed at a random position in the feeding territory of the adults. This was accomplished by mapping the foraging areas of adults by recording the maximum feeding distances traveled from the nest at four of the most accessible nests. These maps were constructed during the two nesting seasons (1959, 1960) prior to the nesting seasons when the environmental measurements were made (1961, 1962) in order to have maps of the potential foraging areas for sampling. Next, the foraging areas were divided into 30 or more equal-size, 10 meter square quadrats to which numbers were assigned for random sampling. This method is an adaption of the random sampling technique proposed by Dice (1952) for irregular-shaped ecosystems. Five sampling boards were used in each nesting territory, and in every case they were placed in the centers of the randomly selected quadrats. The period required for placing or removing all arthropod sampling boards averaged eight minutes.

As has been already indicated, the foraging areas of the adults were carefully mapped during the two years prior to the actual environmental observation and measurements. In every case this was done twice daily (5-6 a.m.; 7-8 p.m.) every other day during the period when the young were in the nest. During 1961 and 1962 (when the actual environmental conditions were studied) the foraging areas were again mapped in a similar fashion so as to determine (1) the accuracy of the maps in regards to the foraging areas for the periods when the environmental studies were actually being made, and (2) for determining the sizes of the foraging areas during the same period. Since no planimeter was available the latter was determined by carefully cutting the foraging area maps from the graph paper on which they were drawn, weighing these maps on the chain balance mentioned on page 12, and comparing their weights with the weights of similar pieces of graph paper on which square areas (enclosing the mapped areas) of a known unit-area size had been drawn (See Figures 2A and 2B). This weight-percentage comparison therefore made it possible to calculate the sizes of the irregularly shaped foraging areas. This method is an adaptation of that suggested by N. L. Cuthbert and used by Niergarth (1964) for analyzing the percentage composition of different vegetative types in a marsh community.

The rate at which the young were visited by the adults was measured with a 6-volt, battery-operated circuit-closing electromagnet in commection with a hand-wound clock recorder (see Plate 5). The trigger for this recorder was a movable perch, mounted on a micro-switch attached to a nesting shelf containing the nest. Both sides of the nesting shelf were closed with 1/4" wire mesh so that the adult had to trip the switch when landing on the nest (see Plates 6A and 6B). This recording arrangement is a modification of the "itograph" recorder designed by Kendeigh (1952). As the adults landed on the perch it touched a metal plate below. This closed the circuit in the recorder and caused the recording stylus to mark a line on the contact sensitive paper in the recorder (see Plate 7). The recording paper revolved on a four-hour cycle drum. As the adult left the perch the circuit was broken and the stylus in the recorder returned to its original position, leaving another line. In this fashion it was possible to measure both the number of trips to the nest and the duration of each trip, providing that the minimum time between trips was greater than 15 seconds (in which case only a single line would be recorded).

Although Kendeigh (1952) and many other investigators (Betts, 1954; Fant, 1953; Greenewalt, 1955; Gurr, 1955) have used recording devices similar to the above to determine attentive behavior of the adult birds, Betts (1955) has suggested that such instruments do not always provide an accurate means of determining the feeding frequency or the amount of food actually brought to the nest. In order to obtain a more accurate measurement of the amount of food fed to the young, four approaches were made: (1) direct observations of the adults' feeding behavior and their subsequent trips to the nest with food after observed catches, (2) direct observations of the adults actually feeding the young at the nest, (3) the construction of an artificial nestling to collect food from the adults, and (4) recording the daily weight changes in the young.

Although the feeding behavior of the adults was carefully observed, it was usually not possible to determine how many insects were being captured on each feeding trip. Neither was it often possible to follow the trips to or from the nest, due, in most cases, to the adult's activities being obscured by dense foilage or other obstructions in the feeding area. All observations, however, were recorded of trips that resulted in an arthropod being captured, brought to the nest, and fed to the young. For convenience, the catches of such arthropods were recorded according to whether they occurred (1) in the open air, (2) on the ground or within six

inches above the ground, and (3) among the foliage of the vegetation in the feeding areas.

There were so few instances when it was possible to identify by observation either the number or kinds of arthropods fed to the young in the nest that this approach was soon abandoned. (At two nests, 61-16 and 61-16A, it was possible to observe the young from a distance of only 23 inches, but on no occasion during 26 hours of intensive observations was it possible to identify the number or kinds of arthropods being fed.)

In 1962 a dummy or artificial nestling, similar to that described and illustrated by Smith (1945), was constructed so as to provide a direct means of obtaining food brought to the nest by the adults. This nestling was placed in Nest 62-1 and later in Nest 62-17A. Although it did not prove successful in either nest for obtaining feeding data, it did illicit very interesting behavioral reactions from the adults and for this reason it seems worthwhile to include a description of its construction and use.

The artificial nestling was electrically controlled by an electromagnet arm serving to pull down a thin metal plate molded so as to resemble a lower mandible of a nestling (see Plate 8). The upper portion of the artificial nestling was the skin and upper mandible of a seven day old phoebe. The inside of the nestling's mouth was painted a bright yellow and the throat was constructed of a bright yellow denim

cloth, rolled into the form of a tube and attached to the bottom of the metal, lower mandible. This tube lead to a glass jar mounted below the floor of the nest. The contact points on the wooden perch (described on page 14) served as a trigger for operating both the artificial nestling's gape and the trip recording instrument. As the adult landed on the perch the lower mandible opened, exposing a bright yellow gape. As the adult left the perch the mandible returned to its original closed position.

A further effort to obtain a measurement of the food fed to the young involved obtaining daily weight changes in the nestlings. Each young was weighed each day at 7:00 p.m. ($\pm$ 10 minutes) in the same manner as in the growth studies carried out earlier in the investigation.

For that portion of the investigation that involved the study of the ecological aspects of the feeding environment and nestling life of the young, the number of young in all but one nest was reduced to two. This was done so as to have comparable data at each nest. One nest was left with its full complement of four young so as to uncover any relationship between the number of young in a nest and the feeding rates of the adults.

All young were marked with paint as soon as they hatched and the two young nearest in age (in the two-brood nests) were left in the nest. The remaining young were transferred to nearby phoebe nests (and in one case to a nearby nest of a Barn Swallow, Hirundo rustica, where they successfully fledged with three Barn Swallow young 14 days later!).

During the 1961 and 1962 nesting seasons nest temperatures were continuously recorded at the bottom of the nests where the feeding environments and growth of the young were being intensively studied. These temperatures were obtained on the floor of the nests under the young. This was accomplished by placing on the bottom of the nest an 8000 ohm thermistor probe in circuit with a YSI millivolt laboratory recorder (see Plate 9A). The low sensitivity of this recorder necessitated the placing of a wheatstone bridge in series with the electrical circuit in order to obtain a greater sensitivity. Using this arrangement it was possible to convert records of electrical changes in the thermistor to degrees of temperature on the contact-sensitive recording paper (see Plate 10). This instrument was calibrated at the beginning and end of each series of experiments at each nest, and varied in its accuracy only $\pm$ .5 C for all experiments in which it was used. Two heavy duty 12-volt automobile batteries were used, one at a time, as the power source for the recorder. The pole wires were connected to a D.C. to A.C. converter (see Plate 9B). Each battery was recharged every other night so that one would always be in a charged condition during the recording periods. The use of house current as a power source for this instrument was, during most of the recording periods, not suitable since the use of electrical appliances, etc., along the electrical lines occassionally affected the recording needle.

All recording instruments were housed with a 9' X 9' umbrella tent which also served as a blind (see Plate 11). This was erected two days prior to the time that records were obtained, and in no case did its presence (within 50' of the nest) cause the adult birds to abandon the nest.

The weather conditions in the nesting territories were measured with a hand-held anemometer, a U. S. Weather Bureau rain gauge, and a Bendix Hygrothermograph (Plate 12). The clock operated hygrothermograph gave continuous inked records of air temperature and relative humidity for a 24 hour period (Plate 13). The speed and direction of the wind were measured and recorded every four hours between 4:00 a.m. and 8:00 p.m. The light conditions (sky cover, sunshine, etc.) were also determined at the same time. An arbitrary coding system was used to describe the amount of light present during the daylight hours. The amount of sky cover in the visable horizon was the basis for this code: <u>Sunny</u> (S), less than 25 per cent of the sky covered by clouds; <u>Cloudy</u> (C), between 25 and 75 per cent of the sky covered by clouds; <u>Overcast</u> (O), more than 75 per cent of the sky covered by clouds. All weather observations and measurements were recorded on a standardized field form (see Plate 14). All weather instruments were calibrated at the beginning of each daily recording period. In no case was the calibration variation greater than two per cent.

If possible, all weather instruments were placed in the center of the foraging areas of the adults as determined by using the scaled maps of these areas described on page 12. In every case the instruments were placed in a sheltered, portable weather cabinet, three feet above the ground.

Detailed notes were also taken of observations made of the activities of the young in the nest (movements, etc.) and of the adults and their behavior. Early in the nesting cycle at several nests(before actual nesting had commenced) the adults were captured in mist nets, color marked, and released.

RESULTS

The general body growth and development of 38 nestling Eastern Phoebes in 32 nests were studied between 1958 and 1961 in Isabella County, Michigan (see growth photos: Plates 15, 16, 17, 18, and 19). Growth measurements were observed daily for 38 individuals (25 first-brood young and 13 second-brood young) from 1 through 14 days of age, and for 31 of the same individuals (21 first-brood young and 10 second-brood young) from 12 through 14 days of age. From the same population from which these young were taken, 15 other first-brood and 10 other second-brood young for each day of age, 1 through 14 days, were subjected to controlled temperature environments of 10°c. and 40°C. for two hour periods to determine their thermoregulatory abilities.

During 1960 and 1961 five young of each day of age, 1 through 6 days, were also subjected to the same controlled temperature environments but at 10°C., 25°C., and 40°C. for only one-half hour periods to determine the effects of these temperatures on behavior.

Weights of 24 adult phoebes from the 1958-1962 populations were also obtained. In addition, the ecological aspects of the nesting and feeding territories (foraging areas and feeding activity, number and kinds of arthropods present, weather conditions, etc.) at eight nests of the Eastern Phoebe were intensively studied during 1961 and 1962. Due to equipment failure, etc., complete data for the first 12 days of nestling life, however, were obtained during only six nesting periods at three nesting sites (Nos. 16, 17, and 22).

Growth of Nestlings

Weight.--Both first- and second-brood young phoebes in this study weighed approximately two grams at hatching. This weight increased to approximately 20 grams by two weeks of age. Tables 1 and 2 show that there is a very rapid gain in weight during the first nine days of life and a gradually decreasing rate thereafter, until the young are nearly ready to fledge. The average weight of a nine day old nestling in this study was 16 grams. This is 88 percent of the weight of an average 14 day old phoebe in the study.

As Tables 1 and 2 indicate, the second-brood young increased in weight, on the average, as rapidly as first-brood young during the first two days of nestling life. At three days of age, however, the first-brood young began to increase their weight at a much faster pace. This average weight-gain difference between first- and second-brood young increased until the birds were nearly 12 days of age, at which time the mean weight for the second-brood young appeared to be increasing rapidly again. From 13 days until fledging, the young included in this study in both first- and second-broods averaged approximately the same weight.

The mean banding-record weight of 24 adult Eastern Phoebes captured in this study was 24.1 grams. The data in Tables 1 and 2, therefore, indicate that the young phoebe gains over one-half of its total adult body weight during the first week of life.

Length.--The difference in growth in length between the first- and second-brood of young phoebes followed a pattern similar to the differences in daily weight gain in this study. Unlike the weight gain pattern, however, Tables 1 and 2 show that for both first- and second-brood young the daily gain in length proceeds at a fairly uniform pace during their entire nestling lives.

At hatching the average young phoebe was approximately 38 millimeters in length. This increased to approximately 125 millimeters at two weeks of age. After three days of age, however, the young in the second broods showed a somewhat slower length gain each day than those young in the first-broods.

Feather growth.--The measurements of the body feathers indicate that they grow at rapid and uniform rates during the entire nestling period. As with weight and length growth-rates, however, the growth of feathers in the second-brood young did not proceed as rapidly as in the first broods.

In general, the entire body of the young phoebe had down feathers along most tracts at hatching. These were either sparsely distributed or extremely thick, with a somewhat matted appearance. Along the caudal tract it was usually only certain pairs of feathers that had down (most often only the outer two pairs of feathers and/or the innermost pair). In most individuals measured in this study only the sixth, seventh, eighth, and ninth primary feathers had down. When the wing was folded the primary down lay next to the dorsal tract down, and the much more plentiful secondary down (occurring at each point where a secondary feather arises) covered all of the cervical apterium. The down on the head (capital tract) was very long (five to eight millimeters) and dense at hatching. When the head was held against the trunk of the body, the head down effectively covered the downless area between the posterior end of the capital tract and the anterior end of the dorsal tract. The dorsal tract appeared to have a very dense covering of down at every point where a definitive feather was to arise. Actually, only the middle pair of dorsal tract feather rows had down. The outer two feather rows were completely bare. The down over the eye, on the back of the head, and along the upper arm was seven millimeters at hatching; the crural tract down was five millimeters. Most down feathers were five-branched and the major portion of the upper surface of the young phoebe (that portion exposed while in the nest) was almost completely covered at hatching with down between five and nine millimeters in length.

The ventral portion of the body was more sparsely covered. At hatching the down was concentrated along the posterior one-fourth of the ventral tract (the portion exposed to the environment while the young is in the nest). In this region it was six millimeters at hatching and it remained approximately the same length until the young was nearly nine days of age, at which time most of it had been rubbed off by the bird's movements. The anterior three-fourths of the ventral tract never had down on the young in this study.

The barbed portions of the juvenal feathers along all major trunk tracts unfurled from their sheaths at approximately six days of age. The growth of down and juvenal feathers along the wings progressed at a rate similar to that of the juvenal feathers and down along the major trunk tracts. The barbed portion of the primaries and secondaries and of their greater covert feathers also began unfurling at six days of age, when the steel gray shafts of feathers along these tracts turned white on their tips and began to disintegrate as the barbed portions unfurled. The barbs along all feather tracts continued unfurling at a very rapid and uniform rate until the young left the nest.

Fledging of Nestlings

No measurements or experiments were made after the young were 14 days of age for fear of interfering with normal fledging time, and in no case were more than one-half of the young from one nest used in any experiments.

Of the 32 nests studied between 1958 and 1961, 83 young (63.4 per cent) successfully fledged (out of a total of 131 eggs laid). Of these nests, 11 were re-used for second-broods. In the 21 first-brood nests (in which 94 eggs were laid), 60 young (63.4 per cent) successfully fledged. In the re-used, second-brood nests (in which 37 eggs were laid), 23 young (62.1 per cent) fledged successfully.

The average fledging time for the 60 first-nest young was 14.8 days (the earliest 14.1 days, the latest 15.5 days). For the 23 second-brood young, the average fledging time was 16.9 days (the earliest 15.8 days, the latest 17.4 days). Thus, in this study, the average fledging difference in time between first- and second-brood young was 2.1 days.

Growth of Ectoparasite Populations on Young

At hatching, no ectoparasites were found on any first-brood young. By the second day of nestling life, however, the 10 young that were sampled (five in 1959; five in 1960) had an average of 11 ectoparasites (the minimum number was 3; the maximum, 16). The parasites belonged to three groups: the bird lice (Mallophaga), the mites (Acarina) and one species of Diptera larvae (only two on one individual). No attempt was made to collect permanently any parasites until the birds were 14 days old, but as accurate a count as possible was made on five randomly chosen first- and second-brood young on each day of nestling life during the 1959 and 1960 nesting seasons. Inasmuch as the number of Mallophaga remained fairly constant (the greatest number on one individual was 5) after five days of age, only the counts of mites are presented in this study. Graph I shows the relationship between the mean number of mites from the individuals in the sample and their ages in both first- and second-broods. The greatest number of ectoparasites on any one young was 242 mites and 4 lice on a 14 day old nestling from a second-brood. As Graph I shows, there was a tremendous increase in the mite populations on the second-brood young in this study.

Cowbird Parasitism

Three nests (9.4 per cent) contained six cowbird eggs which the author removed as soon as they were discovered. All parasitized nests were under bridges.

Development of Temperature Regulation in Young

Internal body temperatures.--The thermoregulatory ability of the 15 first-brood and 10 second-brood young used in the temperature regulation experiments showed considerable correlation with body growth and development of feathers (see Tables 3 and 4). At 10 degrees centigrade the one day old nestling was capable of maintaining a body temperature only a few degrees above that of the experimental environment. At this environmental temperature the average one day old young exhibited no breathing movements or pulse for approximately eight minutes after the conclusion of the experiments. Gradually the thermoregulatory ability improved, and at 10 days of age the young were able to maintain an internal temperature closely approximating that of the adult bird. (The mean body temperature of five adult phoebes subjected to identical environmental conditions was 35.4°C. in 10°C. environments and 37.8°C. in 40°C. environments.) Nestlings between 11 and 14 days of age improved only slightly their ability to maintain high body temperatures in the cool (10°C.) environment. At a 40°C. environmental temperature, the one to ten day old first-brood nestlings maintained body temperatures only a few degrees less than the experimental temperatures. After 10 days they maintained a constant body temperature approximating that exhibited by the adults regardless of the ambient temperature in which they were placed.

In these experiments the pattern of development of the thermoregulatory ability of the second-brood young was, at first, similar to that of the first-brood young at both high and low experimental temperatures. The older, second-brood young, however, differed considerably from the first-brood young in their ability to maintain constant internal temperatures. This was most noticeable at the lower (10°C.) environmental temperature. The 14 day old, second-brood young maintained a body temperature comparable to the average for the nine day old, first-brood nestlings. This is somewhat surprising in view of the similarity in size and development of these 14 day old young (Tables 1 and 2). At higher temperatures, too, the second-brood 10 to 14 day old young, on the average, developed much higher temperatures than any of the first-brood young.

Breathing movements.--Investigations of the breathing movements showed, in general, that both first- and second-brood young developed more uniform breathing movements in both high and low temperature environments as they grew older (see Tables 3 and 4). As Graph II shows, the mean difference in number of breaths/minute between the low (10°C.) and high (40°C.) environmental exposures for first- and second-brood young averaged over 100 breaths/minute until seven days of age. Between 7 and 10 days of age, however, this difference rapidly diminished by one-half, and after 10 days of age by approximately three-fourths. As Graph II also shows there is a considerable difference between the breathing movements of first- and second-brood nestlings in the controlled temperature environments after three days of age. This difference was greatest between 10 and 14 days of age when the mean difference in breathing movements between high and low temperature exposures for first-brood young is approximately one-half that of second-brood young.

Responses of young after two-hour exposures to controlled temperature environments.--After being subjected to two hours of a continuous 10°C. environment, the one to four day old young were mostly immobile. They did not attempt to right themselves when placed on their backs, their mandibles were closed and they exhibited only slight breathing movements. Their skin had a wrinkled, ashy appearance (from the constriction of the blood capillaries in the skin). Within a short period (up to 13 minutes in one day old young; up to two minutes in four day old young) breathing became normal, the skin again appeared pink and all other movements returned to normal. On the average the older (8 to 14 day old) second-brood young in the cool and warm temperature controlled environments and the younger (one to six day old) second-brood young in the warmer environment appeared to move much more than did the first-brood young under similar conditions.

Responses of young after one-half hour exposures to controlled temperature environments.--The 12 first- and 17 second-brood, randomly selected, one to six day old young exposed to shorter, one-half hour controlled temperature environments during 1960 and 1961 showed no significant difference (at the 5 per cent level) in their gaping responses at each day of age under similar temperature exposures. As is evident in Table 5, however, there was a significant difference in the mean number of gapes between each group exposed to 10°C., 25°C., and 40°C. during the 30 trials of trying to illicit the gaping response. As was expected, the young subjected to the one-half hour exposures were much more active than those subjected to longer exposure.

Even during a one-half hour exposure to 10°C. and 40°C. temperature environments, the young in both brood groups showed a significant inability to gape every time when mechanically stimulated when compared to the young exposed to the 25°C. temperature environment.

Study of Nestlings' Environment

During six 12 day periods, complete environmental information for three nesting areas containing five two-young nests and one four-young nest was obtained during 1961 and 1962. For convenience of treatment, the results in this part of the investigation are separated into (1) the general nesting activities of the adults, including the size and nature of the foraging areas (i.e., weather conditions, numbers and kinds of arthropods present, etc.) and the adult's relationships with the young (including feeding and brooding behavior); and (2) the growth and activities of the young.

Size and general nature of foraging areas.--The average size of the three areas where feeding activities of the adults were intensively studied in 1961-1962 was 4727 square meters (3807, 5132, and 5234 square meters). The most striking feature of each foraging area each year was its similarity in size during the four nesting seasons when maps of these same nesting areas were constructed. The total area changes made at any one foraging location during the four year period (determined by calculating the difference between the largest and smallest areas and again setting up a weight-area proportion similar to the technique used for determining total foraging areas) was 18 per cent. The average of all changes at all three locations during the four year period was only 7 per cent.

In general, the foraging areas at all three nesting locations were very similar in vegetative make-up and land use. Two areas bordered streams and all were in openings in mature woods. All these nests were built under overhanging roofs of private homes on ledges approximately seven feet above the ground. This same above-ground height of each nest was approximately maintained after each had been transferred to the nesting platform cage.

The most significant changes noticed in the individual foraging areas occurred during periods of very adverse weather conditions, especially during periods of heavy rainfall and/or strong winds (15 miles per hour or greater). This amounted to a very dramatic change in the portion of the area utilized by the adults at nesting site number 17 (Nests No. 61-17, 62-17, and 62-17B). On August 4 and 8, 1962, the adults at this site fed only along the very sheltered stream bank, 15 meters from their nest during both five hour periods of moderately heavy rain (approximately one inch during each five hour period). This was nearly an 80 per cent reduction in the total foraging area that they had utilized during the previous week. High winds (gusts up to 40 miles per hour for periods of 10 minutes or more) on May 27, 1961, in the foraging area at Nest No. 61-16 resulted in both adults utilizing only the immediate area below the nest, feeding mostly on or near the ground along the leeward side of the house where the nest was placed. This ground-feeding behavior was also recorded at Nests No. 62-17 on May 24, 1962, during several one-half hour periods of high (30-40 mph) winds, and at Nest No. 62-17B on August 4, 1962, during high (20-30 mph) windy periods of 15 minutes or more between moderately heavy periods of rain.

Weather conditions in foraging areas.--Although the overall weather conditions in Isabella County during the phoebe's nesting periods in 1961 and 1962 were very similar and deviated little from the previous ten year averages for the area (U. S. Dept. of Commerce, 1961, 1962), the weather conditions appeared to be the most fluctuating ecological factors in this study.

Table 12 summarizes the mean air temperatures, relative humidity, wind speeds, light conditions, and precipitation during the feeding periods of the adults in all foraging areas studied between May 24-June 4, June 20-July 1, July 8-July 19, 1961, and between May 18-May 29, July 3-July 14, and July 28-August 8, 1962. This table was constructed from daily data summaries shown for each nest in Tables 6 through 11.

Although air temperature, relative humidity, and inches of rainfall were continuously recorded, the criterion used for determining the period during which the weather conditions would be tabulated was the total feeding period of the nightly brooding adult. Thus, the weather conditions presented in this table represent only those conditions which existed from the time of the first feeding trip in the morning until the last feeding trip at night. These daily time periods are shown in Tables 6 through 11 under the column labeled "Total Feeding Day (Hrs.)" and the mean values for the 12 day period at each nest are summarized under the same heading in Table 12.

The daily average weather conditions for all foraging areas during periods of adult feeding for the two year study period (72 days) were: air temperature, 21.5°C (mean range 14.8°C. -- 28.5°C.); relative humidity, 69% (mean range 34.2% -- 94.0%); wind speed, 3.2 miles per hour (mean range = 1 mph -- 20 mph).

During the same time period, there was a total of 3.93 inches of rainfall (28 hours) in 1961 and 2.84 inches (33 during the feeding periods of the adults in all foraging areas studied between May 24-June 4, June 20-July 1, July 8-July 19, 1961, and between May 18-May 29, July 3-July 14, and July 28-August 8, 1962. This table was constructed from daily data summaries shown for each nest in Tables 6 through 11.

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During the same time period, there was a total of 3.93 inches of rainfall (28 hours) in 1961 and 2.84 inches (33 hours) in 1962. The period of rain hours (mean daily values of 2.37 hours in 1961 and 2.73 hours in 1962) was recorded in each foraging area and is tabulated daily in Tables 6 through 11 and summarized in Table 12.

Light conditions were quite variable during the total periods of adult foraging. So as to have light values that could be compared to other weather factors, a light intensity coding system (described on p.19) for per cent of sky cover was employed. The numbers of hours of sunny, cloudy, and over overcast light conditions were then reduced to a fractional value of sunny hours (S) overcase hours (O) for each daily foraging time period. These fractional values are given in Tables 6 through 11. (Hours of "cloudy" sky cover can be determined easily by subtracting the total hours of "sunny" and "overcast" hours from the number of hours, rounded off to the nearest whole number, in the column headed "Total Feeding Day.") The total 12 day period is summarized at the bottom of each of these columns, and a light intensity average (the quotent of S/O) is shown as the mean light intensity quotient for that nesting period. Naturally, the value of S/O increases as the number of "sunny" hours increases. The mean light quotients for all nests are summarized in Table 12. As this table shows, the average light quotient for the six nest study period was 0.85, indicating nearly equal periods of overcast and sunny sky conditions for the entire study period.

Kinds and densities of arthropods in foraging areas.--Representatives of 16 arthropod orders were collected on the wind-vane sampling boards during the entire study period. As Table 13 indicates, 14 insect orders and two arachnoid orders (spiders and mites) were collected in the samples. Table 13 shows the total number of individuals of each order collected and the number of days in the 12 day period when the order was recorded at each nesting location. The nests in this table are arranged in order by earliest month and day (rather than by year). The most striking feature of this table is the seasonal change in numbers of individuals collected. Seasonally, the numbers of Coleoptera and Ephemeroptera seemed to be quite plentiful during the early nesting periods and then gradually diminished as the season progressed. By contrast, the numbers of Hymenoptera, Homoptera, Hemiptera, and Araneae seemed to increase gradually as the season progressed. Diptera numbers increased until the middle of the whole nesting season and then appeared to decrease gradually. Several orders (Acarina, Lepidoptera, and Neuroptera) seemed to fluctuate very little in the samples as the season progressed. However, Plecoptera were captured only during late May and early June, and Odonata were sampled only during early July. The other orders were represented by only a few individuals on such a small number of days that any pattern in their changing abundance was not revealed. An interesting massive occurrence of thrips

(Thysanoptera), however, was recorded at Nest No. 62-17B on July 29, 1962. Approximately 15 minutes before removing the sampling boards for the evening, hundreds of thrips were captured. They were definitely not on the boards in any numbers prior to this time because the tree tanglefood had been changed the previous evening and the speckled appearance caused by the thrip's presence was not evident until a short time before the boards were removed. That evening, a careful examination revealed that 1197 individuals, weighing 0.0352 grams, had been sampled in that short period (compared to 73 other arthropods on the same boards weighing 0.1523 grams for the total feeding day period). Because these were collected at the approximate time that foraging by the adults had ceased for the day, they were not included in that day's calculations.

As Table 13 shows, slightly more than 98 per cent of all arthropods sampled on the collecting boards during the entire nesting study belonged to seven orders. Three orders alone comprised 89 per cent of the total sample in all foraging areas studied (Diptera, 60.2 per cent; Coleoptera, 18.8 per cent; Hymenoptera, 10 per cent). Surprisingly, spiders appeared commonly on the sampling boards during the latter part of June through early August. All specimens were quite small.

The total daily weight and number of arthropods are also shown in Tables 6 through 11, and the means of all six, 12-day nesting periods studied are summarized in Table 12. The data in Table 12 indicate that there were significant seasonal changes in the total numbers and weights of arthropods sampled in the foraging areas during the total period when nestlings were being fed. These data and the data in Table 13 suggest that even though there were noticeable changes in the kinds of arthropods present in these foraging areas, there appeared to be much replacement by other groups.

On a daily basis, there seemed to be dramatic changes in the numbers and total weight of arthropods sampled under different weather conditions in the foraging areas. Furthermore, general observations seemed to suggest that certain groups were not as abundant (or were more abundant) in certain foraging areas during very dramatic weather changes. To help determine whether weather conditions had affected the samples of numbers and weights of the arthropods in the foraging areas, the arthropod data (in this case <u>number</u> of arthropods) and corresponding weather data (rain hours, wind speed, air temperature, relative humidity and light intensity) were graphically plotted to see if there appeared to be any relationship between these data. Graph III shows the mean number of arthropods plotted against the various mean weather conditions already mentioned. Correlation coefficients (r) of these sets of data were then calculated. These r values showed <u>very</u> high positive correlations in the case of mean daily air temperature (r = +0.82) and mean light intensity (r = +0.91), and an <u>extremely</u> high negative correlation in regards to mean daily wind speeds (r = -0.98). When plotted against mean daily rain hours, however, the number of arthropods showed only a suggestive (but perhaps significant) negative correlation (r=-0.55).

Collectively, the above statistics suggest that in this study the number of arthropods (and also the weight of arthropods--inasmuch as the two are so strongly correlated) and the weather conditions were very strongly related within the adult phoebe's foraging areas.

<u>Feeding behavior</u>.--Although it was never possible to distinguish between the sexes of the adults at any of the six nests in this study, this writer was able to color mark and band an adult male at one nest during 1960 when the equipment for the 1961-62 study was being perfected. This occurred when the young in the nest were 13 days old. At 8:15 a.m. the male mounted the female in a nearby tree and flew immediately towards the nest where he was captured in a mist net.

Even though the adults were not sexed at the six nests in this part of the study, over 350 hours of observations at all nests showed that both adults always fed the young. During a total of 48 hours, moreover, it was possible to determine the extent of feeding by individual, color-marked (but not sexed) adults at two nests. The data collected during this period (when the young were one to seven days of age) did not reveal any significant difference in the number of feeding trips made by either adult, except during the first hour of daily feeding. During this latter period, the non-brooding adults at both nests fed 78 per cent times more than the brooding adults; the brooders, on the other hand, seemed to do most of the feeding just prior to nightly brooding.

There appeared to be a regular ritual associated with commencing the feeding day by the adults. Usually this began when the adult non-brooder began calling some distance from the nest. When this occurred, the brooding bird raised in the nest. If calling continued, the broder would occasionally leave the nest. Analysis of the data in this area, however, revealed no definite pattern. Instead, it seemed to be a somewhat individual variation among the different nesting pairs. During the May and early June nesting periods (at Nests 61-16 and 62-17) the non-brooding bird often brought food to the nest during the first eight days when young were in the nest, fed its mate, which in turn passed the food to the young and then left the nest. The non-brooder usually waited for the feces and after obtaining them would fly from the nest, returning almost immediately with food.

At all nesting locations there seemed to be a decided preference for using particular feeding perches during periods of fair weather (no rain, low wind). This was exhibited by both adults and, at the two nests where the adults were individually recognizable, each adult appeared to have individual preferences. At Nest No. 62-22A a favored perching site from which feeding trips were made was a discarded child's slide. This slide was approximately 40′ from the nest from the time the young phoebes hatched until they were five days of age. The adult non-brooding phoebe used the top two bars of this slide as an "approach" perch before flying to the nest every morning. Its mate flew to this same site every morning upon leaving the nest. The non-brooding bird, after calling a few times, always flew from this perch to the ground at the base of an elm tree just in front of the nest, then up to the retaining wall of the dirt around the tree, and then to the next. When this writer left his observation tent at 8:15 p.m., on the night when the young were five days of age, he moved the child's slide 25' further away from the nest, to a point 15' from where the non-brooding adult usually first appeared in the morning on the edge of the woods. When the non-brooding adult appeared at its usual spot on the edge of the woods the following morning, it gave a few calls and then flew to the spot where the slide had been. Here it hovered for a second or two, apparently spotted the slide, and flew to it. It remained there for only an instant (previously it stayed long enough to call two or three times and occasionally to catch an insect) and then flew directly to the nest, where it hovered a few seconds before the brooding adult left. It landed on the recorder perch but definitely did not feed the young. Rather, it left almost immediately to join its mate at the slide where it had perched. The following two mornings the slide was used as an approach and exit perch, but on the third morning, a small tree closer to the nest was used. Although the writer returned the slide that evening to its former position, it was never used as an early morning approach perch again, although it was occasionally used during the day as a feeding perch.

Although the average feeding time varied somewhat seasonally (due to slightly differing daily sunrise and sunset times) the average length of feeding days at all nests, from late May to early August, varied little. The average feeding day at all nests was 14.4 hours with a range of 12.8--15.3 hours. The range of the means, however, for all feeding days at all nests varied by only 0.7 hours, and there appeared to be no significant relationship between the mean hours of feeding days and the weather conditions. The only exception to this was when heavy early morning or early evening rain or very cold early morning or early evening temperatures lengthened the nightly brooding period or shortened the late evening feeding period. There were only two days (on May 28 and 30 at Nest No. 61-16) when the above situations occurred and the loss in feeding time from the previous day in each case averaged nearly one hour.

The most numerous trips (+ 51 per cent) to the nests, presumably each time with food, were made at all nests during the early morning (5:05 a.m. to 7:15 a.m.) and early evening (6:25 p.m. to 7:25 p.m.). Again, however, this time was delayed somewhat by adverse weather. At Nest No. 61-16, during cold, rainy morning weather, the greatest number of early morning feeding trips occurred between 7:30 a.m. and 9:55 a.m. on May 28 and between 7:10 a.m. and 9:30 a.m. on May 30.

Approximately 12 times each day (during a daily minimum of five hours that was spent at each nest), this writer witnessed and recorded food caught by the adults. Careful observations of 783 such catches showed that all feeding was done in a hovering position or made as a swooping catch as an insect jumped (particularly in the case of grasshoppers watched being captured). Of the 783 catches witnessed, 406 (52 per cent) were made in open air, 252 (32 per cent) were made in foliage (partly in open air, partly off leaves), and 125 (16 per cent) were made directly above the ground. The estimated maximum height of all catches was 12-1/2 feet. In all observations the observer never witnessed more than one catch per feeding trip to the nest (but this was determined for only 86 trips or 11 per cent of all observations).

Although Henderson (1924) found that the size of the insects taken increased as the young increased in age; this was not true of this writer's observations. It seemed rather that the adults captured and fed whatever was available.

The total trips made to the nest by the adults is shown for each day at each nest in Tables 6 through 11 and the mean daily trips are summarized in Table 12. The relationships between mean weather conditions and the mean number of nest trips (taken from Table 12) are plotted against one another in Graph IV (D., E., F., G.). Correlations coefficients of these values showed relatively strong correlations between number of trips and air temperatures ($r = -0.65$). Extremely high correlations were calculated for number of trips and daily wind speed ($r = -0.98$), and number of trips and light intensity ($r = +0.83$). These statistics indicate that those weather factors analyzed and the number of trips made to the nests by the adults in this study are very strongly related. The same appears to be true for the mean number of trips to the nest by the adults and number of arthropods present in the foraging areas ($r = +0.95$ for mean numbers of arthropods present and $r = +0.94$ for mean weight of arthropods present). In addition, there appears to be a strong negative relationship ($r = -0.73$) between the mean daily number of trips during the first six days at all nests and the mean daily number of brooding periods by the adults for the same days.

The four-young nest (Table 11) showed that although the weather conditions were approximately the same as the mean weather values at the two-young nests for the 12 day study period (Table 12), the mean daily number of trips to the nest were nearly 70 per cent greater.

Brooding behavior.--Brooding periods were impossible to determine from the thermistor probe records after six days of age due to the increased body temperatures of the young. Nest temperatures, however, were continuously recorded during the entire nesting period.

Temperatures obtained continuously at the bottom of the nests generally followed the temperature of the brooding adult. During daily non-brooding periods of 8 to 10 minutes, however, nest temperatures in the two-young nests in this study often dropped as much as 6°C. (in nests containing 7 day old young) to 18°C. (in nests containing 2 day old young). The nest temperatures at night were fairly uniform during the first ten days of the nestlings' life. Except on very cold nights brooding usually ceased after this period. Of 24 nightly observations (between 11:00 p.m. and 3:00 a.m. at three nests) there was only one instance when it at least appeared that older young (16 days old) were being brooded. This was at Nest No. 62-17 on June 2 (3:30 a.m.) when the air temperature was 7°C.

Usually, one adult was seen on the young or on the rim of the nest (even with young 14 days of age) during the nighttime. In the case of the two nests, where at least one adult was color marked, it was always the same adult that brooded the young at night, but during the day, on six different occasions, the writer observed the other adults brooding for short periods.

In the case of young between the ages of three days to fledging there were often uniform interruptions in the brooding behavior. Twenty-four nightly temperature records of nests with young between three and nine days of age showed uniform temperature changes of five to eight degrees centrigrade approximately every 20-35 minutes. Several observations with a flashlight indicated that the adult bird was standing up in the nest. Perhaps this behavior was in response to movements by the young, or perhaps it was merely due to increasing irritability to the adult's brood patch. This response did not take place when the nestlings were younger (nor very noticeably during the day).

In heavily parasitized second-brood nests there were almost continuous temperature changes during both daily and nightly periods. Analysis of eight days and nights at both first-brood and second-brood nests containing young between three and six days of age showed that the second-brood nests had an average 4°C. higher temperature than nests containing first-brood young

When the mean number of brooding periods for all two-young nests were plotted against the mean feeding trips for the first six days, a negative correlation ($r = -0.73$) was obtained. In the single four-young nest (Table 11) there was a daily average of 2.4 less daily brooding periods and one less hour spent during the first six days in brooding the young. In general, the nest temperatures at the bottom of this nest were always several degrees above the average nest-bottom temperatures in the five two-young nests.

Nest desertion.--During the total five year period when the Eastern Phoebe was being studied (1958-1962) there were three cases of nest desertion. Two of these occurred in 1960 while the equipment and techniques were being perfected for use during the intensive environmental studies. Both cases involved moving the nest to a nesting platform cage before the eggs had hatched (in the first case, three days before the estimated hatching date; in the second case, one day before the estimated date). Switching ten other nests to this platform when the young were only a few hours old, however, did not cause desertion .

The third case of nest desertion occurred in 1962 when the artificial nesting (Plate 8) was being used in a second attempt to collect food fed to the young. Although an attempt in 1961 illicited no response from the adults (and was used for only one hour at a nest containing two eight day old young), the 1962 experiment with this nestling involved a full feeding day in a nest containing two three-day old nestlings. Much directing behavior by the adults was made with this nestling (placing their mandibles into the opened mandibles of the nestling but not feeding it), but many attempts to brood the two live nestlings seemed to be prevented by the presence of the artifical nestling's slightly raised (and closed) mandibles. After three hours of not being brooded, in an air temperature of 18°C., the live nestlings finally slowed their gaping response to only about once every fourth trip made to the nest by the adults. After four hours (at 7:00 p.m.) they appeared to be making only occasional attempts to gape. The adults at this point apparently deserted, even though the live young were returned to their original nest. These observations possibly indicate that desertion was due to a lack of response on the part of the young. The young were inactive, cold, but alive, the following morning and they were removed to another nest where three, five day old phoebes were being raised. All five young fledged together 12 days later.

Development and Activities of the Nestlings

Growth.--Except for being slightly heavier at one day of age, the weight-growth pattern of the nestlings in the two-young nests followed essentially the same growth pattern exhibited by the young in the earlier (1958-1959) growth studies of 25 first-brood and 13 second-brood young (see Tables 1, 2, and 6 through 11). On the average, however, the young in the two-young broods were heavier during the last few days of the measurement period (11 and 12 days of age). The most notable difference was in the case of heavier second-brood young (Nests No. 61-16A, 62-17B, 62-22A) as compared to the second-brood young in the general growth studies of 1958-1959 (Table 2). The latter young were an average of one to two grams lighter for each day of age than the young in the two-brood nests in this part of the investigation. Possibly this was due to the presence of greater mite populations and to a greater number of young per nest. The first-brood in the four-young nest (No. 61-17) also weighed more daily than the second-brood young in the 1958-1959 general growth studies.

The daily weight gains of the nestlings in the two-young nests are shown in Tables 6 through 10 and summarized in Table 12. The mean weight gains for these young are also plotted against environmental factors on Graph V. There appears to be little correlation between the daily weight gains of these young and their fledging age (Graph V,A). Also, there appears to be only slight correlation between number of rain hours ($r = +0.5$), wind speed ($r = +0.45$), or air temperature ($r = -0.45$). When plotted against mean number of adult trips to the nest (presumably with food) there appears to be only a slight (although negative) correlation ($r = -0.46$). This correlation seems to coincide with the correlation coefficient for daily weight gain and the daily mean numbers of arthropods available in the foraging areas of the adults ($r = -0.57$).

The above statistical analysis seems to suggest that the daily weight gain of the young is almost independent of environmental factors (length of time in the nest, amount of food available to the adults, number of trips to the nest by the adults, or the weather conditions, which have already been shown to be strongly correlated with these other factors.)

Development of behavior in the nest.--At hatching the young phoebes were relatively helpless. The muscles in the neck appeared to be the most highly coordinated, and the young were capable of raising and moving the head in several uncoordinated directions. The gaping relfex was evident within one hour after hatching. Touching the edge of the nest, the bill, or the side of the head produced this response. The response consisted of a rapid upward extension of the neck and head, opening of the mandibles and lowering of the head. Simultaneous to the gaping response was an extension posteriorly of the legs and a slight opening and closing of the toes. Although there was some movement of the wings at this time there appeared to be no movement that would extend them. Seven one-hour old nestlings (when the down had just completely dried) were placed on their backs but they immediately turned on their sides (the normal position at this time), apparently using only their neck muscles to attain this position. The eyes were closed at hatching.

Although, as already mentioned, there were some leg movements shortly after hatching, the young could not effectively raise their bodies with their legs until approximately two and one-half days of age. The grasping reflex in the toes was not very effective until three days of age, at which time the young firmly clutched the lining materials of the nest.

The eyes of the young phoebes opened at five and one-half to six and one-half days of age. At this time there was a noticeable increase in body movements; the wings were very often extended and folded as the head raised with a gaping reflex. The gape at first was accompanied by a vertical extension of the neck. With each gape at this time, however, the eyelids opened, and, by the day following the opening of the eyes, the gape began to be directed towards the parent bird (or to a human hand).

Since all young were color-marked on the first day it was possible to keep track of their relative positions in the nest. In two nests in 1961 the young were always returned to the approximate position in which they were originally found. In every case there were no changes in these positions throughout the first seven days of nestling life. Apparently the clutching reflex during the first seven days establishes not only an anchor to the nest lining but also determines the position of each nestling in the nest. The nestlings, from the beginning of time that they clutched the nest lining, huddled together. The cup-shaped nest, determined originally by the ventral contour of the adult, partly assured this huddling effect.

From the first day after hatching until the nestlings fledged, the gaping response was more often accompanied by a short call or "begging" notes. Until the eyes opened these notes could be elicited by any gape releasing stimulus. After the eyes opened this calling became increasingly louder and longer in duration, and, near the end of the nestling period, usually preceded the landing of the adult on the nest rim. Numerous observations indicated that, at least after the young were seven to nine days of age, one young calling caused the other young to gape and to call.

Until the young were approximately eight days old they always gaped when the edge of the nest was jarred except immediately after being fed by the adults. By the ninth day this response decreased considerably. All other movements in the nest seemed to increase considerably at this time, however. On warm days the young often huddled on the windward side of the nest with their heads resting on the nest's rim and their mandibles partly open. In this position they were seen panting in the nest when the ambient temperature was above 30°C. Between nine and ten days of age a crouching reflex (lowering the head and withdrawing it, compressing the wings against the side of the body, tightening the toes) was observed. Foreign objects (a stick or a human hand) presented to the young caused them to extend the wings and snap the mandibles, producing a noise similar to that made by the adults when frightened off the nest. During this same period the young began very active wing movements. This was usually accompanied by raising and lowering the body in the nest. By the tenth to twelfth day of age the nestlings would occasionally raise their toes from the nest lining and grasp either the side of the nest or the feathers of one of their siblings. Then the entangled sibling would also being rapid movements until it was disentangled. This shifting in the nest continued until the young fledged.

In general, the main behavioral difference between first- and second-brood young was the greater movement of the second-broods during the last half (seven days of age or older) of their nestling period. This movement appeared to be mainly directed at rubbing against the sides of the nest and, at approximately nine days of age until fledging, at pecking at mites in the nest and on their siblings.

Fledging.--Although no environmental or growth measurements were made after the end of the twelfth day, several daily observations were continued so as to determine the fledging time of the young. The average age at fledging time of the first-brood two young nestlings was 16.2 days; for the second-brood nestlings it was 17 days. This indicates a somewhat longer (1.4 days) nestling period for the first-brood young than that determined for the 60 first-brood young from normal nests in the 1958-1961 study period. It was almost the same for the second-brood young, however, when compared to the fledging time of 23 second-brood young from normal nests in the 1958-1961 study period.

DISCUSSION AND CONCLUSIONS

Probably the first worker to study in detail the growth and development of temperature regulation in nestling Eastern Phoebes was Stoner (1939). His three year study involved field investigations of growth and body temperatures of 20 young and the body temperatures of two adults. His growth measurements for 12 young included body weight, ulna, humerus, tarsus, hind toe and claw lengths, lengths of feathered areas(outer and inner primary and covert feathers, outer and inner tail feathers), widths of bill at the nostril and at the gape, and width of head behind eyes. In general, he found three distinct periods of growth: " . . . an initial, postnatal interval of comparatively slow growth approximately three days in length; a space of vigorous growth covering nine to ten days; and a stage of retarded and more or less fluctuating growth occupying the remaining four to five days spent in the nest." His measurements and conclusions suggested that feather development followed the most profound increases in body size.

Merry (1941) presented weight, total body length, average length of primaries, primary coverts, and tail feathers, wing length, and very general statements on down feathers at hatching for variable numbers of young between hatching and fledging. Her data, however, were not given in detail, and it is difficult to obtain exact measurements from her graphs showing averages for these measurements. In general, however, they seem to agree with the measurements that Stoner found for this species.

Wetherbee (1957) presented measurements on the down feathers at hatching for six young phoebes.

This investigation followed as closely as possible the techniques used by Stoner for determining daily growth patterns. The measurements which were obtained, however, were those which this writer felt had most to do with development of temperature regulation in the young. Inasmuch as the writer was more interested in those feathers which serve to insulate the young while they are in the nest, he chose to measure the innermost secondaries, primaries, and their covert feathers, rather than the outermost primary feathers which Stoner measured. Total body length measurements were also obtained in this investigation (not in Stoner's, however), so as to gain some appreciation for the rate of increase in mass over surface area which is directly related to increased temperature control ability. In this study these measurements showed an increasing mass to body surface area ratio. This undoubtedly was reflected as greater heat production and lesser heat dissapation per body size in the young. Although bony structures, such as those studied by Stoner, do provide good indications of growth, they were not measured in this investigation.

The growth measurements of nestling phoebes at each day of age obtained in this study showed great variance from those recorded by Stoner. As an example, his average weight measurement for six "one" day old young was 1.9 grams whereas those in this investigation were 3.1 grams for 25 first-brood young and 2.8 grams for 13 second-brood young. His average for this particular age, however, was based on ". . . six individuals varying in age from three to twenty-four hours." The mean measurements in this writer's study were based on individuals no less than 12 nor more than 36 hours in age. Stoner's measurements were all made between "10 a.m. to 12m." The measurements in this report were made between 6:30 p.m. and 7:30 p.m. so as not to interfere with a full day of feeding. The measurements which Merry (1941) collected were so inconsistent in regards to time when recorded that this investigator made no attempt to compare her growth data with the growth data of this report.

In this study, the young phoebes weighed approximately two grams at hatching. By two weeks of age this weight had increased to approximately 20 grams. Weight, in general, increased greatly during the first nine days and gradually leveled off until the day of fledging. There was a significant difference in daily weight gain between first- and second-brood young after the third day, but this difference diminished near the end of the nestling period, so that both brood groups weighed approximately the same at two weeks of age.

The total body length of young Eastern Phoebes in this study increased gradually during the entire nestling period. However, the second-brood young did not show as great a daily body length gain as did the first-brood young. At hatching, the young phoebes were approximately 38 millimeters in length. They increased in length to 125 millimeters at two weeks of age.

Juvenal feather growth progressed at very rapid rates after approximately five days of age in the young in this study. At hatching the young were covered with natal down along most feather tracts. On the alar tracts it was most dense on the secondaries. On the body the down was most dense in areas that are exposed to the surrounding air medium when the young are in the nest. The measurements of these down feathers agree closely with the data presented by Wetherbee (1957). The juvenal feathers that eventually cover exposed areas appeared to grow more rapidly than other body feathers (except for tail feathers), so that by nine days of age the birds were effectively covered with juvenal feathers. A difference in feather growth was evident in first- and second-brood young, following the same general pattern seen in the weight and length differences between these two brood groups.

Stoner (1939) showed that the nestling phoebe developed good temperature control by ten days of age. His method of determining this was by obtaining daily deep body temperatures in the proventriculus of the young, and comparing their body temperatures each day of age with body temperatures of adults obtained in a similar fashion. He concluded that the nestling Eastern Phoebe attains good body temperature control between nine and ten days of age. This writer's results, obtained during carefully controlled experiments in which the young were subjected to temperature control chambers for two hour periods, indicate the same thing. The average body temperatures of adults measured in Stoner's study (109.3°F.) were slightly higher than the temperatures that this report recorded for adults (35.4°C. in 10°C. environments, 37.8°C. in 40°C. environments). This difference is possibly due to the fact that these were cloacal rather than proventricular temperatures. As with other measurements in this study, body temperature control measurements of first- and second-brood young showed that first-brood young developed more effective body temperature control in both high (40°C.) and low (10°C.) temperature environments at an earlier age than second-brood young. As further evidence of this, first-brood young were better able to control breathing movements (which is directly related to temperature regulation), at least at older ages, than were second-brood young. Inasmuch as Stoner did not separate his young into first- or second-brood groups his data could not be compared with this study in regards to any brood group differences.

Several workers (Townsend, 1926; Shelley, 1936; and Abbott, 1922, 1942) have commented on the presence and detrimental effects of ectoparasites on the second-broods of the Eastern Phoebe. This writer's data indicate that this environmental factor has a great effect on the growth and development of temperature control in these second-broods. The data further suggest,however, that the effect is not great enough to affect eventual fledging of normal sized second-broods of young, although it may delay by a day or two their fledging time, rather than hasten fledging by one day as Sherman (as quoted by Bent, 1942) found in her study of 10 nests.

Although Merry (1941) made general comments on the behavior of the young, no behavior study of nestling Eastern Phoebes has been made. The general observations made in this study indicate a pattern of behavioral development similar to other passerine birds. In general, there appeared to be three distinct behavioral periods in the young in this study: (1) hatching to eyes open, (2) eyes open to rapid wing movements, (3) rapid wing movements to fledging. In most respects these three periods coincide with the three distinct growth periods that Stoner (1939) mentioned for this species.

In the environmental portion of this investigation adult attentive behavior data (feeding trips to the nest and number and duration of brooding periods) were collected.

The nature and size of the adult's foraging areas were also investigated to determine if there were any correlations between these various factors in the nestling's environment and the growth of the young.

Several other workers have attempted to show how several of these factors are related in other species. Lack (1956), in summarizing all of his work on the Common Swift, Apus apus, found strong correlations between weather conditions in the foraging areas and the general growth and development of the young. He found that ". . . the weight curve for the swift is interrupted by sharp drops, each of which corresponds to a spell of bad weather." In regards to feather development and fledging he states that ". . . the growth of feathers on the young swift is greatly retarded when food is short. As a result the length of time between the hatching of the swift and its departure from the nest varies from only five weeks when food is abundant to as much as eight weeks when it is scarce." Koskimies (1950), in his thorough review of the literature dealing with the effects of weather on the same species, pointed out that the overall weather (rather than light intensity alone) was responsible for the awakening time in the adult, but that light intensity was the most important factor for cessation of feeding. He also found that the length of time spent searching for food depended upon the weather and the stage of development of the young, and that " . . . the quantitative investigation of the small animals . . . in the habitat of the species studied gives a basis for comparative food-ecological research." He stressed that weather factors which affect aerial food items must be understood as a whole rather than as separate parts if their true effect on biological phenomena is to be correctly interpreted. His conclusions in regards to the work of others on the relationship between the feeding habits and food of the swift, the weight changes of the nestling swifts, and the effect of the weather on these factors can be summarized as follows: temperature directly affects the nature and quantity of insects available to the adults for feeding the young (after Glick, 1939); the morning temperature is distinctly correlated to the first morning flight from the nest (Weitnauer, 1947); low temperatures delay early morning nest departure; the quantity of aeroplanktonic insects in cold weather is smaller than in warm weather (thus, the feeding frequency is directly lowered; Weitnauer, *op. cit.*); the feeding frequency is zero at temperatures of 12°C. or lower; high winds greatly reduce the numbers of insects (Glick, 1939, and Palmen, 1944); the convection of the air controls the altitudinal distribution of insects (Wellington, 1945); rain is directly correlated with the numbers and kinds of insects present (Glick, *op. cit.*); cloudiness, in itself, may have no effect on insect numbers except indirectly, as an indication of the total weather conditions (Palmen, *op. cit.*); and swifts do not feed during poor weather conditions (low temperatures, heavy rain and high winds). Koskimies also found that in the swift, at least, poor weather conditions over long periods of time may cause starvation among the young which may in time adversely affect their temperature regulation abilities, and if continued for a long enough period, may cause death. Sutter (1941) as quoted by Koskimies (*op. cit.*) found that "bad weather" delays the development of temperature regulation and general growth in the Wryneck, *Jynx torquilla*.

In this study those ecological factors were investigated in the phoebes' foraging areas (aerial arthropods and weather conditions) suggested by Koskimies to have the greatest relationship to the growth of the species that he studied. The arthropods sampled in the fairly uniform-sized foraging areas in this study were quite similar to those sampled over a much longer period of time (and covering much larger areas to much greater heights) by Glick (*op. cit.*) in Louisiana. Glick found 44 per cent Diptera, 20 per cent Hemiptera, 17 per cent Coleoptera, 11 per cent Hymenoptera, 6 per cent Araneae, 1 per cent Lepidoptera, and 1 per cent other groups in his samples of 25,947 individuals. At approximately two meters above the ground, this writer found 60 per cent Diptera, 19 per cent Coleoptera, 10 per cent Hymenoptera, 5 per cent Homoptera, 2 per cent

Hemiptera, 2 per cent Ephemeroptera, and 1 per cent Araneae, and 1 per cent other groups during the nestling periods of the phoebe.

The work of Merry (1941) and others indicates that the adult phoebes have certain "preferred" food items (mainly Hymenoptera according to Beal, 1912). This author's observations, however, indicate that the adults were feeding on anything that was available.

The correlation between the weather conditions and insect numbers and their weights was equally significant when compared to the work of Glick (1939) and Palmen (1944) and the summary made by Koskimies (1950), even though this investigator's samples were obtained nearer the ground. High positive correlations were found between numbers of arthropods, air temperatures, and light intensities; and high negative correlations were found between numbers of insects, rain hours, and wind speeds.

In regards to adult attentive behavior and the weather, this investigation of the phoebe agrees very closely with the data that Kendeigh (1952) collected on the effect of air temperature on trips to the nest by one pair of phoebes. This author's studies reval an r value of + 0.66 between trips to the nest and air temperature. Observational data incidate that the length of the feeding day was shortened by adverse weather conditions in the early morning or evening. The data also reveal a high positive correlation between light intensity (+0.83) and nest trips. There were significant negative correlations between nest trips, rain hours and wind speeds for the first 12 days of nestling life, as well as between nest trips and brooding periods (-0.73) for the first six days of nestling life.

The work by Kendeigh (1952) on the attentive and non-attentive behavior of adult Eastern Phoebes during one complete nesting period (June 20-July 8, 1932, at a four-young nest) and one partial nesting period (June 12-16, 1932, at a nest containing one young, 7-12 days in age) showed that the rate of feeding the young ". . . was directly proportional to the number of young in the nest." Although the present investigation of one four-young nest showed a far greater number of trips, it was not directly porportional to the mean number of trips at the five two-young nests.

These data suggest that insect availability and attentive behavior of the adult phoebes were both strongly correlated with the weather factors measured during the five 12 day periods at the two-young nests. The data collected on mean daily weight gain of these young suggest, however, that this factor is not very strongly correlated to these environmental factors. These data suggest, rather, that the growth of the young is even negatively correlated with them (i.e., the correlation between insect numbers and rain hours was -0.55 but between weight gain of the young and rain hours, +0.51; between numbers of trips to the nest and insect numbers it was +0.95 but between numbers of trips to the nest and weight gain of young, -0.46; and between number of arthropods--presumably available for feeding--and weight gain of the young it was -0.57). Perhaps these statistics, however, in the light of observational data on the behavior of the adults and young, do show certain very subtle (although negative) relationship between the rate at which the young in this study grew and the ecological factors that were measured. There were several instances in this study when the adults utilized entirely different foraging areas during periods of very adverse weather conditions (see p. 32). Perhaps in so doing the adults come into contact with larger aerial arthropods on the average than they would find on days when all aerial arthropods were active. This perhaps would reflect fewer trips to the nest and possibly even higher weight gain in the young, especially if the cooler temperatures on such days were at the same time lowering the energy expenditure of the partially poikilothermic young. It is also quite possible that a day with high winds and/or heavy rain would reduce the "availability" of smaller insects. As a result each trip made by the adults would be "worth more" from the standpoint of obtaining larger food items for the young. On the other hand, if the gaping response of the young stimulates the adults to feed, the gaping response experiments performed at cooler temperatures (see p. 30) suggest that the young would not be gaping as often. Possible this would also decrease the number of trips to the nest.

The work with the artificial nesting that resulted in nest desertion by the adults, possibly by preventing brooding, and general observations at all nests, however, suggest that there is a regular sequence of behavioral responses between the young phoebe and the adults. That is, during the daytime feeding periods, as long as the young gape, they are fed. When they no longer gape, they are brooded. When they begin to move actively under the adults, brooding ceases and feeding begins again. This seemed to be the pattern at every nest where close observations of the young and adults at the nest could be made.

Whatever the mechanism involved (and it undoubtedly is a combination of many factors) there appears, at least, to be little statistical correlation between the rate at which the young grew and the weather factors as well as attentive behavior of the adults in this study. This disagrees to a certain extent with the conclusions of Kendeigh (1934) that ". . . the growth of the embryo and the nestling is practically independent of fluctuations or extremes in envrionmental factors . . ." and " . . . as long as the adult birds are able to carry on normal activities, the survival and development of the young progress independently of environmental conditions." This writer's study on the nestling life of the Eastern Phoebe suggests, however, that the "normal" activities of the adults are directly affected by the environment and that there are possibly some very subtle relationships involving the physiological state of the young (temperature regulatory ability) and behavioral relationships between the young and the adults that need further study. It may well be that the altricial nestling phoebe contributes as much to its own survival as does its parents by possessing the poikilothermic condition at a very critical period in its life.

In conclusion, this study indicates that the environment of the nestling Eastern Phoebe indirectly, at least, has a great effect on its growth and development, through the effect of the weather on the food supply and the effect of the weather on the behavior of the adults. It is also seen in the detrimental effect of numerous ectoparasites on second-brood young. The environment appears to have a direct effect on the physiological state and behavior of the young.

Apparently, however, under normal nesting conditions no environmental factor is so detrimental that the young are adversely effected permanently. Otherwise, the Eastern Phoebe simply would be eliminated from those places where it now nests.

SUMMARY

1. A five year investigation (1958-1962) of nestlings to the Eastern Phoebe, <u>Sayornis phoebe</u>, was made in Isabella County, Michigan, to determine if there was any relationship between growth and development of temperature regulation and the environmental factors in the nesting areas.

2. Daily nestling growth measurements were obtained of weight, total body length, feather length (dorsal, ventral, tail, primary, primary covert, secondary, secondary covert) of 25 first-brood young, one to 12 days old and 21 first-brood young, 12 to 14 days old, and 13, second-brood young, one to 12, and 10, second-brood young, 12 to 14 days old between 1958 and 1961. Additional measurements were also made of down length at hatching on both of the above brood groups.

3. The growth measurements showed a significant difference in first- and second-brood young during the first 11 days of nestling life but both groups were approximately the same size near the end of the nestling period.

4. The presence of large numbers of ectoparasites on the second-broods in 1958 prompted an investigation of the numbers of ectoparasites found on first- and second-brood young in 1959 and 1960. Five randomly sampled young for

each day of age, 1 to 14 days, in first- and second-broods for these two years showed a significant increase on the second-brood young.

5. In the 1958-1961 studies of normal-sized broods the fledging success of the first-brood nestlings was 63.4 per cent; of the second-brood nestlings, 62.1 per cent.

6. The average fledging time difference for the 1958-1961 first- and second-brood young was 2.1 days (14.8 days for first-brood young; 16.9 days for the second-brood young.)

7. The effects of cowbird parasitism were not investigated in this study but 9.4 per cent of all nests were parasitized.

8. The 15 (1-14 day old) first-brood and 10 (1-14 day old) second-brood young subjected to two hours of controlled temperature environments in the laboratory showed a significant difference in their ability to regulate their body temperatures in the 10°C. and 40°C. environments. Fourteen day old second-brood young did only as well as nine day old first-brood young in regulating their body temperatures at the 10°C. environmental temperature. In the 40°C. environments the second-brood young always registered higher body temperatures than the first-brood young.

9. Compared to the body temperatures recorded for five adult phoebes subjected to identical controlled

temperature environments in the laboratory (35.4°C. in 10°C. environments; 37.8°C. in 40°C. environments), the nestling phoebe exhibited the poikilothermic condition for the first ten days of its life. The breathing efficiency of these young showed an increasingly greater improvement during the first ten days of nestling life.

10. Gaping-response laboratory experiments conducted during 1960-1961 with 12 first- and 17 second-brood (one to six day old) randomly selected young, showed no significant difference (among brood groups) in their gaping-response ability after shorter, one-half hour, 10°C., 25°C., and 40°C. controlled temperature exposures. There was a significant difference in the number of gaping responses among each brood group at each of the three different temperatures, however, indicating that air temperature has a direct effect on the gaping responsiveness of the young.

11. During 1961-1962, environmental data were collected at three first-brood and three second-brood nests of this species during the first 12 days of nestling life. One of the first-brood nests contained four young. In the other two first-brood nests and the three second-brood nests the number of young was reduced to two, in order to have comparable data to analyze.

12. The size and nature of the adults' foraging areas at the six nests (three nesting locations) were determined during 1959-1960, in order to obtain a random sample of the

arthropod populations at all nesting locations in 1961-1962. The average size of these three foraging areas, which were all mature woods-openings, changed by only 7 per cent (the maximum change was 18 per cent) during the four year period when all areas were mapped. During 1961-1962 the average size of the foraging areas at all three nesting locations was 4,727 square meters. The greatest changes in the foraging areas occurred on days when very adverse weather conditions prevailed (high winds and/or heavy rain).

13. The weather conditions within the foraging areas studied fluctuated greatly during the total study period (between May 24-July 9, 1961 and May 18-Aug. 8, 1962). Daily air temperatures, rainfall (amount and duration), relative humidity, light intensity (cloud cover), and wind speeds were recorded.

14. The kinds and densities of arthropods were determined in all foraging areas during the 1961-1962 study period by using randomly placed, wind-vane type, "sticky-board" insect traps. Ninety-eight per cent of all arthropods sampled during the study period belonged to seven orders (Diptera 60.2 per cent, Coleoptera 18.8 per cent, Hymenoptera 10.0 per cent, Homoptera 4.5 per cent, Hemiptera 2.1 per cent, Ephemeroptera 1.8 per cent, and Araneae 0.9 per cent). There were well marked seasonal fluctuations in these orders during the study period.

15. The daily means of the number and weights of arthropods sampled showed very strong correlations to weather fluctuations during the total nesting study. High positive correlation coefficients were found between mean daily numbers of arthropods and mean daily air temperature ($r = + 0.82$) and between mean daily numbers of arthropods and mean light intensity ($r = +0.91$). An extremely high negative correlation was found between mean daily numbers of arthropods and mean daily wind speeds ($r = -0.98$) and an apparently significant negative correlation ($r = -0.55$) between mean daily numbers of arthropods and mean daily rain hours.

16. Data collected on the feeding activities of the adults indicated that both adults feed the young approximately the same number of times during the day. The data show, however, that the non-brooding adult feeds the young significantly more times in the early morning and that the brooding adult feeds the young a significantly greater number of times before brooding begins.

17. All adult feeding was done in flight. Of the 783 catches observed, 52 per cent were made in open air, 32 per cent were made in foliage, and 16 per cent were made directly above the ground. Although only 11 per cent of these observations resulted in the author being able to follow the adult to the nest, all appeared to result in a nest trip after only one catch. It appeared, also, that the adults

caught whatever aerial arthropods were available rather than showing any food preference for certain arthropod groups.

18. The average length of the feeding day at six nests was 14.4 hours. There was little variation in feeding day length during the total nesting study except on days when adverse weather conditions occurred early in the morning or evening.

19. Trips to the nest, presumably with food each time, were recorded with a modified "itograph" recorder. The correlations between mean daily trips to the nest and mean daily numbers and weights of arthropods present in the foraging areas were extremely high (r = + 0.95 for the former, r + +0.94 for the latter). There was a strong negative correlation (r = -0.73) between the mean daily number of trips to the nest and the mean number of brooding periods by the adults. The number of trips made to the four-brood young nest was 70 per cent greater than the average number of trips to the two-brood young nests.

20. Brooding behavior records indicated that the same adult broods each night, but that the nightly non-brooding adult may occasionally brood during the day. Brooding periods and duration seem to be strongly related to the weather factors (increasing during adverse conditions, decreasing during good conditions).

21. Nest desertion occurred at only three nests: twice by interference while eggs were in the nest, once

possibly because the adults were prevented from brooding the young during the day by the presence of an artificial nestling in the nest.

22. The general growth of the young in the six nests where the nesting environment was intensively studied appeared to be slightly more rapid during the first 12 days than in the general growth studies in 1958-1961. In these nests there appeared to be no great difference between first- and second-broods from the standpoint of daily growth or fledging time. This was possibly due to less irritation from mites because of smaller broods. The fact that the broods had been reduced to two young in itself might also account for heavier average daily weight gains.

23. Correlation coefficients of the daily mean weight gain of the young and the mean weather conditions indicated that there was little direct relationship between the weather conditions in the young's environment and the rate at which the young gained in weight each day. The slight negative character of these coefficients suggested several indirect environmental-young relationships, however. These were: (1) possibly the adverse conditions were making smaller arthropods less available, thus the larger ones, although fewer in number, would be "worth more" in weight-gain value; (2) the changing behavior of the adult's feeding activities during adverse weather might bring them into contact with arthropods having greater weight-gain value to the young;

(3) the lowered air temperature might be reducing the energy expenditure of the young during adverse weather periods, though, of course increased brooding during these periods would offset this gain; and (4) probably it was a combination of the above plus several factors still not investigated.

24. No factor in the environment of the nestling Eastern Phoebe appears to be so detrimental that the young fail to mature, otherwise the Eastern Phoebe would be eliminated from where it now nests.

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TABLE 1.--Summary of Mean Growth Measurements 1 to 14 Day Old First-Brood Eastern Phoebes

	Age in Days After Hatching													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of Young	25	25	25	25	25	25	25	25	25	25	25	21	21	21
Weight (in gms.)	3.1	5.3	7.1	8.9	11.0	12.7	14.0	15.3	15.5	16.6	17.1	16.5	17.0	17.3
Length (in mm.)	44	51	57	64	70	75	82	88	94	102	110	116	120	124
Dorsal Feather Length					.5	1	3	4	6	8	10	12	14	17
Ventral Feather Length					1	2	4	5	7	9	11	12	14	17
Tail Feather Length					.5	2	3	4	5	6	7	9	10	13
Primary Feather Length						1	2	4	6	13	19	20	26	31
Greater Primary Covert FeatherLength							1	2	4	6	14	16	18	19
Secondary Feather Length						1	2	5	8	13	18	21	26	31
Greater Secondary Covert Feather Length				.5	.5	.5	2	5	8	11	16	19	19	20

Table 2.--Summary of Mean Growth Measurements 1 to 14 Day Old Second-Brood Eastern Phoebes

	Age In Days After Hatching													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Number of Young	13	13	13	13	13	13	13	13	13	13	13	10	10	10
Weight (in gms.)	2.8	4.1	5.0	5.5	7.5	9.9	11.0	13.1	13.5	14.5	15.7	17.3	18.6	16.3
Length (in mm.)	44	49	53	55	64	69	75	78	84	91	93	96	108	112
Dorsal Feather					1	2	2	4	5	5	6	8	10	15
Ventral Feather						1	2	2	5	5	6	8	10	14
Tail Feather					.5	1	2	3	5	6	7	8	9	12
Primary Feather							1	2	3	6	10	18	21	30
Greater Primary Covert Feather							1	3	4	4	9	12	15	17
Secondary Feather						1	2	2	3	5	11	15	21	30
Greater Secondary Covert Feather					1	2	2	3	5	7	8	13	20	20

TABLE 3.--Summary of Temperature Regulation Experiments 15 First-Brood Nestling Eastern Phoebes

Days of Age	In 10°C. Environment			In 40°C. Environment		
	$\bar{X}$ Cloacal Temp. °C.	Breaths/Min. $\bar{X}$	Range	$\bar{X}$ Cloacal Temp. °C.	Breaths/Min. $\bar{X}$	Range
1	11.5	0.5	0-2	42.5	64.6	20-98
2	13.5	2.3	1-4	42.5	100.0	65-120
3	13.7	8.4	2-23	42.0	112.3	70-138
4	16.0	28.0	7-49	43.1	147.2	65-119
5	19.5	35.2	20-83	44.5	185.3	101-163
6	25.0	55.3	12-71	42.3	178.0	141-195
7	27.1	109.5	78-125	42.6	187.2	120-205
8	28.5	140.3	110-160	42.5	185.4	172-210
9	28.6	150.1	128-173	41.0	188.3	160-201
10	34.0	164.8	161-190	41.4	189.0	171-200
11	36.3	188,3	185-201	40.2	201.8	187-215
12	35.5	190.1	180-195	40.3	210.5	189-220
13	36.5	187.8	183-196	40.1	215.5	188-225
14	36.7	190.8	185-195	40.1	208.3	193-213

TABLE 4.--Summary of Temperature Regulation Experiments 10 Second-Brood Nestling Eastern Phoebes

Days of Age	In 10° C. Environment			In 40° C. Environment		
	$\bar{X}$ Cloacal Temp. °C.	Breaths/Min. $\bar{X}$	Range	$\bar{X}$ Cloacal Temp. °C.	Breaths/Min. $\bar{X}$	Range
1	11.5	0.5	0-2	42.0	61.3	25-111
2	13.0	2.1	1-3	42.1	101.4	29-108
3	14.0	2.6	1-12	42.5	116.4	89-140
4	16.5	37.4	15-45	42.5	122.0	90-129
5	19.1	49.2	12-68	43.2	184.3	153-242
6	24.3	69.0	34-81	43.0	193.4	136-270
7	25.8	62.3	33-84	43.5	180.1	88-171
8	25.5	108.5	95-210	43.2	187.1	167-195
9	25.8	144.6	122-160	42.0	191.0	160-210
10	27.7	140.3	118-210	43.0	183.4	153-236
11	27.9	167.3	188-200	43.5	198.8	170-201
12	26.8	157.7	187-198	43.5	200.3	190-210
13	27.5	183.6	180-190	44.1	225.7	180-190
14	31.7	177.4	180-190	44.4	210.2	183-196

TABLE 5.--Gaping Responses of Nestling Eastern Phoebes After One-Half Hour Exposures to Controlled Temperature Environments

AGE OF YOUNG (DAYS)	NUMBER OF YOUNG		30 TRIALS					
			1ST BROOD YOUNG $\bar{X}$ NUMBER OF GAPES			2ND BROOD YOUNG $\bar{X}$ NUMBER OF GAPES		
	1ST BROOD	2ND BROOD	10° C.	25° C.	40° C.	10° C.	25° C.	40° C.
1	2	3	5	26	30	5	25	23
2	2	2	7	28	23	5	28	25
3	2	3	6	28	18	6	28	12
4	2	3	4	29	20	6	30	18
5	2	3	7	31	16	7	30	13
6	2	3	6	28	14	6	26	15
TOTAL	12	17	35	170	121	35	167	107
MEAN NUMBER OF GAPES			5.8	28.3	20.1	5.8	27.8	17.8

TABLE 6.--Daily Summary of Nestling and Environmental Conditions at Two-Young Nest No. 61-16, May 24-June 4, 1961

	YOUNG			Arthropods		ADULTS				WEATHER CONDITIONS				
DATE	AGE	MEAN WEIGHT	MEAN WEIGHT CHANGE	WEIGHT	NO. INDIV.	TOTAL TRIPS	TOTAL FEEDING DAY (HRS)	DAILY BROODING PERIODS	DAILY BROODING TIME (HRS)	MEAN TEMP.	MEAN R. HUM.	MEAN WIND SPEED	LIGHT S/O	RAIN (HRS)
5/24	1	3.0		.1321	43	103	14.2	39	5.1	20.1	74	4	10/2	0
5/25	2	3.6	.6	.0914	73	112	14.5	39	6.0	20.0	88	3	0/15	2
5/26	3	4.3	.7	.0836	15	73	14.2	58	3.8	17.3	68	15	7/5	0
5/27	4	6.1	1.8	.0974	28	149	13.9	39	5.3	20.0	63	20	4/8	0
5/28	5	7.0	.9	.0433	15	34	12.8	62	8.6	14.8	88	7	2/9	1
5/29	6	7.6	.6	.0964	48	63	13.5	39	10.4	19.2	63	4	10/0	0
5/30	7	8.0	.4	.0041	29	78	12.1	--	--	15.6	93	2	0/12	4
5/31	8	10.0	2.0	.0079	48	87	14.5	--	--	17.1	78	2	1/10	3
6/1	9	12.8	2.8	.0581	33	123	14.8	--	--	23.0	76	3	3/11	2
6/2	10	15.0	2.2	.0101	32	109	14.8	--	--	20.7	61	3	10/4	0
6/3	11	16.3	1.3	.0191	47	130	14.3	--	--	20.2	68	4	10/1	0
6/4	12	18.0	1.7	.1113	30	105	14.8	--	--	18.4	73	2	4/0	0
SUMMARY:		--	--	.7548	441	1166	168.4	276	39.2	--	--	--	61/77	12
MEANS:		--	1.36	.0629	36.8	97.2	14.0	46.0	6.5	18.9	74.4	5.8	0.79	1.00

TABLE 7.--Daily Summary of Nestling and Environmental Conditions at Two-Young Nest No. 61-16A, July 8-19, 1961

	YOUNG			Arthropods		ADULTS				WEATHER CONDITIONS				
DATE	AGE	MEAN WEIGHT	MEAN WEIGHT CHANGE	WEIGHT	NO. INDIV.	TOTAL TRIPS	TOTAL FEEDING DAY (HRS)	DAILY BROODING PERIODS	DAILY BROODING TIME (HRS)	MEAN TEMP.	MEAN R. HUM.	MEAN WIND SPEED	LIGHT S/O	RAIN (HRS)
7/8	1	3.8		.1073	57	151	13.8	41	7.8	23.4	68.1	1	14/0	0
7/9	2	4.3	0.5	.1150	67	109	14.9	19	5.3	26.8	34.2	2	14/0	0
7/10	3	6.0	1.7	.1053	105	78	14.9	24	4.9	22.0	75.7	2	0/8	2
7/11	4	7.6	1.6	.0348	83	114	14.9	59	6.0	28.0	42.7	2	14/0	0
7/12	5	8.1	0.5	.0567	86	119	14.8	37	5.1	28.5	59.7	3	14/0	0
7/13	6	10.6	2.5	.0040	43	80	14.3	12	10.9	25.7	67.7	3	14/0	2
7/14	7	12.3	1.7	.1497	101	163	14.6	--	--	25.3	73.3	2	3/12	1
7/15	8	14.4	2.1	.1913	71	148	14.6	--	--	27.8	52.7	4	11/2	0
7/16	9	16.8	2.4	.1843	81	190	14.9	--	--	22.5	76.7	1	4/4	0
7/17	10	17.8	1.0	.2101	103	203	14.3	--	--	27.3	53.9	4	4/10	0
7/18	11	18.5	0.7	.1841	87	148	14.0	--	--	27.2	57.0	3	0/10	1
7/19	12	19.0	0.5	.2034	135	139	14.3	--	--	27.3	71.7	2	0/1	2
SUMMARY:		--	--	1.5460	1019	1642	174.3	192	40.0	--	--	--	92/47	8
MEANS:		--	1.38	0.1288	84.9	136.8	14.5	32.0	6.6	26.0	61.1	2.4	1.96	.67

TABLE 8.--Daily Summary of Nestling and Environmental Conditions at Two-Young Nest No. 62-17, May 18-29, 1962

	YOUNG			Arthropods		ADULTS				WEATHER CONDITIONS				
DATE	AGE	MEAN WEIGHT	MEAN WEIGHT CHANGE	WEIGHT	NO. INDIV.	TOTAL TRIPS	TOTAL FEEDING DAY (HRS)	DAILY BROODING PERIODS	DAILY BROODING TIME (HRS)	MEAN TEMP.	MEAN R. HUM.	MEAN WIND SPEED	LIGHT S/O	RAIN (HRS)
5/18	1	3.5		.0953	90	78	14.9	43	6.5	19.1	80.1	2	7/4	0
5/19	2	4.7	1.2	.0048	101	111	14.5	37	3.9	22.0	55.2	3	3/4	0
5/20	3	6.0	1.3	.1769	69	114	15.3	37	4.0	22.0	88.1	3	8/2	0
5/21	4	7.0	1.0	.1431	45	113	14.8	21	5.0	17.4	61.3	3	4/8	2
5/22	5	9.1	2.1	.1825	65	134	15.2	25	6.0	19.3	57.6	4	14/0	0
5/23	6	11.1	2.0	.1596	78	186	14.9	21	3.1	23.0	64.1	4	4/8	3
5/24	7	12.4	1.3	.0722	22	98	14.5	--	--	15.9	77.1	5	0/14	1
5/25	8	14.6	2.2	.0977	49	134	14.9	--	--	19.3	61.4	4	7/5	0
5/26	9	15.2	0.6	.0950	20	155	14.5	--	--	16.6	55.8	3	10/4	3
5/27	10	17.2	2.0	.1353	19	167	14.1	--	--	15.7	61.9	4	4/12	0
5/28	11	18.3	1.1	.3786	207	118	14.4	--	--	19.4	66.6	2	7/5	0
5/29	12	19.1	0.8	.1434	33	194	14.8	--	--	15.1	80.8	3	8/5	0
SUMMARY:		--	--	1.6704	798	1602	1768	184	28.5	--	--	--	76/66	9
MEANS:		--	1.42	.1392	66.5	133.5	14.7	30.7	4.8	18.7	67.5	3.3	1.15	0.75

TABLE 9.--Daily Summary of Nestling and Environmental Conditions at Two-Young Nest No. 62-22A, July 3-July 14, 1962

		YOUNG		Arthropods		ADULTS				WEATHER CONDITIONS				
DATE	AGE	MEAN WEIGHT	MEAN WEIGHT CHANGE	WEIGHT	NO. INDIV.	TOTAL TRIPS	TOTAL FEEDING DAY (HRS)	DAILY BROODING PERIODS	TIME (HRS)	MEAN TEMP.	MEAN R.HUM.	MEAN WIND SPEED	LIGHT S/O	RAIN (HRS)
7/3	1	4.1		.0856	48	147	14.8	44	8.5	21.3	74.0	3	3/10	0
7/4	2	5.3	1.2	.0916	95	113	14.3	28	8.5	24.0	55.6	3	6/0	0
7/5	3	7.3	2.0	.3806	136	141	14.6	29	6.1	25.1	61.6	1	8/0	0
7/6	4	9.0	1.7	.1713	123	123	14.1	9	2.1	26.8	59.9	1	10/3	0
7/7	5	10.5	1.5	.1123	98	124	14.4	13	2.7	28.3	61.6	1	11/3	0
7/8	6	12.9	2.4	.2949	98	164	14.4	17	3.6	26.8	59.9	3	6/5	1
7/9	7	14.3	1.4	.2379	156	215	14.4	--	--	21.2	61.6	3	10/4	0
7/10	8	15.8	1.5	.1646	171	184	14.1	--	--	22.6	70.3	2	12/2	0
7/11	9	16.9	1.1	.1157	116	137	14.2	--	--	27.1	58.4	1	10/2	0
7/12	10	17.7	0.8	.0723	54	157	14.3	--	--	24.8	55.9	3	10/4	0
7/13	11	17.8	0.1	.1890	87	142	14.1	--	--	21.7	58.4	1	10/4	0
7/14	12	17.5	-0.3	.1166	62	128	14.7	--	--	22.6	60.5	2	4/4	0
SUMMARY:		--	--	2.0324	1244	1775	172.4	140	31.5	--	--	--	100/41	1
MEANS:		--	1.22	0.1690	103.7	147.9	14.3	23.3	5.3	24.4	61.5	2.0	2.44	.08

TABLE 10.--Daily Summary of Nestling and Environmental Conditions at Two-Young Nest No. 62-17B, July 28-August 8, 1962

	YOUNG			Arthropods		ADULTS				WEATHER CONDITIONS				
DATE	AGE	MEAN WEIGHT	MEAN WEIGHT CHANGE	WEIGHT	NO. INDIV.	TOTAL TRIPS	TOTAL FEEDING DAY (HRS)	DAILY BROODING PERIODS	DAILY BROODING TIME (HRS)	MEAN TEMP.	MEAN R.HUM.	MEAN WIND SPEED	LIGHT S/O	RAIN (HRS)
7/28	1	3.9		.0203	55	138	14.4	53	7.4	17.7	94.0	2	0/14	10
7/29	2	5.3	1.4	.1523	73	112	14.2	41	6.0	19.3	87.7	2	0/14	0
7/30	3	6.6	1.3	.1002	74	102	14.5	36	5.1	22.5	71.7	4	0/8	0
7/31	4	8.1	1.5	.0174	33	100	14.7	39	4.8	18.2	64.9	5	15/0	0
8/1	5	10.0	1.9	.0236	34	119	14.8	46	3.7	19.8	61.9	6	0/8	0
8/2	6	12.0	2.0	.0459	34	129	14.8	30	3.4	19.2	63.9	4	15/0	0
8/3	7	14.7	2.7	.0800	30	80	14.9	--	--	21.5	76.1	4	1/10	1
8/4	8	15.9	1.2	.0474	81	100	14.7	--	--	22.3	82.3	8	2/13	5
8/5	9	17.7	1.8	.0659	49	167	14.9	--	--	21.7	74.5	3	11/0	0
8/6	10	18.3	0.6	.0364	57	123	15.1	--	--	21.8	83.7	2	2/13	0
8/7	11	19.0	1.3	.0196	58	140	13.5	--	--	23.3	83.9	2	8/1	2
8/8	12	20.0	1.0	.2265	143	86	14.1	--	--	19.6	92.3	10	0/14	5
SUMMARY:		--	--	.8355	721	1396	174.6	245	304	--	--	--	54/95	23
MEANS:		--	1.52	.0696	60.0	116.3	14.6	24.2	5.1	20.6	78.1	4.3	0.57	1.9

TABLE 11.--Summary of Nestling and Environmental Conditions at Four-Young Nest No. 61-17, June 20-July 1, 1961

	YOUNG			Arthropods		ADULTS				WEATHER CONDITIONS				
DATE	AGE	MEAN WEIGHT	MEAN WEIGHT CHANGE	WEIGHT	NO. INDIV.	TOTAL TRIPS	TOTAL FEEDING DAY (HRS)	DAILY BROODING PERIODS	DAILY BROODING TIME (HRS)	MEAN TEMP	MEAN R.HUM	MEAN WIND SPEED	MEAN LIGHT S/O	MEAN RAIN (HRS)
6/20	1	3.7		.1005	111	185	14.3	45	8.8	19.2	57	2	12/2	0
6/21	2	4.8	1.1	.2169	67	183	14.2	43	6.8	21.1	80	3	4/1	0
6/22	3	5.5	0.7	.2808	54	133	13.8	28	5.4	20.1	75	5	0/14	3
6/23	4	7.7	2.2	.3413	167	243	14.8	20	3.0	24.0	63	5	12/2	0
6/24	5	8.5	0.8	.0586	100	189	14.3	14	2.1	16.1	72	6	0/14	2
6/25	6	10.8	2.3	.0901	78	258	14.4	23	2.0	20.4	70	3	14/0	0
6/26	7	12.4	1.6	.1070	88	273	13.7	--	--	21.1	58	4	3/4	2
6/27	8	14.9	2.5	.1113	43	198	14.1	--	--	18.5	59	2	8/2	0
6/28	9	16.7	1.8	.3647	112	224	14.8	--	--	17.4	83	3	6/6	0
6/29	10	17.1	0.4	.0319	83	242	14.3	--	--	23.8	78	1	2/12	0
6/30	11	18.1	1.0	.1135	110	258	14.8	--	--	22.4	85	1	0/12	0
7/1	12	19.3	1.2	.1004	63	149	14.0	--	--	17.5	76	4	3/8	1
SUMMARY:		--	--	1.9179	1076	2535	171.5	173	28.1	--	--	--	64/77	8
MEANS:		--	1.42	0.1598	89.6	211.3	14.3	28.8	4.7	20.1	71.3	3.2	0.83	.7

TABLE 12.--Comparison of the Nesting Environments at Five, 2-Young Nests and One, 4-Young Nest of the Eastern Phoebe During the First 12 Days of Nestling Life (Arranged in Order by Nesting Dates)

YOUNG				ARTHROPODS		ADULTS				WEATHER CONDITIONS				
NEST NO.	FLEDGING AGE	DATES	MEAN WEIGHT CHANGE	DAILY MEAN WEIGHT	MEAN NO. INDIV.	MEAN TOTAL TRIPS	TOTAL FEEDING DAY (HRS)	MEAN FIRST SIX DAYS DAILY BROODING PERIODS	MEAN FIRST SIX DAYS DAILY BROODING TIME (HRS)	MEAN TEMP.	MEAN R. HUM.	MEAN WIND SPEED	LIGHT S/O	RAIN (HRS)
61-16	14.5	5/24-6/4	1.36	.0629	36.8	97.2	14.0	46.0	6.5	18.9	74.4	5.8	0.79	1.00
61-16A	15.0	7/8-7/19	1.38	.1288	84.9	136.8	14.5	32.0	6.6	26.0	61.1	2.4	1.96	0.67
62-17	18.0	5/18-5/29	1.42	.1392	66.5	133.5	14.7	30.7	4.8	18.7	67.5	3.3	1.15	0.75
62-22A	14.0	7/3-7/14	1.22	.1690	103.7	147.9	14.3	23.3	5.3	24.4	61.5	2.0	2.44	0.08
62-17B	15.0	7/28-8/8	1.52	.0696	60.0	116.3	14.6	24.2	5.1	20.6	78.1	4.3	0.57	1.90
SUMMARY	15.3		1.15	.1079	70.4	126.3	14.4	31.2	5.7	21.7	68.5	4.7	1.76	0.86
61-17 (4 Young)	17.5	6/20-7/1	1.42	.1598	89.6	211.3	14.3	28.8	4.7	20.1	71.3	3.2	0.83	0.70

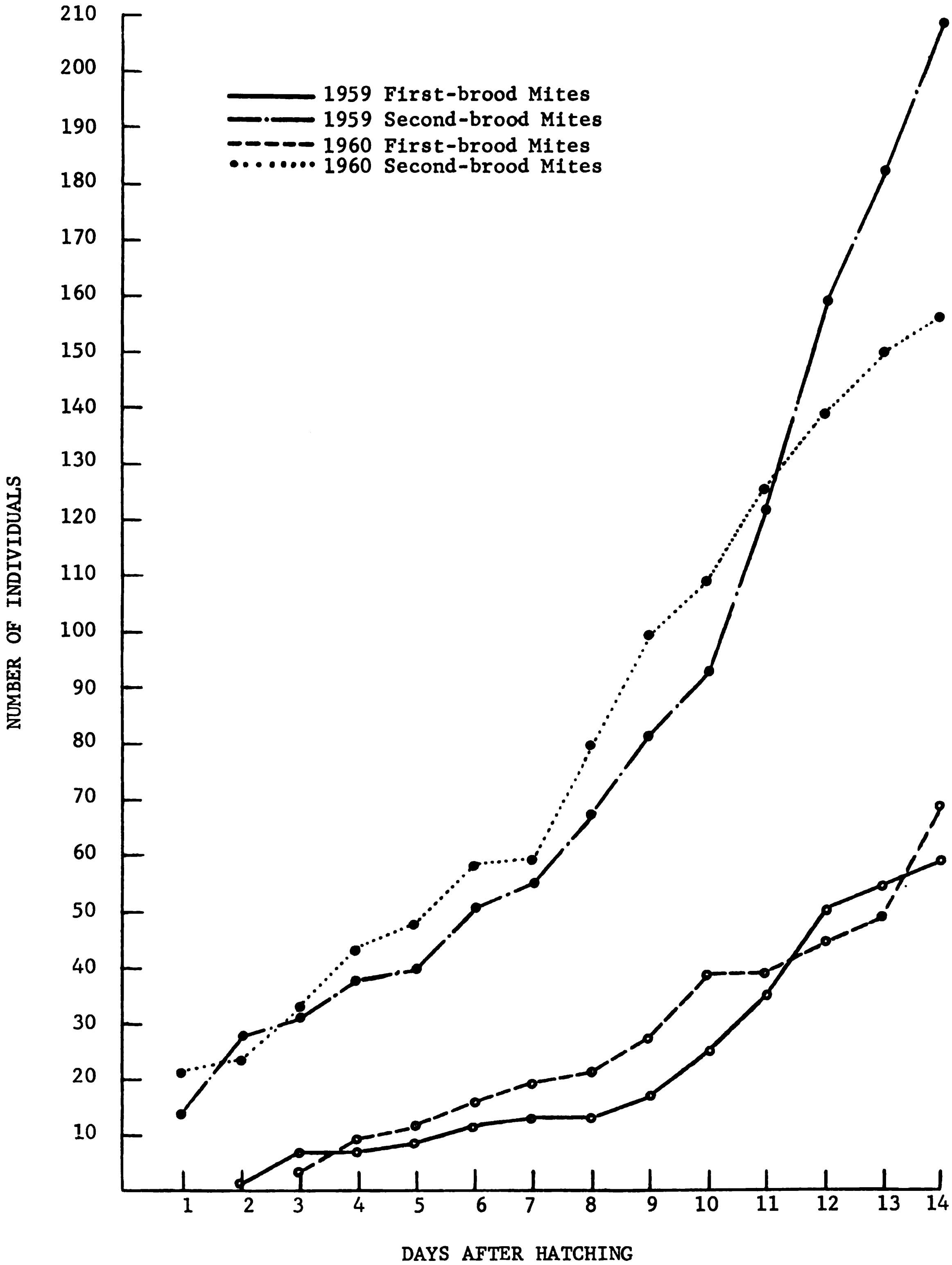
TABLE 13.--Numbers of Individuals of Each Arthropod Order in the Foraging Areas at Six Nests of the Eastern Phoebe During the First 12 Days of Nestling Life (1961-1962)

Number of Each Arthropod Order/Number of Days in Samples																		
Diptera	Coleoptera	Hymenoptera	Homoptera	Hemiptera	Ephemeroptera	Araneae	Lepidoptera	Acarina	Neuroptera	Orthoptera	Plecoptera	Odonata	Mecoptera	Trichoptera	Thysanoptera	Total	Nest	Dates
327/12	285/11	82/11	25/9	8/5	48/8	0/0	10/5	4/3	7/1	1/1	1/1	0/0	0/0	0/0	0/0	798	62-17	5/18-5/29
238/12	109/12	48/12	22/7	8/6	18/5	0/0	1/1	3/3	2/2	0/0	1/1	0/0	0/0	1/1	0/0	441	61-16	5/24-6/4
753/12	168/12	62/12	38/10	19/8	15/6	2/1	8/5	5/2	3/2	0/0	1/1	0/0	1/1	0/0	0/0	1076	61-17	6/20-7/1
903/12	167/12	72/12	51/11	24/9	0/0	8/8	11/3	2/2	0/0	2/1	0/0	1/1	0/0	0/0	0/0	1244	62-22A	7/3-7/14
620/12	149/12	117/12	49/10	39/10	7/3	13/8	13/4	3/2	5/5	3/3	0/0	1/1	0/0	0/0	0/0	1019	61-16A	7/8-7/9
348/12	117/12	151/12	52/11	15/5	5/5	24/10	1/1	3/1	5/5	0/0	0/0	0/0	0/0	0/0	1197 *	721	62-17B	7/28-8/8
531.5	165.8	88.7	39.5	18.8	15.5	7.8	7.3	3.3	3.7	0.5	0.5	0.3	0.2	0.2	0	883.2	Means	
60.2	18.8	10.0	4.5	2.1	1.8	0.9	0.8	0.4	0.4	0.05	0.05	0.02	0.01	0.01	0	100%	Per Cent of Total Sample	

*Not counted in total because they appeared on the sampling boards almost at the same time that feeding for that day ended.

GRAPH I

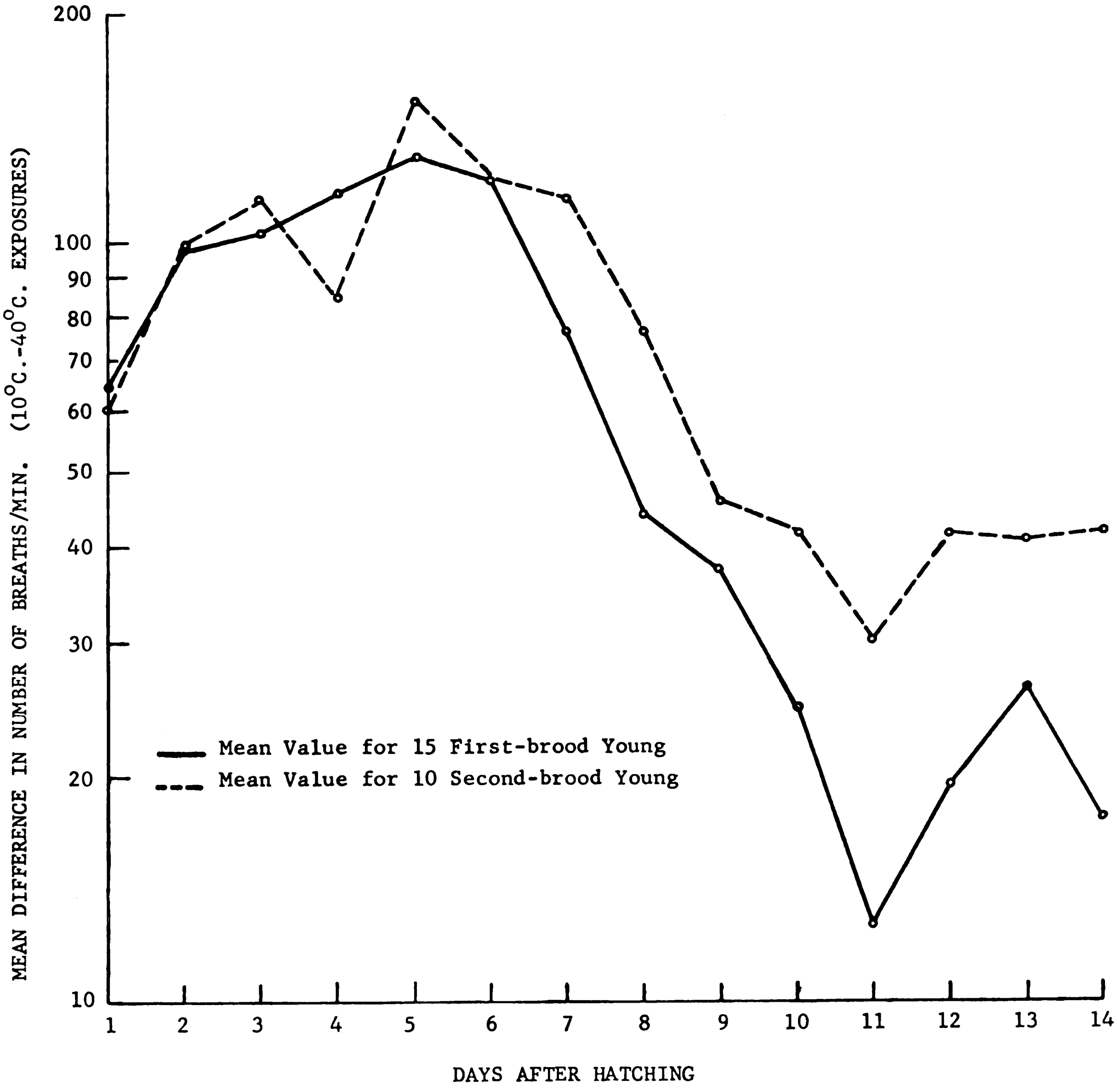
Number of mites found on 20 randomly selected nestling Eastern Phoebes from first- and second-brood nests. Each point represents the mean number of mites on five randomly selected nestlings during either 1959 or 1960.



1959 First-brood Mites
1959 Second-brood Mites
1960 First-brood Mites
1960 Second-brood Mites
NUMBER OF INDIVIDUALS
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
DAYS AFTER HATCHING

GRAPH II

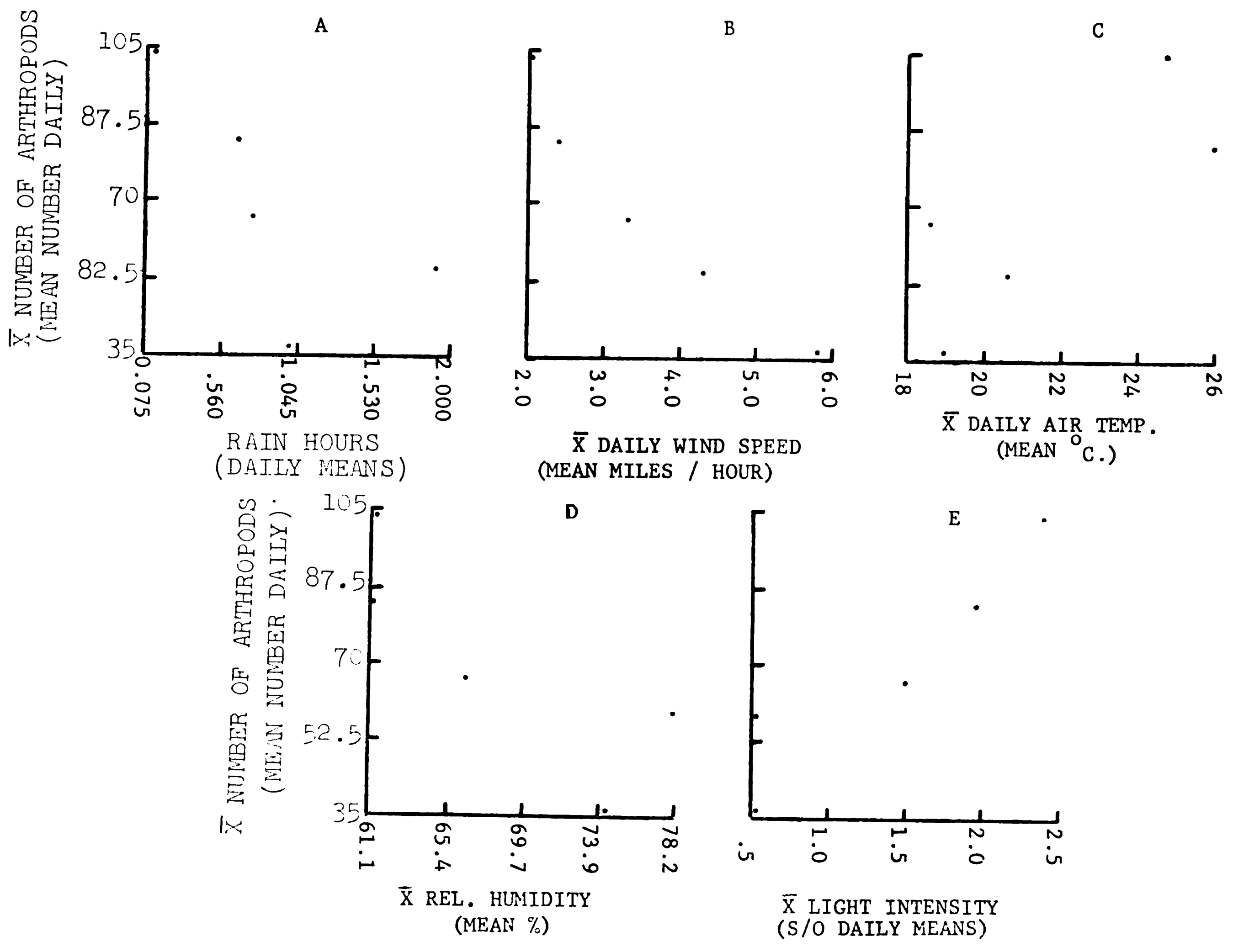
Mean difference in number of breaths per minute between 10°C. and 40°C. two hour controlled temperature exposures for 15 first-brood and 10 second-brood young.


200
100
90
80
70
60
50
40
30
20
10
MEAN DIFFERENCE IN NUMBER OF BREATHS/MIN. (10°C.-40°C. EXPOSURES)
Mean Value for 15 First-brood Young
Mean Value for 10 Second-brood Young
1
2
3
4
5
6
7
8
9
10
11
12
13
14
DAYS AFTER HATCHING

GRAPH III

The relationship between mean daily number of arthropods and weather conditions in foraging areas of 2-young broods of the Eastern Phoebe. (Each point represents the mean values for the first 12 days of nestling life at each nest.)

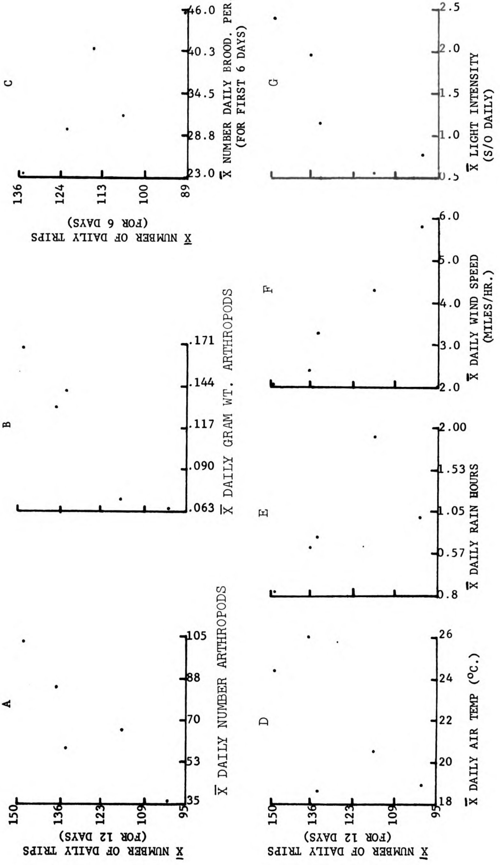
GRAPH III


A
B
C
105
87.5
70
82.5
35
0.075
.560
1.045
1.530
2.000
RAIN HOURS
(DAILY MEANS)
2.0
3.0
4.0
5.0
6.0
X̄ DAILY WIND SPEED
(MEAN MILES / HOUR)
18
20
22
24
26
X̄ DAILY AIR TEMP.
(MEAN °C.)
X̄ NUMBER OF ARTHROPODS
(MEAN NUMBER DAILY)
D
E
105
87.5
70
52.5
35
61.1
65.4
69.7
73.9
78.2
X̄ REL. HUMIDITY
(MEAN %)
.5
1.0
1.5
2.0
2.5
X̄ LIGHT INTENSITY
(S/O DAILY MEANS)
X̄ NUMBER OF ARTHROPODS
(MEAN NUMBER DAILY)

GRAPH IV

The relationship between mean number of trips to the nest daily, brooding behavior daily, and daily environmental conditions in foraging areas of 2-young broods of the Eastern Phoebe. (Each point represents the mean values for the first 12 days of nestling life at each nest.)

GRAPH IV


A
B
C
D
E
F
G
X̄ NUMBER OF DAILY TRIPS (FOR 12 DAYS)
X̄ NUMBER OF DAILY TRIPS (FOR 6 DAYS)
150
136
123
109
95
124
113
100
89
X̄ DAILY NUMBER ARTHROPODS
35
53
70
88
105
X̄ DAILY GRAM WT. ARTHROPODS
.063
.090
.117
.144
.171
X̄ NUMBER DAILY BROOD. PER. (FOR FIRST 6 DAYS)
23.0
28.8
34.5
40.3
46.0
X̄ DAILY AIR TEMP (°C.)
18
20
22
24
26
X̄ DAILY RAIN HOURS
0.8
0.57
1.05
1.53
2.00
X̄ DAILY WIND SPEED (MILES/HR.)
2.0
3.0
4.0
5.0
6.0
X̄ LIGHT INTENSITY (S/O DAILY)
0.5
1.0
1.5
2.0
2.5

GRAPH V

The relationship between mean daily weight gain of 2-young broods of the Eastern Phoebe, adult attentiveness, and environmental factors.

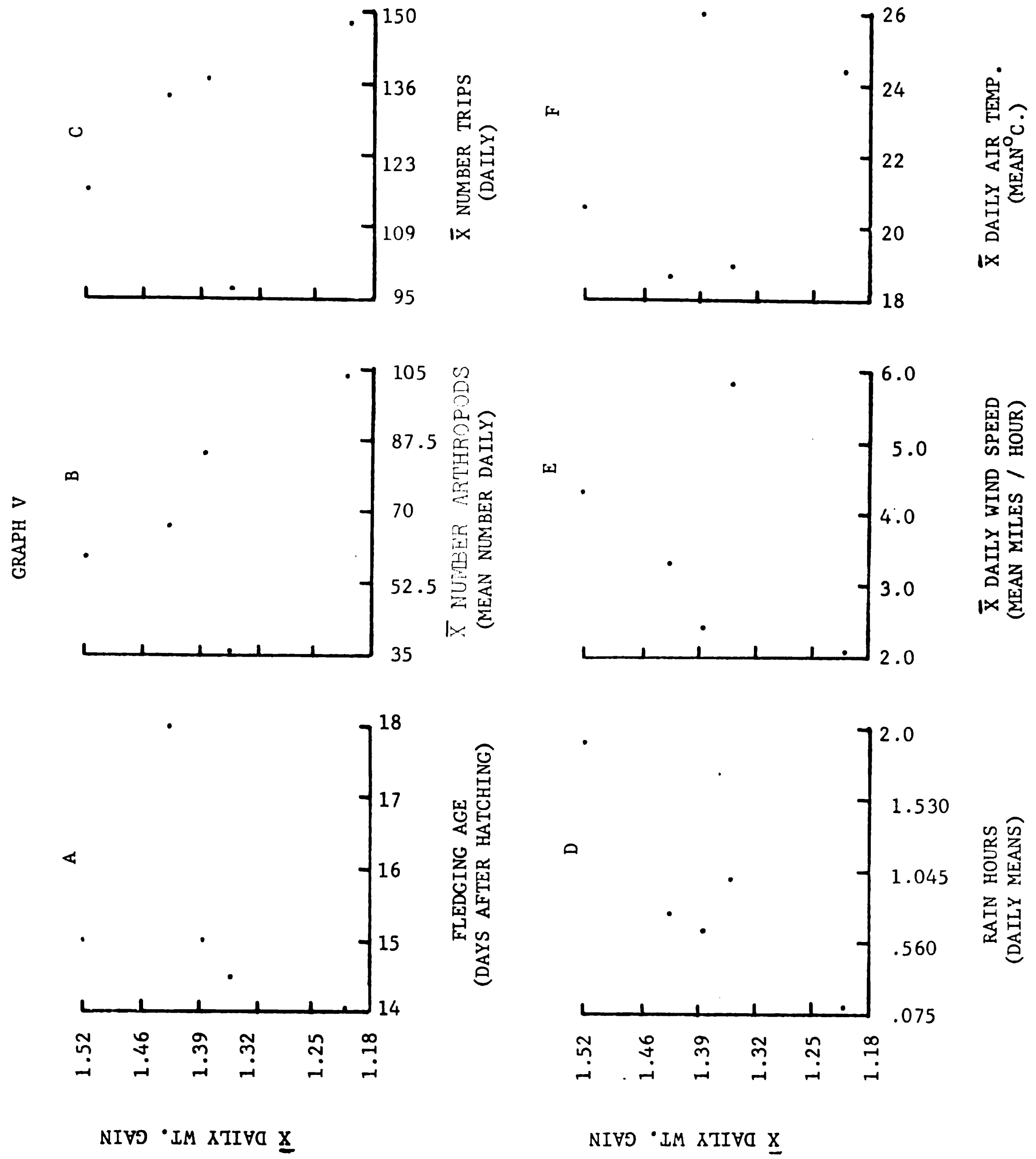

GRAPH V
A
B
C
D
E
F
FLEDGING AGE
(DAYS AFTER HATCHING)
14
15
16
17
18
X̄ NUMBER ARTHROPODS
(MEAN NUMBER DAILY)
35
52.5
70
87.5
105
X̄ NUMBER TRIPS
(DAILY)
95
109
123
136
150
RAIN HOURS
(DAILY MEANS)
.075
.560
1.045
1.530
2.0
X̄ DAILY WIND SPEED
(MEAN MILES / HOUR)
2.0
3.0
4.0
5.0
6.0
X̄ DAILY AIR TEMP.
(MEAN°C.)
18
20
22
24
26
1.52
1.46
1.39
1.32
1.25
1.18
X̄ DAILY WT. GAIN
X̄ DAILY WT. GAIN

FIGURE 1

Diagram of temperature control chamber in cold cabinet with air source, manometer, and position of nest and young in chamber.

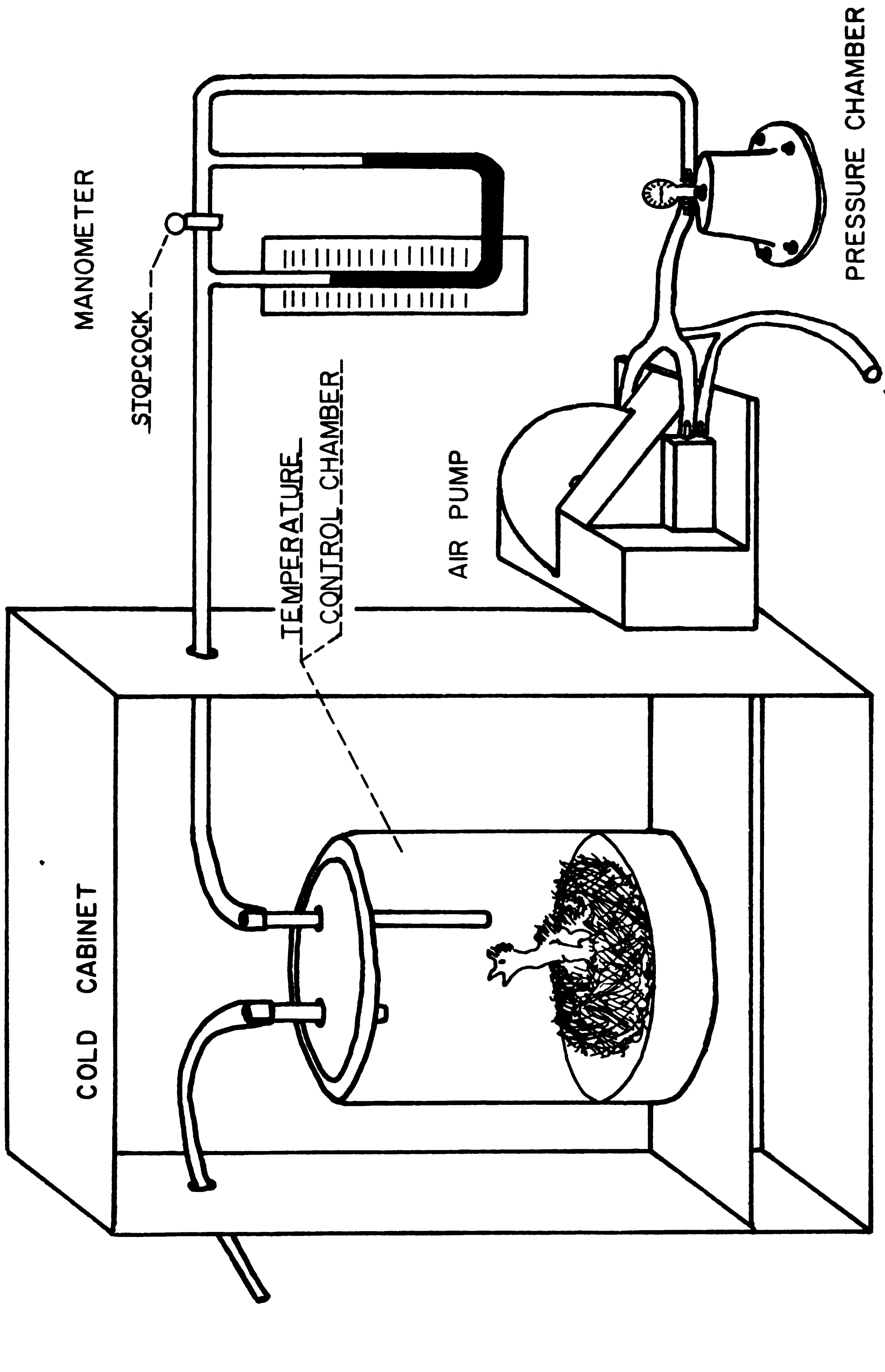

MANOMETER
STOPCOCK
PRESSURE CHAMBER
TEMPERATURE CONTROL CHAMBER
AIR PUMP
INTAKE
COLD CABINET

FIGURE 2

Method used to determine unknown area size of adult Eastern Phoebe foraging areas.

2A. Map of foraging area (reduced to 1/5 actual size) of adult Eastern Phoebes at nest site No. 22 during 1961 and 1962, showing quadrat subdivisions for random sampling insect populations. Map is drawn to scale (each quadrat equals 10 square meters) on larger rectangle of known area size.

2B. Map removed from larger rectangle for weighing. The proportion between weight of rectangle paper and the square area that it represents equals the proportion between the weight of the same map removed from the same rectangle and its (unknown) size.

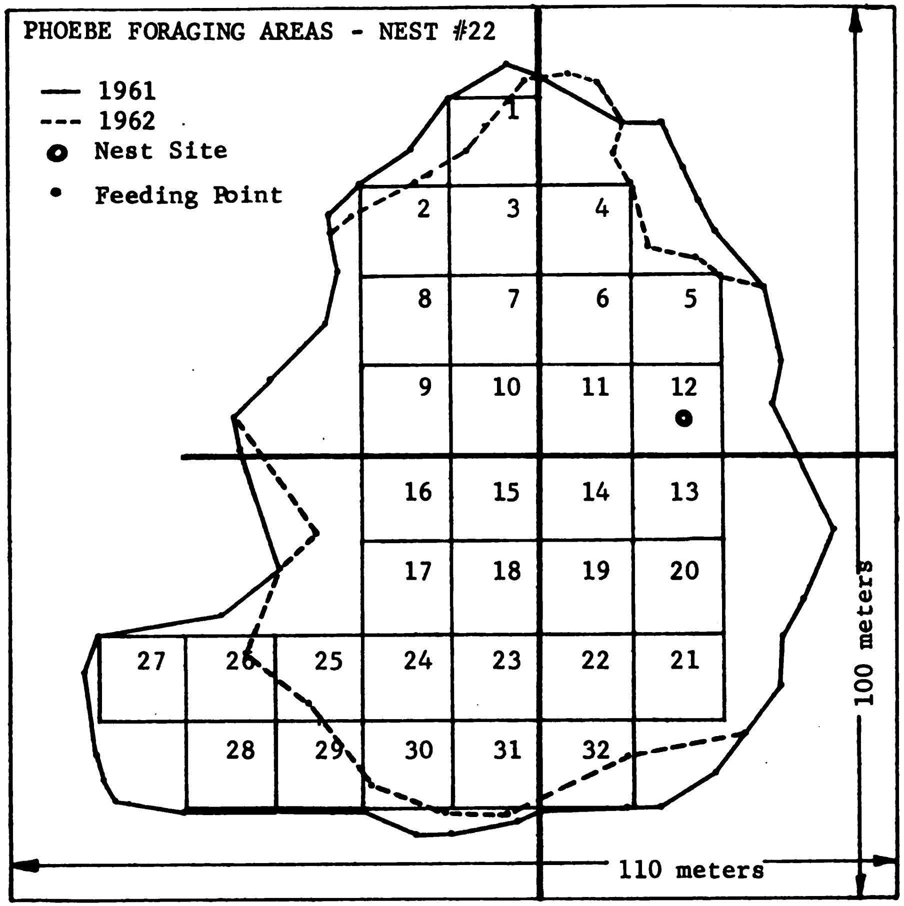


FIG. 2A

WEIGHT OF PAPER = 1.271 gms.
SIZE OF AREA = 11000 sq. meters

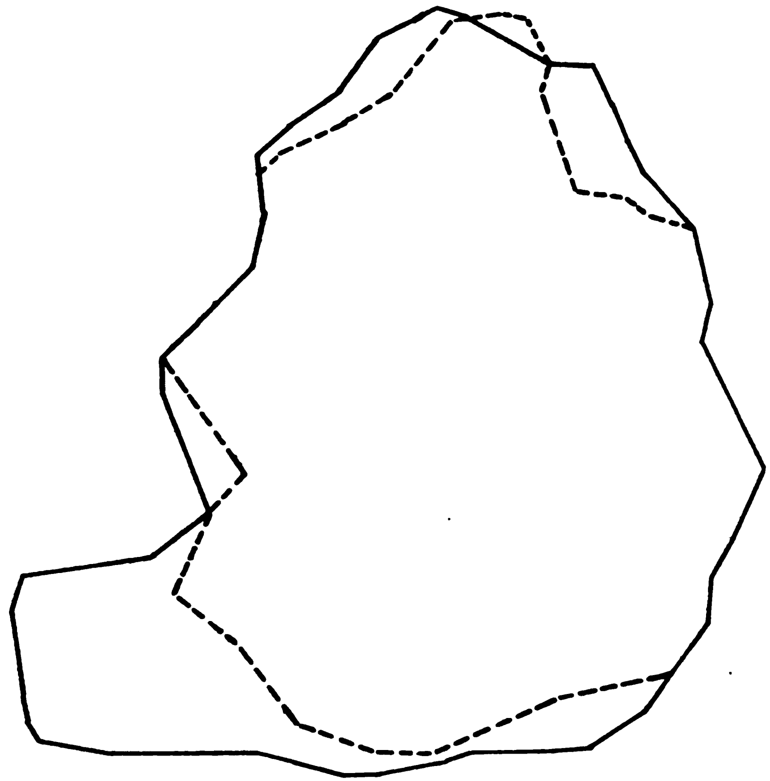
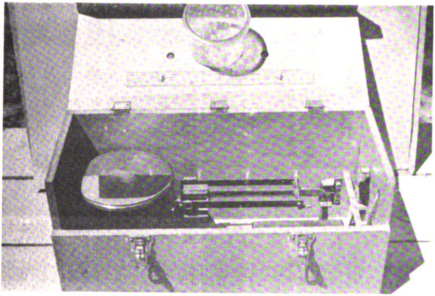


FIG. 2B

WEIGHT OF PAPER = 0.593 gms.
SIZE OF AREA = 5132 sq. meters

PLATE 1

Field weighing kit with Ohaus triple-beam balance and plastic container for weighing young older than none days.



1

PLATE 2

Field Tabulation Forms for recording and tabulating growth measurements of young (reduced 4/5ths.).

2A. Daily field record.

2B. Growth measurement tabulation form.

SPECIES ______________ NEST NO.______
Location ______________________________
Date ______________________________
Nest Contents ______________________________

MEASUREMENTS

No.	Age	Wt.	L												Feeding Data (Interval and Duration)

2A

ORNITHOLOGICAL RESEARCH: MEASUREMENT TABULATION SHEET

SPECIES ______________________ MEASUREMENT OF ______________________

Individual	Age 1 Hr	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.															
2.															
3.															
4.															
5.															
6.															
7.															
8.															
9.															
10.															
11.															
12.															
13.															
14.															
15.															
16.															
17.															
18.															
19.															
20.															
21.															
22.															
23.															
24.															
25.															
26.															
27.															
28.															
29.															
30.															
ΣX:															
n:															
M:															
s^2:															

2B

PLATE 3

Standardized Laboratory and Field Forms (reduced 4/5ths.).

3A. Temperature Regulation Experiment Form

3B. Field Compilation Form

ORNITHOLOGICAL RESEARCH: TEMPERATURE REGULATION EXPERIMENTS

SPECIES: ____________________

Date	Time away from nest		Time of Experiment		Band No.	Nest No.	Age	Weight		Env. Temp.	Cloac. Temp.	Br./M.	Pulse	Remarks.
	Rem.	Ret.	Int.	Rem.				St.	Fin.					

3A

ORNITHOLOGICAL RESEARCH: FIELD COMPILATION FORM

DATE ____________ NEST NO. ________

Recording Time		Nest		Contents	Nest	Young	Air	Rel.	Wind	Wind	Prec.	Clouds	Nest	Density	Insect
Start	Finish	E	Y	Ages	Temp.	Temp.	Temp.	Hum.	Speed	Dir.			Trips	Insects	Fed
12:00M	1:00														
1:00	2:00														
2:00	3:00														
3:00	4:00														
4:00	5:00														
5:00	6:00														
6:00	7:00														
7:00	8:00														
8:00	9:00														
9:00	10:00														
10:00	11:00														
11:00	12:00														
12:00N	1:00														
1:00	2:00														
2:00	3:00														
3:00	4:00														
4:00	5:00														
5:00	6:00														
6:00	7:00														
7:00	8:00														
8:00	9:00														
9:00	10:00														
10:00	11:00														
11:00	12:00														
SUMMARY															

3B

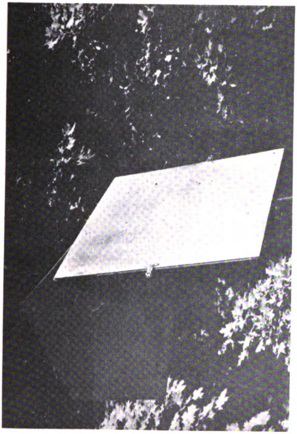
PLATE 4

Wind-vane type arthropod sampling instrument.

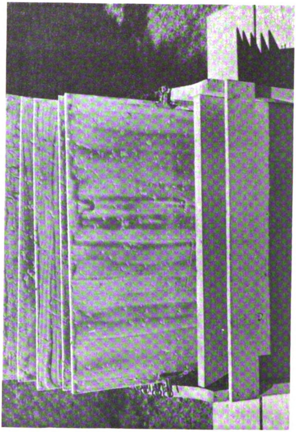
4A. Arthropod sampling board mounted on top of 6' metal pole.

4B. Close-up of masonite board containing "tree-tanglefoot" for trapping arthropods.

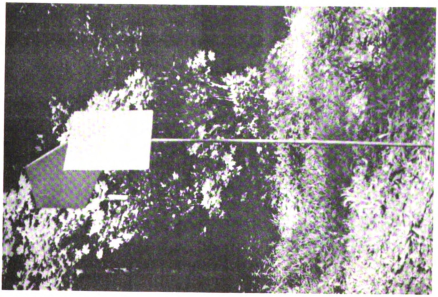
4C. Carrying case for masonite boards.



4B



4C



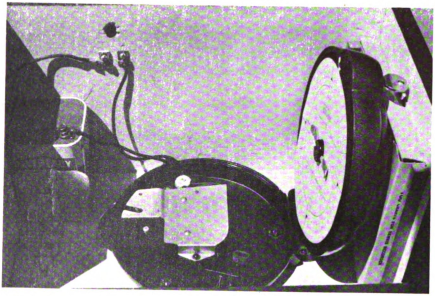
4A

PLATE 5

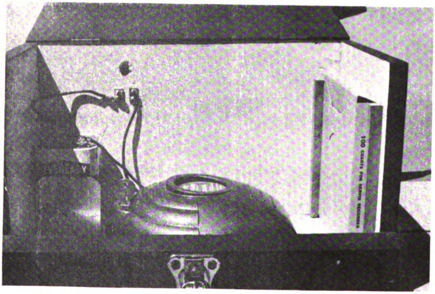
Trip recorder for recording the number and duration of adult trips to the nest during feeding hours.

5A. Hand-wound clock recorder opened to show trip-record paper in place.

5B. Recorder closed during recording period.



5A



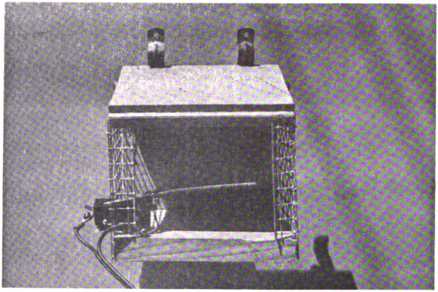
5B

PLATE 6

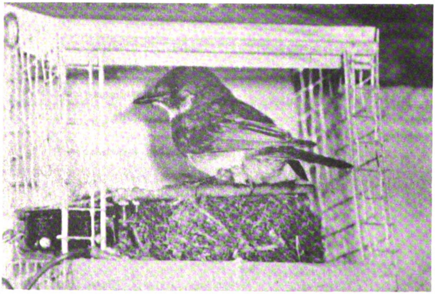
Nestling platform cage with micro-switch perch with electric lines going to trip recorder.

6A. Nesting platform cage in place prior to enclosing nest.

6B. Nesting platform cage in use. Note that micro-switch perch is even with nest rim.



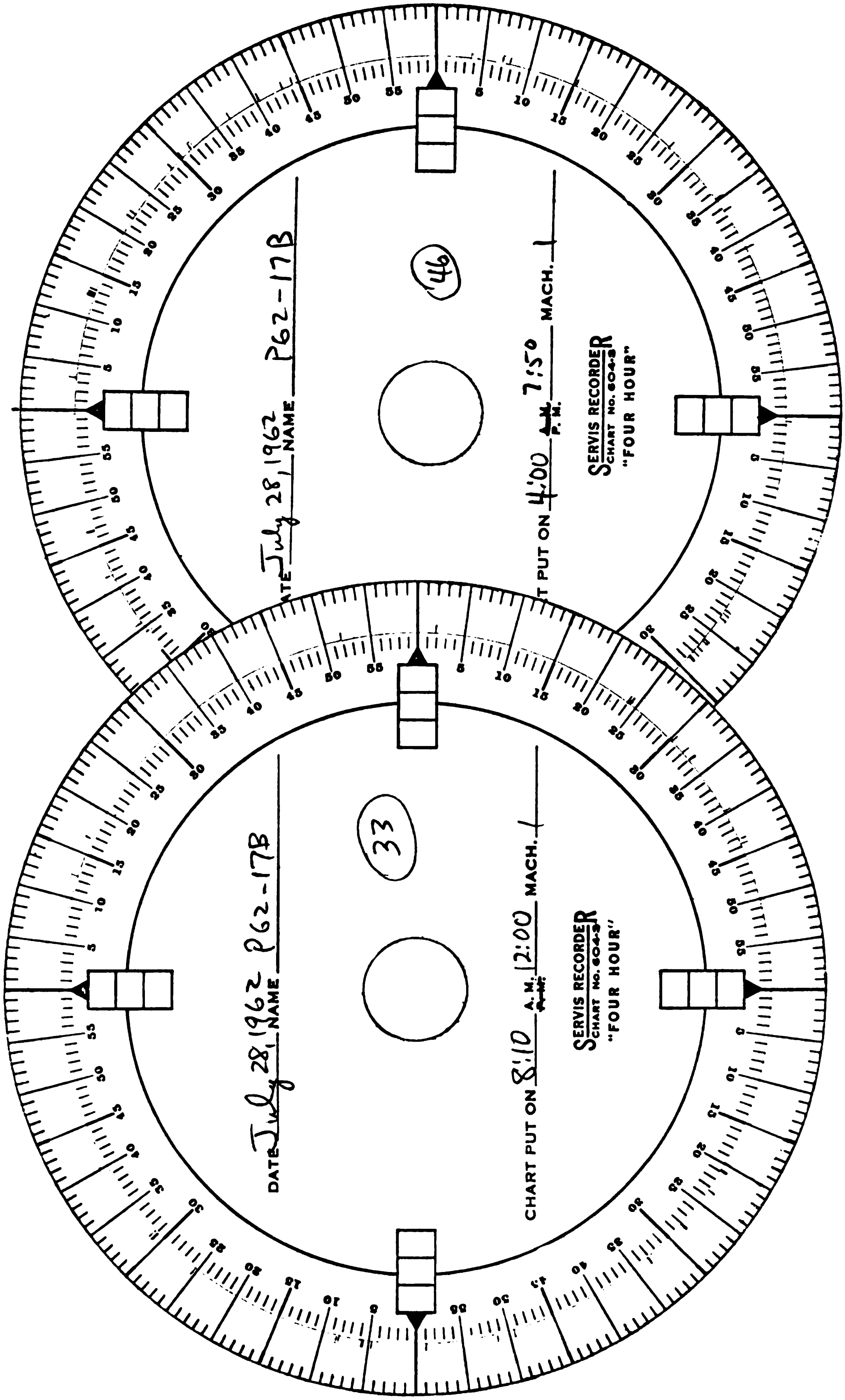
6A



6B

PLATE 7

Four-hour cycle contact sensitive paper for recording trips to the nest by adults at Nest No. 62-17B on July 28, 1962 between 8:10 a.m. and 12:00 p.m. (33 trips) and between 4:00 p.m. and 7:50 p.m. (46 trips).


DATE July 28, 1962 NAME P62-17B
46
CHART PUT ON 4:00 A.M. P.M. 7:50 MACH. 1
SERVIS RECORDER CHART No. 604-S
"FOUR HOUR"
DATE July 28 1962 NAME P62-17B
33
CHART PUT ON 8:10 A.M. P.M. 12:00 MACH. 1
SERVIS RECORDER CHART No. 604-S
"FOUR HOUR"

7

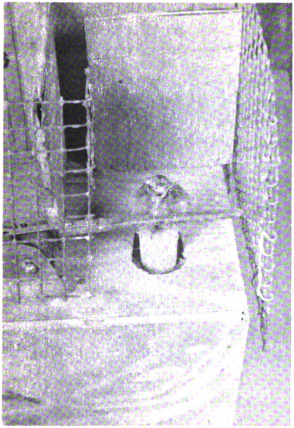
PLATE 8

Artificial nestling used in an attempt to collect food brought to the nest by the adults.

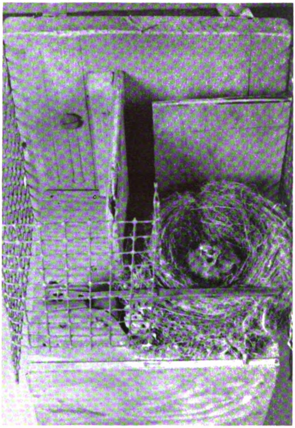
8A. Head of artificial nestling with metal "mandibles" partly open, mounted on end of a tube of stiff muslin.

8B. Artificial nestling with mandibles closed, enclosed by nest on nesting platform.

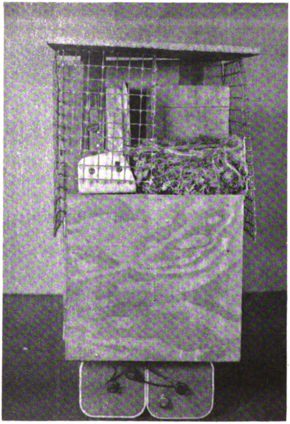
8C. Front of nest platform showing arrangement of micro-switch perch. Two six-volt batteries are attached below.



8A



8B



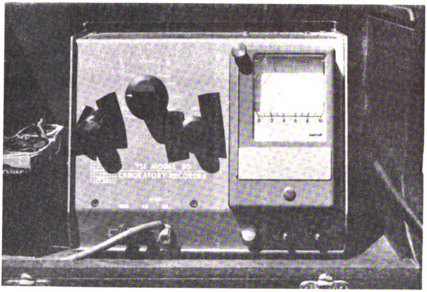
8C

PLATE 9

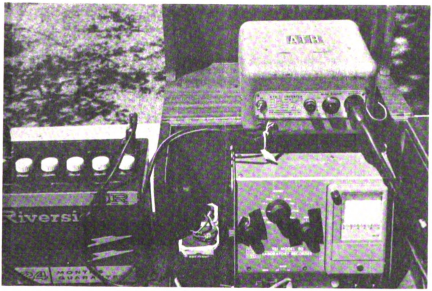
Recorder arrangement for continuously measuring the temperatures at the bottom of the nests.

9A. YSI laboratory recorder with dials set in standardized fixed positions.

9B. YSI laboratory recorder and 12 volt automobile battery power source. Note wheatstone bridge arrangement in circuit with 2, 6 volt batteries to the left of the recorder. The D.C. to A.C. converter is above YSI recorder.


YSI MODEL 80
LABORATORY RECORDER

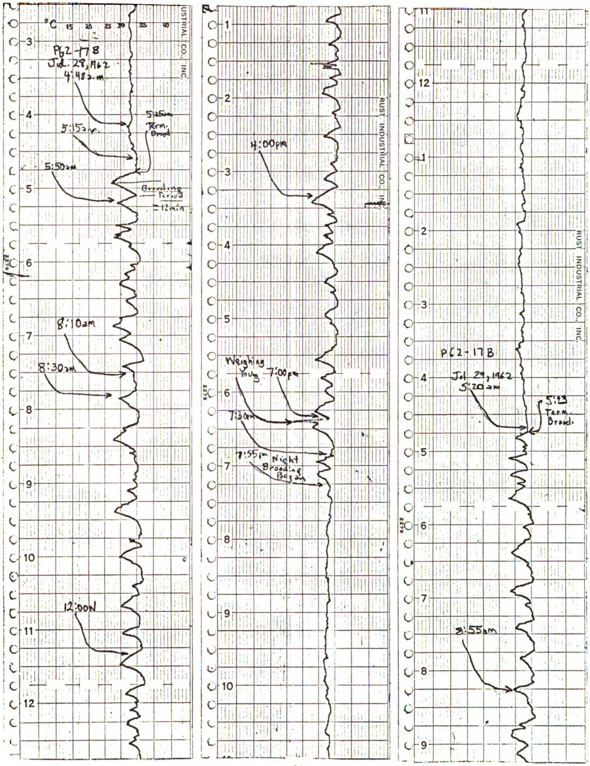
9A


ATR
YSI MODEL 80
LABORATORY RECORDER

9B

PLATE 10

Nest temperature records at Nest No. 62-17B on July 28, 1962, recorded on YSI Laboratory Recorder contact-sensitive paper which moved at the rate of one inch per hour. Note the scale of temperature values at the top of the left chart segment.


°C 15 20 25 30 35 40
P62-17B
Jul. 28, 1962
4:48 a.m.
5:15 a.m.
5:25 am Term. Brood
5:50 am
Brooding Period = 12 min.
8:10 am
8:30 am
12:00 N
4:00 pm
Weighing Young
7:00 pm
7:30 pm
7:55 pm Night Brooding Began
P62-17B
Jul 29, 1962
5:20 am
5:23 Term. Brood.
8:55 am
RUST INDUSTRIAL CO., INC.

10

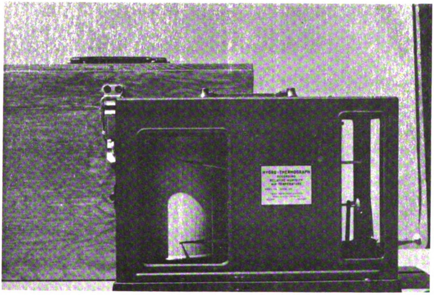
PLATE 11

Instrument and observation tent at Nest No. 22A (circled with arrow). Note electric lines to nest and insect sampling board at far right.

PLATE 12

Hygrothermograph for obtaining 24 hour continuous records of air temperature (C.) and relative humidity (%) in the foraging areas of the adults.

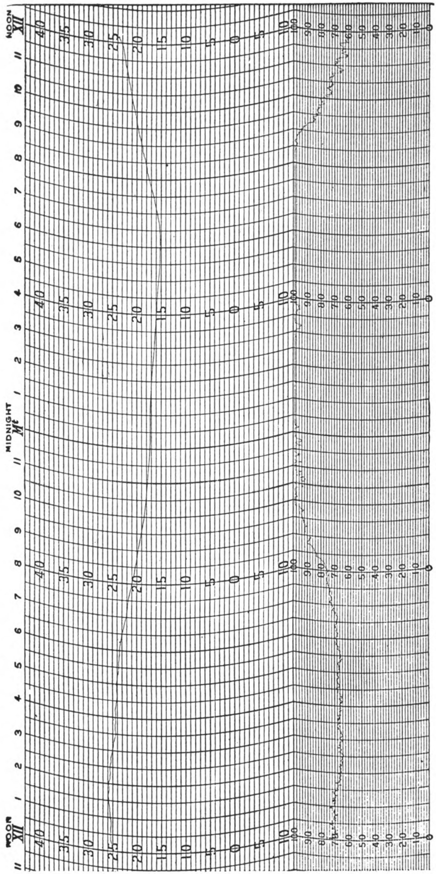
11


HYDRO-THERMOGRAPH
RECORDING
RELATIVE HUMIDITY
AIR TEMPERATURE

12

PLATE 13

Hygrothermograph record at Nest 62-17B on July 28, 1962.



13

PLATE 14

Growth photos of one day old nestling Eastern Phoebes

14A. Side view

14B. Ventral view

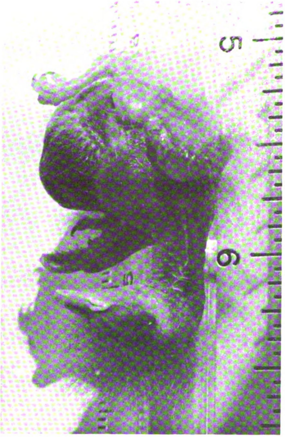
PLATE 15

Growth photos of 3 day old nestling Eastern Phoebes

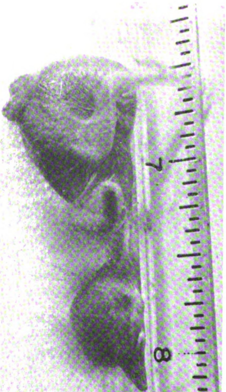
15A. Side view

15B. Ventral view

15A



15B



14A

14B

PLATE 16

Growth photos of nestling 5 day old Eastern Phoebes

16A. Side view

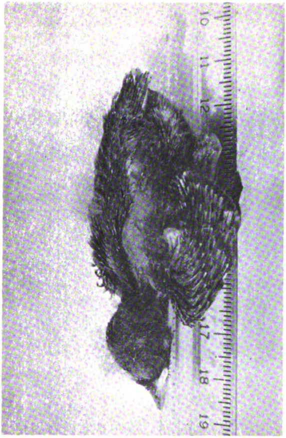
16B. Ventral view

PLATE 17

Growth photos of 10 day old nestling Eastern Phoebes

17A. Side view

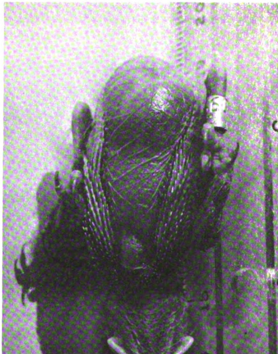
17B. Ventral view



17A

17B

16A



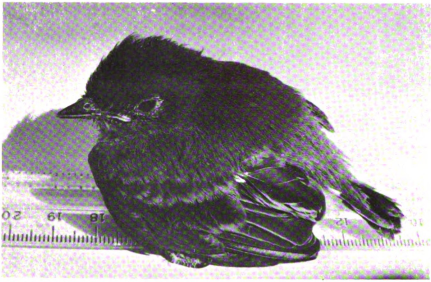
16B

PLATE 18

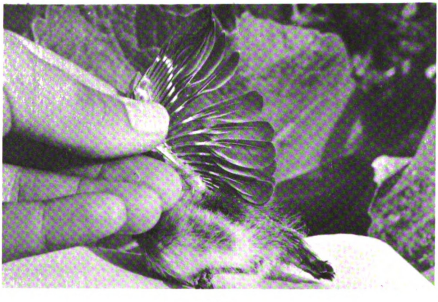
Growth photos of 15 day old nestling Eastern Phoebes.

18A. Side view of normal posture.

18B. Side view showing wing feathers extended and feathers along ventral tract.



18A



18B