EGG TEMPERATURES OF THE RING-NECKED PHEASANT OBTAINED WITH A SELF-RECORDING POTENTIOMETER

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SEVERAL investigators have made detailed studies of the incubation temperatures of birds' eggs, and many incidental observations on the subject can be found in the literature. Ecyclesmeyer (1907), Cadman (1923), Phillips and Brooks (1923), and Murry (1926) used mercurial thermometers to determine the temperatures of incubating eggs of the domestic fowl, while Moran (1925) was apparently the first to use thermocouples to determine such temperatures. Kendeigh and Baldwin (1930) were probably the first to employ thermocouples for investigating the incubation temperatures of the eggs of wild birds. Huggins (1941), using a thermocouple inserted into the egg through an opening made with an egg drill and sealed with collodion, found the egg temperature of the pheasant to vary from 32.7–38.2° C (91.0–100.8° F).

Kossak (1947) measured the incubation temperature of the Canada goose *(Branta c. canadensis)* by using a Leeds and Northrup pyrometer. He attached a thermocouple to the outside of the egg and found the average shell temperature was 38.0° C (100.4° F), and by inserting the thermocouple through the shell, he determined that the average temperature of the developing embryo was 38.5° C (101.3° F). His averages were obtained from approximately 30 measurements in four different nests.

Westerskov (1956) measured the incubation temperature of pheasants by the use of a potentiometer recorder. He placed the thermocouple in the center of the nest on top of the eggs but not in contact with the brood patch of the incubating hen. Measurements were made in a single nest from three to five times daily throughout the incubation period, and the average temperature during the attentive phase was 36.1° C (96.98° F). Holstein (1944) in his study of Danish birds of prey learned that the incubating bird does not warm the nesting material appreciably and that the nesting material assumes the air temperature up to the eggs. By thermoelectric measurements he determined that the internal egg temperature during incubation was approximately 4.8° C (8.6° F) more than the mean of the bird's temperature plus the air temperature. However, his studies were conducted with tree-nesting species. Measurements made during the present study with pheasants indicated that the temperature of the nesting material beneath the egg

was within approximately 1.5° C (2.7° F) of the temperature of the egg during incubation.

Koch and Steinke (1944) found that the body temperature of the domestic goose and the temperature at the dorsal surface of the egg varied from 0.5–0.7° C (0.9–1.3° F). Data in this paper deal with the egg temperatures of the Ring-necked Pheasant during the attentive phase of incubation and with the relationship between the average daily egg temperatures during the attentive period and the stage of incubation. The incubation temperatures were taken with a thermocouple attached to the small end of the egg. Data were collected during a study that was made to determine some effects of weather on pheasants during the reproductive season. A more complete coverage is given in my doctoral dissertation (Kessler, 1959).

METHODS AND MATERIALS

Most of the previous investigators measured the egg temperatures by inserting the measuring device through the shell. This method has the disadvantages of destroying the embryo and of introducing foreign matter into the egg. A method of measuring egg temperature was needed whereby the temperature could be measured without destroying the embryo, a method that could be used with the same egg throughout the entire incubation period.

Kossak (1947), in his work with geese, attached the thermocouple to the outside of the shell with tape. The same method was employed in the present study except that the thermocouple junction was glued to the egg.

A Leeds and Northrup Model G–S–6000 automatic recording potentiometer was used to measure incubation temperatures. This instrument recorded temperatures consecutively from 16 different locations and was adjusted to record temperature at each consecutive location every 30 seconds. The accuracy of the instrument was 0.3 per cent of the scale range —31.8–51.65° C (—25–125° F), and it had a sensitivity of 0.06° C (0.1° F). The machine was installed in a shelter near the center of the study area, and 24-gauge copper constantan thermocouples with extruded nylon insulation were extended to the nests under observation. Some of the nests studied were located over 300 feet from the recording instrument.

The study was conducted during 1955 and 1956 at the Delaware Farm Game Experiment Station near Delaware, Ohio. The study area was a five-acre plot, which was fenced with eight-feet-high poultry-mesh

fencing. The cover consisted of alfalfa and red clovers, timothy, and weeds.

The experimental stock consisted of Ring-necked Pheasants *(Phasianus colchicus torquatus)* from the Urbana State Game Farm located near Urbana, Ohio. The stock was brailed and released during March of each year of the study, and approximately 100 hens and 10 cocks were used each year. With the onset of the nesting season, the area was searched daily for nests, and when a nest was found before incubation of the clutch had started, a thermocouple was attached to the small end of an egg. A complete record of egg temperature for that egg throughout the entire incubation period was obtained.

Preliminary experiments were conducted to determine whether there was a difference between the temperature inside the egg and the temperature on the outside of the shell. This was done by using two thermocouples. A thermocouple junction was attached to the outside of the shell with Duco household cement; another thermocouple was inserted through a hole into the interior of the egg, and the hole around the thermocouple was sealed with Duco household cement. The egg with the two thermocouples was placed in a nest, and a hen was allowed to incubate. Simultaneous internal and external measurements showed an average difference of less than two degrees C between the temperatures measured internally and those measured externally. The external temperatures measured on the shell were usually lower. Kossak (1947) found that the shell temperature averaged approximately 0.4° C (0.7° F) less than the internal egg temperature.

Various locations of attachment of the thermocouple to the outside of the egg were tried, but measurements made with the thermocouple junction cemented to the small end of the egg corresponded most closely to the internal measurements. With the thermocouple in this location, the egg rotated freely in the nest, and the thermocouple junction did not touch the hen's body or the nesting material. This external placement of the thermocouples did not appear to interfere seriously with incubation, because most of the eggs with attached thermocouples hatched.

The egg temperature was recorded in each nest at eight-minute intervals throughout the entire incubation period. This means that approximately 170 measurements were used to compute each daily average temperature for each hen and that approximately 4,000 measurements were used to compute the over-all average egg temperature for any one hen during the entire incubation period. A study of the positions of the eggs during the incubation period revealed that the

eggs were shifted many times daily. By numbering the eggs in a clutch, their position could be determined each time the hen was off the nest. In several instances when a certain egg was at the periphery of the clutch, it was near the center when examined the next time, or vice versa. Shifting of the position of the eggs appeared to be as noticeable in large clutches (10 eggs or more) as in small ones. The important consideration here appeared to be that, due to the change in position in the nest, the incubation temperature for any particular egg varied from time to time throughout the incubation period and in no way could be considered constant. The temperature for any given egg, once the hen had been covering the clutch for a time sufficient for the eggs to reach incubation temperature, depended largely on the location of the egg within the nest. The temperature difference between the eggs in the center and those at the periphery of the nest varied widely; however, the difference was usually less than 2.75° C (5° F). The eggs in the center of the clutch came into contact with a larger surface of the hen's body than did the eggs near or at the periphery of the nest. The eggs near the outside of the nest may not have touched the hen's body at all, or they may have come into contact only with her feathers. In some instances the eggs were partially or entirely exposed.

Temperatures of two eggs in the same nest were recorded 30 seconds apart by using two consecutive points of the recorder. The clutch used was in the 18th day of incubation and contained nine eggs, of which seven hatched, including the two to which the thermocouples were attached. The maximum temperature difference recorded between the two eggs during this period was 2.75° C (5° F); however, the difference was usually 1–3° C (1.8–4.8° F).

RESULTS

In 1955, complete records during the entire incubation period were made of the temperatures of one egg in each of five clutches. Five similar records were also made in five clutches during 1956.

Mean egg temperatures for the entire incubation period for each of the 10 clutches were calculated. Only the measurements taken when the hens were on the nests were used. During 1955, the mean temperature of the egg to which the thermocouple was attached in each of the five nests under observation was 36.8° C (98.3° F), 36.1° C (97.0° F), 35.7° C (96.3° F), 35.1° C (95.1° F), and 34.5° C (94.0° F); and, during 1956, the averages in each of the five nests under observation were 36.3° C (97.3° F), 35.7° C (96.2° F), 34.8° C (94.5° F), 34.6° C (94.2° F), and 33.3° C (92.0° F).

Westerskov (1956) found that the average incubation temperature, which he defines as "the temperature immediately above the eggs," was 36.1° C (96.9° F).

Table 20 in my dissertation (Kessler, 1959) shows the average daily temperatures of one egg in each of 10 different nests during the period of incubation. Egg temperatures when the hen was off the nest were not used in determining these averages.

The relationship between the mean daily egg temperature and the stage of the incubation period was investigated by using a parabolic regression.

The incubation temperature shows no consistent variation from nest to nest and is parabolic with time in only three of the 10 clutches under observation. In these three instances, the highest average temperatures occurred on the 12th, 13th, and 14th days, respectively, with relatively lower average daily egg temperatures at the beginning and end of the incubation periods.

Farner (1958) determined that the incubation temperature (*i.e.*, the temperature measured at the interface between the incubation strip and the egg) in the Yellow-eyed Penguin *(Megadyptes antipodes)*, a species with an incubation period of about 42 days, increased gradually from 20–25° C (68–77° F) during the first two days to a maximum of about 38° C (100.4° F) at 15 days and that this maximum was maintained throughout the remainder of the incubation period. He also found a gradual decrease in the temperature gradient between the upper and lower surfaces of the egg to a level of about 5–8° C (41–46° F) during the latter half of the incubation period. Westerskov (1956), in the single clutch that he observed, found that the incubation temperature rose from 34.5° C (94.1° F) at the beginning of the incubation to 36.0° C (96.8° F) at the end; an increase of 3.5° C (6.3° F) between the onset of incubation and hatching.

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CONCLUSIONS

1. The temperature of an egg, once the hen had been incubating a sufficient length of time for the eggs to reach incubation temperature, appeared to be influenced by its location within the clutch. The highest temperatures were recorded when the eggs were in the center of the clutch, and the lowest when the eggs were at the periphery of the clutch.

2. Egg-temperature measurements were made every eight minutes throughout the incubation period of 10 hens—five hens during 1955 and five during 1956. The mean egg temperature measured during the attentive phase of incubation was calculated for each of the 10 clutches under study. The means of all recordings during the attentive phase were: in 1955, 36.8° C (98.3° F), 36.1° C (97.0° F), 35.7° C (96.3° F), 35.05° C (95.1° F), and 34.5° C (94.0° F); in 1956, 36.3° C (97.2° F), 35.7° C (96.2° F), 34.8° C (94.6° F), 34.6° C (94.2° F), and 33.3° C (92.0° F).

3. The relationship between the mean daily egg temperature and the stage of incubation was investigated by attempting to fit a parabolic regression to the data. The regression showed the temperature was a parabolic function of time in only three of the 10 clutches. If there was a parabolic or a linear relationship in the other seven clutches, it was not demonstrated by the data, since there was no consistent pattern from nest to nest.

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