Effects of Different Preincubation Temperatures on the Hatchability of Pheasant Eggs

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Although there has been much speculation as to the cause of widespread failure of pheasants, *Phasianus*,[1] to become established in the southern United States, no field studies of the limiting factors in or near the unoccupied zone have been reported. Climatographic studies have given evidence that the breeding ranges of several introduced birds may be limited by meteorological influences. Twomey (*6*) showed similarities of temperature and rainfall in the European and North American ranges during breeding seasons of the European skylark, *Alauda arvensis*, and the Hungarian partridge, *Perdix p. perdix*. Bennitt and Terrill (*2*) reported that the southern limit of pheasant range east of the Great Plains follows closely Thornthwaite's line separating microthermal from mesothermal climates. Graham and Hesterberg (*4*) showed that means of temperature and rainfall in different parts of the optimum pheasant range in the United States are very similar during April and May, when the peak of nest establishment occurs, even though they may be at wide variance during the remainder of the year. These authors postulated that in southern latitudes very young pheasant embryos are killed by intense insolation of the exposed eggs while the clutches are being laid.

In the north-central region, highest pheasant populations occur in the northern tier of states and in the northern parts of Iowa, Illinois, Indiana, and Ohio. Hatching there usually reaches a peak during the first 3 weeks of June (often followed by another peak when a large portion of the early nesting attempts are unsuccessful) and continues at a declining rate until late summer (*1*). Brood studies since 1937 in central Illinois, near the southern limit of range, frequently have shown a sharp decrease of successful hatches and in number of young per brood about the first week in July. Nest studies indicated that this decrease is chiefly the result of a decline in hatchability of the eggs. For example, in 1947 and 1948, 68 (42.6%) of the 147 fertile eggs in 16 nests where some young hatched after July 1 contained dead embryos, usually at a very early stage of development. A number of subnormal young which died in the nests or soon after leaving them have been found in late hatches also. This study will be reported more fully elsewhere.

In hatchability studies at Urbana in 1948 and 1949, eggs of the bobwhite *Colinus virginianus* were compared with pheasant eggs by simultaneous exposure to the same range of experimental conditions. This comparison was believed useful because the bobwhite breeds in suitable habitat both inside and outside the Illinois pheasant range, and its breeding cycle grossly resembles that of the pheasant.

Fresh-laid pheasant and bobwhite eggs were obtained from the breeding pens of the Illinois Department of Conservation for these studies. Samples of 60 pheasant eggs laid in mid-June, 1948, failed to hatch after 14 days' exposure in shade to air temperatures varying from 51° F to 88° F, mean 72.3° F, and recorded relative humidities of 34%–100%, without prolonged rainfall or drought. Bobwhite eggs so exposed showed no apparent decline of hatchability after 19 days, nor did bobwhite eggs exposed to an additional 30 min of solar radiation in midday for 5 days. Low retention of hatchability by pheasant eggs and high retention by bobwhite eggs were also found in each of several outdoor exposures of 10 days or more in late June and early July, 1949.

Pheasant and bobwhite eggs laid on May 31, 1949, were used in a controlled experiment to test the effect on hatchability of air temperatures normally experienced in late spring in central Illinois. Fertility shown by Kocsin's method (*5*) was above 95% for both species. It was assumed from observed growth and survival of wild and game farm birds that vigor of the embryos of both pheasants and bobwhites at this time would be high. Paired lots of pheasant and bobwhite eggs were placed in 4 small electric incubators without forced draft (*7*) and exposed continuously from 8 A.M. to 5 P.M. for 7 days prior to incubation, to 4 different temperatures from 73° F to 88° F. Because the average time of clutch-laying is approximately 12 days for pheasants and 18 days for bobwhites, the 7-day exposure was used to test the effect of temperature on eggs laid midway in the production of clutches. The eggs thus exposed were kept in a temperature control chamber at 62° F during the remaining 15 hr of each day. Controls were kept continuously at 62° F. Relative humidity of 65% was constant. All eggs were turned twice daily.

Incubation of these exposed and control eggs indicated (Table 1) that the hatchability of pheasant eggs was reduced by heat exposures, the reduction increasing with the higher temperatures. As was found previously in eggs from late wild nests, about 70% of the dead pheasant embryos in the heat-exposed eggs died prior to

TABLE 1

HATCHABILITY OF PHEASANT AND BOBWHITE EGGS EXPOSED TO DIFFERENT PREINCUBATION TEMPERATURES

Temperature	No. fertile pheasant eggs	Hatchability, %	No. fertile bobwhite eggs	Hatchability, %
Controls (62° F)	40	75.0	42	76.2
73° F	39	64.1	39	79.5
78° F	42	64.3	39	69.2
83° F	37	45.9	40	75.0
88° F	38	42.1	38	68.4

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[1] Hybrids believed mainly of *P. t. torquatus*, native to eastern China and northern Indo-China, and *P. c. colchicus* of western Transcaucasia are widely distributed in the United States north of latitude 40°. In the Pacific Northwest, *P. t. torquatus* is found quite pure in certain regions (*3*).

the 48-hr stage. No significant reduction of hatchability of the bobwhite eggs by high temperatures was evident.

It seems probable that vulnerability of pheasant embryos to air temperature during the laying period has an important influence in limiting the southern distribution of pheasants. Pheasants reported breeding locally in the southern Pacific Coast and Rocky Mountain regions may be predominantly of southern Asiatic origin, and possibly thus more tolerant of higher temperatures.

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Distribution of Absorbed Energy around a Point Source of β Radiation[1]

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The radiation dose delivered to tissue by sources of β radiation distributed through the tissue is easily computed in the interior of a uniform distribution in homogeneous tissue (*1*). The energy delivered to the tissue per second is just the energy emitted by the β radiation per second. Moreover, on the edge of such a homogeneous distribution, at a surface facing tissue free of β emitter, the dose is just half that at the interior. These two simple statements exhaust the generally available information on the distribution of tissue dose caused by β emitters. In order to compute the absorbed energy (or observed ionization) about an arbitrary distribution, it is necessary to know the spherically symmetrical function which gives these quantities as a function of distance from a point source of β radiation in absorbing material.

The direct measurement of the radial ionization function around a point source presents a difficult experimental problem. If attempted in unit density material, the spherical isoionization surfaces will not conform to a practical ionization chamber. If attempted in air, the scattering off the source, external objects, and the ionization chamber will be sources of error, as well as absorption in the walls of the ionization chamber. By using a plane source and plane ionization chamber in unit density material, these difficulties can be avoided. The method is based on the fact that the ionization per cc (I_V) in a vanishingly small cavity in an absorbing material traversed by a flux of ionizing radiation is related to the energy absorbed per cc (E_V) by the equation

$$I_V = E_V/\rho W,$$

where ρ is the stopping power of the absorbing material relative to the gas in the cavity, and W is the average energy per ion pair formed in the gas of the cavity for the ionizing particles (*2*).

Consider now a point source of β radiation in an "infinite" (i.e., larger than the maximum β range) block of unit density absorbing material of low atomic number. Let the energy absorbed in a very thin spherical shell around the point source be

$$4\pi r^2 I(r)\,dr \text{ energy/disintegration.}$$

Then the total energy absorbed per distintegration is the average β particle energy

$$\overline{E}_\beta = 4\pi \int_0^\infty r^2 I(r)\,dr.$$

By straightforward integration of $I(r)$, and using the first equation given, it follows that the ionization that will occur in a very thin, plane air gap parallel to a very thin, plane source in a large block of material is given by

$$D(z) = \frac{2\pi\sigma}{\rho W}\int_z^\infty r I(r)\,dr \text{ ion pairs/cc,}$$

where σ is the surface intensity of the source in disintegrations/cm^2, and z is the perpendicular distance from the source to the air gap. It is easy to show that

$$\sigma = 2\kappa\rho W/\overline{E}_\beta, \qquad \text{where } \kappa = \int_0^\infty D(z)\,dz.$$

It follows that the point source function can be obtained from the equation

$$I(r) = \frac{\overline{E}_\beta}{4\pi\kappa}\,\frac{1}{r}\left(-\frac{dD}{dr}\right) \text{ (energy/disintegration)/cc.}$$

Thus we have an explicit method of computing the radial energy absorption about a point source of β radiation, if measurements are made of the ionization normal to a very thin source. It is seen that $D(z)$ may be arbitrarily multiplied by any constant without affecting the value of $I(r)$. As a result, only relative ionization measurements need be made. Moreover, the numerical value of ρ and W do not enter into the calculation of $I(r)$, to the extent that they are independent of the energy of the β particles.

The experiment has been performed with radioactive phosphorus. Sources not thicker than 0.05 mg/cm^2 were prepared by spraying a solution of P^{32} onto a plane block of polystyrene with a penicillin nebulizer. The absorbing material was sprayed carbon of about 0.1 mg/cm^2, nylon of about 1 mg/cm^2, and polystyrene from 2 to 10^4 mg/cm^2. Measurements were made in a parallel-plate ionization chamber of variable air gap, using a vibrating reed electrometer.[2] The electrodes were carbon-sprayed onto

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[1] This work was done in part under contract with the Atomic Energy Commission, and in part with the support of the Committee on Growth of the American Cancer Society.

[2] The basic design of the ionization chamber used is that of G. Failla and N. Baily, of the College of Physicians and Surgeons, New York City. The instrument was designed and constructed by the Instruments Branch, Medical Division, New York Office, AEC (H. D. LeVine, chief, and H. J. DiGiovanni, assistant chief).