

oder minder regelmässig vollziehenden kurzperiodischen Massenwechsel (vgl. oben z. B. den obenbesprochenen Populationsschwund der Sumpfmiese vom Sommer 1949 [1948?] zum Sommer 1950; vgl. auch die entsprechende Erscheinung, bei den Hühnervögeln, *Tetraonidae*, SIIVONEN 1949, p. 94 und 1952 b, p. 53) müssen sie in erster Linie als zufallsbedingt gedeutet werden. Die durch regionale Bestandesverschiebungen bedingten Veränderungen der Populationsdichte, es möge sich dabei um zufällige oder mit dem kurzperiodischen Massenwechsel verknüpfte Erscheinungen handeln, scheinen ihr relativ grösstes Mass einerseits in der Peripherie der Verbreitungsgebiete und andererseits auf weniger zusagenden Biotopen zu erreichen (SIIVONEN 1942, p. 24; 1949, p. 95; 1952 c, p. 9).

Literatur: KERANEN, J., 1952, *Fennia* 75. — SIIVONEN, L., 1936, *Kuopion Luonnon Yst. Yhd. julk. Sarja B*, 1. N:o 9: 1—95. — 1941, *Ann. Zool. Soc. Zool.-Bot. Fenn. Vanamo* 8, 6: 1—40. — 1948, *Ornis Fenn.* 25: 37—56. — 1949, *Ibid.* 26: 86—97. — 1950, *Ibid.* 27: 68—72. — 1952 a, *Fennia* 75. — 1952 b, *Sveriges Natur* 43, N:o 1 A: 49—56. — 1952 c, *Luonnon Tutkija* 56: 6—10.

On the dependence of standard metabolism upon environmental temperature in the Yellow Bunting (*Emberiza citrinella* L.), and the Ortolan Bunting (*E. hortulana* L.).

Preliminary report.

HENRIK WALLGREN

The great importance of peculiarities in metabolism and temperature tolerance in the ecology of various birds has been experimentally demonstrated by KENDEIGH (1934, '38, '44, '45, '49), SEIBERT (1949), KOSKIMIES (1950), and others. SEIBERT's paper shows that differences of this kind may be factors of fundamental significance in bird migration.

Prof. P. Palmgren suggested to me that a thorough comparative analysis of closely related migrant and non-migrant birds might make it possible to separate and examine the factors regulating migration. As suitable subjects for study he suggested the Yellow

Bunting (*Emberiza citrinella* L.), and the Ortolan (*E. hortulana* L.). In Finland the former is a partial migrant, but winters in considerable numbers and is a decided non-migrant in Central and Western Europe: the latter is a typical migrant throughout its range in Europe and Asia. Otherwise they seem to resemble each other closely biologically.

The program for some preliminary investigations was briefly as follows: 1. Influence of different environmental temperatures on energy production and water loss. 2. Limit of tolerance towards cold. 3. Onset of physical heat regulation. 4. Temperature at which immediate danger of hyperthermy occurs. 5. Minimum metabolism under standard conditions. 6. Respiratory quotient (R. Q.) during fasting. 7. Time required for starved birds to reach a post-absorptive condition.

The experiments were carried out during the period 14. X. 1950—20. IV. 1951. One adult and four young Yellow Buntings, and eight young Ortolans served as experimental animals. The young birds were taken from the nests at an age of 10 days and raised during summer 1950. In control experiments, 4 wild Yellow Buntings, trapped in February and March, were used. These birds were kept all the time at natural outdoor temperatures, whereas the laboratory birds were at room temperature (+ 17—20° C). — During February, 3 Ortolans lost part of their plumage and were used for experiments in which the effect on their metabolism of the diminished insulation was determined.

The experimental procedure was a slight modification of HALDANE'S (1892) method. For the determinations of the R. Q. a small respiratory chamber was used, which could be weighed with the bird inside. The experiments at varying environmental temperatures, which only involved the determination of the CO₂ production and water loss of the birds, were performed with a cylindrical chamber (6.8 l). Within this, the birds could sit in a natural posture, either on the bottom or on a perch. The chamber was completely blacked out and the movements of the birds were recorded electrically. Before each experiment the birds were kept for four hours without food. During this time the R. Q. of both species settled at values about 0.7, indicating the oxidation of fats. 1/2 hour periods were used and all CO₂ and water determinations during which the experimental animal showed activity were eliminated. The experiments were

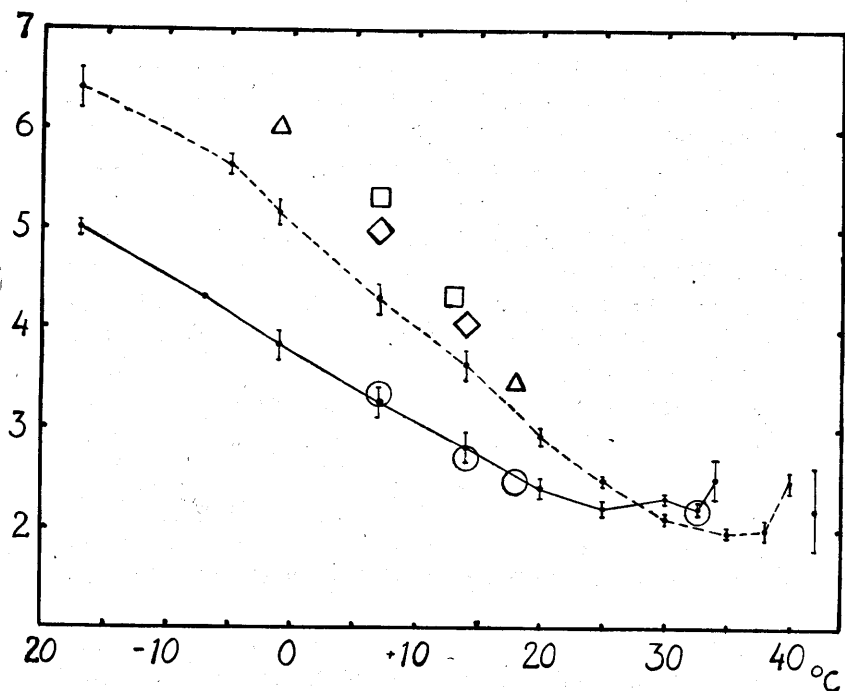


Fig. 1. CO_2 production of the Yellow Bunting (—), and the Ortolan (---) at varying environmental temperatures in mg/g body weight/ $1/2$ hour. Vertical stretches = double standard deviation. Circles = metabolism of wild Yellow Buntings. Individual signs for the metabolism of the Ortolans with defective plumage. — The material consists of 125 periods with laboratory Yellow Buntings, 46 with wild Yellow Buntings, 151 with normal Ortolans, and 26 with plumage-defective Ortolans.

carried out at night, between 8 p. m. and 1.30 a. m. AS BERGMAN (1950) has shown, this is the time when Yellow Buntings most regularly sleep.

The results are summed up in the graphs. The standard deviation is very small and the results of experiments at different temperatures and with both species support each other in a manner that seems to me to offer a satisfactory basis of comparison. Attempts were made to determine the temperature at which the physical heat regulation becomes continuous. The values were $+34-35^\circ\text{C}$ in the Yellow Bunting and $+40-41^\circ$ in the Ortolan.

Unfortunately, it was not possible to carry out experiments at temperatures lower than -17°C . It seems, however, that the limits

of the Ortolan's tolerance of cold had already been passed, because there was a fall in the rectal temperature of the birds (from $+41.1$ to $+34.6^{\circ}\text{C}$ during a 6-hour experiment). As an after-effect of cooling, the resting Ortolan can increase its energy production to 3.5 times the minimum value at thermal neutrality. In all probability the Yellow Bunting has about the same capacity for increasing its metabolism. The graph showing the dependence of its energy production upon environmental temperature hardly deviates from the straight line (cf. e. g. GIAJA 1925, TERROINE & TRAUTMAN 1927, KENDEIGH 1938, 1944). If this curve were extrapolated, it would reach the same maximal value as that of the Ortolan at about -36°C . An approximate estimation based on the results of the experiments indicates the Yellow Bunting tolerates temperatures between $-36 - +34^{\circ}$ and the Ortolan between $-15 - +40^{\circ}$. In the former the zone of thermal neutrality is about $+25 - +32.5^{\circ}$, in the latter $+32 - +38^{\circ}$. Thus the Yellow Bunting seems to be able to survive at temperatures 20°C below the Ortolan's limits of tolerance of cold, while the Ortolan has 6° in its favour at high temperatures.

The metabolism of the wild Yellow Buntings showed no significant deviation from that of the laboratory birds. This fact suggests that the condition of the latter was satisfactory. The result is interesting, considering that the wild birds were kept at 0°C and temperatures below that, whereas the laboratory birds were living at a fairly stable temperature about $+20^{\circ}$.

The great dissimilarity in the temperature tolerance of the two species is presumably mainly due to differences in insulation. This was indicated by the high metabolism of the Ortolans with defective plumage. Similar results have been described for instance by BARBOUR (1921), GIAJA (1925), BENEDICT & FOX (1932), and KENDEIGH (1934). By photographing a Yellow Bunting and an Ortolan of exactly the same weight from the same distance and $+20^{\circ}\text{C}$, and -5.5°C , drawing their silhouettes and measuring the dimensional differences, it was possible to roughly calculate the volume and the mean thickness of the plumage. The result was as follows:

		Mean thickness of plumage	Volume of plumage
Yellow Bunting	-5.5°	6.02 mm	54.8 ccs.
"	$+20^{\circ}$	4.38 "	38.7 "
Ortolan	-5.5°	3.24 "	30.7 "
"	$+20^{\circ}$	1.74 "	16.7 "

These figures are presented without any claim to accuracy. Yet the values obtained indicate the magnitude of the differences. It is evident that the Yellow Bunting is much better protected against heat loss than the Ortolan. In winter, the Yellow Bunting passes the night in dense, snowcovered shrubberies. The Ortolan does not show behaviour of such adaptative value. The way of spending the night increases the advantage of the former, when the strains of a severe climate are to be endured. On the other hand, one indication of the better heat tolerance of the Ortolan is clearly given by the fact that it nests considerably farther south than the Yellow Bunting.

During the prevailing climatic conditions, autumn migration evidently necessary for the existence of the majority of Ortolans. The Yellow Buntings can winter within their nesting region except for the northern and northeastern parts, provided that sufficient amounts of food are obtainable. The NEboundary of their winterrange runs from the mouth of the Dvina in the White Sea to the plains west of the Altai and hence crosses the parallels and the January isotherms obliquely. This confirms KENDEIGH's (1934) statement that the critical effect of low temperatures upon birds is exerted by the average night temperature in conjunction with the number of hours of darkness. The same combination seems to be of great importance in the present autumnmigration habits of the Ortolan, perhaps not as a directly releasing stimulus, but as a factor in the phylogenetic development of the physiological rhythm of the species. The southern boundary of the occurrence of the two species as nesting birds seems to be influenced in an important manner by high environmental temperatures, but whether the mean or the maximum temperatures are of greater importance in this connection is not as yet clear. In any case it seems evident that physiological differences of the kind described above must have a great influence on the distribution and migration habits of these species.

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