Interpretation of regional differences in Sage Grouse body weight is difficult. Although regional differences occur, weight relationships between age and sex classes and seasons are similar; yet absolute differences vary as much as 24% from North Park weights (which were the highest). Lower weights reported may result from regional differences in populations and/or habitat quality. The relationship of habitat to body weight should be investigated in association with survival rates. Weight data from a specific region or population should not be extrapolated to other Sage Grouse populations. The marked seasonal differences in body weights throughout Sage Grouse range hinder the use of weight as a comparative parameter among populations.

SUMMARY

Weights of Sage Grouse from North Park, Colorado are presented. Yearling and adult males and females gained weight during late winter (January–March). Males were heaviest prior to onset of breeding activities, with adults having greater weight losses than yearlings during the breeding period (April–May). Females of both age classes gained weight through the breeding season. Lowest weights for both age classes of males and females occurred in summer and early fall (June–September).

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BODY TEMPERATURE AND HEART RATE OF THE SNOWY OWL

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The Snowy Owl (*Nyctea scandiaca*) is a permanent resident in the arctic tundra of North America and Eurasia. Besides the Snowy Owl, the Common Raven (*Corvus corax*), the Rock Ptarmigan (*Lagopus mutus*), the Willow Ptarmigan (*L. lagopus*) and occasionally the Common Redpoll (*Carduelis flammea*) and the Gyrfalcon (*Falco rusticolus*) inhabit the arctic tundra in winter. When food is available, the Snowy Owl may live farther north than these other birds. It has been seen 82°N on Ellesmere Island (Hart 1880) during winter months. Eskimos report seeing the owls on Banks Island in the Canadian Archipelgo in winter (Manning et al. 1956). The bioenergetics of captive Snowy Owls during an arctic winter was reported earlier (Gessaman 1972). This report explores the precision of body temperature regulation and the pattern of heart rate variation of captive Snowy Owls living outdoors in Alaska during winter.

METHODS

The body temperature (T_B) of one female Snowy Owl living in an outdoor aviary (13.4 m $\times$ 7.3 m $\times$ 4.3 m) at the Naval Arctic Research Laboratory, Barrow, Alaska, was recorded by radio telemetry for 19 days in December, 1966. In January 1973, T_B and heart rate (HR) were telemetered from three female Snowy Owls living in the same aviary.

The birds were removed from the aviary where they had lived for more than one year and taken indoors. They were anesthetized with an injection of sodium pentabarbital (0.9 cc/kg body weight) or Ketamine hydrochloride (0.9 cc/kg body weight) into the muscles at the base of one wing. A temperature transmitter, after being sterilized in alcohol and rinsed in distilled H_2O, was placed in the abdominal cavity of each owl through a 5 cm midventral incision which terminated 2.5 cm from the anal papilla. The transmitter was firmly tied to the interior surface of the flaps of skeletal muscle bordering the incision, in order to stabilize it in the cavity. In addition, in 1973, a pair of electrodes was surgically implanted in the sternum of each of the three owls and was connected to an ECG transmitter (Narco Bio-Systems, Inc. Model E-3) harnessed on the dorsal surface of each bird. A complete description of this method was published earlier (Sawby and Gessaman 1974). The birds recovered at room temperature within 12 to 18 h and were then returned to the aviary. The gut sutures dissolved within one week, and all incisions were completely healed within 14 days.

In 1966 the temperature transmitter: (1) weighed 7–10 g, (2) was 7–8 cm^3 in volume, (3) had a battery life of about one year, and (4) had a transmission range of about 23 m. The design of this transmitter has been described by Folk (1964). In 1973 the temperature transmitters weighed 15 g and were 10 cm^3 in volume, otherwise they were similar to the transmitter used in 1966. Each temperature transmitter was calibrated in a temperature-regulated water bath. In 1966 and 1973 respectively, T_B's were recorded for 20 consecutive seconds every two minutes and for 30 seconds every six minutes each day.

The number of T_B recordings in 1966 was 9,794 and in 1973 was 1,128, 706, and 365 from owls 1, 2 and 3, respectively.

The ECG transmitter: (1) weighed 9 g (including battery and harness), (2) was 7 cm^3 in volume, (3) had a battery life of 100 h, and (4) had a transmission range of 60 m.

Electrocardiograms were recorded on a Physiograph 4 (Narco Bio-Systems, Inc.) for 5 s of every 6 min. Heart rate per minute was determined by summing the R waves within a 5 s ECG recording and multiplying that sum by 12. The number of ECG recordings taken from owls 1, 2 and 3 was 1,745, 615, and 811, respectively.

All owls were fed caribou meat ad libitum with the exception of owl 1 who was not fed during a 5-day period from 28 January to 1 February 1973.

RESULTS

Mean 24-hour body temperature. The average daily T_B for 19 days in December 1966 ranged from 40.8 to 41.1°C, the mean T_B for that period being 41.0°C. In 1973 the average daily T_B of owl 1 ranged from 39.5 to 40.0°C and the mean T_B was 39.7°C over seven days. The average daily T_B of owl 2 ranged from 39.3 to 40.5°C and T_B averaged 40.0°C over five days. The average daily T_B of owl 3 ranged from 40.8 to 41.5°C and over three days averaged 41.1°C. Average daily T_B did not correlate with the air temperature or wind speed in the aviary.

Heart rate. The average daily heart rate (beats/min) of owls 1, 2 and 3, when fed daily, ranged from 189.6 to 222.3 ($N = 7$), 131.8 to 146.3 ($N = 4$) and 131.4 to 161.0 ($N = 5$), respectively. The mean heart rate during these periods was 202.0, 145.3 and 143.7 for owls 1, 2 and 3 respectively. Average daily heart rate was not correlated with average daily body temperature or wind speed. During five subsequent days of starvation, the mean daily heart rate of owl 1 was lowered and ranged from 161.4 to 176.5. The average daily heart rate of owl 1 was 29.6% higher on 15 January 1973, than any of its daily means in the following six days. Apparently the owl had not settled down from the excitement associated with capture and electrode implantation of 24 h earlier. Heart rates of owls 1, 2 and 3 (fed daily) ranged from 130 to 380, 94 to 390 and 94 to 314 beats/min, respectively.

DISCUSSION

Mean 24-hour body temperature. Irving and Krog (1954) reported a mean (4 observations) body temperature of 40.9°C for one captive Snowy Owl exposed to air temperatures ranging from –23°C to –11°C. For 15 days in February–April 1971, Siegfried et al. (1975) monitored the T_B of one captive Snowy Owl living outdoors at 15°C for 2 days on a 12:12 photoperiod; the mean T_B was 38.5°C, and the range from 38.0 to 40.0°C. Its mean T_B indoors was 39.6°C during the light period and 39.0°C during the dark period. All the above observations and my own indicate that the mean daily T_B of any Snowy Owl varies less than 1°C, while the mean T_B among different owls may vary over a range of 2.5°C. Body temperatures of the owls did not vary in a circadian pattern.

Heart rate. The lowest resting heart rates of the three owls, computed from the equation reported by Berger et al. (1970) ($HR = 12.4 \log W^{-0.209}$ where HR = heart beats/s and W = body weight in g), were 146.3, 150.9 and 149.3 beats/min, respectively (Table 1). This equation (based on data from eight avian species ranging in weight from 11.2 to 1,440 g) produced values 12.5, 60.5 and 58.8% greater than the lowest recorded heart rate for owls 1, 2, and 3, and only 4.0% and 3.9% greater than the *mean* heart rate of owls 2 and 3. The lowest resting heart rate of the Snowy Owl is significantly ($P < .01$) overestimated by the equation. This indicates that either the equation is not accurate for birds significantly ($P < .01$) heavier than 1,440 g or that the Snowy Owl, regardless of its weight, does not conform to a body weight-heart rate relationship derived from other avian species. The former seems more likely.

I computed heart rates during flight for birds weighing 2,392, 1,928 and 2,175 g from the equation derived by Berger et al. (1970) ($HR = 25.1\ W^{-0.157}$; HR = beats/s, W = g) from data on ten avian species ranging in weight from 7.0 to 600 g. The resultant rates (443.4, 457.2 and 450.6 beats/min) were 16.7, 17.7 and 43.5% greater than the highest HR recorded for owls 1, 2 and 3, respectively. I noted the highest HR occurred during flight in owls 1 and 2; I was not observing owl 3 during its highest HR recording. The equation significantly

TABLE 1. The low, high and mean heart rates of three Snowy Owls living in an outdoor aviary at Barrow, Alaska. The low and high values are compared with the lowest predicted heart rate and the predicted flight heart rate computed from equations of Berger et al. (1970).

Snowy Owl	Condition	Mean body weight (g)	Lowest heart rate (beats/min) (A)	Mean heart rate	Predicted lowest resting HR[1] (B)	(B − A)/A × 100	Highest HR (C)	Predicted flight HR (D)	(D − C)/D × 100	C/A
1	before starvation	2,392	130	202.0	146.3	12.5	380	443.4	16.7	2.9
	during starvation	2,310	108	166.9	147.4	36.5	352	446.0	26.7	3.3
2		1,928	94	145.3	150.9	60.5	390	459.2	17.7	4.1
3		2,175	94	143.7	149.3	58.8	314	450.6	43.5	3.3

[1] See text for predictive equations.

($P < .01$) overestimates the heart rate of the Snowy Owl during flight.

Flight HR of owls 1 and 2 was 2.9 and 4.1 times greater than their lowest resting heart rate. This is similar to the observation by Berger et al. (1970) that the heart rate of large birds shifting from rest to flight increases by 3× to 4×.

The mean HR of owl 1 prior to the five-day starvation period was 202.0 beats/min and during the starvation period was 166.9 beats/min. This probably reflects a reduced level of daily activity and daily energy metabolism during the starvation period. Mean HR varies directly with mean energy metabolism (for review see Johnson and Gessaman 1973) and the similarity of the air temperature and wind speed between these two periods should have equalized the energy required for thermoregulation. The mean hourly air temperature during and before the starvation period was –30°C (ranging from –26° to –37°C) and the mean wind speed differed by only 1.5 mph between these two periods. T_B and HR of owl 1 were recorded concurrently for six days. The average daily heart rates (ranging from 190.2 to 288.2 beats/min) and average daily T_B's (ranging from 39.5 to 40.0) were not significantly correlated.

In conclusion, the Snowy Owl regulates its body temperature well in the arctic winter. Its daily patterns of body temperature and heart rate resemble those reported for other large avian species.

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