# SOME METABOLIC CHANGES IN CHIMNEY SWIFTS (<u>CHAETURA</u> <u>PELAGICA</u>) AT LOWERED ENVIRONMENTAL TEMPERATURES

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Submitted to the Faculty of the Graduate School
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in partial fulfillment of the requirements
for the degree of
DOCTOR OF PHILOSOPHY
May, 1966

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## ACKNOWLEDGEMENTS

The writer wishes to thank Dr. F. M. Baumgartner of the Department of Zoology for his guidance and suggestions throughout the course of the project. His positive attitude and encouragement has been greatly appreciated. The author is especially grateful to Dr. W. S. Newcomer of the Department of Physiology for his suggestions and help in designing the equipment used and for advice during the time of experimentation. Appreciation is expressed to Dr. G. A. Moore, Dr. B. P. Glass, and Dr. T. C. Dorris of the Department of Zoology for their help in obtaining equipment. An expression of gratitude goes to Dr. R. A. Hultquist of the Department of Statistics, who aided in the analysis of the data, and to the members of the doctoral committee who helped in the preparation and editing of the manuscript: Dr. F. M. Baumgartner, Dr. A. M. Stebler, Dr. B. P. Glass, and Dr. W. S. Newcomer. Finally, the author wishes to thank his wife and family for their patience and help throughout the course of this project.

TABLE OF CONTENTS

## LIST OF FIGURES

# CHAPTER I

## INTRODUCTION

The literature dealing with the Chimney Swift (Chaetura pelagica) contains many references concerning torpor. These birds fly rapidly and almost constantly for long periods. According to Storer (in Marshall, 1960), they can compensate for this great output of energy by becoming torpid at night. McAtee (1947) gave many accounts of inactive swifts and stated that "torpidity from brief to extended periods is possible," and that "under favorable circumstances, hibernation seems a possibility." Campbell and Campbell (1926), Prosser and Brown (1961) and King and Farner (in Marshall, 1961) referred to similar torpid states, and Berger (1961) stated that hibernation is known. Lack (1956) referred to the discovery in December of 1879 of a group of seven Chimney Swifts "stowed away" in a disused stove pipe in New York state.

In discussing torpor in birds, Huxley et al. (1939) defined torpidity as a physiological state resembling hibernation in mammals but of shorter duration. During torpidity the birds were reported to be temporarily hypothermic and were quite rigid with head drawn back and pointed up. Their eyes were closed, and they exhibited no perceptable respiratory movements. This state of hypothermia was also described by Landau and Dawe (1958) and was distinguished from hibernation in that the ability to rewarm themselves without external application of heat, possessed by hibernators, was not found in hypothermic animals.

McAtee (1947) listed many accounts of inactive birds. However, he expressed the feeling that "really sound observations sustained by actual measurements of body temperatures or rate of metabolism are extremely rare for all birds."

Since the food of C. pelagica is almost entirely insects (Bent, 1940) of the families Diptera, Homoptera, Hymenoptera, Ephemerida, and Plecoptera (Fischer, 1958), and since there are times when this food is scarce, the possibility of decreased metabolic activity on these occasions has been postulated. Koskimies (1950) in studying the European Swift (Micropus apus) and Udvardy (1954) in studying the Black Swift (Nephoecetes niger borealis) came to the conclusion that adult swifts leave an area before the occurence of an atmospheric disturbance which would tend to remove these insects from the air. Koskimies (1948) measured weight, body temperature, and metabolic rate of M. apus during fasting and found that under conditions of no food at all a temporary poikilothermy, or torpor, resulted.

Relatives of the swifts have been studied in connection with hypothermia and hibernation. Jaeger (1948, 1949, 1954), Miller (1950), Brauner (1952), Thorburg (1953), Stebbins (1957), and Howell and Bartholomew (1959) studied the Poor-will (Phalaenoptilis nutallii) and the evidences of true hibernation observed in this species; hummingbirds of various genera have been investigated in this connection (Pearson, 1950, 1953; Howell and Dawson, 1954; and Lasiewski, 1963); the White-throated Swift (Aeronautes saxatalis) has been shown to be torpid when exposed to both cold and starvation (Bartholomew et al., 1957); and Marshall (1955) gave an account of two Trilling Nighthawks (Chordeiles acutipennis) which apparently became torpid. Koskimies (1948) referred to Huxley et al. (1939) and said that Colias is able, under certain conditions, to fall into a coma.

Since many references are made to torpor in swifts and since a number of close relatives of the swift have exhibited this physiological phenomenon, this study was undertaken to determine whether the body temperature of the Chimney Swift changes during periods of lowered environmental temperatures. Investigation was also made into the metabolic rate of these birds and any changes of this rate which might be due to lowered environmental temperatures.

## CHAPTER II

## REVIEW OF THE LITERATURE

The body temperatures of many birds have been measured, and in general the relationship between the weight of a bird and its temperature has been shown to be fairly close to an inverse one. The smaller the bird, the higher the temperature. Welty(1962) made the observation that when the body temperatures of various species of birds were plotted against the logarithm of their adult weights, a linear correlation resulted. With every ten-fold increase in body weight there was roughly a decrease of 1.5° C in body temperature.

Egg temperatures have been studied (Baldwin and Kendeigh, 1932; Huggins, 1941; and Irving and Krog, 1956), and newly hatched birds have been shown to be distinctly poikilothermic (Pembry et al., 1895; Gardner, 1930; Randall, 1943; and Dawson and Evans, 1960).

Simpson and Galbraith (1905) observed that diurnal variations of the temperatures of small birds were greater than those for large birds (ducks varied 0.92° C while thrushes varied 4.27° C during a day's time). Doves were exposed to environmental temperatures of 5°, 23°, and 39° C and 24-hour records of body temperatures were obtained by

Bartholomew and Dawson (1954). The daytime temperatures of this species approximated 41.5° C and nighttime temperatures were about 2° lower. Udvardy (1955) and Irving (1955) reported studies of bird temperature variations in the Arctic and in Alaska. Irving reported on seven species of birds and found that at ambient temperatures of -9° C and -22° C the daytime body temperatures were about those reported for these species on warmer days; at night they were from 0.9° C to 4.0° C lower. Dawson and Tordoff (1964) reported that the body temperature of crossbills ranged between 38.5° and 40° C even though the ambient temperature was -15° to 28° C.

The metabolic rates of many animals have been extensively investigated. Dawson and Bartholomew (1956) compared the metabolic rates of lizards with those of shrews and hummingbirds. This comparison showed that the lizard had a very low metabolic rate (1.13 to 1.21 cc $O_2$/gm/hr) as compared to shrews (10.5 cc $O_2$/gm/hr) and hummingbirds (12.3 cc $O_2$/gm/hr). Bats, studied extensively by many investigators (Burbank and Young, 1934; Hock, 1951; and Beer and Richards, 1956, to name a few), are considered essentially poikilothermous in that at all seasons of the year their resting temperature and metabolic rate are dependent upon environmental temperatures.

In considering total metabolism, i.e. the Calories required by an animal per day, Brody and Proctor (1932) reported that for wild birds the metabolism (Q) in Calories per day is related to the weight (m) in kilograms according to the following equation:

$$Q = 89\ m^{0.64}.$$

This was also used by Scholander et al. (1950) and Brody (1945). Lasiewski (1963), reporting on resting metabolism in hummingbirds, quoted King and Farner (in Marshall, 1961) and said that the metabolism was essentially that predicted by the King-Farner equation:

$$\log \text{metabolism (Kcal/day)} = \log 74.3 + 0.744 \log \text{Wt. (Kg)}.$$

The metabolic rate, however, when the weight of the animal is considered, varies inversely with the size. In general, the larger the animal, the slower its rate of metabolism per gram of body weight (Pearson, 1950). Dawson and Tordoff (1959) gave the basal metabolic rate of the Evening Grosbeak as 2.5 cc $O_2$/gm/hr for 50 to 65 gram birds. Dawson and Tordoff (1964) reported that in winter the Red Crossbill (*Loxia curvirostra sitkensis*) had a basal metabolic rate of 3.1 cc $O_2$/gm/hr. They further stated that an essentially linear inverse relation existed between oxygen consumption and ambient temperature between $-15^{\circ}$ C and $10^{\circ}$ C; the slope of the regression line for this relation is $-0.12$ cc $O_2$/gm/hr $^{\circ}$C. The White-winged Crossbill (*Loxia leucopetra leucopetra*) had a basal metabolic rate of 2.8 cc $O_2$/gm/hr during winter and exhibited a linear inverse relation, also (the slope of the regression line being -0.11 cc $O_2$/gm/hr $^{o}C$).

# CHAPTER III

## METHODS AND MATERIALS

Swifts for this study were obtained after they had settled to roost for the night. A large chimney on the Oklahoma State University campus was used as a roosting site by many Chimney Swifts during the spring, summer and fall of 1964. A 46-ounce juice can with a bale and a long cord, as described in Fischer (1958), was used to catch the birds, but most of them were obtained by making noise low in the chimney with this can and capturing the birds as they flew to the top of the chimney. The first ones were caught either in the can or by hand as they flew by. An ordinary fishing dip net proved quite successful for capturing the birds as they flew from the mouth of the chimney.

Captured birds were held in a small cage overnight in a room away from any activity. Adult Chimney Swifts were used in this investigation.

Each bird was weighed on a platform balance and the weight was recorded to the nearest tenth of a gram. A band was placed on the bird for identification purposes.

Since the birds had not fed after entering the chimney at dusk the evening before, it was assumed that these birds were in a post-absorptive state.

Each bird was held immovable on a wire screen of one-half inch mesh in a comfortable resting position by clipping the rectrices and outer primaries to the screen with an alligator clip and tying a cord across the back of the bird twice so that the cord made a cross on the back of the bird and the shoulders and body were held firmly against the screen (Fig. 1). The struggling bird could move the proximal portion of the wing and the head, but was held securely

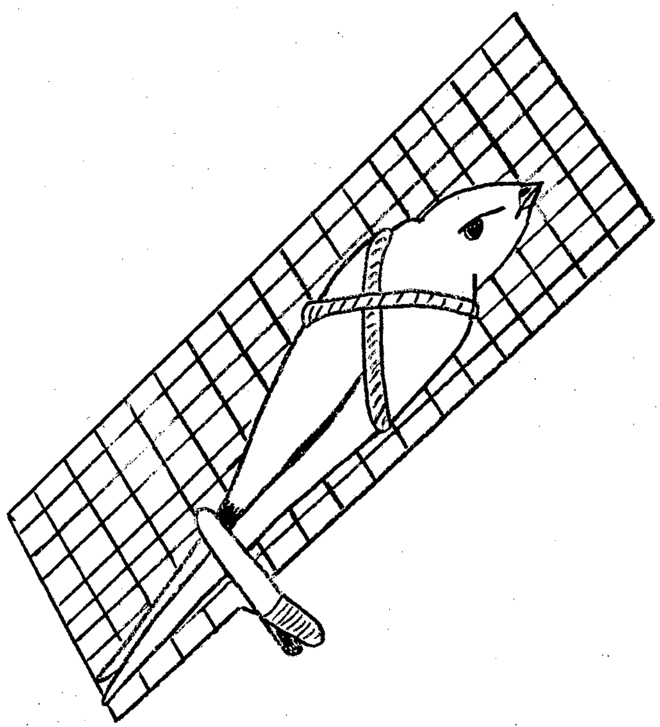

Fig. 1. The bird was rendered immovable by securing it to a screen by one or two alligator clips and ribbon.

against the screen. After one bird was injured, when the cord cut through the skin of the shoulder-neck region, a narrow ribbon was used instead of the cord and this proved more satisfactory. Any movement of head or wing was visually noted and recorded during the progress of the experiment.

The birds were placed in a closed metabolism chamber (Fig. 2) and temperature readings were made using a thermocouple inserted 10 mm into the cloaca and held in place by

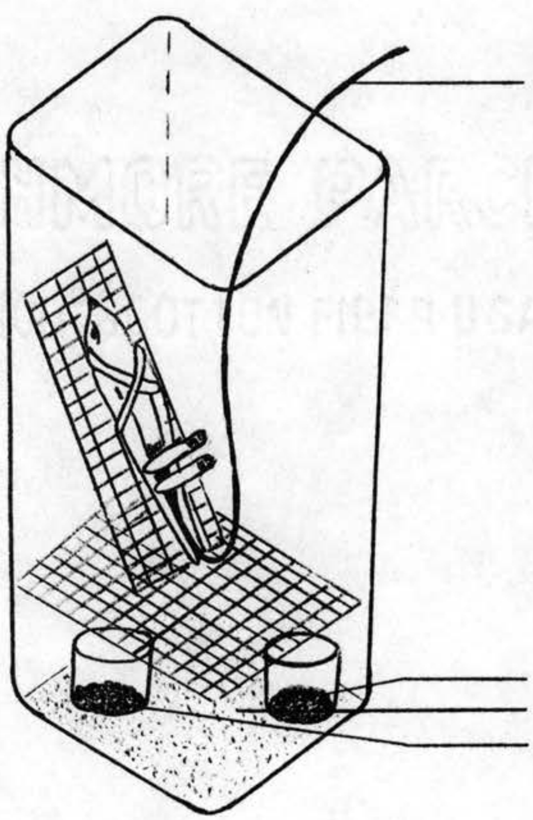


Fig. 2. A diagram of the bird in the metabolism chamber.

clipping it to the rectrices with an alligator clip. Body temperatures were determined to the nearest tenth of a degree using a Tele-Thermometer Model 40B124. No data were recorded until the bird had been in the chamber at least 30 minutes.

Both Ascarite and soda lime were used as carbon dioxide absorbents, and as the carbon dioxide was absorbed a partial vacuum was created in the metabolism chamber. This caused a change in the levels of the liquid in the arms of the "Y" tube indicator (Fig. 3). The three-way valve was adjusted

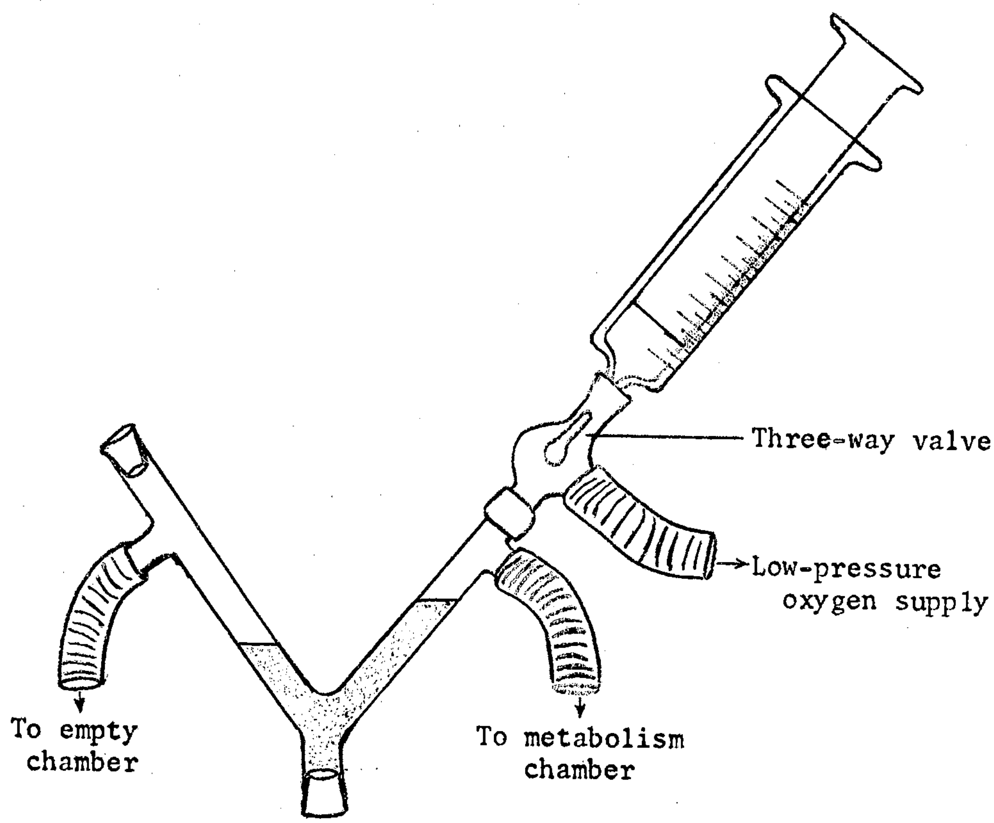


Fig. 3. A detailed diagram of the "Y" tube and the associated apparatus used to measure the oxygen added to the metabolism chamber.

so that the measuring syringe was connected to the low pressure oxygen supply and the syringe was filled with oxygen. The valve was then turned so that the syringe was connected to the metabolism chamber and the oxygen was forced into the chamber until the liquid in the "Y" tube indicated equal pressures on both surfaces of the liquid. The oxygen consumption was recorded as the number of milliliters of pure oxygen which was needed to maintain normal atmospheric pressure during a given time.

In order to minimize differences in pressure due to the changing temperature, an identical chamber was attached to the system as shown in Fig. 4. Both of the chambers were glass jars having inside measurements of 13.0 x 15.5 x 26.0 centimeters. These were clamped securely to a board and rendered air tight using rubber gaskets and a high vacuum sealer. These chambers were opened to the atmosphere at short intervals during the experimentation to insure the maintenance of a constant pressure in the chambers.

Relative humidity was controlled in the chambers by the use of calcium chloride. According to Morrison (1947), calcium chloride exposed to the atmosphere in such a chamber will maintain a relative humidity of approximately 31%.

The chambers were cooled by packing ice and salt around them. Environmental temperatures were determined by using a mercury thermometer with the bulb located approximately 8 cm from the bird (Fig. 4).

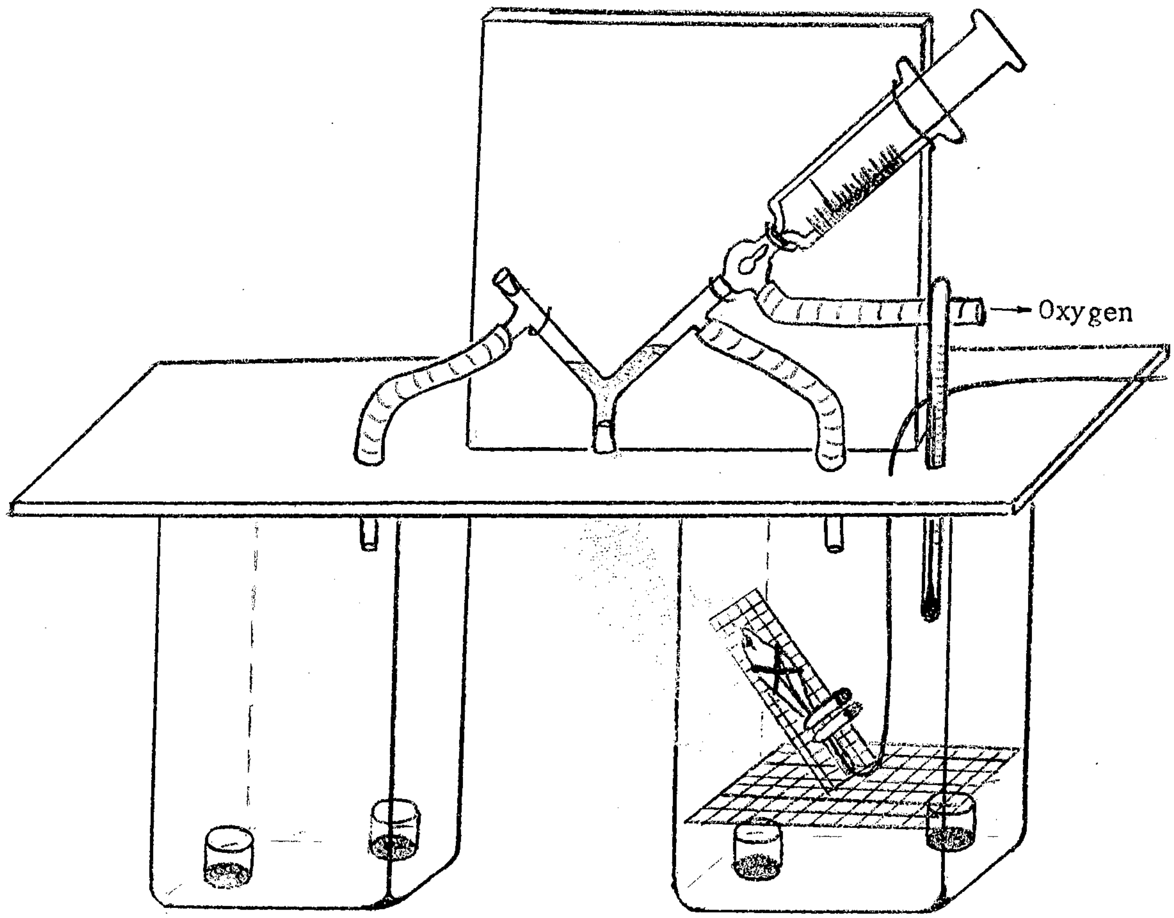


Fig. 4. A diagram of the entire apparatus showing the relationships among the various parts of the system.

Observation was continuous with periodic recording of environmental temperature, bird body temperature and oxygen added. These readings were taken at regular intervals of from one to six minutes depending upon the metabolic needs of the bird. If the indicator showed after one minute that the amount of oxygen needed to restore atmospheric pressure was slight, a reading was delayed for a longer time. Readings were continued until the bird became torpid or had been under observation for twelve hours without significant change.

Four birds were subjected to an environmental temperature of $-5^{\circ}$ C, four were held at $0^{\circ}$ C, five at $5^{\circ}$ C, five at $10^{\circ}$ C, and two served as controls and were kept at room temperature (approximately $25^{\circ}$ C) for the duration of the experiment. One bird was subjected to successive temperatures as follows: $5^{\circ}$ C for $1\frac{1}{2}$ hrs, $0^{\circ}$ C for $\frac{1}{2}$ hr, $-5^{\circ}$ C for 4 hrs. Another bird was held at $20^{\circ}$ C for 45 min, $15^{\circ}$ C for $\frac{1}{2}$ hr, and $5^{\circ}$ C for 2 hrs.

Birds were released after experimentation. Some had to be held over night and were released approximately 34 hours after being captured; others were released earlier (approximately 17 hours after capture).

Attempt was made to feed some of these birds, and five birds were held for four days in feeding trials, but they continually lost weight and died.

# CHAPTER IV

## RESULTS AND DISCUSSION

Control swifts, held at room temperature (about 25° C), showed no fluctuation in body temperature at all and there were no significant changes in metabolic rate even though the birds had had no food for at least 28 to 30 hours. Although lack of food might cause changes to be evident if continued, this period of time was sufficient to show that lack of food alone could not be the cause of variation in body temperature or changes in metabolic rate which might be noted up to 28 to 30 hours.

The body temperature of birds exposed to ambient temperatures of 10° C dropped an average of 11° C. This drop in temperature was almost immediate upon the lowering of the ambient temperature, and remained relatively stable (varying a maximum of 3° C) for a ten hour period. Oxygen consumption was not significantly changed from the basic rate established for each bird (Fig. 5).

When another group of birds was held at environmental temperatures of 5° C, their body temperatures dropped an average of 13° C. The body temperatures fluctuated much more at this ambient temperature, varying as much as 13° C and ranging from 29° down to 17° C (Fig. 6). One bird

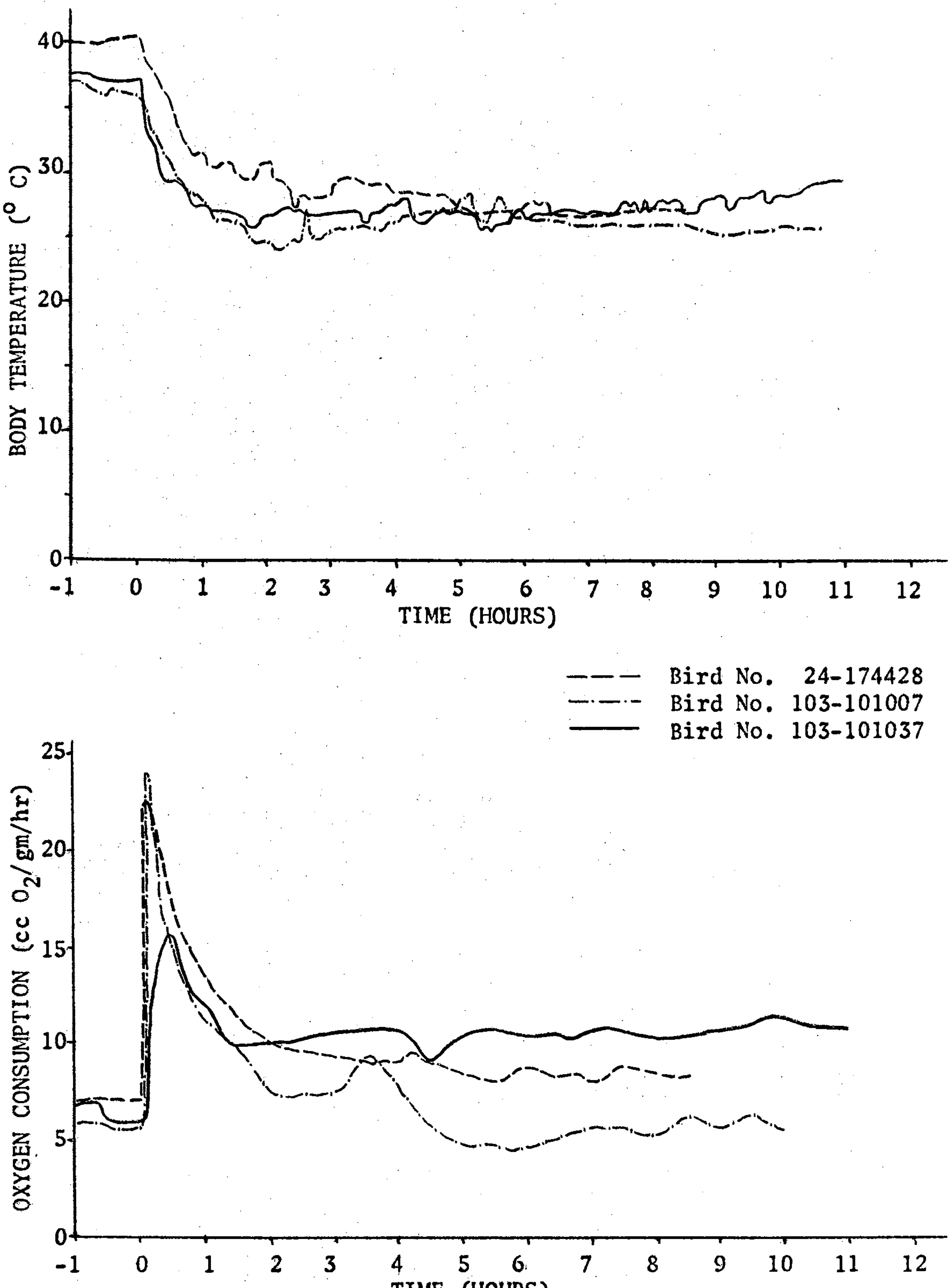


Fig. 5. Body temperature and oxygen consumption of three of the five birds which were exposed to 10° C ambient temperatures. Zero hours is the time at which ice was added around the chamber.

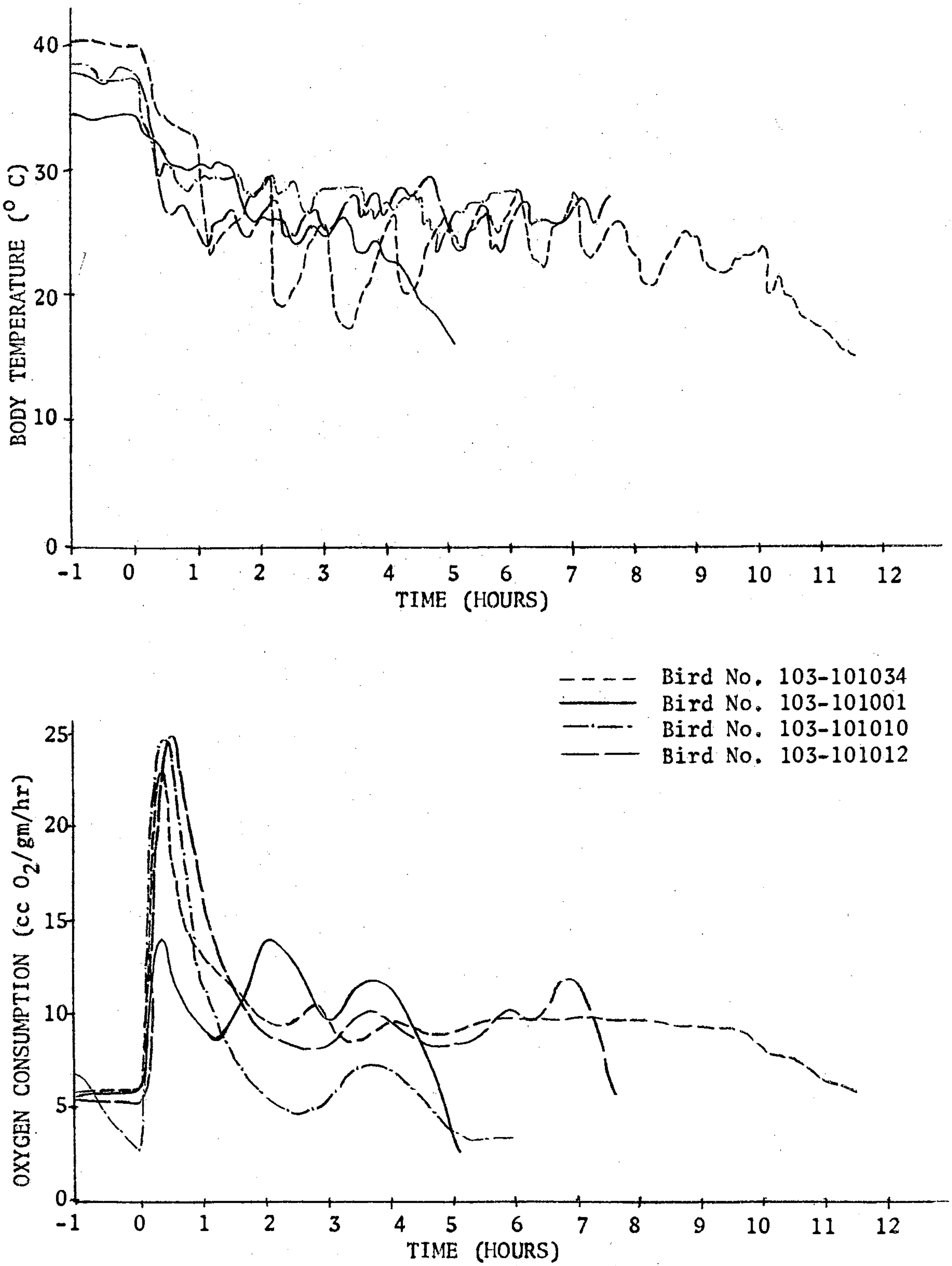


Fig. 6. Body temperature and oxygen consumption of four of the five birds which were exposed to 5° C ambient temperatures.

(103-101001) became torpid at this temperature with a body temperature of 16.2° C and an oxygen consumption of 3.53 cc $O_2$/gm/hr as compared with a body temperature of 34.5° C and an oxygen consumption of 7.21 cc $O_2$/gm/hr at an environmental temperature of 21.0° C. Another bird (103-101034) also became torpid at 5° C ambient temperature with body temperature and oxygen consumption of 15.8° C and 6.26 cc $O_2$/gm/hr respectively as compared to 40.3° C and 5.23 cc $O_2$/gm/hr respectively at 27° C ambient temperature.

Torpid birds had no respiratory movements which could be noted visually and gave little or no response to external stimuli. Their posture was hunched giving the peculiar "pointed up" tilt to the head, and the eyes were closed. The birds gradually began to recover from this torpor after a few minutes at warmer ambient temperatures. The first sign of "life" of a recovering bird was a single, slight, apparently convulsive breathing movement. These movements were repeated at closer intervals and slight shivering movements were noted. The eyes sometimes opened during this time, but responses to stimuli were slight. Breathing movements became closer together and finally a renewed lively condition was noted. All the birds which became torpid at ambient temperatures of 5° C were released after regaining their vitality at warmer temperatures. They all flew normally and each was joined almost immediately by 2 or 3 other Chimney Swifts in the area, and they flew away together. Torpidity occurred after periods of exposure to this test temperature of $1\frac{1}{2}$ hr in one animal (Unbanded "C"), 3 hrs in the second (103-101001), and only after 10 hrs of exposure in the third animal (103-101034). Two other test animals did not show torpidity at this temperature. These birds' temperatures dropped 8° to 10° C and varied around this temperature but never fell to the lower point (Fig. 6).

Three of the four birds which were exposed to an ambient temperature of 0° C exhibited torpidity and one of these torpid birds died subsequently. The fourth bird, however, had a temperature drop of approximately 20° C almost immediately and then gradually its temperature rose from about 20° C up to 28° C over a period of about 5 hours. Oxygen consumption in this bird rose from 2.89 cc $O_2$/gm/hr at room temperature to an average of 9.03 cc $O_2$/gm/hr during the period when the body temperature was rising (Fig. 7).

The birds which showed torpidity at 0° C (103-101016, 103-101031, and 103-101033) had body temperatures and oxygen consumption rates at the end of the experiment of 13.2° C, 3.0° C, and 17.6° C; and 6.55 cc $O_2$/gm/hr, 2.54 cc $O_2$/gm/hr, and 7.47 cc $O_2$/gm/hr respectively. Corresponding data at the beginning of the experiment were 38.2° C, 35.3° C, and 38.4° C; and 5.32 cc $O_2$/gm/hr, 4.43 cc $O_2$/gm/hr, and 4.17 cc $O_2$/gm/hr respectively. One of these (103-101031) had a body temperature which varied between 13° C and 8° C for a period of 1 hour and 40 minutes before its body temperature dropped to 3° C. At this point the bird was

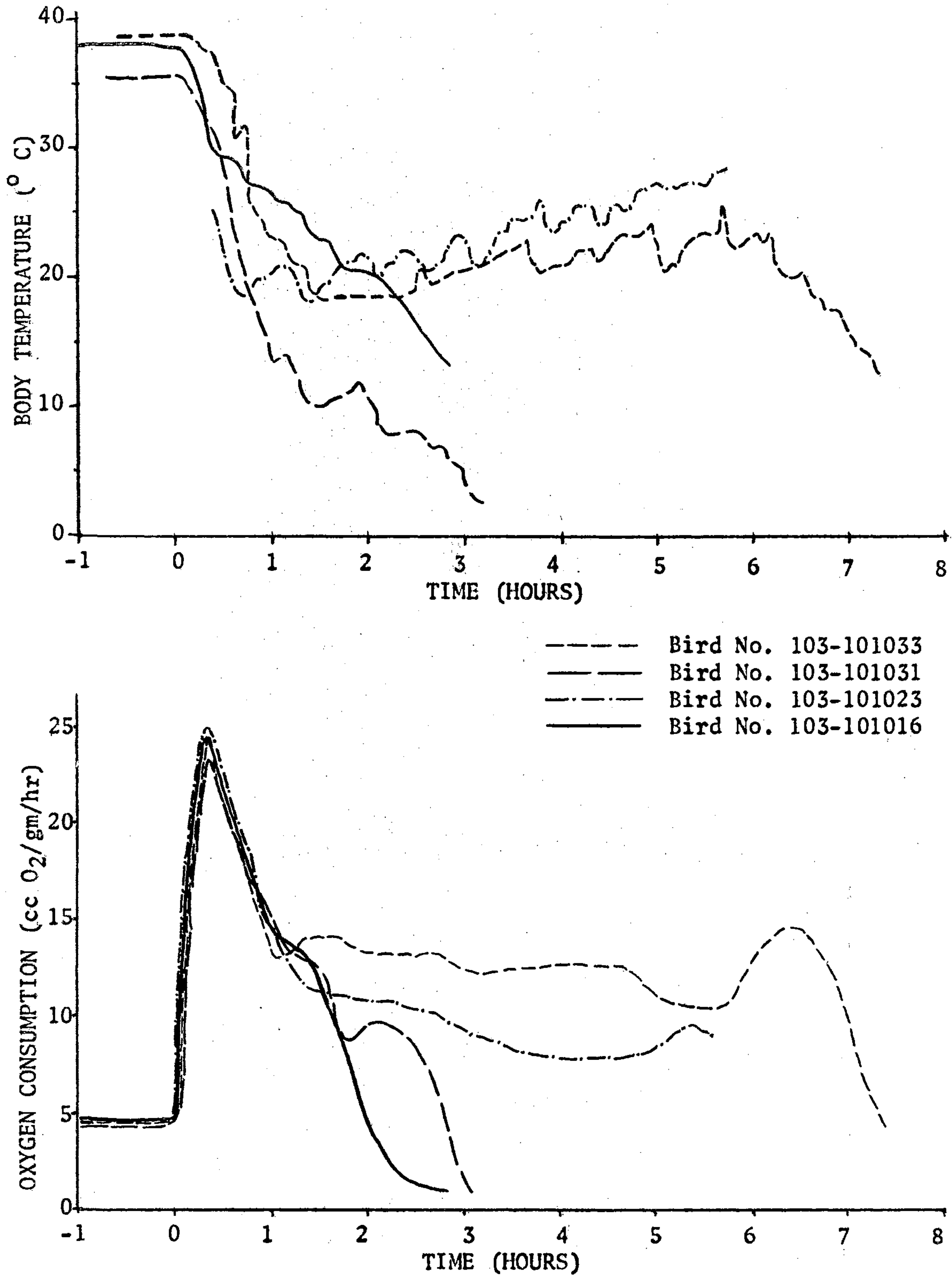


Fig. 7. Body temperature and oxygen consumption of the four birds which were exposed to 0° C environmental temperatures.

removed from the chamber and examined. It was determined that the bird was alive because there was a slight spontaneous movement of the head in response to tapping on the bill region. This bird ultimately died, however. The other two birds (103-101016 and 103-101033) became torpid after 2½ hours and 6 hours respectively at the lowered temperature. These two birds, as well as the one which did not show torpidity, were released successfully.

Three birds (103-101020, 103-101025, and 103-101040), which were placed in environments of $-5^{\circ}$ C, became torpid after 1½ hrs, 3 hrs, and 2½ hrs respectively at cold temperatures. They recovered and were released. Another bird (103-101027) died after about 30 minutes at temperatures below $0^{\circ}$ C. The three birds which became torpid (103-101020, 103-101025, and 103-101040) had body temperatures of $14.9^{\circ}$ C, $14.8^{\circ}$ C, and $10.7^{\circ}$ C respectively at the end of the experiment and had oxygen consumption rates of 4.29 cc $O_2$/gm/hr, 12.90 cc $O_2$/gm/hr, and 5.70 cc $O_2$/gm/hr respectively. Similar figures at the first of the experiment were $40.4^{\circ}$ C, $40.2^{\circ}$ C, and $40.3^{\circ}$ C; and 3.00 cc $O_2$/gm/hr, 3.90 cc $O_2$/gm/hr, and 3.76 cc $O_2$/gm/hr (Fig. 8).

By averaging each bird's data for each half hour period from the time ice was added around the chamber, mean values were obtained from which Figures 9 and 10 were drawn showing the average relationships among the test groups. The lines representing $0^{\circ}$ and $-5^{\circ}$ C environmental conditions are not continuous due to the fact that during some half-hour

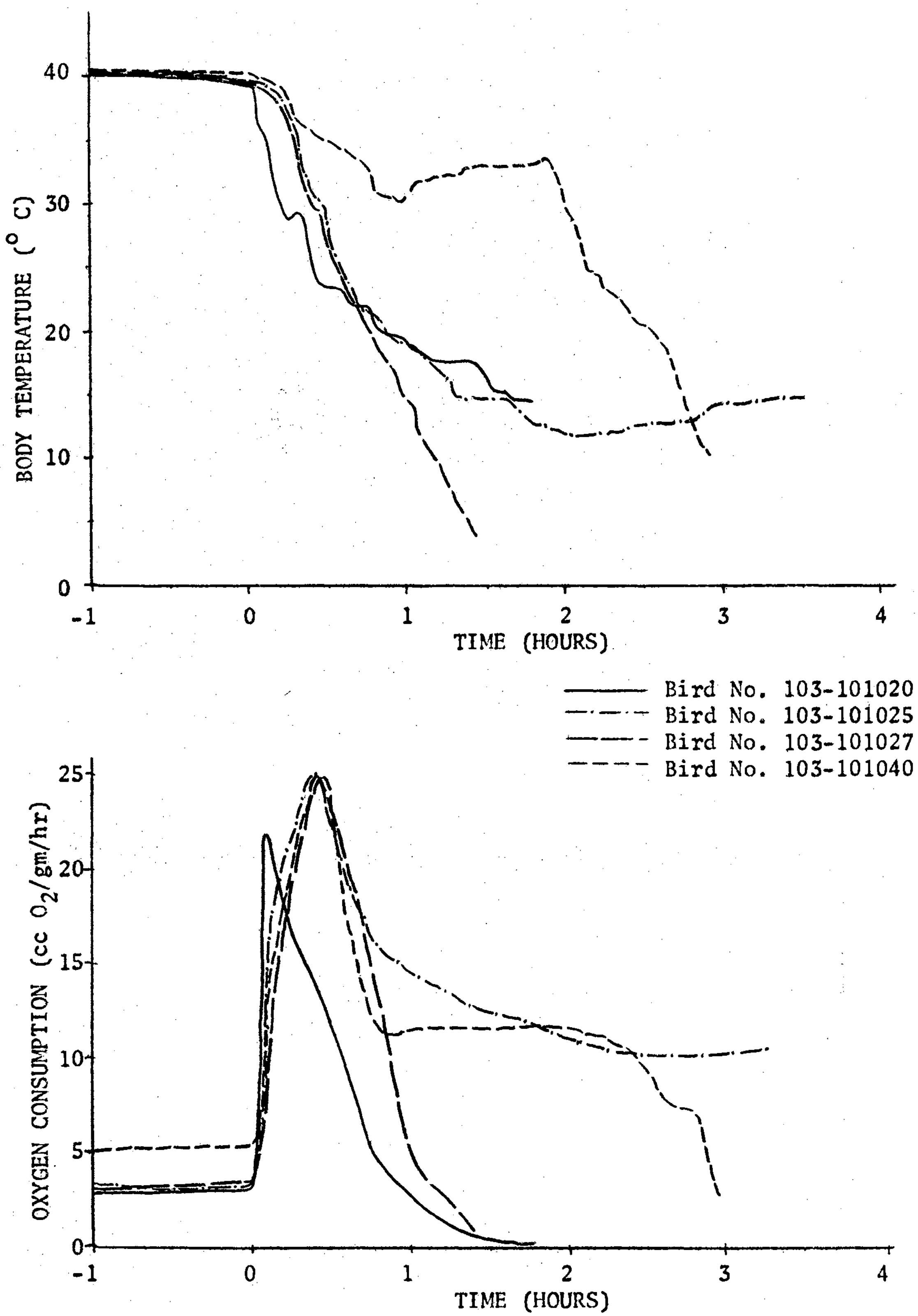


Fig. 8. Body temperature and oxygen consumption of the four birds which were exposed to -5° C ambient temperatures.

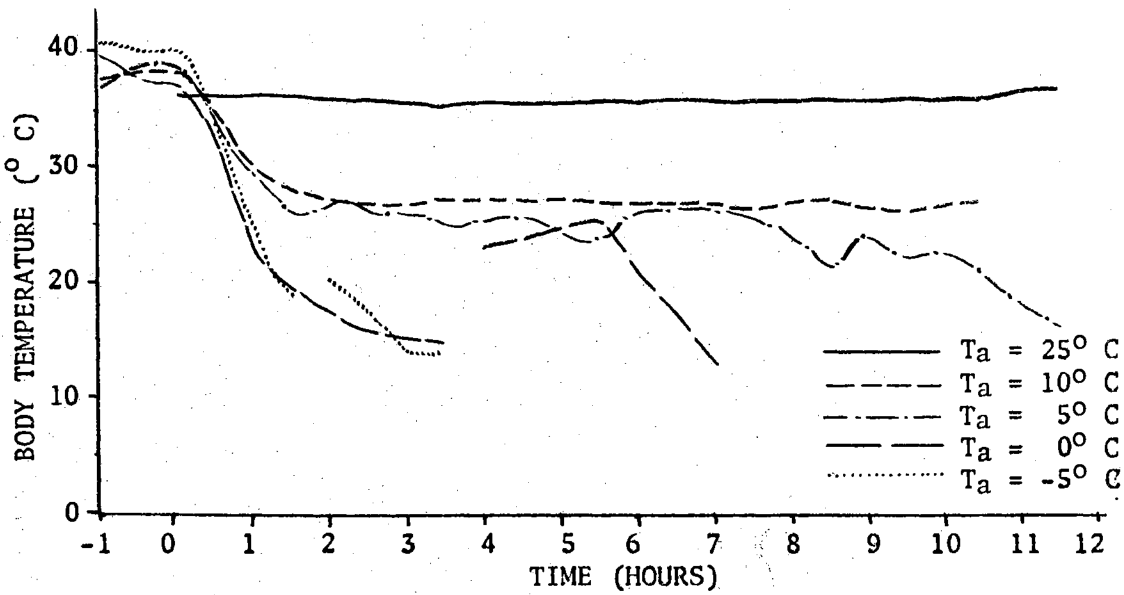


Fig. 9. The average body temperatures at each ambient temperature are compared.

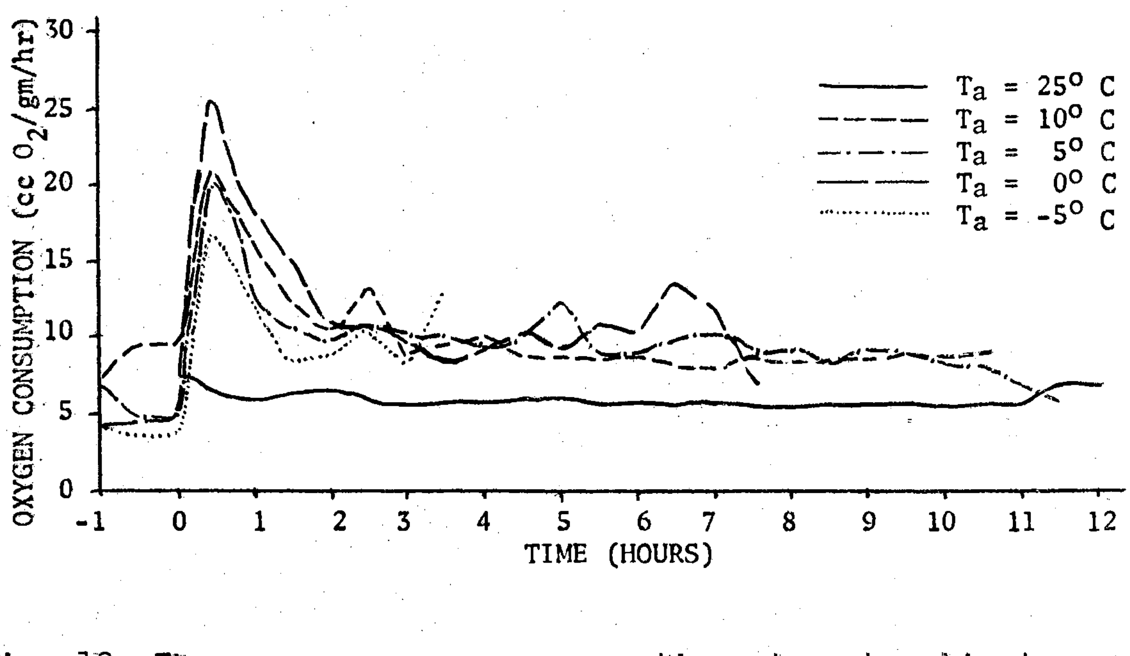


Fig. 10. The average oxygen consumption at each ambient temperature is shown as it is compared with that of other ambient temperatures.

intervals one or more of the experimental animals became torpid and was no longer contributing data to the average. This caused a marked change in the average as shown. Oxygen consumption was consistently higher during subjection to cold than at the beginning of the experiment.

The temperature of the body in Chimney Swifts is definitely related to the temperature of the environment. Two birds were subjected to various stages of cooling for shorter periods of time. Each time the ambient temperature was lowered, the bird's body temperature dropped until the bird's temperature had fallen at least 10° C (Fig. 11).

In order to obtain a relationship between body temperature and environmental temperature, a mean body temperature was obtained for each degree of environmental temperature from -5° C to 33° C. The data for each bird were examined and a mean body temperature was computed for each degree of ambient temperature available in that particular bird's data. No bird temperature reading was included in compiling these mean values if the body temperature was changing markedly. These various means were then used to determine the mean body temperature of the test animals at each degree of ambient temperature. Figure 12 shows the relationship between ambient temperature and mean body temperature.

The line drawn in this figure was obtained by the Method of Least Squares. The straight line is inserted among the points so that the sum of the squares of the

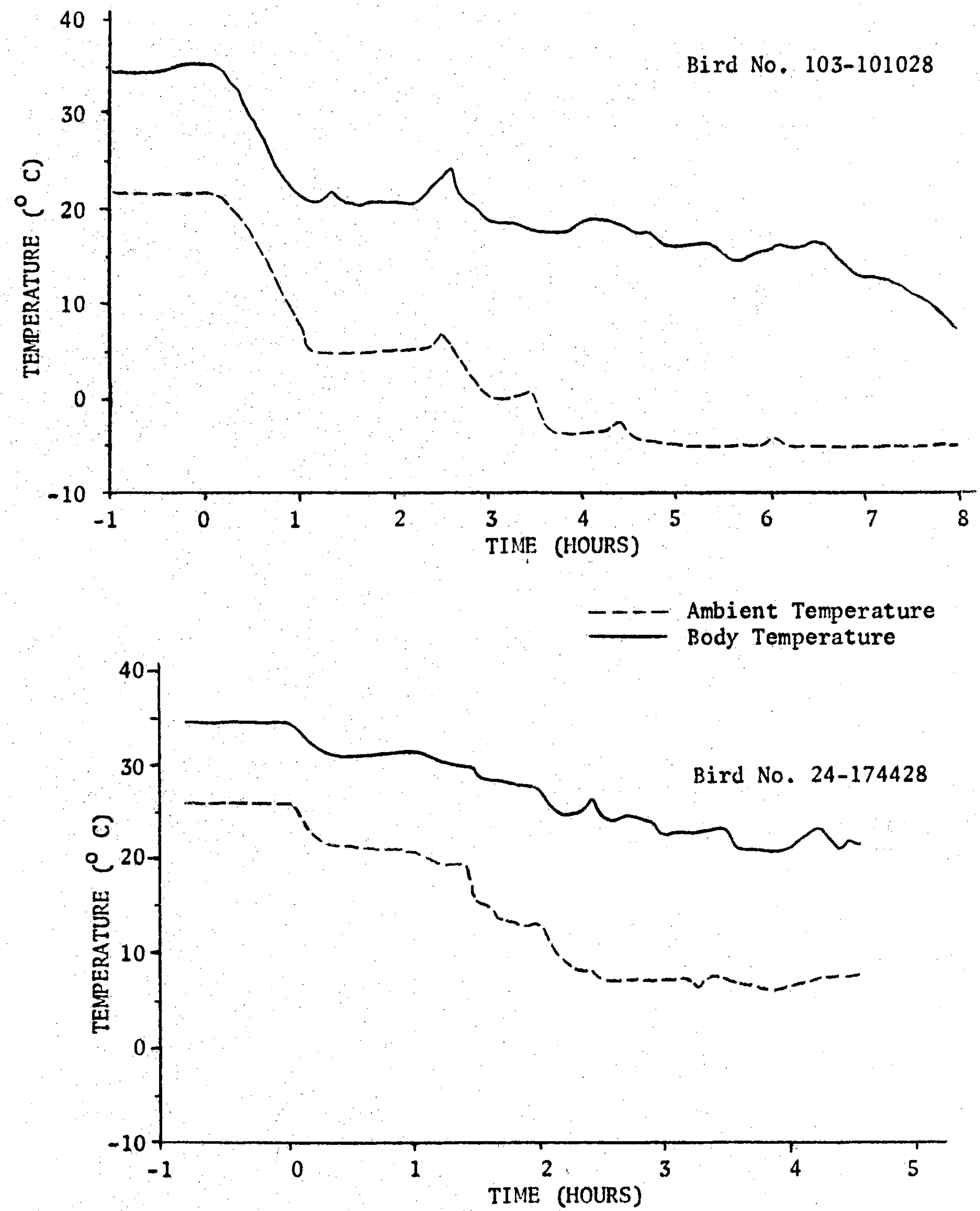


Fig. 11. The relationship between environmental temperature change and body temperature change in two Swifts exposed to various levels of colder environments.

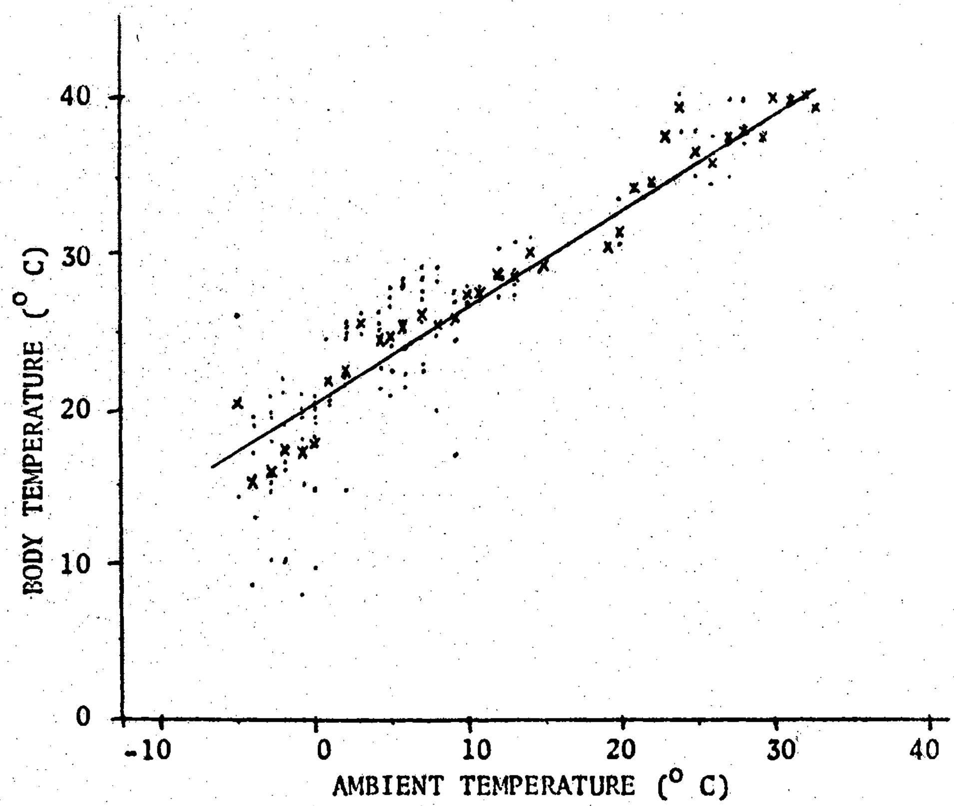


Fig. 12. The relationship between ambient and mean body temperatures. Each dot represents the mean body temperature of one bird at that ambient temperature, and each x shows the mean of all birds at that ambient temperature.

vertical deviations of these mean values from the line is a minimum. The equation of this simple linear regression line is

$$T_B = b_1 T_A + b_o$$

where $b_o = 20.4$ and $b_1 = 0.64$. These values of slope and intercept were obtained using the Abbreviated Doolittle Method as outlined by Ostle (1963). Although the bird's temperature drops with decreasing ambient temperature, it does not drop as fast as does the environmental temperature. This causes the slope of the line to be less than unity.

The rate of warming of the torpid bird was approximately 0.6° C/min when exposed to room temperature. This value may be compared with that reported by Bartholomew et al. (1957) of about 0.4° C/min for the White-throated Swift.

Lowered environmental temperatures raised the oxygen consumption until a torpid state was reached at which time the rate of oxygen consumption dropped markedly.

The data for each bird were examined and a mean oxygen consumption figure was computed for each degree of ambient temperature. The extremely high peaks caused by the rapid change in the environmental temperature were not considered in compiling these mean values. The various means were then used to determine the mean oxygen consumption of the birds at each degree of ambient temperature. Figure 13 shows the relationship between mean oxygen consumption and environmental temperature. As the ambient temperature dropped, the oxygen required rose. However, as a condition of torpor was reached by some of the birds, the oxygen consumption dropped again.

The curved line drawn in this figure was placed so that the sum of the squares of the vertical deviations of these mean values from the line is a minimum. The equation of this quadratic regression line is

$$C = B_o + B_1T_a + B_{11}T_a^2.$$

where $B_0 = 11.7$, $B_1 = 0.08$, and $B_{11} = -0.01$. These values were obtained using the Abbreviated Doolittle Method as outlined by Ostle (1963).

The average oxygen consumption during a state of torpidity was approximately 3.9 cc $O_2$/gm/hr as compared with an average of approximately 4.9 cc $O_2$/gm/hr at room temperature at the beginning of the experiments. One bird (103-101020) required only 0.54 cc $O_2$/gm/hr while in a torpid state. If these values are compared with lizards (1.13 to

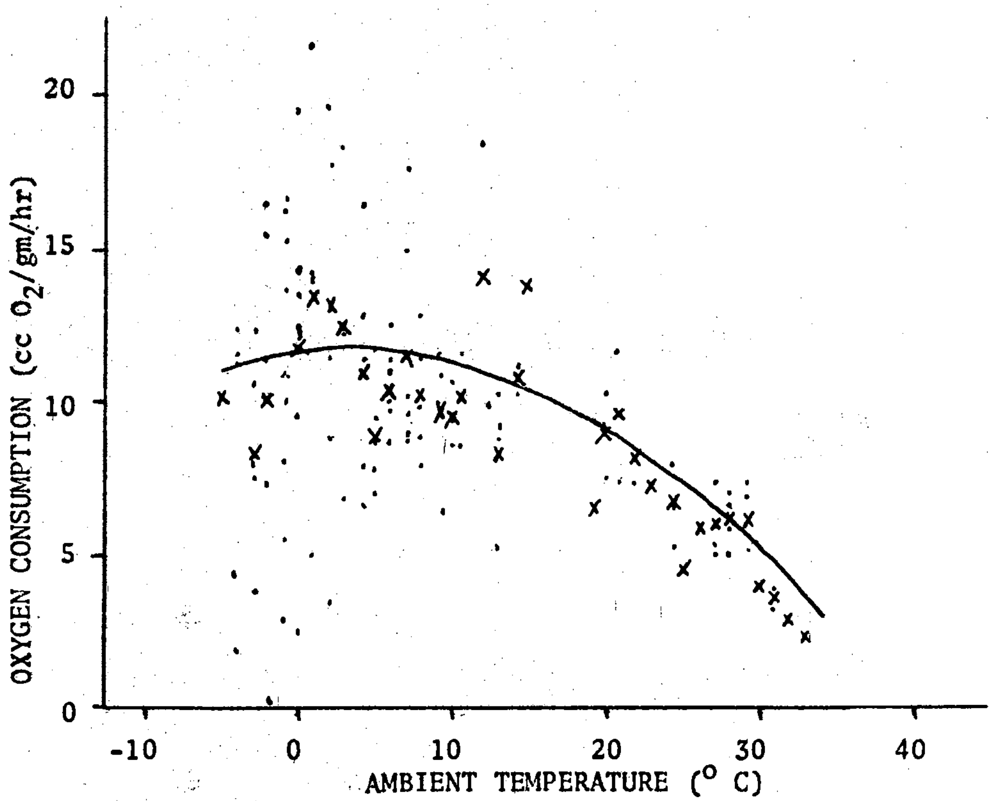


Fig. 13. The relationship of environmental temperature and oxygen consumption. Each dot represents the mean oxygen consumption of one bird at that ambient temperature and each x shows the mean of all birds at that ambient temperature.

1.21 cc $O_2$/gm/hr) as cited on page 5, it would seem that swifts in a torpid state approach or actualy reach temporary poikilothermy.

The mean weight of swifts in this investigation was 21.0 grams. According to Prosser and Brown (1961) the caloric value of oxygen is 4.74 Cal/l $O_2$. Using this conversion factor and the mean weight, the average basal metabolic rate in Cal/day can be calculated. In order to obtain an accurate value of oxygen consumption for birds at ambient temperatures of above 30° C (normal summer temperature), the mean values used in the construction of Figure 13 were used. The mean value of oxygen consumption of swifts at ambient temperature above 30° C was calculated to be 2.9 cc $O_2$/gm/hr. This gave a metabolic rate of 6.93 Cal/day at normal summer temperatures, which is slightly smaller than that predicted for wild birds by Brody and Proctor (1932). According to this equation, cited in the Review of Literature (page 6), the metabolic rate of a 21.0 gram Chimney Swift would be 7.51 Cal/day. The King Farner equation, used to predict weight metabolism relationships in larger birds and also cited on page 6, gives a metabolic rate of only 4.20 Cal/day for a 21.0 gram bird.

The metabolic rate during torpor (calculated with the data from bird 103-101020) was 1.29 Cal/day. This bird, with a reserve equivalent to one normal day at rest, could survive more than 5 days in a state of torpor. This could easily account for any ability of these birds to survive a week of cold inclement weather when their food supply was not available. However, torpidity during the entire winter (hibernation) is probably not usual. At the rate of metabolism during torpor of 1.29 Cal/day and assuming the maximum metabolic rate (predicted by the Brody Proctor equation) of 7.51 Cal/day, a bird would require a metabolic reserve equivalent to over 32 days in order to remain torpid from October to April. Birds were examined internally during the summer, but none of the birds examined showed any brown fat or reserve fat. It may be possible for swifts to remain torpid during the winter months, but torpidity for this long period is highly improbable. There was a great deal of variability shown in the reaction of swifts to cold, however, and some birds doubtless have greater capacities in remaining torpid than others.

## CHAPTER V

## SUMMARY AND CONCLUSIONS

Chimney Swifts were placed in a metabolic chamber and cloacal temperature, environmental temperature, and oxygen consumption were recorded for various environmental temperatures ($-5^{\circ}$, $0^{\circ}$, $5^{\circ}$, $10^{\circ}$, and $25^{\circ}$ C). The birds were held so that movement around the chamber was impossible.

Chimney Swifts were found to exhibit a condition which is far from homeothermous. The body temperature of these animals changed almost immediately with lowered ambient temperature, and a direct relationship existed between environmental and body temperatures. The slope of the line representing this relationship was 0.64. The range of body temperatures in this investigation was $41.0^{\circ}$ C to $10.7^{\circ}$ C with one bird showing slight struggling movements at $5.6^{\circ}$ C and falling to $3.0^{\circ}$ C before removal from the chamber. This bird subsequently died, however. At ambient temperature of $30^{\circ}$ C, the average of the birds' body temperatures was near $40^{\circ}$ C, while at $0^{\circ}$ C ambient temperature, the average body temperature dropped to $20.5^{\circ}$ C.

A state of torpor was demonstrated in this species. When these birds were subjected to cold, their body temperature dropped and eventually the state of torpor was evident.

No movement was noticed and no response could be noted to stimuli of any kind. After a few minutes at warm temperatures, however, the bird began to breathe slowly and gradually returned to a lively condition.

Oxygen consumption increased from approximately 4.9 cc/gm/hr to approximately 12.6 cc/gm/hr as the environmental temperature fell. When a state of torpor was reached, however, the rate dropped and was approximately 3.9 cc/gm/hr. One bird in a torpid state required oxygen supplied at the rate of 0.54 cc/gm/hr.

In recovery from torpor, the rate of warming of the bird was approximately 0.6° C per minute.

If, under natural circumstances, these birds were faced with long periods of cold weather, they could survive with only small amounts of metabolic reserves. Heat loss to the atmosphere is decreased as the body temperature follows the ambient temperature, and as a state of torpor is reached, the metabolic rate is so low that it would be possible for them to pass a period of a week or two quite easily. Torpor during the entire winter months is not an impossibility.

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