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AUTUMN FAT DEPOSITION AND GROSS BODY COMPOSITION IN THREE SPECIES OF *MYOTIS*

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Abstract—1. Mid-August to mid-September fat indices for female *Myotis lucifugus* were 0·58–0·69 g fat/g lean dry wt. with constant gross body composition.

2. During the same time span, fat indices of female *M. yumanensis* showed a gradual significant increase from 0·30 to 0·87 with a concurrent significant increase in percent non-fat and percent water.

3. In mid-September, fat indices of *M. thysanodes* increased significantly from 0·09 to 0·73, while gross body composition was unchanged.

4. *M. thysanodes* body fat had a caloric content of 9·418 ± 0·016 kcal/g.

5. Fatty acid analysis revealed 72–81 per cent unsaturation with oleic acid being the most abundant.

6. For each species, females contained more body fat than males, and adults were fatter than young of the year.

INTRODUCTION

LATE summer fat deposition, which is recognized as a prerequisite for migration in birds (Odum, 1965; King & Farner, 1965; Hicks, 1967), has been reported for *Nycticieus humeralis* (Baker *et al.*, 1968), *Tadarida brasiliensis* (Herreid, 1963), *Eptesicus fuscus* (Weber & Findley, 1970), and several species of bats in Poland (Krzanowski, 1961). The present study was conducted to determine the extent of fat deposition and concurrent changes in gross body composition in *Myotis lucifugus occultus* (= *M. occultus*, Findley & Jones, 1967), *M. yumanensis*, and *M. thysanodes* during the 4–5 weeks prior to their mid-September departure from a common maternity roost.

MATERIALS AND METHODS

Several bats of each of the above species of *Myotis* were removed at random in the early morning from their maternity roost in the attic of Montezuma Seminary, Montezuma, San Miguel Co., New Mexico. Collection days were spaced in 1½ to 2 week intervals from mid-August to late-September, 1969. On 25 September only *M. thysanodes* remained in the roost. Sample sizes were kept small to prevent a serious disruption of the colony.

Approximately 3 hr after collection, the bats were killed, weighed, and dried to constant weight under reduced pressure at 40°C. Dried bats were reweighed and ground in a mortar, and fats were extracted with petroleum ether (b.p. 90–110°C). All fat-free residues were air dried to constant weight and the residues from adults were ashed at 620°C for 8 hr. Fats extracted from selected adults were air dried and analyzed for fatty acid and lipid phosphorous content by gas-liquid and thin layer chromatography (Christopherson & Glass, 1969). Lipids from sub-cutaneous peritoneal adipose tissue, collected from six *M. thysanodes* on 18 September were similarly extracted for determination of caloric content by bomb calorimetry using a Series 1300 Parr oxygen bomb calorimeter.

Fat index (g fat/g lean dry wt.), water index (g water/g lean dry wt.), percent nonfat organic, percent ash and percent water were calculated for each bat. Inter- and intraspecific comparisons of these parameters were made using a simple *t*-test analysis with the 0·05 level of significance indicating rejection of the null hypothesis of no difference.

RESULTS

Mean fat indices (Fig. 1-A, Table 1) for *M. lucifugus* and *M. yumanensis* on the same days were not significantly different, while the *M. thysanodes* fat index for 1 September was significantly lower than that of the other two species ($P < 0·02$). None of the three final fat indices differed significantly. Mean water indices (Fig. 1-B, Table 1) on corresponding days were not significantly different.

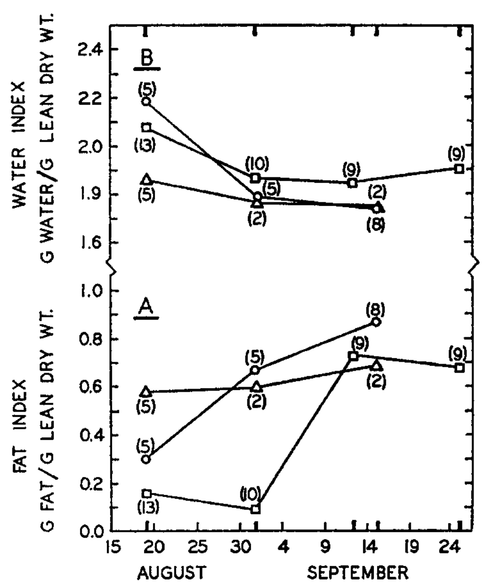

FIG. 1. Mean fat indices (A) and water indices (B) of *M. lucifugus* (△), *M. yumanensis* (○) and *M. thysanodes* (□) in autumn. Sample size is indicated in parentheses.

The fat index of *M. lucifugus* showed no significant intraspecific change throughout the study period, while the fat indices of *M. yumanensis* and *M. thysanodes* increased significantly ($P < 0·05$ and $P < 0·02$, respectively). *M. lucifugus* and *M. thysanodes* showed no significant intraspecific changes in water index, although final values were lower than initial values. The water index of *M. yumanensis* decreased significantly during the study period ($P < 0·001$). Water indices showed a general tendency to complement the increases in fat indices.

TABLE 1—FAT AND WATER INDICES AND WEIGHTS OF THREE SPECIES OF *Myotis*

Date	*N*	Sex/Age	Wet wt.	Lean dry wt.	Fat wt.	Fat index	Water index
				M. lucifugus			
19 Aug.	5	F/ad	8·47 ± 0·81	2·46 ± 0·19	1·44 ± 0·51	0·58 ± 0·19	1·86 ± 0·12
			(7·25 – 9·43)	(2·15 – 2·70)	(0·61 – 1·97)	(0·28 – 0·76)	(1·74 – 2·09)
	3	M/ad	6·96 ± 0·27	2·17 ± 0·04	0·38 ± 0·14	0·18 ± 0·07	2·03 ± 0·06
			(6·57 – 7·20)	(2·13 – 2·23)	(0·26 – 0·58)	(0·12 – 0·27)	(1·95 – 2·11)
	4	F/yy	6·78 ± 0·21	2·05 ± 0·06	0·42 ± 0·07	0·20 ± 0·03	2·10 ± 0·06
			(6·61 – 7·14)	(1·98 – 2·15)	(0·32 – 0·51)	(0·16 – 0·24)	(2·02 – 2·17)
	2	M/yy	5·74 ± 0·06	1·83 ± 0·05	0·11 ± 0·04	0·06 ± 0·02	2·08 ± 0·03
			(5·69 – 5·80)	(1·78 – 1·88)	(0·07 – 0·15)	(0·04 – 0·08)	(2·05 – 2·11)
1 Sept.	2	F/ad	7·81 ± 0·43	2·32 ± 0·19	1·37 ± 0·10	0·60 ± 0·10	1·77 ± 0·00
			(7·38 – 8·23)	(2·13 – 2·51)	(1·28 – 1·47)	(0·51 – 0·69)	(1·77 – 1·77)
	3	M/ad	7·19 ± 0·60	2·31 ± 0·13	0·56 ± 0·24	0·24 ± 0·09	1·87 ± 0·05
			(6·38 – 7·81)	(2·16 – 2·48)	(0·24 – 0·81)	(0·11 – 0·33)	(1·82 – 1·93)
15 Sept.	2	F/ad	8·99 ± 0·13	2·62 ± 0·06	1·80 ± 0·34	0·69 ± 0·15	1·75 ± 0·01
			(8·86 – 9·12)	(2·55 – 2·68)	(1·46 – 2·14)	(0·54 – 0·84)	(1·73 – 1·76)
	6	M/ad	7·08 ± 0·38	2·29 ± 0·11	0·87 ± 0·21	0·38 ± 0·10	1·71 ± 0·03
			(6·38 – 7·48)	(2·16 – 2·47)	(0·59 – 1·17)	(0·26 – 0·51)	(1·67 – 1·75)
	3	M/yy	6·42 ± 0·40	2·17 ± 0·14	0·32 ± 0·03	0·15 ± 0·02	1·80 ± 0·03
			(6·02 – 6·96)	(2·03 – 2·36)	(0·28 – 0·36)	(0·14 – 0·17)	(1·77 – 1·82)
				M. yumanensis			
19 Aug.	5	F/ad	6·40 ± 0·34	1·84 ± 0·08	0·55 ± 0·22	0·30 ± 0·12	2·19 ± 0·05
			(5·85 – 6·83)	(1·75 – 1·98)	(0·34 – 0·96)	(0·17 – 0·53)	(2·10 – 2·25)
	1	F/yy	5·53	1·64	0·44	0·27	2·10
	3	M/yy	5·23 ± 0·28	1·55 ± 0·07	0·37 ± 0·13	0·24 ± 0·08	2·12 ± 0·03
			(4·84 – 5·50)	(1·45 – 1·61)	(0·25 – 0·56)	(0·16 – 0·35)	(2·09 – 2·16)

[*Continued overleaf*

TABLE 1—CONTD.

Date	N	Sex/Age	Wet wt.	Lean dry wt.	Fat wt.	Fat index	Water index
			M. yumanensis—cont.				
1 Sept.	5	F/ad	6·65 ± 0·49 (6·08 – 7·41)	1·92 ± 0·12 (1·80 – 2·13)	1·30 ± 0·28 (0·92 – 1·70)	0·67 ± 0·12 (0·51 – 0·81)	1·79 ± 0·06 (1·68 – 1·86)
	5	F/yy	5·06 ± 0·26 (4·85 – 5·55)	1·65 ± 0·06 (1·57 – 1·75)	0·31 ± 0·09 (0·24 – 0·49)	0·19 ± 0·05 (0·14 – 0·28)	1·87 ± 0·07 (1·78 – 1·96)
	2	M/yy	5·93 ± 0·25 (5·68 – 6·17)	1·97 ± 0·06 (1·91 – 2·04)	0·15 ± 0·02 (0·13 – 0·17)	0·08 ± 0·01 (0·07 – 0·09)	1·93 ± 0·04 (1·88 – 1·97)
15 Sept.	8	F/ad	6·82 ± 0·64 (5·92 – 7·79)	1·89 ± 0·10 (1·68 – 2·02)	1·65 ± 0·45 (1·02 – 2·22)	0·87 ± 0·23 (0·54 – 1·13)	1·74 ± 0·06 (1·68 – 1·83)
	1	F/yy	5·55	1·71	0·55	0·32	1·92
			M. thysanodes				
19 Aug.	13	F/ad	8·73 ± 0·49 (7·65 – 9·41)	2·70 ± 0·15 (2·44 – 2·89)	0·44 ± 0·13 (0·22 – 0·67)	0·16 ± 0·05 (0·09 – 0·24)	2·08 ± 0·17 (1·72 – 2·47)
	3	F/yy	8·06 ± 0·08 (8·00 – 8·17)	2·45 ± 0·02 (2·42 – 2·48)	0·44 ± 0·12 (0·31 – 0·60)	0·18 ± 0·05 (0·13 – 0·24)	2·11 ± 0·10 (1·98 – 2·21)
	1	M/yy	7·87	2·51	0·20	0·08	2·05
1 Sept.	10	F/ad	7·58 ± 0·57 (6·70 – 8·85)	2·56 ± 0·15 (2·41 – 2·87)	0·23 ± 0·06 (0·15 – 0·36)	0·09 ± 0·02 (0·06 – 0·15)	1·87 ± 0·12 (1·62 – 2·06
12 Sept.	9	F/ad	10·00 ± 0·76 (9·04 – 11·68)	2·79 ± 0·17 (2·53 – 3·09)	2·06 ± 0·54 (1·24 – 2·89)	0·73 ± 0·17 (0·47 – 1·06)	1·85 ± 0·11 (1·66 – 1·98)
	2	F/yy	8·08 ± 0·10 (7·97 – 8·21)	2·52 ± 0·09 (2·39 – 2·61)	0·46 ± 0·11 (0·33 – 0·61)	0·18 ± 0·04 (0·13 – 0·23)	2·02 ± 0·12 (1·91 – 2·18)
25 Sept.	9	F/ad	9·51 ± 0·56 (8·40 – 10·21)	2·65 ± 0·15 (2·40 – 2·90)	1·80 ± 0·50 (0·86 – 2·24)	0·68 ± 0·19 (0·35 – 0·93)	1·91 ± 0·08 (1·77 – 2·07)
	1	M/ad	7·07	2·41	0·34	0·14	1·80
	1	F/yy	6·89	2·35	0·21	0·09	1·84
	1	M/yy	6·65	2·30	0·10	0·04	1·85

Figures are arithmetic mean ± standard error. Range is indicated in parentheses.

Fat-free adults showed no significant interspecific differences in nonfat organic, ash, or water content on corresponding days (Table 2). *M. lucifugus occultus* and *M. thysanodes* showed no significant intraspecific differences in these parameters during the study period, while *M. yumanensis* showed significantly increased nonfat organic material and percent water ($P < 0{\cdot}001$ and $P < 0.01$, respectively).

Mean caloric content of *M. thysanodes* fat was $9{\cdot}418 \pm 0{\cdot}016$ (S.E.$_{\bar{x}}$) kcal/g. This value is quite similar to that reported by Baker *et al.*, (1969) for *N. humeralis*.

TABLE 2—PERCENTAGE GROSS BODY COMPOSITION OF FAT-FREE ADULT *Myotis*

Date	*N*	Non-fat Organic	Ash	Water
		M. lucifugus		
19 Aug.	8	29·0 ± 1·4	4·9 ± 0·2	65·7 ± 1·5
		(27·2 – 31·3)	(4·6 – 5·4)	(63·5 – 67·8)
1 Sept.	6	29·9 ± 0·7	5·4 ± 0·5	64·4 ± 0·8
		(29·1 – 30·7)	(4·4 – 5·9)	(63·5 – 66·0)
15 Sept.	8	31·3 ± 0·5	5·6 ± 0·4	63·1 ± 0·4
		(30·4 – 31·4)	(5·2 – 6·5)	(62·5 – 63·8)
		M. yumanensis		
19 Aug.	5	26·5 ± 0·5	4·6 ± 0·2	68·6 ± 0·4
		(26·1 – 27·4)	(4·3 – 4·9)	(67·7 – 69·1)
1 Sept.	5	31·2 ± 0·5	4·8 ± 0·3	64·1 ± 0·5
		(30·5 – 32·1)	(4·4 – 5·3)	(62·7 – 65·0)
15 Sept.	8	31·5 ± 0·7	5·0 ± 0·2	63·7 ± 1·5
		(30·0 – 32·3)	(4·7 – 5·4)	(62·6 – 67·3)
		M. thysanodes		
19 Aug.	10	27·6 ± 1·5	4·9 ± 0·5	67·4 ± 1·8
		(24·4 – 31·0)	(4·2 – 5·5)	(63·2 – 71·1)
1 Sept	10	29·3 ± 1·5	5·5 ± 0·3	65·1 ± 1·5
		(27·3 – 32·0)	(4·8 – 6·2)	(61·7 – 71·1)
12 Sept.	9	30·1 ± 1·3	5·3 ± 0·1	64·8 ± 1·4
		(28·7 – 32·6)	(5·0 – 5·4)	(62·3 – 66·4)
25 Sept.	9	28·8 ± 0·9	5·5 ± 0·2	65·6 ± 1·0
		(27·1 – 30·5)	(5·1 – 5·8)	(63·8 – 67·4)

See Table 1 for explanation of figures.

Results of the fatty acid and lipid phosphorous analysis are presented in Table 3. Data for brown fat analysis of *M. l. lucifugus* (Wells *et al.*, 1965) are presented for comparison. The most plentiful fatty acid in all cases was oleic acid ($C_{18:1}$), followed in varying order by acids 16:0, 16:1, and 18:2.

DISCUSSION

General aspects of fat deposition

Two generalizations are evident from this study that apply to each of the species examined: (1) adults deposit more fat than young of the year, and (2) females

TABLE 3—FATTY ACIDS AND LIPID PHOSPHOROUS AS MEAN PERCENTAGES OF TOTAL BODY FAT IN ADULT *Myotis*

Acid	*M. lucifugus occultus* Females (n = 2)	*M. lucifugus occultus* Males (n = 1)	*M. l. lucifugus** Females	*M. l. lucifugus** Males	*M. thysanodes* Females (n = 3)	*M. yumanensis* Females (n = 3)
Short chain	0·3 (0·0– 0·5)	0·0	0·7	0·3	0·1 (0·0– 0·3)	0·0
Myristic (14:0)	2·3 (1·7– 2·8)	1·1	1·9	6·9	0·7 (0·6– 0·9)	1·4 (0·8– 2·4)
Unknown	1·5 (0·0– 3·0)	0·0	—	—	0·1 (0·1– 0·2)	1·0 (0·3– 1·5)
Palmitic (16:0)	12·3 (12·0–12·6)	15·2	9·2	11·5	14·9 (13·4–16·2)	18·3 (16·4–19·5)
Palmitoleic (16:1)	16·9 (15·6–18·3)	12·5	7·3	7·8	9·1 (8·8– 9·5)	14·5 (13·0–15·5)
Unknown	4·2 (3·1– 5·4)	1·8	—	—	1·3 (1·1– 1·5)	2·5 (1·0– 5·1)
Stearic (18:0)	3·5 (3·0– 3·9)	3·6	4·4	3·2	1·5 (1·4– 1·6)	2·5 (1·4– 4·4)
Oleic (18:1)	31·3 (25·6–36·9)	47·1	54·2	57·3	49·1 (46·1–51·6)	45·0 (42·1–48·4)
Linoleic (18:2)	18·6 (18·5–18·7)	12·0	18·6	15·6	17·0 (15·2–20·0)	9·8 (8·2–11·0)
Linolenic (18:3)	5·3 (4·9– 5·6)	2·8	3·7	3·4	6·2 (4·7– 7·8)	5·2 (4·2– 6·0)
Long chain	4·1 (3·0– 5·2)	3·6	—	—	0·0	0·0
Phosphorous (mg/g)	0·59 (0·48–0·69)	2·44	—	—	0·52 (0·48–0·59)	0·85 (0·51–1·31)

*Brown fat from non-hibernating bats (in Wells *et al.*, 1965).
Range is indicated in parentheses.

deposit more fat than males of the same age group. Similar autumn weight groupings with respect to age and sex have been reported for *M. l. lucifugus* (Davis & Hitchcock, 1965), *M. velifer* (Tinkle & Patterson, 1965), and *Pipistrellus subflavus* (W. H. Davis, 1966). These differences may reflect a trend for survival value. Adult female *M. l. lucifugus* in New England deposit large quantities of fat in the fall, while juveniles remain comparatively lean. Furthermore, while older bats are entering hibernation, juveniles remain active as long as there is an opportunity to feed (Davis & Hitchcock, 1965). Similarly, adult female *M. lucifugus occultus* leave the Montezuma roost earlier in the fall than do juveniles or male adults of the same species (personal observation). The differences in fat content between male and female adult *M. lucifugus occultus* suggest that females have a better chance of surviving the winter than males. It should be noted that fat content was determined immediately prior to leaving the summer roost, and males and juveniles may undergo fat deposition from the time they leave the summer roost until the onset of hibernation.

The fat index is high (2·0–3·0) in birds that fly continuously without foraging during their migration (Odum, 1965), while the fat indices of the *Myotis* in this study are relatively low. Baker *et al.*, (1968), reported autumn fat indices of 1·5–1·7 for *N. humeralis*, and Weber & Findley (1970) reported fat indices of 1·6–1·8 for *E. fuscus* in September. Studier *et al.*, (1970) have shown that *M. lucifugus occultus* may lose roughly 10 per cent of their body weight within a few hours of their return to the roost at dawn. Thus, our fat indices as well as those reported for other bats may indicate a smaller fat store than actually exists.

Energetics

Fat indices and rates of fat deposition differ greatly in adult females of the three species studied. Fat deposition in *M. lucifugus occultus* appears to be nearly completed by mid-August. This observation correlates well with metabolic studies of this animal (O'Farrell & Studier, 1970) and of *M. l. lucifugus* (Stones & Wiebers, 1967) which have shown that this species exhibits a non-homeothermic relationship of metabolic rate to ambient temperature at this time of year. Metabolic studies of *M. yumanensis* from mid-August to mid-September have shown that this relationship is non-homeothermic for some individuals and partially homeothermic for others (O'Farrell & Studier, 1970). This correlates with a significant increase in fat index during the same time span. In *M. thysanodes*, however, the relationship of metabolic rate to ambient temperature has been shown to undergo a clear transition from homeothermic to non-homeothermic during September (O'Farrell & Studier, 1970), during which time this species deposits a highly significant amount of fat.

O'Farrell & Studier (1970) give metabolic rates (dry air, 20·5°C) for *M. thysanodes* of 6·929 cm^3 O_2/g per hr for homeothermic bats and 0·588 cm^3 O_2/g per hr for non-homeothermic bats, a decrease of 6·341 cm^3 O_2/g per hr. Assuming a mean body weight of 7·64 g and a daily rest period of 12 hr (a conservative estimate), the change in oxygen consumption is 581 cm^3/day. Using the energy equivalent of oxygen, 4·825 kcal/l., we calculate that the bat conserves 2·81 kcal/day as it becomes non-homeothermic. During the interval of maximum fat deposition, fat is deposited at a rate of 0·17 g/day. At 9·4 kcal/g fat, the bats require 1·60 kcal/day for fat deposition. It therefore seems justified to state that the energy necessary for fat deposition comes at least in part from the energy conserved by the development of non-homeothermy. This supports Krzanowski's (1961) postulation that in autumn, energy for fat deposition in bats comes from the development of hypothermia during the day.

Gifford & Odum (1965) discuss two hypotheses to explain how birds maintain a positive energy balance during prolonged migratory flights. The first hypothesis, proposed by Wachs (1926), is that birds experience a general reduction in basal metabolism or an increase in assimilation efficiency, and the second is that birds become hyperphagic and deposit fat prior to migration. The latter hypothesis has been shown to apply for many species of birds (Odum, 1960; Gifford & Odum, 1965), while the former applies to the three species of *Myotis* in this study and may apply to many bats that migrate or hibernate. Furthermore, *M. lucifugus* and *M. thysanodes* have been shown not to become hyperphagic during their period of fat deposition (Studier, unpublished data).

Part of the difficulty in interpreting the significance of fat deposition in these *Myotis* is that the winter behaviour of the bats of the Montezuma colony is unknown. We presume that they spend the major part of the winter in hibernation as do other *Myotis* (Davis & Hitchcock, 1965; Tinkle & Patterson, 1965), although hibernacula for the species studied are unknown. The maximum range that a bat can fly with a known level of stored fat can be calculated by the following formula:

$$\text{Maximum range in miles} = \frac{(\text{wt. fat})\,(\text{kcal/g fat})\,(\text{flight speed mph})\,(1000)}{(MR_r)\,(12{\cdot}8)\,(\text{wt. bat})\,(4{\cdot}8\ \text{kcal/l.}O_2)} \qquad (1)$$

The term MR_r is the metabolic rate (cm^3 O_2/g per hr) of a resting homeothermic bat at thermoneutrality. Metabolic rate in flight is estimated by multiplying MR_r by 12·8, a factor reported by Tucker (1968) for birds. This factor has been used for bats as well (Carpenter, 1969). For *M. lucifigus*, MR_r can be estimated at 1·7 cm^3 O_2/g per hr (Stones & Wiebers, 1967), flight speed is considered 20 mph (R. Davis, 1966), weight of the bat is 8·9 g, weight of the fat stored is 1·8 g (Table 1), and caloric content of the fat is 9·4 kcal/g. Hence, the calculated maximum range from the summer roost is 364 miles. For *M. yumanensis*, MR_r is 1·91 cm^3 O_2/g per hr (O'Farrell & Studier, 1970), flight speed is 8·9 mph (Hayward & Davis, 1964), bat weight is 6·8 g, and fat weight is 1·6 g. The calculated maximum range is 168 miles. For *M. thysanodes* MR_r is 1·74 cm^3 O_2/g per hr (O'Farrell & Studier, 1970), flight speed is 9·8 mph (Hayward & Davis, 1964), bat weight is 10·0 g, and fat weight is 2·0 g. The calculated maximum range is 172 miles. The most questionable factor in this calculation is the factor by which MR_r is increased in flight. For example, if this factor were 16·0, the maximum range of *M. thysanodes* would be 137 miles. Studier & Howell (1969) estimated the metabolic rate of *E. fuscus* in flight to be between 25·7 and 38·5 cm^3 O_2/g per hr, which is a factor of

19·8 to 29·6 above MR_r (1·3 cm^3 O_2/g per hr) reported for this species by Herreid & Schmidt-Nielsen (1966). It seems, therefore, that our calculated flight ranges may be considerable overestimates. Furthermore, no correction can be included for the possibility that these bats may forage while flying to the winter roost.

An analagous formula can be designed to calculate the maximum number of days that a bat could spend in hibernation with a known amount of stored fat:

$$\text{Maximum days in hibernation} = \frac{(\text{wt. fat})(\text{kcal/g fat})(1000)}{(MR_h)(\text{wt. bat})(24\ \text{hr/day})(4{\cdot}8\ \text{kcal/1.}O_2)} \qquad (2)$$

Estimating the metabolic rate in hibernation, MR_h, at 0·1 cm^3 O_2/ g per hr (Hock, 1951), we calculate maximum days in hibernation as follows: *M. lucifugus occultus*, 165 days; *M. yumanensis*, 192 days; *M. thysanodes*, 163 days. The most critical variable in this calculation is MR_h. For example, if MR_h for *M. thysanodes* were 0·15 cm^3 O_2/g per hr, the maximum time in hibernation would be 109 days. Furthermore, this calculation assumes that hibernating bats remain totally inactive 24 hr per day. Any periodic arousal would greatly decrease the energy available for hibernation.

We can speculate from these two calculations that these *Myotis* probably migrate for not more than 100–200 miles to their hibernacula and feed for a while prior to hibernation to replenish expended fat stores. It seems most likely that these hibernacula would be located to the south and east of the Montezuma colony where the elevation is lower and the cold season much shorter.

Lipid analysis

Analysis of the fatty acids of body fat showed a predominance of unsaturated fatty acids (72–81 per cent) with oleic acid being most common. This is consistent with the findings of Wells *et al.* (1965) for brown fat of non-hibernating *M. l. lucifugus* and Paulsrud and Dryer (1968) for brown fat of *E. fuscus* entering hibernation. A high level of unsaturated fatty acids is a common occurrence in animals preparing for hibernation and appears to be related to a lowering of the environmental temperature (Fawcett & Lyman, 1954). A high content of palmitoleic acid occurred in each species in our study. This is unusual for animal body fat (Jenness, personal communication), although it has been reported for bat body fat (Wells *et al.*, 1965; Paulsrud & Dryer, 1968).

Gross body composition

Migratory birds studied by Odum *et al.* (1964), Rogers & Odum (1964) and Hicks (1967) have been shown to undergo large changes in gross body weight without appreciable change in gross body composition during seasonal fat deposition and depletion. This phenomenon is attributable to a filling of pre-existing adipose cells rather than a building of new adipose tissue. Such also is the case with *M. thysanodes*, which we have shown to deposit a relatively large amount of fat in a short time without significant change in gross body composition. *M. yumanensis*, however, deposited a significant amount of fat during the entire study period and simultaneously increased nonfat organic and water content. Both gradual fat deposition and increase in gross body composition may be interpreted as a building of new adipose tissue. The constancy of gross body composition in *M. lucifugus occultus* is relatively meaningless because this species underwent no significant change in fat content.

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