A C T A   T H E R I O L O G I C A

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Seasonal Changes in Caloric Value, Body Water and Fat in Some Shrews*)

[With 5 Figs. & 4 Tables]

The caloric equivalent of the body dry mass and biomass of the shrew (*S. araneus*, *S. minutus*, and *N. fodiens*) shows statistically significant changes in the annual cycle and is higher in winter and early spring than in summer and early autumn. For ecological purposes it is suggested to use various caloric values of the shrew biomass in relation to the period of studies. The caloric value of 1 g of biomass of *Soricidae* depends mainly on the degree of hydration of their tissues and is independent of changes in the body fat content. The amount of water in the shrew body is subjected to high, statistically significant variations in the annual cycle. Both the winter depression and spring rise in the body weight of these mammals are result mainly from changes in the tissue hydration. The fat content in the body of *Soricidae* is smaller than in rodents. Fluctuations in the amount of fat are result from the accumulation and utilization of the energy reserves present in *BAT*. All the studied indices showed no statistically significant differences related to the sex of animals.

I. INTRODUCTION

The ecological and physiological literature contain several reports concerning the caloric value and chemical composition of the body of mammals. In most cases, however, the results are based on the limited number of animals usually captured at one time (Golley, 1961; Pitts, 1960; Wipple *et al.* 1963; Myrcha, 1968). Only Górecki (1965) took into consideration, at least partially, seasonal changes in the body caloric value of five species of small rodents. One of the first attempts to compare the chemical composition of the rodents body in summer and winter was made by Hayward (1965) who employed several geographical races of *Peromyscus*. More recently Sawicka-Kapusta (1968) investigated changes in the fat content in the body of *Apodemus flavicollis* (Melchior, 1834) during four seasons of the year. In general, however, there is stiil a great demand for systematic studies on the seasonal changes of the discussed

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indices which are very important in the estimation of productivity in populations of small mammals.

For these reasons it was decided to determine changes in the caloric value as well as in the water and fat contents of the body in 3 species of the shrew during the annual cycle.

II. MATERIALS AND METHODS

The caloric value and water and fat contents were measured in the bodies of 127 specimens of *Sorex araneus* Linnaeus, 1758, 77 specimens of *Sorex minutus* Linnaeus, 1758, and in 38 specimens of *Neomys fodiens* (Pennant, 1771) captured in the area of Kampinoski National Park (52°20′ N, 20°50′ E) as well as in 95 specimens of *S. araneus* captured in Piska Primeval Forest in the Krutyń region (53°30′ N, 21°20′ E). The trapping in Kampinoski National Park was carried out from April 1967 till March 1968 while in Piska Forest only in May, June, and October 1967. In both cases the *Insectivora* were trapped in the biotope of *Pino-Quercetum* Kozłowska, 1925, and *Vaccinio myrtilli-Pinetum* Br. — Bl. et Vlieger 1939. For trapping mainly snap-traps were used with the exception of winter and early spring in Kampinoski National Park where live-traps and cylinders were also employed. Traps were usually inspected twice a day (morning and evening) but in winter only in the morning. Since various types of traps did not produce any statistically significant changes in the studied parameters the whole collected material was analysed together.

Animals supplied to the laboratory were immediately weighted and after sex determination and elimination of pregnant and lactating females the bodies were dried in a vacuum oven in 40—50°C to a constant weight. From the weight difference before and after drying the body water content was calculated. All the dried carcasses were ground fine in an electric grinder.

The caloric indices were determined by combusting 0.4—1.0 g samples in the Berthelot type calorimeter KL-3. From the results were obtained the caloric value of 1 g of dry mass (W_g), caloric value of 1 g dry mass without ash (Wg_{A-F}) as well as caloric value of 1 g of biomass were computed.

The ash content in the sample, required for determination of Wg_{A-F}, was calculated from the difference of weights of crucibles before and after combustion in the calorimeter. The fat content in the bodies of all animals was measured by the method of Puzanov, or Badun and Hannon, or Besson (Krauze *et al.* 1966). This method depends on the double extraction of the material placed in glass vessels with bottoms made of porous, sintered glass. The extraction is carried out at first with vapours of petroleum ether containing 10% ethyl alcohol, and later with the condensed solvent. The time of extraction (3 hr) was established experimentally. With a longer extraction the sample weight after drying remained constant.

For all the indices the mean monthly values were calculated and characterized by the confidence intervals based on the variable *t*. Since no statistically significant differences related to sex were found among the analysed values (Student's *t*-test for the difference between the mean of two independent groups) the material was treated as a whole. The minimum and maximum average monthly values of all the indices calculated for *S. araneus* and *S. minutus* trapped in Kampinoski National Park were compared by Tukey's test.

III. CALORIC EQUIVALENTS OF THE BODY

1. Caloric Value of 1 g of the Body Dry Mass (Wg)

This value in *S. araneus* varies from 4799.0 to 5194.3 cal/g in the annual cycle (Table 1, Fig. 1). The lowest figures were recorded for animals trapped during summer months (July, August) or in early autumn (September, October). Later the value of *Wg* for *S. araneus* rises steadily with a maximum in April. In subsequent months this value decreases till September, at first slowly, and later more abruptly. The difference between the September minimum and April maximum is statistically significant (Tukey's test).

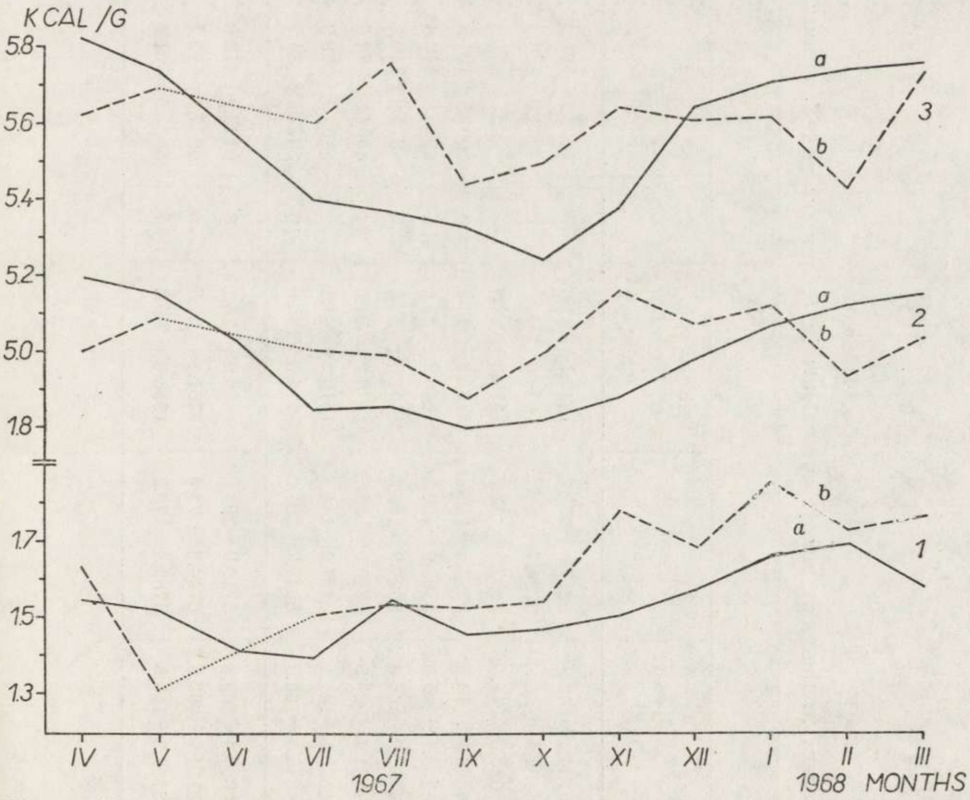

Fig. 1. Seasonal changes in the body caloric equivalents in *S. araneus* (a) and *S minutus* (b): 1 — caloric value of 1 g of biomass; 2 — caloric value of 1 g of dry mass; caloric value of 1 g of ash-free dry mass.

The caloric equivalent of the body dry mass in *S. araneus* captured in May in Piska Primeval Forest is similar to the results obtained for animals captured in the same period in Central Poland (Tables 1 & 2). On the other hand, the value observed in June was lower, and that in

Table 1.

Seasonel changes in the body caloric equivalents in *S. araneus* and *S. minutus* from Central Poland.

Year	Month	*Sorex araneus*				*Sorex minutus*			
		N	*Wg* (cal/g)	Wg_{A-F} (cal/g)	Caloric value of biomass (cal/g)	N	*Wg* (cal/g)	Wg_{A-F} (cal/g)	Caloric value of biomass (cal/g)
1969	IV	12	5194.3±146.9	5217.6±135.4	1547.1± 91.0	7	4999.1±121.2	5621.1±140.0	1633.3± 73.1
	V	2	5152.5	5734.7	1520.0	6	5084.6±168.3	5689.3±190.2	1309.8± 92.1
	VI	8	5028.8± 44.4	5562.5± 52.2	1413.0± 12.3	—	—	—	—
	VII	12	4846.1±110.5	5398.5±146.4	1391.8± 48.9	6	5001.7±101.3	5599.2±165.1	1503.7±101.5
	VIII	10	4853.4± 95.5	5363.0±100.3	1540.6± 49.0	4	4989.8±142.8	5761.4±201.3	1533.2± 96.5
	IX	34	4798.0± 66.0	5326.9± 68.2	1451.9± 33.9	5	4875.8±110.1	5436.5±135.6	1524.4± 61.3
	X	12	4821.4± 20.5	5240.9± 25.7	1470.2± 21.6	14	4994.8± 72.3	5495.7± 83.6	1545.0± 32.[illegible]
	XI	13	4880.1±101.1	5377.9±144.3	1510.2± 41.1	4	5157.7± 99.9	5637.5±112.2	1781.1± 67.7
	XII	9	4979.4±168.8	5641.7±201.2	1574.8±100.0	10	5072.8± 84.7	5604.9±113.1	1691.5± 45.9
1968	I	6	5067.4±269.5	5710.9±293.3	1665.9±126.1	8	5123.9±118.9	5616.5±147.4	1851.5±101.3
	II	5	5124.7± 68.9	5744.8± 75.5	1701.1± 23.7	6	4937.1± 72.1	5430.9±113.6	1736.9± 74.8
	III	4	5152.3±156.8	5765.4±175.5	1596.6± 99.9	7	5039.5± 61.5	5732.5± 95.6	1784.5± 31.2

Table 2.

Caloric value and the content of water and fat in the body of *S. araneus* from Piska Primeval Forest.

Month	N	Body weight g	Water		Fat		Wg (cal/g)	Wg_{A-F} (cal/g)	Caloric value of biomass (cal/g)
			Per cent	g	Per cent	g			
V	29	11.9±0.4	74.0±0.5	8.9±0.4	4.4±0.2	0.54±0.04	5140.0± 44.5	5775.8± 62.4	1342.5±29.3
VI	16	8.6±1.2	69.4±0.9	6.1±0.6	5.2±0.2	0.49±0.06	4823.4±144.9	5362.4±168.4	1478.5±67.4
X	50	7.8±0.2	69.8±0.6	5.5±0.3	4.6±0.3	0.36±0.01	5051.3± 89.8	5561.5±115.6	1527.7±46.1

Table 3.

Caloric value and the content of water and fat in the body of *N. fodiens*.

Year	Month	N	Body weight g	Water g	Fat g	Wg (cal/g)	Wg_{A-F} (cal/g)	Caloric value of biomass (cal/g)
1967	IV	4	15.0±0.7	10.3±0.7	0.45±0.07	4436.3±252.8	5346.6±291.3	1482.2± 94.4
	VI	5	20.0±1.0	14.4±1.3	0.82±0.04	5207.9±133.6	5880.4±175.8	1465.5± 37.7
	VIII	6	11.9±1.7	8.3±1.8	0.41±0.10	4774.9±177.3	5470.5±202.5	1437.1± 95.7
	IX	11	14.0±1.2	9.7±1.2	0.74±0.10	4882.5±189.4	5543.2±245.7	1498.1± 85.8
	X	8	15.8±1.1	11.3±1.1	0.79±0.16	4831.7±122.3	5580.1±143.8	1380.5± 61.7
1968	III	4	10.5±1.3	6.8±1.8	0.59±0.08	4602.9±182.5	5223.9±275.8	1652.6±141.3

October higher in specimens trapped in northern Poland as compared with the animals living in Kampinoski National Park. These differences are statistically significant (Student's t-test).

The caloric value of 1 g of the body dry mass changes in the annual cycle within a more narrow limit in *S. minutus* than in *S. araneus* (Table 1, Fig. 1). The minimum was observed in September (4875.8 cal/g) with a rise in two consecutive months to the highest value in November (5157.7 cal/g). From that moment a slow decrease begins and continues till September. The difference between the minimum and maximum average monthly *Wg* value in *S. minutus* is statistically not significant (Tukey's test).

Due to the limited amount of material it was impossible to investigate changes in the caloric value of the body dry mass in *N. fodiens* in the full annual cycle. The obtained data (Table 3) suggest, however, that the course of these changes is slightly different than in the discussed above two representatives of the *Sorex* genus. The maximum caloric value of the body dry mass in *N. fodiens* was recorded in June with a trend to constant decrease in subsequent months. Animals trapped in April showed the lowest caloric index of the body dry mass. Moreover *N. fodiens* is characterized by generally lower *Wg* values comparing with *S. araneus* and *S. minutus*.

2. Caloric Value of 1 g of the Body Dry Mass Without Ash (Wg_{A-F})

This value depends on the caloricity of the body dry mass from one side and the content of mineral constituents on the other.

In all three studied species the course of the seasonal changes of Wg_{A-F} is very similar to that of the caloric value of 1 g body dry mass of these animals (Table 1, 2 & 3, Fig. 1). In this case however, slightly bigger variations are observed between average monthly values of the discussed index. Also the statistical analysis showed the existence of significant differences between the autumn minimum (October) and spring maximum (April) in *S. araneus*. On the other hand, no statistically significant differences were found between the extreme mean monthly Wg_{A-F} values calculated for *S. minutus*.

3. Caloric Value of 1 g of Biomass

The mean monthly caloric values of 1 g of biomas in *S. araneus* trapped in Kampinoski Primeval Forest show in the annual cycle a broad range of variations from 1391.8 cal/g to 1701.1 cal/g (Table 1, Fig. 1). The minimum value was recorded for animals trapped in July but in consecutive months it increased reaching the maximum in February. During the whole spring till midsummer this value systematically decreases. The difference between the minimum (July) and maximum (February) caloric value of 1 g of biomass in *S. araneus* is statistically significant.

The caloric value of fresh tissue of *S. araneus* trapped in Piska Primeval Forest in May, June and October deviates from the figures given above for this species in Central Poland. They are much more close to the value of this index in *S. minutus* (Table 2).

The caloric value of 1 g of biomass in *S. minutus* fluctuates in the annual cycle within a broader range than in *S. araneus* (Table 1, Fig. 1). The minimum mean monthly value was found for animals trapped in May (1309.8 cal/g). In subsequent months the caloric equivalent of fresh tissue in *S. minutus* rises during summer and autumn. The broad plateau is observed between November and March with a maximum in January (1851.5 cal/g). In the two consecutive spring months the caloric value of 1 g of biomass in *S. minutus* abruptly decreases. Statistical analysis (Tukey's test) showed existence of significant differences between the extreme monthly average values of this index in *S. minutus*.

N. fodiens is generally characterized by the caloric values of biomass similar to the other representatives of *Soricidae* (Table 3).

IV. BODY WEIGHT

Changes in the body weight of *S. araneus* and *S. minutus* in the annual cycle show a similar course (Table 4). In both cases the body weight of animals trapped in summer is fairly constant. Variations observed in this period result from the non-homogenous age composition of particular samples. The autumn-winter depression of the body weight appears since October in both species with return to normal values in spring. In *S. minutus* the spring increase in the body weight appeared slightly earlier than in *S. araneus* and continued one month longer.

The collected data are not sufficient to follow changes in the body weight of *N. fodiens* in the annual cycle (Table 3). It is possible to conclude, however, that the body weight of animals trapped in summer and early autumn remains on a constant, rather low level. It is also clear that in *N. fodiens* a marked increase of this index occurs in spring.

V. SEASONAL CHANGES IN THE BODY WATER CONTENT

The relative (percentage) water content in tissues of *S. araneus* trapped in Kampinoski Primeval Forest varies between 66.8% (February) and 71.9% (June) (Fig. 2). A high hydration of the body of studied ani-

Table 4.

Seasonal changes in the body weight and water and fat contents in *S. araneus* and *S. minutus* from Central Poland.

Year	Month	*S. araneus*				*S. minutus*			
		N	Body weight g	Water g	Fat g	N	Body weight g	Water g	Fat g
1967	IV	12	7.76±0.95	5.41±0.67	0.15±0.02	7	3.52±0.55	2.36±0.35	0.09±0.01
	V	2	7.11	5.01	0.27	6	4.50±0.89	3.34±0.50	0.12±0.03
	VI	8	6.52±1.39	4.69±1.01	0.26±0.07	—	—	—	—
	VII	12	8.10±1.16	5.79±0.95	0.35±0.07	6	3.61±0.62	2.52±0.61	0 13±0.03
	VIII	10	6.53±0.69	4.26±0.55	0.30±0.04	4	3.94±0.40	2.65±0.28	0.12±0.03
	IX	34	7.49±0.33	5.23±0.40	0.34±0.05	5	2.61±0.27	1.79±0.39	0.08±0.01
	X	12	6.56±0.65	4.56±0.45	0.26±0.02	14	2.83±0.15	1.94±0.19	0.07±0.02
	XI	13	6.48±0.55	4.44±0.61	0.33±0.04	4	2.70±0.35	1.77±0.41	0.11±0.01
	XII	9	6.19±0.20	4.23±0.32	0.34±0.05	10	2.65±0.27	1.77±0.25	0.17±0.02
1968	I	6	5.99±0.20	4.13±0.35	0.39±0.07	8	2.52±0.12	1.63±0.19	0.14±0.05
	II	5	5.54±0.64	3.70±0.81	0.25±0.07	6	2.68±0.19	1.31±0.30	0.13±0.04
	III	4	6.20±1.22	4.28±0.80	0.08±0.02	7	2.75±0.31	1.81±0.48	0.08±0.02

mals persists during the whole summer period. On the other hand, in autumn and winter a steady and even decrease of this index is observed. After reaching a minimum in February the water content in tissues of *S. araneus* begins to rise quickly and it continues during the whole spring. The difference between the minimum and maximum average monthly value of this parameter is statistically significant (Tukey's test).

The relative hydration of tissues in *S. minutus* varies in the annual cycle within a broader range than in *S. araneus* (Fig. 2). The highest value of this index is observed in May (74.2%). During the whole summer, autumn and winter the per cent of body water content in *S. minutus* decreases with a minimum occurring in January and February (64.8%). From this moment a rise in the relative tissue hydration in this species occurs, at first slowly, and then more rapidly. The difference between the minimum and maximum mean monthly value of this index is statistically significant (Tukey's test).

The relative water content in tissues of *N. fodiens* (Fig. 2) varies in a similar range as in the two other species. Also in this case the highest body hydration is observed in spring whereas in summer and early autumn a steady and rather significant decrease appears.

The body water content in the discussed three species of *Soricidae*, expressed in absolute units, fluctuates in the annual cycle in parallel to the alterations of body weight of these animals (Tables 2, 3 & 4).

VI. SEASONAL CHANGES IN THE BODY FAT CONTENT

Changes in the relative and absolute amount of the ether extract from bodies of *S. araneus* deriving from Kampinoski Primeval Forest show a similar course in the annual cycle (Table 4, Fig. 2). During summer these indices remain on a constant level. Starting from early autumn (September) their values systematically increases till a maximum in January. On the other hand in February both indices abruptly decrease reaching a minimum already in March. During remaining two spring months these values rise approaching in May the summer level. The differences between the minimum and maximum average monthly values of the relative and absolute fat content in *S. araneus* are statistically significant (Tukey's test). Both the relative and abolute fat contents in the body of *S. araneus* trapped in Piska Primeval Forest are in all the studied months slightly higher than in animals living in Central Poland. These differences are statistically significant (Student's *t*-test).

The course of seasonal changes in the relative and absolute body fat contents of *S. minutus* is slightly different than in *S. araneus* (Table 4, Fig. 2). The minimum average monthly value of these indices was observed in October and maximum in December. The differences between these extreme values are statistically significant (Tukey's test).

N. fodiens contains the least amount of adipose tissue (Table 3) in early spring (March). But already in the next month the fat content (both relative and absolute) in the body of these animals rapidly

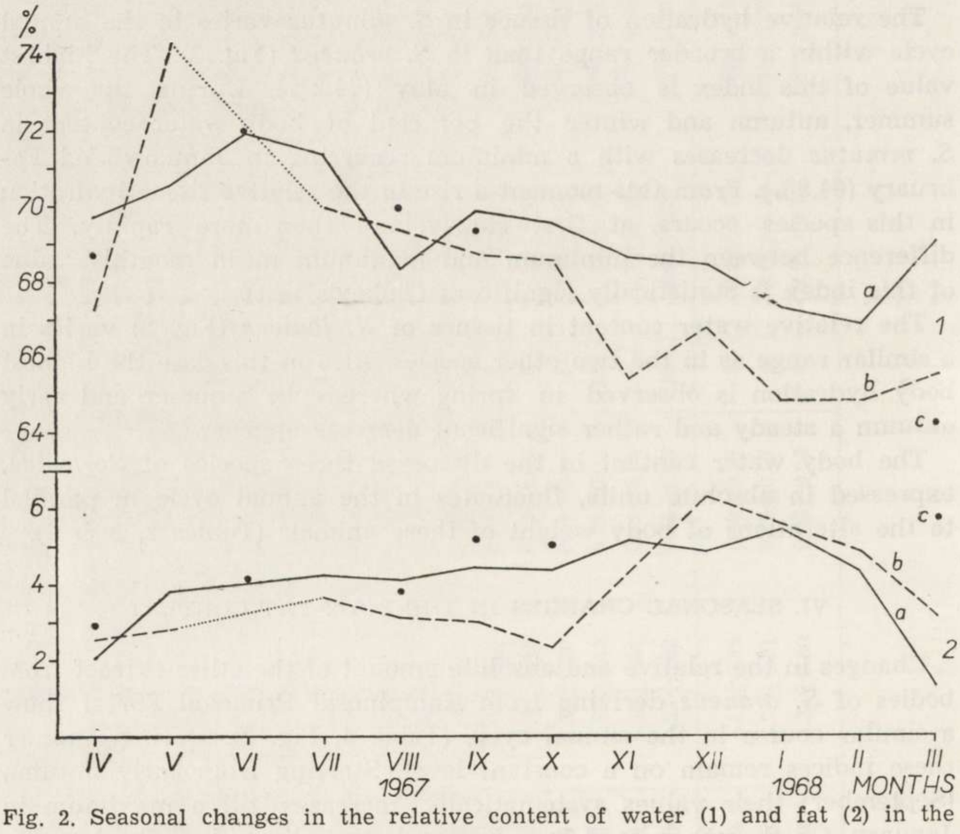

Fig. 2. Seasonal changes in the relative content of water (1) and fat (2) in the body of *S. araneus* (a), *S. minutus* (b), and *N. fodiens* (c).

rises and remains on a fairly high level during spring months. On the other hand, in summer (August) the index of body fatness in *N. fodiens* is very low and increases only in autumn.

VII. DISCUSSION

The results presented above indicate great seasonal differences in the caloric value of the body of three analysed *Soricidae* species. G ó r e c k i (1965) investigated, among others, the caloric value of the body of

S. araneus in three seasons of the year. He found that the caloricity of the body dry mass in this species remains during all the year on a relatively low level (4449.17 — 4682.73 cal/g). In the present study the range of fluctuations was broader and the caloric equivalent of the body dry mass in *S. araneus* was slightly higher. This results from the fact that Górecki (1965) in his studies did not take into consideration the full annual cycle and did not find the apparent minimum (September), and maximum (April). The caloric value of the body dry mass of *S. minutus* is more constant and fluctuates within closser limits. On the other hand, the range of variations between the average monthly values of this index in *N. fodiens* is broader and remains within limits similar to rodents (Golley, 1961; Davis & Golley, 1963; Górecki, 1965).

In analogous manner the caloric value of 1 g of biomass in the studied shrews changes in the annual cycle in broader range than that reported by Górecki (1965).

For the computation of net productivity of the *S. araneus* population Górecki (1965) suggested the use of the mean annual caloric value of 1 g of biomass equal to 1.498 kcal/g. The results presented here indicate the necessity of differentiation of this index and employment of various values in relation to the period of studies. The following values are suggested for *S. araneus* and *S. minutus*, respectively:

S. araneus		*S. minutus*	
Winter and early spring (Dec., Jan., Feb., March)	— 1.635 kcal/g	Late autumn, winter, early spring (Nov., Dec., Jan., Feb., March)	— 1.769 kcal/g
Spring (April, May)	— 1.533 kcal/g	Spring (April)	— 1.663 kcal/g
Early summer (June, July)	— 1.402 kcal/g	Spring (May)	— 1.310 kcal/g
Late summer and autumn (Aug., Sep., Oct., Nov.)	— 1.493 kcal/g	Summer and early autumn (July, Aug., Sep., Oct.)	— 1.527 kcal/g
Annual average	— 1.532 kcal/g	Annual average	— 1.627 kcal/g

In the case of *N. fodiens* the collected data allow to calculate only the mean value of this index for spring and summer (March, April, June, August, September) — equal to 1.503 kcal/g. But already in October *N. fodiens* shows a lower caloric value of 1 g of biomass (1.380 kcal/g). The mean value of this index computed for all the measurements in *N. fodiens* amounts to 1.472 kcal/g and thus is very similar to the annual mean calculated for *S. araneus*.

The caloric value of 1 g of biomass in the studied *Soricidae* depends mainly on the degree of tissues hydration (Fig. 3) and is inversely proportional to changes in the relative content of the body water in these animals. The correlation coeficients calculated both for *S. araneus* ($r = -0.96$), *S. minutus* ($r = -0.86$), *N. fodiens* ($r = -0.66$), and in

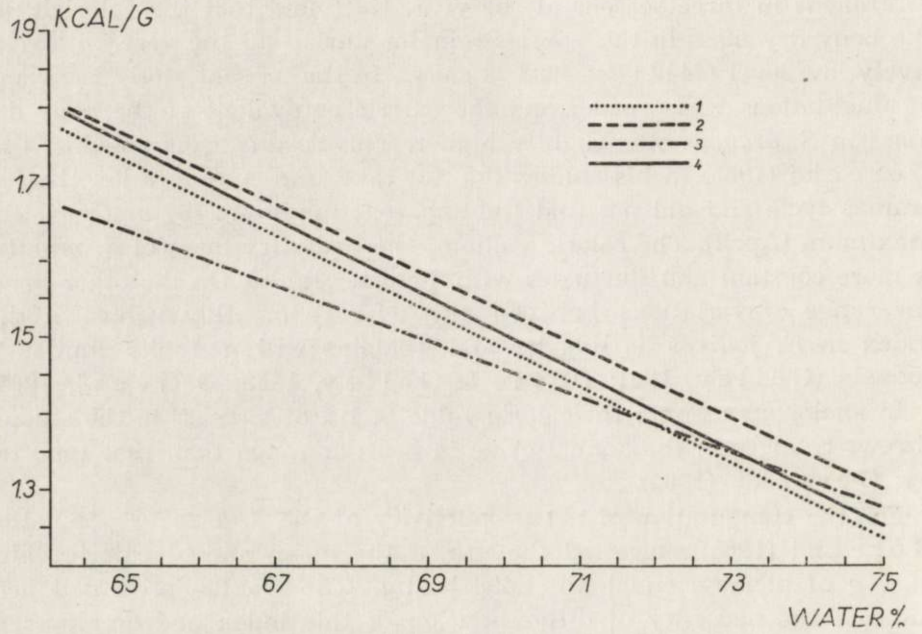

Fig. 3. Relationship between the caloric value of 1 g of biomass (kcal/g) and the body water content (per cent) in *Soricidae:*

1 — *S. araneus* ($y = 4.99 - 0.0499x$; $r = -0.96$; n = 150)
2 — *S. minutus* ($y = 4.81 - 0.0468x$; $r = -0.86$; n = 77)
3 — *N. fodiens* ($y = 4.06 - 0.0372x$; r = —0.66; n = 38)
4 — In general ($y = 5.00 - 0.050x$; $r = -0.98$; n = 265)

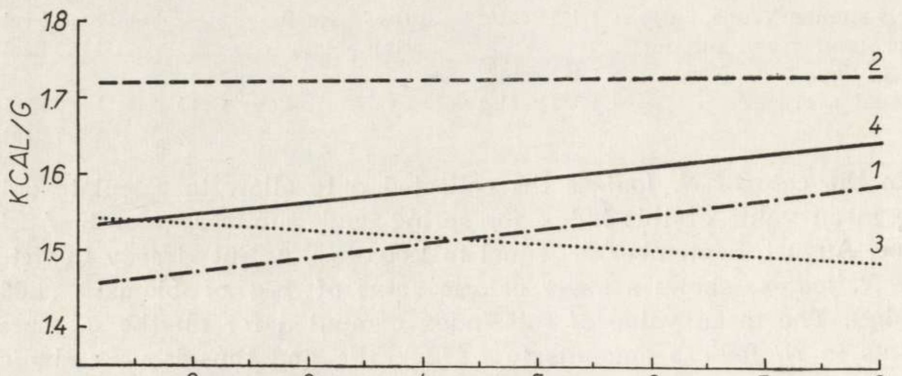

Fig. 4. Relationship between the caloric value of 1 g of biomass (kcal/g) and the fat content (per cent) in the body of *Soricidae:*

1 — *S. araneus* ($y = 1.44 + 0.018x$; $r = -0.024$; n = 100)
2 — *S. minutus* ($y = 1.73 + 0.0076x$; $r = 0.038$; n = 50)
3 — *N. fodiens* ($y = 1.55 - 0.0096x$; $r = -0.121$; n = 37)
4 — In general ($y = 1.50 + 0.0211x$; $r = 0.237$; n = 187)

general for all three species ($r = -0.98$) are very high and statistically significant. In the case of *Soricidae*, in contrast with rodents (G ó r e c k i, 1965), seasonal changes in the body water content in these animals enhance the seasonal variability of the caloric value of 1 g of biomass.

On the other hand, the alterations in caloricity of the fresh tissue of *Insectivora* are independent of the body fat content (Fig. 4). Although the relative and absolute amount of the body fat in the analysed species change in the annual cycle, these variations are smaller than those of the water content and therefore they exert only a slight effect on the value of caloric equivalent of the biomass of *Soricidae*. The correlation coefficients between the caloricity of 1 g of biomass in these animals and the body fat content are statistically non-significant. These results

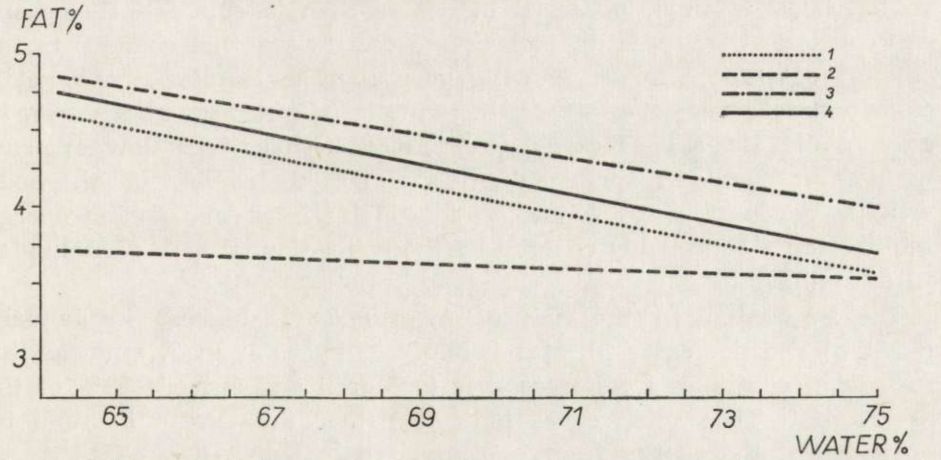

Fig. 5. Relationship between the body fat content and hydration of tissues in *Soricidae*:

1 — *S. araneus* ($y = 11.26 - 0.103x$; $r = -0.178$; n = 100)
2 — *S. minutus* ($y = 4.43 - 0.0113x$; $r = -0.199$; n = 50)
3 — *N. fodiens* ($y = 10.95 - 0.095x$; $r = -0.178$; n = 37)
4 — In general ($y = 15.03 - 0.155x$; $r = -0.265$; n = 187)

differ from the data obtained for other mammals (G o l l e y, 1961; D a v i s & G o l l e y, 1963; G ó r e c k i, 1965; M y r c h a, 1968) in which the caloric value of fresh tissues depends in a significant degree on the amount of fat. Moreover, in other mammals there is an inversely relationship between the body water and the fat contents (S i r i, 1956; P a s s m o r e, 1961; H a y w a r d, 1965). Among the studied *Soricidae* no such relationship was found (Fig. 5) and the correlation coefficients between these indices do not show statistical significance.

The fat content in the body of studied *Soricidae* is not too high and remains in a lower region of typical figures for rodents (P a c e & R a t h b u n, 1945; P i t t s, 1960, 1962; H a y w a r d, 1965; S a w i c k a-

Kapusta, 1968). This is associated with the fact, that shrews in natural conditions do not accumulate the reserve fat in another form than the brown adipose tissue (*BAT*) and they show a certain degree of fatness only during laboratory breeding (Pucek, 1964). The ether extract from the body of *Soricidae* contains mainly lipids from the central nervous system and brown adipose tissue. From the study by M. Pucek (1965) it appears that seasonal changes in the weight of the brain in *Soricidae* are related mainly to the water content while the absolute amount of lipids in this organ shows only negligible variations. On the other hand, Z. Pucek (1965) found that in *S. araneus* the weight of *BAT* expressed in per cent of body weight is highest in winter and lowest in summer. In the present study a higher fat content in the animal body was also observed in winter than in summer. Hence one can conclude that these differences are due to seasonal changes in the amount of *BAT*. Shrews, showing very high metabolism, have particularly great energy expenses in winter (Gębczyńska & Gębczyński, 1965; Gębczyński, 1965) because of a low external temperature, and in spring, due to a marked increase of the body weight. At least part of these additional winter and spring energy requirements is probably covered by the utilization of *BAT* accumulated in autumn.

The fat content in the body of *S. araneus* is highest in January (0.387 g) and decreases till March (0.080 g) by 80%. In *S. minutus* this regression continues from December to March and exceeds 50% of the reserve fat. These differences indicate rather intensive utilization by *Soricidae* of the energy reserves comprised in *BAT*.

The weight of *BAT* reported by Z. Pucek (1965) is markedly lower than the value obtained by the extraction of lipids from the bodies of these animals. This is probably due to the fact that the ether extract contains also some lipids from the central nervous system, and on the other hand, Pucek (1965) analysed only the weight of *BAT* in the interscapular area.

The already mentioned phenomenon of seasonal changes of the body weight of *Soricidae* was described by Dehnel (1949) and others (for references see Pucek, 1963, 1964). It represents probably one of the mechanisms helping to survive such unfavourable period as winter. Dehnel (1949) suggested already that both the winter depression and spring rise in the body weight of shrews result mainly from changes in the body water content. The body weight of *S. araneus* decreases by 1.02 g between October and February. Simultaneously the amount of water in tissues is reduced by 0.86 g what corresponds to 84.3% of the body weight drop. In the period of spring rise in the body weight observed between February and April (2.20 g) the water content in the body of *S. araneus* increases by 1.77 g. This figure constitutes over 77% of a change in the body weight. A similar course in the described phenomenon was found in *S. minutus*. The body weight decreases by 1.42 g between August and January, and at the same time the water content falls by 1.02 g. In the period October—January both the body weight of *S. minutus* and water content in tissues are reduced by 0.31 g. The increase in the body weight of *S. minutus* during spring is related mainly to hydration of tissues. The accumulation of water is responsible for 82.3% of the body gain observed in this animal during spring months till May.

Similarly the seasonal changes of the body weight in *N. fodiens* may be attributed to marked differences in the tissue water content. The body weight in *N. fodiens* increases between March and April by 4.98 g while the amount of water goes up by 4.06 g what corresponds to 81.5% of the body weight gain.

The discussed above seasonal differences in the hydration of tissues in *Soricidae* may be also regarded as an adaptive mechanism enabling the animals to survive difficult periods. The decreased water content in tissues probably leads to the reduction of cellular metabolism. This supposition is confirmed by the high degree of body hydration in young animals as well as by the reduced amount of tissue water in animals hibernating during unfavourable periods of the year (Areševa *et al.*, 1968; Myrcha & Walkowa, 1968).

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SEZONOWE ZMIANY WARTOŚCI KALORYCZNEJ CIAŁA ORAZ ZAWARTOŚCI W NIM WODY I TŁUSZCZU U NIEKTÓRYCH *SORICIDAE*

Streszczenie

Sezonową zmienność wartości kalorycznej ciała oraz zawartości w nim wody i tłuszczu przebadano u 127 *S. araneus,* 77 *S. minutus* i 38 *N. fodiens* odłowionych w Puszczy Kampinoskiej i u 95 osobników *S. araneus* pochodzących z Puszczy Piskiej.

Stwierdzono, że: 1. Kaloryczność suchej masy ciała *Soricidae* zmienia się istotnie statystycznie w cyklu rocznym i jest wyższa zimą i wczesną wiosną w porównaniu z latem i wczesną jesienią. Pomiędzy poszczególnymi gatunkami są jednak dość duże różnice pomiędzy okresami, w których wskaźnik ten osiąga ekstremalne wartości.

2. Przebieg sezonowych zmian wartości kalorycznej suchej masy ciała bez popiołu jest bardzo podobny do zmian kaloryczności suchej masy.

3. Wartość kaloryczna 1 g biomasy badanych *Soricidae* waha się w cyklu rocznym w dość szerokich granicach. Do celów ekologicznych proponuje się użycie różnych wartości tego wskaźnika w zależności od okresu badań:

S. araneus	
Zima i wczesna wiosna (XII, I, II, III)	— 1,635 kcal/g
Wiosna (IV, V)	— 1,533 kcal/g
Wczesne lato (VI, VII)	— 1,402 kcal/g
Późne lato i jesień (VIII, IX, X, X)	— 1,493 kcal/g
Średnia roczna	— 1,532 kcal/g

S minutus	
Późna jesień, zima, wczesna wiosna (XI, XII, I, II, III)	— 1,769 kcal/g
Wiosna (IV)	— 1,633 kcal/g
Wiosna (V)	— 1,310 kcal/g
Lato i wczesna jesień (VII, VIII, IX, X)	— 1,527 kcal/g
Średnia roczna	— 1,627 kcal/g

N. fodiens — wiosna i lato (III, IV, VI, VIII, IX) — 1,503 kcal/g, a w październiku — 1,380 kcal/g (dla pozostałych miesięcy brak jest danych).

4. Wartość kaloryczna 1 g biomasy *Soricidae* zależy przede wszystkim od stopnia uwodnienia ich tkanek, a nie zależy od zmian zawartości tłuszczu w ciele tych zwierząt.

5. Zawartość tłuszczu w ciele ryjówek jest na ogół mniejsza niż u gryzoni, lecz zmienia się istotnie statystycznie w cyklu rocznym (najwyższa jest zimą, a najniższa wiosną). Wahania w ilości tłuszczu spowodowane są prowdopodobnie gromadzeniem i wykorzystywaniem rezerw energetycznych zawartych w *BAT*. Rezerwy te zużywane są głównie wczesną wiosną.

6. Dużym, istotnym statystycznie zmianom sezonowym podlega ilość wody w ciele ryjówek. Zarówno zimowa depresja jak i wiosenny skok ciężaru ciała tych ssaków spowodowane są przede wszystkim wahaniami w uwodnieniu ich tkanek.

7. We wszystkich badanych wskaźnikach nie ma różnic istotnych statystycznie związanych z płcią zwierząt.

8. *S. araneus* z północnej Polski (Puszcza Piska) odznacza się wyższą kalorycznością ciała i zawartością tłuszczu w tkankach w porównaniu z osobnikami tego gatunku pochodzącymi z centralnej Polski (Puszcza Kampinoska).