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Variations in the Length and Weight of the Alimentary Tract of *Clethrionomys glareolus* (Schreber, 1780)

Zmienność długości i ciężaru przewodu pokarmowego *Clethrionomys glareolus* (Schreber, 1780)

[With 2 Figs. & 4 Tables]

I. INTRODUCTION

Rodents form one the most varied groups of mammals in respect of the food they eat and include both animals with highly specialised food requirements and many omnivorous species (Voronov, 1954). Certain food relations are most distinctly decisive in determining the structure of the alimentary tract in the different species of *Rodentia*. The bank vole (*C. glareolus*) belongs to the group of rodents with relatively labile food requirements, the food of this species including both seeds and the green parts of plants, and also to a certain extent roots and small invertebrates. The ratios of the components of its food, however, vary greatly depending on the place in which the rodent lives and the season of the year (Jurgenson, 1937; Löhr, 1938; Naumov, 1948; Obrazcov, 1951; Miller, 1954; Koškina, 1957; Vorontzov, 1961; Górecki & Gębczyńska, 1962).

Vorontzov (1962) put forward the view, on the basis of analysis of the structure of the alimentary tract in many species of rodents, that the evolution of *Muroidea* has been very rapid, its basic trend being the transition from feeding on protein food rich in calories but difficult to obtain, to cellulose foods, low in calories but easy of access.

In view of the above a knowledge of the alimentary tract of *C. glareolus* is of very great theoretical importance. Comparatively few data throwing light on this question are, however, encountered in literature (Naumov, 1948; Kulajeva, 1958; Vorontzov, 1961). While more is known about the histological structure of the alimentary tract of this rodent (Velitshko, 1939, 1949; Luppa, 1958a, 1958b, 1961), I have not found any data on the changes taking place in the anatomical structure of the alimentary tract of *C. glareolus* in connection with the age of the animals.

The aim of the present study has therefore been:

1. to obtain a knowledge of the length and weight of different sections of the alimentary tract of *C. glareolus* and to compare these data with the results given by other authors.
2. to trace the changes in these values with the increasing age of the animals.
3. to compare the anatomical relations of the alimentary tract in both sexes in *C. glareolus*.

II. MATERIAL AND METHODS

Morphological investigation of the alimentary tract of *C. glareolus* was made on animals caught in the Białowieża National Park, in the biotope formed by *Querco-Carpinetum stachyetosum* R. Tx. A total of 169 rodents were examined, consisting of 73 ♂♂ and 96 ♀♀. 149 rodents were caught in the summer and autumn of 1963, and these were supplemented by 20 ♀♀ caught at the end of the winter of 1963/64. The animals were caught in livetraps and taken to the laboratory where, after general measurements of the body had been made, they were dissected and the alimentary tract excised (excluding the oesophagus). The length of the various sections of the intestines was measured on a glass plate on which normal saline solution was poured in order to avoid stretching the walls of the tract. After being measured and thoroughly cleaned of food remnants, the intestines and stomach of 149 rodents were weighed on an automatic scale with accuracy of 0.1 mg.

Calculation was next made of the ratio of length of intestine and of the different sections of the intestine in relation to body length, the values of different parts of the intestine in percentages of its entire length and in percentages of the body weight of each animal.

The sexual activity of all the females was defined on the basis of the appearance of the uterus, the presence of embryos and corpora lutea and the size of the milk gland.

The material was divided into five age groups after W a s i l e w s k i (1952), using the length of the aboral root of M_1 as a criterion in allocating the animals to the groups. The length of the roots was measured under a dissecting microscope using a vernier calipers. As the numbers of animals in classes *IV* and *V* were very small they were combined in one group — *IV*.

The mean values of the indices calculated for each age group, and also for both sexes in each group, were analysed statistically according to the *t*-Student test for the difference between means for two independent groups.

III. RESULTS

The dates given in Table 1 show that the length of the alimentary canal of *C. glareolus* increases with age. This increase is, however, relatively slight, and the increases in length are reduced as the animals grow old. This is borne out by the ratio of length of intestine to the body length of the rodent, which decreases with age. The analysis made revealed statistically significant differences when comparison was made of the total length of the intestines of animals in group *I* with analogical data for animals in groups *III* and *IV*.

The value for each section of the intestine, expressed in percentages of its total length, is in general constant and is not subject to variations during the aging process in these animals (absence of statistically significant differences between each group).

The ratio of the total length of the intestine to body length (excluding the tail) decreases slightly but constantly with the age of the rodent. Statistically significant differences in the index were observed between the extreme groups (*I* and *IV*). These differences did not, on the other hand, occur when neighbouring groups were compared. Detailed analysis of this index showed that the ratio of length of the small intestine to body length decreases most with age, while the analogical values calculated for the large intestine are the most constant.

It will be seen from the data in Table 2 that the weight of the alimentary tract of *C. glareolus* is subject to changes with age. A distinct increase in weight (difference statistically significant) was observed with transition from age group *II* to *III*. This increase is chiefly due to the marked increase in weight of the small intestine. Statistically significant differences were not, however, observed when comparing the weight of the alimentary tract of the animals from group *I* and *II* and *III* and *IV*.

The weight of the stomach and intestines, expressed in percentages of the total body weight of the rodents decreases slightly but distinctly with age, and statistically significant differences occur between age groups *I* and *IV*. On the other hand the percentages of its total weight formed by different parts of the alimentary tract are in general constant values and not subject to any considerable changes with age (differences statistically non-significant).

Changes with age in the length and weight of the alimentary canal of *C. glareolus* are of a different character in the two sexes. The total length of the intestine in males does not exhibit statistically significant differences in any of the age groups. The intestines of females, on the other hand, are subject to continual and very distinct increase throughout the whole of the animals' life (Fig. 1), the greatest increases being observed in the length of the small intestine. Comparison of the total length of the intestine and its different sections revealed the existence of statistically significant differences connected with the sex of the animals, in all the age groups except group *I*. These differences did not occur in age group *IV* when the lengths of the caecum and large intestine were compared.

Distinct sex dimorphism also occurs in the weight of the alimentary tract of *C. glareolus*. The weight of this tract in males, similarly to its length, is almost constant in all the age groups (no statistically significant differences), whereas in females a sudden increase in the weight of the stomach and intestines between age groups *II* and *III* can be observed

Table 1.

Mean values of indices of the length of intestines in *C. glareolus* in different age groups.

Age groups		I			II			III			IV		
		♂♂	♀♀	♂♂ + ♀♀	♂♂	♀♀	♂♂ + ♀♀	♂♂	♀♀	♂♂ + ♀♀	♂♂	♀♀	♂♂ + ♀♀
Weight of intestine in g	small	0.5253	0.5550	0.5376	0.5531	0.5497	0.5514	0.5684	0.8132	0.7316	0.5251	0.8678	0.7179
	large	0.2793	0.2837	0.2831	0.2566	0.3120	0.2843	0.2783	0.4024	0.3610	0.3121	0.4164	0.3708
	caecum	0.2407	0.2145	0.2302	0.2358	0.2293	0.2326	0.2190	0.3266	0.2907	0.2067	0.3305	0.2764
	stomach	0.2434	0.2503	0.2467	0.2533	0.2616	0.2573	0.2387	0.3998	0.3461	0.2701	0.4334	0.3619
	total	1.2817	1.3035	1.2976	1.2988	1.3526	1.3256	1.3044	1.9420	1.7294	1.3140	2.0481	1.7270
% of total weight of the alimentary tract	small	39.9	43.5	41.5	42.6	40.6	41.6	43.6	41.9	42.3	40.0	42.4	41.6
	large	22.7	21.4	22.1	19.8	23.1	21.4	21.3	20.7	20.9	23.7	20.3	21.5
	caecum	18.6	16.0	17.6	18.1	16.9	17.5	16.8	16.8	16.8	15.7	16.1	16.0
	stomach	19.0	19.1	19.0	19.5	19.3	19.4	18.3	20.6	20.0	20.5	21.1	20.9
% of total body weight	small	3.56	3.56	3.56	3.24	3.11	3.17	3.18	3.76	3.57	2.70	2.95	2.84
	large	2.09	1.79	1.97	1.49	1.71	1.60	1.56	1.85	1.75	1.49	1.40	1.44
	caecum	1.67	1.37	1.55	1.37	1.32	1.34	1.24	1.50	1.41	1.00	1.12	1.07
	stomach	1.70	1.72	1.71	1.49	1.52	1.50	1.34	1.85	1.68	1.30	1.46	1.39
	total	9.10	8.32	8.78	7.76	7.70	7.73	7.32	8.96	8.42	6.51	6.94	6.75
n		23	22	45	32	25	57	10	16	26	8	13	21

Table 2.

Mean values of weight indices of the alimentary tract in *C. glareolus* in different age groups.

Age groups		I			II			III			IV		
		♂♂	♀♀	♂♂ + ♀♀	♂♂	♀♀	♂♂ + ♀♀	♂♂	♀♀	♂♂ + ♀♀	♂♂	♀♀	♂♂ + ♀♀
Length of intestine in cm	small	39.0	40.7	39.8	40.2	42.3	41.1	39.6	43.7	42.	38.8	45.5	43.0
	large	16.8	16.9	16.8	17.4	18.6	17.9	16.1	20.2	18.6	17.9	20.3	19.4
	caecum	8.3	8.2	8.3	8.3	9.0	8.8	8.5	9.4	9.0	9.4	9.0	9.2
	total	64.1	65.8	64.9	66.2	69.9	67.8	64.2	73.3	69.7	66.1	74.8	71.6
% of total length of intestine	small	60.8	61.8	61.3	60.7	60.5	60.6	61.7	59.6	60.4	58.7	60.8	60.0
	large	26.2	25.7	25.9	26.3	26.6	26.4	25.1	27.6	26.7	27.1	27.1	27.1
	caecum	13.0	12.5	12.8	13.0	12.9	13.0	13.2	12.8	12.9	14.2	12.0	12.9
Ratio of length of intestines to length of body	small	4.64	4.98	4.81	4.59	4.76	4.66	4.34	4.63	4.52	3.97	4.55	4.33
	large	1.99	2.06	2.02	1.98	2.10	2.04	1.76	2.12	1.98	1.86	2.02	1.96
	caecum	0.99	1.01	1.00	0.98	1.00	0.99	0.93	0.98	0.96	0.96	0.89	0.92
	total	7.63	8.06	7.84	7.55	7.80	7.66	7.03	7.72	7.45	6.78	7.47	7.21
n		23	22	45	32	25	57	10	16	26	8	13	21

(Fig. 2). Statistical analysis showed the existence of significant differences in the weight of the alimentary tract of males and females within groups *III* and *IV*.

The results obtained also show that the decrease in the percentage of the total body weight of the animal formed by the weight of the alimentary tract is far more distinct in the males than in the females of this species.

In order to discover any possible connection between the increase in weight and length of the alimentary tract of females and their sexual activity, analysis was made from this aspect of the results obtained in age groups *II*, *III* and *IV*. Group *I* was not taken into consideration, as the majority of the females in this group were not sexually mature and any differences found might be due not so much to the changes connected

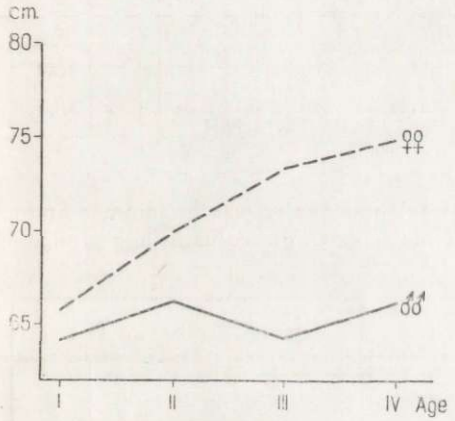

Fig. 1. Length of the intestines in males and females of *C. glareolus* in different age groups.

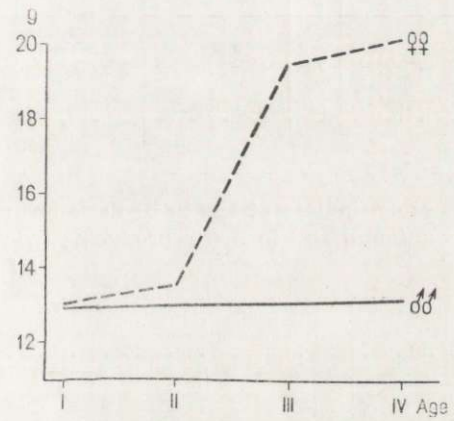

Fig. 2. Weight of the alimentary tract of males and females of *C. glareolus* in different age groups.

with activity, as to the considerable differences in the age of the animals. In groups *III* and *IV* all the females caught in the summer and autumn, with the exception of one specimen only, had reached the stage of nursing their young, and many of them were also pregnant. In the only sexually inactive female the length of the intestines (65.4 cm) and weight of the alimentary tract (1.0270 g) differed very markedly from the analogical values for the remaining females in these groups, and are more similar to the data calculated for males of the same age. In age group *II* 9 sexually inactive females with thin uteri, and 13 active nursing females, the majority of the latter being simultaneously pregnant, were found among the mature animals. The results given in Table 3 point clearly to the

existence of differences between these two groups of animals. The sexually active females have longer alimentary tracts, mainly due to the elongation of the small and large intestines (differences statistically significant). Increase in the weight of both the above sections of the intestines occurs in these females also, and also increase in the weight of the stomach. Analogical results were obtained when the indices of length of 20 non-reproducing females from age groups *III* and *IV*, caught at the end of the winter of 1963/64, were compared with corresponding values

Table 3.

Length and weight of the alimentary tract in sexually active and in non-reproducing females of *C. glareolus* in age group *II*.

	n	Length of intestine in cm				% of total length of intestine			Ratio of length of intestine to length of body			
		small	large	caecum	total	small	large	caecum	small	large	caecum	total
Sexually inactive	20	38.2	17.0	8.5	63.7	60.0	26.7	13.3	4.39	1.95	0.97	7.30
Sexually active	28	44.7	20.3	9.3	74.3	60.2	27.3	12.5	4.58	2.08	0.95	7.60

Table 4.

Mean indices of length of the alimentary tract in sexually active (summer and autumn) and in non-reproducing (winter) females of *C. glareolus* in age groups *III* and *IV*.

	n	Length of intestine in cm				Ratio of length of intestine to length of body				Weight of intestine in g				
		small	large	caecum	total	small	large	caecum	total	small	large	caecum	stomach	total
Sexually inactive	9	37.9	16.5	8.4	62.8	4.49	2.04	1.00	7.45	0.466	0.239	0.229	0.222	1.156
Sexually active	13	45.2	19.9	9.3	74.4	4.91	2.12	0.99	7.95	0.594	0.350	0.205	0.269	1.418

calculated for sexually active females from these same age groups (Table 4). No statistically significant differences were, however, found when comparing the length and weight of the alimentary tract of sexually inactive females with the corresponding data calculated for males from these same age groups.

IV. DISCUSSION

It can be seen from the data given above that both the length and the weight of the alimentary tract increase with the increase in age of the rodent, these changes being greater in females than in males. Contrary to that in males, the length of the intestines in females increases very

distinctly through the animals' life, while a distinct difference in the weight of their alimentary tract occurs between age groups *II* and *III*. Since all the females in groups *III* and *IV* were sexually active (with the exception of one, differing markedly in its indices from the remainder) it must be assumed that this jump in increase in the weight of the alimentary tract is connected with the rodents' reproduction, or, strictly speaking, with the nursing of their young. This hypothesis is confirmed by comparison of the length and weight of the almentary tract of sexually active and non-reproducing females from age group *II* (Table 3), and also by the absence of statistically significant differences between the inactive females and males of the same age. Additional data on the length of the alimentary tract of females not reproducing in the winter, from age groups *III* and *IV* (Table 4) form evidence that these changes are merely periodical and reversible. After the young have been weaned a return to the condition preceding the period of pregnancy and lactation is observed in the anatomical relations of the alimentary tract in females of *C. glareolus*.

The changes discussed above in the alimentary tracts of pregnant and nursing females are most probably connected with the greater food requirements of these animals. In age group *I*, in which all the females were sexually inactive, no statistically significant differences were found in the length and weight of the alimentary tract in either sex. These results agree with the experimental data given by Fell, Smith & Campbell (1963), who found distinct elongation and hypertrophy of the walls of different sections of the intestine in rats during lactation. The sex differences obtained by Kulajeva (1958) in the length of the intestines were probably due to the presence in the material examined by the authoress of older females in process of reproduction.

The results obtained also confirm the assumptions of certain authors (Vorontzov, 1961; Schwarz, 1960) as to the existence of geographical variations in the structure of the alimentary tract in rodents. These variations are due to differences in the food of these animals. In the northern populations of *C. glareolus* the food of these rodents is chiefly formed by the green parts of plants (Naumov, 1948; Vorontzov, 1961) or lichens (Koškina, 1957), whereas the southern populations feed primarily on seeds (Naumov, 1948; Obrazcov, 1951). The results obtained for the Białowieża population of *C. glareolus* are nearest to the data obtained by Naumov (1948) for the Tula district, situated more or less in the same geographical latitude as Białowieża. The northern populations examined by Vorontzov (1961) have longer alimentary tracts, the fact that these animals possess a relatively long caecum, in which digestion of cellulose mainly takes place, being partic-

ularly striking. The reverse relations apply to the southern populations of *C. glareolus* (K u l a j e v a, 1958; G ę b c z y ń s k a, 1961), in which the ratio of length of intestine to body length is smaller (6.5) with simultaneous elongation of the small intestine in relation to the other sections. Our data cannot, however, be exactly compared with the data obtained by other authors, since the latter did not take into consideration in their investigations the changes in the alimentary tract taking place with the increasing age of the animals. The above authors also fail to give the season during which the material they examined was caught, and seasonal variations in the age structure of populations of *C. glareolus* (Z e j d a, 1961; D e h n e l & P u c e k, in preparation) undoubtedly influence the results obtained.

V. SUMMARY

Analysis was made of the length and weight of the alimentary tract (excluding the oesophagus) in 169 specimens of *C. glareolus* (73 ♂♂ and 96 ♀♀) belonging to five age groups. The results obtained make it possible to state that:

1. The length and weight of the alimentary tract increases with the age of the rodents. These increases are not, however, in proportion to the increase in length and weight of the body of the animals examined. The ratio of total length and weight of the alimentary tract to the length and weight of the rodent decreases with the increasing age of the animals.

2. The value of each section of the intestine expressed in percentages of its total length and weight is a fairly constant value and hardly varies at all throughout the animal's life.

3. Age variations in the length and weight of the alimentary tract of *C. glareolus* are of a different character in the two sexes. In the case of males these values do not exhibit statistically significant differences in any of the age groups, while in the case of females they are observed to increase continuously.

4. The increase in the length and weight of the intestines in females of *C. glareolus* is connected with their sexual activity and increased food requirements during the period of pregnancy and lactation. Sexually active females have longer and heavier alimentary tracts. This is, however, a reversible phenomenon, since there are no differences between non-reproducing females and males in any of the age groups.

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STRESZCZENIE

Badania morfologiczne przewodu pokarmowego *Clethrionomys glareolus* przeprowadzono na 169 zwierzętach (73 ♂♂ i 96 ♀♀), odłowionych w Białowieskim Parku Narodowym. Po wypreparowaniu przewodu pokarmowego (bez przełyku) mierzono długość poszczególnych części jelita, a następnie po dokładnym oczyszczeniu z resztek pokarmowych jelita i żołądek ważono. Materiał podzielono na pięć grup wiekowych opierając się na metodzie W a s i l e w s k i e g o (1952). Określono także aktywność płciową wszystkich samic. Uzyskane wyniki pozwalają stwierdzić, że:

1. Długość i ciężar przewodu pokarmowego *C. glareolus* zwiększa się z wiekiem gryzoni. Przyrosty te nie są jednak proporcjonalne do wzrostu długości i ciężaru ciała badanych zwierząt. Stosunek ogólnej długości i ciężaru przewodu pokarmowego do długości i ciężaru gryzoni maleje wraz z ich wiekiem (Tabela 1 i 2).

2. Wielkość poszczególnych odcinków jelita wyrażona w procentach całkowitej jego długości i ciężaru jest wartością dość stałą i prawie nie zmienia się z wiekiem zwierząt.

3. Zmiany wiekowe w długości i ciężarze przewodu pokarmowego mają odmienny charakter u obu płci *C. glareolus*. U samców wielkości te nie wykazują różnic istotnych statystycznie, natomiast u samic obserwujemy ciągły i wyraźny ich wzrost (Ryc. 1 i 2).

4. Wzrost długości i ciężaru jelit samic związany jest z ich aktywnością płciową i zwiększonym zapotrzebowaniem pokarmowym w okresie ciąży i karmienia młodych. Jest to zjawisko okresowe i odwracalne (Tabela 3 i 4).

5. W budowie przewodu pokarmowego gryzoni występuje wyraźna zmienność geograficzna. Północne populacje *C. glareolus* mają dłuższe przewody trawienne od południowych. Populacja białowieska jest najbardziej zbliżona do zwierząt z okolic Tuły, która leży na tej samej, mniej więcej szerokości geograficznej.