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An improved method for age determination in the muskrat, Ondatra zibethica (L.)

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Methods for determining age from tooth wear were studied in muskrats in southern Finland. For separating age classes the use of a molar index based on crown height and total molar height (M^1) was superior to the mere measurement of crown height, for with the latter there was greater variation between individuals. A formula is proposed for the ageing of muskrats in Finland, based on the curvilinear decrease in the molar index as a function of age. Molar wear was greater in males than in females, possibly owing to greater energy needs of males, which are heavier. Body weight is a poor criterion of age in muskrats.

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1. Introduction

For population studies on muskrats (*Ondatra zibethica* L.) it is important to have a method that can be used to separate the different year classes (Lay 1945, Alexander 1951, 1958). In autumn the young of the year are usually easy to separate from older individuals by the appearance of the reproductive organs (Errington 1939) or even by weight, though the latter is usually regarded as a poor criterion of age in muskrats (Alexander 1951, Marcström 1964, Pucek & Lowe 1975). But during the winter and especially in the spring, when all muskrats are attaining sexual maturity, it is difficult to separate the animals born during the preceding summer from older ones. For this purpose investigators have used several properties and measurements, e.g. properties of the skin, zygomatic breadth of the skull, upper incisor width and morphological differences in the baculum (for references, see e.g. Marcström 1964, Becker 1967, Doude van Troostwijk 1976b). The most promising results have been obtained by weighing the eye lens (Vincent & Quéré 1972, Le Boulengé 1977; see also Pucek & Lowe 1975) or by determining the wear of the molars (e.g. Gould & Kreeger 1948, Cygankov 1955, Marcström 1964, Trnková 1966, Becker 1967, Doude van Troostwijk 1976a,b; see however Elder & Shanks 1962). Molar wear is the basis of the methods employed in this study.

On account of differences in diet and also in primary molar hardness, molar wear may differ geographically (Pietsch 1970, Doude van Troostwijk 1976b), so that molar ageing methods are perhaps not directly applicable outside the area in which they were developed. The aim of this study was to test the two molar ageing methods, proposed by Cygankov (1955) and Doude van Trooswijk (1976a,b) and, if necessary, to modify them for age determination in Finnish muskrats.

2. Material and methods

The material was collected in 1978—1979 from Lohjanjärvi, a lake in southern Finland (60°15′ N, 24°00′ E) by local muskrat trappers, who skinned the animals and stored the carcasses by deep-freezing. Most of the animals were trapped between 15 April and 15 May, when muskrats are easy to catch, for their activity increases at the onset of the breeding season (Table 1). In Finland trapping of muskrats is allowed only from 1 January to 15 June; for trapping of animals outside the season a special licence was obtained from the Ministry of Agriculture and Forestry. In the laboratory the skinned carcasses were weighed and sexed, and their reproductive status was determined. The head of the animal was removed, boiled for 1—1.5 h and cleaned. Both first molars of the upper jaw (M^1) were then removed with tongs.

Fig. 1. Changes in the appearance of the first upper molar (M^1) during the life of the muskrat. In very young muskrats (upper left) the molar consists totally of the crown; no roots have yet developed. In old muskrats (lower right) the crown has worn low and the roots are long.

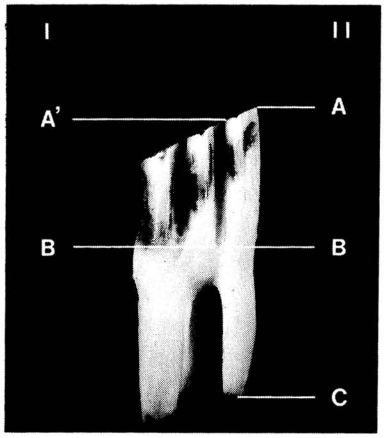

Fig. 2. Measurement of the crown height (I) and molar index (II) of the first upper molar (M^1) in the muskrat. For details see text.

Age determination. In muskrats the first upper molars (M^1) show clear age-dependent changes. The molar of a very young muskrat consists solely of the prismatic part (= crown; Fig. 1). As the animal grows older, this part slowly wears down. The wear is compensated by growth of the roots, which starts at the age of approximately 2.5 months (Cygankov 1955) and is continuous, pushing the crown upwards. In very old animals most of the crown has worn away and the roots are long (Fig. 1).

In *the crown method* (Cygankov 1955) the height of the crown is the only variable measured; in *the molar index method* (Doude van Troostwijk 1976b) the total height of the molar is also taken into the consideration. The molars were measured under a binocular dissecting microscope with an ocular scale to the nearest 0.08 mm.

Table 1. Numbers of muskrats trapped from Lohjanjärvi.

	1978	1979	Total
Feb.	1	0	1
March	0	1	1
April	93	113	206
May	60	77	137
June	0	0	0
July	4	6	10
Aug.	5	0	5
Sept.	1	0	1
Oct.	0	4	4
Nov.	0	6	6
Total	164	207	371

The crown method: Crown height was measured from the neck to the occlusal surface along the sulcus which separates the third and fifth salient angles on the buccal (outer) surface of the right M^1 (Fig. 2, I: distance A'—B). The height of the crown was transformed graphically into age estimates according to the curve in Fig. 6, which was constructed from the results given by Cygankov (1955):

mean crown height (mm)	age in months	mean crown height (mm)	age in months
>10.5	<2.5-3	4.8	18
10.2	2.5-3	3.6	24
8.5	6	2.4	30
7.1	9	1.2	36
6.2	12		

The molar index method: The distance A—B was calculated as a percentage of the distance A—C (Fig. 2, II). (Notice that A—B is a little longer than A'—B.) In the molar index method a mean of the measurements of the two molars was calculated. The percentage, beginning from 100 %, diminishes with the age of the animal. Doude van Troostwijk (1976b) gave a formula for calculating the age of muskrats from this percentage (A):

$$\text{age in months} = \frac{100 - A \pm 1.98}{3.97} + 1$$

According to Doude van Troostwijk (1976b), the term $\pm$ 1.98 corresponds to the variation of the estimate. The addition of 1 month in the formula is needed because during the first month of life the molars of muskrat nestlings do not undergo any wear (Doude van Troostwijk 1976b).

Table 2. The distribution of crown heights (0.5 mm classes) of the first upper molar (M^1) in the muskrat. Spring values for 1978—79 grouped into 10-day classes. The dotted line suggests where the age groups should be separated.

	Crown height (mm) 9		8		7		6		5		4		3		2		1	0	Total
1978																			
11—20 April		1		2	3	1	1	1	3					1					13
21—30 April	1	7	2	7	13	13	11	9	7	3	3	2		2					80
1—10 May			6	4	4	4	9	4	3	4			1						39
11—20 May			1	2	1	1	3	2	1	1	1								13
21—30 May					1	2			2	1	2	1							9
Total 1978	1	8	9	15	22	21	24	16	16	9	6	3	1	3					154
1979																			
11—20 April	1	1	3		7	1	1	3	1	:		1			1				20
21—30 April	7	12	9	16	16	11	10	5	1	1 :		2	1	1					92
1—10 May	1		7	6	8	9	8	5	7	1 :		2		1		1			56
11—20 May					2	2	1	4	2	2 :	1	1						1	16
21—30 May					1				1	:			1						3
Total 1979	9	13	19	22	34	23	20	17	12	4 :	1	6	2	2	1	1		1	187
Total 1978—1979	10	21	28	37	56	44	44	33	28	13	7	9	3	5	1	1		1	341

3. Results

3.1. Comparison of crown height and molar index values

When the crown height and molar index values of the April and May catches are grouped in 10-day classes (Tables 2 and 3), molar wear as a function of time is reflected in the diagonal pattern of the frequencies. The distributions of the pooled results are clearly skewed to the right, because the older age group(s) is smaller than that born the previous summer. In the 1978 values these age classes cannot be separated by their crown heights (Table 2); in the 1979 values the separation line seems to lie at a crown height of about 4 mm or a little less. The molar index distributions show less overlap (Table 3), particularly in 1979; the separation line seems to be at about 40 % (see also Fig. 5). As shown by the

Table 3. The distribution of molar index values of the first upper molar (M^1) in the muskrat. Spring values for 1978—79 grouped into 10-day classes. The dotted line suggests where the age groups should be separated.

	Molar index (%) 80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0	Total
1978																		
11—20 April		1	2	3	2	2	2			1								13
21—30 April		6	8	16	21	12	7	3	3	1	3							80
1—10 May			7	6	11	4	4	4	2			1						39
11—20 May				4	3	4			2									13
21—30 May				1	2		3			2								8
Total 1978		7	17	30	39	22	16	7	7	4	3	1						153
1979																		
11—20 April		1	3	7	2	2	2	1 :	1			1						20
21—30 April		9	20	28	20	8	2	:	2	1	1		1					92
1—10 May	1		6	12	13	15	4	:	1	3			1					56
11—20 May				2	3	4	4	:		2					1			16
21—30 May					1	1		:		1								3
Total 1979	1	10	29	49	39	30	12	1 :	4	7	1	1	2		1			187
Total 1978—1979	1	17	46	79	78	52	28	8	11	11	4	2	2		1			340

coefficients of variation ($CV = s/\bar{x}$, which makes the variations comparable whatever the magnitude of the means), the crown height varies more than the molar index (Table 4).

The mean difference in molar index between the left and right molars (reflecting the variation of the index within the individual) was low, only 1.2 %. The standard deviation of this difference was 1.04 (April-May, $n = 306$). The maximal differences were 7.7 % in males and 3.8 % in females, the differences seeming to be greatest in old individuals.

The measurements made with the two methods were in good accord, the correlation coefficients being strongly positive ($r = +0.952$***, after arcsine transformation (Sokal & Rohlf 1969:386), April-May, $n = 340$). The relationship between the untransformed values is somewhat curved (Fig. 3). Between the sexes or years there are no differences in these correlation coefficients, which are always highly significantly positive.

Table 4. Comparison of coefficients of variation ($CV = s/\bar{x}$) in crown height and molar index. Measurements are for the right M^1 only. April—May 1978—79.

	Males	Females	Total
Crown height	0.226	0.258	0.242
Molar index	0.173	0.205	0.189
n	190	150	340
F	1.72***	1.59**	1.64***

Here, too, the age classes can be separated at the point where the crown height is about 4 mm and the molar index 40 % (Fig. 3). (From here on these values are used to separate "young" and "old" muskrats in the April-May samples.) The animals that had not yet attained these values

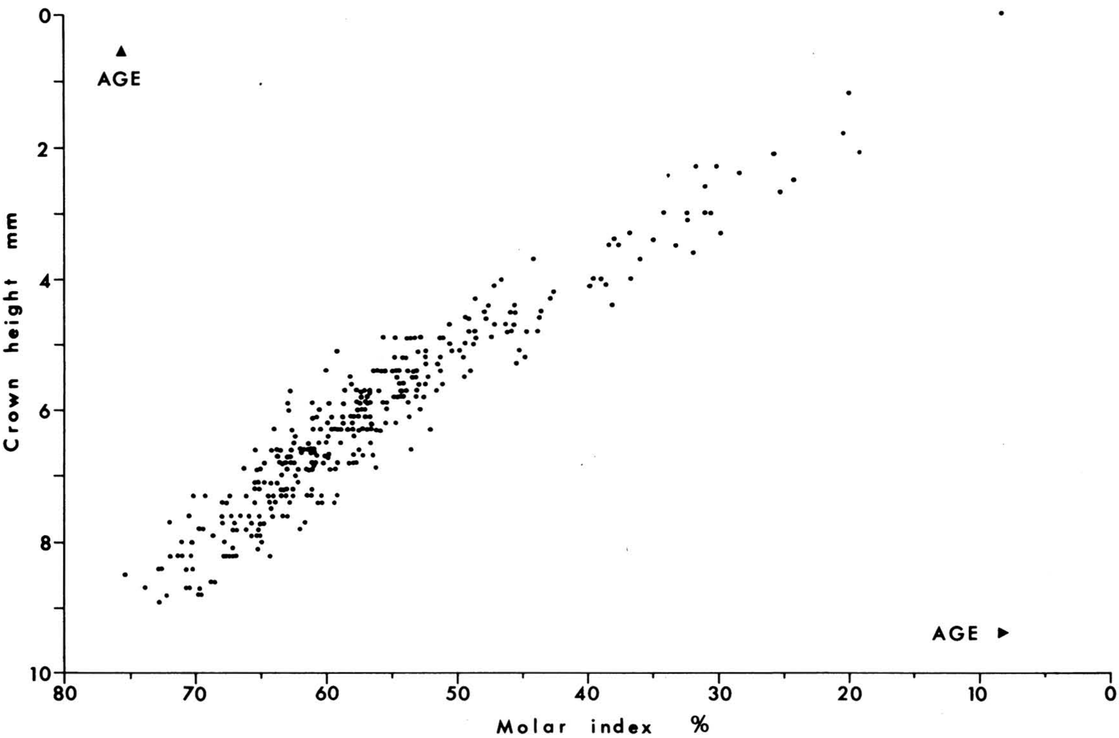

Fig. 3. The relationship between crown height and molar index in the first upper molar (M^1) of the muskrat (April-May 1978—79).

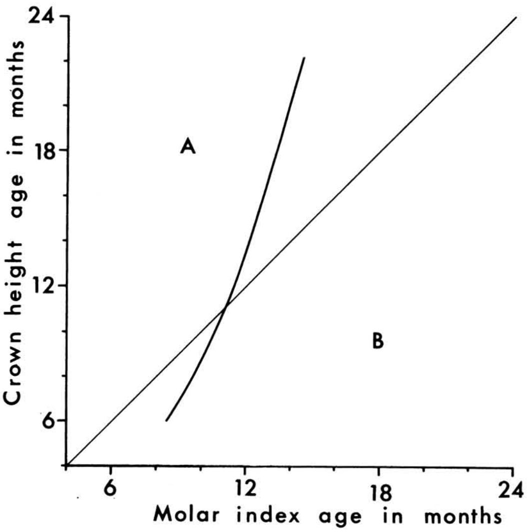

Fig. 4. The relationship of the two different methods for determining age in muskrats. Young (<1 yr) individuals, 21—30 April 1978—79. For details see text.

(<1 year old) were chosen for a more detailed comparison of the ageing methods. The regression computed from this group (independent variable = crown height, dependent variable = molar index value, by arcsine transformation, $n = 159$) made it possible to calculate the corresponding means of the different values for crown height and molar index. These figures were transformed into age estimates (Fig. 4). If the two methods yielded the same estimates, the results would give a diagonal line. In this case, however, the curve deviates strongly from the diagonal. The age estimated by the crown height method is higher in area A (in Fig. 4) and lower in area B than the age estimated by the molar index method. At about 11 months of age the two methods give the same result. Although Fig. 4 shows that the two ageing methods usually do not give the same result for the same individuals, it does not indicate which method is better (see paragraph 3.3).

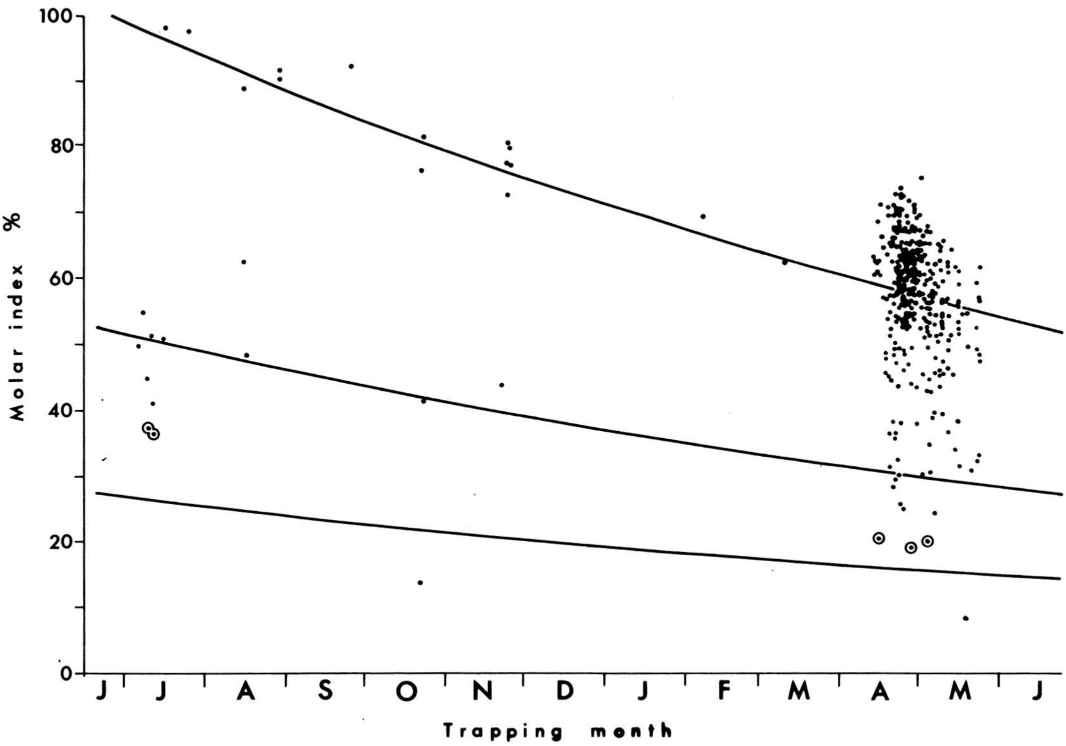

Fig. 5. The changes in the molar index of the muskrat as a function of time. The first, second and third years of life are shown in three descending parts of the same logarithmic function. The points for individuals that were difficult to place in the right age class are circled. For details see text.

3.2. Change of molar index as a function of time

When placed on a time scale, the molar index values show a steeper decline during the first few months of an individual's life than later (Fig. 5). As the change is not linear, it follows that the age groups are easier to separate in summer and autumn than during the next spring. However, a break in the dot cluster for the two age groups in spring is seen at about the index value of 40 % (Fig. 5). After May reliable differentation of age groups gradually becomes more difficult.

The equation of the function in Fig. 5 is

$y = (10^b)^t \times 10^a$ where y = molar index (%), b = the slope, —0.0233 in 1 month, t = time (in months), a = the y intercept = 1.996.

From this equation it is possible to derive a formula to transform the molar index value into approximate age estimates (1 added as a correction for the first month of life, see p. 114):

$$\text{Age in months} = t = \frac{\log y - 1.996}{-0.0233} + 1.$$

3.3. Ageing of muskrats by different methods

The formula presented above was used to determine the age of muskrats from Lohjanjärvi. It was then possible to judge the suitability of the different methods for ageing these animals. After 1 year of age Finnish muskrats show more severe molar wear (Fig. 6) than was found by Cygankov (1955), and consequently the original crown height method gives estimates that make the Finnish animals appear too old. However, it is not worth while correcting these age estimates, because the molar index method has already proved superior to the crown height method for separating age groups. The molar index shows a curvilinear form of decrease (Fig. 7) that fits the actual observations better than either the linear regression line calculated from the Finnish material or the line corresponding to the regression in the Netherlands (Doude van Trooswijk 1976b). The formula proposed by Doude van Trooswijk (1976b) tends to overestimate age until about 13—14 months, but after that it gives clear underestimates for Finnish muskrats.

3.4. Sex and weight comparisons

The crown height and molar index values are significantly lower in young males (<1 yr) than in young females (Table 5). In the cohort that is 1 year older the differences (lower values in females) are not significant. Correspondingly, in young individuals males are heavier (skinned body weight) than females, but in old muskrats there is no difference between the sexes (Table 5).

The correlation coefficients (r) between weight and molar index (after arcsine transformation, April-May) are usually low:

	males	females
young	+0.174* (n=172)	+0.143 ns (n=133)
old	—0.200 ns (n= 16)	—0.033 ns (n= 13)

Because with age the index values diminish, positive correlation coefficients indicate that the older animals weigh less.

4. Discussion

Differences in both crown height and molar index of muskrats clearly reflect differences in age, but for actual age determination the molar index method seems to be more effective, because of the smaller variation between individuals. However, the equation proposed by Doude van Troostwijk (1976b) for transforming the molar index into an age estimate is not really suited for age determination in Finnish muskrats. In Doude van Troostwijk's (1976b) formula the molar index is assumed to change *linearly* by about 4 % during 1 month. This assumption does not accord with the observations of others (Cygankov 1955, Trnkova 1966, Becker 1967: Fig. 4) or with the results of the present study.

Table 5. The differences between the sexes in molar measurements and in skinned body weight in the muskrat (mean, standard error and n). April—May 1978—79; young = < 1 yr, old = >1 yr, with the nearly 3-year-old female (see Fig. 5) excluded.

		Crown height (in mm)	Molar index (in %)	Skinned body weight (in g)
Young	♂♂	6.2±0.08 (174)	57.6±0.50 (173)	944±11.6 (172)
	♀♀	6.7±0.10 (135)	61.1±0.60 (134)	818±12.1 (133)
	t	3.38***	4.52***	7.43***
Old	♂♂	3.2±0.21 (16)	32.8±1.63 (16)	1016±71.3 (16)
	♀♀	3.0±0.19 (14)	31.4±1.47 (14)	1063±40.9 (13)
	t	0.83 ns	0.66 ns	0.54 ns

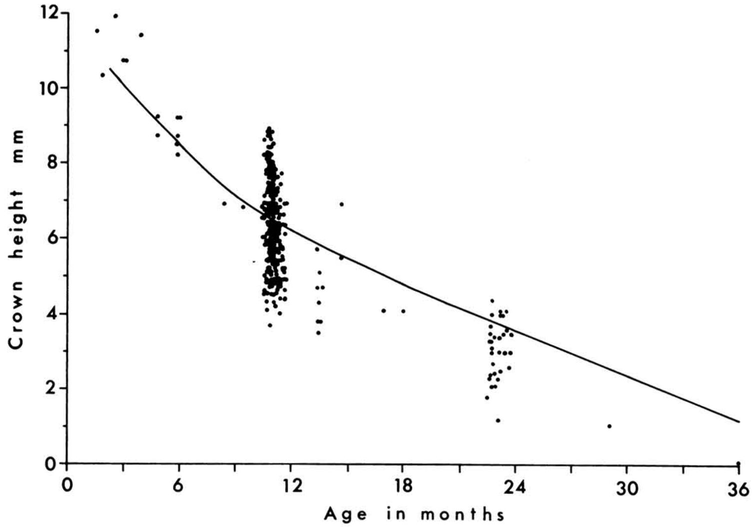

Fig. 6. Decrease in crown height (M^1) in Finnish muskrats (dots) as a function of age, compared with the corresponding average change in the Soviet Union (Cygankov 1955, solid line).

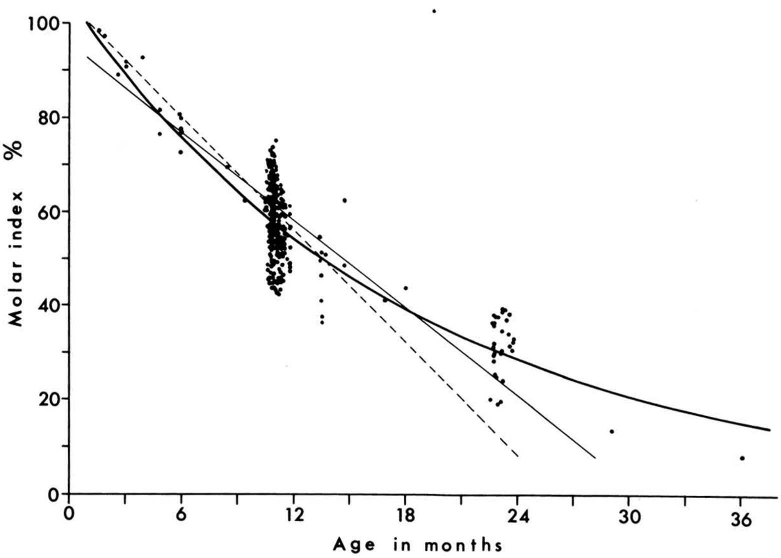

Fig. 7. The suitability of three different functions for describing the changes in molar index values of Finnish muskrats. The solid regression lines (curvilinear and straight) were computed from the Finnish data; the broken line is after Doude van Troostwijk (1976b), representing the corresponding changes in the Netherlands. The age of each individual (dots) was determined from the formula presented in the text.

The molar index values of the present study show such a great variation (Fig. 5) that the formula proposed for age determination must be regarded as an approximation. The ages calculated, particularly for muskrats more than 2 years old, are not very reliable. The accuracy of the formula is reduced by the relatively long breeding season (Artimo 1960) and also by individual differences in molar wear (see also Marcström 1964). Similar age-dependent changes in the molars are seen in *Clethrionomys* (e.g. Zejda 1961, Lowe 1971, Viitala 1971, Perrin 1978). In these vole species the age at which molar root development begins and also the rate of root growth vary with the season of birth (Zejda 1961, Lowe 1971, Viitala 1971). This may be the case with the muskrat, too.

The standard deviation in Doude van Troostwijk's (1976b) formula (±1.98, see p. 114), which he used in calculating the confidence limits of the age estimates, was obtained by computing the variation between the two molars of each muskrat (± 1.04 in the present study). Of course, if only one molar is measured, this variation is included in the error variation, but it reflects only the variation within individuals and takes no account of the variation between individuals of the same age. This quantity should also be measured before confidence limits for age estimates can be calculated.

From the curve in Fig. 5 it appears that in this material a mean molar index of 100 % (no wear) roughly coincides with the end of June. The mean date of birth of these muskrats would then be about the end of May, if the nestling period is taken as 1 month (Doude van Trooswijk 1976b). In Finland, however, (according to Artimo 1960) most muskrat litters are born a little later, in late June or early July. Thus, addition of 1 month in the formula may be too much; perhaps two weeks would be closer to reality. This is supported by the finding of Galbreath (1954) that the teeth of 30-day-old muskrats already showed signs of wear on the occlusal surface.

There are two possible explanations for the differences observed between the sexes in crown height and molar index, and consequently in the age estimates for young (<1 yr) muskrats in spring:

1) males really are older than females, or
2) the sexes are equally old, but differ in the extent of molar wear.

There is no evidence to support the first explanation. In Finland muskrats are trapped only in spring and consequently trapping cannot have affected the age composition of the youngest age group until spring. No statistically significant preponderance of males has been observed in early litters (Becker 1969, Moens 1978: Table 8). Likewise, in my rather scantly records of muskrat embryos the sex ratio was equal throughout the breeding season:

	number of	embryos	
	litters	males	females
5 — 7 May	(3)	11	10
July-Aug.	(3)	10	10

Thus evidently the molars wear differently in males and females. Perhaps the higher energy needs of the males, which are bigger than the females (see also Marcström 1964), lead to more severe wear. It is also possible that owing to the social behaviour of the muskrat population, young males are driven to places where the food is of lower quality.

Owing to the difference in molar wear between the sexes, the change in the molar index as a function of time requires separate equations for males and females. The strong concentration of the present values in the spring does not allow separation of sexes. Individuals of known age, marked as nestlings, are needed to give information about the rate of molar wear in Finnish muskrats. In addition, a combination of the eye lens weighing method (Vincent & Quéré 1972, Le Boulengé 1977) and the molar index method would be valuable.

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