Relative Age, Body Weight, and Reproductive Condition in Three Species of Sorex (Soricidae; Mammalia) in Hokkaido.

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北海道産*Sorex*属（トガリネズミ科；哺乳綱）3種の
相対年齢と体重，繁殖状態について

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Abstract

Methods of determining relative ages are proposed for *Sorex unguiculatus, S. caecutiens,* and *S. gracillimus* in Hokkaido, Japan. Shrews were basically divided into four age categories, which were determined by the wear pattern of the upper tooth row and the condition of cranial ossification. We investigated monthly frequencies of these age categories and the relationships between the age category and three characteristics of a) body weight, b) genital size, and c) female reproductive status of three species. The monthly frequency changes of each age category suggested that these age categories are good indicators of relative ages for these three species of shrews, and these age categories were highly correlated with the changes in body weight and reproductive conditions.

Key words: relative age, *Sorex*, tooth wear, reproductive condition, Hokkaido

Introduction

For the determination of age in *Sorex*, Hamilton (1940), Pruitt (1954) and Rudd (1955) utilized the wear pattern of upper teeth and the morphology of the cranium, and Conaway (1952), Crowcroft (1956), Pernetta (1977), and Grainger & Fairley (1978) used the height of the tooth. These methods cannot be directly applied to *Sorex* in Hokkaido because tooth morphology differs among species. For the determination of the relative ages in *Sorex*

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unguiculatus and *S. ceacutiens* in Hokkaido, Abe (1958, 1967, 1968) applied a tooth wear pattern method and divided shrews into three age categories. However, he did not investigate the relationships between the age categories and the reproductive conditions of shrews, and only three categories are insufficient when applied to some population analyses. Additionally, a relative age method for *S. gracillimus* has not been offered.

In this paper, we offer new relative age methods, including four basic age categories, based upon wear the patterns of upper teeth and the condition of cranial ossification for *S. unguiculatus* (Dobson), *S. caecutiens saevus* (Thomas), and *S. gracillimus* (Thomas) in Hokkaido, Japan. We also investigated the seasonal frequency changes of age categories and the relationships between the age category and the three characteristics of body weight, genital size, and female reproductive status.

Materials and Methods

We examined 740 specimens of *S. unguiculatus*, 376 of *S. caecutiens*, and 107 of *S. gracillimus*, which were collected from various areas in Hokkaido, including Teshio, Tomakomai, and Hiyama Experiment Ferests of Hokkaido University, from 1976 to 1988. The localities and the numbers of the samples are given in the Appendix. Most shrews were captured in pit-fall traps in scheduled periodic surveys, although some were obtained sporadically in Sherman live traps. There were no specimens collected in January and February.

We investigated the wear pattern of upper tooth rows (usually the right side) and the condition of cranial ossification under a binocular microscope and classified them into four main categories. We repeated this procedure three times for each specimen in order to habituate the method and used only the final results. For the description of teeth wear we referred to the tooth terminology by Sakai & Hanamura (1967).

For the investigation of reproductive activity, we used only 406 specimens in 1988 because recording methods for the reproductive conditions were not unified before this year. The size of testis was measured nearest to 0.1mm for the following three dimensions: maximum length, maximum width, and maximum thickness; it was represented as the cubic root of the product of the three dimensions. The size of uterus was measured to 0.1 mm in the length from the point of the conjunction of two uterine horns to the tip of either uterine horn in naturally stretched condition. Reproductive conditions of females were classified as a) pregnant (the condition with visible embryos in uterus), b) lactating (the condition with well developed mammary glands with milk, except for pregnant one), and c) non-breeding (neither of both conditions).

Changes in body weight, testis size, and uterus size between age categories were analyzed by t-test (two tails). When variances were significantly different (at 5% level) between groups, Aspin-Welch's method (Ishii, 1975) was applied. Female reproductive status was analyzed by Fisher's exact test. For *S. caecutiens* and *S. gracillimus*, testis size and uterus size could not be analyzed statistically because of insufficient samples.

Results

Ages of individuals were basically divided into four categories for each species. Age category 4 for *S. unguiculatus* and *S. caecutiens* included a sub-division category 4', and category 1 for *S. gracillimus* included a sub-division category 1'. However, the differences

between categories 4 and 4' and between categories 1 and 1' were trivial. The following diagnostic characters were used for the classification of age category.

S. unguiculatus

Age categories: Category 1 (Fig. 1-A-1). Teeth not or slightly worn; W-shaped cutting ridges (ectoloph) from parastyle through metastyle not or slightly worn; ridges of protocone on M^1 and M^2 not or slightly worn; tips of parastyle and paracone on Pm^3 not or slightly worn on posterior faces but the border of worn and unworn portions ambiguous; tips of unicuspids not or slightly worn on posterior faces; pigmented portion of tooth remaining almost complete; bones of braincase almost transparent and thin; lambdoidal suture open or incompletely closed.

Category 2 (Fig. 1-A-2). Tooth worn; W-shaped ridges of M^1 and M^2 worn, showing narrow grooves; ridges of protocone on M^1, M^2, and M^3, worn showing narrow grooves; tips of parastyle and paracone on Pm^3 worn on posterior faces; tips of unicuspids worn into small crescent shape on posterior faces; pigmented portion of tooth largely remaining (about more than 2/3 of category 1); lambdoidal suture usually closed but not fully closed in some individuals.

Category 3 (Fig. 1-A-3). Tooth worn largely; W-shaped ridges and protocone of M^1 and M^2 worn, showing broad grooves. Posterior faces of parastyle and paracone of Pm^3 fully worn, showing narrow grooves, and the grooves are connected with each other with a narrow groove in some individuals. Posterior and lingual faces of unicuspids worn; the height of cusps of every tooth reduced to about half that in category 2; pigmented portions of main cusps on M^1 and M^2 reduced to about half of those in category 2, and those of M^3 often disappeared completely. Lambdoidal and parietal sutures closed and formed crests in some individuals.

Category 4 (Fig. 1-A-4). Tooth worn heavily; ridges of M^1 and M^2 worn to base level; a ridge from parastyle through metastyle of Pm^3 showing a continuous groove; pigmented portions of teeth becoming less only in a small area and restricted to anterior faces of unicuspids and lingual faces of paracone and metacone on M^1 and M^2; lambdoidal and parietal sutures ridged.

Category 4' (Fig. 1-A-4'). This is an extended type of category 4; W-shaped ridges and ridges of protocone on M^1 and M^2 showing broad hollowed-out grooves, which are often connected with each other; unicuspids worn out; bone of braincase opaque and thick; lambdoidal and parietal crests developed heavily, especially in male.

Age composition: Category 1 individuals began to emerge from May and occupied a large part of the population (about 70%) in July (Fig. 2-A). The proportion of this category decreased gradually from July to November and disappeared in December. Category 2 was present in all months examined except March. The proportion of this category increased from April to December and became a main component of the population from October to December. All individuals were those of category 3 in March. The proportion of this category decreased towards winter and no individuals of this category were present in October and December. Category 4' was present from May through December, but the proportion was small.

Body weight: Body weight abruptly increased from category 2 to 3 for each sex (Fig. 3-A), and these differences were significant ($t=13.89$, $n=53.97$ for male; $t=8.99$, $n=60.29$ for female; Aspin-Welch's method). No significant differences were found in body weight

between categories 1 and 2 ($t=2.07$, $df=257$ for males; $t=0.44$, $df=201$ for females) and between categories 3 and 4+4' ($t=1.26$, $df=134$ for males; $t=1.40$, $df=98$ for females).
Breeding condition: Testis size rapidly increased from category 2 to 3, whereas no obvious differences were observed between categories 1 and 2 and between categories 3 and 4 (Table 1; $t=1.80$, $df=116$ between categories 1 and 2; $t=37.50, n=14.11$ between categories 2 and 3 (Aspin-Welch's method); $t=0.86$, $df=29$ between categories 3 and 4).

Length of uterine horn increased abruptly from category 2 to 3, whereas there were no obvious differences between categories 1 and 2 and between 3 and 4 (Table 2; $t=0.64$, $df=105$ between categories 1 and 2; $t=8.31, n=16.32$ between category 2 and 3 (Aspin-Welch's method); $t=0.30$, $df=25$ between categorier 3 and 4).

No breeding individuals were found in age categories 1 and 2, and most breeding (pregnant or lactating) individuals were of age categories 3, 4, and4' (Tabe 3). The distributions of non-breeding and breeding individuals were not significantly different between categories 1 and 2 ($p=1.0$) and between categories 3 and 4+4' ($p>0.8$), whereas they are significantly different between age categorier 2 and 3 ($p<0.001$).

S. caecutiens

Age category: Category 1 (Fig. 1-B-1). Essentially same as category 1 of *S. unguiculatus*, but tips of paracono on Pm^3 worn into small V-shape on posterior faces.

Category 2 (Fig. 1-B-2). Essentially same as category 2 of *S. unguiculatus*. Tips of parastyle and paracone on Pm^3 worn, showing narrow grooves on posterior faces, but these grooves are not connected with each other.

Category 3 (Fig. 1-B-3). Essentially same as category 3 of *S. unguiculatus*, but tip of paracone on Pm^3 obviously divided; grooves of parastyle and paracone on Pm^3 are obviously connected with each other with a narrow groove.

Category 4 and 4' (Fig. 1-B-4, 4'). The description follows as categories 4 and 4' of *S. unguiculatus*, but no obvious difference in crest development was present between sexes.
Age composition: Category 1 individuals began to emerge from June and occupied a large part of the population (about 60%) in July and August (Fig. 2-B). The occurrence of this category lasted until December, but the proportion decreased gradually towards winter. Category 2 was present in all examined months except May. The proportion of this category increased from spring to winter and became a main component of the population from October to December. In April, most individuals were of category 3 and its proportion decreased gradually towards winter. No individuals of this category were present in November and December. The proportion of category 4 increased from April to May and then decreased gradually towards winter. Category 4' was present from June through October constituting a small part of the population.
Body weight: Body weight abruptly increased from category 2 to 3 for each sex (Fig. 3-B), and these differences were significant ($t=35.86$, $n=37.26$ for males; $t=3.69$, $n=20.94$ for females; Aspin-Welch's method). No significant differences were observed between categories 1 and 2 ($t=3.22$, $df=135$ for males; $t=0.44$, $df=201$ for females) and betwees categories 3 and 4+4' ($t=3.68$, $df=66$ for male; $t=2.23$, $df=29$ for female).
Breeding condition: Testis size rapidly increased from category 2 to 3, whereas there appeared to be no significant differences between categories 1 and 2 and between categories 3 and 4 (Table 1).

Length of uterine horn increased abruptly from category 2 to 3, whereas no significant

differences were detectable between categories 1 and 2 and between 3 and 4 (Table 2).

No breeding individuals were found in age categories 1 and 2, and all individuals of age categories 3 and 4 were in breeding condition (Table 3). The distributions of non-breeding and breeding individuals were not significantly different between categories 1 and 2 ($p=1.0$) or between categories 3 and 4 ($p=1.0$). The distribution was also not significantly different between age categories 2 and 3 ($p>0.3$) probably because of insufficient samples.

S. gracillimus

Age category: Category 1 (Fig. 1-C-1). Teeth almost unworn, but the other description follows that of category 1 of *S. unguiculatus*.

Category 1' (Fig. 1-C-1'). This is an extended phase of category 1; W-shaped ridges of M^1 and M^2 and tips of parastyle and paracone on Pm^3 slightly worn on posterior faces and the border of worn and unworn portions clear; mesostyle of M^1 and M^2 not blunt.

Category 2 (Fig. 1-C-2). Essentially same as category 2 of *S. caecutient*, but lambdoidal suture still incomplete in most individuals. Tips of mesostyle of M^1 and M^2 are more blunt than category 1'.

Category 3 (Fig. 1-C-3). Essentially same as category 3 of *S. unguiculatus*, but development of lambdoidal and parietal ridges weak.

Category 4 (Fig. 1-C-4). Essentially same as category 4 of *S. caecutiens*, but category 4' is not defined, and the development of crest is weak.

Age composition: The emergence of categories 1 and 1' individuals began from July and they occupied large parts of the population (about 80%) in July and August (Fig. 2-C). The occurrence of categories 1 and 1' lasted until September and November, respectively, but the proportions decreased gradually from July to November. Category 2 appeared in April and from September to November, and it was a main component of the population in November. From April to June, most individuals were of category 3, although category 2 occupied a large part in April probably due to small sample size. This category was also present in December. Category 4 was present in June and August and occupied small parts of the populations.

Body weight: Body weight abruptly increased from category 2 to 3 for each sex (Fig. 3-C), and these differences were significant ($t=9.14$, $n=19.37$ for males; $t=20.88$, $n=17.87$ for females; Aspin-Welch's method). There were no significant differences in body weight between categories 1+1' and 2 ($t=1.07$, $df=36$ for males; $t=2.65$, $df=30$ for females), and there seemed to be no significant differences between categories 3 and 4.

Breeding condition: Testis size rapidly increased from category 2 to 3, whereas there seemed to be no obvious differences between categories 1+1' and 2 and between categories 3 and 4 (Table 1).

Length of the uterine horn increased abruptly from category 2 to 3, whereas there seemed to be no obvious differences between categories 1+1' and 2 and between 3 and 4 (Table 2).

No breeding individuals were found in age categories 1', 1 and 2, and most individuals of age categories 3 and 4 were in breeding condition (Table 3). The distributions of non-breeding and breeding individuals were not significantly different between categories 1'+1 and 2 ($p=1.0$) and between categories 3 and 4 ($p>0.8$), whereas they were significantly different between age categories 2 and 3 ($p<0.02$).

Table 1. The size of testis (mm) in each age category.

	AGE	N	MEAN	SD	MAX	MIN
S. unguiculatus	1	81	1.21	0.16	1.65	0.88
	2	37	1.16	0.13	1.44	0.88
	3	15	5.59	0.45	6.49	4.69
	4	16	5.71	0.31	6.33	5.25
S. caecutiens	1	15	1.20	0.16	1.54	1.00
	2	4	1.03	0.13	1.12	0.84
	3	3	5.32	0.74	6.17	4.82
	4	1	5.93	—	—	—
S. gracillimus	1	6	0.92	0.11	1.04	0.76
	1'	13	0.92	0.18	1.19	0.61
	2	2	0.75	0.02	0.76	0.73
	3	13	3.81	0.27	4.42	3.55
	4	1	3.99	—	—	—

Table 2. The size of uterine horn (mm) in each age category.

	AGE	N	MEAN	SD	MAX	MIN
S. unguiculatus	1	94	4.48	0.78	7.9	2.7
	2	20	4.60	0.82	6.1	3.0
	3	17	19.41	7.31	40.0	11.0
	4	10	20.28	7.14	32.5	10.7
	4'	3	24.77	8.42	33.9	17.3
S. caecutiens	1	16	4.28	0.66	6.0	3.4
	2	1	3.00	—	—	—
	3	2	15.00	4.24	18.0	12.0
	4	1	11.4	—	—	—
S. gracillimus	1	5	2.92	0.35	3.3	2.6
	1'	15	2.91	0.46	3.6	1.8
	2	4	2.80	0.20	3.0	2.6
	3	10	9.24	3.88	19.5	5.4
	4	1	11.3	—	—	—

Table 3. Numbers of female shrews in three reproductive conditions in each age category.

	age	non-breeding	pregnant	lactating
S. unguiculatus	1	93	0	0
	2	21	0	0
	3	1	10	8
	4	1	7	3
	4'	0	2	1
S. caecutiens	1	16	0	0
	2	1	0	0
	3	0	2	0
	4	0	0	1
S. gracillimus	1	6	0	0
	1'	16	0	0
	2	4	0	0
	3	2	1	8
	4	0	0	1

Discussion

Most individuals winter in the phase of category 2 (Fig. 2). Shrews gained weight and sexually matured during the period from category 2 to 3 (Fig. 3), and most overwintered individuals were classified into category 3. No older individual than that of category 4 or 4' was recognized. Therefore, referring to the reproductive conditions of shrews (Table 1 to 3), the individuals of the four age categories presented in this study can be referred to as follows: category 1, young individuals after leaving the nest; category 2, sexually immature individuals; category 3, sexually mature individuals; category 4, elder individuals.

In *S. unguiculatus*, age category 1 occurs from May through November, and category 4 occurred in December but was not found in March and April (Fig. 2-A). In central Hokkaido, the first young of *S. unguiculatus* emerge from their nests at the end of May and breeding individuals are found until September, and some overwintered individuals survive at least until November but die before next spring (T. Inoue, personal communication). This is compatible with our finding of the occurrences of age categories 1 and 4.

Seasonal changes in occurrence frequency of age category accorded with the prediction of chronological order (Fig. 2). Therefore, the age categories we offered are good indicators of relative ages of *S. unguiculatus, S. caecutiens*, and *S. gracillimus* in Hokkaido and highly correlated with the body weight and reproductive condition (Table 1 to 3).

Abe (1958) offered aging methods for *S. unguiculatus* and *S. caecutiens* in Hokkaido, which are based upon wear patterns of upper teeth and cranial morphology. His methods are similar to ours, but there are several differences between them.

Firstly, Abe (1958) classified three age categories, A, B, and C, while we classified four basic categories. Comparing monthly changes in age category of Abe (1968) to those of ours, Abe's category A includes categories 1 (+1') and 2 of our methods, category B

includes most of category 3, and category C includes some of category 3 and category 4 (+ 4').

Secondly, Abe (1958) also used angles of some parts of skull for the age determination and examined the relationships between age categories and the condition of tail hairs, but we did not.

Thirdly, our age category can directly refer to body weight and reproductive conditions. On the other hand, Abe (1967, 1968) investigated the monthly changes in body weight, genital size, and female reproductive status ; however, he did not directly examine the relationships between age category and those characteristics.

Finally, we offered an aging method for *S. gracillimus* whereas Abe (1958) did not.

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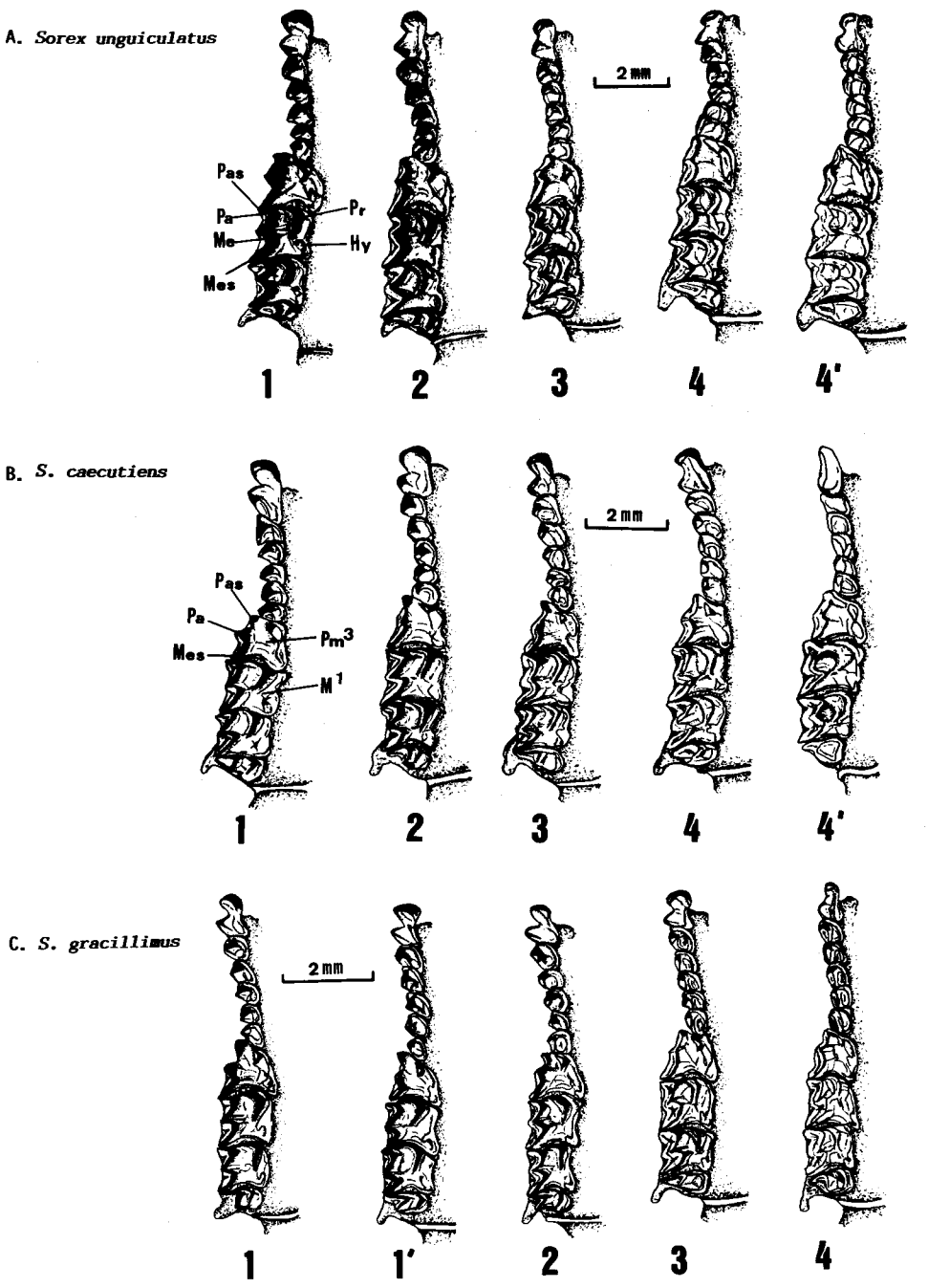

Fig. 1. Typical tooth wear patterns in *S. unguiculatus*, *S. caecutiens*, and *S. gracillimus*. Pm^3: upper third premolar; M^1: upper first molar. Pas: parastyle; Pa: paracone; Pr: protocone; Hy: hypocone; Me: metacone; Mes: mesostyle. Figures represent the right upper rami viewed ventro lingually.

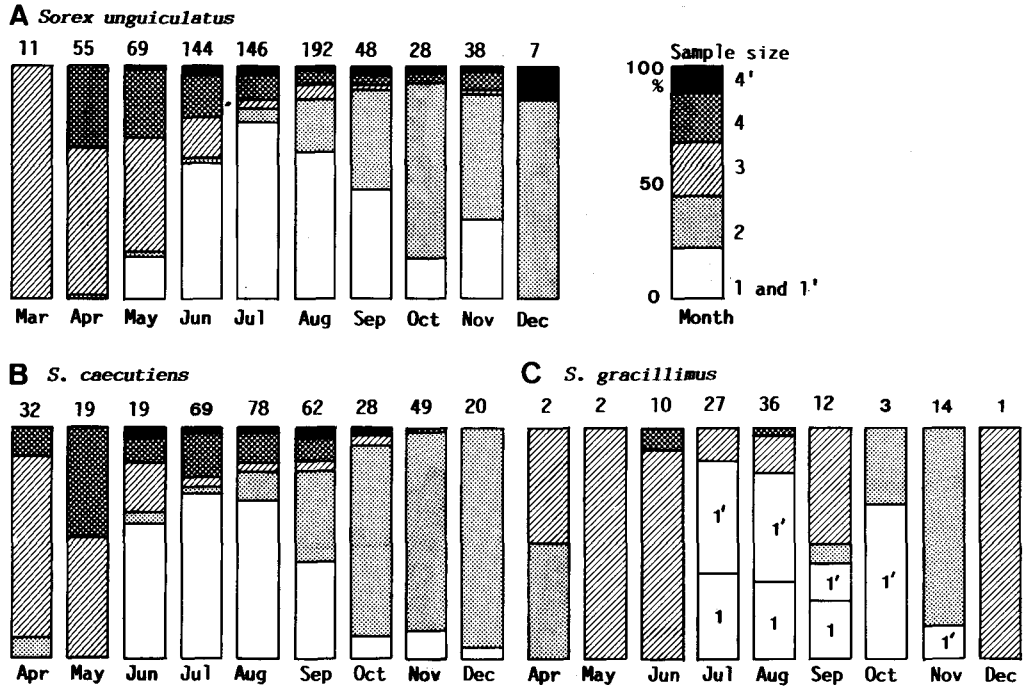

Fig. 2. Monthly changes of the percent occurrence of individuals for each age category in three species of *Sorex*.

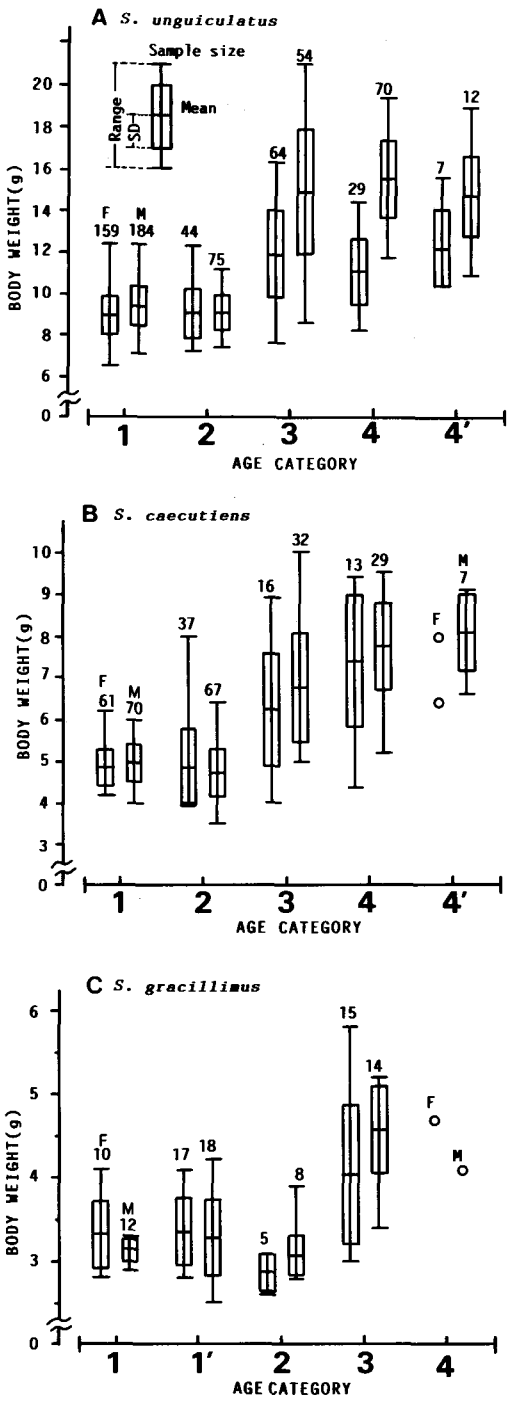

Fig. 3. Relationships between body weight and age category. F: female; M: male.

要　　約

北海道産のオオアシトガリネズミ(*Sorex unguiculatus*), エゾトガリネズミ(*S. caecutiens*), カラフトヒメトガリネズミ(*S. gracillimus*)の相対年齢の査定法を提出した。トガリネズミ類は，上顎歯列の摩耗のパターンと頭骨の骨化の状態に基づいて，4つの主な年齢段階に分けられた。各年齢段階の月別頻度と，年齢段階とa）体重，b）生殖器の大きさ，c）雌の繁殖状態，との関係が調べられた。各年齢段階の月別頻度の結果から，これらの年齢段階は相対年齢の指標として適切であることが示され，またこれらの年齢段階は体重と繁殖状態の変化と大きく関連していた。