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Evaluation of age criteria in New Zealand stoats (*Mustela erminea*) of known age

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Abstract Incremental lines in the canine teeth of 20 stoats (*Mustela erminea*) corresponded exactly with known age in 5 males and 7 females marked as young, and with minimum-known age in 6 males and 2 females marked as adults. The lines are added in autumn (April and May) of each year, beginning when the animals are 6 months old. The correlation is accurate enough to permit determination of the ages of wild-caught adult stoats of unknown age. Two other techniques used previously (baculum weight, post-orbital ratio of the skull) are confirmed as accurate but much less precise methods of distinguishing young from adult stoats.

Keywords age determination; stoat; *Mustela erminea*; New Zealand; known age; techniques; cemental annuli; baculum; post-orbital ratio; skull shape

INTRODUCTION

Incremental lines observed in the canine tooth cementum of stoats (*Mustela erminea*) by van Soest & van Bree (1970), Jensen (1978), Kukarcev (1978), and Grue & Jensen (1979) were assumed by these authors to be correlated with age. However, this supposed relationship has never been verified from material of known or part-known age. Such confirmation is essential if cementum incremental lines are to be used to determine the age of wild-caught animals, as was pointed out by, e.g., Spinage (1973), Steenkamp (1975), and Dapson (1980). Stoats have few other characters useful for determining age after the first year of life (King & Moody 1982a) and, as they may live for several years, the lack of a calibrated method to sub-divide wild-caught adults into year classes is a great handicap to population studies.

The aim of this study was to test the reliability of cementum incremental lines in distinguishing year classes of adult New Zealand stoats of known or partly-known age. Further, the opportunity was taken to evaluate the validity of baculum weight and post-orbital ratio for distinguishing adults from subadults and young, a method used previously by King & Moody (1982a).

Stoats were introduced into New Zealand in the late nineteenth century, and are considered to be a pest, especially in the largest remaining reserves for native fauna, the 10 National Parks. Attempts to control stoats in the parks have, in the past, been hampered by ignorance of the natural population biology of the stoat in New Zealand, and the effects, if any, of trapping operations. The present study arose from the need to understand these processes so that reasonable control policies for stoats in the parks could be developed.

MATERIAL

During a temporary peak in the population of stoats in Fiordland National Park (44°S, 168°E) in the summer of 1979–80, 134 wild stoats were live-trapped, ear-tagged, and released (King & McMillan 1982). During the same summer, 16 stoats were live-trapped on farmland near Upper Hutt (41°S, 175°E) and kept in large outdoor cages in a garden at Eastbourne, several kilometres away. Over the following 1½ years, from April 1980 to August 1981, 14 of the released, tagged stoats were recovered from the wild. Four of the captive stoats escaped and 4 died before May 1980, but the other 8 survived all or part of the winter, 5 of them until all the captive animals were killed in February 1981. Thus 22 stoats (12 males, 10 females) were available for examination (Table 1).

All the tagged and captive stoats were first live-trapped during summer (22 November to 1 February), when young of the year of both sexes are still actively growing. Most New Zealand stoats give birth in October, but physical and reproductive maturity are reached at different ages in the young of the 2 sexes. Females reach adult body weight in

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about March, and males between August and October of their first year of life, i.e., at age 5–6 months and 10–12 months, respectively (King & Moody 1982a). The precocious young females are reproductively mature before leaving the nest in November, and are mated in the season of their birth, but young males remain immature until the following season. Fortunately, these differences in rate of development do not affect the formation of incremental lines; but they do introduce ambiguity to the term 'mature' as applied to stoats.

METHODS

The first 21 stoats recovered were stored frozen; the last (no. 22) was fixed in 75% alcohol in the field. The lower jaw of each was cut out; skin and underlying tissue were removed by gentle scraping and, after drying, the jaws were dispatched to Copenhagen for processing. The skulls were cleaned by gentle boiling, and the bacula were cleaned by dermestid beetles.

Age at first capture

Age at first capture was determined in the field, mainly from the genitalia. Over 99% of adult males, and no young of the year, have enlarged testes in summer (King & Moody 1982b). Adult females have visible nipples, small if they have not borne young, large and obvious if they have; the nipples of female young of the year are invisible. The chance of a non-breeding adult female being scored as young is slight, as the presence of small nipples in non-breeding adults was confirmed from the 3 females held in captivity during this study until the end of the summer; and it is unlikely that any of the wild adult females in Fiordland would have been unable to produce young in the peak year of 1979–80 (King 1981). The state of the canine teeth and the body weight were also considered in assessing age at first capture. The 14 animals judged to be young of the year when first live-trapped are considered to be of known age (6 males, 8 females). The rest (6 males, 2 females) were all adults when first marked; their age is known only since marking, so they are described as being of minimum-known age (Table 1).

Cementum incremental lines

The lower jaws were submerged in boiling water for a few minutes before extraction of the canines, which were then decalcified in 5% by volume nitric acid (HNO_3). Sagittal histological sections were cut at $\simeq 12$ μm and stained with Mayers haemalun and blued in 1% $NaHCO_3$ as described by Grue & Jensen (1979). The cementum incremental lines were counted in the lower canines by the senior author,

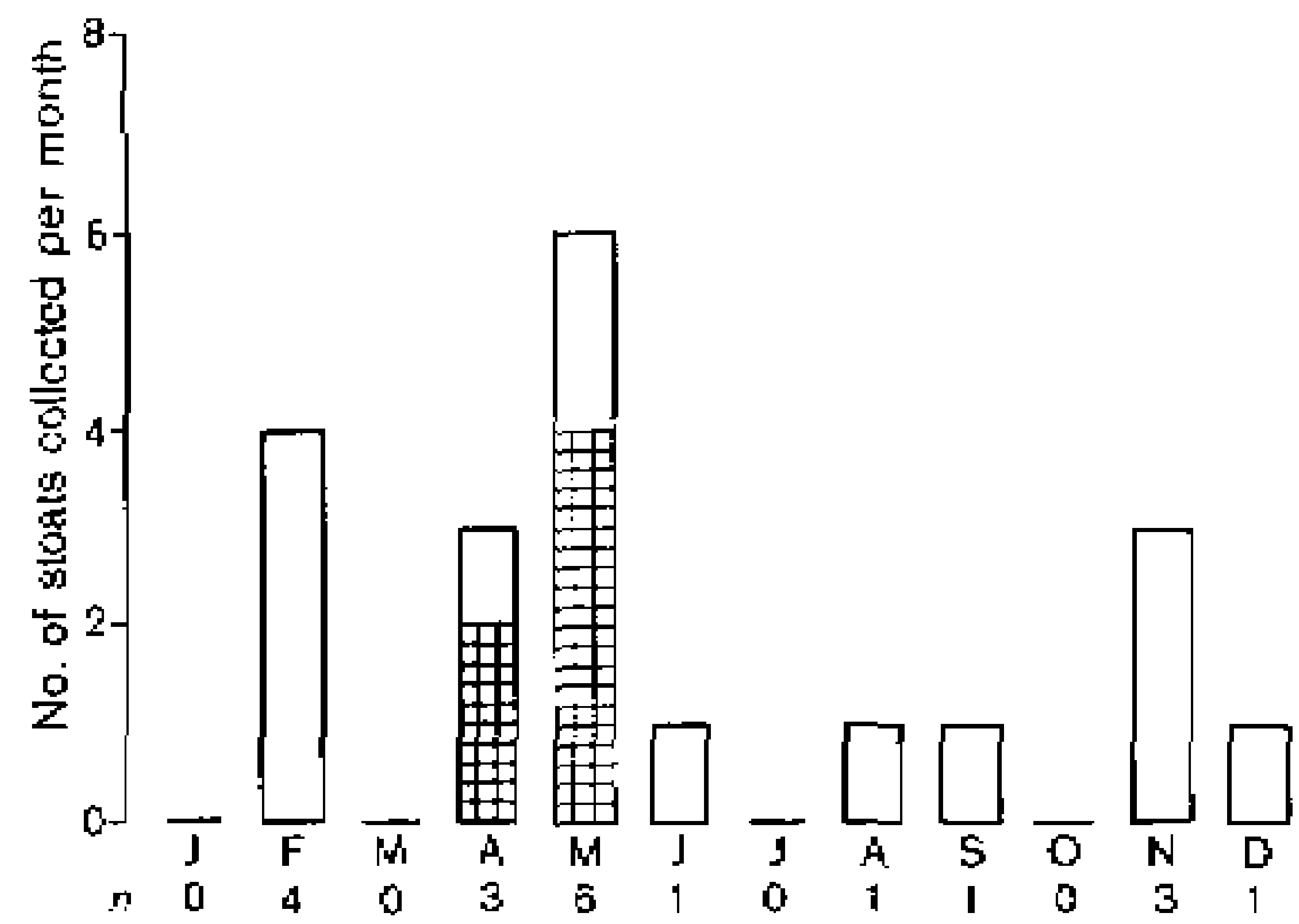

Fig. 1 Number of stoats collected each month, and the proportion (cross checked) that were showing an incremental line under development. Total n=20.

who was unaware of the age-class that had been assigned to them in the field.

Post-orbital ratio

Interorbital width and post-orbital width (defined in diagrams in King (1980)) were measured with a vernier micrometer, and the post-orbital ratio (interorbital width divided by post-orbital width) was calculated as described by King & Moody (1982a) (Table 1). This method is based on study of a series of known-age weasels (*Mustela nivalis*), fully described and illustrated by King (1980).

Date of birth

When estimating age it is an advantage to know the time of year of birth and of kill. For the stoats available for study the date of kill was known; the date of birth was unknown, but, from King & Moody (1982b, fig. 6) the Fiordland animals were assumed to have been born towards the end of October. The captive ones are classified likewise, although they could have been up to 3–4 weeks older, but this difference will not materially affect the calibration of a method of distinguishing year classes of adults, intended to be valid for New Zealand generally.

RESULTS

Incremental lines

Histological sections of canines of the 22 stoats examined all showed a distinct layer of light-staining, amorphous cementum. No fully-developed dark incremental lines in the cementum were observed in the 5 animals killed in April and May and judged by the genitalia to be young of the year (6–7 months old), but in 3 of them an incremental

Table 1 Cementum incremental lines, baculum weight, and post-orbital ratio (POR) in 22 stoats of known or minimum-known age.

Stoat Number	Sex	Date of first capture	Released into wild or kept in captivity	Date of death	Estimated age of death (months)*	No. of incremental lines	Age assessed from no. of lines (years & months)* yr	mth	Baculum weight (mg)	POR (mm)
Known age										
Caught as young and killed as subadult							yr	mth		
4	♂	11.12.79	W	9.5.80	7	0+	0	7	18.4	1.08
5	♂	8.1.80	W	9.5.80	7	0	0	7	18.1	1.14
6	♂	25.1.80	W	9.5.80	7	0+	0	7	25.7	1.15
Caught as young and killed as adults										
1	♀	11.12.79	W	18.4.80	6	0+	0	6	-	1.15
2	♀	1.1.80	W	18.4.80	6	0	0	6	-	1.08
14	♀	17.12.79	C	15.6.80	8	1	0	8	-	1.30
15	♀	17.12.79	C	1.9.80	11	1	0	11	-	1.28
10	♂	3.1.80	W	28.11.80	13	1	1	1	47.7	1.24
11	♀	15.1.80	W	15.12.80	14	1	1	2	-	1.31
18	♂	5.1.80	C	16.2.81	16	1	1	4	-	1.29
19	♀	18.12.79	C	16.2.81	16	1	1	4	-	1.18
22	♀	10.1.80	W	21.8.81	22	2	1	10	-	-
16	♂	18.12.79	C	29.10.80	12	disturbed	-	-	32.6	1.35
20	♀	17.1.80	C	16.2.81	16	disturbed	-	-	-	1.17
Minimum-known age										
Caught and killed as adults										
12	♂	14.12.79	W	30.4.80	≥ 18	1+	1	6	38.3	1.29
3	♂	3.1.80	W	9.5.80	≥ 19	1+	1	7	41.6	1.22
13	♂	14.12.79	W	28.5.80	≥ 19	2	1	7	40.2	1.26
8	♂	1.2.80	W	14.11.80	≥ 25	2	2	1	47.2	1.38
9	♀	22.1.80	W	28.11.80	≥ 25	3	3	1	-	1.29
7	♂	22.11.79	W	9.5.80	≥ 19	3+	3	7	49.7	1.21
17	♂	3.1.80	C	16.2.81	≥ 28	4	4	4	65.5	1.36
21	♀	15.1.80	C	16.2.81	≥ 28	5	5	4	-	1.41

*With an error of ± 1 month, depending on the actual date of birth within a 5-week span (King & Moody 1982b).
**Definitions of age classes as used by King & Moody (1982a):
Young: ♂ and ♀ killed before Feb 28 of their first year of life (♀ reproductively mature; ♂ not).
Subadult: ♂ killed between 1 March and 31 August of their first year of life (immature).
Adult: ♀ killed after 1 March, and ♂ killed after 1 September of their first year of life (♀ entering their second mating season; ♂ their first).

line under development — i.e., a dark layer immediately under the periodontal membrane (see Grue & Jensen 1979: 6) — was observed at the outer edge of the cementum. In all the remaining stoats, distinct dark incremental lines were observed within the light-staining cementum. For 5 animals, it was necessary to section the other lower canine, as readings of the first gave variable results. In 2 of these (no. 16 and 20) both lower canines were broken *in vivo* and, as disturbances of the cementum pattern prevented assessment of the number of lines present, these 2 animals had to be discarded. Results of the cementum readings are listed in Table 1.

As pointed out by Grue & Jensen (1973, 1979), correct classification of age groups by means of cementum incremental lines depends on prior determination of the season for line formation. Fig. 1 shows the monthly distribution of animals with a developing incremental line at the edge of the cementum, as a proportion of the total number of animals available for that month. Deposition of lines was observed in 2 of 3 stoats killed in April and in 4 of 6 killed in May. However, the limited number of animals available from April to June inclusive (total 10), and the lack of animals from March and July, prevents accurate assessment of the season for line formation in New Zealand.

The number of lines observed in the 20 stoats available for study is shown in relation to the number of months of known or minimum-known age in Fig. 2. Fig. 2 and Table 1 show that for the 12 animals of known age, of which 1 had lived almost 2 years in the wild, 7 showed incremental lines,

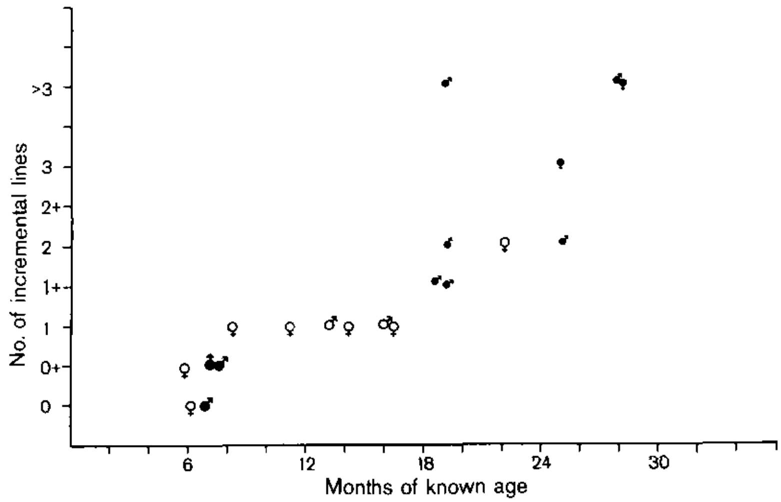

Fig. 2 Number of incremental lines in 20 stoats tagged as young (large symbol) or as adults (small symbol), in relation to known or minimum-known age in months. The plus sign in the vertical margin indicates a line under formation.

whose number corresponds exactly to the age of the animal in years. For the 8 animals of minimum-known age, the number of lines observed was equal to or exceeded the minimum known number of years, as would be expected if the correlation between number of lines and age, observed in animals less than 2 years old, persists with advancing age. We therefore assigned them ages in years and months, as shown in Table 1.

All the undamaged canines examined showed a distinct cementum pattern, and there was no difference in clarity of the lines between the sexes or between wild and captive animals. The maximum number of lines observed in the present study was 5, found in a female (no. 21) killed in February. She presumably lived to the age of 5 years and 4 months, of which the last 14 months were in captivity.

Baculum weight

van Soest & van Bree (1970) showed a correlation between baculum weight and the number of cementum annuli in 20 male stoats of unknown age from Holland, and inferred that baculum weight increased with age for at least the first 4 years of life.

Of the 12 males included in the present study, baculum weight was known for 11, of which 5 were of known age and 6 of minimum-known age (Table 1). The weight of the baculum in relation to age in months (Table 1, col. 9) is plotted in Fig. 3. The oldest males tended to have the heaviest bacula; however, there was considerable individual variation, and the correlation between age and baculum weight was much less precise than that found by van Soest & van Bree (1970).

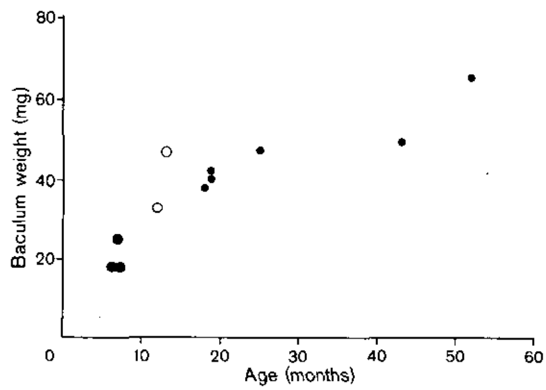

Fig. 3 Baculum weight (mg) in 11 male stoats tagged as young (large symbol) or as adults (small symbol), in relation to known age or to age as assessed from cementum incremental lines (Table 1, column 9). ● tagged/caught as young, killed as subadult; ○ tagged/caught as young, killed as adult; • tagged/caught and killed as adult.

Post-orbital ratio

The analyses of King & Moody (1982a), completed before any known-aged material was available, were based on a simple classification into 2 age classes for females (young ≤ 5 months; adults ≥ 5–6 months), and 3 for males (young ≤ 5 months; subadults 5–6 months to 10–11 months; adults > 11 months, assuming all animals are born late September or October) (Table 1) defined from the date killed, the shape of the skull, and weight of the baculum. The single figure most clearly reflecting the shape of the skull is the post-orbital ratio. In New Zealand stoats, the post-orbital ratio in females usually exceeds 1.10, and in males 1.15, by the time the animals reach adult body size.

Fig. 4 The post-orbital ratio (inter-orbital divided by post-orbital width) in 21 stoats tagged as young (large symbol) or as adult (small symbol) in relation to known age or to age as assessed from cementum incremental lines. □, means for young males and females collected from the wild in January and February, i.e., 3–5 months old (♂, n=137, ♀, n=173: from King & Moody 1982a). ● tagged/caught as young, killed as subadult; ○ tagged/caught as young, killed as adult; • tagged/caught and killed as adult.

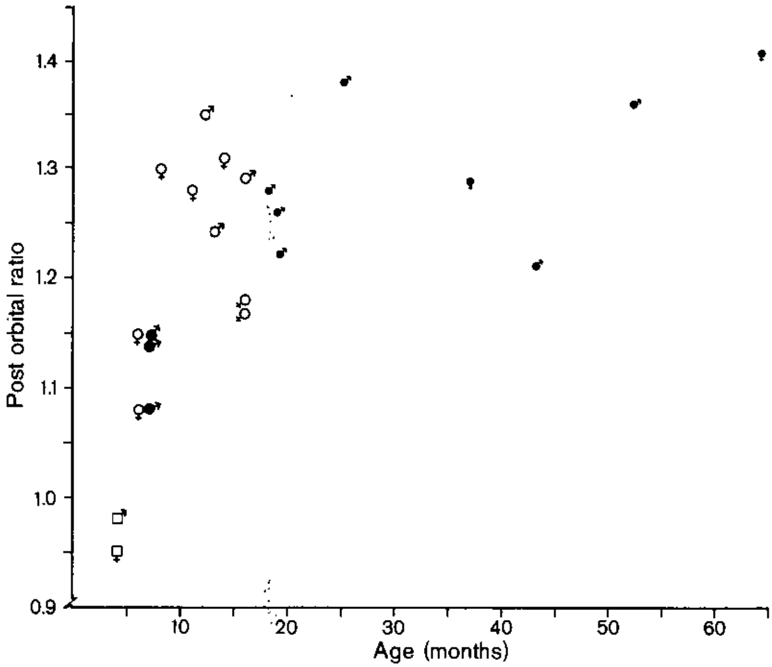

Fig. 4 confirms that the post-orbital ratio is a valid method of distinguishing skulls of full-grown New Zealand stoats. On the criteria used by King & Moody (1982a), one 7-month-old sub-adult male stoat (no. 6) had a post-orbital ratio of 1.15 and would thus have been placed among the adults, and 1 newly matured 6-month-old female (no. 2) had a ratio of 1.08 and would have been classified as young. However, no. 6 could be easily distinguished as a sub-adult from the baculum, and no. 2 was a borderline case, difficult to classify under any criteria. The other 17 stoats of both sexes, all 8 months old or over, were well clear of the suggested threshold values defining the adults (1.10 for females and 1.15 for males) and 2 sub-adult males were below it.

DISCUSSION

This investigation has shown that stoats in temperate New Zealand (41–44°S) develop distinct incremental lines in the canine cementum similar to those seen in stoats from the cooler climates of Denmark and Sweden (55–65°N) (Grue & Jensen 1979). As part of the material was of known age, it has also been possible to establish that the incremental lines develop in a seasonal cycle, and that for the first 2 years of life at least, the number of lines corresponds to the age of the animal in years.

The correlation between number of lines and age was not proven beyond 22 months of age; however, in the 8 stoats of minimum known age available for study (⩾ 18 to ⩾ 28 months), the number of lines observed in each animal was either equal to or greater than the minimum expected number of lines. This is as would be expected if the number of lines in a canine coincides with the age of the animal in years throughout life. However, if cementum reading is to be used for determining absolute age of mature wild-caught stoats, the month of death must be known.

The present material indicates that, in New Zealand stoats, deposition of the first incremental line starts during the first autumn of life, as in stoats from Denmark (Grue & Jensen 1979).

Deposition of incremental lines was observed only in stoats killed in April and May. The limited number of animals available for the present study, especially the lack of material for March and July, prevents an accurate assessment of the period for line formation. It may extend into the Southern Hemisphere winter months, but additional material from June and material from July is required to verify this. In Danish and Swedish stoats, deposition of lines starts in September–October and ends in March–April (Grue & Jensen 1979). Considering the time difference in season of half a year between the Northern and Southern Hemispheres, it seems clear that at least the beginning of the period of line formation is the same time of year (autumn) in stoats from all 3 countries (Fig. 5).

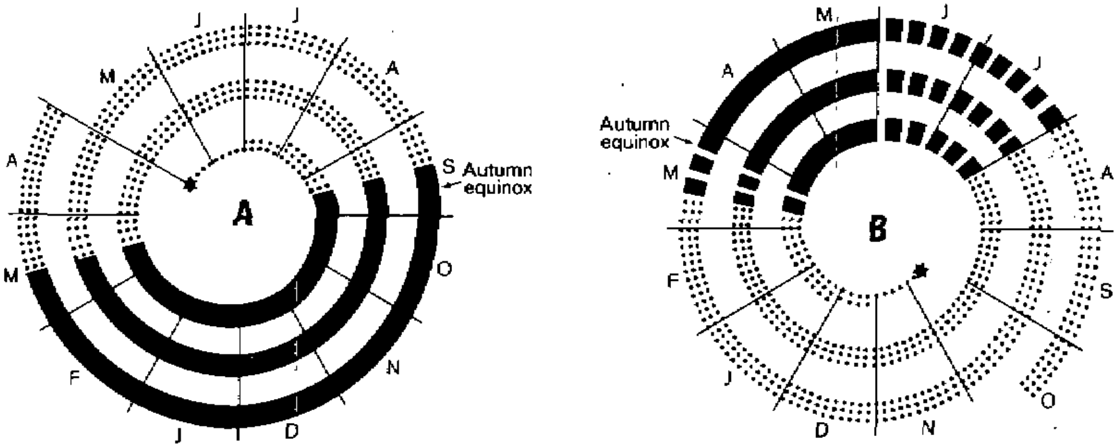

Fig. 5 The seasonal cycle of development of incremental lines in the canine teeth of stoats from: (A) Denmark (Grue & Jensen 1979); (B) New Zealand. Deposition of dark-staining cementum begins at approximately the same season in both countries, although it is not possible to say from the present material whether this process continues throughout the winter in New Zealand as it does in Denmark. *birth; ... deciduous canine; ::::::permanent canine erupting; ::::::permanent canine depositing light-staining cementum; ■permanent canine depositing dark-staining cementum; ı ı ı material insufficient, dark-staining deposition possible.

In the 15 adult specimens giving clear readings, the incremental lines were very similar to those observed in wild stoats in Denmark and Sweden (Grue & Jensen 1979). No variation in clarity of lines between animals from the 3 countries could be detected.

The 2 animals with broken lower canines (no. 16 and 20) were among those that had been kept in captivity. In the canines of both, the cementum growth had been disturbed *in vivo*, and it was not possible to count the many thin lines present. Disturbed cementum growth that obliterates the normal cementum pattern and renders the teeth unsuitable for cementum reading has been observed previously in farm-reared Arctic foxes (*Alopex lagopus*) by Grue & Jensen (1976), who pointed out that the canines of farm foxes are often broken in the wire netting of the cages.

The maximum number of incremental lines observed in this study was 5, found in 1 out of 20 stoats (5%). van Soest & van Bree (1970) found 1 with 5, 1 with 6, and 1 with 8 lines among 37 stoats from Holland (total 8% with 5 or more lines); Kukarcev (1978) found 2 with 5 and 1 each with 6 and 7 lines among 730 stoats from the USSR (0.5%); Grue found 1 each with 6 and 7 lines (total 7%) among 28 stoats from Denmark (Jensen 1978). Among 61 Danish stoats Grue found 3 with 5, and 1 each with 6 and 7 lines (total 8%), whereas in 96 animals from various localities in Sweden the maximum number of lines observed was 4 (this material was included in Grue & Jensen 1979). If the relationship between age and number of lines is as reliable among the older animals as it appears to be in the younger ones (Fig. 2), then it seems that 6 to 8 years is the oldest age attained (infrequently) by stoats in the wild.

We conclude that in New Zealand stoats, no less than in the larger, cooler-climate mustelids (e.g., the mink (*Mustela vison*) (Pascal & Delattre 1981), the fisher (*Martes pennanti*) (Strickland et al. 1982), and the otter (*Lutra lutra*) (Stephenson 1977)) the results of examination of known-aged specimens confirm the cementum incremental lines as the most reliable indicator of age in adult animals. Subadult and young stoats (usually the majority) can be distinguished without sectioning. Baculum weight and post-orbital ratio can reliably separate adults from the young of the previous season, where that is sufficient or where material cannot be sectioned: where exact age determination from cementum reading of adults is required, initial elimination of young animals beforehand can save much time and effort (Grue & Jensen 1976).

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