MOOSE SENESCENCE RELATED TO TOOTH WEAR

Mary Hindelang and Rolf O. Peterson
School of Forestry and Wood Products, Michigan Technological University, Houghton, MI 49931

ABSTRACT: Tooth wear in moose (*Alces alces*) generally follows an age-related sequence. The enamel-dentine interface forms an intricate pattern representing the effective cutting edge of teeth. We measured the linear cutting edges of 6 mandibles from 9 wear classes from Isle Royale moose skeletal remains. We calculated cutting edge for each tooth and toothrow for all wear classes, scaled to a constant toothrow length. Our results suggest that effective cutting surface increases until wear class V and then declines, consistent with progressive eruption and tooth wear. Late eruption of the third molar helps maintain a constant cutting edge for several years after older teeth have deteriorated. Senescence corresponds to the period of tooth decline.

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Patterns of tooth eruption and wear are useful indicators of age in cervids and other mammals. Determination of age at death is invaluable in assessing population structure and age-specific survival rates. The sequential nature of tooth wear provides a method for evaluating the age and vitality of individuals.

As occlusal surfaces come into contact, the enamel on the cusps is worn away revealing the underlying dentine, and because dentine is deposited incrementally, characteristic wear patterns develop (Brown and Chapman 1991). Passmore *et al.* (1955) designed a scale for measuring relative mandibular tooth wear for moose based on 9 classes which span the spectrum of wear. More recently, Brown and Chapman (1991) developed a scoring scheme for the dentition of red deer (*Cervus elaphus*) based on wear of slopes and tips of cusps. In a study of loss of tooth structures and diminished cropping efficiency, Young and Marty (1986) compared tooth wear with age by measuring crown height and facet area of incisors of moose. Attempting to standardize and simplify wear-classing of mandibles, Gibson (1993) performed archaeofaunal age determination using prototype computerized image processing and artificial intelligence techniques. Regardless of technique, methods must be taxa-specific, and the extent of wear ultimately depends on the type, quality, and amount of forage processed.

The cumulative effects of foraging habits throughout a lifetime are exhibited in the condition of the teeth at the time of death, and may contribute to the overall decline in physical condition with age. In a comparative study of senescence in natural populations, Promislow (1991) defined senescence as the decline in age-specific survival and fecundity with age, generally beginning substantially after the age of maturity. He suggested that although it is widely believed that wild species die before they have a chance to grow old, it is a common occurrence for individuals of many species to live long enough to exhibit senescence.

Because the population of Isle Royale moose probably contains a larger proportion of older moose than populations that are harvested, it provides the opportunity for studying age-related changes. In this study, we devised a method for measuring the effective cutting edge of teeth in each wear class. Tooth wear could simply be linearly related to age, but we hypothesized that accelerated mortality in old age classes corresponds to more rapid loss of tooth cutting edge.

METHODS

We examined 6 calf mandibles and 6 mandibles from each of the 9 wear classes

from skeletal remains of moose from Isle Royale National Park, MI. We photographed each mandible, focusing on the occlusal surface, and projected the 35mm slides on a drawing surface. The projected images were all standardized to the same size by adjusting the focal distance. All lines where a dentine-enamel interface occurred were traced, using the actual mandible as a reference (Fig. 1). To account for the 3-dimensional nature of the cusps, which may have been lost in the 2-dimensional projections, we calculated an error factor by examining the triangle formed by the cusp on one tooth from each wear class. We measured the height of the cusp and the linear distance of the edge with a micrometer, and using the Pythagorean theorem, calculated the hypotenuse of the triangle formed.

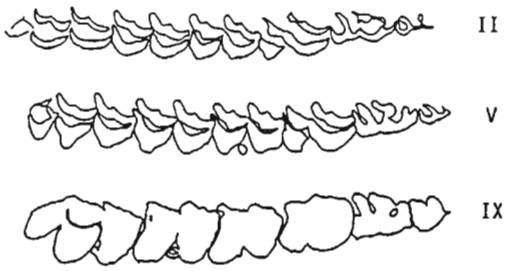

Fig. 1. Cutting surface of toothrows traced from projected images of three moose mandibles from Isle Royale National Park, MI, representative of wear classes II, V and IX.

The linear distance of the edges was then measured with a scaling wheel. A measurement for each premolar and molar (P2 through M3) was obtained as well as for the total toothrow. Mean toothrow length was calculated for all mandibles in each of the 9 wear classes. Using the proportion of measured edge length to the mean toothrow length to account for differences in size of mandibles, we calculated a mean scaled perimeter for each of the 9 wear classes. We considered the latter measurement to be the effective cutting edge.

RESULTS AND DISCUSSION

The wear patterns of the individual teeth suggested that molars more clearly demonstrate a decline of function of the occlusal surfaces with age than premolars. The molars' paired crescent-shaped cusps were flattened on the lingual (tongue) side and rounded on the buccal (cheek) side, separated by the infundibulum (space). In the molars, the mesial slopes wore before the distal slopes. The first wear was on the thin white enamel, followed by the light brown dentine, and then the dark brown secondary dentine formed in the pulp cavity. Wear progressively exposed the secondary dentine so that a continuous line joined the mesial and distal cusps on the lingual or buccal side. Finally, the enamel that lines the infundibulum wore away revealing a continuous core of dentine.

The effective cutting edge of teeth increased with age from calves through wear class V. We had not anticipated an initial increase in cutting surface, but this is consistent with continued replacement and eruption of teeth, and elongation of the mandible and toothrow throughout the first 5 wear classes (Passmore *et al.* 1955). Cutting edge declined starting at wear class VI through IX (Table 1).

Lightly worn specimens displayed some variation in the premolars, P2 and P3, but the greatest changes with increasing wear class

Table 1. Scaled toothrow cutting edge (cm) for 6 mandibles in each wear class from moose in Isle Royale National Park, MI.

Wear Class	n	Mean	SD
C	6	46.83	3.72
I	6	57.17	5.76
I	6	66.67	9.88
III	6	72.67	2.81
IV	6	76.33	8.86
V	6	89.67	2.62
VI	6	83.50	5.56
VII	6	89.50	3.35
VIII	6	83.50	6.75
IX	6	72.67	14.28

were observed in the molars, M1 and M2 (Fig. 2). A progressive decrease in wear was observed from M1 to M3. M3 contributed most of the increase in cutting surface; in fact, M3 continued to increase throughout the span of wear classes, but this was offset by the decrease in the other teeth.

Our calculated error for the height dimension of tooth cutting surface varied with the height of the cusps of the individual teeth. The greatest error (0.05-0.11) occurred in teeth with the steepest-sloped cusps in the lower wear classes. For heavily worn teeth in the higher wear classes, the calculated error was small (0.01-0.05).

Because this method was time consuming, we limited our study to a relatively small sample size (60 mandibles - 6 from each wear class), but this was sufficient to show trends with each tooth type and each wear class. The relationship of mean cutting surface to wear class was modeled by a parabola using multiple regression with a quadratic term (P=.0011, r^2=0.8969) (Fig. 3).

In a previous study, we determined the mean age of Isle Royale moose mandibles in wear class V to be 7.5 years, and in wear class VI 9.8 years (Hindelang and Peterson 1993). The decline in the length of cutting edge occurs at the same age as the accelerated decline in age-specific survival for Isle Royale moose which Peterson (1977) estimated was 7-9 years of age. Because teeth are critical for efficient foraging and digestion of browse, the increased wear of cutting surfaces reduces a moose's ability to acquire the nutrition necessary for survival, and is one of the age-related factors that corresponds to senescence. The results of this study will enhance our knowledge of mandibular tooth wear, and give insight into natural processes that occur with senescence.

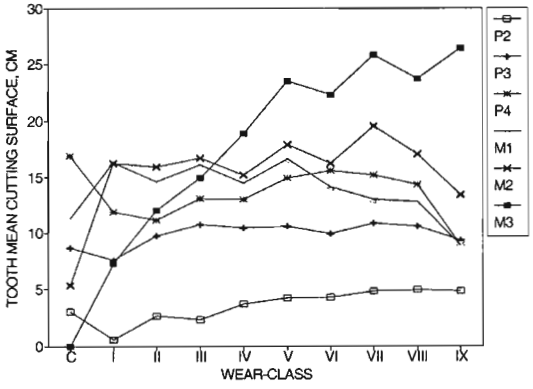

Fig. 2. Mean cutting surface (cm.) for each moose tooth type by wear class from 60 mandibles of Isle Royale moose.

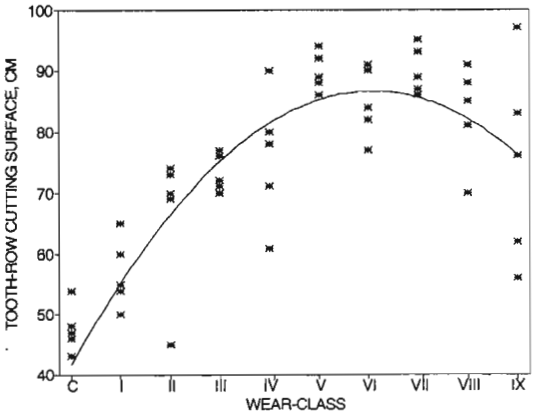

Fig. 3. Relationship of toothrow cutting edge (cm.) by wear class from calves to wear class IX from Isle Royale moose, modeled by a parabola using multiple regression with a quadratic term (ce=41.67+[wc*14.81]-[wc^2*1.22], P=0.0011, r^2=0.89).

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