A Quantitative Evaluation of the Severinghaus Technique for Estimating Age of White-tailed Deer

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Abstract: Subjectivity of tooth wear and replacement (i.e., Severinghaus technique) for estimating ages of white-tailed deer (*Odocoileus virginianus*) is sometimes questioned. To further quantify Severinghaus's description of tooth wear, we used digital photographs and computer-assisted technologies to measure dentine and enamel widths on molars of 67 wild, known-aged deer from South Carolina. Accurate measurements of dentine: enamel ratios did not clearly separate 2.5, 3.5, and 4.5-year-old deer because of excessive variability within age classes. Therefore, we used *K*-nearest neighbor [KNN] analysis to assign deer to age classes based on an overall dentine: enamel ratio. We correctly classified about 54% of deer tested. Based on our results and previous studies, we believed little accuracy in age estimates is gained by measuring dentine and enamel widths. In addition, we believed KNN has value for separating deer into discrete age classes, if less variable tooth or body characteristics are identified.

Key words: aging, deer age, *Odocoileus virginianus*, Severinghaus, South Carolina, tooth wear

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Popularity of quality deer management (QDM) has motivated many property managers to establish age-based harvest criteria for white-tailed deer (hereafter deer) designed to recruit more males into older age classes. Without accurate estimates of deer age, managers practicing QDM cannot evaluate current health of deer based on age-specific biotic potential or recognize when age structure goals have been achieved. Managers have long used visual assessment of tooth wear and replacement of known-aged deer as described by Severinghaus (1949) for estimating deer age. Severinghaus (1949) characterized stages of tooth eruption and replacement and measured tooth height to assign deer into age classes from birth to two years of age. He used height of molar teeth and relative wear on the occlusal surfaces of premolars and molars to assign deer to 2.5- to ≥10.5 year-old age classes.

A second, less-widely used technique involves counting annual rings (cementum annuli) in a stained cross-section of the root of a deer's first incisor (Gilbert 1966). In some studies of known-aged deer, this technique has proven more reliable than the Severinghaus technique (Sauer 1971, Jacobson and Reiner 1989). However, in other studies, counts of cementum annuli were poor predictors of deer age (Cook and Hart 1979, Mitchell and Smith 1991). Furthermore, deposition of cementum annuli in deer teeth can be highly variable and influenced by nutritional status (Rice 1980, McCullough 1996).

Although reliability of the Severinghaus technique declines as variability of tooth wear increases with increasing deer age (Gilbert and Stolt 1970, Sauer 1971), it remains widely used by managers and researchers whom believe it provides acceptable deer age estimates (Jacobson and Reiner 1989). Gee et al. (2002) tested application of the Severinghaus technique with 106 known-age deer from one population in south-central Oklahoma. They determined tooth wear characteristics, including accurate measures of molar heights, were too variable to provide reliable estimates of deer age beyond fawn (0.5-year-old), yearling (1.5-year-old), and adult (≥2.5-year-old) age classes.

Our study differs from others because we quantitatively measured dentine and enamel widths on molars of known-aged deer jaws as qualitatively described by Severinghaus (1949). We used ArcView 3.2a GIS software (ESRI, Redlands, California) and digital photography to measure dentine and enamel widths. We used discriminant analysis to test efficacy of dentine: enamel ratios for assigning deer to age-specific classes. Our objective was to determine if dentine : enamel ratios of molariform teeth, as determined by digital photography and computer-assisted data collection, would provide reliable predictions of deer ages.

Methods

Representatives of South Carolina Department of Natural Resources (SC DNR) captured fawn or yearling deer in Hampton, Jasper, and Williamsburg counties, South Carolina. All deer were ear-tagged and released at their capture sites. During 1986–1998, when ear-tagged deer were killed by hunters, SC DNR representatives removed, cleaned, and stored their mandibles until needed for subsequent data collection.

Hampton and Jasper counties are in the Lower Coastal Plain Physiographic Region. Williamsburg County lies entirely within the Atlantic Coast Flatwoods Physiographic Region. Soils within these counties formed from sandy to clayey Coastal Plain deposits, ranging from moderately-well to poorly-drained on flats and floodplains to well-drained and excessively-well-drained on sandy stream terraces. Vegetative communities within these counties were similar, mostly pine (*Pinus* spp.) and upland hardwood forests with the remainder in bottomland hardwood forests (Stuck 1980, Ward 1980, Eppinette 1995).

We photographed deer mandibles with a 4.0-megapixel digital camera (Nikon, Melville, New York) mounted on a tripod at 44.5 cm above each mandible. Before photographing mandibles, we removed debris from teeth using a dental pick and compressed air and added a metric ruler to the view for size reference. We imported these photos (i.e., raster images) into ArcView to facilitate tooth measurements. Once in ArcView, we created a new line theme (i.e., vector shapefile) for molars one (M1), two (M2), and three (M3). For M1, M2, and the first two cusps of M3, we digitized widths of lingual enamel, lingual dentine, buccal enamel, and buccal dentine (i.e., drew 12 lines on each tooth image, Fig. 1). We used XTools ArcView extension, version 9-15-2003 (Oregon Department of Forestry, Salem) to calculate lingual and buccal enamel and dentine widths to 0.01 mm, based on the reference scale for each image. When measuring dentine width, we included all dentine, regardless of dentine color. We summed lingual and buccal enamel widths (i.e., eight measurements) when we calculated dentine: enamel ratios. We exported data into Excel (Microsoft Corp., Redmond, Washington) for age-class comparisons.

We examined the relationship between deer age and dentine: enamel ratios of lingual and buccal crests of M1, M2, and M3 for 67 known-aged deer that were 2.5–4.5 years old. We plotted means for each tooth crest, with associated standard errors to test for separation among age classes. In addition, within age classes, we combined all dentine: enamel ratio data (lingual and buccal crests of M1, M2, and M3), which we tested in SAS 8.2 (SAS 1999) using *K*-nearest neighbor classification and cross-validation using the CATDAT program (KNN, Peterson et al. 1998). The CATDAT program selected the appropriate number of nearest neighbors to include in the model based on least amount of classification error. *K*-nearest neighbor is a nonparametric discriminant analysis, which predicts an observation response using an estimate of the response distribution of its nearest neighbors and does not assume multivariate normality. However, KNN assumes characteristics of members in the same class are similar and observations closer together in covariate space belong to the same class (Cover and Hart 1967, Hand 1982). To further test the value of *K*-nearest neighbor for estimating deer ages, we pooled data for 3.5 and 4.5 year olds in a subsequent analysis.

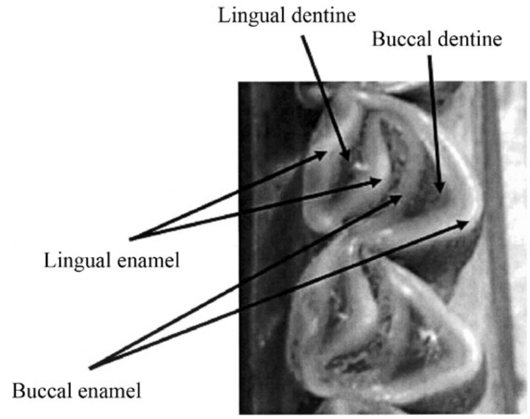

Figure 1. Photograph of deer tooth showing location of dentine and enamel measurements taken on molars 1, 2, and 3 from known-age deer mandibles from Hampton, Jasper, and Williamsburg Counties, South Carolina, 1986–1998.

Results

We found dentine : enamel ratios on the lingual and buccal crests of M1, M2, and M3 were ineffective at separating 2.5-, 3.5-, and 4.5-year-old deer (Fig. 2). Histograms of mean dentine : enamel ratios suggested proportion of dentine on M2 and M3 increased with deer age. However, large variability among individuals within an age class (i.e., overlapping error bars) precluded using tooth-specific characteristics to estimate deer age. By 2.5 years of age, dentine : enamel ratios on the buccal crests of molars 1 and 2 were >1 (i.e., dentine wider than enamel).

The KNN predictive model was poor at distinguishing 2.5-, 3.5-, and 4.5-year-old deer. Overall prediction accuracy for these deer was 54.4% (i.e., 45.6% error; Table1), based on all dentine : enamel ratios. When we combined data for 3.5 and 4.5-year-old deer, prediction accuracy increased to 73.8% (correctly classified 77.5% of 2.5-year-olds and 86.1% of deer ≥3.5 years old).

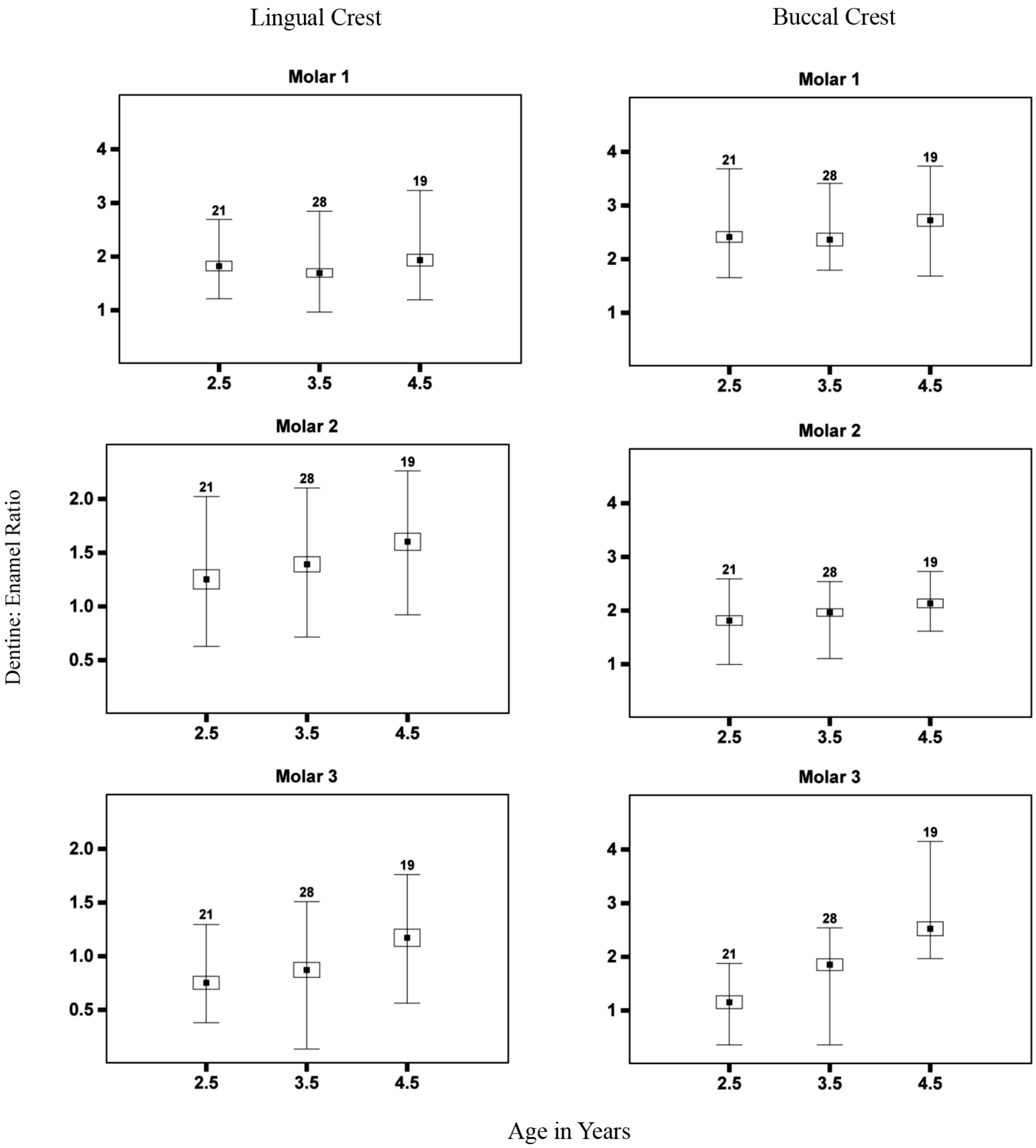

Figure 2. Dentine: enamel ratios for lingual and buccal crests of molars 1, 2, and 3 from known-age deer mandibles (*N* = 67, 2.5- to 4.5-year-olds) from Hampton, Jasper, and Williamsburg counties, South Carolina, 1986–1998. Data are presented as means (periods), standard errors (boxes), and ranges (bars).

Table 1. Correct age classification (%) and associated error (%) using *K*-nearest neighbor analysis with cross-validation of dentine: enamel ratios from lingual and buccal crests of molars 1, 2, and 3 of known-age deer mandibles (*N* = 67, 2.5- to 4.5-year-olds) from Hampton, Jasper, and Williamsburg counties, South Carolina, 1986–1998.

		% Classified into age class			
Age	***N***	**2.5**	**3.5**	**4.5**	**% Error**
2.5	21	71.4	19.1	9.5	28.6
3.5[a]	28	35.7	25.0	35.7	75.0
4.5	18	0.0	33.3	66.3	33.3
Total	67				45.6

a. A tie between two age classes constituted 3.6%.

Discussion

Use of digital photographs and ArcView to quantify dentine : enamel ratios of M1, M2, and M3 did not separate known-aged deer into discrete age classes. The original criteria described by Severinghaus (1949) for the lingual crest of M1 stated that dentine widths do not become wider than enamel widths until age 3.5, which should enable the separation of 2.5- and 3.5-year-old age classes. However, we found overlap in dentine : enamel ratios between these two ages. Similarly, dentine width in relation to enamel width on the lingual crest of M2 is critical for separating 3.5- and 4.5-year-old age classes. We found this criterion to be unreliable. Previous researchers (Cook and Hart 1979, Jacobson and Reiner 1989) reported acceptable levels of accuracy were obtained from biologists' estimates of known-age deer using the Severinghaus (1949) technique, suggesting that subjective evaluation by well-trained observers may increase accuracy of the tooth wear and replacement technique as compared to a strict, quantitative application. Another factor that may influence accuracy rates of biologists is color variation of dentine, likely unrelated to deer age, which ranges from light tan to black. Thus, utility of the technique may depend on an experienced observer's ability to subjectively and simultaneously evaluate multiple tooth wear criteria and to interpret variations in dentine color. Because computer technology allowed us to enlarge our view of each tooth, we believed we were able to distinguish clear borders between enamel and dentine in spite of variations in dentine color.

Using KNN discriminant analysis, we classified 2.5-year-old deer with reasonable accuracy (71.4%; Table 1). However, the 3.5-year-old age class was classified correctly only 25% of the time, with errors split evenly between the 2.5- and 4.5-year-old age classes. When the 3.5- and 4.5-year-old age classes were pooled, accuracy of our age estimates increased. However, for quality deer management purposes, we believed it was desirable to distinguish young, middle-aged, and older adults in the harvest, rather than pooling age classes.

When using KNN analysis to predict deer ages based on dentine : enamel ratios, we achieved accuracy rates exceeding those reported for deer ≥2.5 years old using a more qualitative application of tooth wear and replacement (46%, Mitchell and Smith 1991) and a qualitative application plus accurate measures of tooth heights (40%, Gee et. al 2002). However, our deer age estimates were less accurate than those of other studies that tested the original application of the Severinghaus technique (67%, Cook and Hart 1979; 63%, Jacobson and Reiner 1989) or the cementum annuli technique (71%, Jacobson and Reiner 1989; 93%, Hamlin et al. 2000).

As deer populations continue to expand and hunter objectives change, deer management in many areas of the United States is undergoing dramatic changes. A shift towards quality deer management has increased importance of age-related data. Because deer age affects body growth, antler quality, fertility of does, and sex ratios of offspring, age-specific criteria must be established on a localized basis (Verme 1983, Sauer 1984, Miller and Marchinton 1995). In some areas, managers have experienced difficulties in achieving a higher proportion of older bucks (i.e., ≥3.5 years old) in a herd. It is possible that these difficulties could be associated with age estimation errors rather than lack of response to management strategies.

Our study reinforced the relationship between tooth wear and deer age as characterized by Severinghaus (1949). However, we demonstrated that tooth dentine and enamel widths varied greatly among individuals within an age class, even when using accurate measurements rather than more subjective comparisons. We believed the wide range of accuracy rates reported by previous researchers (Cook and Hart 1979, Jacobson and Reiner 1989, Mitchell and Smith 1991, Gee et al. 2002) likely resulted from inherent variability in tooth wear patterns, rather than from human error in applying the Severinghaus technique. We recognized that alternative dental measurements (e.g., tooth slope), not tested by this study, might be related to deer age and should be evaluated further.

Management Implications

Based on our results, deer population managers should not expect to obtain more accurate deer age estimates by spending additional time and effort to measure dentine and enamel widths on M1, M2, and M3. However, in the future, computer-assisted data collection and KNN discriminant analysis might prove useful for separating deer into age-specific categories, if less variable tooth wear characteristics are identified. Of course, the relative complexity of computer software programs, when compared to subjective application of the Severinghaus technique, would dictate that managers submit their data to a qualified service provider for age estimations. Until a more reliable method for determining deer age has been identified, we recommend that managers confine their use of the Severinghaus technique to determination of fawn, yearling, and adult age categories as stated by Gee et al. (2002). When more precise age estimates for adults are needed, we suggest managers assign individuals to young adult, middle-aged adult, and older adult categories based on tooth wear characteristics, relative body weights, and relative antler characteristics. Using a combination of age-related criteria may be especially important when evaluating age of males in the harvest as a response to QDM management strategies.

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