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Aging Illinois White-Tailed Deer by the Tooth Replacement and Wear and the Cementum Annuli Techniques

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AGING ILLINOIS WHITE-TAILED DEER BY THE TOOTH

REPLACEMENT AND WEAR AND THE CEMENTUM ANNULI TECHNIQUES

(TITLE)

BY

James B. Bertoglio

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Master of Science

and hereby certify that in their opinion is worthy of acceptance.

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INTRODUCTION

Management of the white-tailed deer (*Odocoileus virginianus*) requires an understanding of the dynamics of the population. One aspect of the population dynamics, the distribution of age classes, indicates survival rates and resulting population trends (Ludwig, 1967) and may be used to evaluate population trends and serve as a guide to establishing harvest levels (Andrews and Calhoun, 1968).

The primary means of aging white-tailed deer for the past twenty years has been based upon the tooth wear and replacement technique described by Severinghaus (1948, 1949, 1950). This method, while being a convenient field technique, has several limitations. As the deer become older the diagnostic characteristics on the teeth become depleted and more difficult to interpret (Ryel *et al.*, 1961). There is often human variation in interpretation of the characteristics (Dahlberg and Guettinger, 1956; Ryel *et al.*, 1961; Lueth, 1965; Gilbert, 1966; Ludwig, 1967). Variations in the rate of wear on the teeth in different habitats may also influence the accuracy of this technique.

A recently developed aging technique based upon dentine or cementum annuli (Sergeant and Pimlott, 1959; McEwan, 1963; Gilbert, 1966; Keiss, 1969; McCutchen, 1969) is reportedly more accurate than the replacement and wear method. This method, however, is not adaptable to the field since teeth must be removed, decalcified, sectioned, and stained. The annuli technique may be useful as a supplement to the replacement and wear technique in order to determine variation in aging by that technique. This is a report of comparisons of the tooth replacement and wear method and the cementum annuli technique for hunter-killed white-tailed deer in southern Illinois.

LITERATURE REVIEW

Many techniques have been developed to age various species of wild animals. Some techniques have been found reliable for aging a particular species; others have been found unreliable or are still being tested. A reliable method is one which gives consistently accurate aging to the necessary degree (Alexander, 1958). Certain methods of age determination can be used only with specific animals. The opossum, for example, can be aged by pouch development (Petrides, 1949). Other methods are more general and can be used to age several species of animals. Body weight and length, for example, have been used to set up age classes in humpback whales (Dawbin, 1959), distinguish juveniles from adults in a gray fox population (Wood, 1958), distinguish juvenile from adult swamp rabbits (Holten and Toll, 1960), skunks (Crabb, 1944), and mountain pocket gophers (Hansen and Miller, 1960).

Osteological characteristics have been widely used in aging wildlife. Epiphyseal closure of the long bones is used effectively to distinguish juveniles from adult cottontails (Thomsen and Mortensen, 1946; Hale, 1949; Petrides, 1951), raccoons (Petrides, 1959), and minks (Greer, 1957). Structural characteristics of the skull, such as cranial sutures, saggital crest development, and smoothness of the bone have been used with cottontails (Petrides, 1951), mongoose (Pearson and Baldwin, 1953), mink (Greer, 1957), gray fox (Wood, 1958), and porcupine (Kochersberger, 1950). Greer (1957) studied these osteological characteristics as well as others in ranch mink of known age groups and found them to be 95% accurate for distinguishing juveniles from adults. Sullivan and Haugen (1956) x-rayed the feet of red foxes to determine age, but found it difficult to set up definite categories other than a gradual enlargement of the bones until the adult size was reached. Ear plug laminations and baleen plates seem to be good indicators of age in humpback and North Atlantic fin whales (Laws and Purves, 1956; Dawbin, 1959; Purves and Mountford, 1959; Chittleborough, 1960).

Pelage and molt progression have been used as means of determining age in several species of mammals, particularly the smaller ones such as voles and mice. Ecke and Kinney (1956) found that by correlating body length to molt stage of meadow mice, the age could be determined to within 4 days to 60 days of age with 88% accuracy. After adult pelage is reached however (60 days), no definite molt pattern was discernible. This technique has been applied to other species such as the mountain pocket gopher without success (Hansen and Miller, 1960).

Development of the reproductive system has been studied as a means of age determination in several species of animals. Testis weights of male humpback whales (Chittleborough, 1960) and ovary weight and follicle diameter of females (Dawbin, 1959) have been used to indicate sexual maturity. Dawbin noted that these methods were variable and that the results had to be compared with averages for the species. Juvenile female pocket gophers have been distinguished from adult females by the absence of a "pubic gap" between the pelvic bones which appears at sexual maturity (1 year) (Hansen and Miller, 1960). Juvenile and adult pocket gophers have also been distinguished by the size of the uterine horns. Testis length will also distinguish juvenile from adult male cottontails (Petrides, 1951).

Several workers have used the baculum as a means for determining the age of animals. The length and weight of this structure has been used to distinguish juvenile from adult gray foxes (Wood, 1958), minks (Greer, 1957), raccoons (Petrides, 1959; Sanderson, 1961), and gophers (Hansen and Miller, 1960). Sanderson (1961) found the baculum to be more accurate for male raccoons than epiphyseal ossification. Elder (1951), using the same method, reported little overlap of weight between juvenile mink and adults, but that there was great variation within the two groups. Weight was much more reliable than length because the weight continued to increase yearly while length increase stopped at maturity.

Other methods of aging animals have been devised and tested. Lens weight has been tried with cottontails (Lord, 1959), whales (Nishiwaki, 1950), mule deer (Nellis, 1966), Columbian black-tailed deer (Longhurst, 1964), and many other species. Researchers found a definite correlation between body weight and lens weight. Lord (1959) showed that data for dry lens weight can be used to determine the age composition of populations of the cottontail rabbit (Sylvilagus floridanus). Nellis (1966) found that the lens technique can be perfected for aging prenatal deer and that sex has no effect on lens weight. Aging accuracy may decrease for fetuses less than 60 days old. Longhurst (1964) found lens weight satisfactory for distinguishing yearly age classes through at least 5 years. In general the accuracy of this method varies with the species.

White-tailed Deer

Aging into yearly age classes is necessary for proper deer management because game biologists must know how many deer from each age class have been killed each year so they can set the limits for the following hunting season. Many aging techniques have been tested on the white-tailed deer. Most of the techniques mentioned above, where applicable, have been tried. Lewall and Cowan (1963) found that ossification of the epiphyseal plate in the long bones could be used to age deer from 8 months to 72 months of age at yearly intervals. Lord (1962) reported that eye lens weight in white-tailed deer corresponded to ascending age through 10 years, but other workers reported that lens weight could be used reliably only to separate fawns from adults (Skiff, 1947; Wood, Cowan, and Nordan, 1962; Lueth, 1965). Hoffman and Robinson (1966) concluded that dry lens weight is a function of age only during the first year of life and has limited usefulness as a criterion for assessing age. However the effectiveness of lens weight as a criterion for age is influenced by diet. Friend and Severinghaus (1967) found that lens weight of New York deer showed overlapping between age groups to be much greater among animals with poor range conditions. Dry lens weight has also been perfected for aging placental deer (Nellis, 1966).

Antler growth and development has been investigated as a possible means of age determination in deer. Variations by age class in the antler beam diameters on white-tailed deer can be related to range conditions, but a universal set of aging criteria has not yet been established because the antlers are lost each year leaving no indication of how many racks have been produced in the past (Gandal, 1954; Severinghaus, 1960). Also, this method cannot be used for female deer.

Other techniques have been tried for aging the white-tailed deer with varying degrees of success. Schults and Flyger (1965) sought to find a relationship between age and sex and strontium-90 accumulation in white-tailed deer mandibles. Correlations were obtained, but the method requires special equipment and skill and needs more work before it can be used accurately.

Severinghaus (1948, 1949, 1950) developed criteria for aging New York white-tailed deer into yearly age classes by tooth replacement and wear. Fawns were aged by the replacement of incisors and development of molars. Temporary incisors are smaller than the permanent pincers and are replaced at about 7 to 10 months. At about 6 months three premolars, the third of which has three cusps, and the first permanent molar are present, although not fully erupted. The crests of the second permanent molar are visible at about 8 months and wear may begin to show on the premolars.

The third molar is erupting at 17 months and the premolars are worn. By 18 months the deciduous premolars are being replaced by the permanent premolars, and by 19 months the permanent premolars are all in place, but are unstained. The third permanent premolar is a bicuspid rather than a tricuspid. The molars are all in place and fully erupted except for the last cusp of the third molar. From this point on aging is done by noting the progressive wear on the teeth. Attention is paid to the sharpness of the lingual crests, relative width of the dentine and enamel, degree of infundibulum remaining, and distance from the gum line to the top of the tooth.

The main merit of this method is that it can be used in the field to age the deer into yearly age classes. Aging white-tailed deer by the tooth replacement and wear technique is more accurate when the deer is young, since there are more characteristics available upon which to base a decision. The method becomes less accurate in direct proportion to the age of the animal (Severinghaus, 1949). This is the primary limitation of this method of aging deer. Variations between the biologists doing the aging will also influence the accuracy of this method (Ryel, Fay, and Van Etten, 1961). Variations in wear may also arise due to differences in habitat. Robinette et al. (1957), working with the Rocky Mountain mule deer, studied the effects of environmental factors on tooth wear. He found that fluorosis, caused by fluorine from steel mills and by concentrations in soil and water, interfere with normal calcification of the teeth because of its affinity for calcium. He also noted that a calcium deficiency in the diet causes abnormalities similar to fluorosis and delays tooth eruption.

A modification of the replacement and wear method was developed by Flyger (1958) and Barnes and Longhurst (1960). It involved taking tooth impressions of deer and determining the age of the animals from them. By making casts from the impressions, the deer can be aged using Severinghaus' method. This method can be used on both live and dead specimens. This would allow aging to be done in the laboratory under more ideal conditions and would give a permanent record of the jaw. The impression however did not show the stain on the teeth which is especially important for the 2½ and 3½ year old deer.

White-tailed deer have also been aged by counting the annuli in tha teeth (Ransom, 1966). Various teeth have been used, although the incisors seem to be preferable to the molars since the incisors have but one root while the molars have multiple roots and are thus more difficult to remove without damage and to section (Gilbert, 1966; Keiss, 1969; McCutchen, 1969). The technique followed by most workers (McEwan, 1963; Gilbert, 1966) with certain refinements, has been to decalcify the teeth with 30% formic acid for 96 hours or longer, immerse them in cellusolve for 24 hours, and imbed them in paraffin. Longitudinal sections were then cut at 10 microns with a microtome, mounted, and stained using the standard technique for Delafield's hematoxylin. Sections were mounted in balsam and observed microscopically with transmitted light.

Gilbert (1966) found the cementum easier to read than the dentine and noted that all areas of the root should be observed in case there is damage to part of it. The best area of the cementum in which to observe the annuli is the lateral portion of the gum region of the tooth, called the boss (McEwan, 1963; Gilbert, 1966). Interpretation of the annuli deposited by the cementum is based upon the fact that during the autumn and winter the growth rate is slower and the layers laid down at these times are closer together, thus staining darker than those laid down during the summer. Therefore, the first summer season shows as a pale-staining zone next to the dentine-cementum interface. From this point the annuli can be counted, recording one for each year (Gilbert, 1966). Cementum deposition begins slightly before tooth eruption. Since the deer gets its permanent incisors at about 6 months, one can determine the age of the animal by counting the annuli present and adding 6 months. With this method animals can be aged to yearly classes (Laws, 1953; McEwan, 1963; Gilbert, 1966). Furthermore, by noting the different regions within the last annulus the age can be determined even more accurately (Laws, 1953; Keiss, 1969; McCutchen, 1969). The primary limitation of this method is that it is not a field technique. The teeth must be collected and time and the knowledge of microtechnique procedures are required. Another limitation is that in each area where it is to be used it must be checked against a series of known-age deer.

MATERIALS AND METHODS

Comparisons were made of aging techniques of white-tailed deer killed in southern Illinois during the 1968 hunting season. All deer were killed in Pope County on November 22, 23, 24, and December 6, 7, and 8, 1968.

Hunters were required to check all deer killed at one of three check stations in the county. At the check station each deer was given an accession number, aged by tooth replacement and wear (Severinghaus, 1949), sexed, and weighed. The lower mandible was collected from as many deer as possible; special attempts were made to obtain jaws from older deer. When the hunter would not permit a jaw to be removed from an older deer, he was asked to save the jaw and return it to me in a self-addressed, stamped envelope.

The jaws were removed from deer at the check station by two techniques. One method was to cut the muscles at the back of the mandible and along the gum line. The jaw was disarticulated by prying down on the front of the jaw; the posterior part of the jaw was grasped to pull the bone away from the skin. The other method of removal was to cut the mandible posterior to the last molar with a pair of long-handled pruning shears (Fig. 1). Then the anterior end was forced down and the jaw was removed as before. A card with the accession number of the deer was attached to the jaw with a rubberband. The accession number enabled data collected from the jaw to be correlated with the age and sex as determined at the check station.

The jaws were taken to the Department of Zoology, Eastern Illinois University, cleaned of all flesh, and the accession number was written on the jaw with India ink. Each clean jaw was aged in the laboratory by myself, my advisor, and another graduate student by the tooth replacement and wear method using reference material (Severinghaus, 1948, 1949, 1950; Schwartz and Schwartz, 1959).

The anterior portion of each jaw was cut off posterior to the last incisor and put into an envelope which was marked with the accession number. My advisor renumbered the envelopes and kept a list of the original accession number and the new number for each set of incisors. Renumbering was done to avoid possible bias when the incisors were aged by the tooth cementum technique.

The anterior part of the jaw, with the incisors, was decalcified in 30% formic acid for two days. The right first incisor was then cut away from the jaw with a single-edged razor blade taking care not to damage the root. The incisor was returned to the formic acid, and after two or three more days was placed in a saturated solution of lithium carbonate and 70% ethyl alcohol to neutralize the formic acid. The incisor was then dehydrated, infiltrated by immersion in paraffin, imbedded, sectioned at 10 microns, and stained following the procedure described by Low and Cowan (1963) with the exception that Harris' hematoxylin was used rather than Ehrlich's hematoxylin.

The remainder of the anterior part of the jaw, after the right first incisor was removed, was placed in a saturated solution of lithium carbonate and 70% ethyl alcohol to neutralize the formic acid. The jaw segments were then placed in 70% ethyl alcohol for storage in case they were needed later.

Stained sections of each incisor were examined with a dissecting microscope at 60X and 40X. The number of annuli in the cementum seen at each magnification was counted and recorded. Chi square analyses were made of comparisons of the age structure of the jaws collected using an I.B.M. 360 computer. The following comparisons were made:

1. All deer: tooth replacement and wear at check station versus tooth replacement and wear in laboratory.
2. Males: tooth replacement and wear at check station versus cementum at 60X.
3. Females: tooth replacement and wear at check station versus cementum at 60X.
4. Males: tooth replacement and wear at check station versus cementum at 40X.
5. Females: tooth replacement and wear at check station versus cementum at 40X.
6. Males: tooth replacement and wear in laboratory versus cementum at 60X.
7. Females: tooth replacement and wear in laboratory versus cementum at 60X.

8. Males: tooth replacement and wear in laboratory versus cementum at 40X.
9. Females: tooth replacement and wear in laboratory versus cementum at 40X.
10. Males: cementum at 60X versus cementum at 40X.
11. Females: cementum at 60X versus cementum at 40X.

RESULTS

Jaws were collected from 164 deer during the 1968 hunting season in Pope County, Illinois. One hundred and fifty-four jaws were collected at three check stations (Fig. 1) and 10 of 18 requested were returned by hunters through the mail.

All jaws were aged by check-station workers using the tooth replacement and wear technique. After returning to the laboratory the jaws were cleaned and aged again by the tooth replacement and wear technique using all available reference material. A comparison of this technique as used in the field and in the laboratory (Table 1) showed a high percentage of agreement for the younger age classes. The older age classes had less agreement. Eight deer were aged as 5½ years old in the laboratory, four of these were aged at the check station as 3½ years old. Four deer were aged at 6½ years in the laboratory; at the check station two were aged as 5½, one as 4½, and one as 3½ years old. All three deer aged at 7½ years in the laboratory were called 5½ years old at the check station. The one 8½ year old deer was called a 6½ year-old at the check station.

Analysis of the replacement and wear comparisons separately for males and females gave results similar to those found when the sexes were combined (Table 1). There was a high percentage of agreement for the younger age classes and very little agreement for the older age classes. The major points of difference were in ½, 2½, 3½, and 4½ year males. Fewer 2½ year old males were in agreement with the laboratory age while ½, 3½, and 4½ year-old males were in better agreement with the laboratory age than females.

A high percentage of the 3½ year-old females were aged one year younger and a low percentage were the same age by both methods. Females 5½ years old or older had no agreement for the same age class, but a high percentage of agreement for the one-year-younger and over-one-year-off categories.

The right first incisor was taken from each jaw, sectioned, stained, and examined microscopically for annuli in the dentine and cementum layers as shown in Figure 2. Cementum lines were more consistent than dentine lines. When no lines were present, both zones appeared as homogenous areas (Fig. 3). Many dentine lines were found in most of the teeth (Fig. 4). In about half of the teeth examined definite lines were observed in the cementum while traces of other lines could also be detected (Figs. 5 and 6). In other tooth sections cementum lines were not definite, but appeared only as darker zones in the cementum (Figs. 7 and 8). Many lines were noted at the root apex (Fig. 9), but these converged into fewer lines as one scanned upward along the tooth (Fig. 10) making it difficult to determine a specific number of lines for a given tooth.

Comparisons of laboratory aging by tooth replacement and wear and aging by annuli at 40X and 60X (Table 2) revealed variable agreement up to 5½ years. For the 5½ year age class at 40X, six of the eight deer aged were more than one year off of the laboratory

Fig. 1. Collecting a white-tailed deer jaw at the check station using long-handled pruning shears to cut the mandible at the joint.

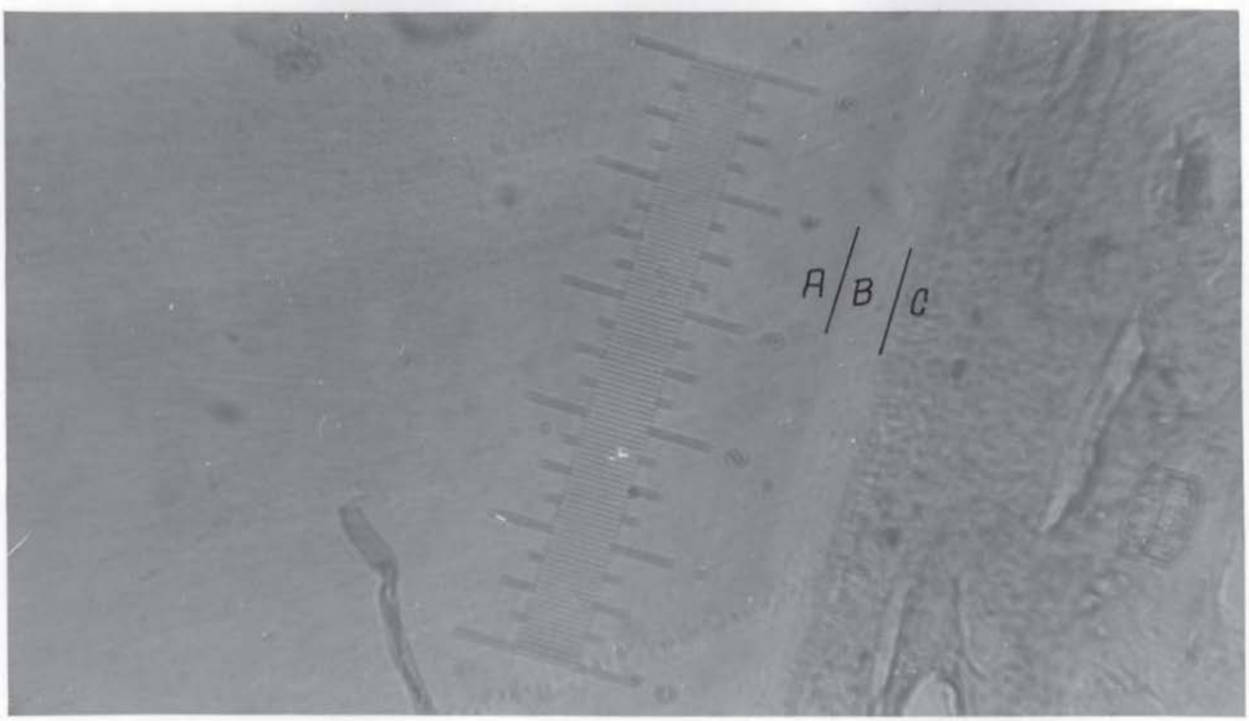

Fig. 2. Regions of a white-tailed deer incisor showing the dentine (A), cementum (B), and connective tissue (C).

Table 1. Comparisons of ages of white-tailed deer as determined by tooth replacement and wear at check station and in the laboratory.

Lab. Age	No. Jaws	Check Station Agreement			
		% Same Age	% 1 Year Older	% 1 Year Younger	% Over 1 Year Off
Sexes Combined					
½	28	93	4	0	3
1½	49	86	10	4	0
2½	30	67	20	7	6
3½	26	27	4	60	9
4½	15	60	0	33	7
5½	8	0	0	50	50
6½	4	0	0	50	50
7½	3	0	0	0	100
8½	1	0	0	0	100
Males					
½	19	90	10	0	0
1½	32	84	9	7	0
2½	5	40	20	0	40
3½	5	60	0	40	0
4½	2	100	0	0	0
5½	2	0	0	50	50
6½	0	-	-	-	-
7½	1	0	0	0	100
8½	0	-	-	-	-
Females					
½	9	67	22	0	11
1½	17	94	6	0	0
2½	25	68	12	8	4
3½	21	29	5	52	14
4½	13	62	0	31	7
5½	6	0	0	50	50
6½	4	0	0	50	50
7½	2	0	0	50	50
8½	1	0	0	0	100

age. Four of these were called 1½ years old and two were designated as 2½ years old. At 6½ years all four jaws were more than one year off of the laboratory age. Three of these were aged as 2½ years old and one was called a fawn. All of the 7½ year old laboratory-aged deer were also more than one year off as determined by annuli. All three were designated as 3½ year old deer. The 8½ year old deer was called 6½ years old by the annuli technique.

For the 5½ year age class, at 60X one deer was said to be a fawn, two were designated as 1½ years old, and three were called 2½ years old. At 6½ years the two deer that were not within one year of the laboratory age were called 1½ years old. The three deer that were more than one year off of the 7½ year age class were aged at 2½, 3½, and 5½ respectively. The 8½ year old deer was aged at 1½ years by the 60X cementum annuli technique.

To determine if sex influenced aging by causing alterations in cementum lines, the data were analyzed separately for each sex (Table 2). A high percentage of the jaws were aged one year older than the replacement and wear age for lower age groups, while most of the deer of 4½ years and older were more than one year off of the laboratory age. There was variable agreement among males up to the 4½ year age class. One male deer was aged at 4½ years in the laboratory, at 2½ years at 40X and 3½ years at 60X. Three males were aged at 5½ years in the laboratory. All three were called 1½ years old at 40X; at 60X one was called a 1½, one a 2½, and one a 6½ year old deer. The male determined to be 7½ years old in the laboratory was aged at 2½ years at 40X and 3½ years at 60X.

Fig. 3. Cross-section of a white-tailed deer incisor showing no annuli in the dentine or cementum.

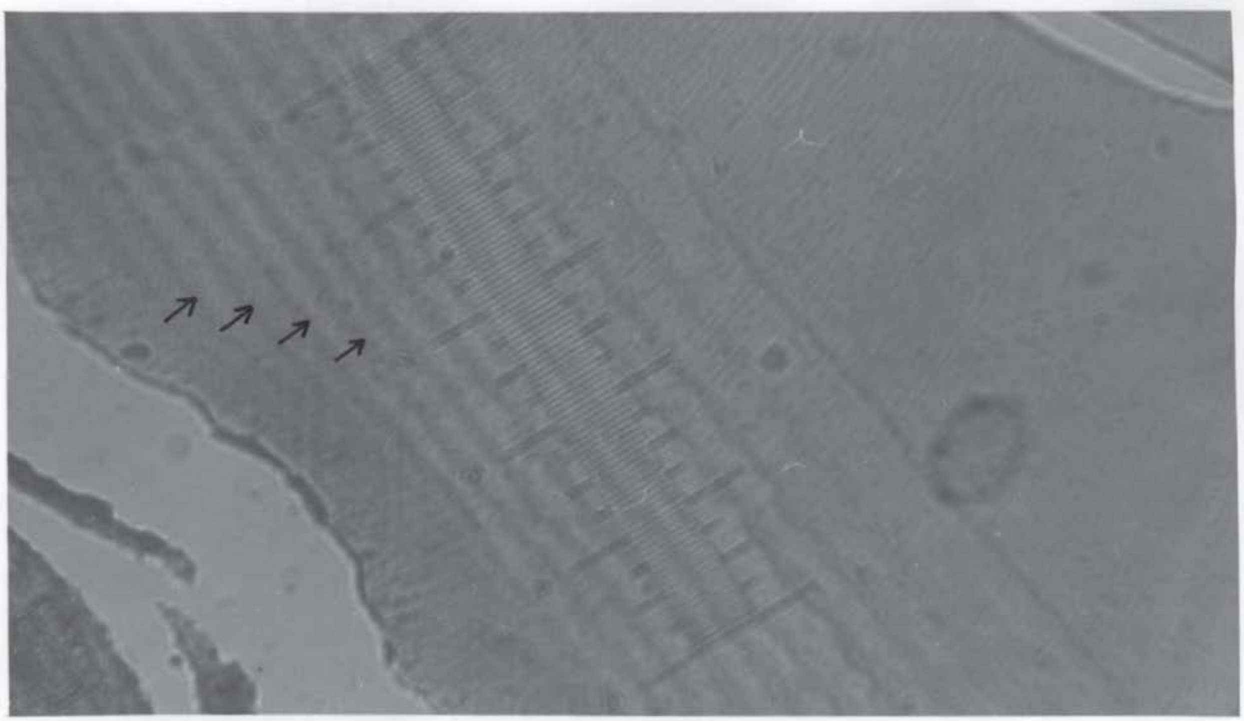

Fig. 4. Cross-section of a white-tailed deer incisor from jaw No. 117 showing 12 lines in the dentine. The cementum had 3 lines and the laboratory age by replacement and wear was 3½ years old.

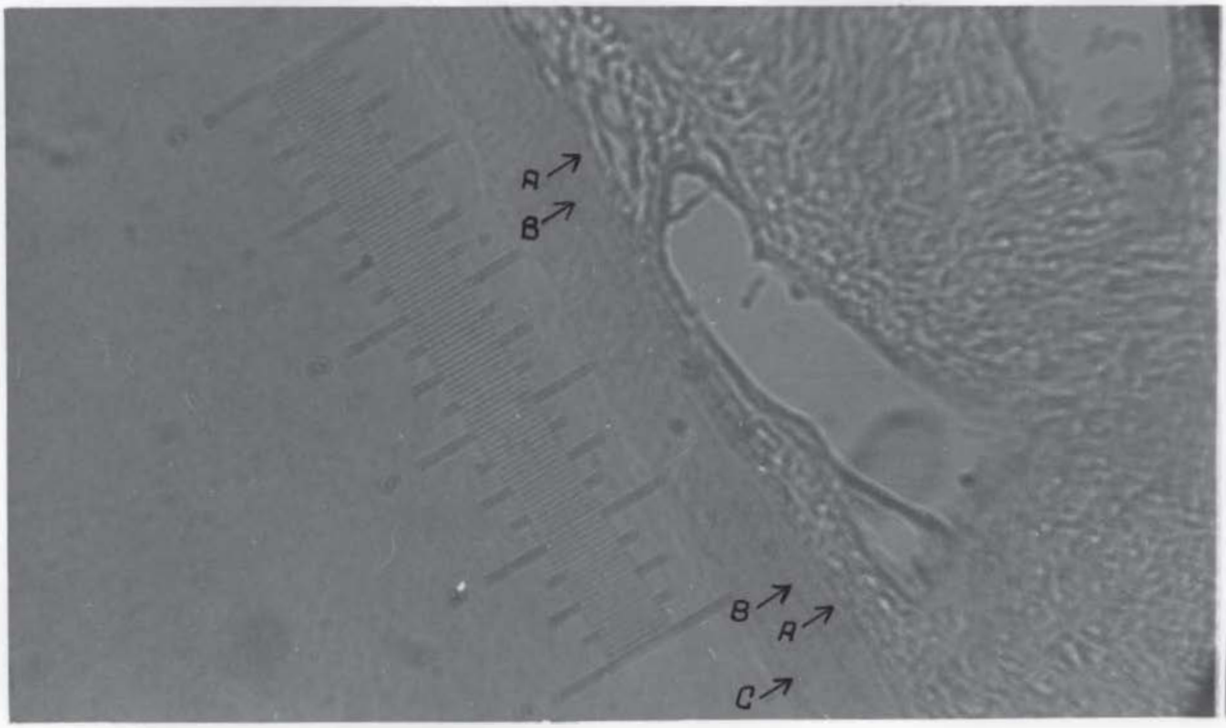

Fig. 5. Cross-section of a white-tailed deer incisor with one cementum annulus (A) and traces of other lines (B and C).

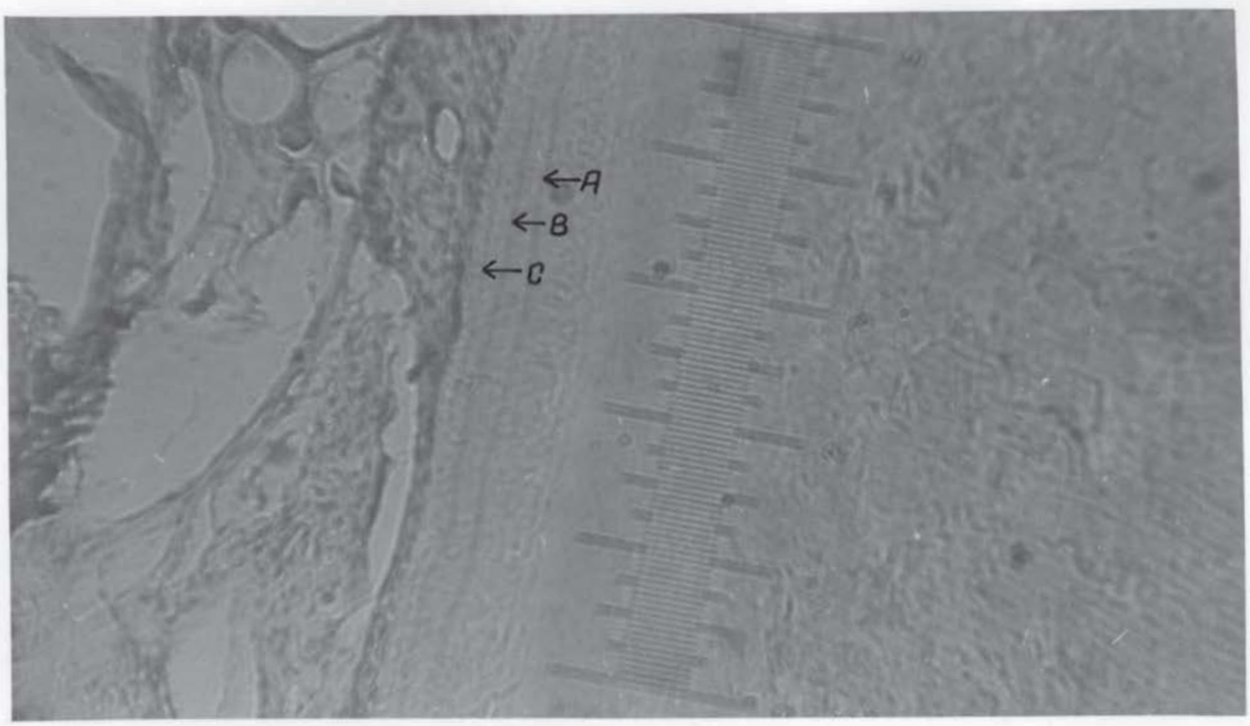

Fig. 6. Cross-section of a white-tailed deer incisor with two cementum annuli (A and B) and traces of a third line (C).

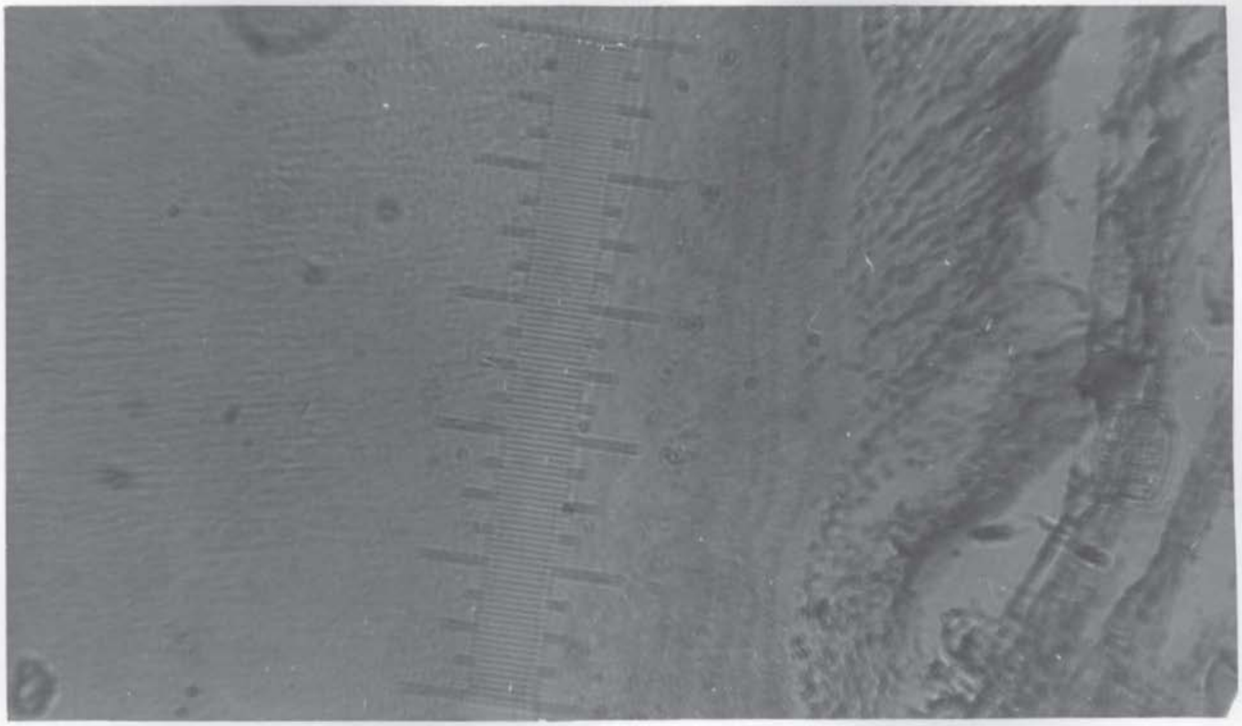

Fig. 7. Cross-section of a white-tailed deer incisor showing three cementum annuli appearing as zones rather than definite lines.

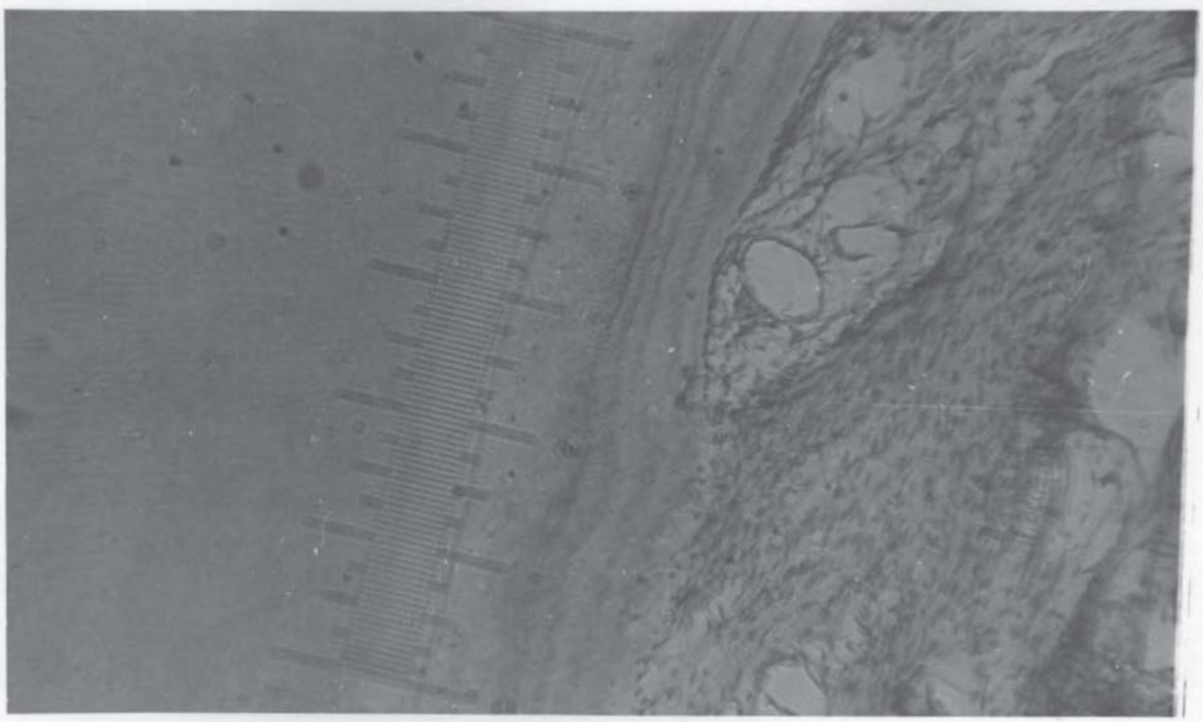

Fig. 8. Cross-section of a white-tailed deer incisor showing four cementum annuli diffusing into darker zones rather than lines.

Fig. 9. Cross-section of white-tailed deer incisor No. 55 showing many lines present near the root apex.

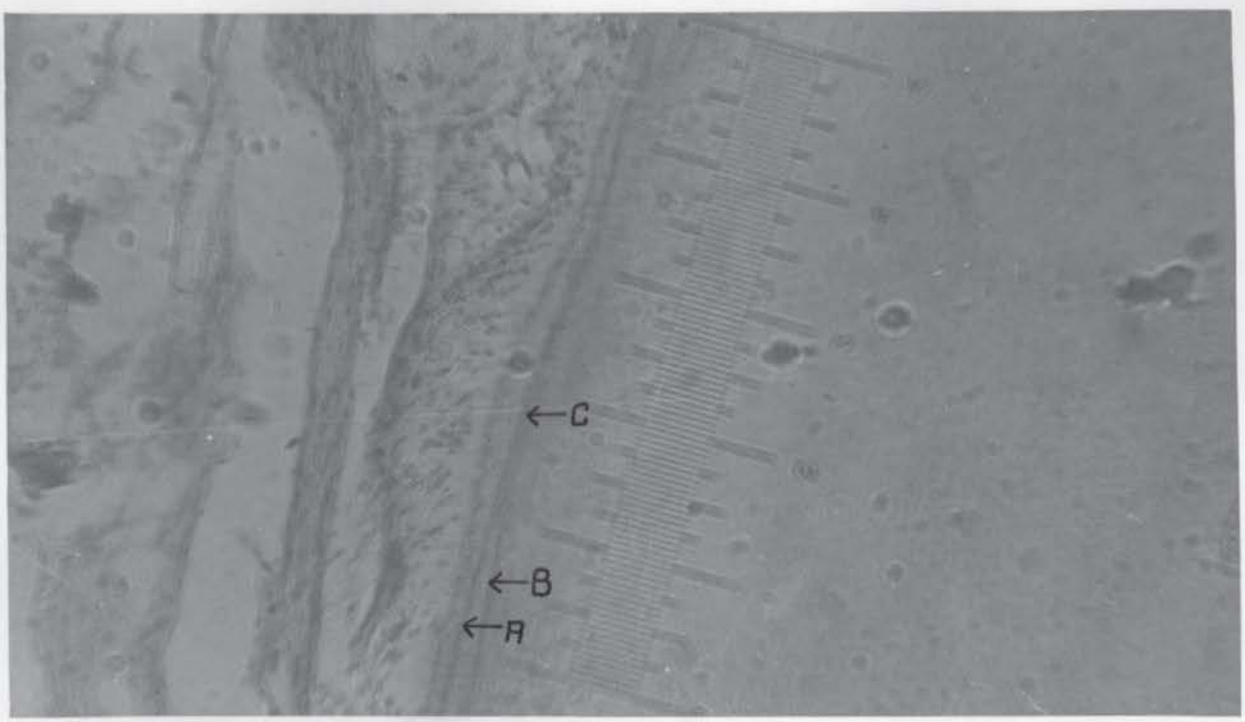

Fig. 10. Cross-section of white-tailed deer incisor No. 55 showing two cementum lines (A and B) converging into one line (C).

Table 2. Comparison of white-tailed deer jaws aged in the laboratory by tooth replacement and wear, and aged by counting cementum annuli in tooth sections.

Lab. Age	No. Jaws	40X % Same Age	40X % 1 Year Older	40X % 1 Year Younger	40X % Over 1 Year Off	60X % Same Age	60X % 1 Year Older	60X % 1 Year Younger	60X % Over 1 Year Off
Sexes Combined									
½	28	25	71	0	4	25	70	0	5
1½	49	31	65	4	0	38	58	2	2
2½	30	50	30	17	3	29	39	29	3
3½	26	23	4	50	23	29	3	48	20
4½	15	20	0	7	73	7	0	30	63
5½	8	8	13	13	74	0	13	0	87
6½	4	0	0	0	100	0	0	50	50
7½	3	0	0	0	100	0	0	0	100
8½	1	0	0	0	100	0	0	0	100
Males									
½	19 35	37	58	0	5	31	58	0	11
1½	32	28	69	3	0	41	56	3	0
2½	5	40	40	20	0	40	40	20	0
3½	5	40	0	40	20	40	0	40	20
4½	1	0	0	0	100	0	0	100	0
5½	3	0	0	0	100	0	33	0	67
6½	0	-	-	-	-	-	-	-	-
7½	1	0	0	0	100	0	0	0	100
8½	0	-	-	-	-	-	-	-	-
Females									
½	9	0	100	0	0	11	89	0	0
1½	17	36	59	5	0	29	65	0	6
2½	25	52	28	16	4	28	40	28	4
3½	21	19	5	52	24	24	5	47	24
4½	14	21	0	8	71	7	0	21	72
5½	5	0	20	20	60	0	0	0	100
6½	4	0	0	0	100	0	0	50	50
7½	2	0	0	0	100	0	0	0	100
8½	1	0	0	0	100	0	0	0	100

Females had similar agreement to males up to the 5½ year age class. Five females were called 5½ years old; three were more than one year off of this age as determined by annuli at 40X. One of these was called a 1½ year old and two were classed as 2½ years old. At 60X two 6½ year old deer were not within one year of the laboratory age, both were called 1½ year old deer. The two female deer that were aged at 7½ years in the laboratory were aged as 2½ years old at 40X; at 60X one was aged as 1½ years and the other at 5½ years. Only one 8½ year-old deer was collected as determined in the laboratory by the replacement and wear technique; at 40X this deer was aged as 6½ years old and as 1½ years old at 60X.

The relative accuracy of each aging method was determined by dividing the number of jaws aged in agreement with the laboratory replacement and wear ages, by the total number of jaws used in that group and multiplied by 100 (Table 3). For example, 66 male jaws were used in this study, 20 aged by cementum annuli at 40X agreed with the laboratory replacement and wear age:

$$\left(\frac{20}{66}\right) \times 100 = 30\%$$

Therefore, the relative accuracy for males aged by cementum annuli at 40X with no tolerance was 30% of the laboratory replacement and wear method.

The relative accuracy of check-station aging for both sexes combined was 34% more than 40X and 37% more than 60X. Males were aged at the check station with 47% more accuracy than males aged at 40X and with 43% more accuracy than males aged at 60X. An average based on these percentages showed that check-station aging was 36% more accurate then cementum annuli at 40X and 39% more accurate than cementum annuli at 60X.

If no error was accepted for the ½ and 1½ year age classes, and ±1 year tolerances for older deer was accepted (Table 3), check-station aging was 32% more accurate than cementum annuli at 40X for both sexes combined and 29% more accurate than cementum annuli at 60X. Allowing this limited tolerance for males alone, check-station deer were aged with 42% more accuracy than males aged by the cementum annuli method at 40X and 34% more accurate than those aged at 60X. Females showed similar results with check-station aging 29% more accurate than deer aged at both 40X and 60X. The average showed check-station aging to be 34% more accurate than 40X and 31% better than 60X.

If a three year range was tolerated for all age classes, the relative accuracies were closer together. For both sexes combined, check-station aging was only 4% more accurate than both 40X and 60X. Check-station male ages were 5% more accurate than 40X and 3% better than 60X. Females aged at the check station were 13% more accurate than those aged by cementum annuli at 40X and 14% better than those aged at 60X. The average showed check-station aging to be 7% better than the cementum annuli technique at either 40X or 60X.

The chi-square analysis indicated no significant difference between any of the comparisons.

Table 3. Comparisons of percent accuracies for aging white-tailed deer by tooth replacement and wear and by cementum annuli.

Degree of Tolerance				Percent Accuracy
No tolerance[1]	-check station		males and females	63
			males only	77
			females only	54
	-cementum annuli	-40X	males and females	29
			males only	30
			females only	27
	-cementum annuli	-60X	males and females	26
			males only	34
			females only	17
Limited tolerance[2]	-check station		males and females	79
			males only	83
			females only	82
	-cementum annuli	-40X	males and females	47
			males only	41
			females only	53
	-cementum annuli	-60X	males and females	50
			males only	49
			females only	53
Three year tolerance[3]	-check station		males and females	84
			males only	94
			females only	87
	-cementum annuli	-40X	males and females	80
			males only	89
			females only	74
	-cementum annuli	-60X	males and females	80
			males only	91
			females only	73

[1]Accepting no error.

[2]Accepting no error for ½, and 1½ year olds and a three-year range for older deer.

[3]Accepting a three-yeer range for all age classes.

DISCUSSION

This study was a comparison of the tooth replacement and wear and the cementum annuli methods of aging southern Illinois white-tailed deer. All available jaws were not collected; a special effort was made to collect jaws from older deer, therefore, the sample used for this study was not an indication of the age structure of the deer population. Likewise this study did not determine the validity of any of the age techniques used since no known-age deer were available. The comparisons were made to determine the agreement of the cementum annuli technique and the replacement and wear technique.

The replacement and wear technique is now the best available method of aging white-tailed deer in the field. The accuracy of this technique has been shown to be inversely proportional to the age of the deer (Severinghaus, 1949, 1950). Agreement between check-station aging and laboratory aging in this study was likewise inversely related to age in that there was close agreement among younger deer and progressively less agreement as older deer were aged. Check-station aging in this study may have been more accurate than usual since the workers were aware that the jaws would be aged later in the laboratory. This fact may have encouraged them to use more care than usual when aging. In addition, since the jaws were removed, the workers had a better opportunity to examine tooth wear than under usual conditions.

Table 1 concurs with and verifies the work of Severinghaus (1949, 1950), Flyger (1958), Barnes and Longhurst (1960), and Ryel et al. (1961), showing the disagreement involved in the replacement and wear technique. A perfect aging method would yield identical results regardless of who did the aging. The accuracy of the replacement and wear technique was limited by human variability and interpretation and carelessness of the check station worker. Table 1 also shows that older deer were more difficult to age. A relative accuracy of 93% was found for aging fawns. There was no agreement for the 7½ and 8½ year age classes; 100% were more than one year off the laboratory age.

There should have been no reason for misaging a fawn because of the distinct characteristics to be noted on the jaw, such as a third premolar with three sharp, distinct cusps, only two molars instead of three as in older age classes, the generally smaller dimensions of the incisors, the amount of stain on the teeth, the lack of wear on the teeth, and the size of the jaw itself. The carelessness of the workers, which gave rise to the 7% error, may have been caused by rushing to get the work done, fatigue, boredom, or lack of interest.

An additional source of error in aging deer by replacement and wear at check stations was that all jaws were not exactly ½, 1½, 2½, etc. years of age. Several jaws in the 1½ year age class were obviously intermediate between ½ and 1½ or 1½ and 2½ years. These deer were either very early fawns of that year which would have made them closer to one year old, or very late fawns of the previous year which would have made them closer to two years in actual age. If not killed, these variations would carry on to following years and become increasingly difficult to age. Check stations were staffed with college students who had been trained and tested with a collection of typical age jaws.

A tendency yielding error or variability in aging older deer in the field was to over age deer up to the 3½ year class and to under age the 3½ and older deer assuming the laboratory age was more accurate than the check station age. This analysis was, however, restricted by the limited number of older age jaws available. Sixteen jaws to represent four age groups could not provide sufficient data from which to draw accurate conclusions.

Separating the jaws into male and female categories for aging by the replacement and wear method indicated that one sex was no easier to age than the other. Random variation in accuracy was exhibited (Table 1). Lack of agreement for the 5½ year old and older age classes was due to inadequate sample numbers. If more jaws for the older age groups had been available a percentage would probably have been derived even if it was low.

A close correlation between field aging and laboratory aging was expected since both were based upon identical characteristics. Ideally this study should have used known-age jaws. This study was also limited by the number of jaws available; it would have been better to collect jaws over a longer period of time, say ten years, and of the many collected, use only those which were undisputable for each age class. The accuracy of the replacement and wear technique as done in the laboratory would be increased, thus giving a sounder basis upon which standards and comparisons could be set. More readily comprehendible results might have been obtained if the same number of jaws was used for each age class. Comparisons between different age classes would then be more meaningful and all percentages would be based upon an equal number of samples for each age class.

Several problems were encountered in preparing and aging the incisors by the cementum annuli technique. The incisor had to be removed carefully in order to avoid damage to the cementum thus destroying the annuli. Some of the teeth were difficult to section due to incomplete decalcification. The teeth were worked up in groups of 10 and the largest tooth of the group was tested for complete decalcification. When this tooth showed no positive test for calcium it was assumed that the smaller teeth were also decalcified completely. Apparently some teeth contained a higher density of calcium than others and size was not necessarily a factor regarding the amount of calcium present. To avoid this problem each tooth should have been tested for calcium.

Interpretation of the sections was sometimes difficult. There was no apparent correlation between dentine lines and cementum lines. The dentine of most of the teeth had many dark-staining lines varying in number, but without relation to age. A tooth which read 2½ years old by cementum lines may have had ten lines appearing in the dentine. Another tooth reading 2½ by cementum annuli might have had only seven or eight dentine lines. A different staining technique might have brought out other dentine features which could have been usable for age determination.

The number of lines in the cementum varied with the area examined. The cementum at the neck of the tooth had few or no lines while at the root apex many lines were present. The cementum lines converged from the numerous layers at the apex into fewer, but darker lines at the neck. The most accurate reading was found in the boss region of the tooth (McEwan, 1963; Gilbert, 1966), that is, the lateral portion of the gum region where the cementum lines had converged to form annuli. All slides were examined several times before they were placed in age classes.

The magnification used to locate cementum annuli also influenced the ages (Table 2). In general more lines, i.e., older age, were seen at a magnification of 40X. At 40X the closest agreement between replacement and wear and cementum annuli was at 2½ years. At 60X the closest agreement was at 1½ years. If one accepted a tolerance of one year either way, a three year range, the acceptable percentage was much higher. Using a three year range, however, also increased the acceptable percentage of the check station aging. Younger deer must be aged with more accuracy than older deer because the younger animals have a potentially longer effect upon the herd condition. Aging criteria are better at these age classes, therefore there should be no aging error for the younger age classes.

If no tolerance was permitted for the ½ and 1½ year classes and the three year range permitted for the remaining classes, the replacement and wear technique was significantly more accurate than the cementum annuli technique. This was contrary to the findings of Laws (1958) using crabeater seals Lobodon carcinophagus jacquinot and L.C. pucheran, Hewer (1960) working with seals, McEwan (1963) using barren ground caribou, Keiss (1969) with elk, and McCutchen (1969) working with pronghorns. These workers found the cementum annuli technique to be at least as accurate as previous dental aging techniques. Sergeant and Pimlott (1959), working with moose incisors, said the cementum annuli technique was good, but that a range of ±1-2 years must be used. Tolerating a three-year range, as in this study, made the cementum annuli method of aging white-tailed deer comparable in accuracy to the tooth replacement and wear technique now used.

The value of the cementum annuli technique in age determination for Illinois white-tailed deer depends upon the accuracy necessary for the particular study. If an approximate number of deer per age class is required, this method will suffice because it gives the wildlife biologist the necessary accuracy to manage a deer population. However, if the age of an individual animal is required, this method does not have the necessary validity. This study indicates that the replacement and wear technique is at least as accurate as the cementum annuli method for Illinois white-tailed deer.

SUMMARY

Jaws were collected from 164 white-tailed deer during the 1968 hunting season in Pope County, Illinois. The jaws were aged at the check station using Severinghaus' replacement and wear technique; they were brought back to the laboratory at Eastern Illinois University, cleaned, and re-aged by the replacement and wear method. The right first incisor was removed from each jaw, decalcified, sectioned, stained, and observed microscopically at 40X and 60X magnifications. Layers were counted in the dentine and cementum in an effort to place the teeth into yearly age classes. Comparisons were made of check station aging versus laboratory aging, laboratory aging versus 40X magnification, and laboratory aging versus 60X magnification.

Laboratory aging, deemed the most accurate of the four methods, was used as the standard. No correlation was noted between dentine and cementum layers. The cementum was easier to read and was thus used for this study. Relative accuracies were calculated for the three remaining aging techniques allowing three degrees of tolerance. The relative accuracy was calculated using the following formula:

$$\text{Relative accuracy} = \frac{\text{No. jaws in agreement with laboratory age}}{\text{Total no. jaws used in the group}} \times 100$$

The degrees of tolerance allowed were: no tolerance for any age class; no tolerance for the ½ and 1½ year age classes, and ±1 year for older

age classes; and ± 1 year for all age classes. To determine if sex influenced aging by causing alterations in cementum lines, the data were analyzed separately for each sex.

Check station aging had the highest relative accuracy in all cases. When no tolerance was accepted it averaged 36% higher than 40X and 39% higher than 60X. For the limited tolerance category it averaged 34% better than 40X and 31% better than 60X. When the three year range was accepted, check station aging averaged only 7% better than both 40X and 60X.

The cementum annuli technique for aging Illinois white-tailed deer was not valid for aging an individual animal, but, accepting the three year range, it did provide the necessary accuracy for the game biologist to manage a deer population.

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