Development of a Field Technique for Sexing and Aging Marten

Final Report

by

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Introduction

In recent years, the annual harvest of martens in Alaska has been between 20,000 and 40,000 animals per year. At present, marten hides are sealed only in southeast Alaska, so very limited data are available on the sex or the ages of the animals harvested. In Canada, sex and age ratios of trapped marten are viewed as useful management tools for adjusting marten trapping seasons and bag limits (Strickland and Douglas 1987). Strickland and Douglas (1987) stated that the difference in trapping vulnerability between the various sex and age classes are reflected in harvest sex and age ratios and that these ratios can be used to monitor harvest intensity. They suggest that the proportion of juvenile to adult females and the ratio of males to females are the most useful indices of marten population status and harvest pressure.

Currently, the most accurate method of aging martens appears to be tooth cementum analysis (Strickland and Douglas 1987). Radiography has proved to be useful in identifying juvenile martens (Dix and Strickland 1986). Both methods require that marten teeth be pulled and processed in a laboratory. With the number of marten that are trapped in Alaska annually, radiography and tooth cementum analysis for determining harvest sex and age ratios would be prohibitively expensive and time consuming. Our objective in this study was to develop a field technique for determining marten sex and age ratios that would eliminate the need for laboratory analysis. We recognized that the technique would have to be inexpensive, easily and consistently applied, and accurate within an acceptable margin of error.

Marshall (1951) recognized the need for a "readily observable" age determination method for marten. At the time of his study, cementum ages were not available. His approach was to take a series of measurements of marten carcasses and analyze them with respect to frequency distribution of occurrence. The bimodal curves which resulted led Marshall to conclude that martens could be aged as mature or immature based on sagittal crest development. Males with sagittal crest <20mm were immature; females with no sagittal crest were immature.

Whitman (1978) carried out a similar study on aging marten. He concluded that males with saggital crests <30mm were young animals and that females did not form sagittal crests until they were older than yearlings. Whitman did not have cementum ages available to verify his conclusions. Johnson (1981), using sagittal crests and body weights, concluded that marten could be separated into 2 age classes, young-of-the-year and 3+ years. He could not separate yearlings and 2-year-old animals and did not verify his results using cementum ages.

Whitman (1978) also analyzed skull measurements as a means of sexing marten and concluded that skull length was the best single measurement for discriminating between male and female skulls.

In the 1980's, researchers began to compare cementum age with marten skull morphology. Brown (1983) concluded that zygomatic skull width and postorbital constriction showed the greatest correlation with age. Marshall (1951) had rejected these 2 measurements because they had only poorly defined bimodal curves, were difficult to make, and required careful cleaning of the skull.

Giannico (1986) examined geographic and sexual variation in marten from the Pacific Northwest with a focus of subspeciation and sexual dimorphism. He concluded that marten from the Northwest Territories and southeastern Alaska showed remarkable similarities. He agreed with Brown (1983) that size was the main difference between the 2 sexes with males averaging larger than females in most skull measurements.

We chose to examine marten skulls as the basis for a field technique because previous research had indicated that sexing marten by skull measurements, particularly skull length, was possible, and aging marten, at least into juvenile, yearling, and adult age classes might be possible using measurements associated with cranial development. We chose to examine temporal muscle development as a means of aging marten because it was the most variable and readily measured characteristic of uncleaned marten skulls and had been shown to increase with age (Marshall 1951, Whitman 1978, Johnson 1981, Brown 1983). Length of temporal muscle coalescence approximates length of sagittal crest.

Methods

The study was conducted in interior Alaska using 327 female and 303 male marten skulls collected from a trapper near McGrath over a 3-year period (1983-85) and 83 female and 135 male marten skulls collected from a number of trappers in and adjacent to the Gates of the Arctic National Park (GAAR) during 1987-88. GAAR is approximately 600 km northeast of McGrath. For the development of an aging technique, we used 127 of the female skulls from McGrath and all the skulls from GAAR. For the sexing technique, we used all the skulls for which we could obtain skull lengths (408 females, 438 males).

The female skulls from the McGrath area were arranged subjectively in order of increasing temporal muscle development (Fig. 1). A systematic sample of these skulls was taken by selecting every fourth skull (Sample 1). A canine was pulled from each skull for age analysis based on tooth cementum annuli.

Teeth were placed in a commercial decalcifying solution (10% HCL and chelating agents, American Scientific Products, McGaw Park, IL) approximately 7-10 hours. Crowns were removed from the teeth. The decalcifying solution was leached out by soaking in tap water (which was changed 3-4 times) for a minimum of 24 hours. Roots were sectioned using an IEC cryostat. Sections were 28 mm in thickness. The sections were then stained using a modified Harris' hematoxylin hot staining method originally developed in this laboratory and outlined in Goodwin and Ballard (1985). Dark staining cementum lines (annuli) were counted under a binocular dissecting microscope at 50x power. Slides that were difficult to interpret were viewed at higher magnification under a compound microscope.

A visual comparison between the cementum age of a skull and its position in the continuum of temporal muscle development suggested that there was a relationship between age and temporal muscle development, but that a better "fit" was possible if the skulls were rearranged according to the length of temporal muscle coalescence (MUSLGTH) (Fig. 2). This measurement is roughly equivalent to sagittal crest length (SAGLGTH) (Fig. 2). Sagittal crest lengths were no more than 4 mm, and usually less than 3 mm, longer than MUSLGTH. Five measurements (Figs. 1 and 2) were made on all the skulls: total length of the skull (TSKLGTH), sagittal crest length, length of temporal muscle coalescence, width between the temporal muscles at the narrowest point if the muscles had not coalesced (NARWID), and width between the temporal muscles at the point where zygomatic width is measured if the muscles had not coalesced at this point (MIDWID). Widths between the temporal muscles were measured in order to rank those skulls in which coalescence had not occurred and to rank skulls with the same MUSLGTH.

We analyzed Sample 1 to statistically test for a relationship between MUSLGTH and cementum age (CEMAGE). We used Sample 1 as a predictor of age distribution in 2 other samples of female skulls. Sample 2 comprised 48 additional female skulls from the McGrath collection drawn in the same manner as Sample 1, except that we eliminated most skulls in the MUSLGTH = 0 category because our initial sample showed very little variation in this category and we wanted to increase our sample of older-aged marten. A canine was used for cementum age analysis as described above. Sample 3 was the 83 GAAR female marten. All GAAR marten were aged using radiography and tooth sectioning of canine teeth by Matson's Lab, Milltown, Montana and cementum annuli counts by the authors.

Due to time and money constraints, CEMAGE was available for the GAAR males only. Therefore, our statistical analysis of the males was limited to a test for linear correlation between CEMAGE and MUSLGTH for this sample. Because we were interested in determining if the lengthening of temporal muscle coalescence anteriorly could be used to determine age in males, we used MUSLGTH rather than SAGLGTH. Posterior extension of the sagittal crest did not occur before the males were at least 1-year-old. Furthermore, there was no relationship of the posterior extension of the sagittal crest and cementum age.

The statistical tests used in the following analysis of the data included simple linear correlations, the Chi-square goodness of fit test (χ^2), the Kolmogoroff-Smirnoff 2-sample test (K-S), the normalized Mann-Whitney test (M-W), and the Median test (Norusis 1984).

Results

Age of Female Marten

There was a significant linear correlation ($P < 0.05$) between CEMAGE and MUSLGTH in Samples 1 and 3. No correlation could be shown for Sample 2 even though it was drawn from the same population as Sample 1 after excluding skulls in MUSLGTH = 0. It was obvious from an examination of Figures 3-5 that the exact age of marten could not be determined using MUSLGTH except for MUSLGTH = 0 (juvenile marten). Using MUSLGTH = 0, there was only a 4% and 3% error (Samples 1 and 3, respectively) in identifying juveniles and those incorrectly identified as juveniles were all yearlings. However, some juvenile martens were missed using MUSLGTH = 0 (12% in Sample 1 and 2% in Sample 3).

After eliminating skulls with MUSLGTH = 0, we again tested for a linear correlation between CEMAGE and MUSLGTH and found that, in Samples 1 and 3, CEMAGE and MUSLGTH were significantly correlated but in Sample 2, they were not.

We then ran statistical tests to determine if the marten could be separated into 3 age classes (0, 1, and 2+) corresponding to juvenile, yearling, and adult, respectively, using MUSLGTH. The following cut-off points for the different age classes based on MUSLGTH were established after examining Sample 1 (Figure 3):

Muscle Group 0 (juvenile) - MUSLGTH = 0

Muscle Group 1 (yearling) - MUSLGTH = 1-10 mm

Muscle Group 2 (adult) - MUSLGTH = 11+ mm

Data in Table 1 indicate that Muscle Group 0 and, to a lesser extent, Muscle Group 2, gave a fairly accurate estimate of the age classes of female marten in those Groups, but that Muscle Group 1 was inadequate for predicting the yearling age class. When we tested for differences between Muscle Groups within each Sample, we found a significant difference ($\underline{P} < 0.05$) for Sample 1 (K-S, M-W, and Median tests), Sample 2 (K-S and M-W tests), and Sample 3 (K-S, M-W, and Median tests) indicating that the Muscle Group classification did tend to separate the skulls into different age classes (Table 1). The only nonsignificant test result was for the K-S test in Sample 3 between Muscle Groups 1 and 2. Sample size was small in Muscle Group 1 (n = 6) which could have influenced the results.

Next, we tested to see if there was a difference in the distribution of ages in each of the Muscle Groups between Samples 1, 2, and 3. For Muscle Group 0, we could compare only Sample 1 and 3 (only 1 skull occurred in Muscle Group O for Sample 2). The results (Table 2) indicate no significant differences in the distribution of age classes within Muscle Groups. Admittedly, sample sizes are small and the statistical tests are not particularly powerful for detecting differences. Ideally, larger samples should be analyzed before final conclusions are drawn.

Finally, we were interested in determining how well the percentages of age classes in each Muscle Group in Sample 1 predicted accurate age class structure in Samples 2 and 3. The percentage of each age class (0, 1, and 2+, respectively) in each Muscle Group in Sample 1 were the following:

Muscle Group 0 = 95.8%, 4.2%, and 0.0%, respectively

Muscle Group 1 = 28.6%, 38.1%, and 33.3%, respectively

Muscle Group 2 = 0.0%, 0.0%, and 100.0%, respectively

In Sample 2, the Muscle Group counts were 1, 17, and 27. The Sample 1 percentages would generate an expected age class distribution of 5.8, 6.5, and 32.7. The actual empirical age class distribution was 3, 15, and 27. A chi-square goodness of fit test between these 2 distributions yields a test statistic of 4.781 ($0.05 < \underline{P} < 0.10$) which is indicative of a poor fit. This result was surprising because Samples 1 and 2 were drawn in the same manner from the same population.

In Sample 3, our Muscle Group counts were 60, 5, and 19. The Sample 1 percentages would generate an expected age class distribution of 58.9, 4.4, and 20.7. The actual empirical age class distribution was 58, 5, and 21. A chi-square goodness of fit test between these 2 distributions yields a test statistic of 0.045 which is indicative of a good fit.

MUSLGTH measurements were most effective in identifying juvenile female marten. Of 112 juvenile females identified by radiography or cementum analysis, 103 (92%) were aged correctly by MUSLGTH = 0 mm. Only 52 of

69 (75%) adult females (2+ years) were identified using MUSLGTH = 11+ mm. Most of the remaining juveniles and all the remaining adults fell within the MUSLGTH = 1-10 mm group. The majority of yearlings (81%) fell within this group as well, but because there was so much overlap with juveniles and adults, the percent error in identifying yearlings using MUSLGTH measurements is much higher than for juveniles and adults (Table 3).

Age of Male Marten

CEMAGE and MUSLGTH were correlated for males (Fig. 6), but the overlap in ages once the animals were at least 1 year of age precluded the use of MUSLGTH to differentiate between the age classes. Based on radiography of canine teeth, male marten with no temporal muscle coalescence were invariably juveniles and no yearling males were encountered until MUSLGTH >33mm. Male marten falling within the 1-33mm range made up 6% of GAAR males. No 0-age animals occurred for MUSLGTH >33mm.

We questioned the accuracy of radiography in detecting juveniles in the 1-33mm range, so we determined the cementum age of 3 animals at the upper end of this range (1 with MUSLGTH = 30mm caught in March; 2 with MUSLGTH = 33mm caught in April) using canine teeth. All 3 marten had 1 newly formed cementum annuli indicating that they were actually yearlings or well-developed juveniles. Strickland and Douglas (1987) stated that the first cementum annulus is usually not visible until June, but we consider it possible that rapidly developing juveniles could show a cementum annulus by March. To remain consistent, however, we considered these 3 animals to be yearlings based on their cementum age. Only 3% of the 135 male skulls from GAAR had MUSLGTH of 1-29mm. Of the 303 male skulls from the McGrath collection, only 6% had MUSLGTH of 1-29mm.

Sex Determination

TSKLGTH was measured on 408 female marten skulls and 438 male marten skulls. The cementum ages of 51% of the females and 19% of the males were known and included all age classes (juvenile, yearling, and adult). Frequency distributions of TSKLGTH (Figures 7 and 8) shows that most male skulls fall in the 84-87mm range ($\bar{x}$ = 85.797) and most female skulls in the 77-79mm range ($\bar{x}$ = 78.047). The area of overlap between male and female skulls was the 80-83mm range. In this range there were 41 male skulls and 66 female skulls or 12.6% of all the skulls. However, within this overlap area, most of the male skulls (92.7%) were $>$81mm; most of the female skulls (95.4%) were $<$82mm. If all marten skulls $\leq$81mm were classified as females and all skulls $\geq$82 mm were classified as males, then, for this sample of 846 skulls, only 6 skulls (0.7%) would have been classified as the wrong sex.

Mean TSKLGTH for males and females were also calculated separately for the McGrath collection and the GAAR collection to determine if there were geographic differences in the 2 samples. Mean TSKLGTH for males and females were not statistically different between the 2 areas. However, the 6 skulls that would have been classified as the wrong sex using the cut-off points stated above were all from the McGrath collection. The 3 females that fell within the male range were 0, 2, and 6 years old. The female with the longest skull measurement was a juvenile. The ages of the 3 males that fell within the female range were not known.

Discussion

Age Determination

MUSLGTH is correlated with CEMAGE in female marten and can be used to separate female marten into age classes, but the usefulness of this measurement for aging female marten appears to be limited to the juvenile and adult age classes in which we had a 92% and 75% success in identification, respectively. The variability and percentage error in the yearling age class preclude the use of MUSLGTH as a predictor of age for yearling females.

To identify the yearling females and the remainder of the adult and juvenile females, cementum ages would have to be determined for the female skulls in the MUSLGTH = 1-10 mm range. When cementum analysis is not possible due to time or money constraints, females in Muscle Groups 1 and 2 can be combined and considered to be all adults. The resulting juvenile to adult female ratio would be biased toward adults and would result in an error on the conservative side for management purposes (Strickland and Douglas 1987).

As the proportion of females in Muscle Group 1 increases in relation to Muscle Group 2, cementum ages should be obtained for Muscle Group 1. A large number of juveniles and yearlings in Muscle Group 1 would result in a juvenile:adult female ratio considerably lower than the actual age ratio of the harvest and could lead to an incorrect assessment of reproductive success and unnecessary restrictions on subsequent harvests. Until additional research is conducted, we cannot determine what proportion of females should occur in Muscle Group 1 before cementum analysis must be carried out on this Muscle Group. Only 7% of the GAAR females were in Muscle Group 1 compared with 23% in Muscle Group 2. The age ratio of juveniles to females ≥1.5 years (i.e., combining Muscle Groups 1 and 2) was 4.8:1. The actual juvenile to females ≥1.5 years was 5.2:1.

The percent error (Table 3) in identifying adult females in the MUSLGTH = 11+ mm range also results in an age ratio that is lower than the actual ratio of the trapped population, but, again, this would be an error on the conservative side. However, some upper limit to the allowable percentage error in identifying adult females should be established and additional samples of female marten skulls examined for CEMAGE vs. MUSLGTH to determine what the maximum error might be.

If female skulls in the MUSLGTH = 1-10 mm range are analyzed for cementum ages before deriving an age ratio for the harvest, there would probably be less than a 10% error in assigning correct age classes to the harvest. In this study the percent error in assigning age classes would have been 2% (Sample 1, n = 82), 13% (Sample 2, n = 45), and 4% (Sample 3, n = 83). A combination of Samples 1 and 2, which came from the same population, would have given an error of 6%. Age ratios derived from harvests with a 90% accuracy in aging would probably be acceptable for most management purposes.

Though we had only 1 sample of male skulls, we see a pattern for males similar to that of females. The majority of juvenile males could be identified using MUSLGTH = 0; 7% of the juvenile males were missed. Most of the remaining juvenile males were in the MUSLGTH = 1-29 mm range. By assigning a higher cut-off point for juvenile males, a larger proportion of juveniles might be identified.

A better cut-off point for juvenile males will probably occur at or about 20mm. The absence of trapped male marten with MUSLGTH (or sagittal crest lengths) in the 12-23 mm range has been repeatedly demonstrated (Marshall 1951, Brown 1983, this study) and can probably be explained by the coalescence of temporal muscles that occur in the marten's second summer when trapping does not occur. Small samples of trapped marten (n $\leq$ 100) may show an even larger gap in MUSLGTH measurements (Whitman 1978) due to the small number of male marten in the 1-30 mm range.

The variability in ages for males with MUSLGTH >0 indicates that MUSLGTH would not be useful for differentiating between yearling and adult males. However, if our objective is to arrive at a juvenile:adult female ratio, it would not be necessary to identify any but juvenile males.

Brown (1983), in his thorough study of sex and age variation in skull measurements for marten in Ontario, concluded that sagittal crest length (SAGLGTH), while generally increasing with age, was not correlated with age. Of all measurements which he examined, Brown (1983) found that zygomatic skull width (ZYGO) and postorbital construction width (POCD) were best correlated with age for male and female marten. ZYGO increased with age, leveling off at 3 years, and POCD decreased with age, continuing to decrease linearly with increasing age. However, an examination of Brown's (1983) data indicated that the overlap in ZYGO and POCD for the 3 age classes was at least as great as the overlap in MUSLGTH in this study. A combination of MUSLGTH and ZYGO may be of some use in reducing the amount of error in aging marten, but, because zygomatic width is related to sagittal crest development, we do not believe the use of ZYGO will significantly improve the aging technique. POCD is of no use because it cannot be measured on uncleaned skulls.

Using MUSLGTH = 0 as an indicator of juvenile marten is at least as accurate as radiography. In a separate study, 416 marten teeth (male and female) from the Nowitna National Wildlife Refuge (northcentral Alaska) were examined by radiography (Matson's Laboratory, Milltown, Montana) and then tooth cementum ages (canines; Matson's Lab) were determined for all those not identified as juveniles and on approximately 50% of those that were identified as juveniles using radiography. Matson's radiography correctly identified 84% of the juveniles as compared with 92% in our lab using MUSLGTH = 0. Matson's Lab did not differentiate between males and females for the radiography and this could have influenced their success rate (Nagorsen et al., in press). There was a 3% error in the juvenile classification by radiography as compared with 2% using MUSLGTH = 0 (Magoun, pers. obs.). If additional information can be obtained on MUSLGTH vs. CEMAGE in male marten in the 1-29mm range, the use of our technique may identify as many as 97% of juveniles.

Our success rate in using MUSLGTH measurements to age marten was comparable to that of other studies using radiography (Nagorsen et al., in press; Dix and Strickland 1986). The lowest percentage of juveniles aged correctly using radiography was 80.0% for male marten from the Queen Charlotte Islands in British Columbia (Nagorsen et al., in press); the highest percentage was 98.6% for female marten from the Algonquin Region in Ontario (Dix and Strickland 1986). Our success rate using MUSLGTH was 91.9% for females and 92.6% for males. The lowest percentage of adults (i.e., 1+ years) aged correctly by radiography was 90.0% for male marten from the Alexander Archipelago in Alaska (Nagorsen et al., in press) and the highest percentage was 100% for males from Vancouver Island in British Columbia (Nagorsen et al., in press), the Algonquin Region in Ontario (Dix and Strickland 1986), and GAAR (this study). Our success rate for identifying adult (1+ years) females was 95.9%. Nagorsen et al. (in press) pointed out that Dix and Strickland's (1986) high success rate may have been influenced by the short collection period of their sample (Nov-Dec vs Nov-Mar).

Sex Determination

TSKLGTH shows considerable promise as an indicator of sex for marten skulls based on the results of this and other studies. Brown (1983) concluded that marten skull length approaches adult size during the first year of life. Brown (1983) found that the difference in average basilar skull length (Brown 1983) and average greatest skull length (Fig. 2) between males and females in each of 4 age groups (0, 1, 2, and 3+) were statistically significant ($\underline{P} > 0.001$). Unfortunately, Brown

(1983) did not compare all males with all females. His data indicate that there was some overlap in skull lengths between males and females, but the degree of overlap cannot be determined from the data presented in Brown (1983). Juvenile skulls of the same sex appear to be somewhat shorter on average than those of older marten of that sex (Brown 1983; Magoun, pers. obs.), but this size difference had little or no effect on sexing marten by TSKLGTH in this study.

Measurements of condylobasal skull lengths (Giannico 1986) for martens in the Pacific Northwest further supports the use of skull length as an indication of sex for marten. Giannico (1986) measured marten skulls from 5 areas in the Pacific Northwest and his data show no overlap between male and female skull lengths in 4 of the 5 areas. Some overlap was found for marten from the southern coast of British Columbia but the degree of overlap cannot be determined from the data presented in Gianncio (1986).

Whitman (1978) measured 83 marten skulls (40 males, 43 females) from Idaho and concluded that, of 9 cranial measurements, greatest skull length (Fig. 2) was the best single measurement for discriminating between males and females. He correctly categorized 95% of the males and 93% of the females using 79mm as the cut-off point between males and females.

The skulls in this study were measured before they were cleaned; skull length in the other studies were measured on clean, dried skulls which probably gives somewhat shorter lengths.

Feasibility of the Field Technique

A field technique for sexing and aging marten to obtain juvenile:adult female ratios and male:female ratios appears feasible for the majority of harvested martens. The difficulty in aging female skulls in the MUSLGTH = 1-10mm range necessitates cementum analysis for a portion of the harvest. In the GAAR collection, only 7% of the female skulls were in the 1-10mm range, but in the McGrath collection, 26% of the female skulls were in this range. If, in addition, male skulls in the MUSLGTH = 1-29mm range were also aged by cementum analysis, then 13% of the combined GAAR-McGrath collections would need cementum ages to determine the sex and age ratios desired. For the sample of 345 marten for which we had cementum ages in this study, our field technique would have correctly sexed and aged 85% of the marten and incorrectly sexed or aged 4%; the remaining 11% would have required tooth cementum analysis.

The sex ratio and a rough estimate of the age ratio of a harvest could be determined using our field technique without waiting for laboratory results. Fine-tuning the age ratio could be done after cementum analysis. Use of our field technique could eliminate the need to pull teeth on 85% or more of harvested marten. The savings in time and money would be considerable. Factors which increase the percentage of marten in the yearling age class would increase the percentage of marten that would have to be aged by cementum analysis.

A juvenile:adult female age ratio would not require laboratory analysis if all yearling females (MUSLGTH = 1-10 mm) were considered "adults."

Because the success rate in identifying juveniles and "adults" (i.e., $\geq$1.5 years) using our field technique is more than 92% and most of the incorrectly aged marten would be juveniles that fall within the adult category, the age ratio that resulted would be a conservative estimate (Strickland and Douglas 1987).

Conclusions

1. Total skull length (lamdoidal crest to posterior surface of the incisors) can be used to differentiate between male and female marten. For martens from interior Alaska, uncleaned skulls with total lengths $\leq$81mm should be classified as females, those with skull $\geq$82mm should be classified as males. The percent error will probably be <1%.

2. Length of temporal muscle coalescence (MUSLGTH) can be used to correctly categorize most harvested martens into the juvenile (0 cementum annuli) or adult (2+ cementum annuli) age classes.

3. MUSLGTH for yearling (1 cementum annuli) marten considerably overlaps that of some juveniles and adults; therefore, yearlings cannot be aged using this field technique. Until additional research is conducted, female marten in the MUSLGTH = 1-10 mm range and male marten in the MUSLGTH = 1-29 mm range must be aged by cementum analysis.

4. Female and male marten with MUSLGTH = 0 are juveniles (2% error). Female marten with MUSLGTH >10mm are adults (12% error). Male marten with MUSLGTH >29mm are at least 1 year old (0% error).

5. Separation of juvenile marten from other age classes using MUSLGTH = 0 is at least as effective as radiography.

6. A cut-off point for juvenile male marten of MUSLGTH <20 mm may increase the percentage of juvenile males that can be identified using the field technique.

Recommendations

1. A larger sample of male marten in the MUSLGTH = 1-29mm range and female marten in the MUSLGTH = 1-10mm range should be analyzed for MUSLGTH vs. CEMAGE. Additional skull characteristics, including zygomatic width, should be examined to devise a technique for identifying juveniles, yearlings, and adults in these MUSLGTH categories.

2. Additional analysis of female skulls in the MUSLGTH = 11+ mm range should be carried out to determine the range in percent error in identifying adult females.

3. The percent error in using the field technique should be determined by testing a number of biologists and trappers on their ability to use the technique after a brief training period.

4. Continued testing of the technique should be carried out by taking more samples of marten skulls from various areas within interior Alaska, under different trapping intensities and with different reproductive rates.

5. The results of this study should be considered preliminary and applicable to marten from interior Alaska only.

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Table 1. Statistical tests[a] to determine if there is a significant difference ($P < 0.05$) in the distribution of age classes for the Muscle Groups[b] in 3 samples of female marten skulls from interior Alaska.

Age classes	0	1	2+	Total		K-S	M-W	M
Sample 1								
Muscle Group 0	46	2	0	48	A[c]	.000	.000	.000
Muscle Group 1	6	8	7	21	B	.002	.000	-[d]
Muscle Group 2	0	0	13	13	C	.000	.000	.000
Sample 2								
Muscle Group 1	0	11	6	17	B	.046	.015	-[d]
Muscle Group 2	2	4	21	27				
Sample 3								
Muscle Group 0	57	2	0	59	A	.002	.000	.000
Muscle Group 1	1	2	3	6	B	.321	.009	-[d]
Muscle Group 2	0	1	18	19	C	.000	.000	.000

[a] Kolmogoroff-Smirnoff (K-S), normalized Mann-Whitney (M-W), Median (M).

[b] Muscle Groups based on length of temporal muscle coalescence (MUSLGTH).

Muscle Group 0 - MUSLGTH = 0 mm
Muscle Group 1 - MUSLGTH = 1-10 mm
Muscle Group 2 - MUSLGTH = 11+ mm

[c] Muscle Group 0 vs. Muscle Group 1 = A, Muscle Group 1 vs. Muscle Group 2 = B, Muscle Group 0 vs. Muscle Group 2 = C.

[d] Not calculated.

Table 2. Statistical tests[a] to determine if the distribution of age classes within Muscle Groups[b] is the same for 3 samples of female marten skulls from interior Alaska.

	Age classes 0	1	2+	Total	χ^2	K-S	M-W	M
Muscle Group 0 (MUSLGTH = 0)								
Sample 1	46	2	0	48	n.s.	n.s.	n.s.	n.s.
Sample 3	57	2	0	59				
Muscle Group 1 (MUSLGTH = 1-10 mm)								
Sample 1	6	8	7	21	n.s.	n.s.	n.s.	n.s.
Sample 2	0	11	6	17				
Sample 1	6	8	7	21	n.s.	n.s.	n.s.	n.s.
Sample 3	1	2	3	6				
Sample 2	0	11	6	17	n.s.	n.s.	n.s.	n.s.
Sample 3	1	2	3	6				
Muscle Group 2 (MUSLGTH = 11+ mm)								
Sample 1	0	0	13	13	n.s.	n.s.	n.s.	-[d]
Sample 2	2	4	21	27				
Sample 1	0	0	13	13	-[d]	n.s.	n.s.	-[d]
Sample 3	0	1	18	19				
Sample 2	2	4	21	27	n.s.	n.s.	n.s.	n.s.
Sample 3	0	1	18	19				

[a] Chi-square (χ^2) Kolmogoroff-Smirnoff (K-S), normalized Mann-Whitney (M-W), Median (M).

[b] Muscle Groups based on length of temporal muscle coalescence (MUSLGTH).

[c] $\underline{P} < 0.05$ considered significant; n.s. = not significant.

[d] Not calculated.

Table 3. Mean and median cementum ages (CEMAGE) of female marten in 3 Muscle Groups based on length of temporal muscle coalescence (MUSLGTH) and the percentage error in predicting cementum age from MUSLGTH.

Sample	n	Mean CEMAGE	Median CEMAGE	Range	% error
Muscle Group 0 (MUSLGTH = 0)					
1	48	0	0	0 - 1	4
2	1	0	0	0	-
3	58	0	0	0 - 1	3
Muscle Group 1 (MUSLGTH = 1-10 mm)					
1	20	1.1	1	0 - 2	62
2	17	1.6	1	1 - 4	35
3	6	1.8	2	0 - 3	60
Muscle Group 2 (MUSLGTH = 11+ mm)					
1	13	3.8	3	2 - 7	0[a]
2	27	2.6	2	0 - 7	22[a]
3	19	3.3	3	1 - 7	5[a]

[a] The combined percentage error of Sample 1 and 2 drawn from the same population is 15%; the combined percentage error of all 3 samples is 12%.

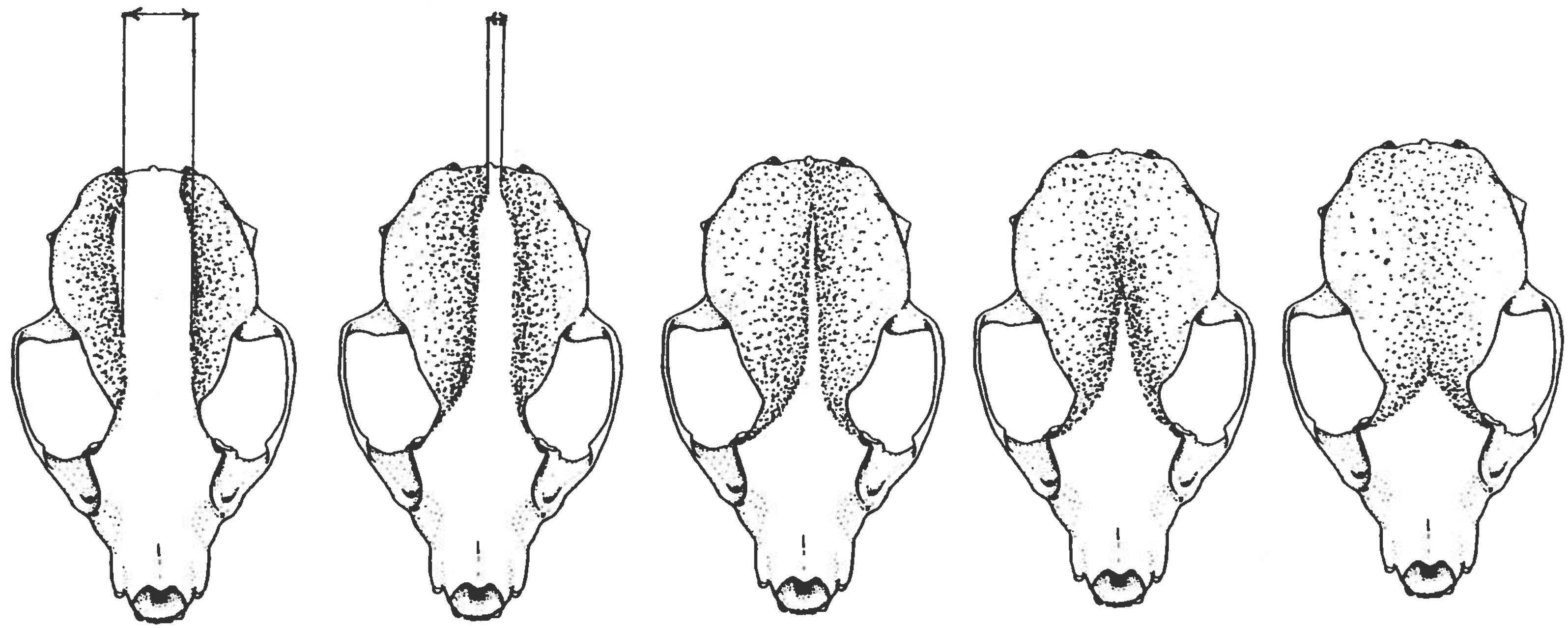


Figure 1. Variations in the degree of temporal muscle coalescence in marten skulls. Measurement A is the width between the temporal muscles at the greatest zygomatic width (MIDWID); measurement B is the width between the temporal muscles at the narrowest point if the muscles had not coalesced (NARWID). (Drawing of the marten skull was taken from Mammalian Species No. 289, The American Society of Mammalogists, specimen from private collection of Tim Clark, drawn by Denise Casey.)

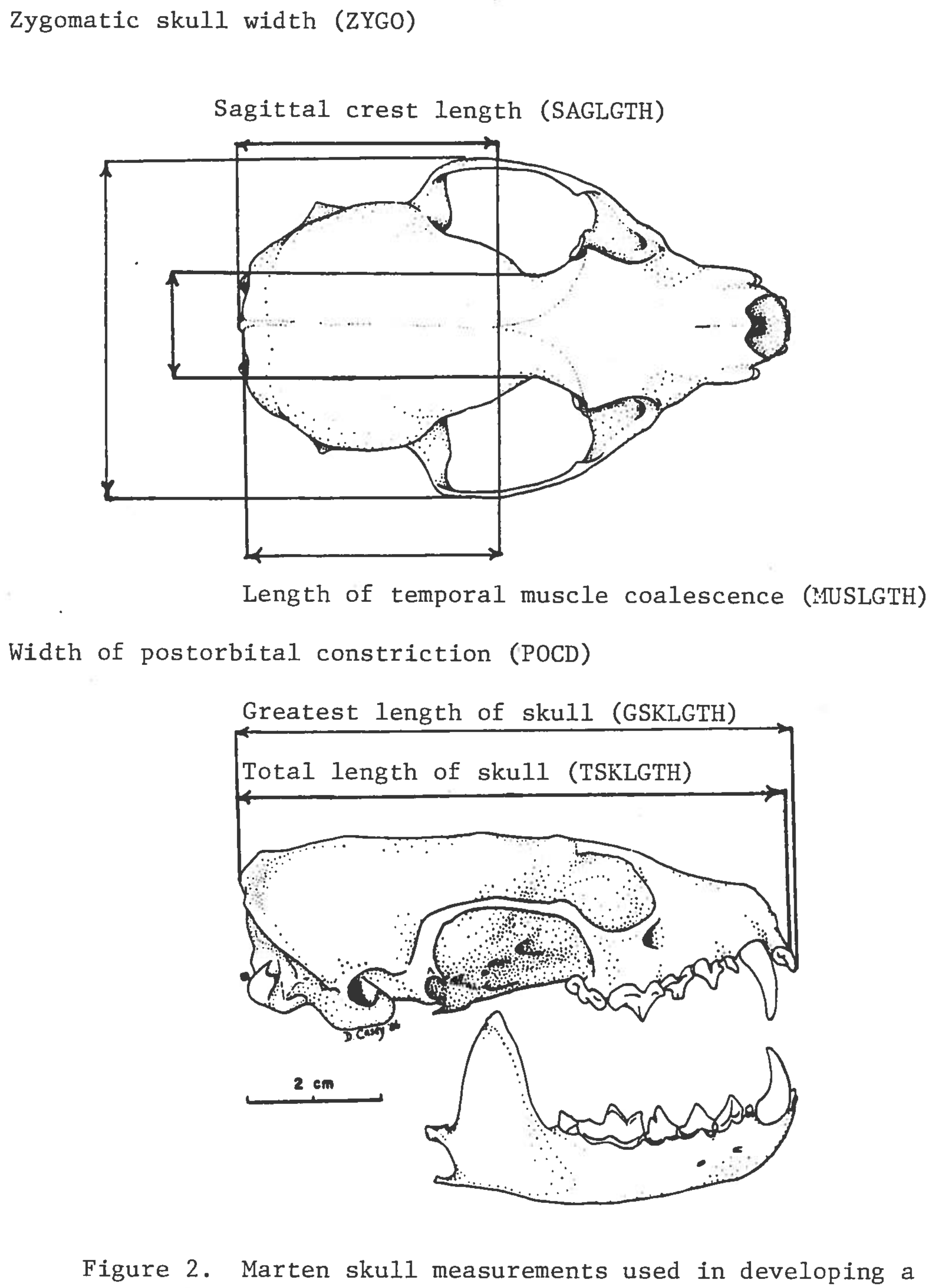
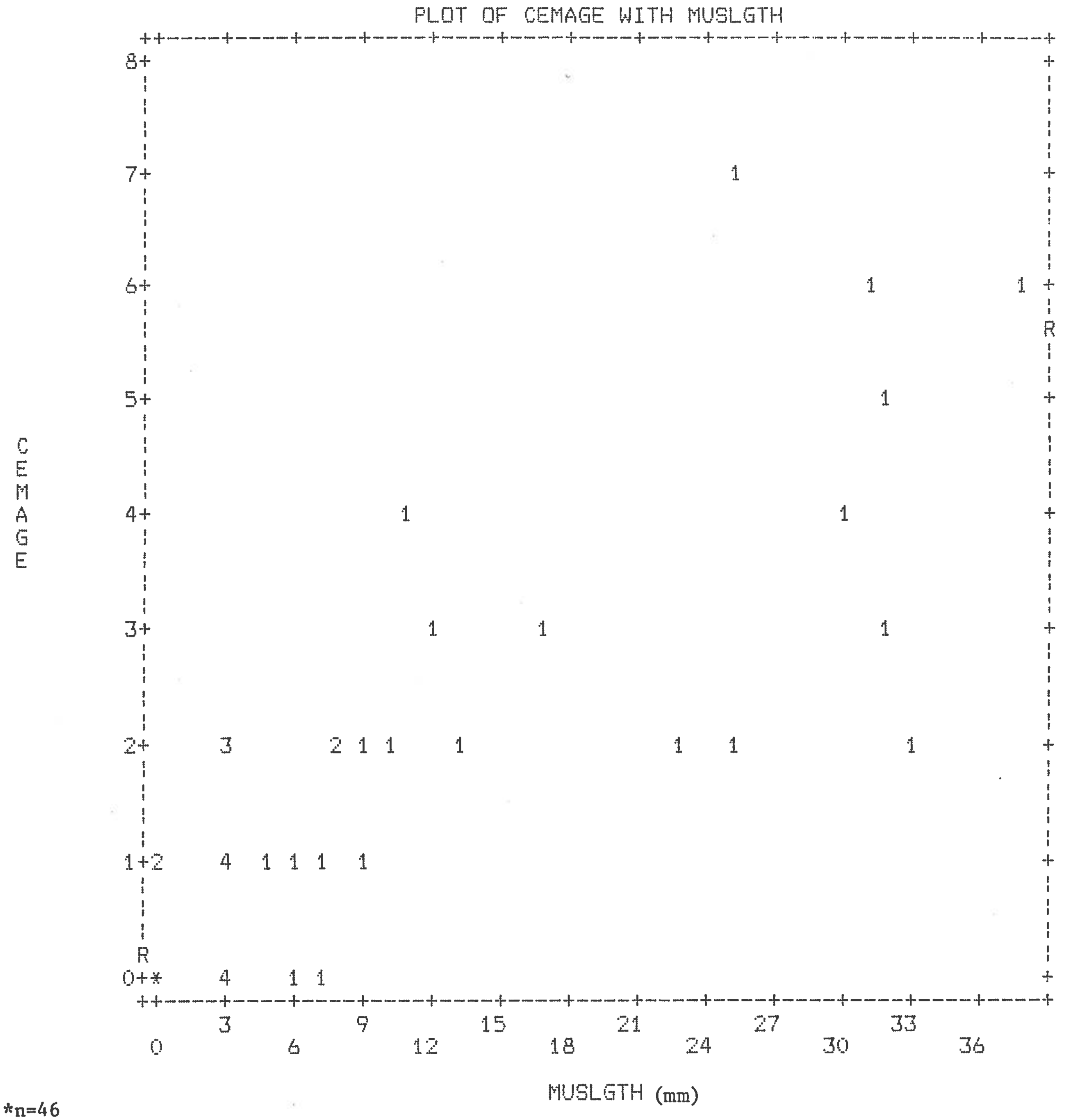


Figure 2. Marten skull measurements used in developing a technique for sexing and aging. (Drawing of the marten skull was taken from Mammalian Species No. 289, The American Society of Mammalogists, specimen from private collection of Tim Clark, drawn by Denise Casey.)

Prelim Anal - marten skull aging 8/25/88
Sample 1



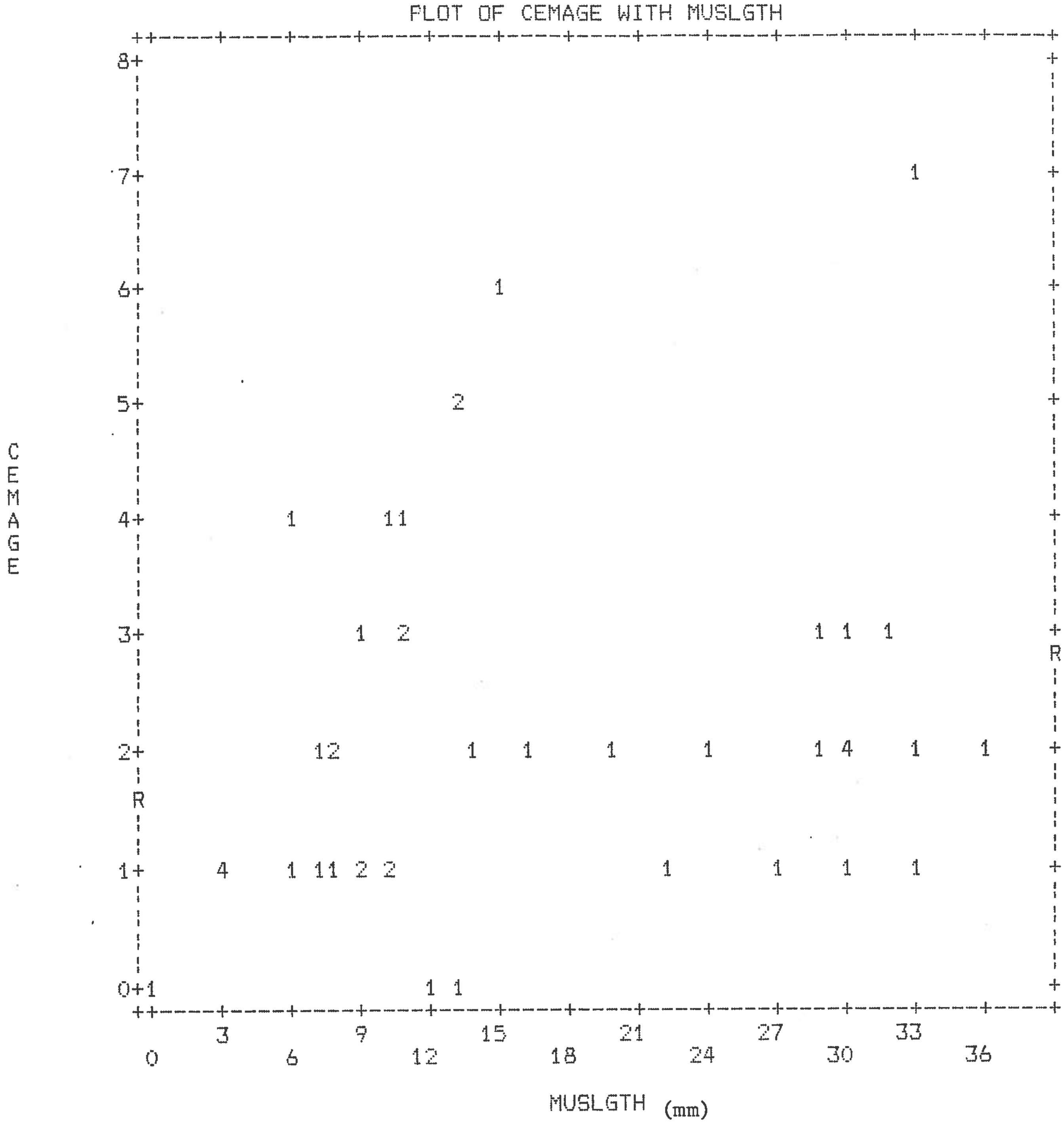
*n=46

82 cases plotted. Regression statistics of CEMAGE on MUSLGTH:
Correlation .85968 R Squared .73904 S.E. of Est .79552 Sig. .0000
Intercept(S.E.) .15897(.10039) Slope(S.E.) .13945(.00926)

Figure 3. Linear regression of cementum age (CEMAGE) on length of temporal muscle coalescence (MUSLGTH) for Sample 1 female martens from interior Alaska.

Prelim Anal - marten skull aging 8/25/88

Sample 2

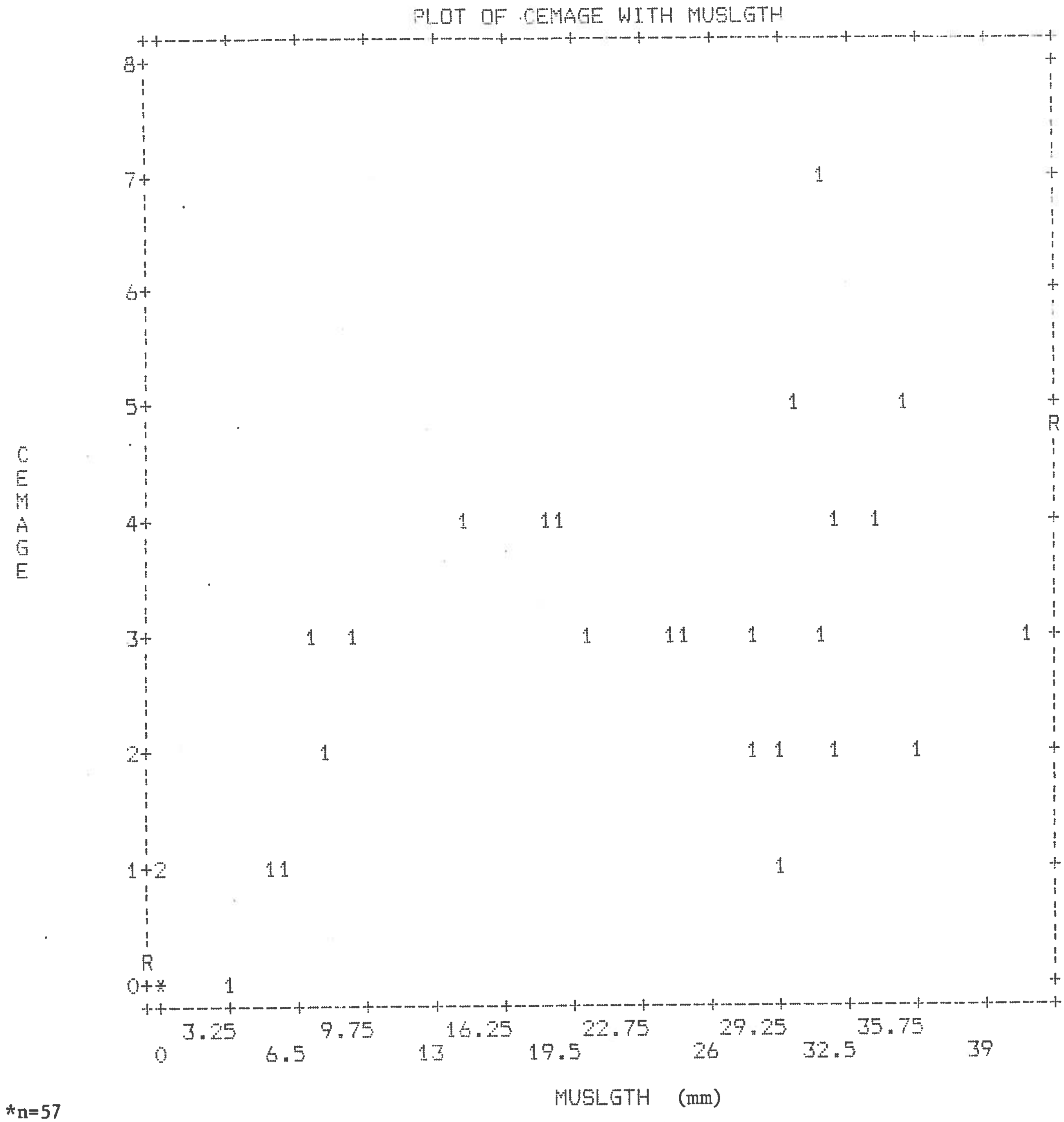


45 cases plotted. Regression statistics of CEMAGE on MUSLGTH:
Correlation .20153 R Squared .04061 S.E. of Est 1.51741 Sig. .1843
Intercept(S.E.) 1.65916(.41796) Slope(S.E.) .02860(.02120)

Figure 4. Linear regression of cementum age (CEMAGE) on length of temporal muscle coalescence (MUSLGTH) for Sample 2 female martens from interior Alaska.

Prelim Anal - marten skull aging 8/25/88

Sample 3

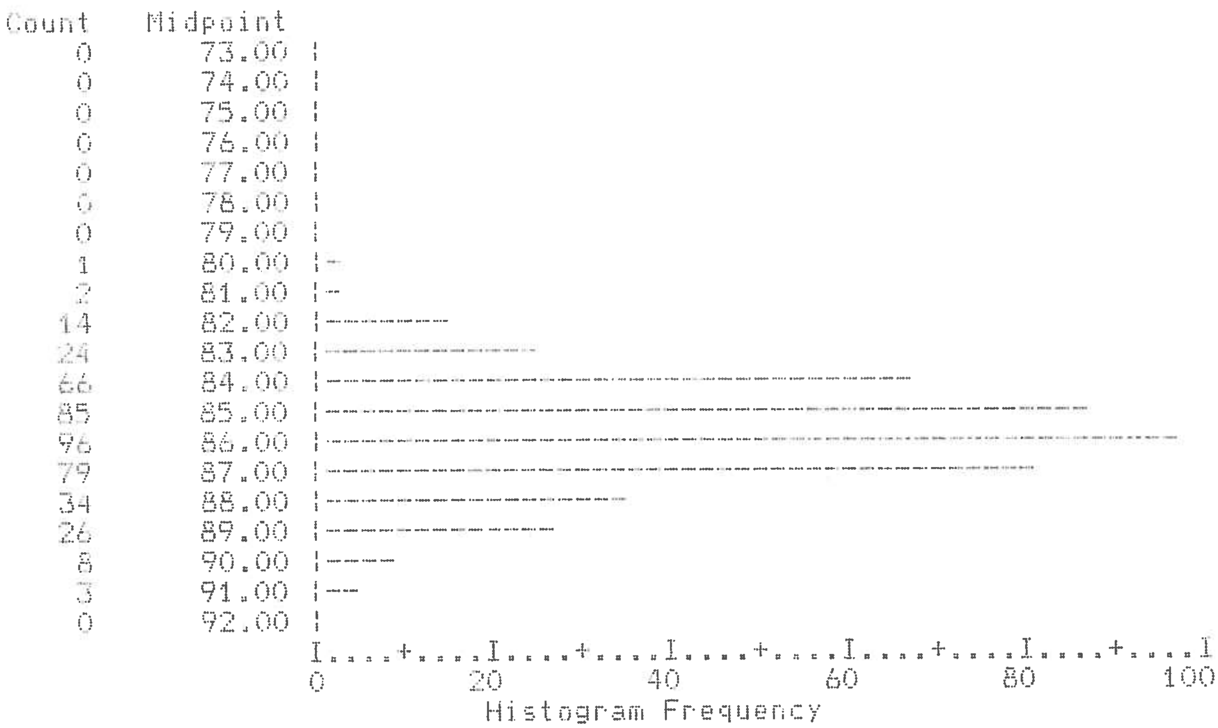


84 cases plotted. Regression statistics of CEMAGE on MUSLGTH:
Correlation .84655 R Squared .71665 S.E. of Est .84624 Sig. .0000
Intercept(S.E.) .15394(.10603) Slope(S.E.) .10988(.00763)

Figure 5. Linear regression of cementum age (CEMAGE) on length of temporal muscle coalescence (MUSLGTH) for Sample 3 female martens from interior Alaska.

ALL MALES 9/8/88

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	80	1	.2	.2	.2
	81	2	.5	.5	.7
	82	14	3.2	3.2	3.9
	83	24	5.5	5.5	9.4
	84	66	15.1	15.1	24.4
	85	85	19.4	19.4	43.8
	86	96	21.9	21.9	65.8
	87	79	18.0	18.0	83.8
	88	34	7.8	7.8	91.6
	89	26	5.9	5.9	97.5
	90	8	1.8	1.8	99.3
	91	3	.7	.7	100.0
	TOTAL	438	100.0	100.0	



Mean	85.797	Std Err	.089	Median	86.000
Mode	86.000	Std Dev	1.858	Variance	3.453
Kurtosis	.032	S E Kurt	.233	Skewness	.086
S E Skew	.117	Range	11.000	Minimum	80.000
Maximum	91.000	Sum	37579.000		

Valid Cases 438 Missing Cases 0

Figure 6. Frequency distribution of total skull length for male marten skulls collected in interior Alaska.

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	74	4	1.0	1.0	1.0
	75	12	2.9	2.9	3.9
	76	43	10.5	10.5	14.5
	77	86	21.1	21.1	35.5
	78	111	27.2	27.2	62.7
	79	86	21.1	21.1	83.8
	80	45	11.0	11.0	94.9
	81	18	4.4	4.4	99.3
	82	2	.5	.5	99.8
	83	1	.2	.2	100.0
	TOTAL	408	100.0	100.0	

```
Count   Midpoint
  0      73.00 |
  4      74.00 |-
 12      75.00 |---
 43      76.00 |-----------
 86      77.00 |----------------------
111      78.00 |----------------------------
 86      79.00 |----------------------
 45      80.00 |-----------
 18      81.00 |-----
  2      82.00 |-
  1      83.00 |
  0      84.00 |
  0      85.00 |
  0      86.00 |
  0      87.00 |
  0      88.00 |
  0      89.00 |
  0      90.00 |
  0      91.00 |
  0      92.00 |
               I....+....I....+....I....+....I....+....I....+....I
               0         40        80        120       160       200
                          Histogram Frequency
```

Mean	78.047	Std Err	.074	Median	78.000
Mode	78.000	Std Dev	1.499	Variance	2.246
Kurtosis	.018	S E Kurt	.241	Skewness	.035
S E Skew	.121	Range	9.000	Minimum	74.000
Maximum	83.000	Sum	31843.000		

Valid Cases 408 Missing Cases 0

Figure 7. Frequency distribution of total skull length for female marten skulls collected in interior Alaska.

ALL FEMALES 9/8/85

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	74	4	1.0	1.0	1.0
	75	12	2.9	2.9	3.9
	76	43	10.5	10.5	14.5
	77	86	21.1	21.1	35.5
	78	111	27.2	27.2	62.7
	79	86	21.1	21.1	83.8
	80	45	11.0	11.0	94.9
	81	18	4.4	4.4	99.3
	82	2	.5	.5	99.8
	83	1	.2	.2	100.0
	TOTAL	408	100.0	100.0	

```
Count   Midpoint
    0     73.00 |
    4     74.00 |-
   12     75.00 |---
   43     76.00 |-----------
   86     77.00 |----------------------
  111     78.00 |----------------------------
   86     79.00 |----------------------
   45     80.00 |-----------
   18     81.00 |-----
    2     82.00 |-
    1     83.00 |
    0     84.00 |
    0     85.00 |
    0     86.00 |
    0     87.00 |
    0     88.00 |
    0     89.00 |
    0     90.00 |
    0     91.00 |
    0     92.00 |
                I....+....I....+....I....+....I....+....I....+....I
                0        40        80       120       160       200
                          Histogram Frequency
```

Mean	78.047	Std Err	.074	Median	78.000
Mode	78.000	Std Dev	1.499	Variance	2.246
Kurtosis	.018	S E Kurt	.241	Skewness	.035
S E Skew	.121	Range	9.000	Minimum	74.000
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Valid Cases 408 Missing Cases 0

Figure 7. **Frequency distribution of total skull length for female marten skulls collected in interior Alaska.**

Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
	80	1	.2	.2	.2
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	82	14	3.2	3.2	3.9
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	89	26	5.9	5.9	97.5
	90	8	1.8	1.8	99.3
	91	3	.7	.7	100.0
	TOTAL	438	100.0	100.0	

```
Count   Midpoint
  0      73.00 |
  0      74.00 |
  0      75.00 |
  0      76.00 |
  0      77.00 |
  0      78.00 |
  0      79.00 |
  1      80.00 |-
  2      81.00 |-
 14      82.00 |-------
 24      83.00 |------------
 66      84.00 |---------------------------------
 85      85.00 |-------------------------------------------
 96      86.00 |------------------------------------------------
 79      87.00 |----------------------------------------
 34      88.00 |-----------------
 26      89.00 |-------------
  8      90.00 |----
  3      91.00 |--
  0      92.00 |
                I....+....I....+....I....+....I....+....I....+....I
                0        20        40        60        80       100
                          Histogram Frequency
```

Mean	85.797	Std Err	.089	Median	86.000
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Valid Cases 438 Missing Cases 0

Figure 6. Frequency distribution of total skull length for male marten skulls collected in interior Alaska.