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Determining Sex and Age of Martens in the North Pacific Coast: Using Skull Length and Temporal Muscle Coalescence

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Cover Photo: Collection of marten skulls used in this study. ©2016 ADF&G. Photo by Rodney Flynn.

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Abstract

Several methods have been employed to determine the sex and age of harvested martens (*Martes americana, M. caurina*) in North America. Most of these methods use skull characteristics. Because of their high vulnerability to trapping, close monitoring of marten populations is important for sustained-yield management. Managers have sought sexing and aging methods that are inexpensive, but still relatively reliable. During 1991–1998, we collected 2,998 marten carcasses from trappers in Southeast Alaska and surrounding areas to examine relationships among certain skull characteristics and an animal's sex and age. Our specimens included animals from both the *americana* and *caurina* genetic clades, or species. We found that using a dividing point of 81 mm for total skull length classified over 98% of the carcasses to the correct sex. We found that temporal muscle development could be used to classify many martens into the correct juvenile and adult age classes. For males, a dividing point of 28 mm in length of temporal muscle coalescence (LTMC) correctly classified about 90% of the carcasses into the correct age class. For females, a dividing point of 1.0 mm in the width between the temporal muscles (WBTM) correctly classified about 81% of the carcasses into juvenile and adult age classes. Unknown errors in cementum ages probably contributed to lower correct classification rates. Also, inconsistent measurement probably contributed to the observed errors. Based on the agreement with previous studies, large geographic area sampled, and genetic clades included, we concluded that the methods could probably be applied to most of western North America. Before deciding on a method, managers need to decide on the reliability needed and the funds available. To increase reliability of aging, cementum analysis should be used for males with a LTMC between 20–30 mm and females with WBTM < 2 mm and LTMC < 10 mm.

***Key words**:* Aging, carcasses, martens, *Martes americana, M. caurina*, population management, skull measurements.

Introduction

Biologists have sought inexpensive and reliable methods to determine the sex and age of American marten (*Martes americana*) and Pacific marten (*M. caurina*) carcasses collected from trappers to inform management decisions (Strickland and Douglas 1987). Poole et al. (1994) reviewed recent methods and provided an analysis of reliability and cost effectiveness. They concluded that martens could be best aged by cementum analysis. However, this method (cementum analysis) is relatively expensive and time consuming because skulls must be heated to extract teeth, and then the teeth must be processed in a lab.

Often, the manager wants to know only age class (i.e., juvenile or adult) to guide management decisions (Strickland and Douglas 1987). Magoun et al. (1988) explored using measurements of the uncleaned skull as a field method for rapidly classifying harvested martens into age classes. This method used the development of the temporal muscles to classify ages of martens. Temporal muscles originate from the dorsal cranium along the temporal ridges (Fig. 1). In young animals of both sexes, the temporal ridges are widely separated, but grow together (coalesce) as animals mature. Magoun et al. (1988) and Poole et al. (1994) found that the degree of temporal muscle coalescence classified most juvenile martens correctly, but classification of yearlings and adults was less reliable, especially for females.

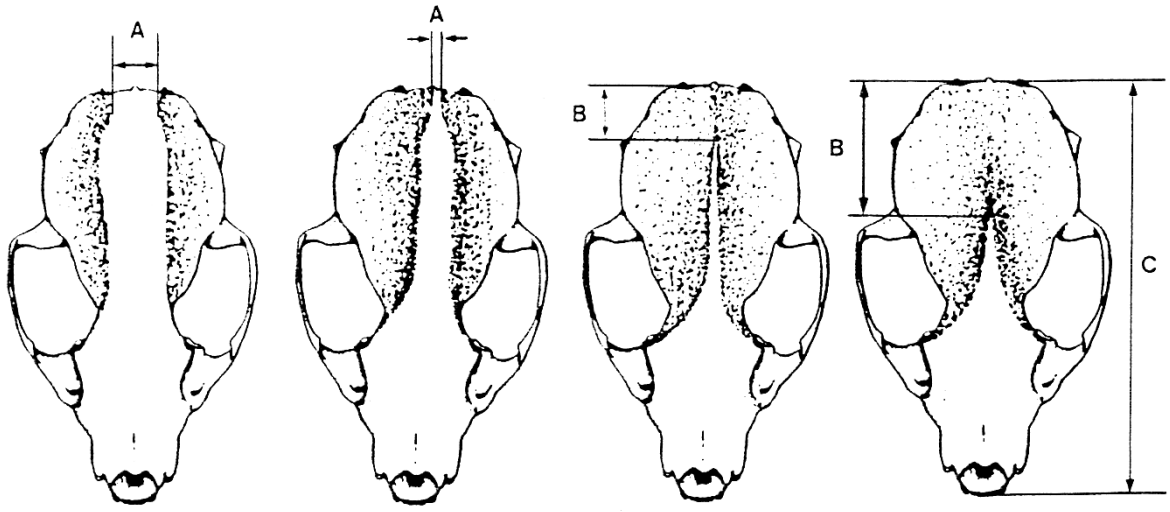

Figure 1. Measurements of marten skulls used in the analysis. A = width between the temporal muscles (WBTM); B = length of temporal coalescence (LTMC); and C = total skull length. Drawing and terminology adapted from Poole et al. (1994).

Because of potential regional differences, Magoun et al. (1988) and Poole et al. (1994) recommended that the parameters for using this method be evaluated in each study area. Giannico and Nagorsen (1989) reported that marten skulls from the Pacific coast varied in size based on 25 cranial measurements. They recognized 3 morphological groups as follows: 1)

Vancouver Island and southern British Columbia coast; 2) Queen Charlotte Islands; and 3) Southeast Alaska. Martens were introduced to POW, Baranof, and Chichagof islands from mainland stock (Burris and McKnight 1973, Paul 2009). Stone et al. (2002), Small et al. (2003), and Dawson and Cook (2012) discussed the genetic relationships of martens in the Pacific Northwest and Southeast Alaska. When we did this project, Stone et al. (2002) and Small et al. (2003) reported that 2 genetic clades (*americana* and *caurina)* of martens occurred in the Pacific Northwest and Southeast Alaska. Dawson and Cook (2012) described the 2 genetic clades as separate species (*M. americana* and *M. caurina*). We recognized the 2 clades, or species, of martens from where they were captured.

In this paper, we evaluate this sex and aging technique for martens in the North Pacific coast and provide recommendations for its implementation. Although other methods for aging martens have been proposed including the development of the suprafabellar tubercle (Leach and Hall 1982), we did not evaluate any of these methods.

Study Area

We collected marten carcasses taken by trappers throughout Southeast Alaska and some adjacent areas in Canada and the North Pacific Coast (Fig. 2) during 1990–1998. Many of the carcasses came from Chichagof Island (n = 1,409), located in the northern portion of Southeast Alaska (57–58°N, 135–136°E; 80–160 km west of Juneau). Nearly all of the major islands of Southeast Alaska were represented, including Prince of Wales (POW) (n = 821), Baranof (n = 178), Mitkof n = (140), Kupreanof (n = 85), Wrangell n = (12), and Revillagigedo (n = 54) islands. Carcasses were also collected from the entire mainland coast (n = 300) from Yakutat to near Ketchikan. In addition, we included 23 carcasses from adjacent areas of British Columbia near Prince Rupert, Smithers and the upper Stikine River.

Most of the carcasses (98.0%) represented martens of the *americana* genetic clade or species (Stone et al. 2002, Dawson and Cook 2012). The carcasses from the *caurina* clade were from Admiralty (n = 25), Queen Charlotte (n = 11), and Vancouver (n = 23) islands and Wyoming (n = 5). Cementum ages were obtained for only a few of these individuals because we wanted to deposit the skulls in museums, so we did not want to destroy any teeth from these animals. Because the sample sizes for the *caurina* clade ended up being small, we couldn't identify any differences between these 2 groups.

Methods

Altogether, we collected 3,103 marten carcasses (males = 1,842; females = 1,261) from Southeast Alaska and surrounding areas along the North Pacific Coast during 1991–1998. Most trappers were paid $3.00 for each carcass to ensure a large, unbiased sample. Only carcasses with

Figure 2. Sample sites along the north Pacific Coast and adjacent areas.

known sex and intact skulls were retained. Of these carcasses, 1,409 animals (males = 845; females = 564) were taken on Chichagof Island and processed by the authors or under their direct supervision. Marten carcasses (n = 821) from Prince of Wales Island (POW) were processed by a variety of less experienced cooperators not under the immediate supervision of the authors. Because of greater experience of the biologists, we assumed that the Chichagof Island samples represented consistently more accurate measurements than those from elsewhere. In contrast, we assumed that the POW samples represented results typical of less experienced staff. The other carcasses were collected from a variety of areas and processed by several staff under the immediate supervision of the authors.

Prior to heating or cleaning, all skulls were measured for size and temporal muscle development (Poole et al. 1994). To collect data for determining sex, we used calipers to measure total skull length (TSL), the maximum length of the skull from the most anterior of the rostrum (excluding teeth) to the most posterior point of the skull (Fig. 1). To gather data on age from skulls, we measured features of temporal muscle development. If the temporal muscle had coalesced, we measured the length of temporal muscle (LTMC) from below the lambdoidal crest at the rear of the skull forward to the point where the temporal muscles diverge (Fig. 1). For animals with LTMC = 0, we measured the minimum width between the temporal muscles (WBTM).

Cementum ages (CAGE) were obtained for 2,998 carcasses using standard methods (Poole et al. 1994). We heated the skulls to 80˚C for about 2 hours and then extracted a pM4 and C1 tooth from each skull. These teeth were further cleaned, placed in a paper coin envelope, and then frozen for storage. All the teeth were sent to Matson's Laboratory (Matson's Laboratory, Milltown, MT) for cementum analysis. The pM4 was examined first and C1 tooth was used for a backup. Although aging by cementum analysis has errors associated with it (Poole et al. 1994), we assumed that the cementum age was the animal's actual age at death.

For most analyses, martens were grouped into the following age classes based on cementum age: juvenile (age class = 0) or adult (age > 1). For some analyses, the carcasses were grouped as juvenile, yearling (age class = 1), or mature adult (age > 2). Given that nearly all carcasses were collected in the months of December and January, age class 0 animals were about 8–9 months old; age class 1 animals were about 1.6–1.8 years old; and age class 2+ animals ranged from 2.6 to 13.6 years old.

We compared the mean TSL of males and females using t-tests. Assuming sexual dimorphism (Giannico and Nagorsen 1989, Poole et al. 1994), we separated males and females for all further analyses. Using the criteria of Dix and Strickland (1986), we computed likely dividing points to separate males from females using TSL and juveniles from adults using LTMC and WBTM for males and females. We reported the mean and standard deviation (SD) unless otherwise noted.

We developed relationships between cementum age and temporal muscle development using categories described by Magoun et al. (1988) and Poole et al. (1994). We grouped skulls into the

following temporal muscle coalescence (TMC) groups: WBTM ≥ 4.0 mm; WBTM = 3.0–3.9 mm; WBTM = 2.0–2.9 mm; WBTM = 0.1–1.9 mm; LTMC = 0.1–9.9; LTMC = 10.0–19.9; LTMC = 20.0−29.9; LTMC = 30.0–39.9, and LTMC ≥ 40.0. Every skull fell into a unique group because LTMC will be 0 if WBTM > 0 and WBTM = 0 if TMC > 0. We computed frequency distributions of TMC group by cementum age. Next, we compared the distributions with those published by Magoun et al. (1988) and Poole et al. (1994) using goodness-of-fit tests (Snedecor and Cochran 1980). We compared the distributions among juveniles, yearlings, and adults for males and females with tests of independence (Snedecor and Cochran 1980).

We classified all carcasses into age classes (FAGE) based on features of temporal muscle development and their calculated dividing points. We determined correct classification rates by comparing FAGE with age determined by cementum analysis (CAGE). For males, we considered a skull with LTMC < 28.0 mm to be a juvenile and a skull with LTMC ≥ 28 mm an adult. For females, we classified skulls with WBTM ≥ 1.0 mm as juveniles and skulls with WBTM < 1.0 mm as adults.

Results

SEX DETERMINATION

We found the TSL of male martens ($\bar{x}$ = 85.3 ± 2.4 mm) significantly longer than females ($\bar{x}$ = 76.9 ± 2.3 mm) (t = 94.9, df = 2,909, P < 0.01). We computed a dividing point of 81.0 mm in TSL between males and females. Using this dividing point (81.0 mm), we classified 98.2% of the carcasses to the correct sex. The successful classification rate was similar for males (98.2%) and females (98.1%). Only 6.6% of the samples (134 males and 65 females) had a TSL within the range 80–82 mm. The TSL of 22 female martens exceeded the 81 mm dividing point. Likewise, we found the TSL of 55 males ≤ 81.0 mm. Of the 55 small males, 58.2% were juveniles and 14.5% were yearlings. For the females, 50.0% of the 22 large females were juveniles and 27.3% were yearlings. The dividing point for the *caurina* clade was calculated to be 81.3, similar to the entire sample, with a correct classification rate to sex of 100%.

AGE CLASS DETERMINATION

For male martens, we found that LTMC varied by age class (Table 1). Few juvenile martens had a LTMC ≥ 30 mm (12.8%) and few adults had a LTMC < 20 mm (2.7%). Although yearlings and mature adults had different distributions (Table 1), we found substantial overlap. For samples with LTMC ≥ 30, 38.6% were yearlings and 49.5% mature adults. Although there was substantial overlap, most yearlings (48.6%) had a LTMC in the 30–39.9 mm category and most mature males (80.6%) were > 40 mm.

We found that the distribution of TMC groups for juveniles varied from those published by Poole et al. (1994) for Interior Alaska and Northwest Territories of Canada (X^2 = 191, 8 df, P <

0.01). In the Interior Alaska sample, more of the juveniles were in the shortest LTMC classes. Our sample had more juveniles in the longer LTMC (> 20 mm) classes. The sample from the Northwest Territories had most of its specimens in the shortest LTMC group, then had a longer tail to the distribution like our sample.

Table 1. Percentage of juvenile (age class 0), yearling (age class 1), and mature (age class 2+) male martens in each temporal muscle coalescence (TMC) class for Southeast Alaska and nearby areas, 1991–1998.

Length TMC (mm)	Juveniles %	Yearlings %	Mature adults %	*n*
= 0	97.8	2.2	0.0	274
0.1–9.9	96.7	2.8	0.6	362
10–19.9	94.5	5.5	0.0	73
20–29.9	54.4	40.4	5.3	57
30–39.9	23.4	53.4	23.1	350
≥40	4.1	27.5	68.4	536

We computed the dividing point in LTMC between juvenile and adult males (age class 1+) at 28.0 mm. Using this dividing point, the correct classification rate to age class for males was 90.6%. The correct classification rate for juveniles (85.5%) was lower than for adults (95.5%). Only 3.5% of the samples (31 juveniles and 26 adults) had a LTMC within the range 20–29.9 mm. Of the 37 misclassified adult males, 15 had a LTMC in the range 20–27.9 mm with the remainder a LTMC < 20 mm. For juveniles, 14 had a LTMC in the range 28.0–29.9 mm and 105 had a LTMC > 30 mm.

For female martens, we found that WBTM was a better indicator of age class (Table 2) than LTMC. Few juvenile females (25.3%) had a WBTM = 0 mm and few adult females had a WBTM > 2 mm (7.0%). Although yearlings and mature adults had slightly different distributions (Table 3), we found substantial overlap. For samples where the temporal muscles had coalesced, 28.8% were yearlings and 47.8% were mature adults. Although we found substantial overlap, most yearlings (57.7%) had a LTMC in the 0.0–9.9 mm category and most mature females (60.2%) had a LTMC > 10 mm.

We found that the distribution of TMC groups for juvenile females varied from those published by Poole et al. (1994) for Interior Alaska and Northwest Territories of Canada ($X^2 = 44.7$, df = 3, $P < 0.01$). In the Interior Alaska sample, more of the juveniles were in the widest WBTM classes. Our sample had more juveniles in the narrowest WBTM (> 2 mm) class. Most specimens from the Northwest Territories were in the narrowest WBTM group, but the frequency distribution had a longer tail like our sample.

We computed a dividing point in WBTM between juvenile and adult females (age class 1+) at 1.0 mm. Using this dividing point, the correct classification rate for females was 80.9% with the rate for juvenile females (73.3%) lower compared with adults (90.8%). Thus, 26.7% of the juvenile females were incorrectly classified as adults, but only 9.2% of the adults were incorrectly classifies as juveniles. For many of the misclassified juveniles (85.1%), the temporal muscles had coalesced somewhat with a LTMC from 0.1–9.9 mm.

We found substantial overlap in age class for female martens with LTMC = 0.1–9.9. For this TMC category, 38.2% of the samples were juveniles, 37.7% were yearlings, and 24.1% were mature adults. For the entire sample, we found that 37.3% of the skulls had a WBTM < 2 and LTMC < 10. In this group, only 61.7% of the samples were classified correctly as juveniles or adults.

Table 2. Percentage of juvenile (age class 0), yearling (age class 1), and mature (age class 2+) female martens in each temporal muscle coalescence (TMC) class for Southeast Alaska and adjacent areas, 1991–1998. Distributions among the 3 age classes are significantly different (X^2 = 644, df = 10, P < 0.001). TMC classes used are Width Between Temporal Muscles (WBTM) and Length of Temporal Coalescence (LTMC).

TMC	Juveniles %	Yearlings %	Mature adults %	*n*
WBTM (mm)				
> 4	96.1	1.8	2.1	330
3.0–3.9	88.8	9.0	2.2	89
2.0–2.9	84.4	11.7	3.9	77
0.1–1.9	55.0	40.0	5.0	40
LTMC (mm)				
0.1–9.9	38.2	37.7	24.1	369
> 10	9.5	26.1	64.5	242

Using the dividing points calculated in this study, we achieved an overall correct classification to juvenile or adult age classes of 86.2% (Table 3). Males had a higher successful classification rate than females (90.6 vs. 80.9%).

Table 3. Correct classification of martens into juvenile and adult age classes using length of temporal muscle coalescence (LTMC) for males (dividing point = 28.0 mm) and width between temporal muscles (WBTM) for females (dividing point = 1.0 mm) from all samples, 1991–1998.

Age class	Males		Females		All	
	%	*n*	%	*n*	%	*n*
0	83.9	899	74.0	693	79.6	1,592
1+	96.2	879	89.2	527	93.6	1,406
Totals	96.2	1,778	80.9	1,220	86.2	2,998

Discussion

Total skull length accurately identifies the sex of American martens in the North Pacific Coast. We found a dividing point of 81.0 mm in TSL best classified our carcass sample into males and females. Although, we found slight variation in dividing points among our study sites, these differences may be more the result of measuring inconsistencies than actual skull size differences. The uncleaned skull presents some difficulties in obtaining accurate, consistent measurements because of extra tissue covering rear and front of the skull. Also, caution must be used in comparing measurements from cleaned, dried skulls with uncleaned ones. Field and lab workers must also be adequately trained and procedures standardized. Because skull lengths can be obtained without any special preparation of the skull, the cost and time needed are minimal. Therefore, TSL is a valuable and cost-effective management tool to determine the sex of marten skulls.

Poole et al. (1994) listed dividing points using TSL ranging from 80.5 to 82.7 mm for several marten populations in northwestern North America. Magoun et al. (1988) used a dividing point of 81.5 mm for interior Alaska. Poole et al. (1994) reported a dividing point of 79.6 mm for dried samples from northern British Columbia. Our dividing point of 81.0 mm fell within the range of similar previous studies using raw skulls. Thus, the method proposed by Poole et al. (1994) can be used for martens in the North Pacific Coast. Because few marten skulls fall into the 80–83 mm range, any of the previously discussed dividing points would still correctly classify most martens to the correct sex. A larger dividing point would tend to increase the correct classification of females and reduce males.

Although most of our specimens were from Southeast Alaska, our results indicated that the same dividing points could probably be used over a greater portion of the North Pacific Coast. Wright (1953) reported that TSL wasn't useful in separating martens from Montana, northern Idaho, and southern British Columbia into morphological groups because of size overlap. Whitman (1978)

used 79.0 mm to separate dried skulls by sex for specimens collected in central Idaho. Giannico and Nagorsen (1989) reported pronounced sexual dimorphism in Pacific Coast marten, especially among the island populations. Although they didn't report TSL for their specimens, the difference in overall cranial size suggested a difference in TSL. We found no differences in TSL among our limited samples of the *caurina* genetic clade, the genetic group more characteristic of the western contiguous United States (Stone et al. 2002, Dawson and Cook 2015).

We found that TMC can be used to classify American martens into juvenile or adult age classes. For males, we found a dividing point of 28.0 for LTMC would correctly classify over 90% of the animals as juveniles or adults. Adult age classes could not be further refined into yearlings or mature adults because of substantial overlap. Neither Magoun et al. (1988) or Poole et al. (1994) listed specific dividing points using LTMC for separating juvenile from adult male martens. Their data suggested a dividing point between 10–30 mm for interior Alaska and 20–30 mm for Northwest Territories. Fortunately, few specimens fall in the 20–30 mm range. Only 3.3% of our male samples were in this range. Poole et al. (1994) reported 2.9% of their sample from the Northwest Territories and 5.3% of the Alaskan Interior samples falling within this range. Thus, small changes in dividing points do not greatly affect the classification rate. Classification rates for males could be improved slightly by using tooth cementum analysis for skulls with LTMC between 20 and 30 mm. Of greater concern, we had 12.8% of our juveniles with a LTMC ≥ 30 mm. These animals were either an anomaly to the pattern, or the cementum ages were incorrect. These individuals may have actually been adults. Because the trapping seasons in the Northwest Territories and the Alaskan Interior begin earlier in the season, some of these animals may have been younger than in Southeast Alaska. Therefore, the temporal muscles may have shown less development in some of their specimens.

Although less successful than with males, we found that TMC can be used to classify female American martens into juvenile or adult age classes. In females, the development of the temporal muscles is slower compared to males. Thus, the temporal muscles have not coalesced in most juveniles. We calculated a dividing point of 1.0 mm for WBTM that would correctly classify about 80.8% of the animals as juveniles or adults. This dividing point identified adults better than juveniles (88.6% to 74.9%) because some juvenile females showed substantial coalescence of their temporal muscles. Adult age classes could not be further refined into yearlings or mature adults because of substantial overlap.

Although Magoun et al. (1988) or Poole et al. (1994) didn't list specific dividing points using WBTM for separating juvenile from adult female martens, their data suggested a dividing point between 0–2.0 mm for interior Alaska and the Northwest Territories. Fortunately, few specimens fall in the 0–2.0 mm range. Only 3.5% of our female samples were in this range. Poole et al. (1994) reported 13% of their sample from the Alaskan Interior falling within this range. Thus, small changes in dividing points do not greatly affect the classification rate. Of greater concern was 25.3% (164) of our juvenile females showing temporal muscle coalescence (LTMC ≥ 0

mm). Most of these skulls (141) had a LTMC < 10 mm. The temporal muscles of these animals either developed more quickly or the cementum ages were incorrect. We were unable to determine the accuracy of our cementum ages. In contrast, most adult females showed temporal muscle coalescence with only 10.6% (53) of our adult females with a LTMC = 0.0 mm.

Magoun et al. (1988) recommended that female skulls with WBTM from 0.1 to 2.5 mm be aged by tooth cementum analysis to improve correct age classification. However, we recommend that females with LTMC < 10 and WBTM < 2 should be included in the cementum analysis. In our samples, 33.5% of the female specimens were in this category. Most improvement would be possible with juveniles because one would be able to correct 144/158 (91.1%) of the errors. For adults, only 11 of 60 errors (23.3%) could be corrected. Cementum analysis would substantially improve correct classification rates for juveniles (from 74.9 to 95.7%). For adults, the correct classification rate would increase from 88.6 to 91.3%. The overall classification rate for females would increase from 80.8 to 93.8%.

Although previously reported data indicated some regional variation in dividing points, our results were consistent with their findings. Unfortunately, we didn't obtain cementum ages from many our limited samples of the *caurina* genetic clade. Despite that, the dividing point of 28.0 mm correctly classified 11 of 13 these male carcasses (84.6%) indicating that the same dividing points could probably be used over a larger area. Similarly, 11 of 12 (91.7%) of our limited female sample were correctly classified to age class. These animals were all taken on Admiralty Island within Southeast Alaska. Although Giannico and Nagorsen (1989) measured a large number of marten skulls from the Pacific Northwest including Queen Charlotte and Vancouver islands, they did not report any information on temporal muscle coalescence.

This study included specimens measured by a large number of biologists, many working independently. Although personnel received standard directions, the point of temporal muscle separation is often difficult to determine and measure precisely. Also, measurements were often done quickly to accommodate the large sample. Unfortunately, we did not complete any blind testing of our personnel working at remote sites to check accuracy. Thus, we may have introduced more measurement error than by using a few, highly trained technicians.

Sex and age ratios are used extensively in marten population management (Strickland and Douglas 1987). Managers have used the ratio of juveniles to adults in the trapper catch as a measure of recruitment (Strickland and Douglas 1987). Some managers prefer the ratio of juveniles to adult females as a measure of harvest intensity (Strickland and Douglas 1987). For these analyses, the manager needs to determine the sex and age of their harvested martens. These ratios should be used with caution unless the classifications to sex and age are accurate. Otherwise, the harvest data may lead the manager to incorrect conclusions. This study provides procedures for accurately determining the sex and age of harvested martens.

Future research needs to incorporate known-aged animals. Otherwise, unknown errors in age determination by tooth cementum analysis would cloud the results. Also, a study is needed to measure the development of the temporal muscle throughout the early life of martens to more clearly establish the growth pattern. Another method for aging martens, i.e., the development of the suprafabellar tubercle (Leach and Hall 1982), should be evaluated simultaneously to determine their consistency and applicability. Alternate methods may be complementary for certain sex and age classes. Also, some trappers and situations may be more receptive to collecting certain biological samples.

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