Estimating the Age and Sex of Caribou from Mandibular Measurements

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Formulae for estimating the age and sex of caribou are derived from measurements taken from a control sample of caribou mandibles collected by the Canadian Wildlife Service. A robust linear relationship was found to exist between first molar crown height and age, while male and female mandibular measurements are statistically distinguishable on either side of a linear regression line. The application of these formulae to three 19th century archaeological assemblages from the western Canadian Arctic indicates their usefulness in estimating the age and sex of fossil populations, although some problems due to geographical variability remain. Tentative results indicate that traditional western Arctic Inuit were unable to exert strong control over the age and sex of the caribou they killed, perhaps because of the use of large-scale communal hunting techniques. This situation seems to have changed radically with the introduction of firearms in the 1870s.   © 1997 Academic Press Limited

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Introduction

For several decades, archaeologists have attempted to determine the age and sex profiles of large herd animals in archaeological faunal assemblages, in order to understand better the decision-making processes of ancient hunters. As a result, excellent osteometric data are now available for assessing age and sex in a number of important species particularly bison in North America (Bedord, 1974; Reher & Frison, 1980; Speth, 1983; Todd, 1987; Morlan, 1991). North America's other major herd animal, caribou, has proved far more difficult to deal with, for several reasons. Caribou are less sexually dimorphic than bison, so that few discrete measurements are capable of distinguishing adult males from females with acceptable accuracy (Miller, 1974). Also, caribou are less hypsodont than bison; in other words their teeth are much lower crowned and total attrition from wear over a given period of time is far less. It has thus proved impossible to group caribou mandibles-with-teeth into seasonal cohorts on the basis of metaconid heights, as is commonly possible with bison at kill sites (e.g. Reher, 1974). Instead, the few studies which have attempted a look at caribou age structure

have been based on gross tooth wear and eruption categories (e.g. Speiss, 1979; Gronnow, Meldgaard & Nielsen, 1983), or destructive and expensive dental thin-sectioning (Miller, 1974; Gordon, 1988).

This study explores the relationship between mandibular and dental osteometrics and age and sex based on a control sample of caribou mandibles of known age and sex. It is meant to compliment rather than supplant earlier studies, including several briefly described attempts to infer the sex of caribou on the basis of post-cranial measurements (Gronnow, Meldgaard & Nielsen, 1983: figures 79–80, Stenton, 1989: 277–279; see also Speiss, 1979: 84–97).

The Database

The control sample of over 70 left mandibles was derived from a much larger sample of nearly 1000 mandibles and associated crania collected by the Canadian Wildlife Service (CWS) during the late 1960s. They were taken as part of a major study of the Kaminuriak herd of barren-ground caribou (*Rangifer tarandus groenlandicus*) (see Miller, 1974), and are currently part of the collections of the Canadian

Table 1. Summary statistics for variables used in sex classification

Sample	Group	N	Corpus height		m3–mf length	
			Mean	S.D.	Mean	S.D.
Control sample	All cases	74	31·77	2·49	151·25	5·45
	Males	37	32·78	2·40	153·78	5·36
	Females	37	30·75	2·17	148·73	4·29
Kugaluk	All cases	18	32·46	3·37	158·11	7·21
	*Males	13	33·37	3·50	160·48	6·70
	*Females	5	30·10	1·33	151·94	4·53
Barry	All cases	5	32·12	3·16	158·16	7·93
	*Males	3	33·57	3·00	162·43	6·05
	*Females	2	29·95	2·47	151·75	6·43

*According to results of discriminant analysis.

Museum of Nature. Barren-ground caribou are found on the Canadian mainland between Hudson Bay and the Mackenzie River, on Baffin Island, and in western Greenland. Kaminuriak is the easternmost of four major mainland herds, living in the Keewatin District and northernmost Manitoba, just west of Hudson Bay.

About one-quarter of the total CWS collection was examined in selecting the control sample. This smaller sample was chosen to keep the volume of data manageable, but a serious attempt was made to represent all relevant age and sex categories. In general it was found that younger males and older females tended to be far more abundant than older males and younger females in the CWS collection (see Miller, 1974: 63), while in the control sample they are more equally balanced. Immature animals under about 3 years of age, however, were excluded. Miller's (1974: 37) study makes is clear that they cannot be accurately sexed from any osteometric data (this is true even of species more dimorphic than caribou), while age can be more accurately estimated using eruption sequences than any other technique.

The CWS collection is ordered by catalogue number, with accompanying data including the precise collection location and the sex of the animal. The age in months is also given, determined by dental thin-sectioning and from the known birth (early June) and death dates. All measurements were taken by a single measurer (Morrison) using the same pair of Mitutoyo electronic callipers throughout.

Sex and mandibular size

In his 1974 study of the Kaminuriak herd, Miller found that sex could be accurately estimated from overall mandibular length, particularly for animals aged 5 years and older (Miller, 1974: figure 20). Unfortunately for the archaeologist, complete caribou mandibles are exceedingly rare in archaeological assemblages, and some smaller measurement is clearly required. Miller (1974: 36) found that diastema length was highly correlated with overall mandibular length,

and hence with sex, but unfortunately this measurement still requires that the fragile anterior end of the mandible be intact. Most archaeological mandibles are broken through the diastema, and in our experience very few have suffered no damage to the anterior end, particularly around the delicate incisor sockets. Speiss (1979: 82, figures 3–4) suggests another, more practical, measurement; the distance from the posterior alveolar margin of the third molar to the posterior border of the mental foramen (m3–mf).

However, m3–mf proved to be insufficiently robust to be truly helpful on its own. Results from the control sample were not bimodally distributed for this measurement, even when sorted into age categories (3–5, 6–9, and 10+ years). Male and female curves had distinct midpoints, but at one S.D. the lower half of the male range overlapped almost completely with the upper half of the female range (see Table 1). Three ancillary measurements were then considered: maximum thickness of the corpus (normally below pm4 or m1), length of the tooth row, and maximum height of the corpus, between m2 and m3 (Figure 1).

A stepwise discriminant analysis was initially performed on a data set of 41 mandibles classified by sex, and measured on the four above variables (Figure 2), using SPSS for Windows v. 6.0. As Figure 2 suggests, only height and m3-mf length proved to be statistically useful discriminators of sex, and so just these two variables were evaluated with an expanded control sample of 74 specimens (37 males and 37 females) (see Figure 3 and Appendix Table A1). Analysis of this larger data set produced the following linear discriminant function (in this and subsequent equations, measurements are in mm and ages in months):

discriminant score =
$$0.319*\text{height} + 0.169*\text{length} - 35.647. \qquad (1)$$

Any case with a discriminant score greater than or equal to zero is classified as male, and cases with a score less than zero as female. Applying this rule to the control sample results in the correct allocation of 77% of cases, as illustrated in the ''confusion matrix''
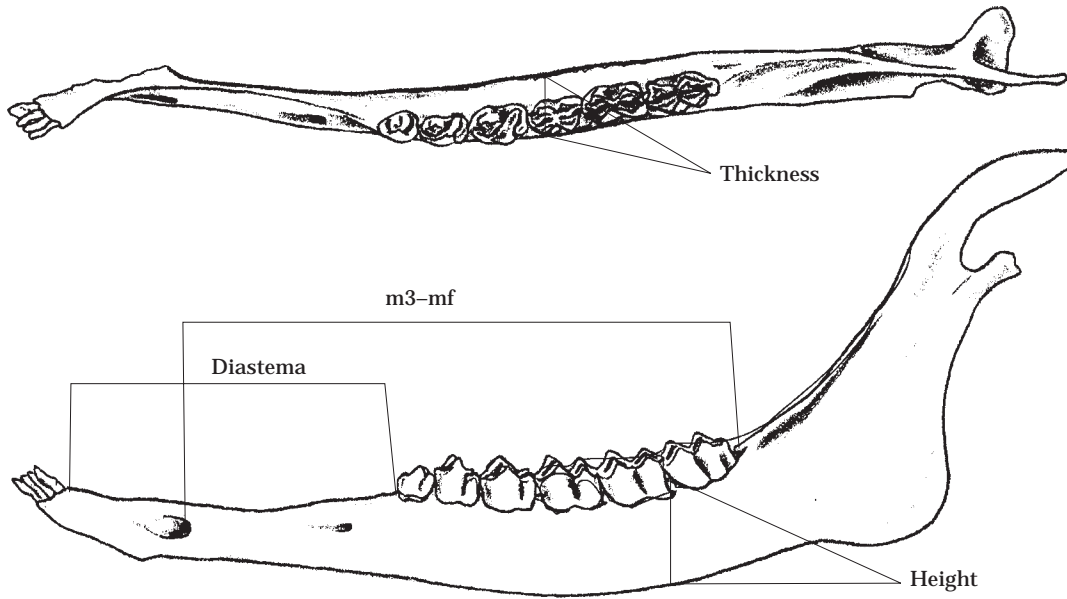
Figure 1. Caribou mandibular measurements used in this study. Only m3–mf (third molar to mental foramen) and height proved to be statistically useful in estimating sex.
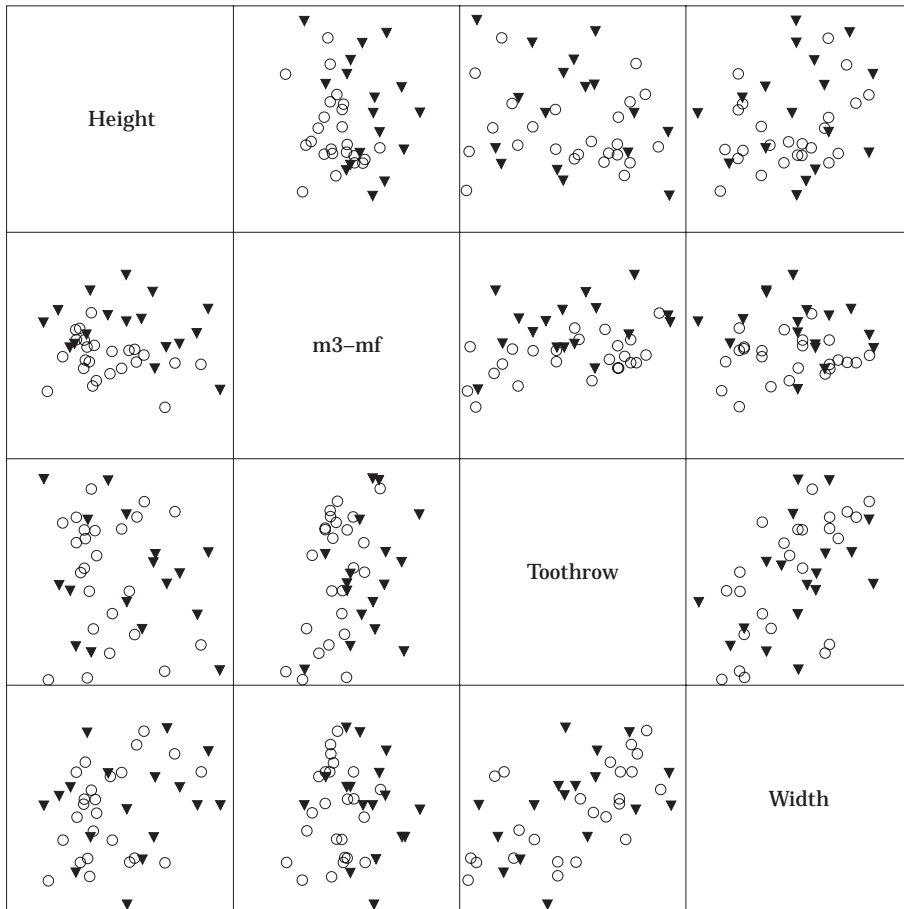

Figure 2. Scatterplots showing the covariation of sex and four mandibular measurements. ▼, male; ○, female.
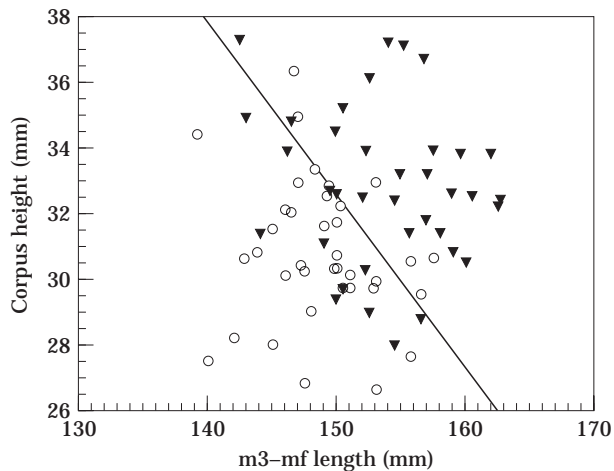
Figure 3. Scatterplot showing covariation of sex, m3–mf length, and mandibular height. The regression line distinguishes males from females with an accuracy of 77%. ▼, male; ○, female.

Table 2. Results of using discriminant function to classify control sample

Actual group		Predicted group	
		Male	Female
Male	N	27	10
	%	73·0	27·0
Female	N	7	30
	%	18·9	81·1

(Table 2). Table 2 reveals a bias in the misclassification of males (27%) versus females (19%), due in part to the greater variance in the male group. Since the misclassified cases tend to consist of younger males ($\bar{X}=51\cdot9$) and older females ($\bar{X}=74\cdot1$), and our sample is somewhat skewed towards younger animals, this sort of discrepancy in sex discrimination is not unexpected. However, excluding young (<5 years of age) animals from the analysis does not produce an appreciable improvement in the classification success rate, and tends to reduce robusticity due to smaller sample size.

These results indicate that caribou mandibles can be assigned to sex on the basis of height and m3–mf length, with an apparent error rate of 23% (the actual error rate when classifying new cases of unknown affiliation normally tends to be somewhat higher). While the sex of a particular case may be difficult to ascertain if it falls in the area of overlap, with a reasonably large sample it should be possible to estimate the sex *structure* of a population with reasonable confidence. In addition, a statistic referred to as the ''posterior probability'' can be calculated, which expresses the likelihood that a case has been correctly classified, based on the magnitude of its discriminant score. Cases with a discriminant score close to 0 will have a posterior probability close to 0·5, while cases

with large (+/−) discriminant scores will have posterior probabilities approaching 1. This allows an assessment of the strength of particular sex determinations.

An application of these results to archaeological assemblages is presented below.

Crown height and age

Dentally mature caribou over about 27 months in age can be sorted into age categories based on a visual assessment of tooth wear (Miller, 1974: 15–22). The usual categories employed are; 2 years (27–35 months), 3–5 years, 6–9 years, and animals of 10 years and older (see Speiss, 1979: 78–84; Gronnow, Meldgaard & Nielsen, 1983: 74). These categories are sufficiently precise to construct at least rough age profiles. The problem with basing age on a visual assessment of tooth wear is its subjectivity. When attempting to sort mandibles-with-teeth it is surprising how many seem to fall between categories; is this animal 5 years old or 6 years old (3–5 or 6–9)? Is this one 9 years old or 10 (6–9 or 10+)? Comparing results after resorting the same sample does not inspire confidence.

It is primarily for this reason that mortality profiles are generally based on crown height rather than gross wear categories for many species, including not only bison (Reher & Frison, 1980), but also elk/red deer (*Cervus*) and a variety of South African ungulates (Klein *et al.*, 1981; Klein, Allwarden & Wolf, 1983; Klein & Cruz-Uribe 1984). As these studies demonstrate, crown height provides a good metric index of wear and age.

This study is based on the crown height of the mandibular first molar (m1). This tooth was chosen because it is the first permanent tooth to erupt and shows the least variation in eruption age: from 3 to 5 months after birth (see Miller, 1974: table 4). Many crown-height studies have been based instead on m3, because with its three lobes this tooth is readily distinguishable from m1 and m2 in loose-tooth samples (see Klein & Cruz-Uribe, 1984: 53). However, in this study loose teeth were not used. Preliminary results by Miller (1974: figure 13) seem to show a relatively simple and robust correlation between crown height and age for m1. Following Miller's study, and what is now common practice (Klein & Cruz-Uribe, 1984: 46), the measurement is taken buccally, from the root-enamel junction to the occlusal surface (Figure 4). The readings from the two occlusal ridges are then averaged.

m1 crown height was obtained on a sample of 78 mandible (36 females, 42 males) ranging in age from 34 to 181 months (see Appendix Table A1). A linear regression of age on crown height is very strong ($r=-0\cdot936$, $r^2=87\cdot6\%$, $P<0\cdot0005$; Figure 5), the r^2 value indicating that about 88% of the variability in m1 crown height is accounted for by the age of the individual. While the 181-month-old outlier is in a
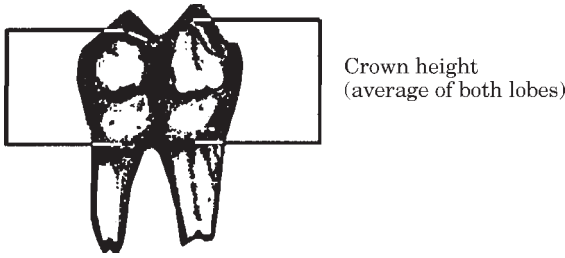
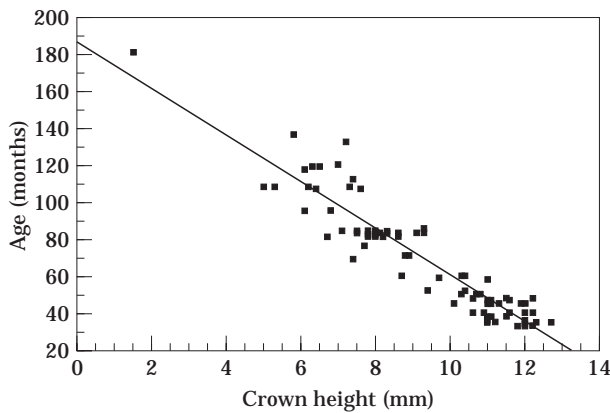Figure 4. Measurement of m1 crown height, from the root-enamel junction to the occlusal surface, buccal side.

Crown height
(average of both lobes)

Figure 6. Distribution of the standardized residuals, control sample. ▼, male; ○, female.

Figure 5. Scatterplot showing the relationship between age and m1 crown height, control sample.
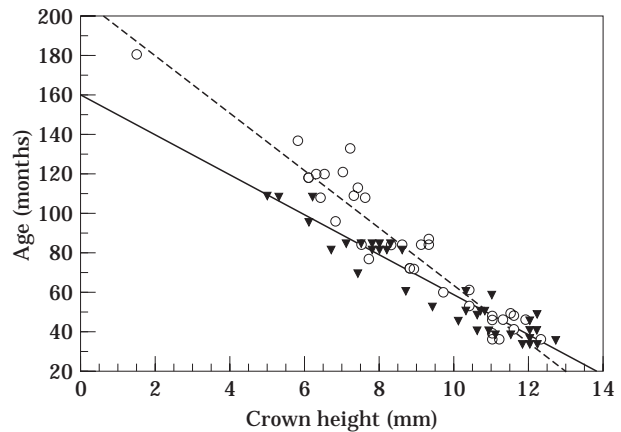
Figure 7. Relationship between sex, age, and crown height, control sample. ▼, male; ○, female.

position to exert significant leverage on the regression line, excluding it from the analysis produces a negligible change in the linear regression (beyond a slight reduction in the strength of the correlation: $r= -0.924$, $r^2=85.4\%$, $P<0.0005$):

all cases:
$$\text{age}= -12.56*\text{crown height}+186.97 \qquad (2)$$

excluding outlier:
$$\text{age}= -12.27*\text{crown height}+184.13. \qquad (3)$$

Since this outlier corresponds closely to the pattern of variation in younger individuals it is retained in subsequent analyses. Quadratic and cubic regressions produce only slightly larger r values (-0.938 in both cases) for the data set as a whole, and with the outlier excluded (-0.925 in both cases), along with much reduced F statistics (which measure in the significance of the model) and t statistics (which measure the significance of particular coefficients). The linear regression is felt to be the most robust and parsimonious model for the sample at hand. The question of the shape of the regression line is discussed in greater detail below.

Of some concern is the distribution of the standardized residuals when broken down by sex (Figure 6).
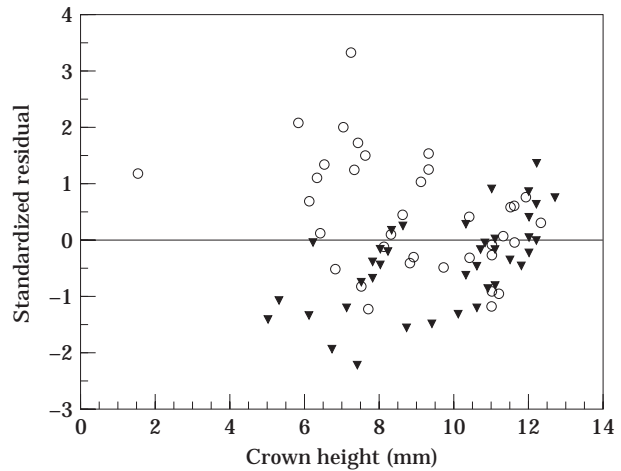
Males and females diverge as crown height decreases, such that the regression ((2) above) will tend to underestimate the age of females and overestimate the age of males as they become older. It appears that males wear down m1 at a faster rate than females, presumably due to their somewhat larger body size and greater nutritional requirements. This effect is clearly revealed in a scatterplot of age and crown height broken down by sex, with new linear regressions calculated for each group (Figure 7):

males only:
$$\text{age}= -10.20*\text{crown height}+160.25 \qquad (4)$$

females only:
$$\text{age}= -14.53*\text{crown height}+209.26. \qquad (5)$$

These sex-specific regressions are moderately stronger than that for the sample as a whole (males only:

$r= -0.958$, $r^2=91.8\%$, $P<0.0005$; females only: $r= -0.957$, $r^2=91.5\%$, $P<0.0005$), and do not exhibit any strong anomalies in the residuals. Again, very slight increases in r values can be obtained with quadratic and cubic regressions, but do not appear warranted for such small samples.

These analyses suggest that caution be exercised in the application of the regression of age on crown height ((2) or (3) above). Depending on the sex structure of the sample, ages may be slightly over- or underestimated. Ideally, m3–mf length and mandibular corpus height could be used to group the sample by sex using the discriminant function (1), and then the sex-specific regressions ((4) and (5)) used to estimate ages from crown height for each sex.

Discussion: measuring accuracy and quadratic solutions

After beginning the study on which this paper was based, it came to our attention that Anne Pike-Tay *et al.* (n.d.) were engaged in a very similar task. They too had been investigating the mathematical relationship between crown height and age for barren-ground caribou. Their study remains unpublished as this article goes to press, making it difficult to compare results in detail. Nonetheless, three general observations can be made: (1) their sample is considerably larger than ours, but drawn from the same Kaminuriak population, (2) they were unable to distinguish distinct male and female regression lines and (3) they choose a quadratic regression model as the best fit with their data, rather than the linear solution proposed here.

Regression formulae for crown height and age applied to hypsodont species are, in fact, generally quadratic, reflecting a curvilinear relationship between age and wear (see Gifford-Gonzalez, 1991). As Klein *et al.* (1981: 10) explain, "Theory suggests that the rate of dental wear will not be constant in high-crowned ungulates, largely because the occlusal surfaces of teeth become smoother with age, so that friction between apposing upper and lower teeth decreases . . . The rate of wear will thus be relatively rapid on freshly erupted teeth and relatively slow on well-worn ones".

As will be recalled, only marginal improvements in age-crown height correlations were obtained with our sample using quadratic or cubic regression models, while the significance of the model and of particular coefficients (as measured by the F and t statistics) was substantially reduced. It is possible that with a larger sample one of the statistically more demanding non-linear models would prove preferable to the linear regression model proposed here. In particular, more measurements on older individuals would close the gap in the critical portion of the point scatter between the 181 month outlier and the rest of the sample, and help resolve the present ambiguity.

Measurement accuracy, however, may be of greater practical importance. Caribou are not a very hypsodont species; bison are more high crowned by a factor of more than two (see Reher & Frison, 1980: table 5), and even elk teeth are higher crowned by about one-third (see Klein *et al.*, 1981: figure 3). It is not that occlusal surfaces do not wear smooth over time; they do. However, absolute differences in attrition rates caused by this seem to be so small as to be practically impossible to measure.

At eruption, caribou first molars reach an average maximum height of about 14 mm. Wild caribou rarely live longer than about 12 years, by which time their teeth are very seriously worn (Miller, 1974: 73). In fact, average attrition for measured Kaminuriak caribou is just under 1 mm annually, using a straight-line regression. Measuring accuracy thus becomes critical in evaluating any fine-scale relationship between age and height. To test measuring accuracy, about half of the Kaminuriak sample was measured twice. The average discrepancy proved to be 0·4 mm, or about 5 months, while the greatest discrepancy was 1·1 mm (or 14 months). It is suggested that these are relatively good figures, good enough to distinguish male and female regression lines (another "theoretical" expectation). The fact that they are not good enough to distinguish a curvilinear relationship suggests that this relationship, if it exists, may be of little practical significance. In short, a quadratic relationship between crown height and age may be overly precise for an animal as low-crowned as caribou.

Application

Results from the control sample can be applied to archaeological assemblages. Three sites were chosen from the western Canadian Arctic (Figure 8). All lie within the range of the Bluenose caribou herd, the most westerly of the mainland barren-ground herds (Martell, Dickinson & Casselman, 1984), just as Kaminuriak is the most easterly. It is assumed that the caribou represented in these sites belong to the same *R. t. groenlandicus* subspecies as the control sample.

All three sites can be assigned to the 19th century Mackenzie Inuit (also called Inuvialuit) and yielded faunal assemblages heavily dominated by caribou and fish. The largest assemblage comes from Kugaluk, the only site of the three yet to be described in print (Morrison, 1988). The site is located on the tree-line just east of the Eskimo Lakes. It has three semi-subterranean "winter" houses, one of which was excavated, and a faunal assemblage of just under 46,000 specimens. Caribou represent over 98% of mammalian NISPs (number of identified specimens), with an MNI (minimum number of individuals) of 109 animals. The nature, variety, and relative abundance of European trade goods suggest that Kugaluk was probably occupied in about the 1860s.

The Barry site is located at the mouth of the Anderson River, beyond the tree-line to the east-north-east of Kugaluk. It has two houses and was more or
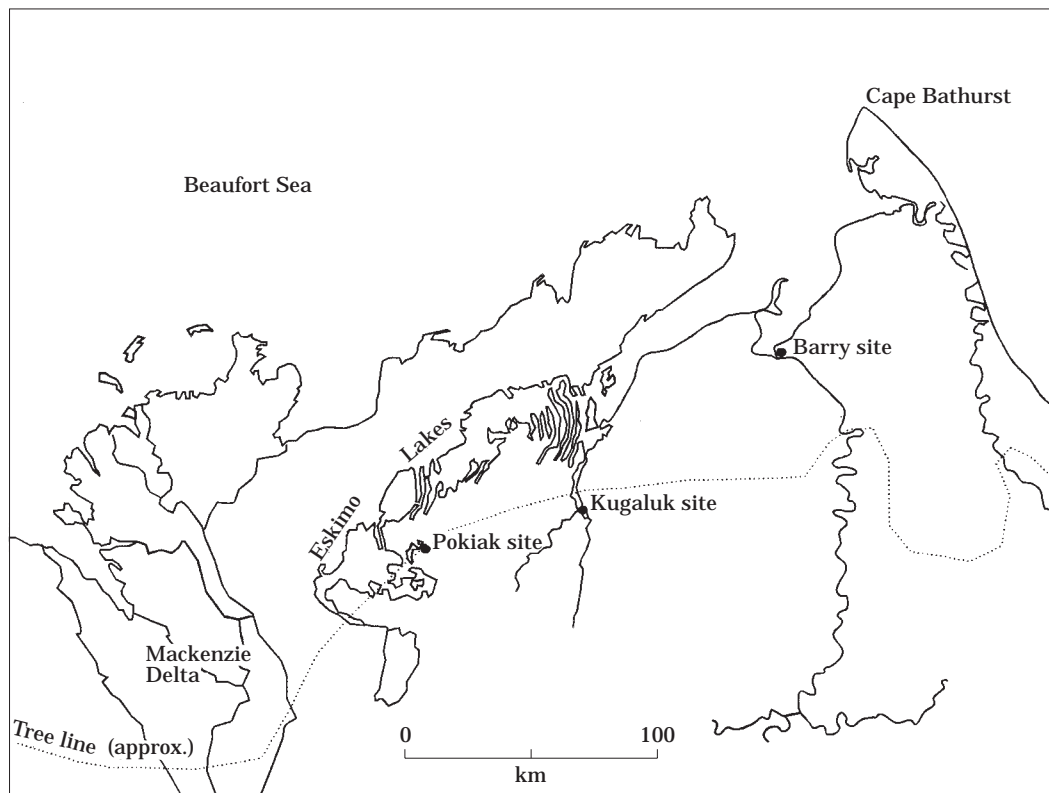
Figure 8. Location of study sites in the western Canadian Arctic.

less totally excavated (Morrison, n.d.a). Judging from the recovered trade goods, it dates to perhaps a decade or so earlier than Kugaluk, and like Kugaluk seems to represent a single occupation. The total faunal assemblage recovered was nearly 15,000 specimens. More than 93% of mammalian NISPs were caribou, with an MNI of 52 animals.

The third site, Pokiak, is located just east of the upper Eskimo Lakes, again more-or-less at tree-line. It has 10 semi-subterranean houses, one of which was excavated (Morrison, n.d.b), and a faunal assemblage of about 16,000 specimens. Almost 91% of mammalian NISPs were assigned to caribou, with an MNI of 16 animals. The Pokiak house proved to have been re-occupied and rebuilt several times over the latter part of the 19th century, with a terminal date probably in the post-1890 commercial whaling era, as witnessed by trade goods such as glazed china and tin snuff boxes. It is the only site in the sample occupied after the adoption of firearms in the area in the 1870s, an event which must have revolutionized caribou exploitation.

The three sites may have differed slightly in their overall seasons of occupation. Pokiak and Kugaluk presented architectural evidence of a warm-weather occupation, in the form of in-ground cache pits and, at Pokiak, a large smoking pit for processing meat or fish; Barry did not. With their snug, sod and driftwood houses, however, all three were evidently occupied well into the winter. Perhaps most importantly for this

study, all may have also focused on the same autumn season for caribou hunting. The most compete seasonal data come from Kugaluk (Morrison, 1988), although the results are somewhat equivocal. Almost all of the intact caribou first molars from Kugaluk were thin-sectioned. Microscopic analysis of annular growth rings suggested a bimodal distribution of death dates, with peaks in the early summer and autumn, apparently corresponding to the ''spring'' and autumn caribou migrations. However, patterns of tooth eruption suggested a different picture. At least 17 individuals exhibited first molar eruption, indicating they were killed between September and November of their first year (Miller, 1974: table 4). None exhibited complete first molar occlusion without any m2 eruption, which would have indicated a winter kill. Only two exhibited m2 eruption, indicative of a spring or summer kill (early June plus 10–14 months), and on re-examination both are equivocal. Tooth eruption patterns, then, suggest a mainly or entirely autumn kill at Kugaluk, a conclusion also in keeping with the complete absence of foetal or neonatal caribou remains.

The other two sites provide evidence of a similar pattern of tooth eruption. They produced only a single neonate specimen killed during the first summer of life (probably July or August), without any molar eruption (Barry site). A minimum of six individuals were killed during m1 eruption, between September and November of their first year. No individuals were killed

Table 3. Barry site mandibular measurements

Catalogue	m3–mf (mm)	Height (mm)
1173-1	147·2	31·7
472-1	162·6	36·6
933-1	168·4	33·5
1015	156·3	30·6
907	156·3	28·2

Table 4. Kugaluk site mandibular measurements

Catalogue	mf–m3 (mm)	Height (mm)
300-10	155	28·7
100-45	159	29·5
100-27	153	32·7
100-39	159·5	28·5
4-24	162·5	38·4
405-2	161	38
12-48	153·9	31·1
4-26	161	33·5
6-502	166·4	38·7
6-853	165	31·4
8-532	154·5	30
8-727	147·8	31·3
3-7	146·3	31·6
7-50	156·1	28·9
4-25	158	30·7
100-56	177·7	36
107-2	156·3	30·6
11-17	153	34·7

Figure 9. Height and length (m3–mf) of Kugaluk and Barry site caribou mandibles, compared with control sample. ▼, male; ○, female; *, sex unknown.

with complete first molar occlusion and no m2 eruption (December–March), nor with m2 erupting (April–July). Individuals with m3 erupting were well represented, but variation for this state encompasses a 12-month period, so that it has no value as a seasonal index. Again foetal remains were entirely absent.

Throughout the Inuit world, autumn was by far the most important season for caribou hunting, since at this time of year the herds are at their nutritional best, hides are prime for clothing, and cool temperatures make it possible to store meat with ease (Burch, 1991). Caribou remains from the three study sites seem to represent kills made mainly or entirely during this season of the year.

Sex

Because of extensive breakage, only the Kugaluk and Barry sites produced mandible suitable for sex classification: 18 from Kugaluk (all rights) and five from Barry (lefts). Measurements are presented in Tables 3 & 4. None of the Pokiak mandibles was complete enough to yield the two required measurements. A comparison of these figures with mandibular MAUs (minimal animal units; see Binford, 1984) of 103, 16·5 and 12·5 for the three sites respectively, suggests the
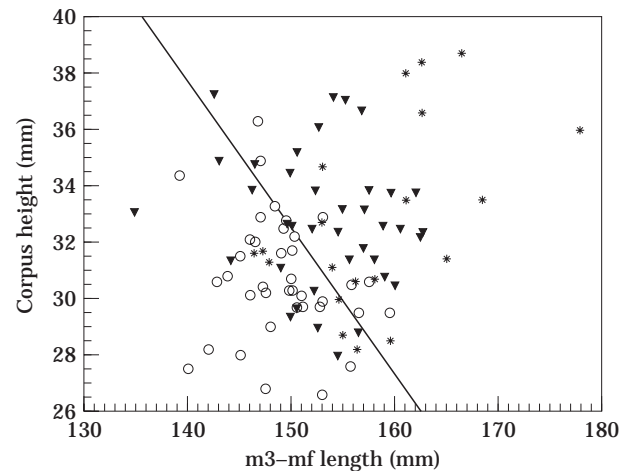
degree of breakage characteristic of many caribou-bone assemblages from the western Arctic. No single mandible from any site was absolutely complete from incisor sockets to the angle of the ramus or the mandibular condyle.

To apply the discriminant function to the sexing of these specimens it must be assumed that the archaeological sample is drawn from the same population as the control sample. There is some indication that the archaeological mandibles are in fact slightly larger (Table 1). Independent sample t-tests comparing the means of corpus height and m3–mf length between the control sample and the two sites suggest that the length of the Kugaluk mandibles is significantly different from that of the control sample ($P=0.001$, separate variances). The Barry sample is very similar to the Kugaluk sample, but too small to be shown to differ significantly from the control. The mean heights of the three groups are not significantly different.

It should be borne in mind, however, that the control is evenly divided by sex, while the sex structure of the archaeological samples is unknown, and may be dominated by males. Comparing the archaeological samples with the male subset of the controls reduces the strength of the differences, but the mean lengths of the Kugaluk and control samples are still significantly different at the 95% confidence level ($P=0.03$). It must also be considered that our control sample is drawn from a purportedly random sample of the Kaminuriak herd (Miller, 1974: 62–76), while the archaeological sample may have been deliberately selected for size.

Incorporating the Kugaluk and Barry measurements into the discriminant function (1) leads to the classification of 70% of the combined sample as males and 30% as females (Figure 9). The values are 72% (13 out of 18) male for Kugaluk and 60% (three out of five) male for Barry. Given the length differences between the samples noted above, a number of interpretations

of these results are possible. It may be that size variability of 19th century Bluenose males is simply greater than that of 20th century Kaminuriak males, and the results are a true reflection of the sex structure of the assemblage. Alternatively, selective hunting may have preferentially sampled the larger end of the size spectrum for males, thus presenting a biased picture of size variability but, again, an accurate picture of the sex structure of the assemblage.

A more cautious interpretation, however, is preferred. If Bluenose mandibles are in fact slightly larger on average than Kaminuriak mandibles, as the *t*-tests indicate, then it seems likely that some or all of the archaeological specimens classified as male that fall close to the male–female boundary may in fact be female. Balancing this possibility is the observed tendency in the discriminant analysis for males to be misclassified as females more often than the reverse. Six specimens (five Kugaluk and one Barry) in particular, with posterior probabilities of group membership at the low end of the range (0·586–0·709), seem open to misclassification. Four of these fall into adult dental wear categories (≥ 5 years old), while two fall in the 2–3-year-old range. Given the tendency to misclassify older females and younger males, the two younger individuals may in fact be male, as already classed, while the four older individuals may be female. This reassignment would result in an essentially equal (12:11, 52% male, 48% female) overall ratio of males to females (9:9 for Kugaluk, 3:2 for Barry). Lacking a control sample from the Bluenose herd with which to generate a herd-specific discriminant function, this may be the best estimate of the sex structure of the Kugaluk and Barry samples.

It can be contrasted to the sexual structure of live caribou populations. Throughout Arctic North America, male and female caribou do not exhibit similar mortality profiles; despite similar birth rates, males are underrepresented in all or nearly all adult age categories. Male:female ratios for animals aged 36–118 months commonly vary between 1:3 and 2:3. Hunting pressure appears to be an important factor, with heavily hunted populations exhibiting lower frequencies of males, but even in little-hunted herds the frequency of males seems rarely to exceed about 40%. In older age categories this tendency is exacerbated; only 6% of Kaminuriak animals aged over 10 years were found to be male (Kelsall, 1968: table 15; Miller, 1974: 72–73).

Caribou bands presently frequenting the Barry-Kugaluk area during the autumn-period—when most or all of the archaeological specimens seem to have been killed—demonstrate various compositions, including ''cow–calf'' bands, ''cow-calf-bull'' bands, and ''bull-cow-calf'' bands (see Miller, 1974: table 14). Over the course of the several months when hunting seems to have occurred, it is assumed that hunting *opportunities* would tend to balance out to a fairly accurate reflection of the overall herd structure. This hard

structure was, to judge from modern data, preponderantly female, yet the archaeological sample is either evenly balanced between males and females, or (less likely) shows a preponderance of males. Evidently, the sites' inhabitants were preferentially selecting males, but not to the complete exclusion of females (cf. Gronnow, Meldgaard & Nielsen, 1983: 74–75).

A bias in favour of males is to be expected. As with most herd animals, male and female caribou have quite different annual cycles. Males are in far better shape from a nutritional point of view during the summer and autumn, when females suffer greatly from the demands of birth and lactation. This male nutritional superiority, however, comes to an abrupt end with the November rut, and throughout the winter the slowly recovering females would be preferred by anyone deriving a significant portion of their diet from caribou (Kelsall, 1968; see also Speiss, 1979: figure 2.2). These facts of caribou biology are well known to any caribou-hunting people, and recent caribou hunters have consistently targeted the most appropriate animals depending on the season (Burch, 1972; Brink, 1992).

Given an autumn kill, then, the Kugaluk and Barry site hunters *should* be targeting males. What is surprising, perhaps, is that there are any females in the sample at all. Some could be non-breeding. About 20% of adult females fail to give birth in any given year (Parker, 1972: 71), and would present a nutritional profile similar to that of males. It is not clear, however, that they could be distinguished by hunters from their breeding sisters. It is difficult to escape the conclusion that Kugaluk and Barry site hunters were either unable to exert complete control over sex selection, or that females despite being in poor nutritional shape had some minor specific uses.

Age

Unfortunately, the large sample of intact first molars from the Kugaluk site was thin-sectioned before a crown height measurement was taken (over 125 specimens representing at least 75 individuals: see Morrison, 1988: 70–72). Thin sections embedded in resin remain in the collections of the Canadian Museum of Civilization, but they cannot be accurately measured.

Instead we can turn to the Pokiak and Barry sites. Together they produced 23 ''independent'' mandibles (that is, each representing a single caribou without any possibility of duplication), all dentally mature and with an intact first molar (10 from Pokiak, and 13 from Barry). Crown height was measured for each and then applied to the regression formula derived from the control sample. Results are presented in Tables 5 & 6. It was not found possible to correct for sex, since very few mandibles were complete enough to yield both the two sex-discriminant measurements and an intact m1.

Crown height provides a relatively accurate indicator of age only for animals which are dentally mature, and only such animals have been thus far considered.

Table 5. *Pokiak site age estimates*

Catalogue number	Crown height (mm)	Age (months)	Age (years)
494a			<1 (m1 erupting)
397			1 (m3 erupting)
411b	13	24	2
409a	12·4	31	2
494d	11·7	40	3
452	11	49	4
409e	9·9	63	5
494b	9·5	68	5
409h	9·5	68	5
494c	9	74	6
411a	8·5	80	6
409f	2·3	158	13

Table 6. *Barry site age estimates*

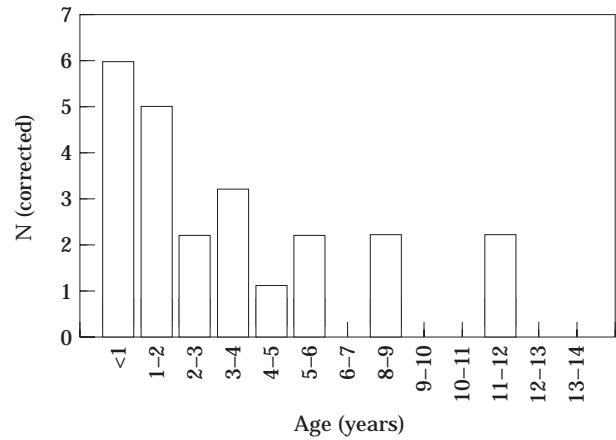| Catalogue number	Crown height (mm)	Age (months)	Age (years)
753-7			<1 (m1 unerupted)
638-2			<1 (m1 erupting)
856-3			<1 (m1 erupting)
986-2			<1 (m1 erupting)
1051			<1 (m1 erupting)
472-2			<1 (m1 erupting)
533-3			1 (m3 erupting)
533-2			1 (m3 erupting)
753-3			1 (m3 erupting)
800-3			1 (m3 erupting)
800-4			1 (m3 erupting)
1015	12·7	27	2
933-2	12·2	34	2
907	12	36	3
472-1	11·5	43	3
800-2	11·2	46	3
933-1	10·5	55	4
933-5	9·8	64	5
604	9·5	68	5
1173-1	8·2	84	7
856-2	8	86	7
638-1	7	99	8
1224	4	137	11
688-1	3·7	140	11

Figure 10. Corrected ages of Barry site caribou.

and immature mandibles, they are differentially identifiable. At the Pokiak site, for example, there was mandibular evidence for 16 caribou, 14 of them adult (counting on right mental foramens), and two immature (both rights). All of the immature specimens are represented in Table 5, but only 10 out of the 14 adults had measureable first molars. The situation was similar in the Barry sample (Table 6); all of the immature specimens could be identified to 1-year age categories, but only 13 out of 14 of the mature specimens could. A similar situation would obtain whatever aging technique was used on adults, since not all represented individuals would have enough teeth to accurately establish an age, while immature specimens are often much more easily identifiable. Simple age histograms like those reported by Speiss (1979: figure 3.2) and Gronnow, Meldgaard & Nielsen (1983: figure 77) cannot be directly read as accurate reflections of past hunting practices. The effect is clearly to overestimate the relative frequency of immature individuals.

A correction factor can be used to compensate for this overestimation. The one proposed is based on the assumption that the adult first molars we can measure are representative of the total population from which they were derived. Thus for the Pokiak site example above, the correction is calculated as the reverse of 10/14, the ratio of assignable to total adult mandibles (14/10 or 1.4). The number of specimens in all adult yearly age categories is then multiplied by this factor. A similar correction factor has been calculated for the Barry site, and results are reflected in the age bar charts appearing as Figures 10 & 11.

There is another potential problem, and that is the possibility of differential taphonomic destruction. Immature skeletal elements are consistently less dense, and hence more vulnerable to destruction, than their adult counterparts. In a review of white-tailed deer mortality profiles from the eastern United States, Munson (1991) notes that many archaeological assemblages have been interpreted as indicating a hunting bias in favour of prime-age adults, when most of the

Obviously, however, younger animals must be included in any age profile, and here we must turn to eruption sequences to provide age estimates. There are two major eruption categories present in all samples in this study. Animals with m1 either unerupted or just erupting are in their first year of life (indeed their first 6 months), while animals with m3 erupting are, for counting purposes, in their second year (15–27 months). Twelve immature, independent mandibles from the site samples were thus assigned age categories, and the results included in Tables 5 & 6.

Unfortunately, the inclusion of immature mandibles in our age profiles, while necessary to consider all age categories, introduces several problems. Because different criteria were used to estimate the ages of mature
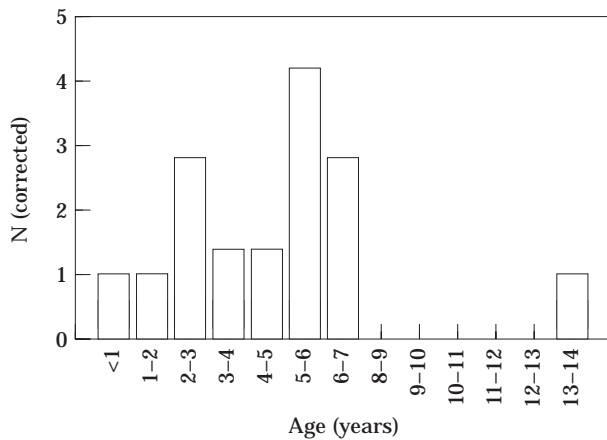
Figure 11. Corrected ages of Pokiak site caribou.

discrepancy can in fact be referred to the much greater survivability of mature over immature mandibles. In a heavily gnawed sheep assemblage, for instance, only 6% of mandibles in the less-than-1-year age category survived, as compared to 50% of 1-year-olds, 80% of 2-year-olds, and 88% of 5-year-olds. The effect here would be to underestimate dramatically immature mandibles in any ravaged context.

This is a much more difficult problem to control for. Spearman's rho correlations suggest that bone density (Lyman, 1984) does not seem to be a significant mediating factor affecting overall caribou anatomical part frequencies (MAUs) at either Pokiak ($r= -0.010$, $N=24$) or the Barry site ($r=0.193$, $N=24$). However at both sites, the youngest immatures—those in the m1 erupting category—are much better represented by mandibles, one of the densest elements, than by any other anatomical part.

The likelihood that the youngest age categories are underrepresented should be considered when interpreting the age-profile bar graphs. With this *caveat* in mind, the two bar graphs present very dissimilar profiles. That from the Barry site (Figure 10) could be termed ''modified catastrophic'' when compared with the overall population profile of a barren-ground caribou herd (Figure 12); that is they show a similar trend toward decreasing frequency with age, but the slope is much less steep. As discussed, some of this gentleness of slop may be due to taphonomic destruction in the youngest age categories, but in the adult categories the shape of the line is almost flat. This can probably be interpreted as deliberate choice on the part of hunters in favour of larger, mature individuals, both as sources of food and of hides. As with sex selection, however, this bias was less than complete.

The mortality profile from the Pokiak site is quite different (Figure 11). It approaches a bell curve, or at least the first half of a bell curve, with a marked preponderance of prime-age animals in the 5- and 6-year-old age categories. Unlike the other sites in the sample, Pokiak was occupied after the 1870s, when
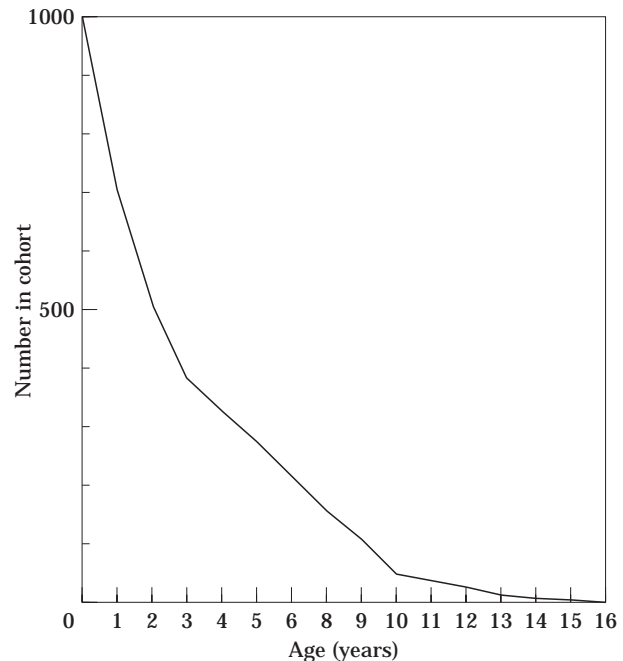

Figure 12. Age structure of the Kaminuriak caribou herd (*R. T. groenlandicus*). Adapted from Miller, 1974: figure 22.

firearms began to supplant the traditional bows and spears for caribou hunting (see Morrison, 1988: 59). Possibly, the highly selective age profile reflects the far greater selective control which firearms would allow.

Discussion

Data from the Kugaluk, Barry and Pokiak sites suggest that caribou selection by both age and sex may have varied over time. Early contact sites dating to before the adoption of firearms in the western Arctic exhibit only modest degrees of selectivity when compared to the population from which they were drawn, while the single post-firearm site shows a much greater degree of selectivity. It is possible that the age and sex profiles from the earlier sites are complicated by the operation of more than one selection factor. Non-breeding females, for instance, may have been selected as equivalent to males from a nutritional point of view (if they could be identified), and both immatures and females may have had specific minor uses beyond strict nutrition. There is, at least, ethnographical evidence of this in the case of immatures, which supplied particularly fine, soft hides, prized especially for children's clothing (Jenness, 1946: 9). However, these complications are likely to have been minor. Female hides do not offer any known advantages over male hides, nor are females particularly useful as a source of antler. Instead, it is argued that the change in degree of selectivity is real, and that it reflects (mainly if not entirely) much increased selective control on the part of the Inuit hunters with the adoption of firearms.

Prior to the introduction of firearms to the western Arctic, Inuit hunters relied on a number of hunting techniques. Most were co-operative, involving up to several dozen people and similar numbers of caribou. Drives were employed, where small bands of caribou were herded into the water to be speared from kayaks or shot, using bows and arrows, by hunters waiting in blinds or behind cover. Given the short effective range of the Inuit bow, and the need to secure as many animals as possible, the final kill must have often been something of a *mêlée* (Stefansson, 1914). Firearms changed all this. Hunting became much more individualistic, and effective killing range was vastly increased, from 1 m or so in the case of a spear, or 20–30 m in the case of a bow (see Jenness, 1922: 146), to several hundred metres with a rifle. Hunters now had the time and the ability to choose calmly which of a band of browsing animals to shoot, without having to make split-second decisions at close range. Before rifles, hunters must have generally tried to maximize a brief window of hunting opportunity by killing every animal they possibly could.

Conclusions

Two formulae have been proposed, one which distinguishes adult males from females on the basis of mandibular measurements, and another which provides age estimates based on m1 crown height. Through the use of discriminant analysis we have formally assessed the relative discriminatory power of the variables employed, and have established well-defined rules for classifying unknown specimens. Application to archaeological data has allowed us to plot graphically the age and sex structure of kill assemblages, and provides the basis for insights into the nature of caribou selection by traditional Inuit hunters.

Some caution, however, is advised. Both formulae are quite powerful, but the resulting estimates are associated with degrees of error. Male and female mandibular measurements overlap, and the difference of only a single millimetre in crown height changes the estimated age by about a year. For reasons of measuring accuracy alone, it is not suggested that dental crown height be used as a seasonal estimate.

A major difficulty is the potential for variability within different caribou populations. This is true even within the *R. t. groenlandicus* subspecies, where geographical variation in size is mosaic-like and hence difficult to control for (Branfield, 1961: 54). The archaeological mandibles from the Bluenose herd area considered here seem, for instance, to be slightly larger than the Kaminuriak control sample, and differences can be expected to be considerably greater across subspecies lines (Banfield, 1961, 1974). Briefly, woodland caribou (*R. t. caribou*) are significantly larger than their barren-ground cousins; the Grant caribou

(*R. t. granti*) of Alaska are slightly larger; and High Arctic Peary caribou (*R. t. pearyi*) are considerably smaller. Of the formulae suggested here, that based on mandibular length/height is the more obviously affected by this variation in size. It is nearly certain that the location and perhaps the slope, of the regression line distinguishing males from females, varies between subspecies, and probably between different populations within subspecies.

Variation in the relationship between m1 crown height and age may relate more to environmental and dietary differences that to population morphology. A tougher, grittier diet will cause teeth to wear faster, making younger animals appear older, shifting age estimates, and decreasing the steepness of mortality profiles.

Only the analysis of more control data sets will help resolve these problems.

Acknowledgements

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Appendix

Table A1. Control sample measurements

Catalogue	Sex	Age (months)	m3–mf (mm)	Height (mm)	Max width (mm)	Tooth row (mm)	m1 crown height (mm)
39338	M	34					12·2
39357	M	34					11·8
39359	M	34					12
39442	F	36	152·8	29·7	15·1	102·1	12·3
39454	F	36	157·5	30·6			11·2
39455	F	36	153	26·6			11
38653	M	36	155·6	31·4	16·1	106·6	12·7
39506	M	37	159	30·8			12
39085	F	39	151	30·1	15·5	100·3	11
39079	M	39	156·5	28·8	15·6	99·2	11·5
39110	M	39	150·5	29·7	13·9	94·9	11·1
39181	F	41	156·5	29·5			11·6
38768	M	41	156·9	31·8			10·9
38769	M	41	157	33·2			12
38770	M	41	158	31·4			12·2
38863	M	41	149·9	29·4	15·8	98·8	10·6
39159	M	41	154·4	28	15·4	106·7	12
38913	F	46	147·5	30·2	16·3	102·4	11
39320	F	46	153	32·9			11·9

Continued

Table A1. Continued

Catalogue	Sex	Age (months)	m3–mf (mm)	Height (mm)	Max width (mm)	Tooth row (mm)	m1 crown height (mm)
39346	F	46	149	31·6	14·6	97·1	11·3
39265	M	46	152·5	29			12·1
39316	M	46	152·2	30·3	17	103·8	11·1
39337	M	46	152·3	33·9			10·1
39037	F	48	150	30·7	15·5	103	11·6
39370	F	48	148	29	14·6	103·5	11
38977	M	48	146·2	33·9	16	101·4	11·1
39504	F	49	153	29·9	14·1	100	11·5
39514	M	49	162·5	32·2			12·2
39526	M	49	144·1	31·4			10·6
38747	M	51	159·6	33·8	14·7	100·8	10·8
38749	M	51	154·9	33·2	14·2	96·1	10·7
39087	M	51	154·5	32·4	13·2	98	10·3
38848	F	53	149·8	30·3	14·2	92·6	10·4
39183	M	53	158·9	32·6			9·4
39090	M	59	162·7	32·4	15·3	104·2	11
39424	F	60	155·7	27·6			
39456	F	60	150·5	29·7			9·7
39483	F	61	140	27·5			10·4
39490	M	61	150	32·6			8·7
39497	M	61	152	32·5			10·3
38900	M	70	149·9	34·5	17·1	99·3	7·4
38666	F	72	147	32·9	16·7	103·9	8·8
39422	F	72	145	28			8·9
39239	F	77	147·2	30·4	13·8	98·7	7·7
39267	M	82					6·7
38958	M	82	142·5	37·3	15·4	93·2	7·8
38961	M	82	156·8	36·7	16·6	101·5	8·2
38967	M	82	152·6	36·1	15·4	97·1	8
39266	M	82	157·5	33·9			8·6
39425	F	84	146	30·1	15·4	103	9·1
38671	F	84	155·7	30·5	15·7	105·9	8·3
39026	F	84	142·8	30·6	14·8	96	8·1
39046	F	84	139·2	34·4	14·1	93	7·5
39389	F	84	149·4	32·8	14·2	95·6	8·6
39431	F	84	150	31·7			9·3
39432	M	85					7·8
39481	M	85	149	31·1			8·3
39532	M	85	143	34·9			7·5
39542	M	85	150·5	35·2	15·8	100	7·1
39546	M	85	154	37·2			7·5
39557	M	85	162	33·8			8
39133	F	87	151	29·7	16·1	103·9	9·3
38659	F	96	145	31·5	16	94·3	6·8
38984	M	96	160	30·5	14·7	94·5	6·1
39405	F	108	147	34·9	16·5	104·3	7·6
39433	F	108	142	28·2	13·7	92·4	6·4
39470	F	109	148·3	33·3	17	105	7·3
39479	M	109	149·5	32·7			5
39480	M	109	155·2	37·1			6·2
39543	M	109	160·5	32·5			5·3
39553	M	109	146·5	34·8			5·3
39160	F	113	149·2	32·5	14·1	98·7	7·4
39336	F	118	150·3	32·2			6·1
39024	F	120	146·7	36·3	16·1	94·9	6·5
39440	F	120	143·8	30·8	15·2	101·2	6·3
39476	F	121	150	30·3			7
39491	F	133	146	32·1	16·1	103·1	7·2
39182	F	137	146·5	32			5·8
39475	F	181	147·5	26·8			1·5