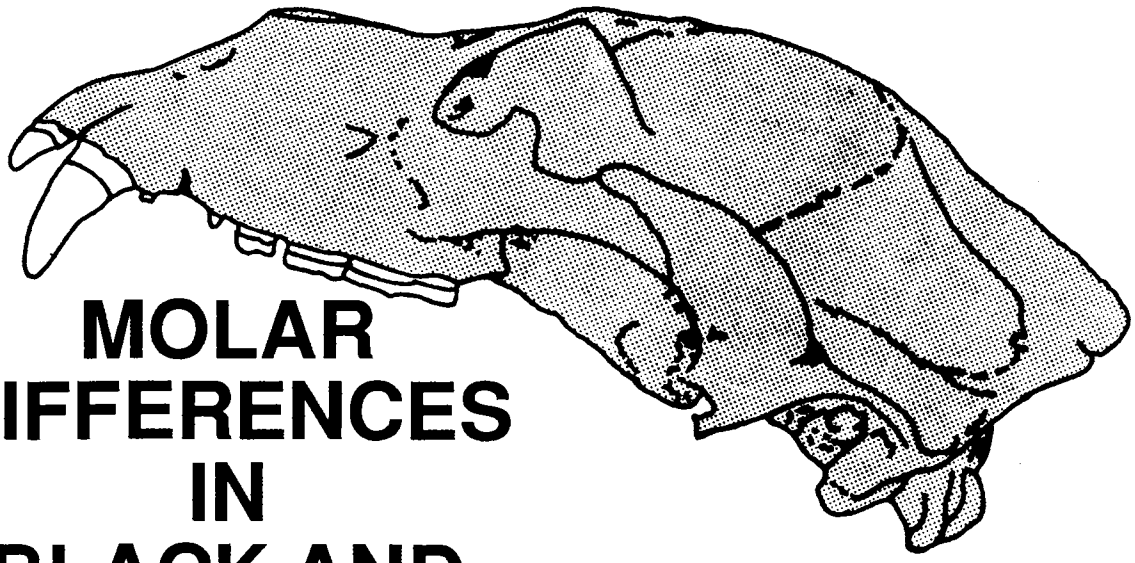
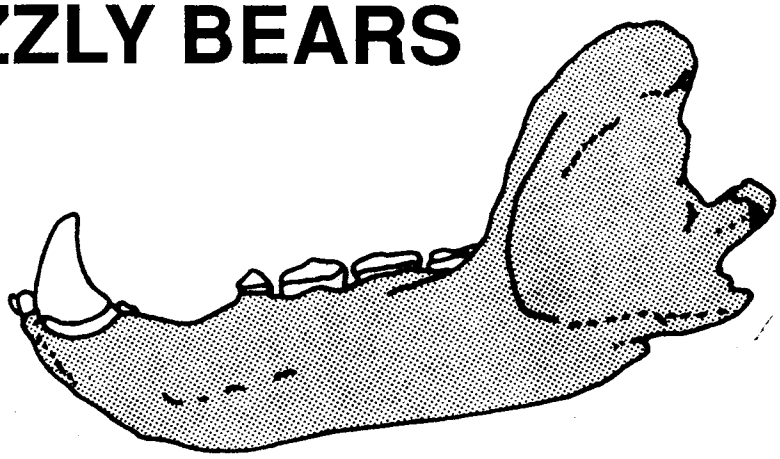


MOLAR DIFFERENCES IN BLACK AND GRIZZLY BEARS



a new system to distinguish interior bears from the central Yukon and northern British Columbia

Yukon
Renewable Resources

MOLAR DIFFERENCES IN

BLACK AND GRIZZLY BEARS

A NEW SYSTEM TO DISTINGUISH INTERIOR BEARS

FROM THE CENTRAL YUKON AND NORTHERN BRITISH COLUMBIA

Skeeter W. A. Verlaine-Wright[1]
Bernard L. Smith[2]
Steven G. Meester[3]

1 Biotic Interactions, Box 5251, Whitehorse, Yukon Y1A 4Z1
2 Fish and Wildlife Branch, Yukon Department of Renewable Resources, Box 2703, Whitehorse, Yukon Y1A 2C6
3 Department of Statistics and Actuarial Science, University of Waterloo, Waterloo, Ontario N2L 3G1

Director, Fish and Wildlife Branch

Senior Big Game Biologist

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EXECUTIVE SUMMARY

1. Every year there is at least one serious disagreement in bear species identification between hunters and wildlife officials.

2. A few disagreements cannot be resolved using published dental criteria. The Yukon bears are substantially different in a morphological sense from southern British Columbia or California bears that other researchers have used. A cooperative study between Simon Fraser University and the Yukon Fish and Wildlife Branch was set up to resolve the problem.

3. Teeth are used because they don't grow after erupting above the gum and have minimal variation between individuals of the same species.

4. Wild black and grizzly bears do not interbreed.

5. Eight measurements and observations, mainly of molars, were taken for each of 30 grizzly and 59 black bears, mainly from the southern Yukon.

6. One of the 8 previously published techniques correctly identified all bears. The other techniques correctly identified 80-100% of the grizzly bears and 0-100% of the black bears.

7. A method was developed that will correctly identify the skull as follows:

   a. 1. On the lower jaw locate the third tooth from the back on either the left or right side (Mandibular Premolar 4).
      2. Observe if a medial cusp is located in the valley of the tooth.
      3. If the tooth is heavily worn or missing go on to the next technique. If a medial cusp is present, a grizzly is indicated. If a medial cusp is not present, a black bear is indicated.

   b. 1. Measure the length of the hindmost tooth on the upper jaw (Maxillary Molar 2). Measure both the right and left teeth.
      2. Measure the length of the next to hindmost tooth on the upper jaw (Maxillary Molar 1). Measure both the right and left teeth.
      3. Insert the averages of each of the two tooth measurements into the formula M=(3.6 x Average length of hindmost upper teeth) + (3.1 x Average length of next to hindmost upper teeth) - 170.
      4. If M is greater than 0, a grizzly is indicated. If M is less than 0, a black bear is indicated.

   c. 1. Measure the length of the hindmost tooth on the upper jaw (Maxillary Molar 2). Measure both the right and left teeth.
      2. Measure the width of the next to hindmost tooth on the upper jaw (Maxillary Molar 1). Measure both the right and left teeth.

3. Insert the averages of each of the two tooth measurements in the formula M=(3.6 x Average length of the hindmost upper teeth) + (3.8 x Average width of the next to hindmost upper teeth) - 163. If M is greater than 0, a grizzly is indicated. If M is less than 0, a black bear is indicated.

8. It is recommended this method be adopted by the Yukon Fish and Wildlife Branch. Further study, particularly of northern bears, is recommended.

9. All measurement data is summarized in Appendix B.

ACKNOWLEDGEMENTS

We gratefully acknowledge the funding provided by the Department of Indian and Northern Affairs and the Yukon Department of Education. We are grateful to Dr. Alton Harestad of the Department of Biological Sciences at Simon Fraser University for his help and expertise and to Philip Merchant of the Yukon Fish and Wildlife Branch for his editorial assistance and providing unique sample skulls. We thank the Conservation Officers of the Yukon Fish and Wildlife Branch for their time and aid in sample procurement and the Vertebrate Museum of the University of British Columbia for samples. We also appreciate the time and artistry of Thom Rodger for the graphics and drawings. Thanks to Stephen Waterreus for his perseverance at bear skull cleaning. Last, but far from least, we thank the hunters and outfitters of the Yukon for allowing us to use their bear skulls in this study.

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1.0 INTRODUCTION

Approximately once each year a serious disagreement occurs in the Yukon between a hunter and a wildlife official whether a bear being submitted for inspection is a black bear (*Ursus americanus*)[1] or a grizzly bear (*Ursus arctos*)[2]. If the bear is in fact a very dark small female grizzly and if an outfitter believes it is a black bear, under the current point harvest system, this error can cost the outfitter $10,000 to $15,000 in lost income and could lead to legal action.

In most cases errors are easily dealt with using published dental characteristic techniques. In some cases however, some published techniques identify a skull as coming from a black bear while other techniques suggest that the same skull came from a grizzly bear. Since these published techniques were developed using southern bear populations, regional differences in bear morphology likely are the source of the misclassification problem.

To resolve this, that is to determine a species separation method relevant to the northern interior black and grizzly bears found in the Yukon, a sample of northern interior skulls was examined in a cooperative study involving Simon Fraser University and the Yukon Fish and Wildlife Branch.

This paper outlines the results of the study in a non technical format and language. Another technical paper (Verlaine-Wright et al, in prep.) will summarize this information in a scientific journal for academic audiences. We have included all measurement data to permit future morphological comparisons.

At present, we are reasonably confident with the method advocated, but recognize that additional samples, particularly of small grizzly and large black bears and bears from the northern Yukon, would be beneficial.

Dental characteristics are used instead of claw size and shape, forehead profiles, hair colour, etc., to distinguish species. There are 3 reasons for this:

a) Teeth, once emerged, do not grow. Except for wear on the crown or cavities, the rear molars of a fall yearling will be the same size when this yearling is an old adult. Everything else measurable on a bear either grows or wears.

---

[1]Subspecies *U. a.* Pallas, after Youngman (1975). Cowan and Guiguet (1965) suggest *U. a. cinnamomum* (Audoban and Bachman) as the subspecies in northern interior British Columbia, however this is inconsistent with Youngman's (1975) later interpretation.

[2]Subspecies *U. a. horribilis* Ord after Youngman (1975). None of the skulls were of a size that suggested *U. a. middendorfi* that Youngman (1975) suggests may occasionally wander from the southeast Alaskan coast into the Yukon.

b) There is comparatively little variation in tooth measurements compared to other skeletal measurements. As in people, there can be enormous variation in skull size or femur (thigh bone) length, but little variation in teeth. Nearly all mammals are classified by dental characteristics.

c) These characteristics are simple to use and easy to measure.

It should also be pointed out that there are no records of wild grizzlies and wild black bears interbreeding and producing offspring (Jonkel 1988).

2.0 METHODS

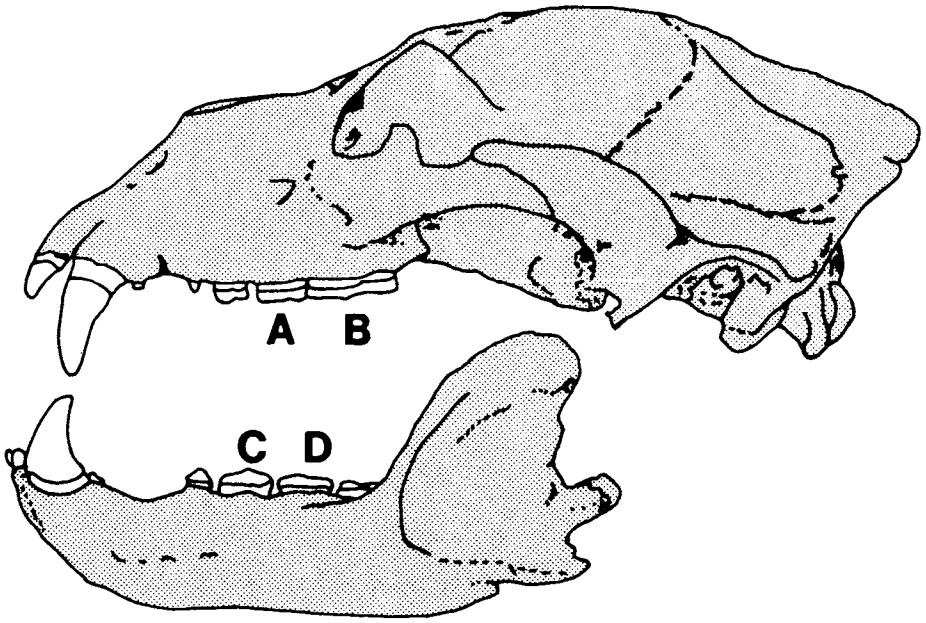
Bear skulls were obtained from Yukon hunters and outfitters, conservation officers, and from the biology department at the University of British Columbia. Only Yukon bear skulls and those from northern interior British Columbia were used.

Species identity of these bear skulls was determined by individuals who have assessed over 500 bears and these determinations were mainly based on dental criteria. 'Borderline' cases were further assessed using hide and claw characteristics. Obviously, when starting a study like this it is essential that correct initial species determinations are made. We included as many of the 'borderline' skulls as we could since rejecting them would have seriously compromised the study and not solved our problem.

Measurements, that a literature review indicated had some potential in species identification, were taken with a dial caliper (Figure 1). In all, the 4 measurements and 4 observations took about 4 minutes per skull. These data were analyzed using the Stepwise Discriminant Analysis computer program BMDP7M (Dixon 1983).

The Stepwise Discriminant Analysis computer program was used to find the best mathematical way to separate black from grizzly bear skulls. This involved graphing one dental measurement against another. Each skull included on the graph was represented by one point. The black bear skulls formed one clump of points on the graph while the grizzly skulls formed another clump. The analysis procedure found the line that best divided the two clumps and provided a mathematical formula describing this line. When two tooth measurements are inserted in this formula, and the solution to the formula calculated, the resulting number is either above or below 0. A number below 0 indicates a black bear and a number above 0 indicates a grizzly. The technique is illustrated in Figure 2.

Figure 1: Location of teeth used to distinguish species.



A. next to hindmost upper tooth *(Maxillary Molar 1)*

B. hindmost upper tooth *(Maxillary Molar 2)*

C. third lower tooth from back *(Mandibular Premolar 4)*

D. next to hindmost lower tooth *(Mandibular Molar 1)*

3.0 RESULTS AND DISCUSSION

This section is broken into 3 parts. First we explain the samples and measurements, then evaluate the previously published techniques, and then propose a new way that should work best for Yukon bears.

3.1 Skull samples and measurements

We measured 30 grizzly and 59 black bear skulls. Most were from the southern Yukon. Most bears were males but some were of unknown sex.

Tooth measurements were made with a dial caliper (Appendix A). We took the measurements a number of times and found the measurements all +/-0.2 mm. Teeth were similar (no significant difference, $P<.05$) between left and right side, so in most cases we used an average of the two in our analysis. Damaged teeth were not measured. For example, a cavity on the end of a tooth would have affected the length measurement. All measurements are included in Appendix B.

Descriptive statistics were calculated. They are presented with the following evaluations.

3.2 Evaluation of previously published techniques

In the next few pages we separately describe each of the 8 techniques and determine how accurately each one classified the sample skulls. Not all the techniques were used on all the skulls since in some cases damaged or missing teeth prevented their use.

3.2.1 Technique 1 - Length of hindmost upper tooth

Using the length of the hindmost upper tooth (Maxillary Molar 2) as a species separation technique was first reported by Grinnell in 1937.

If the upper hindmost tooth (Maxillary Molar 2) length is greater than 31 mm (millimeters), a grizzly is indicated. If the length is less than 31 mm, a black bear is indicated (Grinnell 1937, Storer and Tevis 1955).

When tested on the skulls in this study, Technique 1 correctly identified 28 of 30 grizzly skulls (86 %); 2 grizzly skulls were identified as black bears. All the black bear skulls were correctly identified.

Table 1. Statistics describing length of upper hindmost tooth (in mm)

Species	Number of Skulls	Mean	Standard Deviation	Range
Black	58	13.7	.8	11.6-16.4
Grizzly	28	18.6	1.0	16.1-21.1

3.2.2 Technique 2 - Width of hindmost upper tooth

The location of the widest portion of the hindmost upper tooth technique was developed by Hall and Kelson in 1959 and reaffirmed by Glass in 1973.

If the greatest width of the hindmost upper tooth (Maxillary Molar 2) is located at the front 1/3 of the tooth, a grizzly is indicated. If the widest portion is in the middle 1/3 of the tooth, a black bear is indicated (Appendix A) (Hall and Kelson 1959, Glass 1973).

When tested on the skulls in this study Technique 2 correctly identified 25 of 30 grizzly skulls (83 %) and incorrectly identified 5 grizzly skulls as black bears. Forty-one of 59 black bear skulls (69 %) were correctly identified. The other 18 black bear skulls were incorrectly identified as grizzlies.

3.2.3 Technique 3 - Accessory cusp on next to hindmost lower tooth

The presence or absence of an accessory cusp (extra cusp) is used in this technique and no measurements are required.

If an accessory cusp is located on the next to hindmost lower tooth (Mandibular Molar 2), a grizzly is indicated. If no accessory cusp is found, a black bear is indicated (Hall and Kelson 1959).

When tested on the skulls in this study, Technique 3 correctly identified 19 of 20 grizzly skulls (95 %). One grizzly skull was incorrectly identified as a black bear. Forty of the 55 black bear skulls (72%) were correctly identified. The other 15 black bear skulls were incorrectly identified as grizzlies.

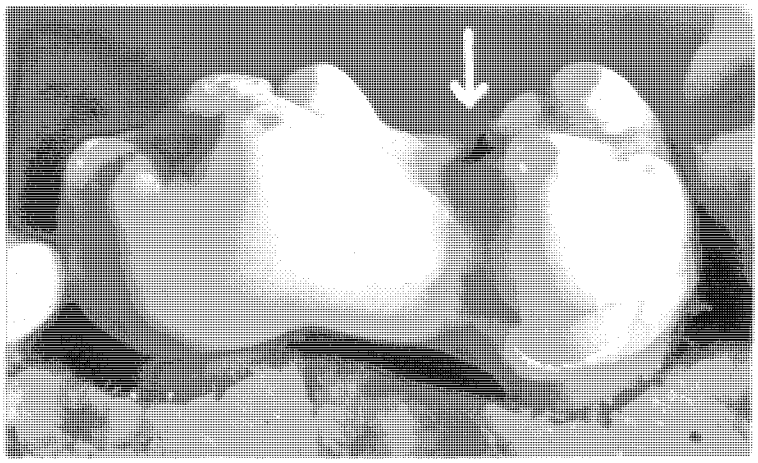
3.2.4 Technique 4 - Medial cusp on third lower tooth from back

A medial cusp is an extra cusp in a 'valley' on the tooth.

The presence of a medial cusp on the third lower tooth from the back (Mandibular Premolar 4) indicates a grizzly. Absence of the cusp indicates a black bear (Fig. 2) (Hall and Kelson 1959).

When tested on the skulls in this study, Technique 4 correctly identified all the grizzly and black bear skulls (100%).

Black Bear



Grizzly Bear

Figure 2 : A medial cusp on the third lower tooth from the back was found on all grizzly bear skulls (sample size = 22) but not found on the black bear skulls.

3.2.5 Technique 5 - Length ratio of two upper teeth

This technique uses the ratio of two length measurements.

If the length of the hindmost upper tooth (Maxillary Molar 2) is greater than 1.5 times the length of the next to hindmost upper tooth (Maxillary Molar 1), a grizzly is indicated. If the ratio is less or equal to 1.5, a black bear is indicated (Glass 1973).

When tested on the skulls in this study, Technique 5 correctly identified 21 of 30 grizzly skulls (70 %) and incorrectly identified 9 of the grizzly skulls as black bears. Fifty of 59 black bear skulls (84%) were correctly identified. Nine of the black bear skulls were incorrectly identified as grizzlies.

Table 2 summarizes measurement statistics for the next to hindmost upper tooth. Statistics for the measurement of the hindmost upper tooth are provided in Table 1.

Table 2. Statistics describing length of next to hindmost upper tooth (in mm)

Species	Number of Skulls	Mean	Standard Deviation	Range
Black	59	17.0	.8	15.4-18.6
Grizzly	25	22.1	1.0	18.9-23.7

3.2.6 Technique 6 - Valley on third lower tooth from back

Rather than using a measurement or cusp, this technique uses the presence or absence of a valley.

If there is a lengthwise valley on the back part of the top of the third lower tooth from the back (Mandibular Premolar 4), a grizzly is indicated. Absence of a valley indicates a black bear (Hall and Kelson 1959).

When tested on the skulls in this study, Technique 6 correctly identified all the grizzly skulls and none of the black bear skulls. All the grizzly skulls had the described valley on the appropriate tooth and therefore were correctly identified as grizzlies by this technique. All of the black bear skulls had the valley on the particular tooth so were incorrectly identified as grizzlies using this technique.

3.2.7 Technique 7 - Length of next to hindmost lower tooth

In 1977 K.R. Gordon studied bear skulls from California and British Columbia and developed the most recently published techniques, Techniques 7 and 8.

If the length of the next to hindmost lower tooth (Mandibular Molar 1) is greater than 20.4 mm, a grizzly is indicated. If the length is less than 20.4 mm a black bear is indicated (Gordon 1977).

When tested on the skulls in this study, Technique 7 correctly identified all the grizzly skulls and 50 of the 59 black bear skulls (84 %). Nine black bear skulls were incorrectly identified as grizzlies.

Table 3. Statistics describing length of next to hindmost lower tooth (in mm)

Species	Number of Skulls	Mean	Standard Deviation	Range
Black	59	18.7	1.1	15.4-21.4
Grizzly	26	24.2	1.1	22.2-26.3

3.2.8 Technique 8 - Width of next to hindmost lower tooth

Another technique developed by Gordon (1977) uses the width of the tooth.

If the width of the next to hindmost lower tooth (Maxillary Molar 1) is greater than 10.5 mm, a grizzly is indicated. If the width is less than 10.5 mm a black bear is indicated (Gordon 1977).

When tested on the skulls in this study, Technique 8 correctly identified all the grizzly bear skulls and 56 of 59 black bear skulls (94 %). Three black bear skulls were incorrectly identified as grizzly bear skulls.

Table 4. Statistics describing width of next to hindmost lower tooth (in mm)

Species	Number of Skulls	Mean	Standard Deviation	Range
Black	58	11.1	.8	1.0-13.4
Grizzly	27	14.8	1.0	12.2-16.0

3.2.9 Conclusions regarding published techniques

The results of testing the published techniques on Yukon bear skulls were not satisfactory except for Technique 4, the one using a medial cusp. When Gordon (1977) published the techniques he developed, he included the results of an evaluation of previously developed techniques using skulls from California and British Columbia. He also found that previously published techniques were less than 100% accurate. Since it is common to find bears whose teeth are too worn to verify the presence or absence of a medial cusp, reliable techniques still had to be found.

A Stepwise Discriminant Analysis computer program BMDP7M was used to provide the following techniques (Techniques 9 and 10, below). This particular computer program is often used by scientists to identify characteristics that separate one group of subjects from another.

3.3 Recommended strategy to identify Yukon bear skulls

Since Technique 4 correctly identified all the Yukon bear skulls with minimal tooth wear, it is part of our recommended method. It is suggested that it be used first since no measurements are needed.

3.3.1 Technique 4 - Medial cusp on third lower tooth from back

1. On the lower jaw locate the third tooth from the back on either the left or right side (Figure 1).

2. Observe if a medial cusp is located in the valley of the tooth as shown in Figure 2.

3. If a medial cusp is present in the valley, a grizzly is indicated.

4. If there is no medial cusp in the valley, a black bear is indicated.

5. If the teeth are too worn or missing go on to the next technique.

3.3.2 Technique 9 - Discriminant Formula 1

The lengths of the hindmost and next to hindmost upper teeth (Maxillary Molar 1 and 2) are used in this technique.

1. Measure the length of the hindmost upper tooth(Maxillary Molar).The tooth is measured from the middle of the front edge to the furthest point of the edge as shown in Appendix A.

2. Measure both the right and left teeth, then find the average of the two. If one tooth is damaged or missing, use only the measurement of the undamaged tooth.

3. Measure the length of the next to hindmost upper tooth (Maxillary Molar 1). The length of this tooth is found by placing the dial caliper along the outside of the tooth.

4. Measure both the right and left teeth, then find the average of the two. If one tooth is damaged of missing, use only the measurement of the undamaged tooth.

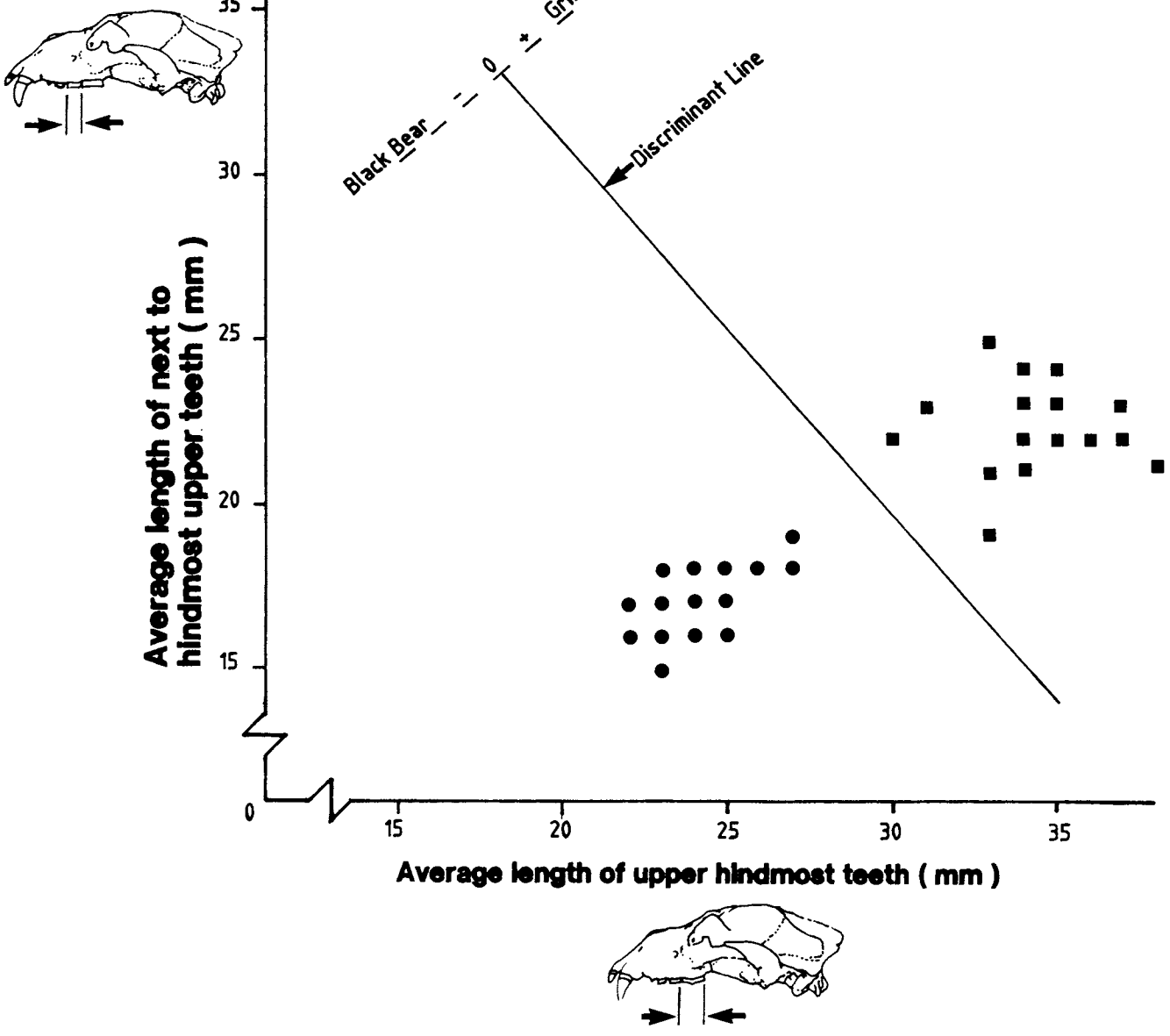
5. Insert the averages of both teeth or the measurements of the single good tooth into the formula below. Calculate the value of M.

   M = (3.6 x Average length of hindmost upper tooth) + (3.1 x Average length of next to hindmost upper tooth) - 170.

   If the value of M is greater than 0, a grizzly is indicated.
   If the value of M is less than 0, a black bear is indicated.

Figure 3 : Length of hindmost upper tooth versus length of next to hindmost upper tooth showin discriminant line m = (3.6 x Average length of hindmost upper teeth) + (3.1 x Average length of next to hindmost upper teeth) – 170.

Grizzly Bear = ■
Black Bear = ●



3.3.3 Technique 10 - Discriminant Formula 2

The length of the hindmost upper tooth is also used in this technique along with the width of the tooth next to it.

1. Measure the length of the hindmost upper tooth (Maxillary Molar 2). The tooth is measured from the middle of the front edge to the furthest point of the back edge, as shown in Appendix A.

2. Measure both the left and right teeth, then find the average of the two. If one tooth is damaged or missing use only the measurement of the undamaged tooth.

3. Measure the width of the next to hindmost upper tooth (Maxillary Molar 1). This tooth is measured at the widest part of the tooth that is perpendicular to a line connecting the two large cusps as shown in Appendix A.

4. Measure both the right and left teeth, then find the average of the two. If one tooth is damaged or missing use only the measurement of the undamaged tooth.

5. Insert the averages or single undamaged tooth measurements into the formula below. Calculate the value of M.

   M = (3.6 x Average length of hindmost upper teeth) + (3.8 x Average width of next to hindmost upper teeth) - 163.

   If M is greater than 0, a grizzly is indicated.
   If M is less than 0, a black bear is indicated.

3.3.4 Evaluation of recommended methodology

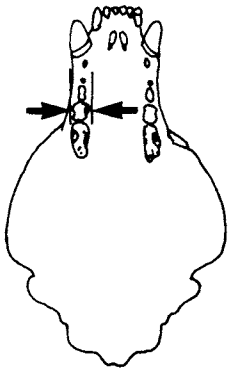
In order to test our developed method we had to test Techniques 9 and 10. We already knew Technique 4, using the medial cusp, correctly identified all the skulls with teeth not worn too much.

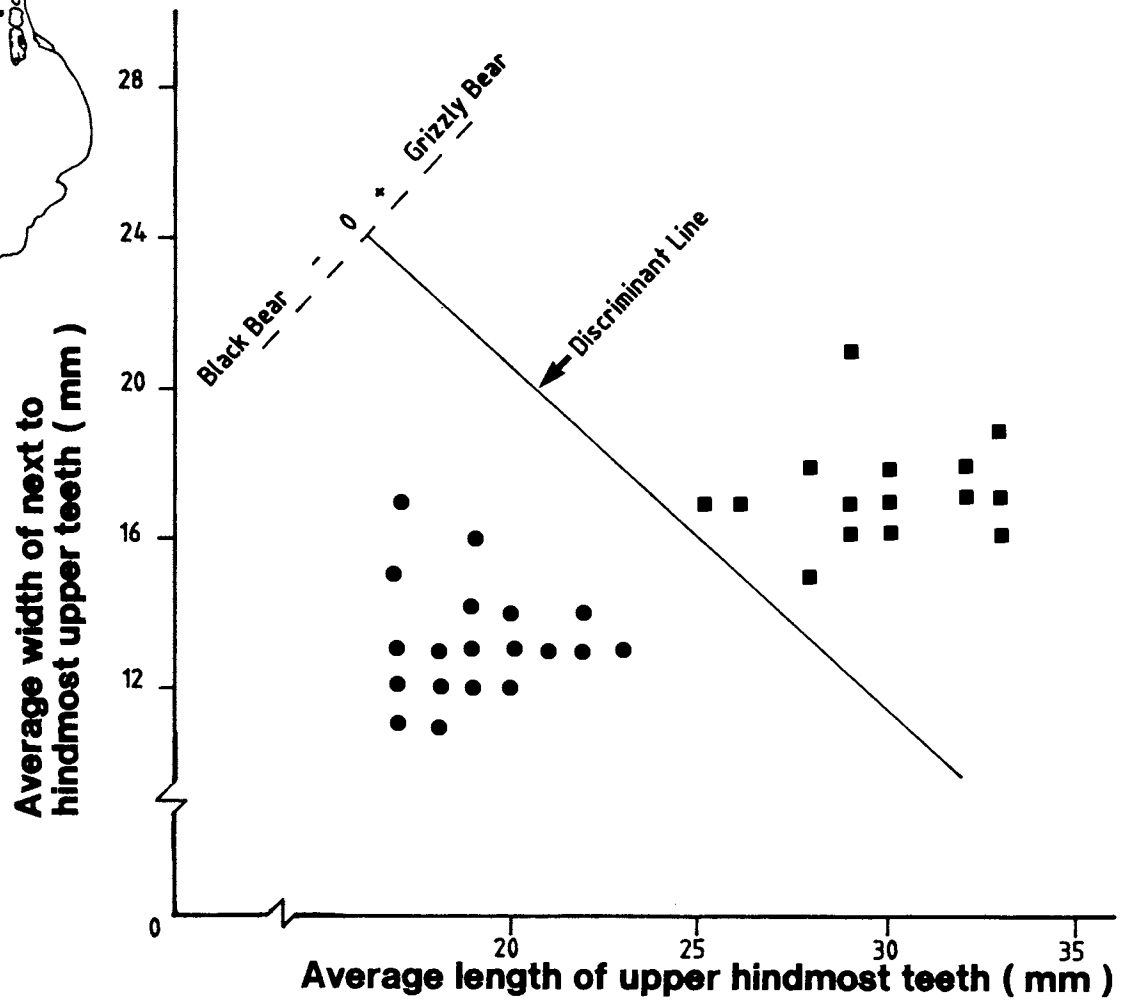
We used a procedure known as Lachenbruch's holdout procedure. This holds the set of measurements from one skull out of the computer program, calculates a formula, then classifies the withheld skull. Each set of skull measurements is in turn withheld and then classified by the formula that was developed without it. This procedure is well known and respected by scientists and has itself been tested many times.

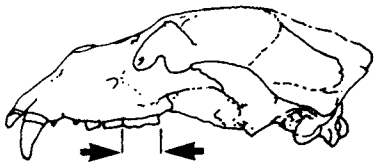
Using Lachenbruch's holdout procedure, we found Techniques 9 and 10 to have an error rate of 0.0%. Therefore the techniques perform extremely well.

Figure 4 : Width of next to hindmost upper tooth versus length of hindmost upper tooth showing discriminant line
m = (3.6 x Average length of hindmost upper teeth) + (3.8 x Average width of next to hindmost upper teeth) – 163.

■ = Grizzly Bear
● = Black Bear







4.0 CONCLUSION

Seven of the eight previously published techniques to separate black from grizzly bears using dental criteria were found to be inadequate in these northern interior bears. One technique, the absence or presence of a medial cusp, was found to correctly identify 100% of the bear skulls that had teeth in suitable condition to observe the absence or presence of the cusp.

The BMDP7M-Stepwise Discriminant Analysis computer program was used to find the best combination of tooth measurements which, in a mathematical formula, would correctly identify the bear skulls. The combination of measurements were found and formulated Techniques 9 and 10.

The error rate of developed Techniques 9 and 10 were tested and found to be 0.0%.

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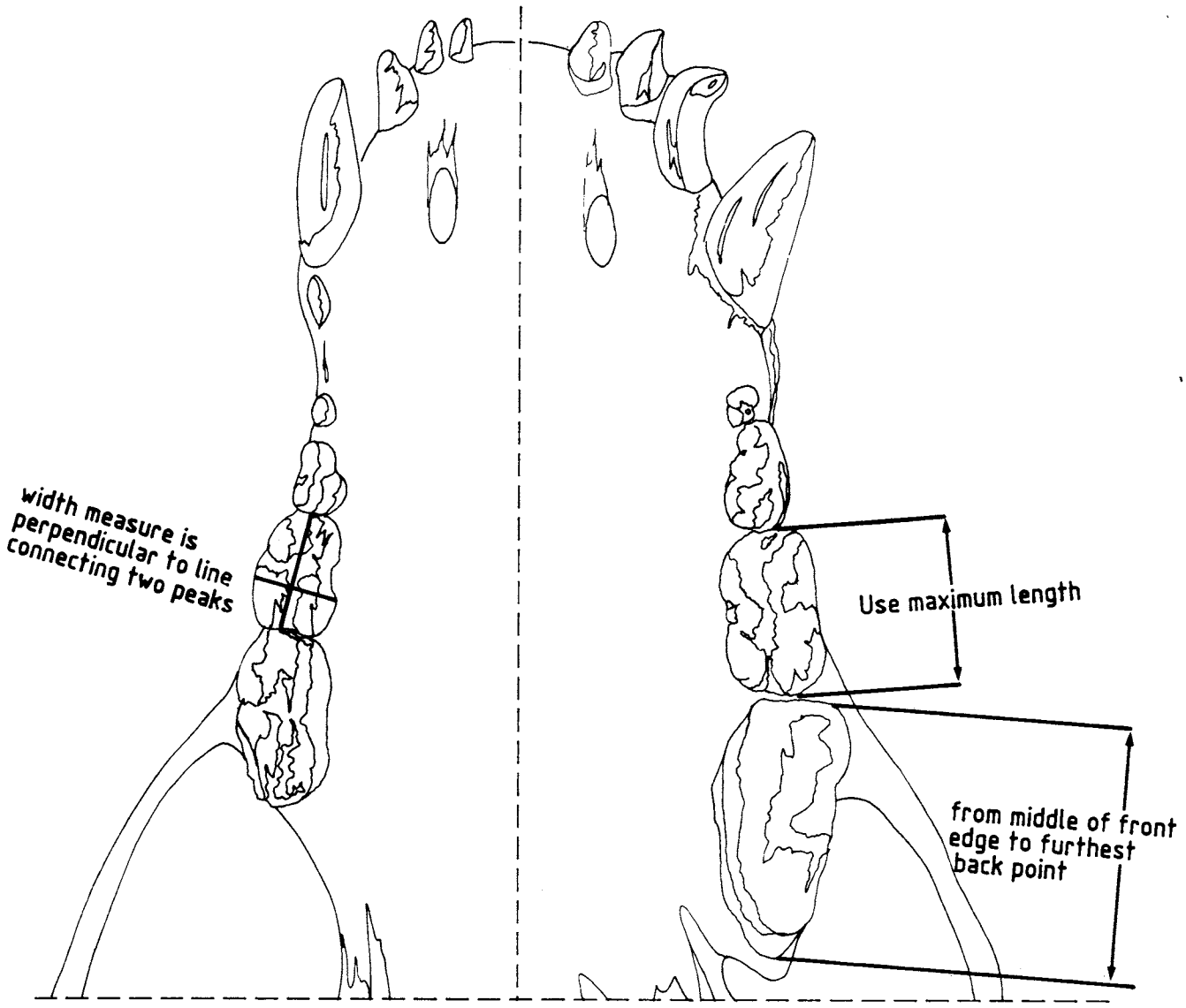
Appendix A : Details of tooth measurements on upper jaw



APPENDIX B Tooth measurement data (all measurements in millimeters)

				MANDIBULAR M1 LENGTH		MANDIBULAR M1 WIDTH		MAXILLARY M2 LENGTH		MAXILLARY M2 WIDTH		MAXILLARY M2 WIDEST PART		MAXILLARY M1 LENGTH		MAXILLARY M1 WIDTH		MANDIBULAR PM CUSP		MANDIBULAR M1 CUSP	
OBS	SKULL	SP	SEX	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
1	4789	B	?	19.3	19.9	11.9	11.8	24.8	25.0	14.1	14.5	ANT 1/3	ANT 1/3	17.1	17.3	12.8	12.8	NO	NO	YES	YES
2	YBS?	B	?	19.5	19.8	12.6	11.9	25.8	25.4	15.7	15.2	MID 1/3	MID 1/3	17.5	17.6	13.0	12.9	NO	NO	YES	YES
3	4032	B	?	18.9	18.9	10.8	10.7	22.6	23.3	13.0	13.3	MID 1/3	MID 1/3	16.6	15.4	11.6	11.5	NO	NO	YES	YES
4	4325	B	?	18.6	18.8	11.2	10.8	22.6	22.0	13.6	13.4	MID 1/3	ANT 1/3	16.9	17.4	13.0	13.1	NO	NO	NO	NO
5	YBS?	B	?	18.7	18.1	10.4	10.7	23.5	23.8	13.8	13.6	MID 1/3	MID 1/3	16.4	16.4	12.3	12.5	NO	NO	NO	NO
6	YBS?	B	?	16.9	17.4	10.3	9.9	22.6	22.0	12.5	12.9	MID 1/3	MID 1/3	16.4	16.2	11.6	16.7	NO	NO	NO	NO
7	YBS?	B	?	20.1	19.5	10.7	11.0	.	.	.	.	.	.	17.2	17.4	12.5	12.5	NO	NO	NO	NO
8	YBS?	G	?	25.2	25.1	15.5	15.1	37.1	37.1	18.6	18.4	ANT 1/3	ANT 1/3	22.3	23.4	17.2	17.4	YES	YES	YES	YES
9	YBS?	G	?	24.1	23.5	12.6	14.8	34.6	34.3	18.6	18.7	ANT 1/3	ANT 1/3	21.9	21.8	16.6	16.4	WORN	WORN	WORN	WORN
10	4984	G	?	24.7	25.6	15.9	15.7	34.5	34.8	19.9	19.3	MID 1/3	MID 1/3	23.4	23.3	17.9	17.9	YES	YES	YES	YES
11	YBS?	G	?	24.1	.	12.8	.	37.3	38.5	20.2	19.6	ANT 1/3	ANT 1/3	21.6	20.1	18.7	18.2	WORN	WORN	WORN	WORN
12	4788	B	?	20.3	20.4	12.3	12.6	26.5	27.0	15.3	15.5	MID 1/3	MID 1/3	18.8	18.4	13.8	13.8	NO	NO	NO	NO
13	4847	B	?	18.6	18.5	12.0	12.3	24.0	23.5	13.7	13.7	MID 1/3	MID 1/3	17.9	18.1	13.7	13.6	NO	NO	NO	YES
14	YBS?	B	?	19.9	20.1	12.2	12.1	25.5	26.0	14.3	14.3	MID 1/3	MID 1/3	17.7	17.9	12.8	13.0	NO	NO	NO	YES
15	4787	B	?	17.2	17.4	10.4	10.5	21.9	21.9	12.8	12.8	MID 1/3	MID 1/3	15.9	15.9	11.9	11.7	NO	NO	NO	NO
16	4985	B	?	18.5	18.6	11.2	11.4	25.3	25.4	13.5	13.5	ANT 1/3	ANT 1/3	16.8	16.7	12.1	12.1	NO	NO	NO	NO
17	4133	B	?	17.0	17.5	10.0	10.3	22.0	22.1	12.1	12.2	MID 1/3	MID 1/3	15.8	15.8	11.2	11.2	NO	NO	NO	NO
18	YBS?	B	?	17.7	17.9	10.8	10.3	22.5	22.5	12.3	12.4	MID 1/3	MID 1/3	17.1	16.6	12.0	12.3	NO	NO	NO	NO
19	4149	B	?	18.6	18.6	10.6	10.5	23.4	23.0	12.9	12.8	MID 1/3	MID 1/3	15.3	15.1	11.3	11.0	NO	NO	YES	YES
20	4135	B	?	16.8	16.8	9.8	10.2	21.5	22.2	13.0	13.1	MID 1/3	MID 1/3	15.7	16.1	12.4	12.5	NO	NO	NO	NO
21	4774	B	?	19.0	18.8	11.5	11.7	24.5	24.4	13.7	13.4	MID 1/3	MID 1/3	17.6	17.6	13.0	12.8	NO	NO	WORN	WORN
22	YBS?	B	?	17.0	17.3	10.5	10.1	24.6	24.3	13.1	13.1	MID 1/3	MID 1/3	16.6	16.5	12.0	12.2	NO	NO	NO	NO
23	YBS?	B	?	20.9	20.1	12.4	11.8	24.7	24.8	14.9	14.7	MID 1/3	ANT 1/3	18.3	18.2	12.7	12.5	NO	NO	NO	NO
24	3963	B	?	15.2	15.6	9.6	9.7	24.7	24.8	14.0	14.0	MID 1/3	MID 1/3	17.6	17.6	13.0	13.1	NO	NO	NO	NO
25	4027	B	?	16.4	16.7	9.7	9.9	21.9	21.2	13.0	12.6	MID 1/3	MID 1/3	16.1	16.2	11.4	11.8	.	.	NO	NO
26	4771	B	?	20.4	20.3	12.2	12.4	26.2	26.8	14.5	14.5	MID 1/3	ANT 1/3	18.2	17.9	12.9	12.8	NO	NO	NO	NO
27	3882	B	?	17.1	17.0	10.2	10.3	22.9	22.7	13.3	13.2	MID 1/3	MID 1/3	17.3	17.3	11.6	11.6	NO	NO	NO	NO
28	YBS?	B	?	18.1	17.6	11.1	11.2	25.0	24.8	13.4	13.3	ANT 1/3	ANT 1/3	17.1	17.1	12.5	12.8	WORN	WORN	WORN	WORN
29	YBS?	B	?	18.3	18.8	11.2	11.4	23.8	24.1	13.6	13.5	ANT 1/3	ANT 1/3	17.3	17.2	12.3	12.8	NO	NO	NO	NO
30	4811	B	?	19.1	18.8	10.8	11.1	24.7	24.8	13.8	13.7	MID 1/3	MID 1/3	16.1	16.5	12.0	11.9	NO	NO	YES	YES
31	UBC1	G	?	24.3	24.3	15.4	15.5	34.5	33.9	19.2	19.1	ANT 1/3	ANT 1/3	22.1	22.1	16.5	16.7	YES	YES	YES	YES
32	UBC2	G	?	.	24.6	.	14.2	33.5	34.0	18.9	18.7	.	.	23.0	21.5	16.9	17.3	WORN	WORN	WORN	WORN
33	UBC3	G	?	23.4	23.5	15.8	15.1	34.9	34.9	22.3	19.9	ANT 1/3	ANT 1/3	23.0	23.1	17.2	17.3	YES	YES	YES	YES
34	UBC4	B	?	19.3	18.9	11.2	11.6	23.0	22.3	14.2	14.0	MID 1/3	MID 1/3	17.3	17.3	12.2	13.0	NO	NO	NO	NO
35	UBC5	G	?	25.5	25.5	15.4	15.8	35.2	34.8	19.4	20.1	ANT 1/3	ANT 1/3	23.6	23.8	17.0	17.4	YES	YES	YES	YES
36	UBC6	B	?	18.9	18.5	11.9	10.6	23.4	23.4	13.5	13.3	MID 1/3	MID 1/3	16.7	17.1	12.8	12.6	NO	NO	NO	NO
37	UBC7	B	?	18.9	18.5	10.1	10.5	23.7	23.8	13.6	13.4	MID 1/3	MID 1/3	15.8	15.8	12.5	12.2	NO	NO	NO	NO
38	UBC8	B	?	17.7	18.3	10.3	10.6	23.1	23.3	12.9	12.8	MID 1/3	MID 1/3	16.1	17.3	11.8	11.6	NO	NO	NO	NO
39	UBC9	G	F	.	24.1	12.1	12.2	.	.	.	.	.	.	22.6	.	16.2	.	.	.	WORN	WORN
40	YBS?	G	M	22.6	22.9	12.9	12.9	33.8	33.3	19.0	18.8	ANT 1/3	ANT 1/3	21.2	21.2	17.3	16.9	WORN	WORN	WORN	WORN
41	YBS?	G	M	24.5	24.7	15.1	14.9	34.9	34.9	18.8	18.6	ANT 1/3	ANT 1/3	23.1	22.5	17.6	18.1	YES	YES	YES	NO
42	YBS?	G	?	22.3	22.0	13.4	13.4	33.0	.	16.9	.	ANT 1/3	.	18.7	19.1	15.2	15.1	YES	YES	YES	YES
43	YBS?	B	?	18.5	19.2	11.0	11.1	24.6	24.0	13.7	13.5	MID 1/3	MID 1/3	17.0	16.3	12.2	12.1	NO	NO	NO	NO
44	YBS?	G	M	24.3	24.1	14.3	14.6	34.8	34.8	18.9	18.6	ANT 1/3	ANT 1/3	22.0	22.2	15.9	16.1	YES	YES	YES	YES
45	YBS?	G	F	24.9	24.9	15.7	16.1	37.5	37.4	18.1	18.2	MID 1/3	MID 1/3	20.8	21.1	15.7	16.1	YES	YES	WORN	WORN
46	YBS?	G	M	22.1	26.8	15.4	15.1	33.3	33.5	17.9	16.1	ANT 1/3	ANT 1/3	.	25.2	.	17.5	WORN	WORN	WORN	WORN
47	YBS?	G	M	25.5	24.8	15.3	15.5	36.7	36.8	19.2	18.8	ANT 1/3	ANT 1/3	22.4	21.9	18.2	17.2	YES	YES	YES	YES
48	YBS?	G	M	22.4	22.6	15.7	15.1	34.4	33.8	19.3	18.8	ANT 1/3	ANT 1/3	21.0	22.1	16.1	16.3	YES	YES	YES	YES
49	YBS?	B	?	17.4	16.9	.	.	21.8	22.3	12.6	12.5	MID 1/3	MID 1/3	16.1	16.2	12.4	12.2	WORN	WORN	WORN	WORN
50	YBS?	B	M	19.2	19.2	10.8	10.8	23.8	23.7	13.8	13.7	MID 1/3	MID 1/3	17.6	17.5	12.7	12.6	NO	NO	YES	WORN

APPENDIX B (cont'd).

				MANDIBULAR M1 LENGTH		MANDIBULAR M1 WIDTH		MAXILLARY M2 LENGTH		MAXILLARY M2 WIDTH		MAXILLARY M2 WIDEST PART		MAXILLARY M1 LENGTH		MAXILLARY M1 WIDTH		MANDIBULAR PM CUSP		MANDIBULAR M1 CUSP	
OBS	SKULL	SP	SEX	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
51	YBS?	B	M	19.3	19.3	12.4	12.5	26.3	27.1	14.7	14.8	MID 1/3	MID 1/3	18.4	18.2	13.5	13.0	NO	NO	YES	YES
52	YBS?	B	M	20.2	20.5	13.5	13.3	27.0	27.0	16.6	16.2	ANT 1/3	ANT 1/3	17.6	17.6	14.3	14.1	NO	NO	WORN	WORN
53	3044	B	?	18.1	18.1	10.8	10.8	22.1	22.3	12.8	12.8	MID 1/3	MID 1/3	16.5	15.9	12.0	12.2	NO	NO	YES	YES
54	4798	B	M	19.7	19.5	11.0	11.0	24.6	24.6	14.9	14.9	MID 1/3	MID 1/3	16.7	16.8	13.5	13.5	NO	NO	NO	NO
55	4832	B	M	19.4	19.2	11.0	11.3	23.6	24.0	13.7	13.7	ANT 1/3	ANT 1/3	17.9	17.5	12.1	12.3	NO	NO	NO	YES
56	4997	B	F	17.4	18.1	10.1	10.1	21.8	21.6	13.3	13.0	MID 1/3	MID 1/3	15.7	15.4	11.7	11.4	NO	NO	NO	NO
57	5004	G	F	24.6	24.5	14.6	14.3	35.1	34.8	17.3	17.3	ANT 1/3	ANT 1/3	22.6	22.0	16.4	16.4	YES	YES	YES	YES
58	5004	G	F	25.5	25.5	14.5	13.9	34.3	33.6	17.9	18.3	ANT 1/3	ANT 1/3	22.2	21.7	16.4	16.5	YES	YES	YES	YES
59	5005	B	F	17.4	18.0	10.0	11.6	22.6	22.9	11.4	11.6	MID 1/3	MID 1/3	15.9	15.7	11.3	11.2	NO	NO	NO	NO
60	5015	G	?	23.6	23.9	13.9	14.3	33.7	34.1	18.0	18.6	ANT 1/3	ANT 1/3	21.1	21.3	16.7	17.0	YES	YES	YES	YES
61	5040	G	F	24.4	24.5	15.3	15.5	36.7	37.3	18.2	18.7	ANT 1/3	ANT 1/3	23.0	22.9	17.1	16.7	YES	YES	YES	YES
62	5042	G	M	24.0	23.6	14.9	13.6	30.8	30.0	17.1	16.9	MID 1/3	MID 1/3	21.2	20.8	17.2	16.3	YES	YES	YES	YES
63	5043	B	?	18.9	18.9	10.8	11.1	22.6	22.0	13.5	14.3	MID 1/3	MID 1/3	16.7	16.3	12.3	12.4	NO	NO	NO	NO
64	5114	G	M	24.0	.	15.6	.	31.0	.	18.6	.	ANT 1/3	ANT 1/3	22.9	.	16.8	.	YES	YES	YES	YES
65	5116	G	?	24.0	26.2	15.4	15.1	35.4	35.9	20.2	20.0	MID 1/3	MID 1/3	21.9	22.5	17.0	17.3	YES	YES	YES	YES
66	5118	G	?	24.3	24.2	16.5	15.5	34.5	33.2	18.3	18.9	ANT 1/3	ANT 1/3	24.4	23.0	17.3	17.3	WORN	WORN	WORN	WORN
67	5120	B	?	18.8	18.9	11.2	11.1	23.5	24.1	13.8	13.9	ANT 1/3	ANT 1/3	16.1	16.6	12.5	12.6	NO	NO	NO	NO
68	5121	B	M	20.6	22.1	12.4	12.5	26.9	27.3	14.6	14.7	ANT 1/3	ANT 1/3	17.5	18.1	13.0	12.9	NO	NO	YES	YES
69	5122	B	M	20.1	20.5	11.6	11.7	23.4	23.4	13.7	13.6	ANT 1/3	ANT 1/3	17.8	17.8	13.0	13.1	NO	NO	NO	NO
70	5123	B	M	18.3	18.5	11.6	11.7	25.1	24.9	14.1	14.0	MID 1/3	MID 1/3	18.0	18.0	13.2	13.2	NO	NO	YES	YES
71	5124	B	M	18.8	18.7	10.3	11.2	23.0	22.4	12.9	12.7	MID 1/3	MID 1/3	17.9	17.3	11.6	11.7	NO	NO	NO	NO
72	5125	B	M	18.3	18.0	10.7	10.6	25.1	25.1	13.5	14.0	MID 1/3	MID 1/3	16.4	16.1	12.6	12.6	NO	NO	NO	NO
73	5126	B	?	19.9	19.9	11.3	11.2	24.5	24.8	14.1	14.1	ANT 1/3	ANT 1/3	18.6	18.0	13.3	13.3	NO	NO	NO	NO
74	5127	B	M	18.1	18.7	11.4	11.7	23.5	23.7	13.7	13.3	MID 1/3	MID 1/3	16.8	17.6	12.3	12.3	NO	NO	NO	NO
75	5128	B	?	17.2	17.4	10.6	10.7	23.1	23.7	13.4	13.3	MID 1/3	MID 1/3	16.9	17.2	11.9	11.8	NO	NO	NO	NO
76	5131	B	M	19.5	19.5	12.0	11.9	25.4	25.5	14.3	13.9	MID 1/3	MID 1/3	17.4	17.1	12.8	12.8	NO	NO	YES	YES
77	5132	G	M	26.3	26.2	14.4	15.3	36.5	36.4	18.0	17.8	ANT 1/3	ANT 1/3	22.2	22.2	17.4	17.6	YES	YES	YES	YES
78	5133	B	M	18.9	18.8	10.7	11.4	23.0	23.7	13.6	13.8	ANT 1/3	MID 1/3	17.0	17.3	12.6	12.6	NO	NO	NO	NO
79	5134	B	M	19.1	19.1	11.7	11.6	25.1	25.4	13.7	13.5	MID 1/3	MID 1/3	17.0	16.8	12.6	12.4	NO	NO	NO	NO
80	5136	B	F	17.6	17.6	11.4	10.8	25.5	25.1	13.3	12.7	MID 1/3	ANT 1/3	16.2	16.2	11.8	12.1	NO	WORN	NO	NO
81	5137	B	M	18.6	18.0	10.1	10.5	24.8	24.4	13.9	14.0	MID 1/3	MID 1/3	16.9	16.7	12.8	12.8	NO	NO	NO	NO
82	5138	G	M	23.3	23.1	14.0	14.4	33.5	32.5	14.8	17.3	ANT 1/3	ANT 1/3	18.8	.	14.7	14.8	WORN	WORN	WORN	WORN
83	5139	B	M	19.4	18.3	11.3	11.1	21.8	22.0	13.8	13.6	MID 1/3	MID 1/3	16.3	15.9	12.1	12.3	NO	NO	NO	NO
84	5141	B	?	20.4	20.6	11.6	11.4	.	.	14.8	14.8	ANT 1/3	MID 1/3	18.2	18.1	13.8	13.9	NO	NO	NO	NO
85	5143	B	F	17.0	18.3	10.4	10.9	23.3	24.5	14.0	13.9	MID 1/3	MID 1/3	16.9	16.8	12.7	12.9	NO	NO	NO	NO
86	5146	G	M	22.7	22.9	15.0	15.1	34.4	34.4	18.4	18.6	ANT 1/3	ANT 1/3	.	23.9	24.0	17.7	YES	YES	YES	YES
87	5148	G	F	22.8	22.5	13.4	13.6	33.0	34.1	17.6	17.8	MID 1/3	ANT 1/3	21.2	21.5	16.8	16.7	YES	YES	YES	YES
88	5149	B	M	18.7	18.4	11.0	11.0	22.2	22.5	13.0	12.9	ANT 1/3	MID 1/3	17.0	16.5	12.1	12.2	NO	NO	YES	YES
89	5153	G	M	24.4	24.1	15.4	15.4	34.6	35.2	17.9	18.1	ANT 1/3	ANT 1/3	22.3	22.6	17.6	17.8	WORN	WORN	WORN	WORN

Appendix C Species Identification Worksheet

1. Third lower tooth from back badly worn
   Yes - go to step 3
   No - go to step 2

2. Medial cusp present (see Fig. 2)
   Yes - bear is a grizzly
   No - bear is a black

3. Measure length of hindmost upper teeth (see page 10 if one tooth is damaged)

	right	__.__ mm
	left	__.__ mm
Total		__.__ mm
divide by 2 to get average		__.__ mm **(A)**

4. Measure length of next to hindmost upper teeth (see page 10 if one tooth is damaged)

	right	__.__ mm
	left	__.__ mm
Total		__.__ mm
divide by 2 to get average		__.__ mm **(B)**

5. Calculate M where

   $M = (3.6 \times A) + (3.1 \times B) - 170$

6. If M is greater than 0, the skull is a grizzly. If M is less than 0, the skull is a black bear.

   If you want to double check by using Discriminant Formula 2, use steps 7-10.

7. Use the same measurements from step 3

	right	__.__ mm
	left	__.__ mm
Total		__.__ mm
divide by 2 to get average		__.__ mm **(C)**

8. Measure the width of the next to hindmost upper teeth. (if one tooth is damaged see page 12)

	right	__.__ mm
	left	__.__ mm
Total		__.__ mm
divide by 2 to get average		__.__ mm **(D)**

9. Calculate M where

   $M = (3.6 \times C) + (3.8 \times D) - 163$

10. If M is greater than 0, the skull is a grizzly.
    If M is less than 0, the skull is a black bear.