Maximum Estimated Bite Force, Skull Morphology, and Primary Prey Size in North American Carnivores

by

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Abstract

This study was established to estimate the bite-forces of North American carnivores and relate this parameter to primary prey size and skull morphology. Eight hundred and eighty eight (888) skulls, from five different families within the Order Carnivora were utilized. Animals of both sexes from each of the Families of Canidae, Felidae Mustelidae, Ursidae, and Procyonidae were divided so as to represent a cline from smaller to larger species. Twelve (12) skull measurements were taken from each individual. Of these measurements, eight were applied to a bite force estimation formula developed by Thomason (1990). Since estimated bite force can be observed as a result of a function of size, bite force estimations were correlated with different skull parameters to determine if estimated bite forces can be easily and accurately predicted by one or a few skull measurements. Three selected parameters were also used in a Discriminant Analysis to determine if all the species in the study could be classified accordingly. Results of the Principle Component Analysis indicated that of the measured parameters, the maximum skull length, maximum skull width, and the cross sectional length of the masseter muscle were the three parameters most highly related to the estimated bite force. Further analysis showed that these three parameters combined could create equations that could discriminate the population of carnivores with a high degree of accuracy. Furthermore, it was revealed that the estimated bite forces were highly correlated with maximum skull width in certain species; however; not as highly in others. Also, when correlated with maximum skull width, each species maximum estimated bite force creates

lines-of-best-fit that do not differ significantly in slope ($F=1.76$ $P>.05$), but do in y-intercept ($F=24.35$, $P<.0001$). When maximum estimated bite force was plotted versus primary prey weight, a strong positive correlation occurred. Results will be discussed in terms of the evolution of maximum estimated bite force in relation to primary prey size in the Order Carnivora.

It was concluded that:

1) maximum estimated bite forces of the Order Carnivora in North America represent a continuum from the smallest to largest;

2) three skull parameters (maximum skull width, maximum skull length, and the length of the cross- sectional area of the masseter muscle) are highly correlated with the maximum estimated bite force;

3) maximum skull width was most highly correlated skull parameter with maximum estimated bite force for all species;

4) 82 – 85% of the members of the fourteen species studied could be correctly designated to their appropriate grouping on the basis of the maximum skull width, maximum skull length, and the length of the cross-sectional area of the masseter muscle;

5) the accuracy was greater when only species considered to be true carnivores as opposed to those considered omnivores were utilized in the analysis;

6) the slopes of the relationship between the maximum estimated bite force and the maximum skull width in all families of the Order Carnivora were not significantly different, suggesting that similar evolutionary forces have influenced all groups;

7) variability in skull parameters and maximum estimated bite force increases with the number of biomes and prey species that a species occupies and utilizes;

8) significant correlations exist between the maximum estimated bite force and the primary prey weight within the Families Mustelidae, Felidae, and Canidae, and the Order Carnivora;

9) the correlation coefficient between the maximum estimated bite force and primary prey weight increases when omnivorous species are eliminated from the analysis;

10) high variances of frequency distributions of the maximum estimated bite force are representative of niche breadth and associated with species with a wider geographic distribution and primary prey species diversity;

11) in all cases where overlap of frequency distributions of the maximum estimated bite force were significant, the species were allopatric and filled similar niches in their perspective geographic ranges;

12) the degree of overlap between sympatric species in the frequency distributions of the maximum estimated bite force reflect varying levels of interspecific competition and character displacement.

This thesis is dedicated to Mrs. J. Epp, who initiated my interest and desire to do research in the biological sciences, to my father, Mr. Hessel Wiersma who although is no longer of this earth would be pleased of my accomplishments, and mostly to my mother, Mrs. Marie Wiersma, who without her support, this project and life would not have been accomplished.

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To my many friends and colleagues Sarah Proceviat, Liane Capodagli, Andrew Deck, John Wilson and Jeff Waltenbury to name a few, I send out complete gratitude for understanding and helping me through the ups and downs.

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Introduction

The Order *Carnivora* first appeared 70 million years ago and the causal factors influencing the evolution and radiation of modern families from ancestral forms remain unclear (MacDonald 1984). Radinsky (1981) explored the differentiation of modern carnivore families in relation to niche selection, changes in skull morphology, and specifically variables that were primarily related to strength of bite. Radinsky (1981) suggested that among the four groups of carnivores (mustelids, canids, felids, and viverrids), the mustelids and felids would have the most powerful bites and canids, the least when properly scaled. Radinsky (1981) also showed that 62 species of viverrids, canids, mustelids and felids could be grouped into their respective families on the basis of functionally significant aspects of skull morphology. Further studies by Radinsky (1981b) included the Families Ursidae and Procyonidae, and he concluded that there was a lack of correlation between diet and aspects of skull morphology related to bite strength. The same study also concluded that the skull shape and ability of the morphological measurements of the skull to classify the families might be related to other factors besides adaptative ones. Rosenzweig (1966; 1968) found that larger carnivorous mammals specialize on larger vertebrate prey and postulated that in mammalian predator/prey systems a strong relationship would exist between predator size and prey size. Emerson (1985) concluded further that the varying foraging strategies found among modern mammalian carnivores were linked to differences in skull morphology and jaw conformation. Studies by Mallory *et al.* (1996) found that of 47 cranial parameters, 6 were statistically significant for discriminating wolves (*Canis lupus*) from coyotes (*Canis latrans*) and these six parameters were associated with the lever mechanics of the jaw (temporalis moment arm, masseter moment arm, tympanic bulla width, condyle to first molar length, brain case length, and mandibular length). This suggested that bite force was a major factor influencing differences in foraging strategies and speciation between these closely related species.

The Order Carnivora is composed of mammalian species whose diets are principally mammalian vertebrate prey that are captured, killed, and consumed (Biknevicius and Van Valkenburgh 1996). Species have been subdivided into "true carnivores", those that consume primarily meat and "omnivores", those that consume a variety of items including plant, invertebrate, and vertebrate tissues (Pianka 1994). In this study, "true carnivores" were considered members of the Families Mustelidae (weasel), Felidae (cats), and Canidae (dogs); while the Families Procyonidae (raccoons) and Ursidae (bears) were considered "omnivores".

Predators require adequate skull, jaw, muscle, and tooth morphology to capture, kill, and consume prey. In addition, predation has associated risks, as prey resist capture and often have defense systems such as antlers, horns, hooves, and teeth (Mallory et. al. 1994; Biknevicius and Van Valkenburgh 1996). Natural selection should favour predators with the optimal cranial morphology to minimize risk and maximize predation efficiency. Relationships of strength to loading may be fundamental to the mechanical design of the predator skull and the mechanical demands of mastication (Thomason 1991). During the evolution of mammals from reptiles, the skull has been modified in direct association with changes in the masticatory ability (Van Valkenburgh and Koepfli 1993; Walker and Liem 1994). During this period, the lever mechanics of the masticatory apparatus and the cranium both adapted in response to changes in dietary specialization (Turnbull 1970; Eisenberg 1981).

Morphological specialization in the skull and lower jaw have been shown to be correlated with differences in feeding habits in the Orders Primata, Chiroptera, and Carnivora (Radinsky 1981; Jaslow 1986) and analyses among higher taxa have revealed important information on morphological and ecological associations (Emerson 1985; Schmitz and Kolenosky 1985; Jaslow 1986; Wayne 1986; Walker and Liem 1994). However, comparative analysis among related taxa are not well documented and further analysis may provide insight into resource partitioning, competition avoidance, and speciation in the Order Carnivora.

In North America, there are five main families of eutherian carnivores (*Mustelidae, Felidae, Canidae, Procyonidae,* and *Ursidae*) each with distinctly different diets and hunting strategies. Ewer (1973) stated that carnivores were very adaptable in feeding habits and few species were restricted to or even largely dependent upon a single food source. However, Krohne (1998) concluded that although a variety of prey items were consumed, carnivores specialized on a single prey or a guild of closely related prey species to minimize competition and increase foraging efficiency. A search of the literature indicated that prey specialization did exist in all families studied (Ewer 1973; Pianka 1994; Krohne 1998).

Mustelidae

The Family Mustelidae has the smallest species and largest number of species of any carnivore family in North America (Ewer 1973; Linscombe *et al.* 1982). The smallest member of the Family Mustelidae studied during this research was the ermine (*Mustela erminea*). Although prey items consumed by this species ranged from plant material, invertebrates, rodents, small birds, and rabbits (Rosenzweig 1966), small rodents, particularly of the genus *Microtus* were considered the primary prey (Osgood 1936; Ewer 1973) and usually comprised more than 50% of the diet.

The mink (*Mustela vison*) which is an efficient hunter in both aquatic and terrestrial environments has a diversified diet that commonly includes insects, crustaceans, fish, amphibians, reptiles, birds, and mammals (Linscombe *et al.* 1982). However, the primary prey were from the Subfamily Microtinae and include voles and muskrats.

The marten (*Martes americana*) is an opportunist and takes a wide variety of prey, especially when the preferred prey items are unavailable (Strictland *et al.* 1982). Although berries, eggs, insects, voles, chipmunks, squirrels, and hares have been found in the diet (Burt and Grossenheider 1952), rodents of the

Subfamily Micotinae and the Family Sciuridae are considered the primary prey of this mustelid (Francis and Stephenson 1972).

The fisher (*Martes pennanti)* is also an opportunistic feeder (Strictland *et al.* 1982) and the diet varies with geographic location and season (Ewer 1973). According to Coulter (1960) and Clem (1977), there is no significant difference between the diets of males and females in spite of the large degree of sexual dimorphism. Rosenzweig (1966) noted that fisher consumed larger prey than marten and primary prey species include small rodents, snowshoe hare, and porcupine.

The wolverine (*Gulo gulo*) is limited to the Sub-Arctic and Boreal Forest Biomes and is the largest member of the Family Mustelidae. In Scandinavia during winter, wolverine feed primarily on reindeer (Ewer 1973; Wilson 1982); however; they have also been observed attacking young and diseased moose, roe deer, fox, hares, birds, rodents, and eating carrion. For the purpose of this study, the primary prey of wolverine was considered to be caribou and hares.

Felidae

The Family Felidae is composed of species, which range from moderate sized predators such as the lynx and bobcat to the largest predator on the continent, the cougar (Ewer 1973; Linscombe *et al.* 1982). The bobcats (*Lynx rufus*) is found in many biomes throughout North America (Eastern Deciduous, Prairie, Coastal Plain, Cordillerian, and Desert Biomes) and has been found to utilize a wide range of prey species including invertebrates, amphibians, reptiles, birds, small mammals, and the occasional deer (Matson 1948; Petraborg and Gunvalson 1962). Matson (1948) found that when small game was plentiful, larger ungulates comprised a very small portion of the diet, while during harsh winters, shrews although not preferred, comprised a significant portion of the diet (Rolling 1945). However, data indicate that lagomorphs constitute the primary prey in the bobcat diet throughout the range (Young 1958).

The lynx (*Lynx canadensis*) is limited to the Boreal Forest Biome in North America. In a study by Saunders (1963), 73 percent of the lynx diet was found to be composed of snowshoe hare, while the remaining 27 percent was represented by small rodents, birds, moose and caribou carrion. Similarly, Nellis and Keith (1968) found that the diets of lynx in Alberta were comprised of snowshoe hares, ruffed grouse, and carrion, which were represented at 61, 17, and 11 percent, respectively. All studies on this species indicate that lagomorphs and specifically snowshoe hare are the primary prey of lynx.

Historically, the cougar *(Felis concolor)* was found in all biomes throughout North America except the Arctic and Boreal Forest (Burt and Grossenheider 1952) and represented one of the most adaptive and ubiquitous mammalian species on the continent. In an extensive investigation of 3000 scats, Hibben (1939) found that deer remains (*Odocoileus spp.*) comprised 82 percent of the scat volume, while porcupine and lagomorphs each represented 6 percent. Other mammals killed and consumed included badgers, skunks, foxes, and coyotes (Ewer 1973). All studies indicate that members of the Family Cervidae (deer) are the primary prey of this felid.

Canidae

The Family Canidae is composed of species that range from moderate to large sizes and representative species are found in all biomes throughout North America (Mech 1970; Ewer 1973). The range of the arctic fox (*Alopex lagopus*) is limited to the Tundra Biome in North America. It preys on a variety of items including plant material, invertebrates, eggs, small to medium sized birds, microtine rodents, arctic ground squirrels, arctic hare, and scavenges on wolf and polar bear kills and garbage around communities (Barabash-Nikiforov 1935; Burt and Grossenheider 1952; Chesemore 1968). However, arctic fox primarily prey on small mammals of the genus *Lemmus* and *Dicrostonyx*.

The red fox (*Vulpes vulpes*) is found throughout much of North America and occupies the Boreal Forest, Eastern Deciduous, Prairie, and Cordillera Biomes. It is an opportunistic feeder and has been reported to consume plant material, berries, invertebrates, birds, small and medium sized rodents, and lagomorphs (Errington 1935; Scott 1943; Fisher 1951; Samuel and Nelson 1982; Henry 1986). Scavenging on the remains of wolf kills has also been observed; however, small mammals (voles and mice) are considered the primary prey of this species (Samuel and Nelson 1982).

Historically, the coyote (*Canis latrans*) was primarily associated with the Prairie, Desert, and Dry Tropical Forest Biomes of North America; however, it has recently expanded its range to include most of the continent, with the exception of the Tundra Biome. According to Ewer (1973), the food habits of the coyote resembles that of foxes more than the wolf and the primary prey are lagomorphs and rodents. Carrion is readily eaten and killing of large prey such as deer is uncommon (Bekoff 1982). Birds do not constitute an important item of the diet and Sperry (1933) found in a five-year study with >8000 stomachs samples, that lagomorphs were the principle prey item.

Historically, the wolf (*Canis lupus*) was found in all biomes throughout North America, although in recent times this species has been extirpated from most of its former range south of the 49th parallel (Mech 1970; Ewer 1973; Carbyn *et al.* 1993). In all biomes, wolves subsisted primarily on large ungulate prey (Lamothe 1991) and to a lesser extent on beaver, marmot, lagomorphs, and medium sized birds (Ewer 1973; Paradiso and Nowak 1982). As the sizes of ungulates varied with biome, wolf morphology varied widely across the continent (Mulders 1997).

Procyonidae

The Family Procyonidae is composed of species that are medium in size and representative species are found in the Eastern Deciduous Forest, Coastal Plain, Prairie, Cordillera, and Tropical Forest Biomes in North America. The most common species, the raccoon (*Procyon lotor*) has spread northward during the past century (Kaufmann 1982) and is considered omnivorous (Ewer 1973; Kaufmann 1982). Stuewer (1943) found that animal matter was most common in the diet during the spring (approx. 50%) and microtine rodents and crayfish were the most common items consumed. As fruit and berries ripened throughout the summer, vegetation become increasingly important and between July and

September plant material represented almost 80% of the diet. For the purpose of this study, crayfish and small rodents were considered to be the primary prey items.

Ursidae

Historically, the Family Ursidae was found in all biomes throughout North America except in the Coastal Plan, Desert, and Tropical Forest Biomes. With the exception of the polar bear (Ursus arcticus), which specializes on seals and is a true carnivore, all ursid species (black bear, *Ursus americanus* and grizzly bear, *Ursus horribilus*) are highly dependent on vegetable food (Ewer 1973) and are omnivorous.

The black bear (*Ursus americanus*) is considered an omnivorous feeder (Ewer 1973), although animal matter has been found in the diet in the spring and early summer. Franzmann *et al.* (1980) identified moose and deer remains in a stomach analysis and described a moose killed by a black bear. However, vegetable matter forms the bulk of the diet in this species during most of the year (Ewer 1973) and Burt and Grossenheider (1952) indicated that the food of the black bear included berries, nuts, tubers, insects, small mammals, eggs, and carrion.

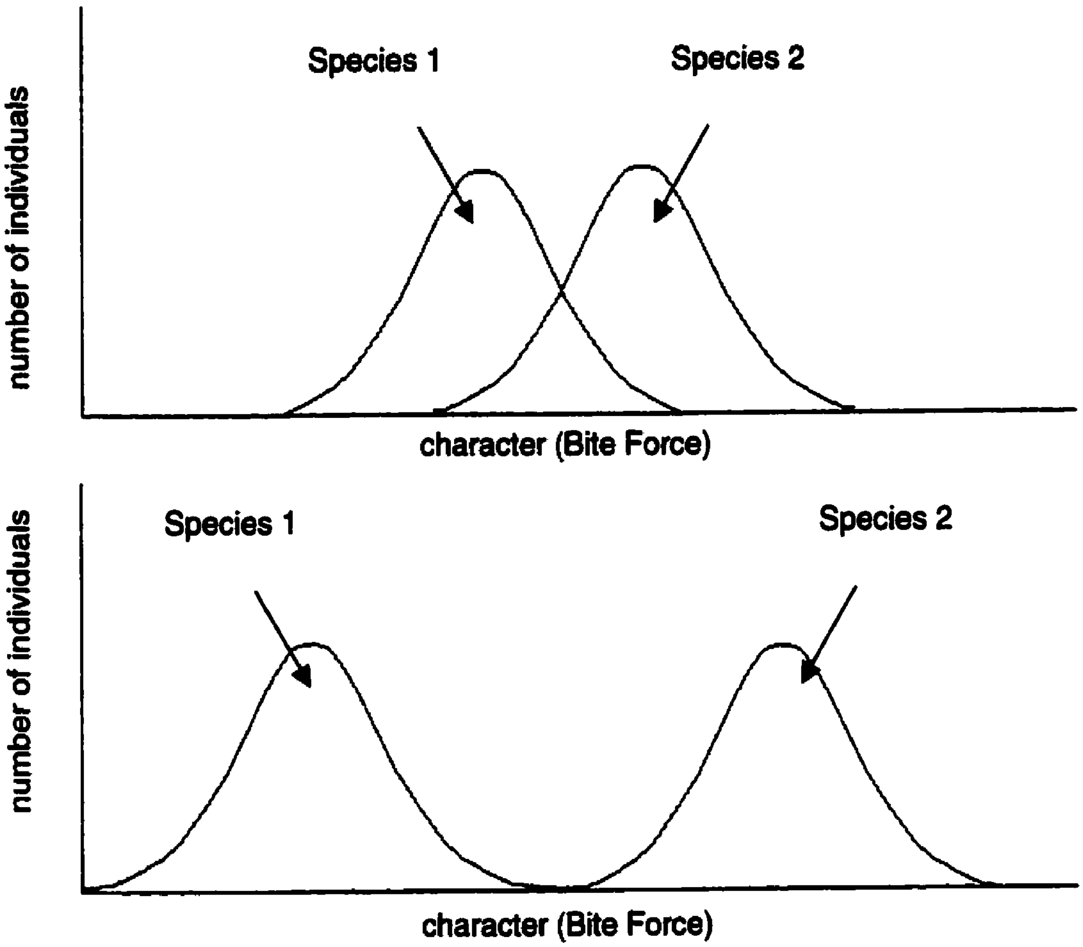
Competition, Niche Separation, and Character Displacement

Evolutionary theory is based on the premise that limited resources result in competition among individuals and this in turn drives the process of natural selection. Any variation that enhances the ability of an individual to obtain and utilise resources will be selected for and lead to adaptations associated with niche separation and character displacement (Darwin 1859; Pianka 2000).

The concept of "niche" was first described by Grinnell (1917) and was used to describe the physical location of an organism in the environment. In contrast, Elton (1927) defined "ecological niche" as the role a species played in the ecosystem. Although both theories were valuable, they could not be quantified or analyzed mathematically. Hutchinson (1957) developed the concept further and indicated that a species "niche" could be described, quantified, and analyzed as a series of resources for which the species had a range of tolerances.

Character displacement is defined as the separation of morphological and/or physiological characteristics among related populations, as a consequence of competition (Krohne 1998). If successful resource utilization depends on a particular morphological character and the distributions of the character overlap in the two populations (species), direct competition will occur and natural selection will select against individuals of both species that have morphological characters that occur in the range of overlap (Figure 1). Over time, character displacement will occur and the two populations will differ in morphological character and resource specialization. Evidence suggests that differences in jaw morphology and related lever mechanics are a direct result of natural selection

Figure 1. Hypothetical distribution frequency of a characteristic adapted from Krohne (1998). As can be seen in the top figure, the two species have a large amount of overlap between the characteristic, but as competition for resources dependant on the character occurs, so does character displacement. The bottom portion of the figure represents the result of the competition on the distribution of the character.



Species 1
Species 2
number of individuals
character (Bite Force)
Species 1
Species 2
number of individuals
character (Bite Force)

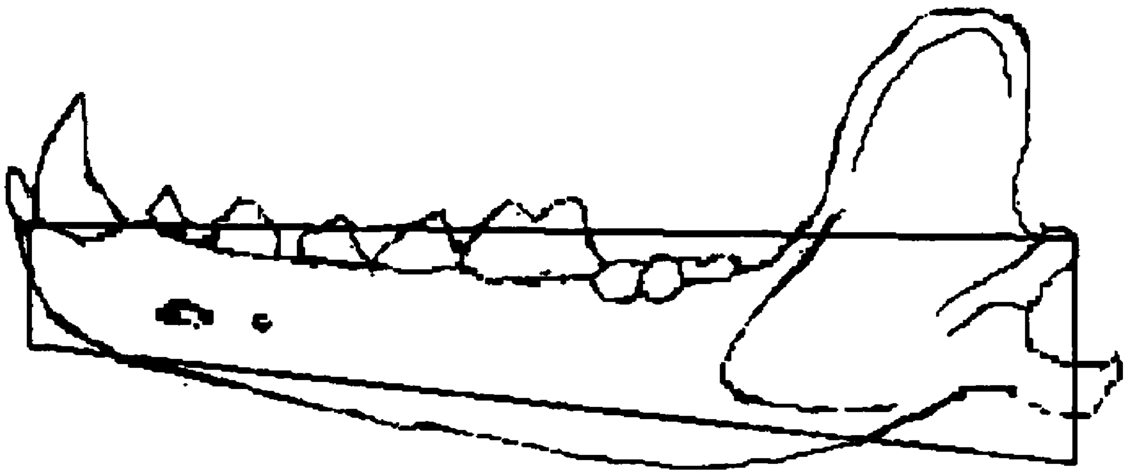
and the evolution of divergent foraging strategies (Emerson 1985; Schmitz and Kolenosky 1985; Jaslow 1986; Walker and Liem 1994).

Jaw Mechanics

Differences in morphology associated with diet have been found in both dentition and jaw mechanics. In all eutherian mammalian carnivores, anterior jaw morphology is specialized for capturing, killing, and tearing, while posterior jaw morphology is specialized for shearing and crushing (Radinsky 1981). In addition, the structure of the lower jaw is analogous to a tapered beam (Benedek and Villars 1994) (Figure 2). Vogel (1988) observed that resistance would be least and the deflection maximal, if a load was placed at distal end of a cantilever beam (anterior end of the lower jaw) and that the resistance to the load would increase steadily, as the load moved proximally towards the fulcrum (temporomandibular joint). Also as the load moved closer to the fulcrum, the force that could be applied would increase and the deflection would become less indicating that the applied force could be greater, as one moved from the anterior end of the jaw to the joint (Vogel 1988).

The primary objective of this research was to calculate and compare the maximum estimated bite forces of North American terrestrial eutherian mammals of the Order Carnivora in an attempt to understand ecological and evolutionary relationships among different species and families. The secondary objectives were to examine the correlation between primary prey sizes and estimated bite

Figure 2. As can be seen by the overlaid drawing, the shape of the lower jaw can be viewed analogous to a tapered beam, and thus allow for simple lever mechanics to be applied.



forces in fourteen carnivore species and to examine the distribution of the estimated bite force for each species of true carnivores within each family.

It was hypothesized that:

1) maximum estimated bite force represents a continuum from small to large carnivores;
2) maximum estimated bite force is highly correlated with a single or few skull parameters;
3) variance in maximum estimated bite force is greater in species identified as omnivores compared to those identified as true carnivores;
4) families of carnivores will exhibit similar trends with respect to the correlation of skull parameters and the maximum estimated bite force;
5) variance in maximum estimated bite force is greater in species inhabiting a larger number of biomes;
6) there is a correlation between primary prey size and the estimated bite force within each family and in the Order Carnivora in North America;
7) omnivores with greater dietary diversity (Families Procyonidae and Ursidae) will vary from true carnivores;
8) the distribution of the relative frequency of the maximum estimated bite force will reflect the diet of a species, such that animals that have a greater variance in their diet will also demonstrate greater variance in the maximum estimated bite forces; and,

9) the distribution of the maximum estimated bite force will exhibit character displacement among species of true carnivores and reflect the competition between the species of true carnivores in each family.

Materials and Methods

Skull Parameters

Eight hundred and eighty eight (n=888) skulls representing the major families of North American Carnivores were utilized in this study. The Family Mustelidae was represented by the ermine (*Mustela ermina)* (n=55), the mink (*Mustela vison)* (n=51), the marten (*Martes americana)* (n=61), the fisher (*Martes pennanti)* (n=41), and the wolverine (*Gulo gulo)* (n=54). The Family Felidae was represented by the bobcat (*Lynx rufus)* (n=51), the lynx (*Lynx canadensis)* (n=96), and the cougar (*Felis concolor)* (n=17). The Family Canidae was represented by the arctic fox (*Alopex lagopus)* (n=74), the red fox (*Vulpes vulpes)* (n=42), the coyote (*Canis latrans)* (n=137), and the wolf (*Canis lupus)* (n=101). The Family Ursidae was represented by the black bear (*Ursus americana)* (n=70) and the Family Procyonidae by the racoon (*Procyon lotor)* (n=38). Specimens were obtained from trappers and hunters and museum collections at Laurentian University (Sudbury, Ontario), the Royal Ontario Museum (Toronto, Ontario), and the Museum of Nature (Hull, Quebec). Geographical location, sex, and age were recorded for all specimens.

Skull, foramen, and mandibular measurements were recorded using electronic digital calipers (Canadian Scientific 300 Model #:24160-15) and entered onto Microsoft Excel Spreadsheets using CalExcel v1.04 (Heaton 1998) and a Electronic Digital Caliper captioned-adapter intelligent interface device (Model # 0000-01) created by Marathon Management Company, specifically for this project. All data were measured to the nearest one-hundredth of a millimeter by the same person (J.H.W.). A random sub-set of samples were re-measured to estimate sampling error.

Maximum Estimated Bite Force

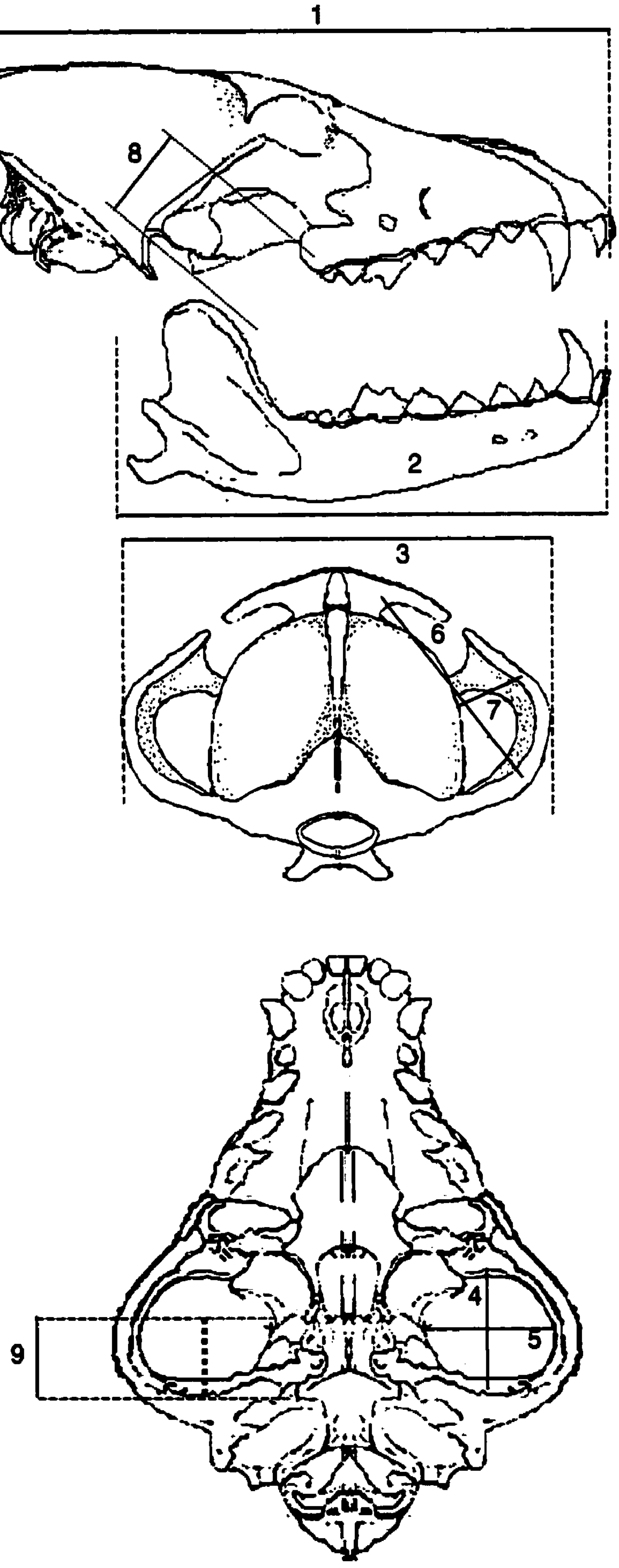
Maximum bite force was estimated using a modified technique developed by Thomason et al. (1990). The cross-sectional area of the temporalis and the masseter/medial pterygoids muscles were required to estimate these parameters (Figure 3). To determine the best method for measuring these cross-sectional areas, both an elliptical and rectangular model were considered using sub-samples from the Families Mustelidae, Felidae, and Canidae. Image analysis was performed by a Scan Jet Hp (Hewlett Packard) using Desk Scan II: 1.5.2 on a Macintosh IIci in the Fine-Particle Analysis Lab at Laurentian University. All measurements were conducted using the Ultimage^{tm}/Pro 2.5.1 program (Grafetek co. 1994) to accurately determine the cross-sectional area of the muscles and allow data to be compared to estimate values.

Thomason (1991) compared the intraspecific means of biting forces estimated by muscle dissection for seven rats and eight opossums, with the means recorded in vivo for the same individuals. For both species, the means obtained by the two techniques were not significantly different and no significant difference occurred when the $\log_{10}$ values of the bite force estimated from muscle dissection was plotted against the $\log_{10}$ values of the bite force estimated from skull measurements.

Estimated bite force was calculated by the following equation:

$$\text{(1) Maximum Estimated Bite Force} = \frac{2\,(M \times m\ + T \times t)}{\text{Lower Jaw}}$$

Figure 3. Shown here on a *Canis lupus* skull are all the measurements taken and used in this study. All measurements were taken with digital calipers to 1/100 mm.



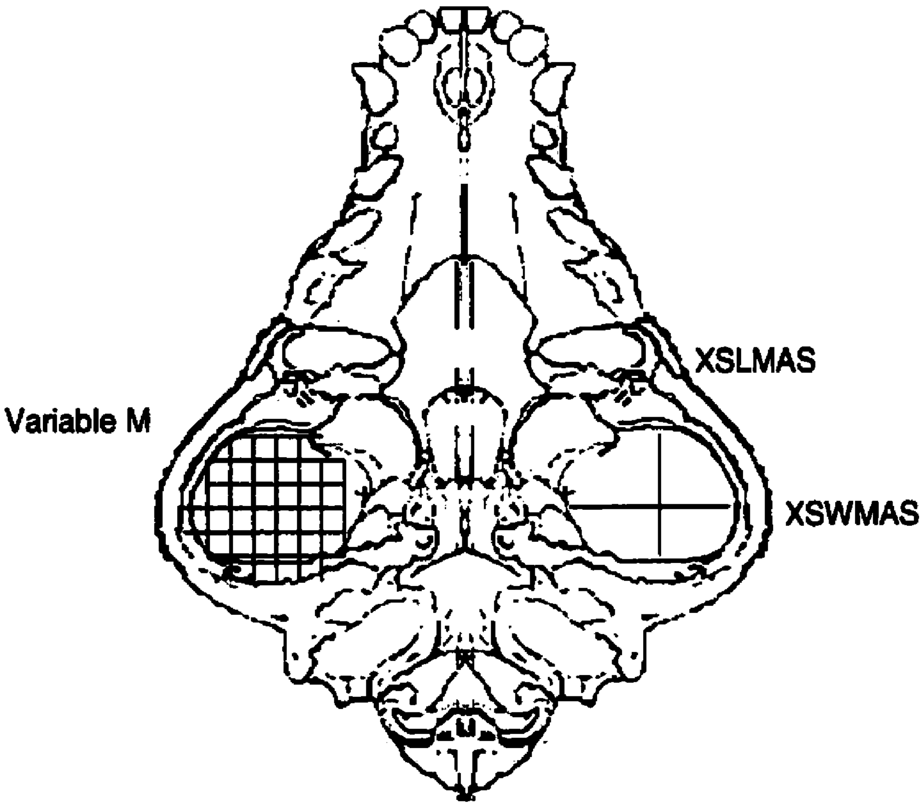
1) Total Skull Length
2) Length of Lower Jaw
3) Maximum Skull Width
4) Cross-Sectional Length of Masseter Muscle
5) Cross-Sectional Width of Masseter Muscle
6) Cross-Sectional Length of Temporalis Muscle
7) Cross-Sectional Width of Temporalis Muscle
8) Moment Arm of Temporalis Muscle
9) Moment Arm of Masseter / Medial pterygoid Muscle

The variable M represents the rectangular cross-sectional area of the combined masseter and pterygoidal muscles multiplied by 300 Mpa (mega pascal), the mean force per unit area of mammalian muscle (Weijs and Hillen 1985; Thomason 1991). Variable M was determined by measuring the width (XSWMAS) and length (XSLMAS) of the foramen created by the lateral surface of the skull and the zygomatic arch (Figure 4). Variable T was the estimated rectangular cross-sectional area of the temporalis muscle multiplied by 300 Mpa. This variable was determined by measuring the length (XSLTEMP) and width (XSWTEMP) of the foramen accommodating the temporalis muscle (Figure 5).

As established by Thomason (1991), estimated muscle forces were determined from the cross-sectional area of the masseter/medial pterygoidal muscles and the cross-sectional area of the temporalis muscle multiplied by 300 Mpa. These values were subsequently multiplied by the length of the moment arms of the masseter (MARMM [m]) and temporalis (MARMT [t]) muscles. Length of the moment arm was determined by measuring from the center of the cross-section of each muscle to the joint where the muscle attached to the mandible (Figure 6). These components were doubled to account for both sides of the skull. The calculation was subsequently divided by the lower jaw distance. This was the distance between the temporal mandibular joint and the 30% location along the lower mandible (LJ), where the maximum bite force occurred (Greaves 1982; Greaves 1995).

Figure 4. The shaded area on this *Canis lupus* skull represents the rectangular cross sectional area occupied by the masseter and medial pterygoid muscles.

Figure 5. The shaded area on this *Canis lupus* skull represents the area occupied by the temporalis muscle.


XSLMAS
Variable M
XSWMAS

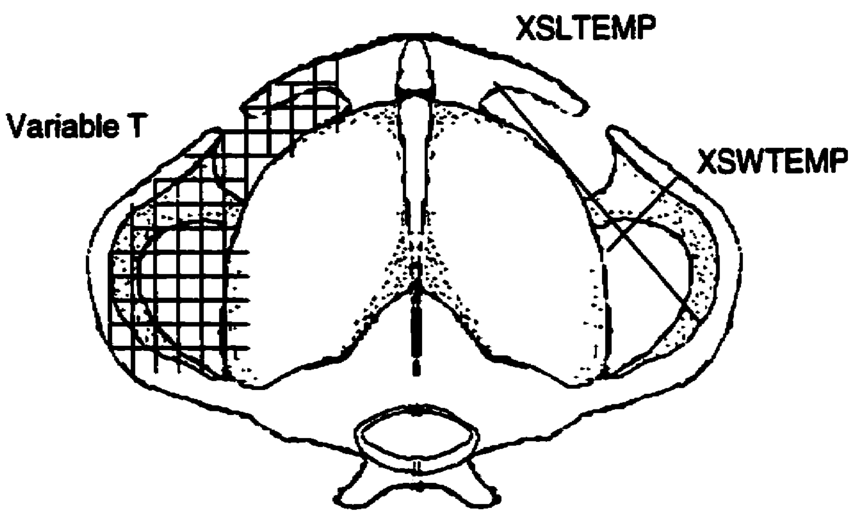
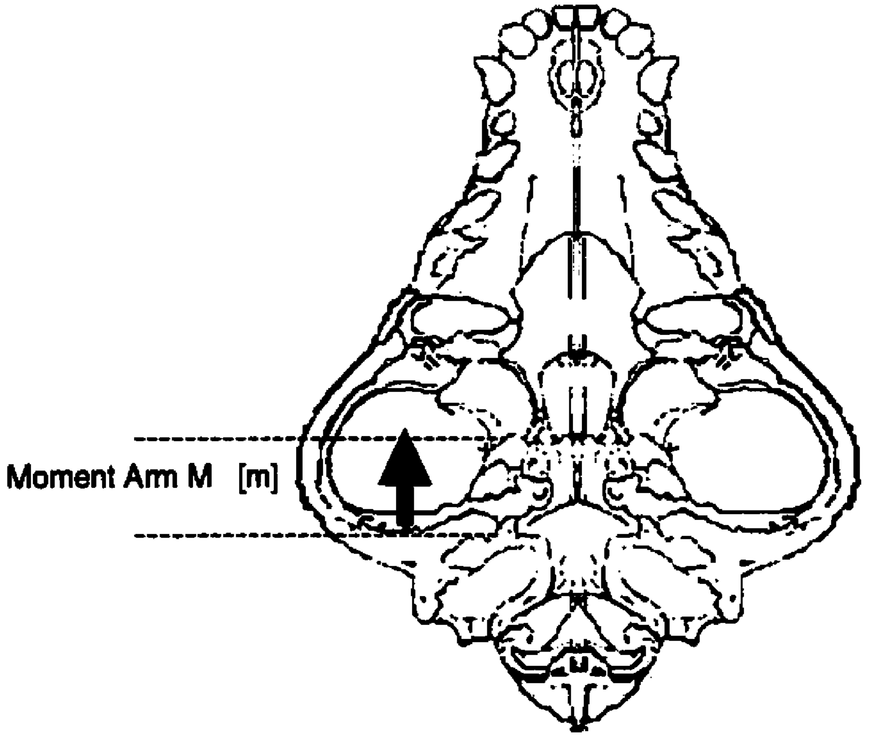
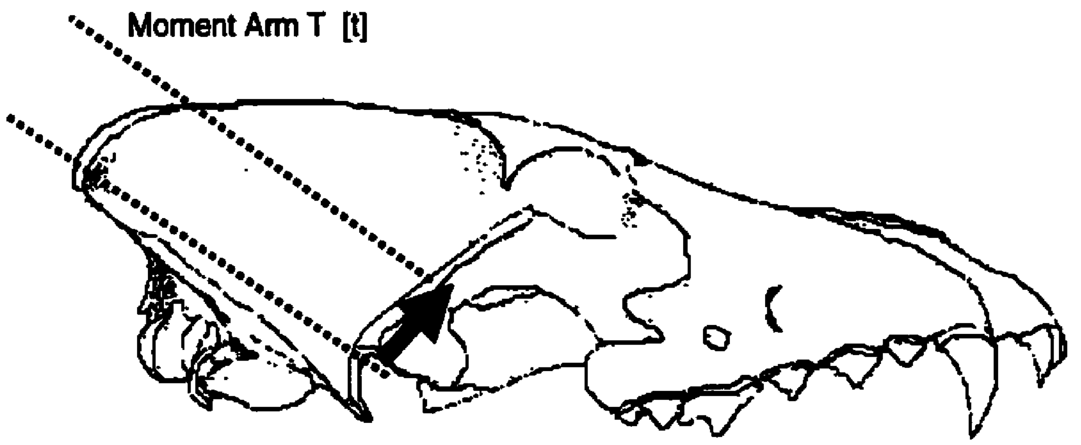

XSLTEMP
Variable T
XSWTEMP

Figure 6. Length of the moment arms of the temporalis muscle and the masseter / medial pterygoid muscles. A moment arm is measured as the distance from the center of the maximum cross section area of the muscle to the joint where the muscle translates the force (temporal mandibular joint or TMJ).


Moment Arm M [m]


Moment Arm T [t]

Mean Estimated Primary Prey Weight

In order to understand the relationships between variation in skull morphology, estimated bite force, and primary prey weights, body weights for primary prey species consumed by each carnivorous species were obtained from the literature. In the Family Mustelidae, primary prey weights for ermine (Burt and Grossenheider 1952), marten (Strickland et al. 1982), mink (Linscombe et al. 1982), fisher (Strickland et al. 1982), and the wolverine (Wilson et al. 1982) were obtained as indicated. In the Family Felidae, primary prey weights for bobcat and lynx were obtained from McCord and Cordoza (1982) and for cougar from Burt and Grossenheider (1952). In the Family Canidae, primary prey weights were obtained for arctic fox (Underwood and Mosher 1982), red fox (Samuel and Nelson 1982), coyote (Bekoff 1982), and the wolf (Mulders 1997). Data on primary prey weight for black bear and raccoons came from Burt and Grossenheider (1952). For each predator, primary prey were identified as the prey with the highest frequency in the diet. If two or more prey were recorded with equal frequent, the mean weight of the combined species was calculated. In order to arrive at a representative primary prey weight, the mean weight of both males and females were used for each prey species.

Statistical Analysis

Statistical analyses were performed only on adult specimens and a total of eight hundred and eighty eight skulls were measured. Data were tested for normality and considered normally distributed if skewness was less than $\pm$ 2.0

(DESCRIPTIVE Program on SPSS 9.0 [SPSS Inc.] for Windows95©). "DESCRIPTIVE" was also utilized to calculate the n statistic, range, minimum, maximum, sum, mean, and variance for all variables and the mean maximum estimated bite forces. Probabilities of less than 5% were considered to have biological significance. One-way ANOVAs were used to determine significant differences in mean maximum estimated bite forces among species and families. Outliers were identified using the sub-routine EXAMINE VARIABLES and BOXPLOT in ANALYZE DATA (SPSS 9.0).

In carnivores, there are differences in variability within and among families. Thus, a multivariate approach was used to explore differences in variance. Relationships of populations may be more accurately interpreted when characters are considered as an integrated whole, rather than when each is considered separately (Skeel and Carbyn 1977).

Principal Component Analysis and Discriminant Analysis were conducted using SPSS-PC Windows 9.0 Graduate Student Edition, sub-programs FACTOR and DISCRIMINANT. These methods have been used by Sokal and Sneath (1963), Seal (1964), Morrison (1967), Sokal and Rohlf (1969), Child (1970), Blackith and Reyment (1971), Zar (1974), Krzanowski (1977), Neff and Marcus (1980), Williams (1983), Romesburg (1984), and Manly (1986).

Skull parameters with the highest factor-score and that were not directly related to maximum estimated bite force were examined for correlation with the maximum estimated bite forces. Analyses were done for the Order Carnivora, Families Mustelidae, Felidae, and Canidae and for each species. The parameter with the highest mean correlation coefficient was transformed to decrease the heteroscadacity and curvilinearity (Zar 1974) and correlated with the maximum estimated bite force to create higher correlation coefficients, as well as lines-of-best fit. Lines-of-best-fit for each correlation were tested for significant differences in slope and y-intercept.

Estimated bite-forces were correlated with primary prey weight for the three families of true carnivores (Mustelidae, Felidae, and Canidae). Homogeneity of the slope of the correlation's lines-of-best-fit was determined and an ANCOVA was performed to determine significant differences in the y-intercepts. Correlation lines were not computed for the omnivore families (Procyonidae and Ursidae), due to the fact that only one species from each family was represented.

Results

Maximum Estimated Bite Force

One of the primary objectives of this thesis was to determine the mean maximum estimated bite force in Newtons (N) for each species (Table 1). In the Family Mustelidae, the mean maximum estimated bite force ranged from 40N for ermine, 126 N the marten, 207 N for mink, 539 N for fisher and 844 N for wolverine. In the Family Felidae, the mean maximum estimated bite force for lynx was 541 N, which was similar to the closely related bobcat (548 N). The largest member of the Family, the cougar, had a mean maximum estimated bite force of 1311 N. In the Family Canidae, the arctic fox had an mean maximum estimated bite force of 350 N, while the red fox had a mean maximum estimated bite force of 430 N. The coyote, the second largest member of the Family Canidae had a mean maximum estimated bite force of 681 N, while the wolf had a mean maximum estimated bite force of 2255 N. The other two species included in this analysis were the black bear and raccoon, which had mean maximum estimated bite forces of 2160 N and 346 N, respectively. Table 1 summarizes the mean maximum estimated bite forces, sample size, standard deviation, and the difference in Newtons to the next largest estimated bite force or interspecific distance.

Table 2 identifies the homogenous subsets of animals according to mean maximum estimated bite forces as classified by the Tukey Post-hoc test. The smallest comprised of the ermine, mink and marten represented Group I, while Group II contained the marten, raccoon and arctic fox. Group III was the largest containing the raccoon, arctic fox, red fox, bobcat, lynx and fisher, while Group IV

Table 1: Displayed is the Mean Estimated Bite Force of the 14 species of carnivores in the study. Included is the sample size, the change in the mean between the species (interspecific estimated bite force distance) and the standard deviation of the mean.

Species	Mean	N	ΔMean	Std. Deviation
Ermine	40.79	55	0.00	13.12
Mink	126.48	51	85.73	32.73
Marten	207.56	61	81.12	50.56
Raccoon	346.54	38	138.94	104.00
Arctic Fox	350.64	74	4.16	54.42
Red Fox	430.50	42	79.98	61.44
Fisher	539.07	41	108.64	101.23
Lynx	541.04	96	1.95	69.31
Bobcat	548.52	51	7.45	127.18
Coyote	681.95	137	133.42	143.78
Wolverine	844.88	54	162.93	163.54
Cougar	1311.47	17	466.61	186.67
Bear	2160.76	70	772.53	734.73
Wolf	2255.66	101	95.17	369.65
Total	823.12	888		783.07

Table 2: Homogenous subsets of animals according to their maximum estimated bite forces as classified by the Tukey Post-hoc test from a one-way A N O V A..

Maximum Estimated Bite Force

Tukey [a,b]		Subset for alpha						
SPECIES	N	1	2	3	4	5	6	7
Ermine	55	40.792						
Mink	51	126.48						
Marten	61	207.56	207.56					
Raccoon	38		346.54	346.54				
Arctic	74		350.64	350.64				
Red Fox	42			430.50				
Fisher	41			539.07	539.07			
Lynx	96			540.79	540.79			
Bobcat	51			548.52	548.52			
Coyote	137				681.95	681.95		
Wolverine	54					844.88		
Cougar	17						1311.47	
Black Bear	70							2160.76
Wolf	101							2255.66
Sig		.35	.62	.09	.62	.39	1.00	.97

a. Means for groups in homogeneous subsets are displayed.

b. Uses Harmonic Mean Sample Size = 33.070.

was comprised of fisher, lynx, bobcat and coyote. Group V contained the coyote and the wolverine, while Group VI was the cougar. Group VII was the wolf and the black bears. Overlap occurred among Groups as outlined in Table 2.

Principle Component Analysis

Fifteen (15) variables were processed by Principle Component Analysis. Variables such as group, family, species, geographic location, sex, primary prey weight, and nine skull parameters were allowed to enter the analysis. Variables calculated from the skull parameters, such as areas and bite forces were not used. A summary of the derived dimensions, eigen values, and factor loading for all components is illustrated in Table 3. Factor 1 (skull parameters) had an eigen value of 9.06 and accounted for 64.7% of the variance amongst the 14 species. Factor 2 (species and family membership) had an eigen value of 2.02 and was responsible for 14.4 % of the combined total of 79.1%. Factor 3 (sex, primary prey weight and location) had an eigen value of 1.2 and explained 8.8 % of the variance, bringing the total explained variance to 87.8%. Table 4 displays the results of the Rotated Component Matrix. Factor I was comprised of skull morphological parameters. The three variables with the greatest factor loading included maximum skull length (0.981), maximum skull width (0.982), and cross-sectional length of the masseter muscle (0.989).

Table 3: Results of the Principle Component Analysis.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Loadings			Rotation Sums of Loadings		
	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %	Total	% Variance	Cumulative %
1	9.05	64.67	64.67	9.05	64.67	64.67	8.96	64.06	64.06
2	2.01	14.41	79.08	2.01	14.40	79.08	2.01	14.38	78.44
3	1.23	8.81	87.88	1.23	8.80	87.88	1.32	9.44	87.88
4	0.86	6.15	94.03						
5	0.50	3.57	97.60						
6	0.15	1.13	98.73						
7	0.06	0.47	99.20						
8	0.03	0.24	99.45						
9	0.03	0.21	99.65						
10	0.02	0.13	99.79						
11	0.02	0.12	99.91						
12	0.01	0.05	99.96						
13	0.0	0.02	99.98						
14	0.0	0.01	100.00						

Extraction Method: Principal Component Analysis.

Table 3a: Definition of components extracted by the Principle component analysis

#	Definition of Component
1	Skull Parameters, Prey Weight
2	Family and Species Label
3	Geographic location and Sex

Table 4: As can be seen in the Rotated Component Matrix, the first component is comprised of skull parameters, the second is comprised of species and family labels while the third is the geographic location and sex.

Rotated Component Matrix [a]

	Component		
	1	2	3
FAMILY		0.985	
SPECIES		0.980	
Eco			-0.807
Sex			0.583
PREYWT	0.617		
Aream	0.977		
Areat	0.934		
LENGTH	0.981		
WIDTH	0.982		
XSLMAS	0.989		
XSWMAS	0.963		
TEMPL	0.971		
TEMPW	0.977		
LOWERJ	0.961		

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 4 iterations.

Family: Family which the animal belongs to
Species: Species
Eco: Eco Zone in which animal was found
PreyWt: Primary Prey weight of the species to which the skull belongs
AreaM: Cross Sectional Area of the Masseter / Pterygoidal muscles
AreaT: Cross Sectional Area of the Temporalis muscle
Length: Maximum length of skull
Width: Maximum width of skull
XSLMAS: Cross sectional Length of the Masseter / Pterygoidal foramen
XSWMAS: Cross sectional Width of the Masseter / Pterygoidal foramen
TEMPL: Cross sectional Length of the Temporalis foramen
TEMPW: Cross sectional Width of the Temporalis foramen
LowerJ: Total length of the Lower Jaw

Discriminant Analysis

The variables, total skull length, total skull width, and cross-sectional length of the masseter muscle, were the three most highly related variables to Factor I and were utilized in the Discriminant Analysis. Table 5 represents the descriptive statistics for the 14 species. The first three canonical discriminant functions were used in the analysis. A summary of the eigen values and the % variance for each discriminant function is shown in Table 6. As indicated, the first, second, and third functions contributed 87.2%, 12.0%, and 0.9% of the variance, respectively. Table 7 represents the classification results of the three discriminant functions. Within the Family Felidae, the discriminant analysis accurately classified 77.1% of the lynx, 66.7% of the bobcat, and 100.0% of the cougar. Within the Family Canidae, the functions correctly classified 77.0% of the arctic fox, 83.3% of the red fox, 97.1% of the coyotes, and 78.2% of the wolves. For the Family Mustelidae, the discriminant analysis correctly classified all (100 %) of the three smallest members (ermine, mink, marten), 82.9% of the fisher, and 94.4% of the wolverines. In the Family Ursidae, 64.3 % were classified correctly, while in the Family Procyonidae, 76.3 % of the specimens were classified correctly. In total, the three functions, skull length, the skull width, and the cross-sectional length of the masseter muscle correctly classified 85.0% of the North American carnivores ranging from the ermine to the black bear.

To determine if the discriminant functions were generalizable, the total number of specimens were randomly halved. With n = 451, a new set of

Table 5: Group Statistics for the fourteen species of carnivores in the Discriminant Analysis.

Species		Mean	Std. Deviation	Valid N (listwise)
Lynx	LENGTH	122.86	5.36	96.00
	WIDTH	86.88	3.32	96.00
	XSLMAS	33.03	2.18	96.00
Bobcat	LENGTH	124.05	10.81	51.00
	WIDTH	85.88	8.09	51.00
	XSLMAS	33.85	4.02	51.00
Cougar	LENGTH	184.41	10.91	17.00
	WIDTH	126.71	8.27	17.00
	XSLMAS	51.57	4.69	17.00
Arctic Fox	LENGTH	130.73	9.56	74.00
	WIDTH	68.97	4.29	74.00
	XSLMAS	28.73	2.64	74.00
Red Fox	LENGTH	146.31	9.96	42.00
	WIDTH	74.39	3.85	42.00
	XSLMAS	33.54	2.79	42.00
Coyote	LENGTH	191.00	11.54	137.00
	WIDTH	95.01	7.30	137.00
	XSLMAS	42.57	4.16	137.00
Wolf	LENGTH	255.60	14.34	101.00
	WIDTH	137.67	9.05	101.00
	XSLMAS	59.01	4.36	101.00
Ermine	LENGTH	40.91	3.95	55.00
	WIDTH	22.73	2.69	55.00
	XSLMAS	7.94	1.16	55.00
Mink	LENGTH	61.01	4.72	51.00
	WIDTH	35.00	3.53	51.00
	XSLMAS	13.67	1.63	51.00
Marten	LENGTH	83.91	5.02	61.00
	WIDTH	46.50	4.32	61.00
	XSLMAS	19.88	1.59	61.00
Fisher	LENGTH	120.63	5.16	41.00
	WIDTH	65.68	4.44	41.00
	XSLMAS	32.17	1.78	41.00
Wolverine	LENGTH	153.62	10.19	54.00
	WIDTH	98.34	7.44	54.00
	XSLMAS	37.96	3.63	54.00
Black Bear	LENGTH	262.58	25.83	70.00
	WIDTH	151.86	20.85	70.00
	XSLMAS	62.56	8.53	70.00
Raccoon	LENGTH	111.53	5.07	38.00
	WIDTH	67.35	6.21	38.00
	XSLMAS	28.24	2.78	38.00
Total	LENGTH	152.47	66.53	888.00
	WIDTH	86.81	36.56	888.00
	XSLMAS	36.34	15.71	888.00

Table 8 a). Classification Function Coefficients

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
LEN	0.81	0.84	1.19	1.98	2.21	3.03	3.60	0.65	0.82	1.11	1.40	1.54	3.26	1.19
WID	0.77	0.64	0.84	-0.48	-0.76	-1.09	-0.85	-0.04	-0.05	-0.21	-0.51	0.41	-0.27	0.01
XSLM	-1.26	-1.05	-1.16	-2.40	-2.18	-3.13	-3.96	-1.11	-1.14	-1.19	-0.60	-2.20	-3.86	0.81
(Const)	-64.80	-64.1	-135.9	-81.0	-99.3	-173.2	-287.6	-11.1	-19.0	-32.4	-60.4	-99.1	-289.7	0.77

Fisher's linear discriminant functions

Table 8 b). Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	39.626	87.2	87.2	0.988
2	5.442	12.0	99.1	0.919
3	0.387	0.9	100.0	0.528

Table 6 c). Wilks' Lambda

Test of Functions	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.003	5178.3	39	0.001
2 through 3	0.112	1923.9	24	0.001
3	0.721	287.5	11	0.001

a First 3 canonical discriminant functions were used in the analysis.

Species Classification:

Lynx	= 1
Bobcat	= 2
Cougar	= 3
Arctic Fox	= 4
Red Fox	= 5
Coyote	= 6
Wolf	= 7
Ermine	= 8
Mink	= 9
Marten	= 10
Fisher	= 11
Wolverine	= 12
Black Bear	= 13
Raccoon	= 14

Table 7: Classification Accuracy of the Discriminant Analysis n = 888.

Classification Results

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lynx (1)	**77.1**	22.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Bobcat (2)	31.4	**66.7**	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	2.0
Cougar (3)	.0	.0	**100.0**	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Arctic Fox (4)	.0	.0	.0	**77.0**	21.6	.0	.0	.0	.0	.0	.0	.0	.0	1.4
Red Fox (5)	.0	.0	.0	16.7	**83.3**	.0	.0	.0	.0	.0	.0	.0	.0	.0
Coyote (6)	.0	.0	.0	.0	2.9	**97.1**	.0	.0	.0	.0	.0	.0	.0	.0
Wolf (7)	.0	.0	.0	.0	.0	4.0	**78.2**	.0	.0	.0	.0	.0	17.8	.0
Ermine (8)	.0	.0	.0	.0	.0	.0	.0	**100.0**	.0	.0	.0	.0	.0	.0
Mink (9)	.0	.0	.0	.0	.0	.0	.0	.0	**100.0**	.0	.0	.0	.0	.0
Marten (10)	.0	.0	.0	.0	.0	.0	.0	.0	.0	**100.0**	.0	.0	.0	.0
Fisher (11)	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	**82.9**	.0	.0	17.1
Wolverine (12)	.0	1.9	1.9	.0	.0	.0	.0	.0	.0	.0	.0	**94.4**	.0	1.9
Black Bear (13)	.0	.0	.0	.0	.0	1.4	34.3	.0	.0	.0	.0	.0	**64.3**	.0
Raccoon (14)	.0	15.8	.0	.0	.0	.0	.0	.0	.0	.0	7.9	.0	.0	**76.3**

a 85.0% of original (all carnivores) grouped cases correctly classified
b 88.0% of first twelve (true carnivores) grouped cases correctly classified

discriminant functions for each species were created and the first three canonical discriminant functions were used in the analysis. A summary of the Classification Functions for each species is shown in Table 8a. A summary of eigen values and the % variance for each discriminant function are shown in Table 8b and the Wilk's Lambda and significance of the functions in shown in Table 8c. As indicated, the first (total length of the skull), second (total width of the skull), and third (cross-sectional length of the masseter muscle) functions contributed 86.5%, 12.1% and 1.4% of the variance for the North American Carnivores, respectively. As can be seen in Table 9, the classification results of the three discriminant functions for one half of the random sample was 84.5%. When the same functions were applied to the second half of the sample, 83.1% of the cases were correctly classified (Table 10).

Mean Maximum Estimated Bite Forces and Skull Morphology

Figures 7 through 9 represent the distribution of the mean maximum estimated bite forces for each of the three families of true carnivores (Mustelidae, Felidae, and Canidae, respectively). As can be seen the range, of maximum estimated bite force increases as the size of the species increases, when animals were plotted along the x-axis from smallest to largest.

To examine the relationship between skull morphology and maximum estimated bite force, the measured parameters extracted from the Principle Component Analysis were plotted against the mean maximum estimated bite force for all of the animals studied. As illustrated in Figure 10, in the Order Carnivora maximum estimated bite force has a curvilinear relationship with each of the three skull parameters.

Table 8 a). Classification Function Coefficients

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
LEN.	0.66	0.70	1.04	1.79	1.94	2.69	3.18	0.58	0.73	0.97	1.16	1.33	2.81	1.07
WID.	1.02	0.89	1.18	-0.23	-0.42	-0.66	-0.26	0.06	0.07	-0.01	-0.36	0.74	0.35	0.25
XSLM	-1.27	-1.04	-1.26	-2.36	-2.17	-3.16	-3.98	-1.13	-1.14	-1.18	-0.20	-2.18	-3.85	-1.40
Const	-66.0	-66.9	-144.	-78.9	-92.6	-161.2	-274.6	-10.5	-18.4	-31.6	-58.26	-100.5	-275.5	-50.8

Fisher's linear discriminant functions

Table 8 b). Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	40.1	86.5	86.5	0.988
2	5.6	12.1	98.6	0.921
3	0.6	1.4	100.0	0.624

a First 3 canonical discriminant functions were used in the analysis.

Table 8 c). Wilks' Lambda

Test of Function	Wilks' Lambda	Chi-square	df	Sig.
1 through 3	0.002	2692.61	39	0.00
2 through 3	0.092	1052.13	24	0.00
3	0.610	218.19	11	0.00

Species Classification:

Lynx	= 1
Bobcat	= 2
Cougar	= 3
Arctic Fox	= 4
Red Fox	= 5
Coyote	= 6
Wolf	= 7
Ermine	= 8
Mink	= 9
Marten	= 10
Fisher	= 11
Wolverine	= 12
Black Bear	= 13
Raccoon	= 14

Table 9: Classification results of Discriminant Analysis for n = 451 of the Selected individual Carnivores.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lynx	**68.2**	31.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bobcat	30.0	**66.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3
Cougar	0.0	0.0	**100**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arctic Fox	0.0	0.0	0.0	**67.6**	29.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9
Red Fox	0.0	0.0	0.0	15.8	**84.2**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coyote	0.0	0.0	0.0	0.0	1.6	**98.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wolf	0.0	0.0	0.0	0.0	0.0	2.9	**76.5**	0.0	0.0	0.0	0.0	0.0	20.6	0.0
Ermine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**100**	0.0	0.0	0.0	0.0	0.0	0.0
Mink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**100**	0.0	0.0	0.0	0.0	0.0
Marten	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**100**	0.0	0.0	0.0	0.0
Fisher	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**100**	0.0	0.0	0.0
Wolverine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**100**	0.0	0.0
Black Bear	0.0	0.0	0.0	0.0	0.0	2.8	33.3	0.0	0.0	0.0	0.0	0.0	**63.9**	0.0
Raccoon	5.6	5.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**88.9**

a. 84.5% of selected original grouped cases correctly classified

Table 10: Classification results of Discriminant Analysis for n = 437 of the remaining Non-Selected individual Carnivores.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lynx	**63.5**	36.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bobcat	28.6	**71.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cougar	0.0	0.0	**100.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arctic Fox	0.0	0.0	0.0	**87.5**	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Red Fox	0.0	0.0	0.0	17.4	**82.6**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coyote	0.0	0.0	0.0	0.0	4.1	**95.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wolf	0.0	0.0	0.0	0.0	0.0	6.1	**81.8**	0.0	0.0	0.0	0.0	0.0	12.1	0.0
Ermine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**100**	0.0	0.0	0.0	0.0	0.0	0.0
Mink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**100**	0.0	0.0	0.0	0.0	0.0
Marten	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**100**	0.0	0.0	0.0	0.0
Fisher	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**50**	0.0	0.0	0.0
Wolverine	0.0	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**88.9**	0.0	3.7
Black Bear	0.0	0.0	0.0	0.0	0.0	0.0	44.1	0.0	0.0	0.0	0.0	0.0	**55.9**	0
Raccoon	0.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	**70.0**

b. 83.1% of unselected original grouped cases correctly classified

Figure 7. Mean (Distribution, Standard Error, and Standard Deviation) of the maximum estimated bite force of the five species representing the Family Mustelidae.

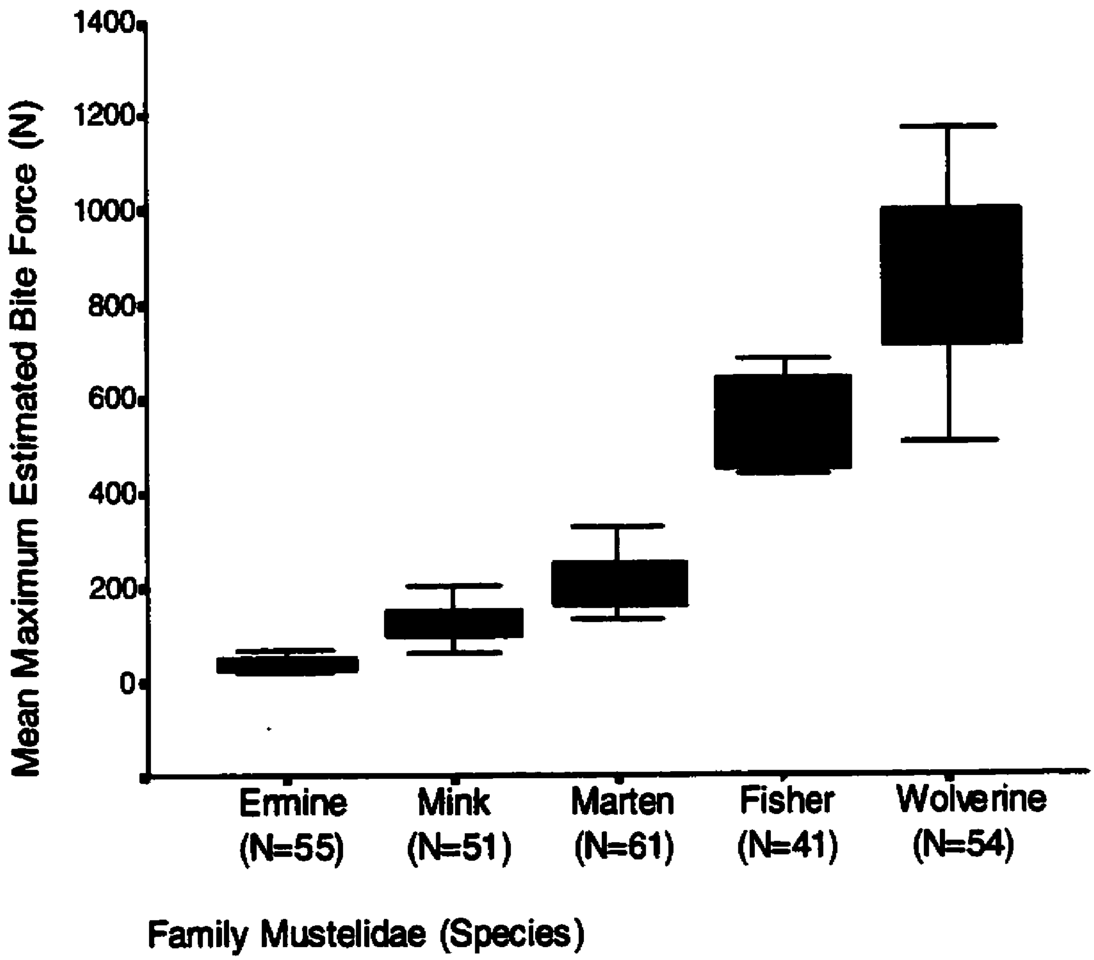

1400
1200
1000
800
600
400
200
0
Mean Maximum Estimated Bite Force (N)
Ermine
(N=55)
Mink
(N=51)
Marten
(N=61)
Fisher
(N=41)
Wolverine
(N=54)
Family Mustelidae (Species)

Figure 8. Mean (Distribution, Standard Error, and Standard Deviation) of the maximum estimated bite force of the five species representing the Family Felidae.

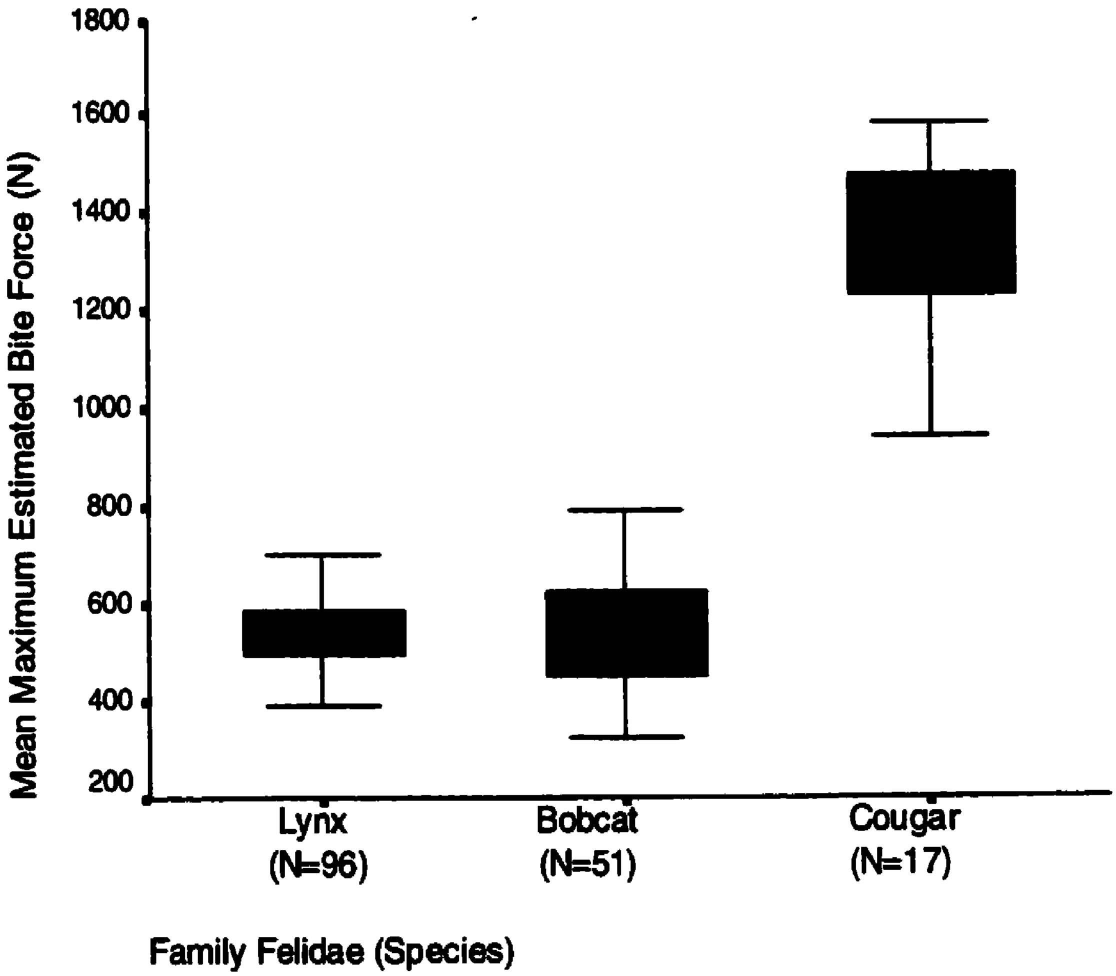

1800
1600
1400
1200
1000
800
600
400
200
Mean Maximum Estimated Bite Force (N)
Lynx
(N=96)
Bobcat
(N=51)
Cougar
(N=17)
Family Felidae (Species)

Figure 9. Mean (Distribution, Standard Error, and Standard Deviation) of the maximum estimated bite force of the five species representing the Family Canidae.

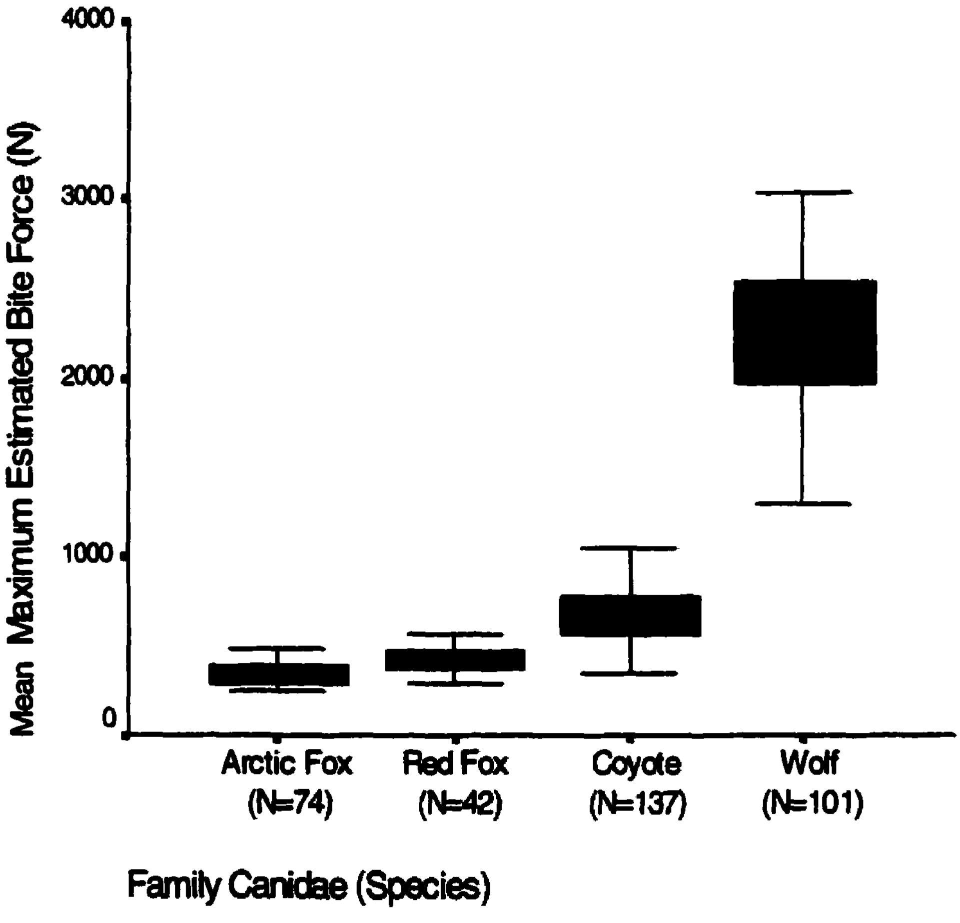
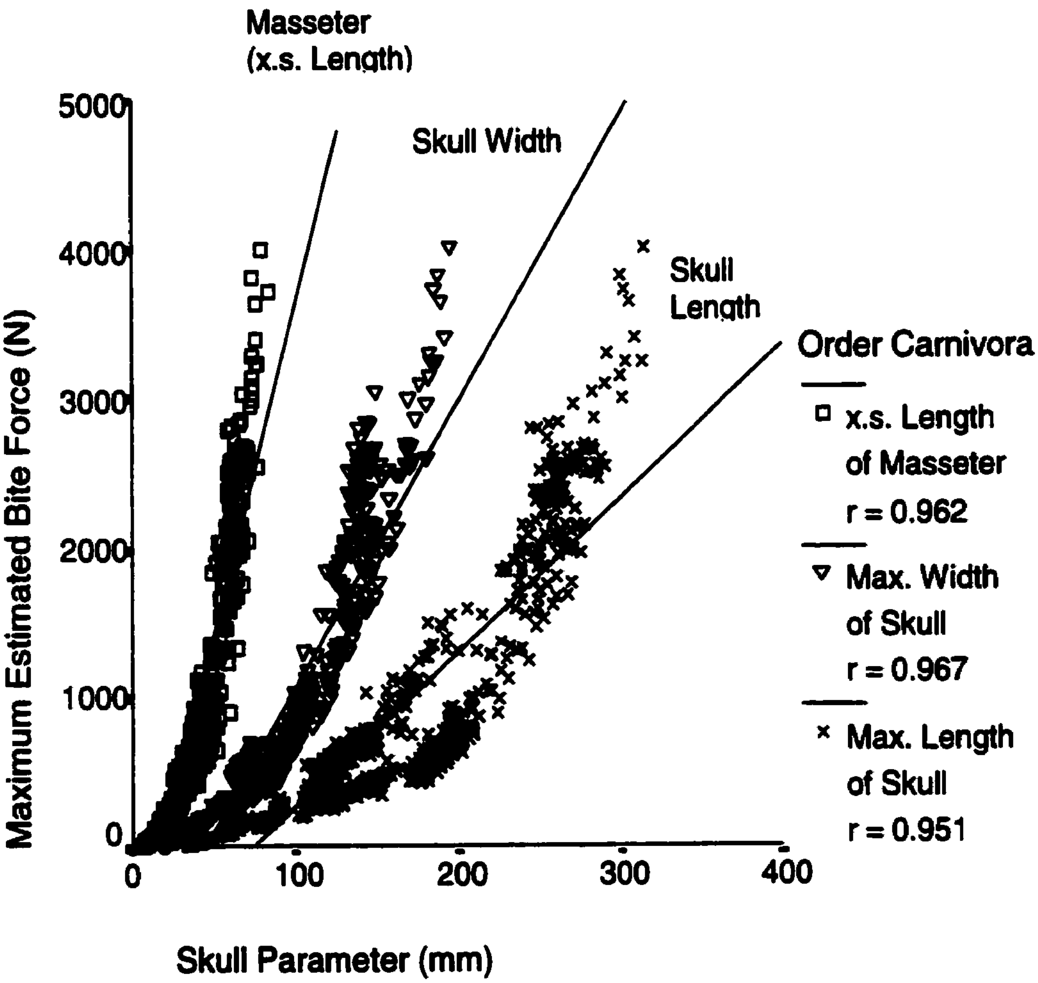

4000
3000
2000
1000
0
Mean Maximum Estimated Bite Force (N)
Arctic Fox
(N=74)
Red Fox
(N=42)
Coyote
(N=137)
Wolf
(N=101)
Family Canidae (Species)

Figure 10. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the Order Carnivora in North America.


Masseter
(x.s. Length)
Skull Width
Skull
Length
Order Carnivora
x.s. Length
of Masseter
r = 0.962
Max. Width
of Skull
r = 0.967
Max. Length
of Skull
r = 0.951
5000
4000
3000
2000
1000
0
Maximum Estimated Bite Force (N)
0
100
200
300
400
Skull Parameter (mm)

When applying a line-of-best fit to each figure, a quadratic equation was utilized, creating r^2 values for each relationship. Since the skull parameters were not independent variables, the r^2 values were converted to r-values and the strength of the correlation was considered. When all specimens were considered, the strongest relationship ($r = 0.967$) was observed when the variable maximum estimated bite force was plotted against the maximum skull width. The other two skull parameters, maximum skull length, and cross-sectional length of the masseter both had significantly lower values ($p < 0.05$, $t = 2.166$), ($r = 0.9505$ and $r = 0.9618$, respectively).

When each of the three families of true carnivores was analyzed, they exhibited similar trends. Within the Family Mustelidae, the maximum skull width was the most highly correlated skull parameter with the maximum estimated bite force (Figure 11). The correlation of the maximum estimated bite force and this skull parameter ($r = 0.982$) was significantly higher than the correlation of the other two skull parameters (maximum skull length $r = 0.968$ and cross-sectional length of the masseter $r = 0.965$). The Family Felidae exhibited similar trends to the Order Carnivora (Figure 12) and once again, the maximum skull width exhibited the highest correlation with the maximum estimated bite force ($r = 0.977$). Again, the cross-sectional length of the masseter muscle and the maximum skull length were slightly less with r-values of 0.966 and 0.971, respectively. All of the lines-of-best fit were highly significant ($p < 0.0001$) and the maximum skull width had a significantly higher correlation, than the cross-sectional length of the masseter muscle ($t = 2.87$, $p< 0.05$).

Figure 11. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the Family Mustelidae in North America.

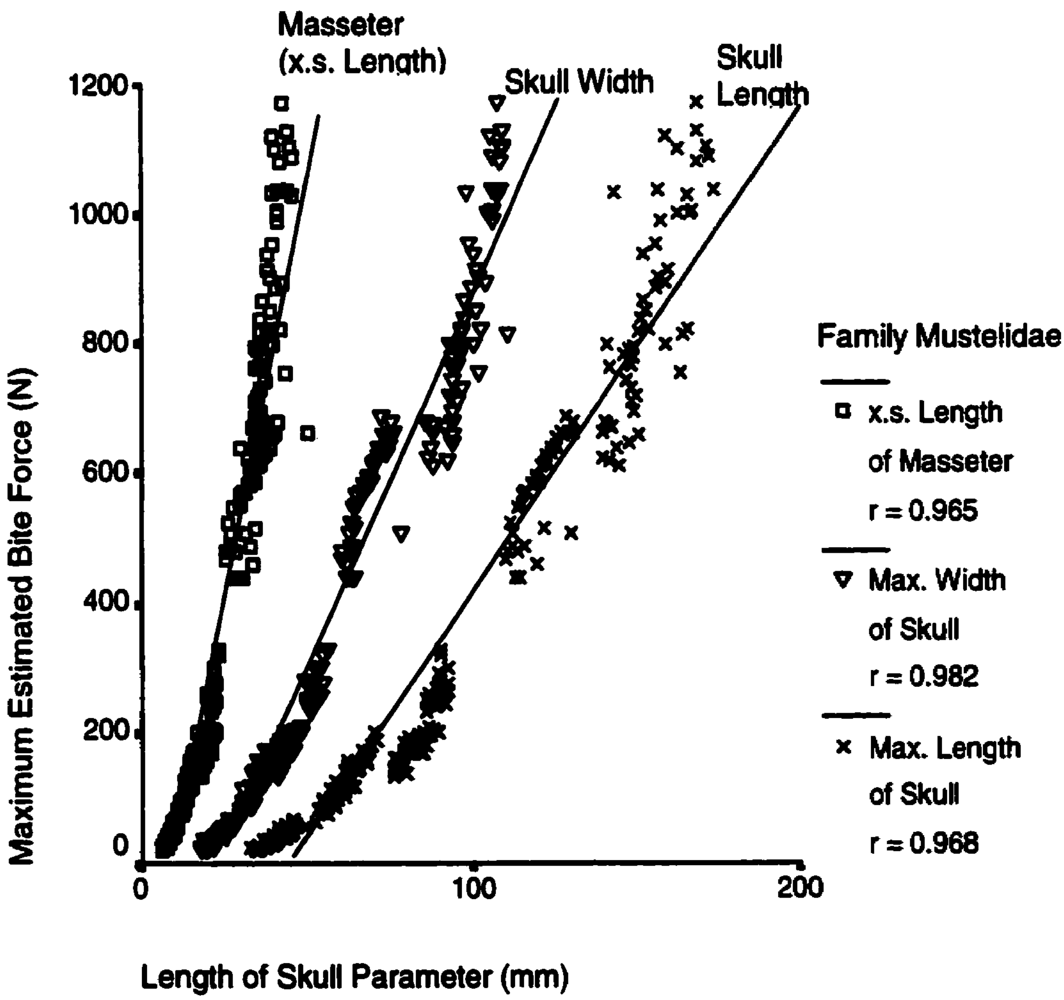
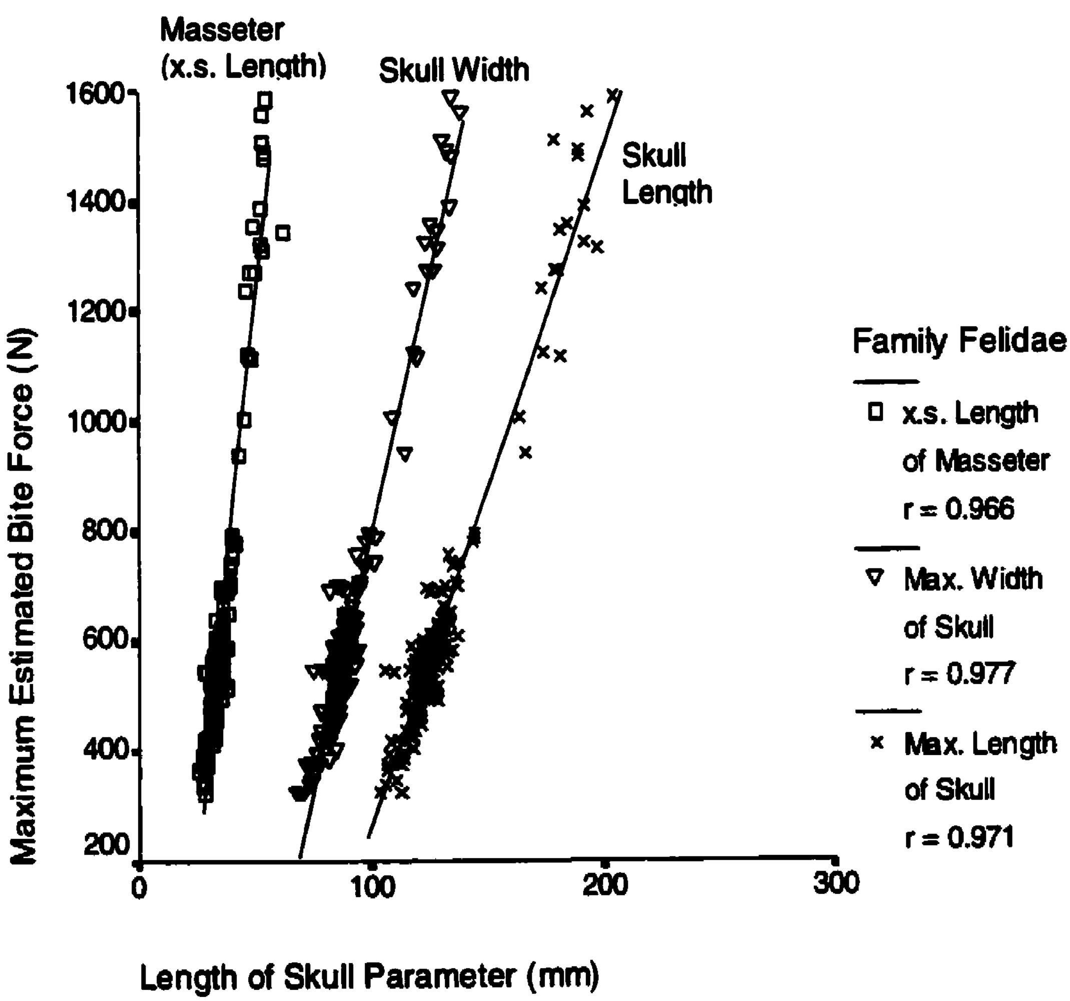

Masseter
(x.s. Length)
Skull Width
Skull
Length
1200
1000
800
600
400
200
0
0
100
200
Maximum Estimated Bite Force (N)
Length of Skull Parameter (mm)
Family Mustelidae
x.s. Length
of Masseter
r = 0.965
Max. Width
of Skull
r = 0.982
Max. Length
of Skull
r = 0.968

Figure 12. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the Family Felidae in North America.



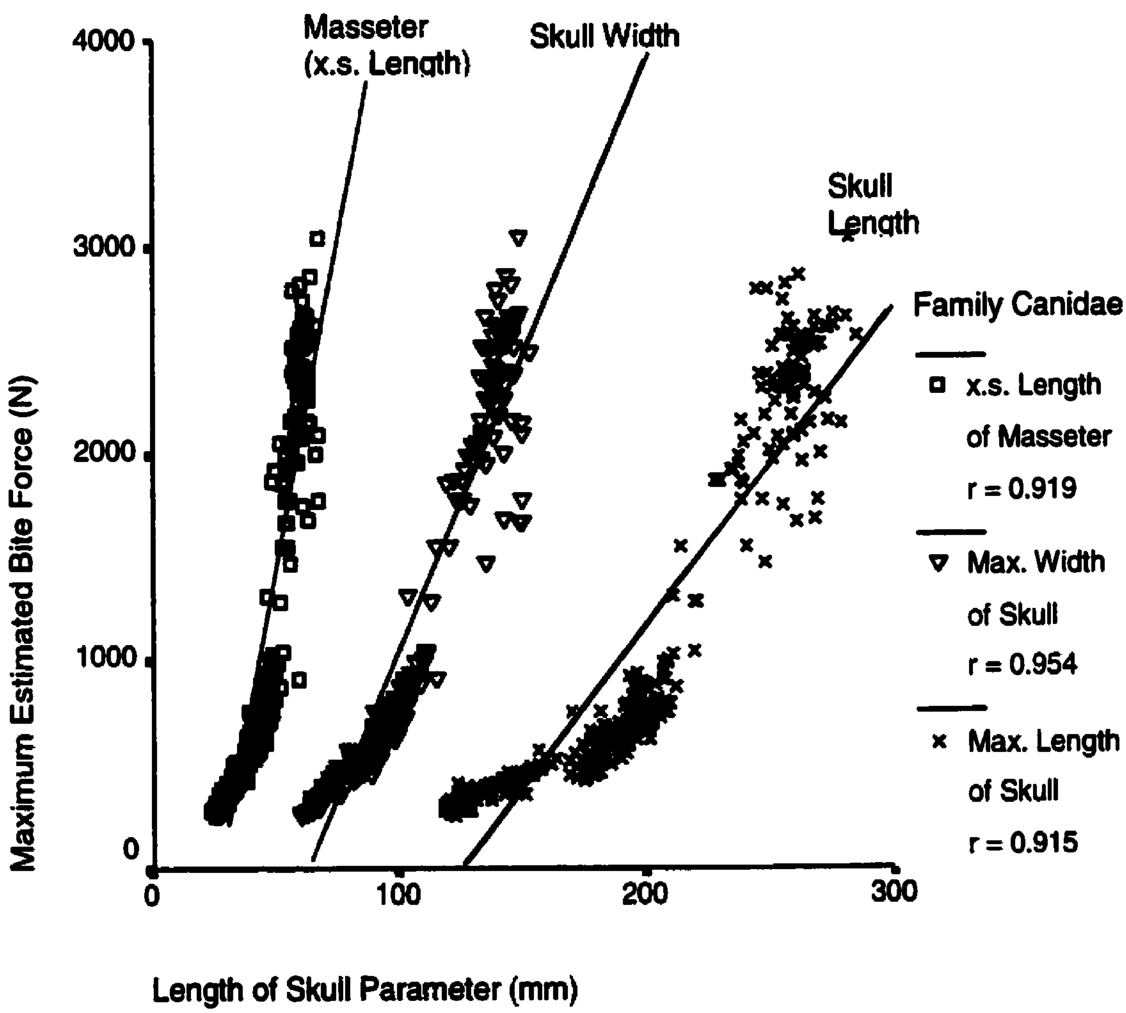
Masseter
(x.s. Length)
Skull Width
Skull
Length
1600
1400
1200
1000
800
600
400
200
Maximum Estimated Bite Force (N)
0
100
200
300
Length of Skull Parameter (mm)
Family Felidae
x.s. Length
of Masseter
r = 0.966
Max. Width
of Skull
r = 0.977
Max. Length
of Skull
r = 0.971

The Family Canidae showed similar trends (Figure 13). The r-value for the correlation of maximum estimated bite force with the maximum skull width was significantly higher than the other two skull parameters ($t = 2.87$, $p < 0.05$). The maximum skull width had a correlation coefficient of $r = 0.954$ with the maximum estimated bite force compared to $r = 0.919$ for the cross-sectional length of the masseter muscle and $r = 0.915$ for the maximum skull length.

In order to determine if there were similar trends in the species considered omnivorous, the Families Ursidae and Procyonidae were analyzed. Within the Family Procyonidae, the maximum estimated bite force was most highly correlated ($r = 0.954$) with the maximum skull width (Figure 14). The cross-sectional length of the masseter muscle had a correlation coefficient of $r = 0.875$ with the maximum estimated bite force, which was significantly lower than the previous parameter ($t = 3.84$, $p > 0.05$). When the skull parameters of the Ursidae were plotted versus the maximum estimated bite force (Figure 15), the maximum skull width had a correlation coefficient of $r = 0.965$, which was significantly higher than the correlation of the other two skull parameters.

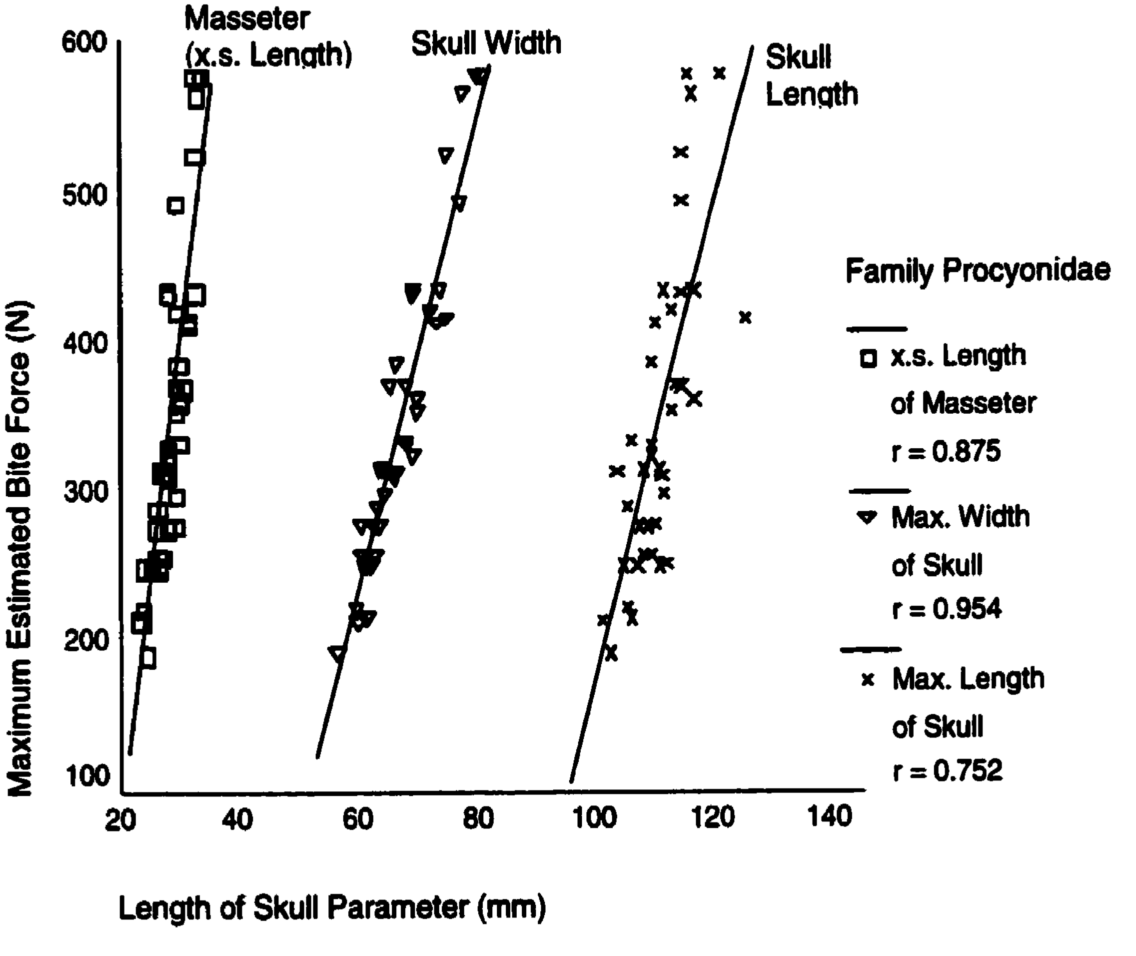
Thirdly, the relationships of the three skull parameters with maximum estimated bite force were examined by species to determine which skull parameter had a higher correlation coefficient. In the Family Mustelidae, the ermine had a maximum estimated bite force which was highly correlated with all parameters of the skull; however, the highest ($r = 0.929$) was with the maximum skull width (Figure 16). The mink had both the maximum skull length ($r = 0.921$) and maximum skull width ($r = 0.919$) highly

Figure 13. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the Family Canidae in North America.



4000
3000
2000
1000
0
Maximum Estimated Bite Force (N)
0
100
200
300
Length of Skull Parameter (mm)
Masseter
(x.s. Length)
Skull Width
Skull
Length
Family Canidae
x.s. Length
of Masseter
r = 0.919
Max. Width
of Skull
r = 0.954
Max. Length
of Skull
r = 0.915

Figure 14. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the raccoon (*Procyon lotor*) in North America.



Masseter (x.s. Length)
Skull Width
Skull Length
600
500
400
300
200
100
20
40
60
80
100
120
140
Maximum Estimated Bite Force (N)
Length of Skull Parameter (mm)
Family Procyonidae
x.s. Length of Masseter r = 0.875
Max. Width of Skull r = 0.954
Max. Length of Skull r = 0.752

Figure 15. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the black bear (*Ursus americanus*) in North America.

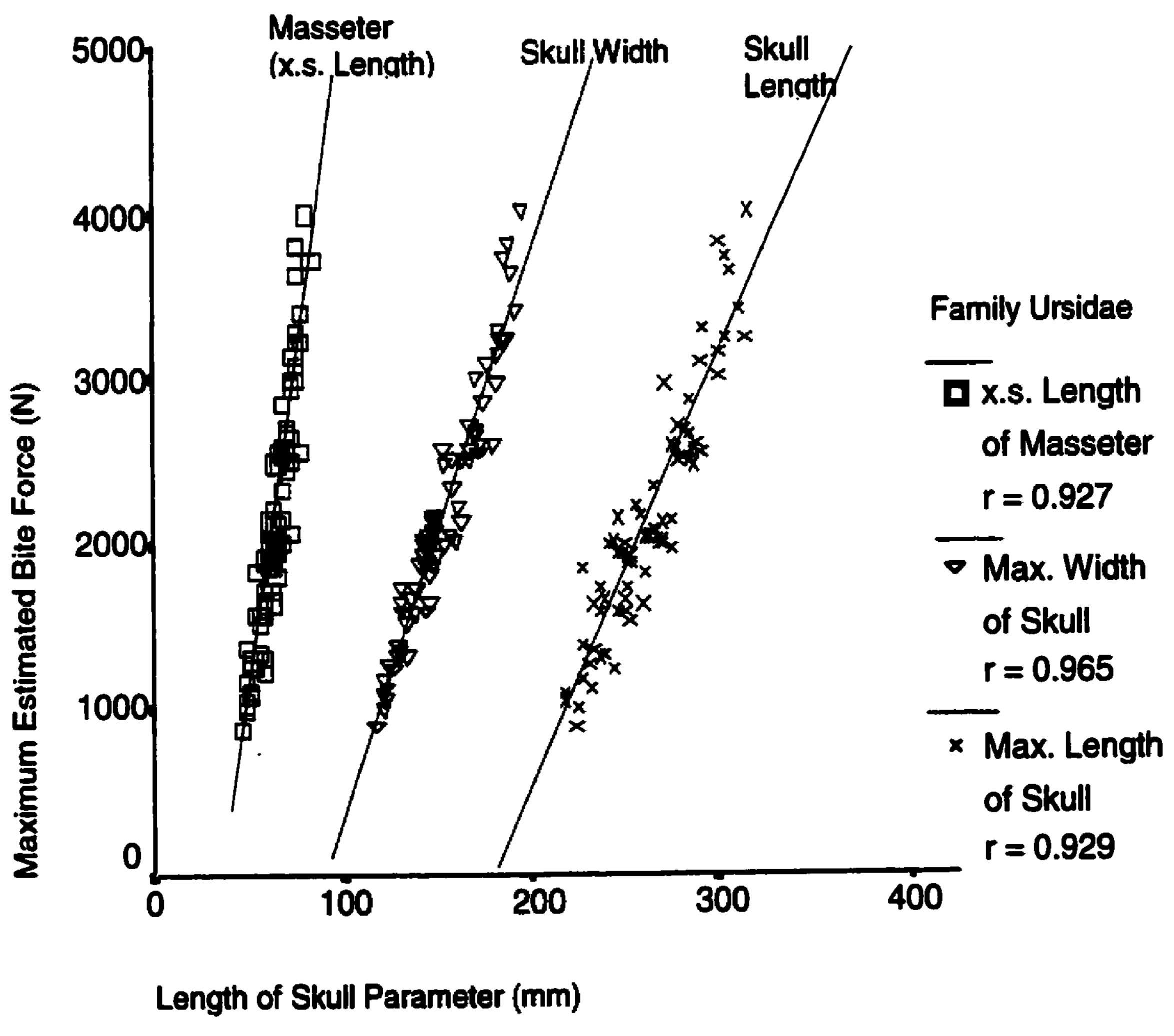
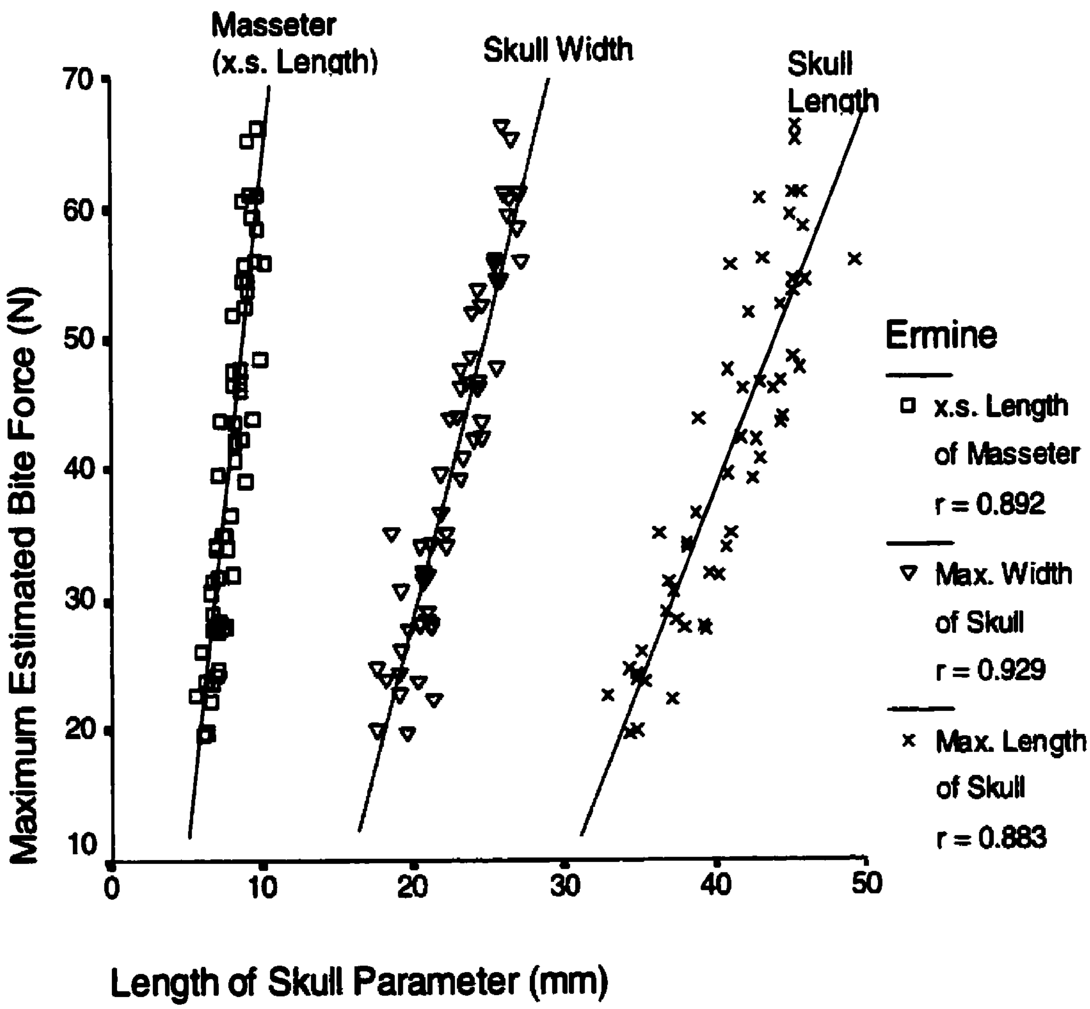

Masseter
(x.s. Length)
Skull Width
Skull
Length
Family Ursidae
x.s. Length
of Masseter
r = 0.927
Max. Width
of Skull
r = 0.965
Max. Length
of Skull
r = 0.929
Maximum Estimated Bite Force (N)
0
1000
2000
3000
4000
5000
0
100
200
300
400
Length of Skull Parameter (mm)

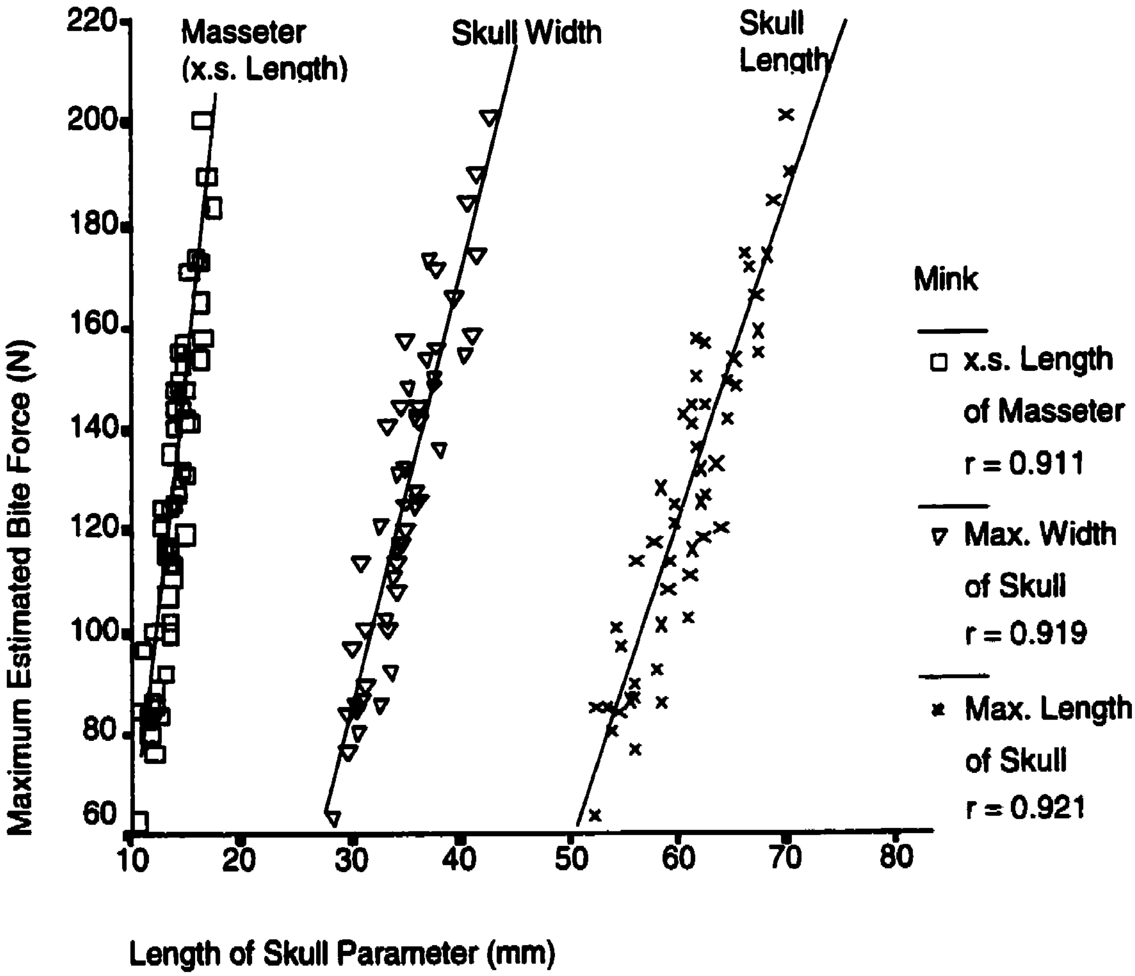
Figure 16. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the ermine (*Mustela erminae)* in North America.


Masseter
(x.s. Length)
Skull Width
Skull
Length
Maximum Estimated Bite Force (N)
70
60
50
40
30
20
10
0
10
20
30
40
50
Length of Skull Parameter (mm)
Ermine
x.s. Length
of Masseter
r = 0.892
Max. Width
of Skull
r = 0.929
Max. Length
of Skull
r = 0.883

correlated with the maximum estimated bite force (Figure 17). These values did not differ significantly from the r-value ($r = 0.911$) of the correlation between the maximum estimated bite force and the cross-sectional length of the masseter muscle. Figure 18 represents the correlation of the three skull parameters of the marten with the maximum estimated bite force. Again, the highest correlation was with the maximum skull width ($r = 0.940$), while the fisher similarly had a very strong ($r = 0.994$) correlation coefficient between the maximum skull width and the maximum estimated bite force (Figure 19). The largest member of the Family Mustelidae, the wolverine had the highest correlation ($r = 0.891$) between the maximum skull width and the maximum estimated bite force and this was significantly different ($t = 2.22$, $p < 0.05$) from the correlation values for the relationships between the maximum estimated bite force and the other two skull parameters (Figure 20).

Figure 21 represents the distribution of the maximum estimated bite force with the three skull parameters for the lynx. As can be seen, the r- value for this species was lower than the r-value of all other species in the Family Felidae and the cross-sectional length of the masseter muscle had the highest correlation with the maximum estimated bite force. Figure 22 represents the bobcat and the relationships that the skull parameters had with maximum estimated bite forces. As can be seen, maximum skull width had the second highest r-value (0.958), which was significantly higher than the correlation with the maximum skull length

Figure 17. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the mink (*Mustela vison)* in North America.



Masseter
(x.s. Length)
Skull Width
Skull
Length
Mink
x.s. Length
of Masseter
r = 0.911
Max. Width
of Skull
r = 0.919
Max. Length
of Skull
r = 0.921
Maximum Estimated Bite Force (N)
220
200
180
160
140
120
100
80
60
10
20
30
40
50
60
70
80
Length of Skull Parameter (mm)

Figure 18. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the marten (*Martes americana)* in North America.

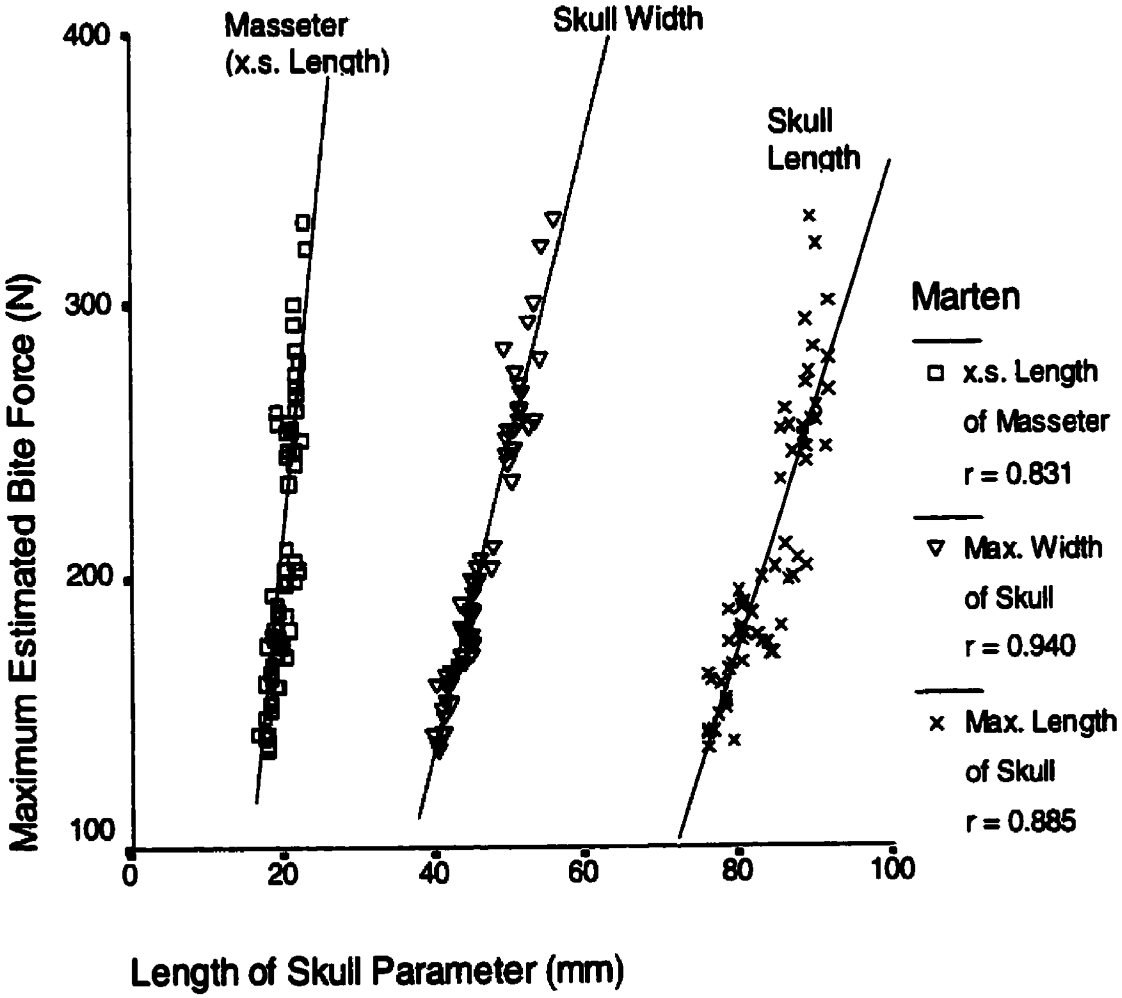
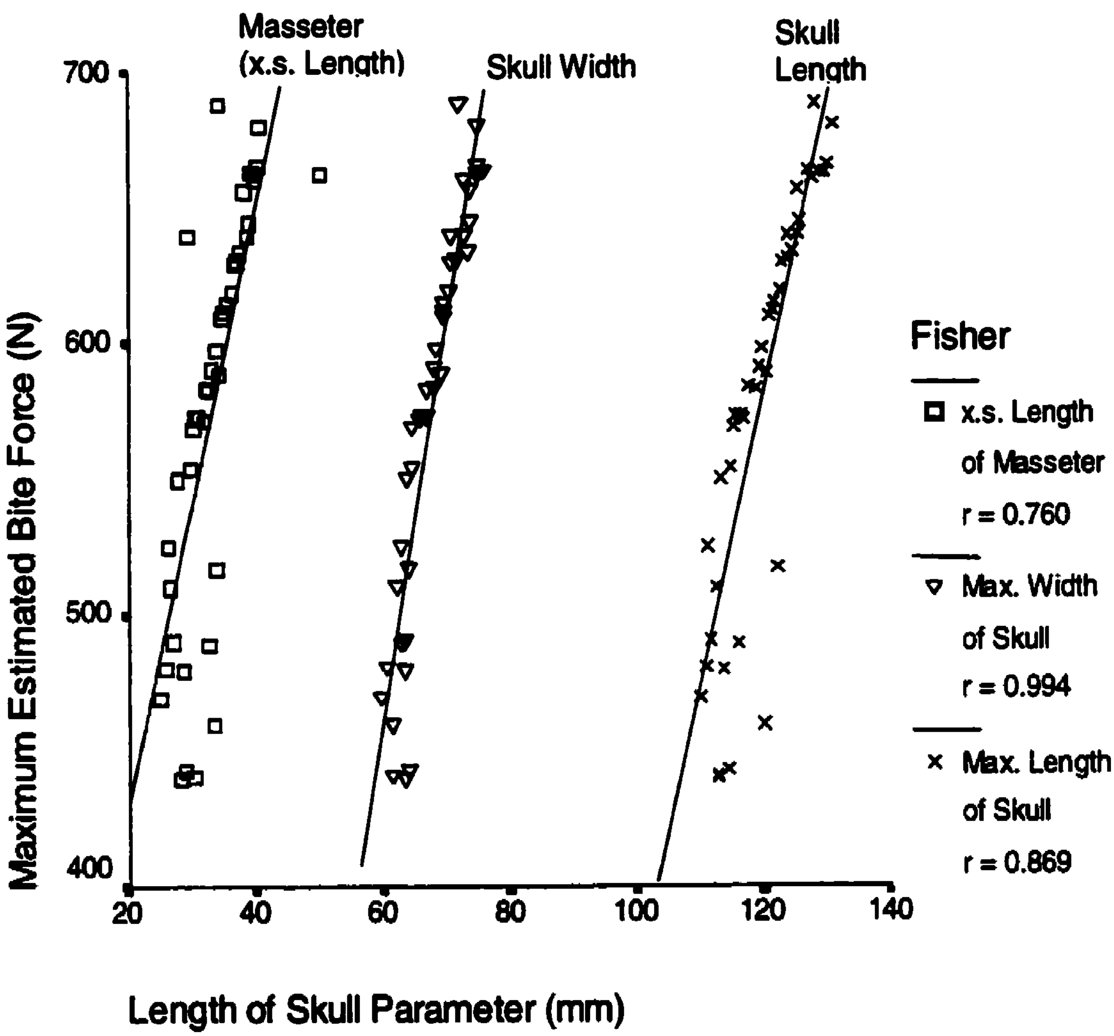

Masseter
(x.s. Length)
Skull Width
Skull
Length
Maximum Estimated Bite Force (N)
400
300
200
100
0
20
40
60
80
100
Length of Skull Parameter (mm)
Marten
x.s. Length
of Masseter
r = 0.831
Max. Width
of Skull
r = 0.940
Max. Length
of Skull
r = 0.885

Figure 19. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the fisher (*Martes pennanti*) in North America.



Masseter
(x.s. Length)
Skull Width
Skull
Length
700
600
500
400
20
40
60
80
100
120
140
Maximum Estimated Bite Force (N)
Length of Skull Parameter (mm)
Fisher
x.s. Length
of Masseter
r = 0.760
Max. Width
of Skull
r = 0.994
Max. Length
of Skull
r = 0.869

Figure 20. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the wolverine (*Gulo gulo*) in North America.

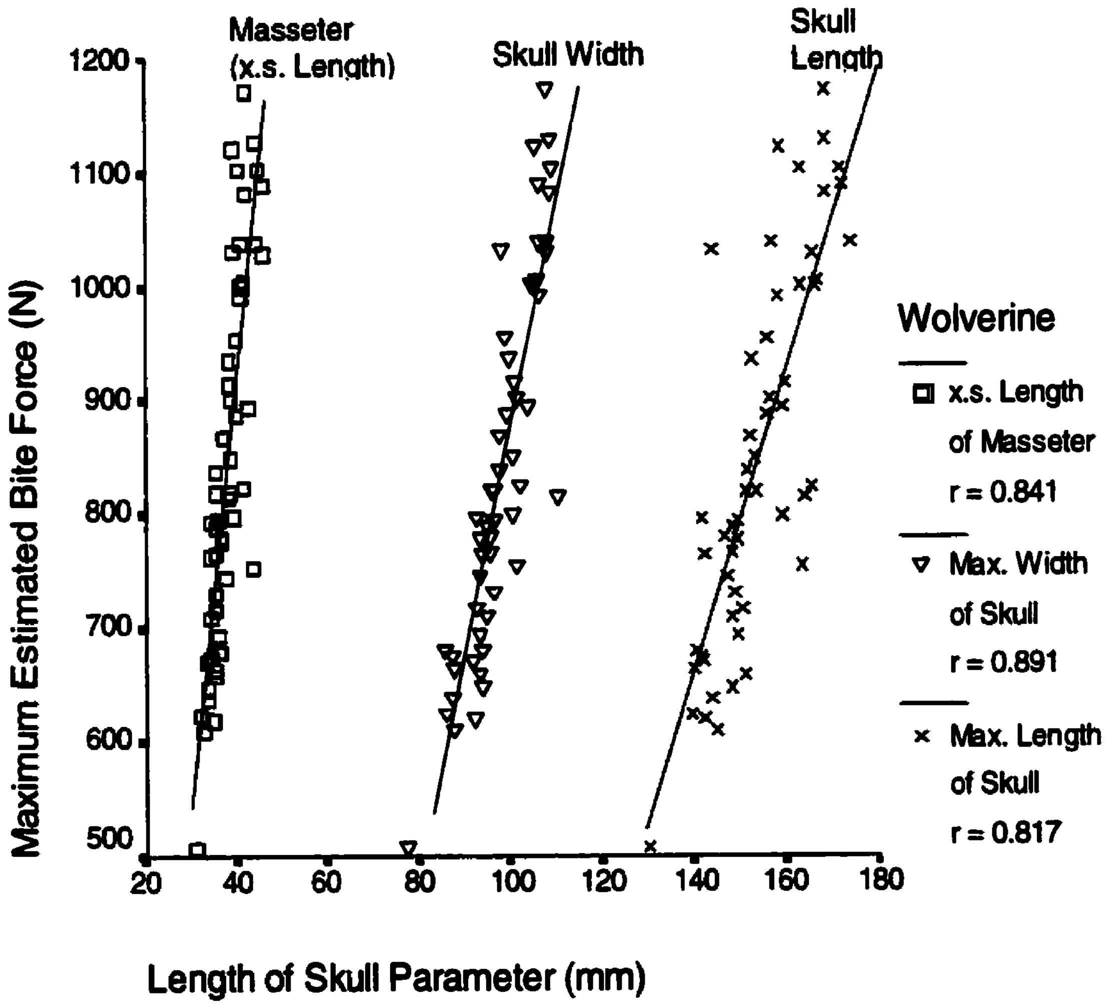

Masseter
(x.s. Length)
Skull Width
Skull
Length
Maximum Estimated Bite Force (N)
1200
1100
1000
900
800
700
600
500
20
40
60
80
100
120
140
160
180
Length of Skull Parameter (mm)
Wolverine
x.s. Length
of Masseter
r = 0.841
Max. Width
of Skull
r = 0.891
Max. Length
of Skull
r = 0.817

Figure 21. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the Lynx (*Lynx canadensis*) in North America.

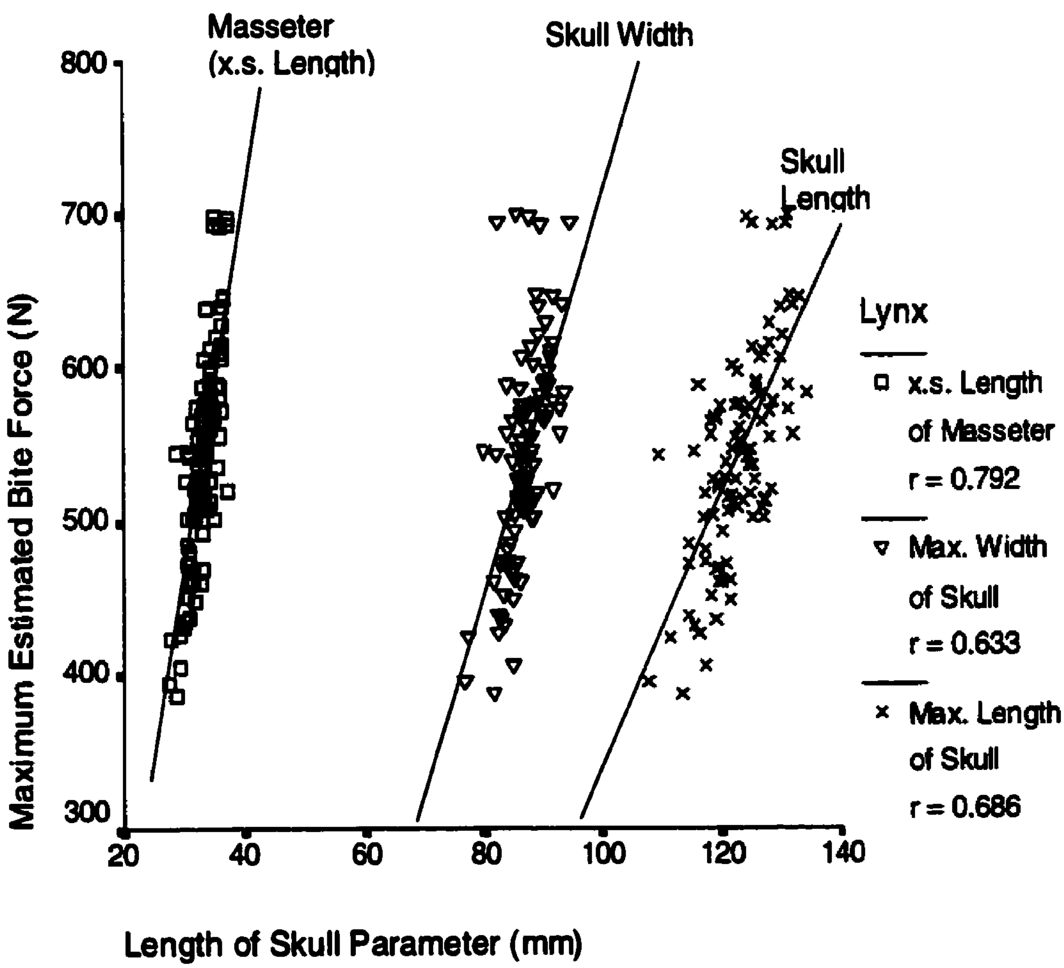
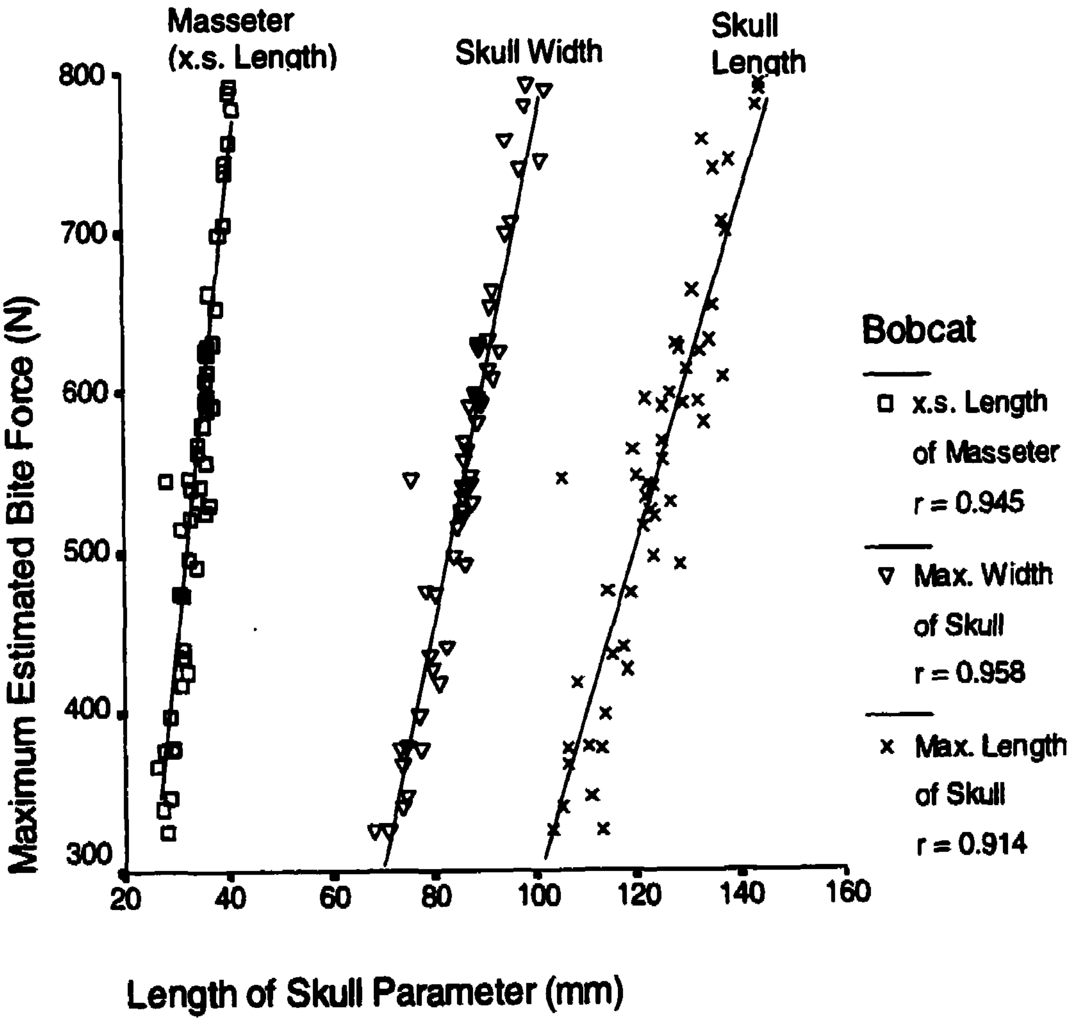

Masseter
(x.s. Length)
Skull Width
Skull
Length
Lynx
x.s. Length
of Masseter
r = 0.792
Max. Width
of Skull
r = 0.633
Max. Length
of Skull
r = 0.686
Maximum Estimated Bite Force (N)
300
400
500
600
700
800
20
40
60
80
100
120
140
Length of Skull Parameter (mm)

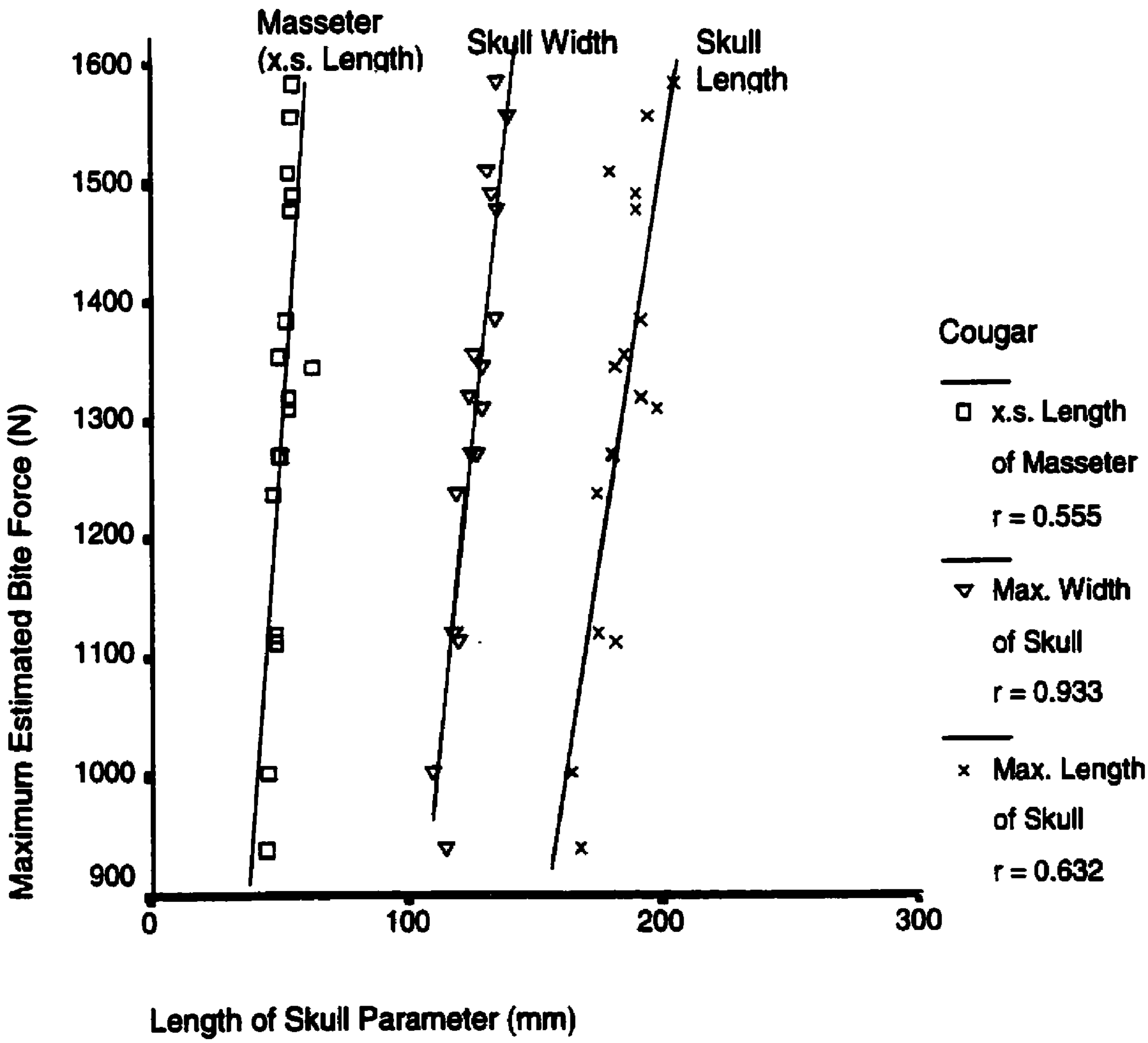
Figure 22. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross sectional length of the masseter muscle) for the bobcat (*Lynx rufus*) in North America.


Masseter
(x.s. Length)
Skull Width
Skull
Length
800
700
600
500
400
300
20
40
60
80
100
120
140
160
Maximum Estimated Bite Force (N)
Length of Skull Parameter (mm)
Bobcat
x.s. Length
of Masseter
r = 0.945
Max. Width
of Skull
r = 0.958
Max. Length
of Skull
r = 0.914

($r = 0.914$, $t = 3.2$, $p < 0.05$), but not ($t = 0.922$, $p > 0.05$) with the cross-sectional length of the masseter muscle ($r = 0.945$). The r-values for the correlation between the skull parameters and the maximum estimated bite forces for the cougar were strongest with the maximum skull width ($r = 0.933$) (Figure 23). This correlation was significantly higher than the correlation with the maximum skull length ($r = 0.632$) and the cross-sectional length of the masseter muscle ($r = 0.555$).

Within the Family Canidae, the highest correlation coefficients were found with the correlation between the maximum estimated bite forces and the maximum skull widths. As can be seen in Figure 24, the maximum skull width of the arctic fox was correlated ($r = 0.951$) with the maximum estimated bite force, and this was significantly higher than the other two measured skull parameters (length, $r = 0.860$ and masseter, $r = 0.913$). In the red fox, all three skull parameters were correlated with the maximum estimated bite force and although the maximum skull width had a stronger correlation than the other two skull parameters there was no significant difference between the r-values ($t = 0.25$, $p > 0.05$, Figure 25). In the coyote, there was a strong correlation between the maximum estimated bite force and the maximum skull width with an r-value of 0.935 (Figure 26). This correlation coefficient was significantly higher ($t = 4.6$, $p < 0.05$) than the other two correlation values of $r = 0.860$ and $r = 0.805$ for the cross-sectional length of the masseter muscle and the maximum skull length, respectively. In the wolf, the highest correlation was with the maximum skull width ($r = 0.665$); however, there were no

Figure 23. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the cougar (*Felis concolor*) in North America.



Masseter
(x.s. Length)
Skull Width
Skull
Length
1600
1500
1400
1300
1200
1100
1000
900
Maximum Estimated Bite Force (N)
0
100
200
300
Length of Skull Parameter (mm)
Cougar
x.s. Length
of Masseter
r = 0.555
Max. Width
of Skull
r = 0.933
Max. Length
of Skull
r = 0.632

Figure 24. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the arctic fox species (*Alopex lagopus*) in North America.

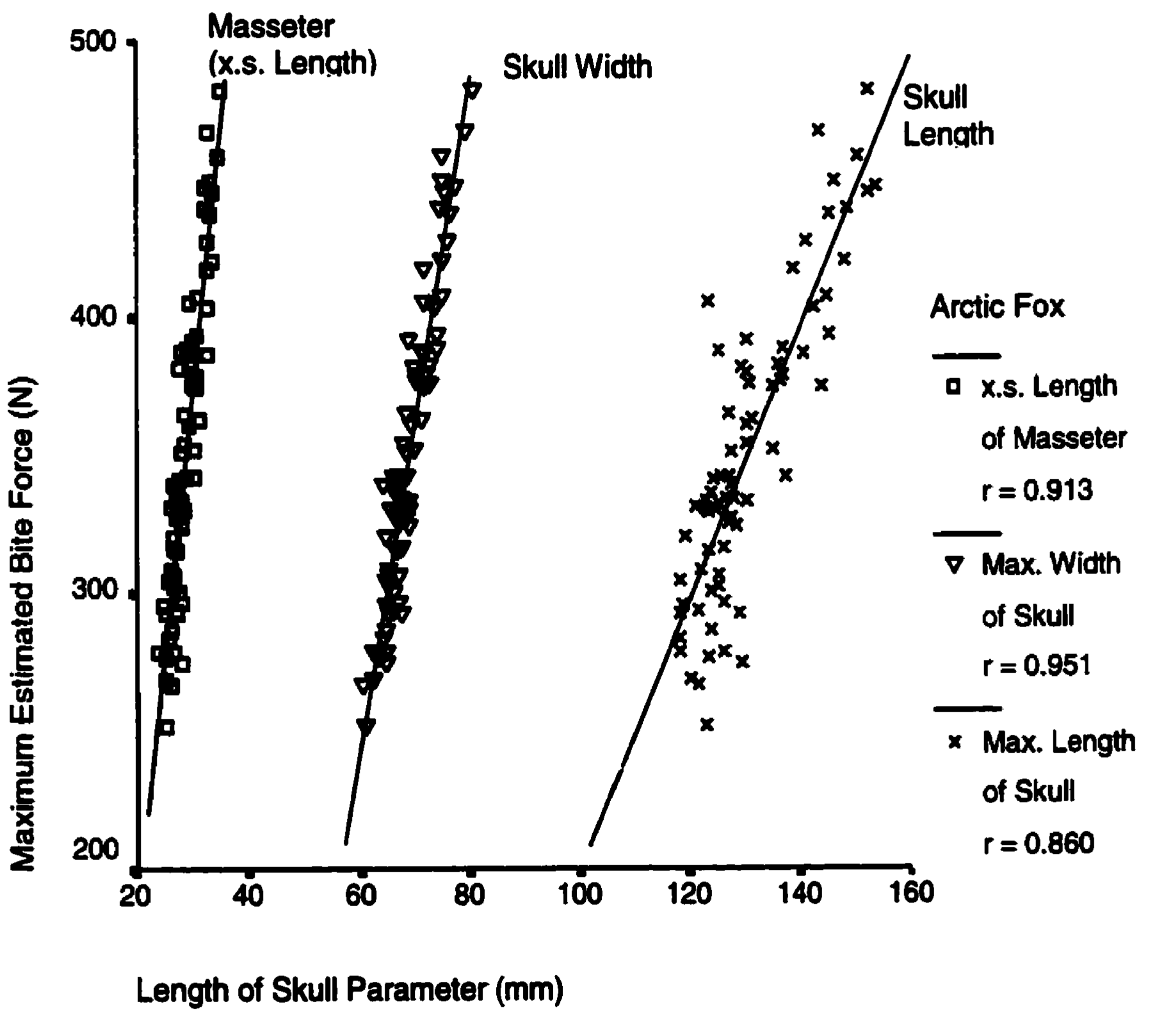
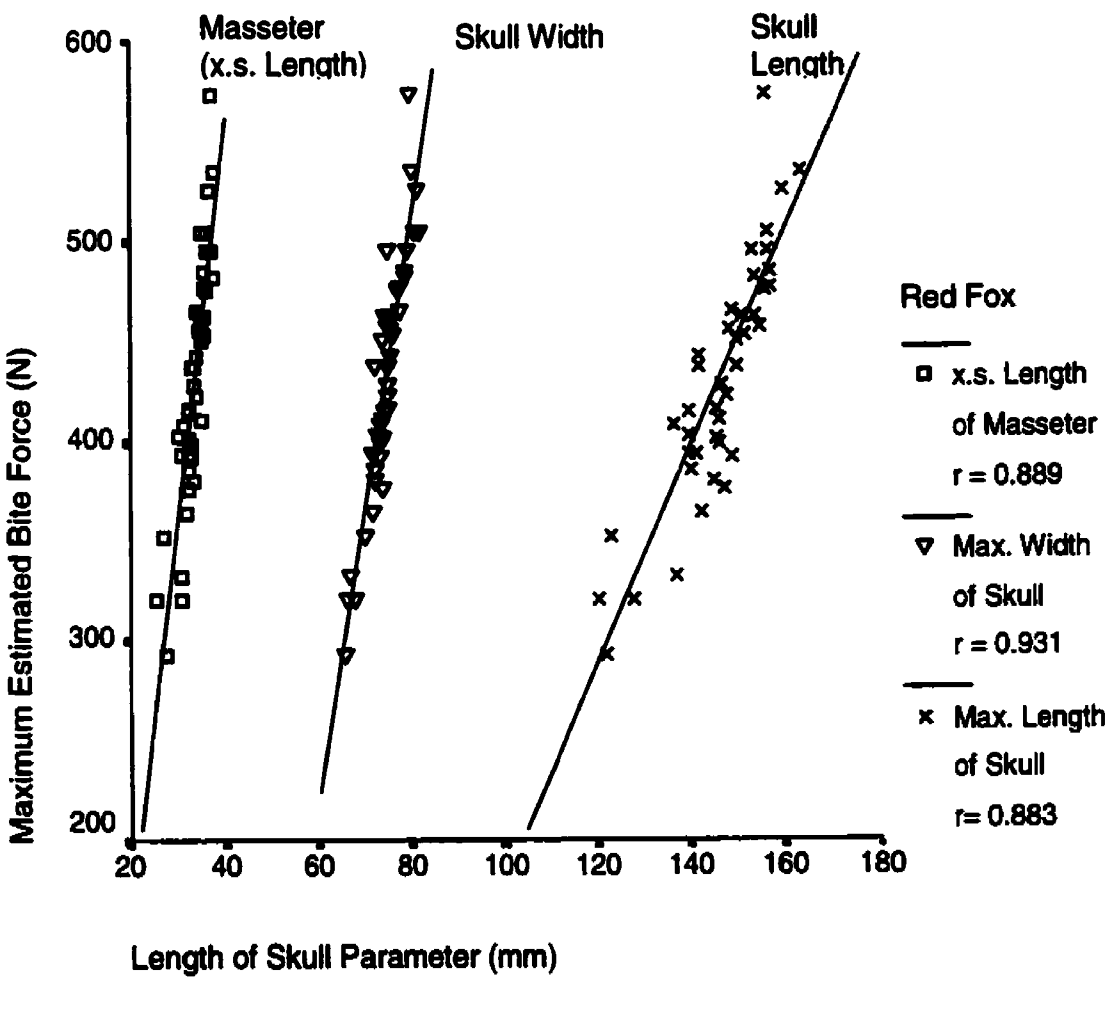
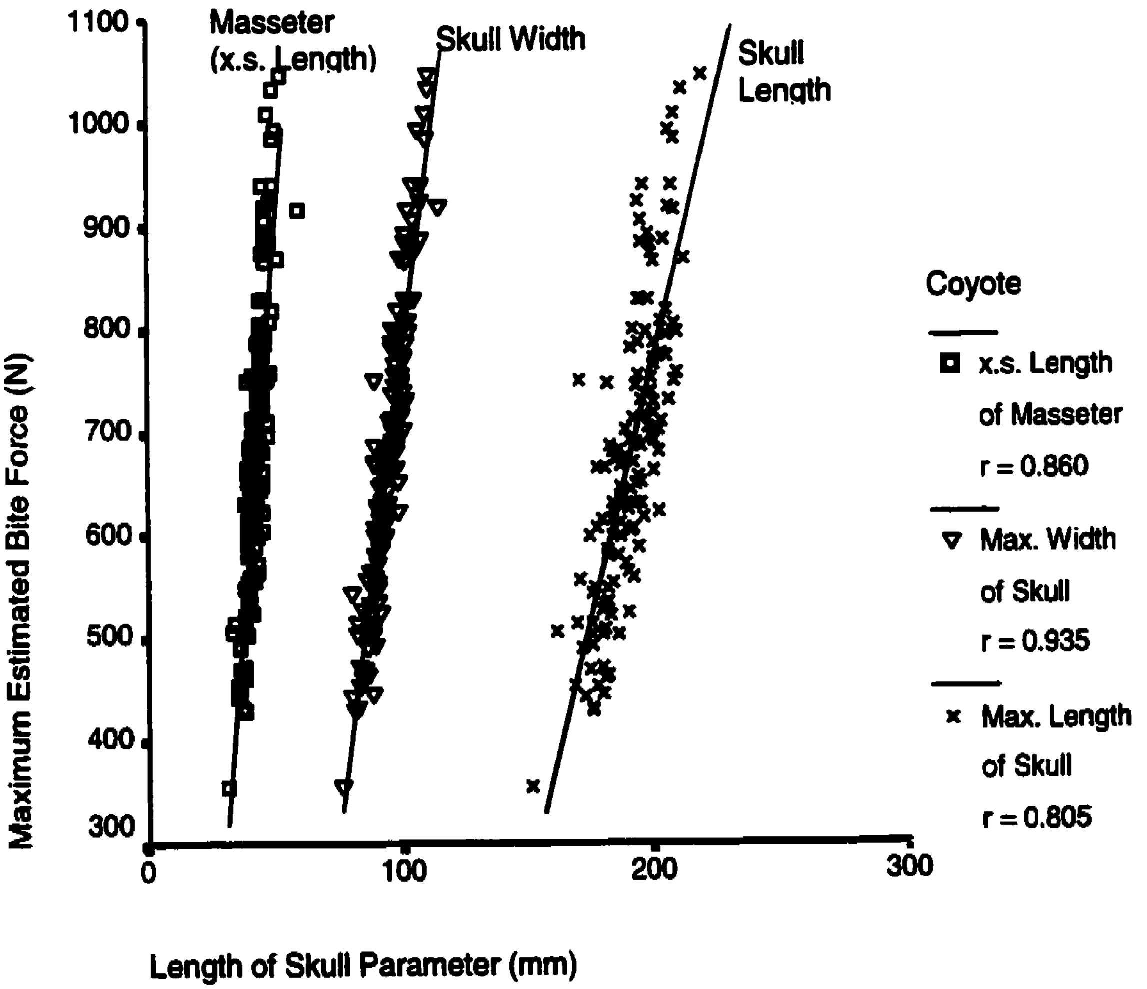

Masseter
(x.s. Length)
Skull Width
Skull
Length
Arctic Fox
x.s. Length
of Masseter
r = 0.913
Max. Width
of Skull
r = 0.951
Max. Length
of Skull
r = 0.860
Maximum Estimated Bite Force (N)
500
400
300
200
20
40
60
80
100
120
140
160
Length of Skull Parameter (mm)

Figure 25. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the red fox (*Vulpes fulva)* in North America.



Masseter
(x.s. Length)
Skull Width
Skull
Length
600
500
400
300
200
20
40
60
80
100
120
140
160
180
Maximum Estimated Bite Force (N)
Length of Skull Parameter (mm)
Red Fox
x.s. Length
of Masseter
r = 0.889
Max. Width
of Skull
r = 0.931
Max. Length
of Skull
r= 0.883

Figure 26. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the coyote (*Canis latrans)* in North America.

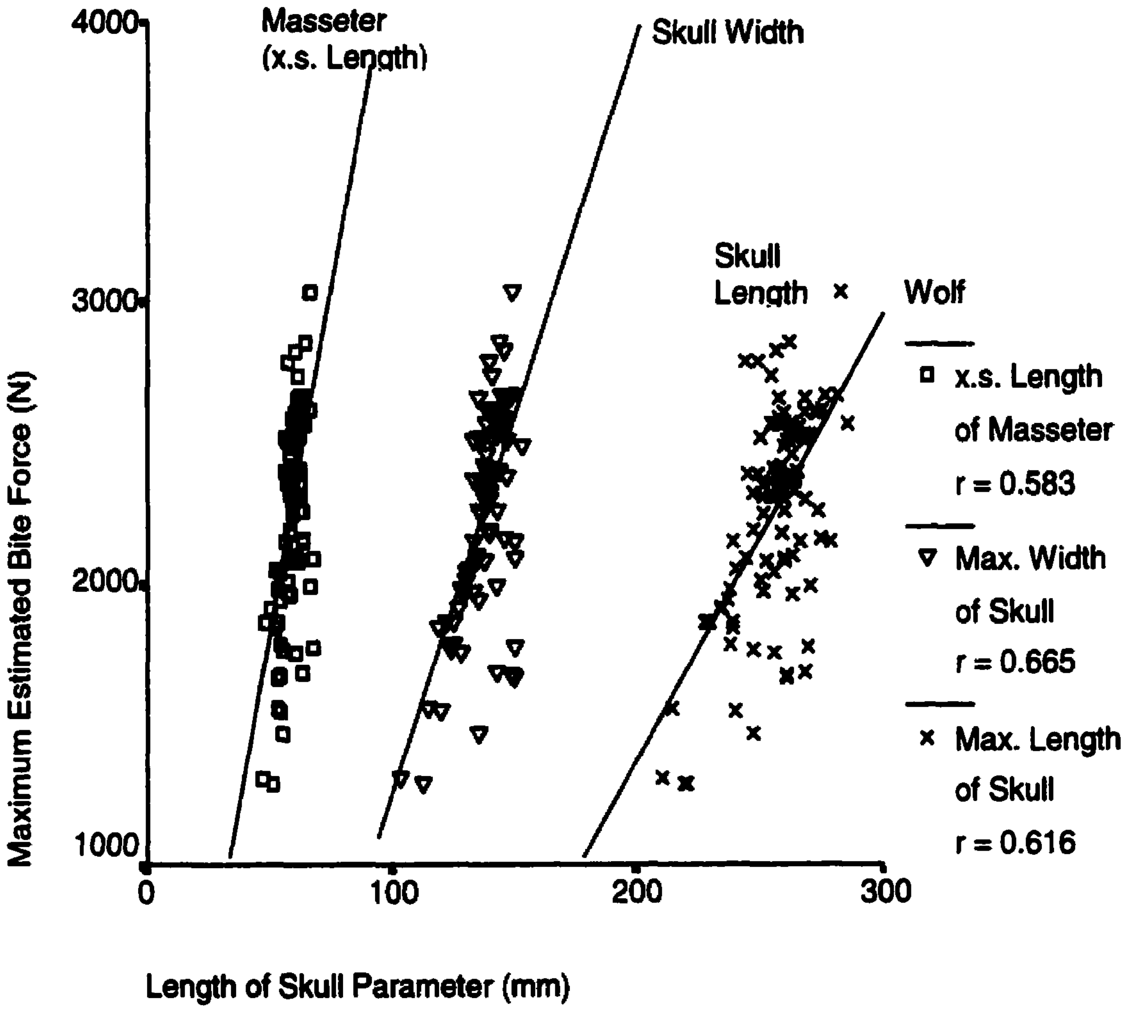

Masseter (x.s. Length)
Skull Width
Skull Length
Maximum Estimated Bite Force (N)
1100
1000
900
800
700
600
500
400
300
0
100
200
300
Length of Skull Parameter (mm)
Coyote
x.s. Length of Masseter r = 0.860
Max. Width of Skull r = 0.935
Max. Length of Skull r = 0.805

significant differences between the correlation values of the cross-sectional length of the masseter muscle (r = 0.583) nor the maximum skull length (r = 0.616) (Figure 27).

Although the three skull parameters (maximum skull length, maximum skull width, and cross-sectional length of the masseter muscle) were all highly correlated, in most cases, the maximum skull width was the variably more highly correlated with the maximum estimated bite force. Due to the curvilinear relationship between maximum estimated bite force and this parameter, the data were transformed to the square roots in order to minimize curvilinearity and reduce the amount of heteroscadacity. The new transformed equations were developed solely using the maximum skull width for all species to determine the line-of-best-fit and compare slope and intercept within and between families and species (Table 11).

Slopes were evaluated for significant differences with an ANCOVA and Tukey post-hoc analysis was used to determine sources of significant differences. As demonstrated above, the slope of the relationships between the square root of the maximum estimated bite force and the width of the skull for all carnivores was 0.327 and increased to 0.332, when the "omnivores" were removed. The line-of-best-fit for the relationship between the transformed maximum estimated bite force and the maximum skull width for all of the carnivores and the true carnivores did not significantly differ. When all families

Figure 27. Lines-of-best-fit and correlation between the maximum estimated bite force and the three skull parameters (maximum skull width, maximum skull length and cross-sectional length of the masseter muscle) for the wolf (*Canis lupus)* in North America.


Masseter
(x.s. Length)
Skull Width
Skull
Length
Wolf
x.s. Length
of Masseter
r = 0.583
Max. Width
of Skull
r = 0.665
Max. Length
of Skull
r = 0.616
Maximum Estimated Bite Force (N)
4000
3000
2000
1000
0
100
200
300
Length of Skull Parameter (mm)

were compared, the ANCOVA for the slopes of the regression lines of the square root of the maximum estimated bite force with the skull width showed that there was a significant difference ($F = 123.1$, $p < 0.0001$) between the five families. Post hoc analysis revealed that the Family Canidae had a steeper slope than all the other carnivores, but did not differ from the Family Procyonidae. It was also revealed that the black bear (slope = 0.365) was significantly different from the Mustelidae and the Felidae. Finally, it also revealed that the two families with the lowest slopes (Felidae, m = 0.321 and Mustelidae, m = 0.296) were significantly different from all the other three Families, but did not significantly differ from each other. When all species were compared, there was no significant difference between groups ($F = 1.75$, $p = 0.051$). Again, when the two omnivorous species (black bear and raccoon) were omitted from the analysis, the lack of significant differences became more evident ($F = 1.07$, $p = 0.379$). True carnivorous species were grouped into families to determine if any general trends became discernable between the larger and smaller species. Within the Family Mustelidae, the slopes ranged from 0.339 width for the largest member to 0.388 width for the smaller marten. There were no significant differences ($F = 1.54$ $p = 0.1915$) amongst the slopes of the square root of the maximum estimated bite force and the skull width for this family. Within the Family Felidae, the slopes ranged from 0.297 width for the largest member to 0.327 for the smaller bobcat. There were no significant differences amongst the slopes of the square root of the maximum estimated bite force and the skull width for this family. Within the Family Canidae, the slopes of the lines defining the correlation between the

Table 11: Summary of Lines of best fit for the correlation between the square root of the maximum estimated bite force and the maximum skull width.

n	Classification	Force (N)	Slope	Y-Inter √N	Sub Set	Corr. Coeff	Equation
888	All Carnivora	823.1	0.335	-3.10	a	0.97	y = 0.33x – 3.10
780	True Carnivora	656.6	0.330	- 2.74	a	0.98	y = 0.33x – 2.74
262	Mustelidae	351.8	0.296	0.26	c	0.99	y = 0.30x + 0.26
164	Felidae	800.5	0.320	- 4.42	c	0.97	y = 0.32x – 4.42
354	Canidae	929.7	0.420	- 11.78	a	0.98	y = 0.42x – 11.78
38	Procyonidae	346.5	0.418	- 9.74	a	0.96	y = 0.41x – 9.74
70	Ursidae	2160.8	0.365	- 9.56	b	0.97	y = 0.36x – 9.56
55	Ermine	40.8	0.360	- 1.88	a	0.93	y = 0.36x – 1.88
51	Mink	126.5	0.380	- 2.19	a	0.92	y = 0.38x – 2.19
61	Marten	207.6	0.390	- 3.75	a	0.97	y = 0.39x – 3.75
41	Fisher	539.1	0.448	- 6.23	a	0.99	y = 0.45x – 6.23
54	Wolverine	844.9	0.339	- 4.41	a	0.90	y = 0.34x – 4.41
96	Lynx	541.5	0.304	- 3.18	a	0.67	y = 0.30x – 3.18
51	Bobcat	548.5	0.327	- 4.79	a	0.96	y = 0.33x – 4.79
17	Cougar	1311.5	0.297	- 1.45	a	0.93	y = 0.30x – 1.45
74	Arctic Fox	350.6	0.319	- 3.29	a	0.95	y = 0.32x – 3.29
42	Red Fox	430.5	0.364	- 6.35	a	0.94	y = 0.36x – 6.35
137	Coyote	681.9	0.355	- 7.71	a	0.94	y = 0.36x – 7.71
101	Wolf	2255.7	0.301	5.83	a	0.67	y = 0.30x + 5.83

transformed maximum estimated bite force and the skull width ranged from 0.301 (maximum skull width) for the largest member to 0.364 (maximum skull width) for the red fox. Although there was a greater range in maximum estimated bite forces for the Canidae, there were no significant differences (F = 1.309, p = 0.200) amongst the slopes of the square root of the maximum estimated bite force and the skull width for this family.

Y-intercepts were evaluated for significant differences with an ANCOVA. When all species were allowed in the analysis, there was a significant difference within the Order Carnivora (F=104.55, p < 0.001). Likewise, when the two omnivores species were omitted, significant differences were still evident (F = 2.816, p = 0.013). The Order Carnivora was separated into the respective families to determine if any general trends became discernable between the families. For the Family Mustelidae, the line-of-best-fit for the correlation between the square root of the maximum estimated bite force and the maximum skull width had a y intercept of – 0.268. The Family Felidae had a y- intercept of – 4.425 while the Family Canidae had a y-intercept of –11.789 for the same line-of-best-fit. The above data are also summarized in Table 11. When all families are compared, the ANCOVA for the y-intercepts of the regression lines for the square root of the maximum estimated bite force with the skull width showed that there is a significant difference (F = 179.59, p < 0.0001). Tukey post hoc analysis revealed that the Family Canidae had the lowest y-intercept of –11.78 and that the true carnivores did each differ significantly from one another. The post hoc analysis also showed that the two omnivores were not different from each other and the family Canidae, but did significantly differ from the Felidae and the Mustelidae. Families were then separated into species to examine if trends became discernable.

The y-intercepts of the relationships between the square root of the maximum estimated bite force and the width of the skull ranged from 5.83 $N^{1/2}$ (square root maximum estimated bite force) for the *Canis lupus* to –9.74 $N^{1/2}$ for the *Procyon lotor.* Within the Family Mustelidae, the y-intercepts ranged from -1.88 $N^{1/2}$ for the smallest member (ermine) to –6.23 $N^{1/2}$ for the larger fisher. There were no significant differences (F=1.108 p=. 3536) amongst the y-intercepts of the line-of-best-fit for the square root of the maximum estimated bite force and the skull width for the species in this family. Within the family Felidae, the y-intercepts ranged from –1.45 $N^{1/2}$ for the largest member to –4.79 $N^{1/2}$ for the smaller bobcat. There were no significant differences amongst the y-intercepts of the line-of-best-fit for the square root of the maximum estimated bite force and the skull width for this family. Within the Family Canidae, the y-intercepts ranged from 5.83 $N^{1/2}$ for the largest member to –7.71 $N^{1/2}$ for the second largest member, the coyote. There was a greater range in bite forces for the Family Canidae, resulting in significant differences (F=5.835, p = 0.0007) amongst the y-intercepts of the square root of the maximum estimated bite force and the skull width for this family. Post hoc (Tukey) analysis showed that the wolf had a significantly higher y-intercept than the other members of this family. The remaining members of the family showed no significant difference between the y-intercepts for the lines-of-best-fit defining the correlation between the square root of the maximum estimated bite force and the maximum skull width. The scaling relationship between any linear skull dimension and the maximum estimated bite force is outline in Appendix 1.

Primary Prey Weights

To determine if a relationship between estimated bite forces for the North American carnivores and prey weights exist, an extensive literature search was conducted to identify the primary prey of each of the 14 species. The weights used in this project were determined from the single mammalian prey species, which were recorded in the literature as composing the highest percentage of the diet. In the case of the omnivores, the largest mammalian prey species was used.

The smallest member of the Mustelidae family represented in this study was the ermine, whose diet is comprised primarily of mice resulting in a prey weight of 0.07 kg. The second member of this family, the mink feed primarily on muskrat, resulting in a primary prey weight of 0.22 kg. The medium sized member of the Family Mustelidae, the marten, also preys on small mammals, although its primary prey item weight (red squirrel) is heavier at 1.12 kg. The fisher, has a diet composed of three primary items (red squirrel, hare, vole) with an average weight of 1.23 kg. The largest member of the Mustelidae family, the wolverine feeds primarily on small ungulates with an average estimated prey weight of 23.75 kg.

Within the family Felidae, three species were utilized in this study. Lynx and bobcat are similar sized relatives; however, it is known that lynx is considered a specialist whose diet is composed almost entirely of the snowshoe hare (Nellis et al., 1972; Brand and Keith 1979; Van Zyll de Jong 1966a). Thus the prey weight according to McCord and Cordoza (1982) would be 1.49 kg. The bobcat, although similar in size, is not considered to be a specialist, but more of a generalist with a diverse diet (Young 1958). The primary prey item for this Felidae member is that of the cotton tail rabbit, which according to McCord and Cordoza (1982) is recorded as having an average weight of 1.35 kg. The largest member of the Family Felidae family, the cougar, is known also to have a diverse diet, primarily comprised of large ungulates (Hibben 1939), such as deer with an average weight of 71.00 kg.

Within the Family Canidae, four species were studied. The smallest member being that of the Arctic Fox. The primary prey item for this member of the Canidae family was recorded as the lemming, with an average weight of 0.07 kg. The second largest member of the Family Canidae, the red fox, is recorded by Samuel and Nelson (1982) as having a diet composed primarily of small mammals (voles, rabbits, squirrels, mice). According to the Wild Mammals of North America (Johnson and Johnson. 1983; Bittner and Rongstad 1983; Tomich 1983; Flyger and Gates 1983) the average weight of these species is 0.15 kg. The second largest member of the Family Canidae, the coyote, has a diet ranging from birds to ungulates, but the diet is primarily composed of rabbits and hares with an average weight of 1.53 kg. The wolf, has a diet that shifts depending on location (Mulders 1997). In total, the average weight of prey items for the North American wolf sampled four locations (Low Arctic, Tree line, Boreal Forest and Algonquin Park) was 229 kg.

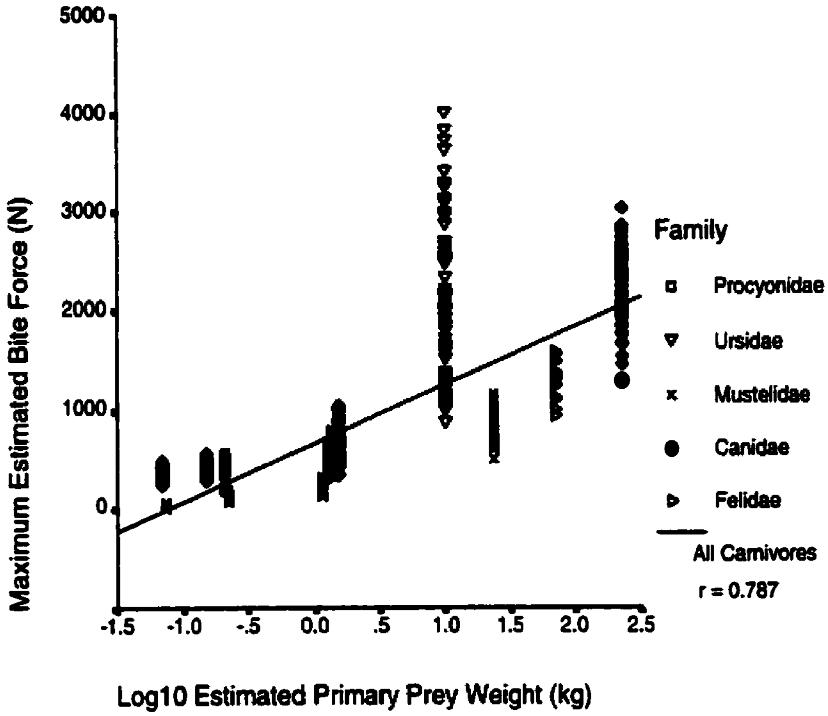
Maximum Estimated Bite Force and Primary Prey Weight

Within the Order Carnivora, there was no correlation between maximum estimated bite force and the mean estimated primary prey weight. However, $\log_{10}$ transformation of the primary prey weight did result in significant positive correlations. When families were analyzed there was a significant relationship between the $\log_{10}$ prey weight and the maximum estimated bite force ($F = 1400.1$, $p < 0.001$) with the line-of-best-fit having a $r = 0.787$ (Figure 28). When the two omnivores were removed from the analysis, the correlation coefficient increased by 9.0%, $r = 0.851$ ($F = 1979.8$, $p < 0.001$), which was significantly different from the previous analysis (Figure 29). When each family was analyzed separately, the Mustelidae (Figure 30) had the highest correlation coefficient of $r = 0.920$ ($F = 1239.95$, $p < 0.001$) for the relationship of the maximum estimated bite force and the $\log_{10}$ of the primary prey weight. A strong correlation between these variables was also demonstrated by the Family Felidae (Figure 31), which had a correlation coefficient $r = 0.909$ ($F = 682.2$ $p < 0.001$), and the Family Canidae (Figure 32), which had a correlation coefficient $r = 0.915$ ($F = 1874.6$, $p < 0.001$).

In order to determine if differences existed in the relationship between maximum estimated bite force and prey weights among the families, a correlation analysis was conducted. To determine if there were significant differences among the correlation values for all carnivores including omnivores and true carnivores, a Student t-test was conducted. Results of the t-tests indicated that the r-value of the maximum estimated bite force and the $\log_{10}$ of the prey

Figure 28. Line of best fit of the maximum estimated bite force (N) correlated with the mean $\log_{10}$ primary prey weight (kg) for the Order Carnivora in North America.

Figure 29. Line of best fit of the maximum estimated bite force (N) correlated with the mean $\log_{10}$ primary prey weight (kg) for the North American Order of Carnivora with the two families of omnivores (Procyonidae and Ursidae) removed.


5000
4000
3000
2000
1000
0
Maximum Estimated Bite Force (N)
-1.5
-1.0
-.5
0.0
.5
1.0
1.5
2.0
2.5
Log10 Estimated Primary Prey Weight (kg)
Family
Procyonidae
Ursidae
Mustelidae
Canidae
Felidae
All Carnivores
r = 0.787

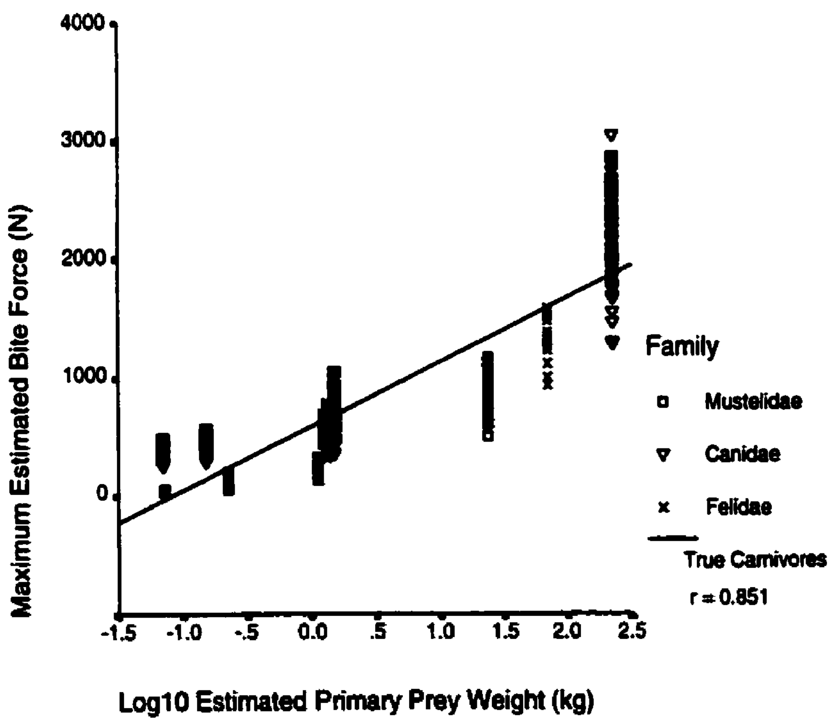
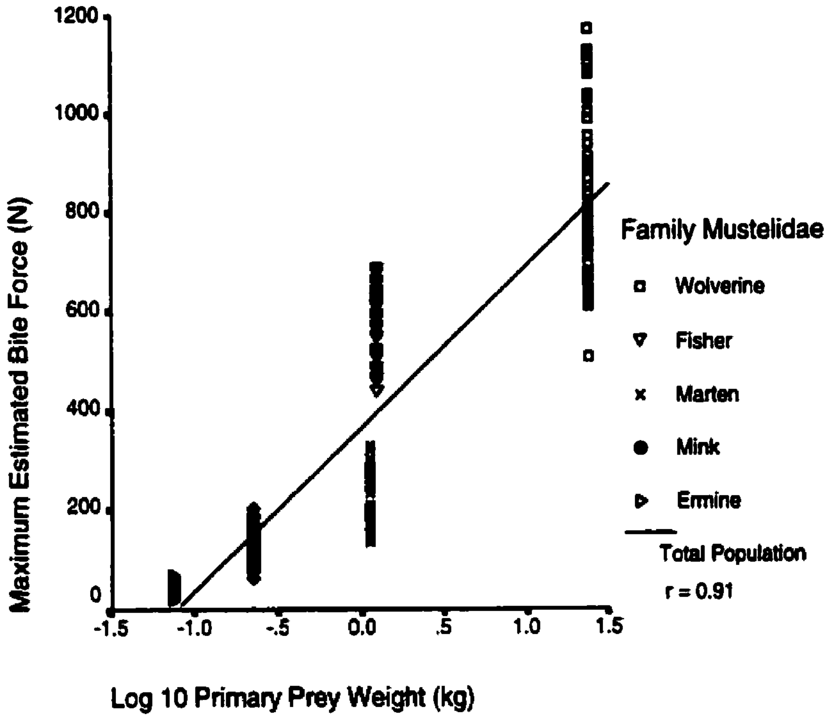
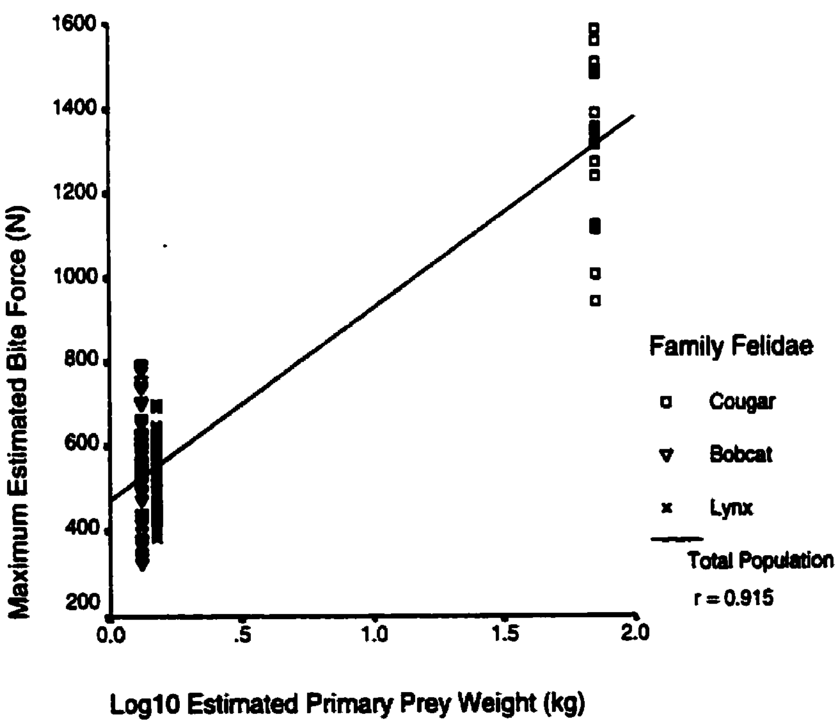

4000
3000
2000
1000
0
Maximum Estimated Bite Force (N)
-1.5
-1.0
-.5
0.0
.5
1.0
1.5
2.0
2.5
Log10 Estimated Primary Prey Weight (kg)
Family
Mustelidae
Canidae
Felidae
True Carnivores
r = 0.851

Figure 30. Line of best fit of the maximum estimated bite force (N) correlated with the mean log_{10} primary prey weight (kg) for the Family Mustelidae in North America.

Figure 31. Line of best fit of the maximum estimated bite force (N) correlated with the mean log_{10} primary prey weight (kg) for the Family Felidae in North America.

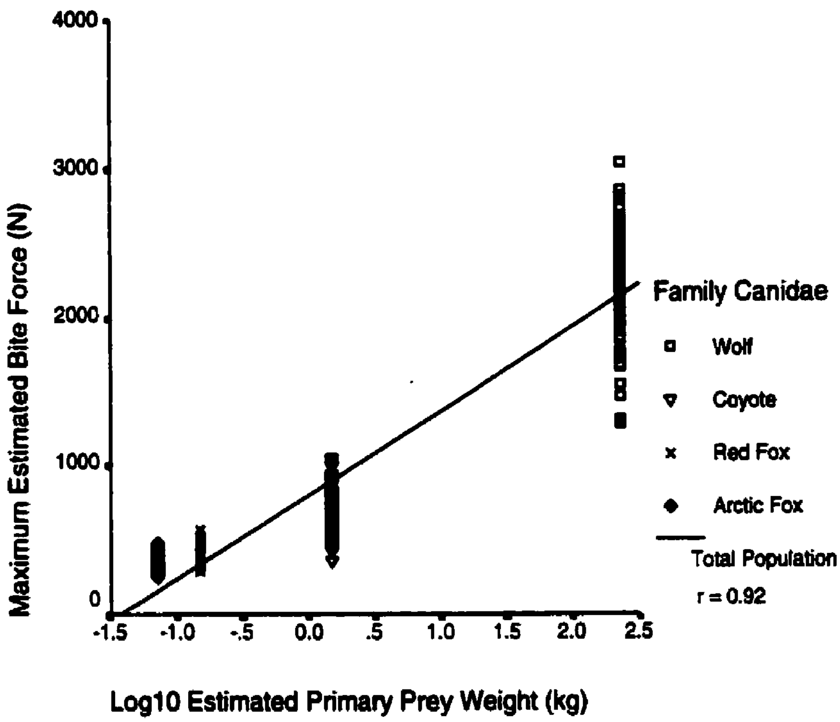


1200
1000
800
600
400
200
0
Maximum Estimated Bite Force (N)
-1.5
-1.0
-.5
0.0
.5
1.0
1.5
Log 10 Primary Prey Weight (kg)
Family Mustelidae
Wolverine
Fisher
Marten
Mink
Ermine
Total Population
r = 0.91



1600
1400
1200
1000
800
600
400
200
Maximum Estimated Bite Force (N)
0.0
.5
1.0
1.5
2.0
Log10 Estimated Primary Prey Weight (kg)
Family Felidae
Cougar
Bobcat
Lynx
Total Population
r = 0.915

Figure 32. Line of best fit of the maximum estimated bite force (N) correlated with the mean $\log_{10}$ primary prey weight (kg) for the Family Canidae in North America.



4000
3000
2000
1000
0
Maximum Estimated Bite Force (N)
-1.5
-1.0
-.5
0.0
.5
1.0
1.5
2.0
2.5
Log10 Estimated Primary Prey Weight (kg)
Family Canidae
Wolf
Coyote
Red Fox
Arctic Fox
Total Population
r = 0.92

weight for all carnivores were significantly lower ($t = 7.78$, $p < 0.001$) than the correlation when omnivorous animals removed. When the correlation values of the three Families of true carnivores were examined, no significant differences were found.

Slopes of the lines-of-best-fit for the correlation of the maximum estimated bite force and the $\log_{10}$ of the primary prey weights were compared with an ANCOVA. The slope of the line-of-best-fit for the Order Carnivore was significantly different from that of the three species of true carnivores ($t = 7.65$ $p < 0.001$) and the slope of the three true carnivore families combined was significantly different from that of each individual family. Of the three families of true carnivores, the Family Canidae had the steepest slope, m = 512 (N / Log Prey Wt.), the Family Felidae had the second steepest slope m = 430 (N / Log Prey Wt.), while the Family Mustelidae had the lowest slope with m = 321 (N / Log Prey wt.) and each slope was significantly different from one another (Table 12).

The y-intercepts created by the lines-of-best-fit for the correlation between the maximum estimated bite force and the $\log_{10}$ of the primary prey weight ranged between 876 N for the Family Canidae to 334 N of the Family Mustelidae. The Order Carnivore had a y-intercept of 702 N. Once the animals considered to be "omnivorous" were removed from the analysis, this y-intercept decreased to 626 N. When each of the "true carnivores" were analyzed separately, it was shown that y-intercept of the Family Canidae was almost twice that of the Family Felidae, which had a y-intercept of 487 N. As with the slopes, all of the y-

Table 12: Summary of lines-of-best-fit for the correlation between the maximum estimated bite force and the $\log_{10}$ mean primary prey weight.

N	Classification	Bite Force (N)	Slope N/kg	Y-Inter N	Sub-Set	Corr. Coeff.	Equation
888	All Carnivora	823.1	546.4	702.0	a	0.787	$y = 546\ x + 702$
780	True Carnivora	656.6	495.4	626.1	b	0.851	$y = 495\ x + 626$
262	Mustelidae	351.8	321.7	334.3	c	0.910	$y = 321\ x + 334$
164	Felidae	800.5	451.2	474.5	d	0.915	$y = 451\ x + 474$
354	Canidae	929.7	512.6	876.1	e	0.920	$y = 512\ x + 876$

intercepts of the lines-of-best-fit for the correlation between the maximum estimated bite force and the $\log_{10}$ of the primary prey weight were significantly different from each other.

Distribution of the Maximum Estimated Bite Force

Relative frequency and distribution of the maximum estimated bite force were graphed to access degree of overlap, niche breadth and potential competition. When the distribution of the maximum estimated bite force were examined within the Family Mustelidae, five (5) relatively distinct narrow bell shaped distributions were found (Figure 33). Within the Family Felidae, the same type of plot resulted in one narrow and two more widely overlapping distributions (Figure 34). Within the Family Canidae, the two smaller species (arctic and red fox) had overlapping maximum estimated bite force distributions, while the remaining larger species (coyote and wolf) had distributions that did not overlap (Figure 35).

Figure 33. Frequency distribution (% of population) of the maximum estimated bite force (N) for the five species of the Family Mustelidae in North America.

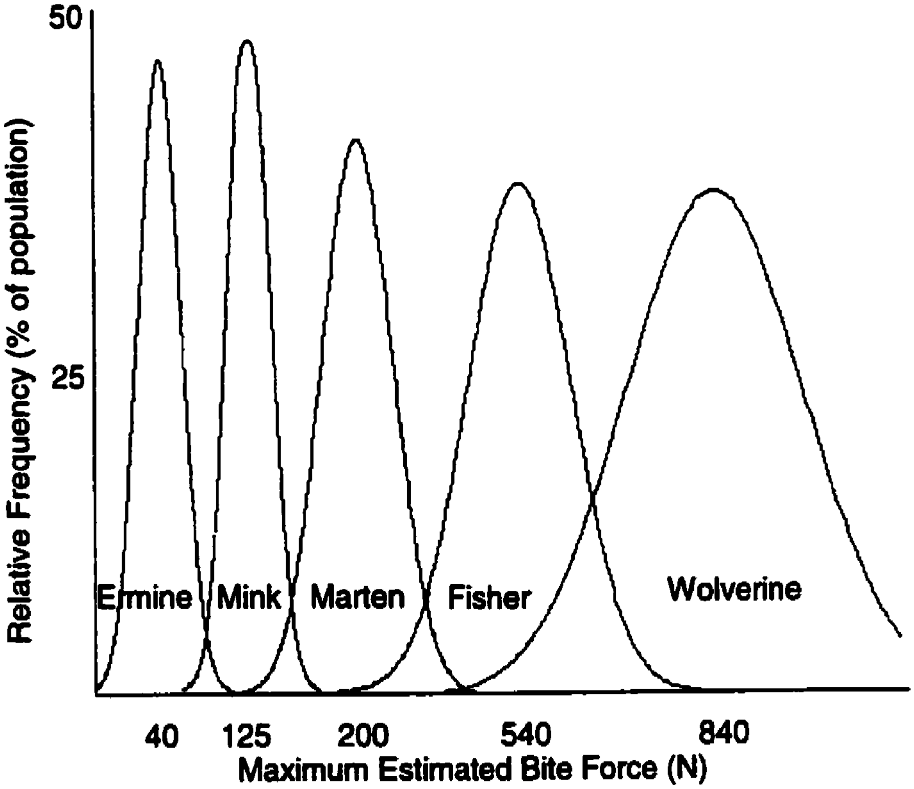

50
25
Relative Frequency (% of population)
Ermine
Mink
Marten
Fisher
Wolverine
40
125
200
540
840
Maximum Estimated Bite Force (N)

Figure 34. Frequency distribution (% of population) of the maximum estimated bite force (N) for the three members of the Family Felidae in North America.

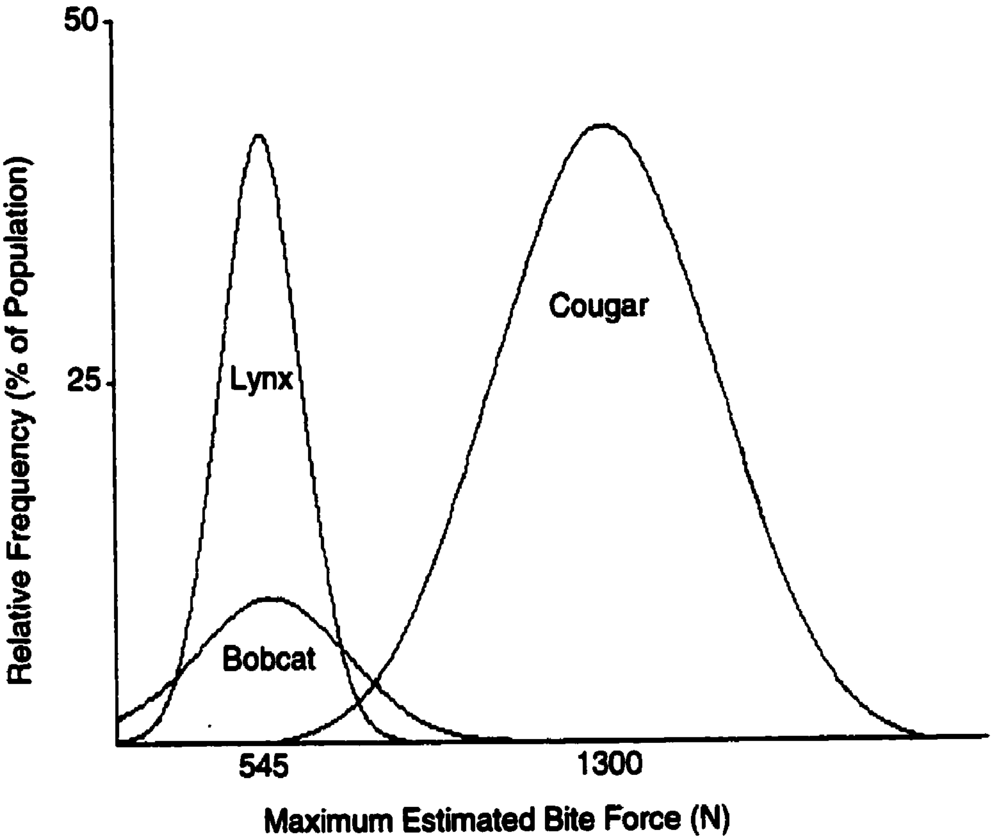
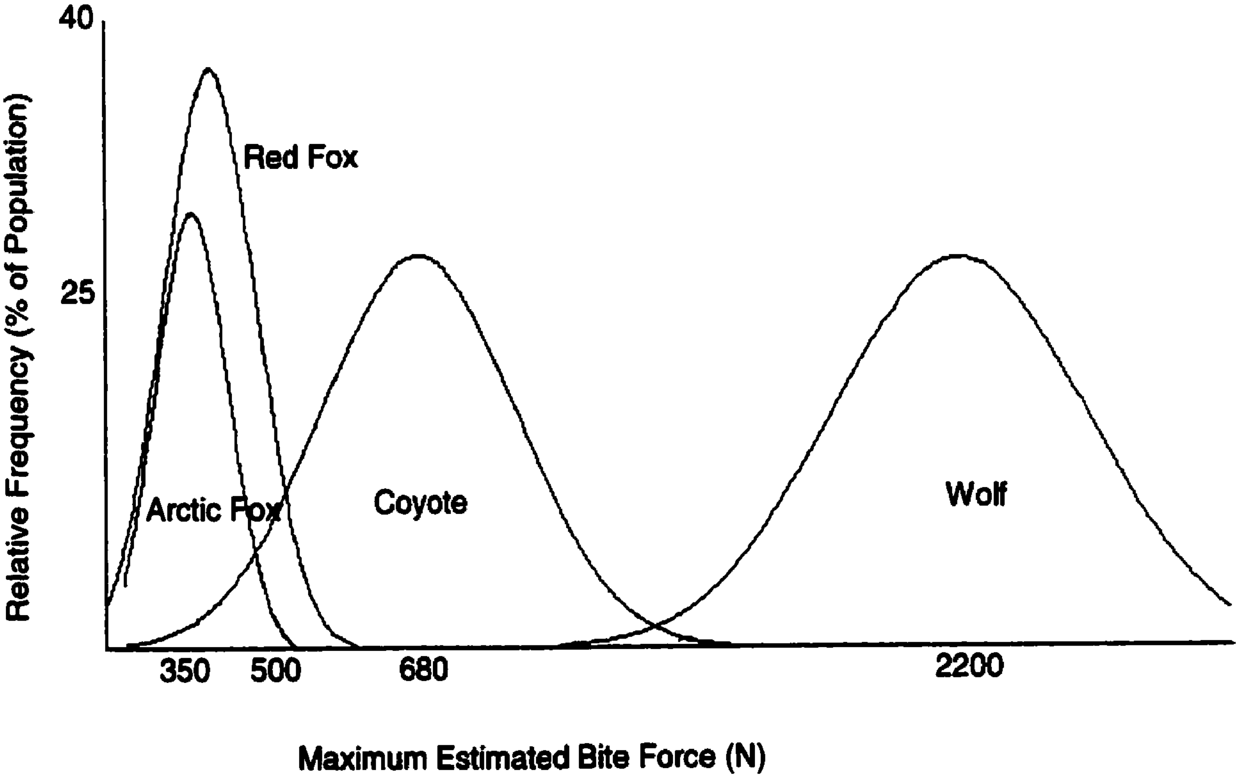

50
25
Relative Frequency (% of Population)
Lynx
Cougar
Bobcat
545
1300
Maximum Estimated Bite Force (N)

Figure 35. Frequency distribution (% of population) of the maximum estimated bite force (N) for the four members of the Family Canidae in North America.


40
25
Relative Frequency (% of Population)
Red Fox
Arctic Fox
Coyote
Wolf
350
500
680
2200
Maximum Estimated Bite Force (N)

Discussion

Maximum Estimated Bite Force

As noted by Thomason (1991), during the evolution of reptiles to mammals, the skull was modified extensively to meet the demands of capturing, killing, and masticating prey and the evolution of incisors and canine teeth was necessary so carnivores could undertake these processes. Ewer (1973), Van Greaves (1988a), Valkenburgh (1989), and Thomason (1991) noted the incisor teeth are primarily used to separate muscle tissue from bone and sheer meat into consumable sizes. Van Valkenburgh (1996) also observed that more than 66% of the flesh consumed is separated from bone by the actions of the incisors and canine teeth and that over half of the action is due to the incisor teeth alone, while in the Family Canidae, the majority (>90%) of the muscle and bone was masticated by the larger carnassial teeth and molars (Van Valkenburgh 1996). This differed from the Family Hyenidae, which have been shown to use the pre-molars primarily for this process (Van Valkenburgh 1996). The greatest amount of the bite force should be found along the tooth row of the lower jaw. Greaves (1982) demonstrated that maximum estimated bite forces for a given jaw length would occur along the length of the lower jaw, approximately 33% of the distance anterior from the temporal mandibular joint.

Thomason (1991) reported the mean estimated dry skull bite forces for lynx, cougar, red fox, coyotes, and wolves as being 345 N, 829 N, 238 N, 484 N, and 636 N, respectively. The mean maximum estimated bite forces for each of the same species in this study was lynx = 540 N, cougar = 1311 N, red fox =

430N, coyote = 681 N, and wolf = 2255 N. Although differences occurred between the values calculated by Thomason (1991) and those in this study, the small sample sizes used in Thomason's study likely explain these differences. The estimated bite forces for the animals in Thomason's study were obtained by dissecting the musculature as well as dry skull estimation, but were only done on one sample of each species. It is important to note that the values reported here are mean values and that the majority of Thomason's reported bite forces do fall within the range of the values in this study. As the strength of a muscle and in turn bite force is determined in part by muscle size and cross-sectional area (Thomason 1991), several cranial features have been used to estimate the size of the jaw muscles, in both fossil and extant species (Greaves 1995, Biknevicius and Van Valkenburgh, 1996). This project, for lack of significant difference from other methods used a length by width estimation for cross-sectional area of the lower jaw adducting musculature allowing ease of cross species comparison.

It was originally hypothesized that all species would have distinct mean maximum estimated bite forces, although this was not shown by the data. All species in the study were different in body size and skull morphometrics, yet as seen for species such as the coyote and wolverine or the fox, lynx, and fisher, statistically similar estimated bite-forces were found. Species considered to be omnivorous (black bear and raccoon) had larger standard deviations for maximum estimated bite force, as compared to species identified as true carnivores, which had similar sample sizes and mean maximum estimated bite forces.

According to Radinsky (1981) most recent carnivores (viverrids, canids, felids, and mustelids) could be classified according to modifications in skull parameters such as length, width, temporalis muscle size, and masseter muscle size. However, he also demonstrated that carnivores with omnivorous foraging habits, such as the ursids and procyonids did not readily classify within the true carnivore assemblages. As seen in the first Discriminant Analysis (created with all species in this study, n = 888), the overall classification rate of the three Discriminant Functions created using the three skull parameters of maximum skull width, maximum skull length, and cross-sectional length of the temporalis muscle was 85 %. However, the classification rate increased to 88 % when the two omnivorous species (black bear and raccoon) were removed from the analysis. This showed that the species with different foraging habits could be classified according to modifications in the skull and that true carnivores were more readily classified by skull parameters than were omnivorous species of similar size. Similar results were found by Radinsky (1981).

To establish whether a single skull parameter could be used to estimate maximum bite force, a second Discriminant Analysis was run using the three skull parameters that were most highly correlated with maximum estimated bite force (skull length, skull width, and cross-sectional length of the masseter muscle). However, the second discriminate functions were created using a random 49.8% of the population and reapplied to the remaining 50.2% of the population to determine if the functions were generalizable. Of the initial subset of species, 84.5% of the cases were correctly classified, while the discriminate functions classified 83.9% of the remaining species correctly. Thus although species had similar maximum estimated bite forces, it was possible to distinguish them using the three parameters. Also, since the functions generated by the random sample of 49.8% of the population correctly classified 83.9% of the species not used to generate the original functions, it was concluded that the functions were generalizable for the Order Carnivora. The Discriminant Analysis also revealed that species classified as true carnivores had higher classification rates than those that were classified as omnivorous. True carnivores had less statistical variation in the maximum estimated bite force as compared to omnivorous species. Since meat and bone are similar in composition regardless of prey species, it was hypothesized that the predominant meat diet of true carnivores would represent a significant evolutionary force creating similarities in skull and muscle design. Omnivorous species with a more diverse diet (live prey, vegetation, insects etc. - Ewer 1973) would be expected to have evolved greater variance in maximum estimated bite forces as seen in this study.

Maximum Estimated Bite Force and Skull Parameters

After determining that North American carnivores could be classified accurately according to a specific set of skull parameters (maximum skull length, maximum skull width, and cross sectional length of the masseter muscle), attempts to identify which skull parameter was most highly correlated with maximum estimated bite force was pursued. When all species were used in the analysis, the maximum width of the skull was the parameter most highly correlated with maximum estimated bite force. Turnball (1970) using dentition, the direction of jaw movement in the power stroke, and the relative mass of the four jaw muscles (masseter, temporalis, medial pterygoids, lateral pterygoids) subdivided mammals into five categories, according to masticatory type. These categories were generalized as carnivore shearing, ungulate grinding, rodent gnawing, and miscellaneous. All species in this study were similar and fell into Turnball's carnivore shearing group. Weijs (1994) proposed that there are three main muscles utilized in the adduction of the lower jaw in carnivores, the temporalis, the masseter, and the medial pterygoids. According to Turnball (1970), the carnivore shear group has a hinge jaw joint with vertical movements, a dentition specialized for shearing, and a dominant temporalis muscle. It is the dominant temporalis muscle, which would cause the strong correlation between maximum estimated bite force and the maximum skull width.

When all the species were analyzed independently, the maximum skull width was the most highly correlated with the maximum estimated bite force in all species except the mink, lynx, and cougar. The cougar and the mink exhibited a stronger correlation with the maximum skull length and the lynx exhibited the stronger correlation with the cross-sectional width of the masseter muscle. The length of the skull had the second highest correlation in all species. The strong correlation with the skull width in most of carnivore species appeared to be due to the fact that maximum skull width is representative of the size of the temporalis muscle, which is related directly to bite force (Weijs 1994, Greaves 1995). In the present study, mean maximum estimate bite force was easily estimated from maximum skull width, when the maximum estimated bite force was transformed (square root).

When the square root of the maximum estimated bite force was plotted with the maximum skull width, no significant differences ($F=1.75$, $p = 0.051$) among the slopes of the fourteen equations for North American carnivores was found. It was hypothesized that this trend would be similar in true carnivores, due to homogeneity of the meat diet. Removing the two omnivorous species, whose diet was more variable (Family Ursidae and Family Procyonidae) strengthened this finding, as the similarity between the slopes of the transformed maximum estimated bite forces and the maximum skull width increased. It is interesting to note that although the species and families differed, the trends between each species and their respective families were similar. It was thus concluded that there should be a similar relationship between primary prey weight and maximum estimated bite force. According to Radinsky (1981), there was no observable relationship between prey size and maximum estimated bite force in mammals. Since "optimal foraging theory" predicts that predators should attempt to maximize the benefit of foraging by preying on the largest food item that they can safely capture and consume (Pianka 1994), it therefore seems reasonable to assume that a direct relationship between primary prey weight and maximum estimated bite force exists (Thomason 1991). As predators should pursue only animals that they can safely kill and consume and as a result specialize in prey species in certain size ranges (primary prey species), a correlation between maximum estimated bite force and primary prey size should exist. When all species were grouped into their respective families, the slopes generated by plotting the maximum estimated bite force and the maximum skull width did not differ significantly. Except for overall changes in size, the skull designs of North American carnivores were similar, as had been previously found by Radinsky (1981). The high correlation between maximum estimated bite force and maximum skull width in North American carnivores indicated that as the width of the skull increased so proportionately did the bite force. Since species can be separated according to skull parameters and one parameter, the maximum skull width can accurately predict maximum estimated bite force, these relationships could be used to estimate maximum bite force in field studies.

Radinsky (1981) suggested that differences occurred among the Families Mustelidae, Felidae, and Canidae and that felids and mustelids would have larger relative bite forces, while the canids would have relatively weaker bite forces. Since in all cases in this study there was a positive correlation between maximum skull width and maximum estimated bite force and the rate of increase was similar in all families, it was concluded that no significant differences occurred within the Order Carnivora in North American. However as noted by Radinsky (1981), the dimensions of skulls of the Families Mustelidae and Felidae are wider with respect to the length, than the skulls from the Family Canidae. What this difference infers still remains unknown. According to Thomason (1991), in the maximum estimated bite force equation, the maximum estimated bite force is calculated from the cross-sectional area of the lower jaw adducting muscles divided by the length of the lower jaw. In this study, the wolf (*Canis lupus*) had the largest maximum estimated bite force, due to the larger size of the skull. If species were scaled according to body mass or some other parameter, it would seem likely that the mustelids and the felids, which have relatively wider skulls, would have larger mean maximum estimated bite forces relative to body mass.

Although primary prey size may be a significant factor causing the evolution of differences in maximum estimated bite forces between carnivore species in North America, there maybe a possible relationship between the extent of geographical distribution and the degree of variability in maximum estimated bite force. For example, the wolf (*C. lupus*) had one of the largest variances in maximum estimated bite force of the true carnivores. Historically, the wolf occupied every biome in North America, with the exception of the very hot deserts. Within each biome, wolves preyed predominately on ungulate species and subspecies that differed in size and catchability and the size of ungulates in North America varied from the bison (*Bison bison*) to the small peccary (*Tayassu tajacu*), with many intermediary species between these two extremes. Mulders (1997) found that the prey of wolves in Canada varied from the small Peary's caribou (60 kg) in the High Arctic to the bison (720 kg) of the north-central Prairies and postulated that prey size was a major evolutionary force influencing differences in wolf size and morphology.

Similarly, the maximum estimated bite force of the bobcat was highly variable compared to the lynx, which was similar in size and conformation. Historically, the bobcat was found in the Eastern Deciduous Biome, the Coast Plan Biome, Cordillerian Biome, the Prairie Biome, West Indian Biome, and the

Desert Biome, while the lynx was only found in the Boreal Forest Biome. It can be concluded that as the distribution of a species increases and includes a greater number of biomes, so does the amount of variation in the maximum estimated bite force.

Maximum Estimated Bite Force and Primary Prey Size

Andrews and Bertram (1996) noted that the bite force work associated with mechanical processes and prey handling behaviour required to subdue prey varied with prey size and that the bite force and the work associated with biting, increased with increasing prey body mass. As all carnivores appear to be under similar evolutionary forces, it was hypothesized that maximum estimated bite force would be highly correlated with the primary prey size and that behaviour would vary in relation to prey of different sizes and catchability.

Leyhausen (1965 b) concluded that the canine teeth in different carnivores were specialized in size and shape to separate the first and second vertebrae and severe the spinal cord of primary prey species. However, Radinsky (1981) reported that there was no correlation between prey size and estimated bite force. Similarly in this study, when the maximum estimated bite force was plotted against the mean estimated primary prey weight, there was little or no correlation. However, when the data were transformed to minimize curvilinearity and heteroscadasity and the maximum estimated bite force was plotted against the $\log_{10}$ of the primary prey size, a strong positive correlation emerged for all carnivores. When the two omnivore species were removed from the correlation, the r value (r = 0.808) increased to r = 0.878, further supporting the relationship between these two parameters. Similarly, within each family of true carnivores (Mustelidae, Felidae, and Canidae) correlation coefficients between the maximum estimated bite force and primary prey weight ranged between r = 0.893 and r = 0.911.

The results of this study indicated that there was a high correlation between maximum estimated bite force and primary prey size and as prey size increased so did the maximum estimated bite force. However, when the omnivores were included in the analysis, the correlation coefficient was lower than when they were removed.

Maximum Estimated Bite Force, Niche Breadth, and Inferred Competition

When the frequencies of the maximum estimated bite force were analyzed to compare differences between species, bell-shaped distribution curves resulted. In the Family Felidae, the lynx known to specialize on the snowshoe hare (*Lepus americanus*) (Keith 1983) had a very narrow distribution, demonstrating reduced variance in maximum estimated bite force for this species (Figure 31). In contrast, the bobcat although very similar in size, had a broader distribution of the maximum estimated bite force, demonstrating the high variability of this parameter in this species (Figure 31). In both these cases, the evidence supports the conclusion that the degree of variability is directly related to niche breadth and the variety of primary prey species that the species is associated with rather than competition, as these species are allopatric throughout most of their range. The cougar, the largest member of the Family Felidae, which is sympatric with the bobcat throughout most of its range has a similar broad niche breadth and shows little overlap with the bobcat in maximum estimated bite force. The evidence would suggest that in both these widely distributed species, primary prey diversity and competition are working synergistically, causing the co-evolution of broad niche breadths and prey specialization which minimizes competition, as cougar specializes on medium sized ungulates and the bobcat specialize on lagomorphs,

Crompton (1989) stated that in extant mammals, that the jaw adductor activity levels are directly related to food hardness. However, as muscle activity levels are directly related to muscle size, it can be concluded that carnivores, which feed on larger prey items, will have increased muscle mass in the lower jaw adductors and in turn have an increased bite force. The high correlation of the maximum estimated bite force with the maximum skull width supports this conclusion. Kiltie (1982) reported that in two closely related species of peccary, the white-lipped peccary (*Tayassu tajacu)* and the collared peccary (*T. pecari)*, that *T. pecari* could generate a bite force 1.3 x greater than *T. tajacu*. In turn, this allowed them to eat a larger variety of nuts and fruits and gave them a competitive edge over their close relatives in some environments.

When examining the distribution of the maximum estimated bite force for each of the species of true carnivores, it was seen that many of the species had overlapping frequency distributions of the maximum estimated bite force. It is hard to quantify the amount of overlap between the species within the Order

Carnivora that would be representative of competition between species. However, when examined at a species level, trends in competition become clearer.

Within the Family Mustelidae, the effects of intense intraspecific competition appears evident. The distribution of the maximum estimated bite forces for the five mustelid species resulted in five distinct narrow bell curves with relative little overlap, the exception being the fisher and the wolverine, which are allopatric in distribution and appear to occupy similar niches in different biomes. Unlike the other Families in this study, this family has the greatest number of members and the least amount of variation in maximum estimated bite force from the smallest to largest member. The fact that each species had a narrow distribution in the estimated bite force and little overlap supports the conclusion that the primary evolutionary force influencing this Family is interspecific competition resulting in prey specialization.

Within the Family Canidae, both the arctic and red fox have relative narrow distributions that overlap significantly. As both these species are allopatric and fill the same niche specializing primarily on small mammals, the overlap should be expected as interspecific competition would be minimal between these two species. However, the geographic distribution and prey diversity appears to be reflected in the distribution of the red fox, which inhabits both the Boreal Forest and Eastern Deciduous Forest Biome, while the arctic fox is limited to the Tundra Biome. In contrast, the distributions of maximum estimated bite force in the coyote and the wolf both wide ranging species found in many different biomes have a broad range indicating both species utilize a large diversity of primary prey species. In addition, the limited overlap between these two closely related species supports the conclusion that interspecific competition is a major force separating these species.

The results of this study support the conclusions that:

1) maximum estimated bite forces of the Order Carnivora in North America represent a continuum from the smallest to largest;

2) three skull parameters (maximum skull width, maximum skull length, and the length of the cross- sectional area of the masseter muscle) are highly correlated with the maximum estimated bite force;

3) maximum skull width was most highly correlated skull parameter with maximum estimated bite force for all species;

4) 82 – 85% of the members of the fourteen species studied could be correctly designated to their appropriate grouping on the basis of the maximum skull width, maximum skull length, and the length of the cross-sectional area of the masseter muscle;

5) the accuracy was greater when only species considered to be true carnivores as opposed to those considered omnivores were utilized in the analysis;

6) the slopes of the relationship between the maximum estimated bite force and the maximum skull width in all families of the Order Carnivora were not significantly different, suggesting that similar evolutionary forces have influenced all groups;

7) variability in skull parameters and maximum estimated bite force increases with the number of biomes and prey species that a species occupies and utilizes;

8) significant correlations exist between the maximum estimated bite force and the primary prey weight within the Families Mustelidae, Felidae, and Canidae, and the Order Carnivora;

9) the correlation coefficient between the maximum estimated bite force and primary prey weight increases when omnivorous species are eliminated from the analysis;

10) high variances of frequency distributions of the maximum estimated bite force are representative of niche breadth and associated with species with a wider geographic distribution and primary prey species diversity;

11) in all cases where overlap of frequency distributions of the maximum estimated bite force were significant, the species were allopatric and filled similar niches in their perspective geographic ranges; and

12) the degree of overlap between sympatric species in the frequency distributions of the maximum estimated bite force reflect varying levels of interspecific competition and character displacement.

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Appendix 1

Suppose for one species, different individuals have that each linear dimension is scaled by factor (S) relative to one "reference", (R) Individual.

Thus using

Lm: for cross sectional Length of the Masseter / Medial Pterygoid Muscles
Wm: for cross sectional Width of the Masseter / Medial Pterygoid Muscles
Lt: for cross sectional Length of the Temporalis Muscles
Wt: for cross sectional Width of the Temporalis Muscles
Lj: for the Length of the Lower Jaw

For Reference Individual from equation (1) we get : $MEBF_R = \frac{2\,(M_R m_R + T_R t_R)}{Lj_R}$

Arranging the equation we get: $MEBF_R = \frac{2}{Lj_R}(L_{mR} W_{mR} m_R + L_{tR} W_{tR} t_R)$

Any other individual has all linear dimensions scaled by Factor (S):

$$MEBF = \frac{2}{sLj_R}([sL_{mR}][sW_{mR}][sm_R] + [sL_{tR}][sW_{tR}][st_R])$$

$$= \frac{2s^3}{sLj_R}(L_{mR} W_{mR} m_R + L_{tR} W_{tR} t_R)$$

So $MEBF = s^2 MEBF_R$

Example with the Maximum Width of Skull (W_S) : $W_S = S\,W_{SR}$, $S = \frac{W_S}{W_{SR}}$

$$MEBF = \left(\frac{W_S}{W_{SR}}\right)^2 MEBF_R = \left[\frac{MEBF_R}{W_{SR}}\right] W_S^2$$

$$\text{So} \quad (MEBF)^{1/2} = \left[\frac{(MEBF)^{1/2}}{W_{SR}}\right] W_S$$

Proportional to the W_s with no intercept.

Appendix 2 -Original Data

Family	Species	Eco	Sex	Pi	AreaM	AreaT	LJBF	LJBFmax
Lynx=48.5%		Area 6						
1	1	6	2	3.14	457849.4	347734	311.67	1038.88
1	1	6	1	3.14	385079.5	315839.7	272.61	908.71
1	1	6	1	3.14	257244.5	198974.2	164.11	547.02
1	1	6	1	3.14	355832.2	227917.8	222.88	742.93
1	1	6	1	3.14	330941.1	185311.8	199.83	666.09
1	1	6	1	3.14	271220.4	179209	167.79	559.29
1	1	6	2	3.14	397701.4	248953.5	248.54	828.48
1	1	6	2	3.14	335188.4	211051.9	198.86	662.86
1	1	6	1	3.14	281642.8	181915.7	165.34	551.13
1	1	6	1	3.14	216743.8	157172.5	133.12	443.72
1	1	6	2	3.14	386423.3	221865.6	222.23	740.76
1	1	6	2	3.14	335525.4	218373.8	208.05	693.48
1	1	6	1	3.14	297879.3	173633.8	178.57	595.23
1	1	6	2	3.14	357007.5	235684.1	224.16	747.2
1	1	6	2	3.14	367078.2	219718	221.57	738.58
1	1	6	2	3.14	319572	237631.3	209.72	699.05
1	1	6	1	3.14	345258	203709.5	207.79	692.62
1	1	6	1	3.14	305452.6	213501.5	204.65	682.17
1	1	6	2	3.14	398934	282919.8	268.51	895.04
1	1	6	1	3.14	298238	176904	173.66	578.87
1	1	6	1	3.14	352638.4	264096.2	229.15	763.82
1	1	6	1	3.14	373235.8	246818.1	234.51	781.69
1	1	6	2	3.14	323005.1	206446.8	200.02	666.72
1	1	6	1	3.14	357370.4	189273.6	194.13	647.1
1	1	6	2	3.14	380587.3	245855.1	238.47	794.9
1	1	6	2	3.14	393845.8	269318.4	250.37	834.58
1	1	6	2	3.14	316663.3	235704.8	214.63	715.42
1	1	6	1	3.14	300236.1	184558	181.45	604.84
1	1	6	1	3.14	321068.8	184032.1	191.31	637.69
1	1	6	2	3.14	364558.2	242672.6	218.58	728.59
1	1	6	2	3.14	311355	208026.1	194.3	647.67
1	1	6	2	3.14	376222.2	221223.6	225.4	751.35
1	1	6	1	3.14	370631.5	231956.7	228.61	762.02
1	1	6	1	3.14	311629.4	185003.5	182.37	607.91
1	1	6	2	3.14	366984	243698.4	225.93	753.11
1	1	6	1	3.14	322443.2	201862.1	204.02	680.06
1	1	6	1	3.14	331351.6	207949.1	200.67	668.91
1	1	6	1	3.14	328235.5	227631.4	214.75	715.83
1	1	6	2	3.14	306735	217711.8	203.7	679.01
1	1	6	1	3.14	287006.4	195993.6	179.2	597.32
1	1	6	1	3.14	308139.7	232989.5	208.35	694.49
1	1	6	1	3.14	325908	219438.8	201.12	670.41
1	1	6	2	3.14	318859.2	218911.7	197.16	657.19
1	1	6	2	3.14	333331.7	200472.1	199.19	663.95
1	1	6	2	3.14	368004	264199.3	251.12	837.08
1	1	6	2	3.14	331364.9	226630.3	209.76	699.2
1	1	6	1	3.14	222603.4	154213.3	153.08	510.26
1	1	6	1	3.14	328438.8	263929.5	223.39	744.65
1	1	6	1	3.14	350455.6	253899.9	142.12	473.75
Bobcat=71.2%		Area 6						

Length	Width	ZagLen	BaseWt	TempL	TempW	VectorM	HalfVM	VectorT
136.51	104.32	38.04	40.12	41.59	27.87	32.07	16.04	38.52
126.49	91.97	34.72	36.97	40.26	26.15	29.14	14.57	36.57
115.48	80	28.64	29.94	35.89	18.48	22.94	11.47	32.43
122.32	86.25	34.52	34.36	38.37	19.8	31.11	15.56	34.15
121.19	85.44	32.9	33.53	36.9	16.74	28.71	14.36	33.01
115.6	83.06	29.7	30.44	36.16	16.52	24.99	12.5	31.36
131.88	93.25	36.28	36.54	40.98	20.25	30.06	15.03	36.3
127.34	88.5	32.91	33.95	36.47	19.29	27.38	13.69	33.9
116.18	82.23	29.21	32.14	34.73	17.46	23.33	11.67	31.61
106.4	76.6	26.12	27.66	32.36	16.19	21.56	10.78	29.8
131.26	92.85	36.01	35.77	38.72	19.1	29.27	14.64	34.3
124.68	88.51	32.55	34.36	38.76	18.78	27.8	13.9	35.16
120.11	81.76	32.63	30.43	37.51	15.43	27.05	13.53	33.04
128.67	91.69	33.75	35.26	39.96	19.66	28.67	14.34	36.93
127.92	89.48	34.9	35.06	38.71	18.92	29.89	14.95	34.4
124.7	87.81	33	32.28	38.34	20.66	27.47	13.74	34.41
125.13	86.74	35.27	32.63	38.98	17.42	29.56	14.78	34.52
120.57	86.77	32.94	30.91	40.39	17.62	28.88	14.44	34.57
130.58	94.34	37	35.94	41.97	22.47	31.15	15.58	37.64
121.5	84.83	31.65	31.41	37.44	15.75	24.34	12.17	34.76
126.08	90.5	34.28	34.29	41.98	20.97	27.69	13.85	35.19
129.95	91.3	36.24	34.33	40.31	20.41	30.45	15.23	35.56
121.7	86.25	33.19	32.44	37.79	18.21	26.91	13.46	35.24
127.19	87.92	34.74	34.29	38.4	16.43	27.48	13.74	34.7
127.88	91.52	36.02	35.22	40.45	20.26	29.1	14.55	36.43
133.12	91.8	36.63	35.84	43.16	20.8	30.6	15.3	36.94
128.12	88.17	33.34	31.66	40.52	19.39	27.46	13.73	35.69
118.88	84.92	31.09	32.19	36.86	16.69	25.59	12.8	33.17
120.33	85.1	32.92	32.51	37.82	16.22	28.19	14.1	33.44
126.8	90.05	35.02	34.7	39.04	20.72	27.34	13.67	33.93
125.13	88.29	31.45	33	39.11	17.73	26.73	13.37	35.63
126.27	89.51	35.8	35.03	37.7	19.56	29.45	14.73	35.3
125.78	90.22	35.44	34.86	40.63	19.03	27.71	13.86	35.78
119.53	83.91	32.81	31.66	35.36	17.44	27.09	13.55	31.19
134.2	93.77	33.98	36	40.8	19.91	29.79	14.9	34.87
122.26	87.09	33.97	31.64	38.76	17.36	28.9	14.45	34.54
117.57	87.31	33.48	32.99	37.94	18.27	27.48	13.74	33.23
122.15	87.77	32.67	33.49	36.78	20.63	27.56	13.78	34.94
125.35	86.07	32.5	31.46	40.05	18.12	27.98	13.99	36.03
121.3	85.14	31.47	30.4	37.12	17.6	26.8	13.4	33.24
120.7	84.69	32.68	31.43	37.41	20.76	27.93	13.97	33.84
124.73	88.88	32.92	33	37.88	19.31	27.24	13.62	33.92
126.61	87.44	33.55	31.68	38.98	18.72	26.87	13.44	33.65
127.17	85.64	34.23	32.46	39.17	17.06	29.34	14.67	34.14
131.4	88.9	36.4	33.7	42.36	20.79	31.16	15.58	37.79
124.11	87.35	33.11	33.36	38.78	19.48	26.8	13.4	35.47
107.67	76.86	27.16	27.32	31.79	16.17	27.4	13.7	28.99
122.9	88.72	33.48	32.7	39.54	22.25	26.74	13.37	35.47
121.31	90.37	34.84	33.53	40.65	20.82	13.67	6.84	27.76

HalfVT	LowerJ	ThrdLj	Scale L	Scale W
19.26	90.09	27.03	7.61	9.96
18.29	83.53	25.06	7.18	9.88
16.22	75.28	22.58	4.74	6.84
17.08	84.59	25.38	6.07	8.61
16.51	78.16	23.45	5.5	7.8
15.68	73.89	22.17	4.84	6.73
18.15	84.46	25.34	6.28	8.88
16.95	82.13	24.64	5.21	7.49
15.81	74.52	22.36	4.74	6.7
14.9	70.29	21.09	4.17	5.79
17.15	85.14	25.54	5.64	7.98
17.58	81.74	24.52	5.56	7.84
16.52	77.25	23.18	4.96	7.28
18.47	84.49	25.35	5.81	8.15
17.2	83.63	25.09	5.77	8.25
17.2	80.85	24.26	5.61	7.96
17.26	82.96	24.89	5.54	7.98
17.29	79.17	23.75	5.66	7.86
18.82	85.94	25.78	6.85	9.49
17.38	77.21	23.16	4.76	6.82
17.6	83.17	24.95	6.06	8.44
17.78	85.89	25.77	6.02	8.56
17.62	79.83	23.95	5.48	7.73
17.35	84.42	25.33	5.09	7.36
18.22	84	25.2	6.22	8.69
18.47	87.87	26.36	6.27	9.09
17.85	79.71	23.91	5.58	8.11
16.59	76.08	22.82	5.09	7.12
16.72	79.48	23.84	5.3	7.49
16.97	83.27	24.98	5.75	8.09
17.82	80.98	24.29	5.18	7.34
17.65	83.8	25.14	5.95	8.39
17.89	81.23	24.37	6.06	8.45
15.6	77.93	23.38	5.09	7.24
17.43	86	25.8	5.61	8.03
17.27	79.85	23.96	5.56	7.81
16.61	79.81	23.94	5.69	7.66
17.47	79.16	23.75	5.86	8.16
18.02	80.64	24.19	5.42	7.89
16.62	79.28	23.78	4.92	7.02
16.92	79.15	23.75	5.75	8.2
16.96	81.15	24.35	5.37	7.54
16.83	80.82	24.25	5.19	7.52
17.07	83.46	25.04	5.22	7.75
18.9	85.42	25.63	6.37	9.42
17.74	80.66	24.2	5.63	8
14.5	69.05	20.72	4.74	6.64
17.74	81.22	24.37	6.06	8.39
13.88	83.3	24.99	3.91	5.24

1	2	6	2	3.14	488984.1	444338.3	389.85	1299.5	
1	2	6	1	3.14	250387.4	231537.5	211.24	704.14	
1	2	6	1	3.14	260912.4	211033.2	168.84	562.8	
1	2	6	1	3.14	309525.7	251508.3	217.88	726.26	
1	2	6	2	3.14	432032.6	359298.2	288.13	960.45	
1	2	6	1	3.14	216100.6	164894.4	141.81	472.69	
1	2	6	1	3.14	439033.8	316060.4	286.2	954	
1	2	6	2	3.14	441461.4	344947.7	301.61	1005.37	
1	2	6	2	3.14	367383.6	285746.2	244.2	814.01	
1	2	6	1	3.14	335692.2	254560.3	230.48	768.26	
1	2	6	2	3.14	273393.5	196931.8	170.4	567.99	
1	2	6	1	3.14	336752.6	216310.5	209.55	698.52	
1	2	6	1	3.14	315443.7	227548.1	206.66	688.87	
1	2	6	2	3.14	244433.7	181130.1	145.69	485.62	
1	2	6	2	3.14	363571.9	259308.3	237.39	791.29	
1	2	6	2	3.14	355394	232872.9	205.38	684.59	
1	2	6	1	3.14	339884.1	250056	215.69	718.97	
1	2	6	2	3.14	304365.6	234541.3	190.87	636.24	
1	2	6	1	3.14	218533.7	145595.1	131.27	437.57	
1	2	6	1	3.14	213337.9	143356.1	125.87	419.56	
1	2	6	1	3.14	231573.6	135254.9	134.35	447.82	
1	2	6	2	3.14	265779.4	197862	165.19	550.63	
1	2	6	1	3.14	349966.1	247367.3	231.89	772.97	
1	2	6	2	3.14	378593.3	287456.4	252.91	843.03	
1	2	6	2	3.14	402992.6	335298.3	270.63	902.1	
1	2	6	2	3.14	324529.9	247742.6	220.11	733.71	
1	2	6	1	3.14	350609.4	243184.1	228.62	762.08	
1	2	6	1	3.14	362275.2	279543	241.59	805.3	
1	2	6	2	3.14	424632.6	317530.1	293.17	977.23	
1	2	6	1	3.14	214169.5	156207.8	125.51	418.37	
1	2	6	1	3.14	321458.9	242799.1	209.12	697.08	
1	2	6	1	3.14	358244.5	281823.1	243.72	812.39	
1	2	6	1	3.14	259059.6	192432.2	161.56	538.53	
1	2	6	1	3.14	283123.2	228944.1	192.79	642.63	
1	2	6	2	3.14	358589.2	255654.5	224.82	749.42	
1	2	6	2	3.14	346912.7	283286.6	229.4	764.66	
1	2	6	1	3.14	292845.5	230387.9	202.42	674.72	
Mt. Lion=72.2%		Area 6							
1	3	6	1	3.14	605088	521489.3	434.14	1447.14	
1	3	6	2	3.14	623970.7	507785.6	430.76	1435.87	
1	3	6	1	3.14	596344.3	631648.3	480.03	1600.09	
1	3	6	1	3.14	635131.1	628251	491.84	1639.46	
1	3	6	2	3.14	775962.7	673481.8	584.52	1948.4	
1	3	6	2	3.14	729142.8	612752.8	492.57	1641.9	
1	3	6	1	3.14	531467.6	473265.8	389.34	1297.79	
1	3	6	1	3.14	522707.2	474736.7	364.24	1214.14	
1	3	6	2	3.14	822454.5	765874.3	602.68	2008.94	
1	3	6	2	3.14	839076.5	775437.4	613.58	2045.28	
1	3	6	2	3.14	766682.3	696910.8	536.32	1787.72	
1	3	6	2	3.14	655631.3	644404.8	520.94	1736.45	
1	3	6	2	3.14	686887.9	626294.8	511.35	1704.5	
Fox=58.1%		Area 1							

148.52	102.16	41.74	39.05	47.64	31.09	35.43	17.72	42.36
105.41	75.55	27.97	29.84	33.91	22.76	25.83	12.92	29.49
115.32	79.04	31.15	27.92	36.26	19.4	24.78	12.39	30.6
119.79	86.56	34.04	30.31	38.09	22.01	28.68	14.34	33.86
138.5	101.53	39.52	36.44	40.64	29.47	32.11	16.06	35.16
106.5	73.34	25.93	27.78	31.68	17.35	23.43	11.72	25.95
135.77	97.34	39.8	36.77	41.38	25.46	32.69	16.35	36.36
143.61	98.28	41.07	35.83	41.48	27.72	35.62	17.81	35.94
134.77	90.78	36.72	33.35	37.47	25.42	31.98	15.99	34.85
121.79	88.72	35.31	31.69	38.64	21.96	29.77	14.89	33.4
117.56	82.31	31.22	29.19	32.61	20.13	26.01	13.01	31.07
122.27	87.19	34.56	32.48	36.75	19.62	30.13	15.07	32.3
121.89	85.58	33.54	31.35	35.51	21.36	28.15	14.08	31.59
112.92	77.25	28.74	28.35	33.73	17.9	22.94	11.47	27.83
129.98	90.86	35.76	33.89	37.63	22.97	30.69	15.35	33.42
126.73	87.57	36.35	32.59	36.29	21.39	30.02	15.01	29.89
125.07	86.36	35.46	31.95	37.75	22.08	28.24	14.12	32.57
128.46	86.4	33.55	30.24	36.67	21.32	27.7	13.85	33.26
105.73	73.74	26.87	27.11	31.15	15.58	22.05	11.03	26.97
103.14	70.72	28.13	25.28	31.73	15.06	21.57	10.79	26.92
110.99	74.37	28.4	27.18	31.44	14.34	24.34	12.17	28.77
118.3	79.73	31.96	27.72	33.65	19.6	25.63	12.82	30.4
126.63	88.12	35.74	32.64	39.19	21.04	31.44	15.72	33.13
134.98	91.22	37.92	33.28	40.26	23.8	32.46	16.23	34.91
138.07	94.74	38.26	35.11	41.97	26.63	31.87	15.94	33.95
125.22	86.21	34.32	31.52	37.35	22.11	28.9	14.45	33.3
125.18	87.21	35.74	32.7	36.93	21.95	29.71	14.86	34.35
132.69	93.47	35.94	33.6	39.4	23.65	31.03	15.52	35.58
133.21	94.63	40.2	35.21	40.46	26.16	34.25	17.13	35.76
113.14	67.99	28.04	25.46	33.68	15.46	22.21	11.11	26.99
123.27	85.81	32.51	32.96	37.89	21.36	28.21	14.11	33.45
128.12	88.92	35.99	33.18	40.72	23.07	30.63	15.32	35.73
108.16	81.3	30.6	28.22	32.76	19.58	25.88	12.94	29
123.3	83.83	32.32	29.2	37.1	20.57	27.31	13.66	34.09
133.33	88.37	34.94	34.21	37.36	22.81	28.96	14.48	32.23
132.2	89.24	35.89	32.22	40.79	23.15	29.11	14.56	33.49
123.64	85.67	32.68	29.87	35.97	21.35	28.87	14.44	31.06

174.92	118.64	48	42.02	56.53	30.75	41.79	20.9	46.25
181.86	119.9	48.28	43.08	54.06	31.31	41.44	20.72	48.84
174.31	118.78	47.06	42.24	55.06	38.24	40.66	20.33	47.83
179.49	125.02	48.86	43.33	57.85	36.2	41.55	20.78	47.79
180.11	131.03	53.92	47.97	63.56	35.32	46	23	53.38
181	127.62	50.31	48.31	60.18	33.94	40.94	20.47	49.95
164.69	109.44	45.32	39.09	55.45	28.45	37.82	18.91	45.29
167.04	114.77	43.69	39.88	53.88	29.37	37.56	18.78	45.39
194.83	139.64	54.02	50.75	64.37	39.66	45	22.5	52.48
205.66	135.97	55.76	50.16	66.43	38.91	47.38	23.69	54.62
192.61	134.87	52.78	48.42	61.57	37.73	41.86	20.93	50.96
182.12	129.77	63.09	34.64	59.8	35.92	42.3	21.15	53.89
192.32	124.52	53.21	43.03	61.71	33.83	44.43	22.22	54.13

21.18	92.72	27.82	8.75	12.72
14.75	62.94	18.88	6.68	9.32
15.3	76.54	22.96	4.88	7.12
16.93	79.83	23.95	6.06	8.39
17.58	91.99	27.6	6.93	9.46
12.98	65.88	19.76	4.44	6.45
18.18	90.3	27.09	7.03	9.8
17.97	93.24	27.97	7	10.23
17.43	88.89	26.67	6.04	8.97
16.7	80.25	24.08	6.31	8.66
15.54	77.64	23.29	4.83	6.9
16.15	81.76	24.53	5.71	8.01
15.8	77.75	23.33	5.65	8.05
13.92	73.09	21.93	4.3	6.29
16.71	83.51	25.05	6.09	8.71
14.95	85.84	25.75	5.4	7.82
16.29	82.26	24.68	5.75	8.33
16.63	85.04	25.51	4.95	7.36
13.49	66.62	19.99	4.14	5.93
13.46	67.22	20.17	4.07	5.93
14.39	70.92	21.28	4.03	6.02
15.2	77.65	23.3	4.65	6.91
16.57	82.79	24.84	6.1	8.77
17.45	88.27	26.48	6.25	9.24
16.98	89.52	26.86	6.53	9.52
16.65	80.09	24.03	5.86	8.51
17.18	82.1	24.63	6.09	8.74
17.79	87.7	26.31	6.07	8.62
17.88	88.34	26.5	7.34	10.33
13.5	71.49	21.45	3.7	6.15
16.73	82.2	24.66	5.65	8.12
17.86	86.34	25.9	6.34	9.14
14.5	76.04	22.81	4.98	6.62
17.05	80.59	24.18	5.21	7.67
16.11	82.84	24.85	5.62	8.48
16.75	85.38	25.61	5.78	8.57
15.53	77.12	23.14	5.46	7.88
23.13	113.8	34.14	8.27	12.2
24.42	117.6	35.28	7.9	11.98
23.92	113.45	34.03	9.18	13.47
23.9	114.7	34.41	9.13	13.11
26.69	122.57	36.77	10.82	14.87
24.98	122.74	36.82	9.07	12.87
22.65	106.68	32	7.88	11.86
22.7	113.06	33.92	7.27	10.58
26.24	128.1	38.43	10.31	14.39
27.31	133.82	40.15	9.94	15.04
25.48	126.06	37.82	9.28	13.26
26.95	119.9	35.97	9.53	13.38
27.07	125.98	37.79	8.86	13.69

2	4	1	2	3.14	209171.4	189399.6	130.35	434.5
2	4	1	2	3.14	245888.4	171901.3	136.13	453.78
2	4	1	1	3.14	194643.5	148907.7	107.05	356.84
2	4	1	2	3.14	235174.2	183026.6	136.94	456.45
2	4	1	2	3.14	230685.9	169055.1	129.56	431.86
2	4	1	2	3.14	219372	171783.6	127.7	425.67
2	4	1	1	3.14	200669.1	152484.8	113.19	377.31
2	4	1	2	3.14	193374.9	162115.3	113.72	379.07
2	4	1	1	3.14	199446	157209.1	119.23	397.43
2	4	1	1	3.14	195953.6	147875	111	370
2	4	1	1	3.14	194386.2	145846.8	109.59	365.32
2	4	1	2	3.14	233020	178511.3	135.78	452.61
2	4	1	1	3.14	206811.5	167989.3	127.91	426.37
2	4	1	2	3.14	194261.8	162022.5	114.31	381.04
2	4	1	2	3.14	201120.1	154564.2	124.02	413.39
2	4	1	2	3.14	204517.2	167905.9	118.47	394.91
2	4	1	1	3.14	196672	141472.8	107.74	359.12
2	4	1	1	3.14	199691.3	163122.6	117.82	392.73
2	4	1	1	3.14	244615.5	188549.7	141.29	470.95
2	4	1	2	3.14	238883.8	188410.4	139.95	466.49
2	4	1	1	3.14	232937.3	167118.8	129.07	430.23
2	4	1	1	3.14	228670.1	169540.8	126.01	420.03
2	4	1	1	3.14	182471	138753.4	104.18	347.27
2	4	1	1	3.14	172568.9	152308.1	107.77	359.22
2	4	1	1	3.14	219754.3	157983.1	122.27	407.56
2	4	1	1	3.14	185703	136229.5	103.18	343.93
2	4	1	2	3.14	218775.5	185984.3	129.32	431.05
2	4	1	1	3.14	201097.6	162414	117.13	390.43
2	4	1	2	3.14	256754.3	205948.5	157.24	524.15
2	4	1	1	3.14	243460.7	157109.3	127.29	424.29
2	4	1	2	3.14	220973.4	154237.9	113.3	377.67
2	4	1	2	3.14	245412.6	206828.3	150.15	500.51
2	4	1	2	3.14	253868	222028.8	150.65	502.17
2	4	1	2	3.14	225000.2	177800	126.85	422.83
2	4	1	2	3.14	218308	231131.3	147.88	492.93
2	4	1	1	3.14	164505.6	141361.6	97.54	325.15
2	4	1	2	3.14	255265.1	193757.8	151.6	505.34
2	4	1	2	3.14	197493.8	205376.4	131.4	438.01
2	4	1	1	3.14	217798.5	165135.2	122.55	408.5
2	4	1	2	3.14	258571	205254.2	145.8	486.02
2	4	1	2	3.14	255922.2	189592.7	147.02	490.08
2	4	1	1	3.14	199881.9	162422.1	114.82	382.73
2	4	1	2	3.14	227924.4	176085.8	125.63	418.77
2	4	1	1	3.14	227915.1	172531.1	129.08	430.27
2	4	1	1	3.14	245959.2	164303.5	132.58	441.95
2	4	1	1	3.14	204828.8	176159.1	128.16	427.2
2	4	1	2	3.14	208357.8	143624.6	118.61	395.36
2	4	1	2	3.14	245085.9	203977.3	145.34	484.45
2	4	1	1	3.14	234051.3	163365.4	132.44	441.48
2	4	1	2	3.14	249093.8	185662.4	140.38	467.94
2	4	1	2	3.14	279916.6	210809.2	161.51	538.38
2	4	1	1	3.14	222123.4	182166.4	132.19	440.62

124.06	66.44	26.91	25.91	40.47	15.6	25.71	12.86	34.18
135.33	69.57	30.2	27.14	39.22	14.61	29.04	14.52	35.16
123.4	63.3	25.07	25.88	37.89	13.1	26.17	13.09	32.09
130.49	67.95	28.61	27.4	40.43	15.09	27.58	13.79	35.93
128.04	67.21	27.73	27.73	38.65	14.58	28.08	14.04	34.45
124.68	68.72	27.73	26.37	39.22	14.6	26.25	13.13	35.13
118.3	64.92	25.27	26.47	36.28	14.01	25.14	12.57	32.99
121.43	65.91	26.97	23.9	37.71	14.33	26.11	13.06	32.43
121.94	65.31	26	25.57	38.56	13.59	26.67	13.34	34.58
124	64.54	26.19	24.94	36.73	13.42	26.51	13.26	32.69
118.21	64.34	25.51	25.4	38.1	12.76	25.24	12.62	34.47
127.38	68.48	27.81	27.93	39.59	15.03	27.27	13.64	35.63
122.74	65.75	28.51	24.18	38.38	14.59	26.77	13.39	32.32
118.89	64.65	24.64	26.28	37.9	14.25	25.08	12.54	32.13
118.97	64.69	26.54	25.26	39.48	13.05	27.4	13.7	32.42
125.28	66.84	26.02	26.2	38.44	14.56	25.71	12.86	34.05
126.27	64.61	26.36	24.87	39.2	12.03	27.16	13.58	34.23
118.11	64.46	25.75	25.85	39.09	13.91	24.97	12.49	32.74
126.91	68.46	28.61	28.5	40.47	15.53	27.67	13.84	34
130.59	69.38	29.47	27.02	40.13	15.65	28.69	14.35	34.82
130.49	67.55	27.84	27.89	39.01	14.28	29.47	14.74	34.51
127.13	67.12	27.89	27.33	39.52	14.3	27.14	13.57	34.21
120.15	62.16	25.28	24.06	37.42	12.36	26.36	13.18	31.28
118.22	62.5	23.76	24.21	38.52	13.18	24.28	12.14	33.58
123.43	66.32	27.06	27.07	37.19	14.16	27.53	13.77	33.82
121.34	60.59	25.9	23.9	36.68	12.38	25.7	12.85	31.48
126.65	67.35	26.87	27.14	38.53	16.09	26.37	13.19	32.01
125.08	64.88	26.37	25.42	38.67	14	27.09	13.55	32.9
123.5	71.56	29.17	29.34	41.43	16.57	29.11	14.56	35.54
123.58	67.12	28.11	28.87	38.31	13.67	27.41	13.71	33.48
129.17	67.63	27.1	27.18	35.07	14.66	26.58	13.29	31.69
125.13	71.44	27.91	29.31	39.99	17.24	27.72	13.86	35.62
137.15	73.92	29.13	29.05	41.3	17.92	28.69	14.35	35.59
127.79	68.2	26.93	27.85	38.94	15.22	26.37	13.19	34.67
129.5	69.8	27.69	26.28	41.09	18.75	27.53	13.77	32.52
122.9	60.72	25.2	21.76	37.22	12.66	25.13	12.57	32.32
130.51	68.92	29.72	28.63	41.19	15.68	30.79	15.4	36.56
127.55	64.28	26.62	24.73	38.46	17.8	26.23	13.12	34.1
125.97	67.23	26.75	27.14	38.52	14.29	25.93	12.97	34.15
136.53	70.24	30.64	28.13	43.33	15.79	29.26	14.63	35.44
130.62	72.23	29.88	28.55	41.55	15.21	29.72	14.86	35.7
126.23	66.85	28.03	23.77	37.65	14.38	27.72	13.86	32.57
128.74	68.78	27.85	27.28	39.34	14.92	26.83	13.42	33.55
122.87	68.67	27.23	27.9	38.52	14.93	26.54	13.27	33.27
125.79	67.35	28.95	28.32	38.87	14.09	28.28	14.14	33.72
120.83	68.53	26.01	26.25	39.33	14.93	25.56	12.78	35.75
125.44	65.25	26.6	26.11	36.49	13.12	27.5	13.75	35.23
135.23	71.87	30.37	26.9	40.91	16.62	29.47	14.74	36.07
127.27	66.09	29.1	26.81	40.07	13.59	28.35	14.18	35
131.25	71.25	31.25	26.57	39.57	15.64	30.52	15.26	34.49
138.87	71.91	32.67	28.56	43.43	16.18	31.92	15.96	38.73
124.09	67.48	27.71	26.72	39.61	15.33	27.14	13.57	34.34

17.09	90.92	27.28	3.5	6.54
17.58	96.85	29.05	3.35	6.52
16.05	92.22	27.67	2.89	5.64
17.97	95.39	28.62	3.5	6.72
17.23	94.95	28.49	3.37	6.43
17.57	92.35	27.71	3.41	6.19
16.5	89.01	26.7	3.19	5.81
16.22	90.63	27.19	3.12	5.75
17.29	90.21	27.06	3.26	6.09
16.35	90.35	27.1	2.98	5.73
17.24	90.64	27.19	3.09	5.68
17.82	93.64	28.09	3.55	6.61
16.16	85.73	25.72	3.47	6.48
16.07	88.16	26.45	3.21	5.89
16.21	84.84	25.45	3.47	6.39
17.02	92.64	27.79	3.15	5.91
17.11	94.53	28.36	2.84	5.56
16.37	87.65	26.3	3.33	6.09
17	93.28	27.98	3.71	6.88
17.41	95.85	28.76	3.57	6.72
17.26	97.87	29.36	3.3	6.37
17.11	95.28	28.58	3.3	6.26
15.64	87.83	26.35	2.89	5.59
16.79	86.34	25.9	3.04	5.75
16.91	93.18	27.95	3.3	6.15
15.74	87.82	26.35	2.83	5.68
16.01	90.65	27.2	3.4	6.4
16.45	92.13	27.64	3.12	6.02
17.77	94.08	28.22	4.24	7.32
16.74	93.75	28.13	3.43	6.32
15.85	94.98	28.49	2.92	5.58
17.81	94.37	28.31	4	7.01
17.8	100.8	30.24	3.66	6.79
17.34	95.37	28.61	3.31	6.2
16.26	91.47	27.44	3.81	7.06
16.16	89.22	26.77	2.65	5.35
18.28	98.57	29.57	3.87	7.33
17.05	92.72	27.82	3.43	6.81
17.08	92.1	27.63	3.24	6.08
17.72	101.78	30.53	3.56	6.92
17.85	97.77	29.33	3.75	6.78
16.29	94.33	28.3	3.03	5.73
16.77	95.7	28.71	3.25	6.09
16.64	91.33	27.4	3.5	6.27
16.86	94.25	28.28	3.51	6.56
17.88	89.99	27	3.54	6.23
17.61	90.97	27.29	3.15	6.06
18.04	100.32	30.1	3.58	6.74
17.5	93.27	27.98	3.47	6.68
17.25	99.77	29.93	3.57	6.57
19.36	105.87	31.76	3.88	7.49
17.17	92.93	27.88	3.55	6.53

2	4	1	1	3.14	232762.1	164362.8	128.61	428.71
2	4	1	2	3.14	249223.7	199601.9	145.73	485.77
2	4	1	1	3.14	273296.2	229235.2	157.77	525.91
2	4	1	1	3.14	269936.6	234142.4	152.52	508.39
2	4	1	1	3.14	319098.8	251982.6	180.8	602.67
2	4	1	2	3.14	325067.6	237418	172.35	574.5
2	4	1	1	3.14	270585.9	197754.2	148.07	493.57
2	4	1	1	3.14	312213.9	234858.8	169.37	564.55
2	4	1	2	3.14	291146.2	264431	173.21	577.38
2	4	1	2	3.14	301507.5	227843.8	173.93	579.76
2	4	1	2	3.14	292786.6	249369.6	170.07	566.9
2	4	1	2	3.14	261199.5	202714.8	145.2	483.99
2	4	1	2	3.14	298214.2	237224.3	162.68	542.26
2	4	1	2	3.14	337916.7	243666.7	186.87	622.91
Coyote=51.7%		Area 6&7						
2	5	6	2	3.14	526759.8	404838	290.06	966.86
2	5	6	2	3.14	495789.8	341823.9	233.8	779.34
2	5	6	2	3.14	730242.5	539266.7	419.59	1398.65
2	5	6	2	3.14	600940.6	460722.8	342.97	1143.24
2	5	6	2	3.14	574533.1	450518	346.37	1154.56
2	5	6	2	3.14	628550.5	476147.8	351.57	1171.9
2	5	6	2	3.14	710870.2	406715.8	355.35	1184.51
2	5	6	2	3.14	574533.1	450518	336.03	1120.09
2	5	6	2	3.14	657087.5	503890.7	384.78	1282.61
2	5	6	2	3.14	557547.8	510734.4	364.46	1214.86
2	5	6	1	3.14	631359.4	449018.9	337.13	1123.78
2	5	6	1	3.14	543443.8	401777	304.78	1015.93
2	5	6	2	3.14	394855.7	307161.6	213.01	710.03
2	5	6	1	3.14	465971.6	356055.5	250.41	834.7
2	5	6	1	3.14	613713.9	456493	342.37	1141.23
2	5	6	2	3.14	703424	555126	405.51	1351.7
2	5	6	1	3.14	546966.4	398298	286.29	954.3
2	5	6	2	3.14	460519.5	356707.3	244.3	814.35
2	5	6	1	3.14	493876.5	396304.8	256.67	855.55
2	5	6	1	3.14	414261.2	292444.2	203.61	678.69
2	5	6	2	3.14	589428.5	463596.8	321.7	1072.34
2	5	6	2	3.14	525281.9	428320.2	282.89	942.97
2	5	6	2	3.14	542867.9	448757.8	299.24	997.46
2	5	6	2	3.14	487511.6	362760.9	241.7	805.67
2	5	6	2	3.14	573495.4	462900.6	321.01	1070.02
2	5	6	2	3.14	667326.9	504022.4	382.21	1274.04
2	5	6	2	3.14	516321	432115.6	285.56	951.86
2	5	6	2	3.14	596929.5	512076.6	344.42	1148.06
2	5	6	2	3.14	616160.9	550737.3	364.61	1215.38
2	5	6	1	3.14	607409.9	396386.7	317.01	1056.69
2	5	7	2	3.14	662474.6	530333.7	399.94	1333.14
2	5	7	2	3.14	540270.5	432307.1	291.03	970.11
2	5	7	2	3.14	574239.9	344263.3	275.62	918.72
2	5	7	2	3.14	438469.2	339016.3	228.29	760.98
2	5	7	2	3.14	381138	285411	190.65	635.52
2	5	7	1	3.14	532116	377131.3	278.1	927
2	5	7	1	3.14	445315.5	310811.6	221.81	739.36

125.15	68.5	27.69	28.02	38.61	14.19	27.14	13.57	33.61
130.88	72.5	29.84	27.84	39.58	16.81	28.5	14.25	36.28
145.18	75.07	30.86	29.52	44.79	17.06	31.37	15.69	37.6
145.41	74.04	30.72	29.29	44.02	17.73	31.21	15.61	34.61
143.62	76.97	32.89	32.34	46.1	18.22	31.63	15.82	38.57
152.34	75.38	33.63	32.22	44.94	17.61	32.55	16.27	38.56
135.84	72.42	29.65	30.42	40.64	16.22	30.37	15.19	35.32
145.58	76.44	33.07	31.47	43.42	18.03	31.58	15.79	36.06
153.7	77.43	32.21	30.13	46.86	18.81	32.72	16.36	37.11
146.24	74.85	33.29	30.19	42.86	17.72	33.21	16.61	38.42
148.51	74.66	32.37	30.15	43.52	19.1	31.8	15.9	38.42
143.84	71.54	30.82	28.25	41.84	16.15	31.65	15.83	36.59
148.43	74.99	33.56	29.62	44.25	17.87	30.78	15.39	36.28
152.29	80.37	35.09	32.1	47.14	17.23	33.09	16.55	39.5

181.36	99.99	43.7	40.18	55.08	24.5	39.77	19.89	48.56
190.94	91.94	45.08	36.66	53.07	21.47	41.91	20.96	34.97
208.69	108.37	52.19	46.64	59.66	30.13	49.81	24.91	51.13
195.51	102	48.42	41.37	57.54	26.69	46.34	23.17	49.21
198.25	102.16	45.97	41.66	57.67	26.04	46.22	23.11	49.73
195.32	104.64	46.58	44.98	58.33	27.21	42.09	21.05	50.91
208.24	102.83	59.18	40.04	58.74	23.08	48.26	24.13	49.94
200	102.16	45.97	41.66	57.67	26.04	46.22	23.11	49.73
207	106.37	50.19	43.64	57.66	29.13	48.81	24.41	50.13
196.57	104.86	45.12	41.19	56.9	29.92	45.53	22.77	50.2
212.32	100.1	51.28	41.04	58.88	25.42	47.26	23.63	51.39
194.59	96.27	45.93	39.44	58.33	22.96	43.15	21.58	51.09
177.18	88.34	38.44	34.24	48.64	21.05	37.4	18.7	42.74
186.88	91.91	40.47	38.38	53.51	22.18	39.07	19.54	46.19
199.14	103.83	46.61	43.89	58.39	26.06	45.49	22.75	51.11
220.12	110.84	52.42	44.73	64.7	28.6	50.42	25.21	54.61
199.8	100.31	45.23	40.31	53.47	24.83	44.65	22.33	47.17
187.97	93.47	42.37	36.23	55.51	21.42	39.51	19.76	45.28
200.81	93.82	45.59	36.11	54.14	24.4	40.27	20.14	45.11
189.77	91.64	40.83	33.82	48.45	20.12	39.2	19.6	42.5
198.01	104.16	45.82	42.88	59.55	25.95	45.06	22.53	46.41
195.13	100.25	43.48	40.27	55.88	25.55	41.14	20.57	45.83
200.05	101.18	44.45	40.71	56.32	26.56	42.29	21.15	47.15
201.93	94.89	44.99	36.12	52.46	23.05	41.32	20.66	42.98
194.05	103.11	45.81	41.73	56.15	27.48	43.17	21.59	45.73
208.73	109.42	49.73	44.73	60.11	27.95	48.51	24.26	50.34
197.1	96.53	44.13	39	53.19	27.08	42.23	21.12	45.6
204.23	108.29	45.9	43.35	59.85	28.52	44.87	22.44	50.09
207.32	107.51	49.36	41.61	61.01	30.09	47.11	23.56	50.54
205.26	98.37	49.54	40.87	58.49	22.59	45.43	22.72	49.85
211.47	110.52	48.92	45.14	61.19	28.89	45.17	22.59	60.85
208.61	99.58	46.26	38.93	57.48	25.07	43.92	21.96	49.52
203.08	95.12	47.45	40.34	55.33	20.74	44.12	22.06	48.09
193.75	91.44	41.64	35.1	51.18	22.08	40.16	20.08	45.15
175.55	89.4	36.33	34.97	45.11	21.09	35.61	17.81	41.03
200.71	99.39	45.48	39	53.02	23.71	44.19	22.1	45.23
188.56	90.6	42.79	34.69	50.22	20.63	39.07	19.54	43.39

16.81	92.07	27.62	3.43	6.26
18.14	98.43	29.53	3.71	6.7
18.8	108.97	32.69	3.62	7.01
17.31	108.37	32.51	3.5	6.87
19.29	109.58	32.87	4.2	7.63
19.28	114.51	34.35	3.77	7.62
17.66	102.67	30.8	3.63	6.82
18.03	108.22	32.47	3.88	7.39
18.56	111.65	33.49	3.76	7.46
19.21	107.9	32.37	3.96	7.75
19.21	111.08	33.32	3.82	7.59
18.3	108.02	32.41	3.36	6.77
18.14	109.33	32.8	3.65	7.23
19.75	111.34	33.4	4.09	7.75
[redacted]				
24.28	140	42	5.33	9.67
17.49	140	42	4.08	8.48
25.57	152.4	45.72	6.7	12.91
24.61	147.3	44.19	5.85	11.21
24.87	141.35	42.4	5.82	11.3
25.46	144.2	43.26	6	11.2
24.97	153.7	46.11	5.69	11.52
24.87	145.7	43.71	5.6	10.96
25.07	149	44.7	6.2	12.06
25.1	140	42	6.18	11.59
25.7	156.95	47.08	5.29	11.23
25.55	144.29	43.29	5.22	10.55
21.37	130.96	39.29	4.01	8.04
23.1	138.38	41.51	4.47	9.08
25.56	149.69	44.91	5.73	10.99
27.31	162.22	48.67	6.14	12.2
23.59	150.93	45.28	4.78	9.51
22.64	140.59	42.18	4.33	8.71
22.56	147.14	44.14	4.26	9.12
21.25	140.8	42.24	3.58	7.41
23.21	149.44	44.83	5.42	10.3
22.92	145.78	43.73	4.83	9.41
23.58	147.43	44.23	4.99	9.86
21.49	147.85	44.36	3.99	8.49
22.87	143.07	42.92	5.51	10.38
25.17	151.08	45.32	6.1	11.64
22.8	145.36	43.61	4.83	9.86
25.05	152.24	45.67	5.62	10.6
25.27	155.95	46.79	5.86	11.3
24.93	149.38	44.81	5.15	10.74
30.43	155.51	46.65	6.3	12.06
24.76	155.09	46.53	4.65	9.74
24.05	151.99	45.6	4.52	9.66
22.58	144.18	43.25	3.93	8.32
20.52	132.61	39.78	3.62	7.11
22.62	145.89	43.77	4.62	9.33
21.7	139.24	41.77	3.92	8.16

2	5	7	1	3.14	440680.5	289007.3	215.62	718.75
2	5	7	2	3.14	487678.3	331783.6	244.71	815.7
2	5	7	1	3.14	416975.5	275885.8	204.56	681.85
2	5	7	2	3.14	565901.2	400726.6	293.9	979.68
2	5	7	1	3.14	493263.3	393280.2	276.29	920.95
2	5	7	2	3.14	658101.6	554945.2	391.06	1303.54
2	5	7	1	3.14	484824.3	316901.3	232.49	774.96
2	5	7	2	3.14	595054.3	445309.7	338.52	1128.4
2	5	7	1	3.14	557461.8	400990.3	288.54	961.8
2	5	7	2	3.14	484822.8	344291.6	257.73	859.1
2	5	7	1	3.14	422901.6	307933.7	207.8	692.67
2	5	7	1	3.14	458265.6	345900	234.7	782.33
2	5	7	2	3.14	453507.4	311175.5	238.69	795.64
2	5	7	2	3.14	588982.1	438827.2	321.85	1072.85
2	5	7	1	3.14	420425.9	337650.4	231.8	772.66
2	5	7	1	3.14	505452.9	321585.4	249.24	830.79
2	5	7	2	3.14	588041.3	409017.7	313.63	1045.42
2	5	7	2	3.14	571755	376721.6	291.61	972.04
2	5	7	1	3.14	549548.5	328482	269.87	899.58
2	5	7	2	3.14	437982.4	284079.2	212.42	708.07
2	5	7	1	3.14	470385.6	332662.7	260.53	868.45
2	5	7	1	3.14	457411.4	329915	243.28	810.93
2	5	7	2	3.14	475122.2	342204.7	239.28	797.61
2	5	7	2	3.14	371281	241510	179.21	597.38
2	5	7	2	3.14	375083.3	234472.3	172.63	575.45
2	5	7	1	3.14	500851.2	342395.5	251.8	839.34
2	5	7	1	3.14	485636.9	358875.8	261.74	872.47
2	5	7	1	3.14	446322	276821.1	206.09	686.98
2	5	7	2	3.14	539804.6	411471.1	309.63	1032.1
2	5	7	1	3.14	354126.6	280725.7	190.29	634.28
2	5	7	1	3.14	331044.1	239521.8	171.73	572.42
2	5	7	2	3.14	579910.8	438211	320.99	1069.97
2	5	7	2	3.14	550837.5	392029	283.66	945.55
2	5	7	2	3.14	639745.9	477941.3	357.95	1193.17
2	5	7	1	3.14	538255.9	406917.7	292.98	976.61
Wolf=48.1%	Area 3							
2	6	3	2	3.14	1285800	922105.9	687.49	2291.65
2	6	3	2	3.14	1013119	1241767	750.46	2965.88
2	6	3	2	3.14	1042153	1152894	725.43	2685.23
2	6	3	1	3.14	616471.6	721053.9	423.09	1687.79
2	6	3	2	3.14	1193469	1195077	738.83	2578.23
2	6	3	2	3.14	913269.6	1049279	645.7	2264.07
2	6	3	2	3.14	764754.5	934684.4	547.77	2002.1
2	6	3	1	3.14	1021552	1271547	780.79	2829.62
2	6	3	2	3.14	1003046	1301276	802.49	3037.15
2	6	3	2	3.14	922325.9	1187881	736.28	2779.82
2	6	3	2	3.14	989386.2	1250981	796.33	2994.18
2	6	3	2	3.14	1026929	1323451	810.98	3051.55
2	6	3	1	3.14	986499.1	1188252	745.57	2684.73
2	6	3	2	3.14	840613.1	1012278	633.41	2282.94
2	6	3	1	3.14	651638	789031.5	425.67	1666.62
2	6	3	1	3.14	1015126	1203272	702.23	2696.99

170.86	85.79	41.85	35.1	50.81	18.96	39.08	19.54	43.93
195.69	94.15	41.94	38.76	52.02	21.26	41.28	20.64	43.88
179.57	83.96	39.86	34.87	48.58	18.93	35.75	17.88	43.29
209.37	98.27	48.17	39.16	56.03	23.84	45.2	22.6	49.77
191.84	96.91	41.26	39.85	53.29	24.6	41.16	20.58	46.11
208.69	109.87	47.4	46.28	60.61	30.52	45.88	22.94	52.45
186.79	93.92	43.13	37.47	49.71	21.25	39.47	19.74	42.58
198.82	104.79	45.64	43.46	57.87	25.65	45.1	22.55	51.3
193.56	98	43.95	42.28	53.02	25.21	42.62	21.31	44.82
177.92	98.01	40.81	39.6	53.23	21.56	38.15	19.08	46.55
181.85	90.13	38.6	36.52	49.23	20.85	35.92	17.96	42
191.92	89.85	41.6	36.72	50	23.06	39.95	19.98	43.13
180.01	91.79	41.61	36.33	48.11	21.56	39.2	19.6	44.13
195.25	104.99	44.63	43.99	56.74	25.78	41.36	20.68	49.7
174.8	89.79	39.51	35.47	51.02	22.06	37.06	18.53	43.34
191.38	94.16	44.21	38.11	50.35	21.29	41.64	20.82	45.28
203.43	102.57	47.89	40.93	53.32	25.57	46.28	23.14	46.05
198.93	98.34	47	40.55	55.91	22.46	44.18	22.09	47.96
199.52	97.49	46.79	39.15	52.14	21	45.2	22.6	46.73
181.87	90.58	39.64	36.83	46.35	20.43	40.37	20.18	41.45
185.39	94.38	42.4	36.98	50.13	22.12	42.21	21.11	47.72
187.64	90.64	43.01	35.45	50.96	21.58	42.82	21.41	43.02
196.45	93.63	42.38	37.37	51.92	21.97	41.58	20.79	45.03
181.15	84.19	37.64	32.88	42.73	18.84	38.58	19.29	40.11
180.03	88.49	36.43	34.32	45.23	17.28	35.54	17.77	40.71
193.02	92.91	45.33	36.83	51.62	22.11	40.28	20.14	45.78
189.55	95.09	41.84	38.69	49.33	24.25	41.34	20.67	45.21
181.26	87.12	40.09	37.11	46.65	19.78	38.07	19.04	42.76
192.63	96.61	44.95	40.03	56.42	24.31	42.85	21.43	49.94
171.84	85.96	35.63	33.13	45.14	20.73	35.76	17.88	41.3
172.35	79.77	35.02	31.51	44.93	17.77	35.03	17.52	41.85
198.62	102.18	45.85	42.16	52.28	27.94	45.06	22.53	47.52
206.18	102.18	44.97	40.83	56.89	22.97	44.26	22.13	48.2
193.73	107.51	48.29	44.16	58.25	27.35	46.02	23.01	50.15
194.57	99.43	46.23	38.81	53.57	25.32	44.05	22.03	46.27

269.11	150.27	67.72	63.29	65.86	46.67	61.63	30.82	66.3
268.07	139.92	59.33	56.92	72.72	42.24	58.19	29.1	69.14
260.19	138.02	61.17	56.79	67.67	39.06	59.14	29.57	66.76
211.01	104	46.98	43.74	54.95	27.91	43.26	21.63	55.13
270.1	142.75	66.76	59.59	66.85	38.97	61.07	30.54	67.01
255.54	128.82	60.97	49.93	70.05	36.19	63.68	31.84	61.52
240.4	120.51	54.68	46.62	66.83	33.71	57.47	28.74	57.09
247.99	139.84	58.72	57.99	73.09	40.33	65	32.5	62.22
251.81	137.47	58.32	57.33	75.66	38.67	62.94	31.47	63.73
239.25	133.11	56.37	54.54	72.6	38.11	60.94	30.47	61.81
247.64	138	58.85	56.04	74.41	38.81	63.3	31.65	64.78
255.22	138.79	57.94	59.08	74.67	37.98	63.89	31.95	64.26
253.17	134.51	58.48	56.23	70.44	38.91	63.18	31.59	61.63
247.25	124.03	55.53	50.46	66.87	34.41	62.78	31.39	61.38
220.99	113.36	51.46	42.21	62.31	29.71	45.63	22.82	53.65
244.12	134.4	61.4	55.11	72.78	39.11	55.22	27.61	63.33

21.97	138.75	41.63	4.21	8.38
21.94	141.76	42.53	4.17	8.66
21.65	131.26	39.38	3.8	8.12
24.89	154.89	46.47	4.68	9.97
23.06	139.12	41.74	4.8	9.5
26.23	151.64	45.49	6.25	11.86
21.29	140.35	42.11	4.15	8.25
25.65	146.76	44.03	5.68	10.77
22.41	144.63	43.39	4.97	9.81
23.28	133.95	40.18	4.83	8.77
21	135.34	40.6	3.81	7.69
21.57	141.57	42.47	4.08	8.71
22.07	132.01	39.6	4.42	8.67
24.85	143.45	43.04	5.49	10.22
21.67	130.35	39.1	4.42	8.61
22.64	142.87	42.86	4.34	8.82
23.03	146.83	44.05	5.14	10.19
23.98	148.58	44.57	4.89	9.88
23.37	148.92	44.68	4.51	9.23
20.73	138.67	41.6	3.89	7.82
23.86	137.14	41.14	4.68	9.2
21.51	138.85	41.65	4.32	8.95
22.52	146.96	44.09	4.06	8.52
20.06	133.98	40.19	3.3	7.1
20.36	132.51	39.75	3.2	6.5
22.89	142.37	42.71	4.35	9.03
22.61	138.69	41.61	4.6	9.18
21.38	139.88	41.96	3.79	7.89
24.97	141.07	42.32	5.36	10.68
20.65	127.48	38.24	3.69	7.38
20.93	125.9	37.77	3.32	7.18
23.76	146.28	43.88	5.39	10.47
24.1	152.56	45.77	4.59	9.25
25.08	149.21	44.76	6.16	11.1
23.14	145.19	43.56	5.02	9.82
33.15	204.19	61.26	8.52	15.25
34.57	192.96	57.89	11.06	21.2
33.38	191.06	57.32	10.32	19.46
27.57	156.99	47.1	8	16.23
33.51	207.04	62.11	9.55	18.06
30.76	190.04	57.01	8.86	17.58
28.55	177.65	53.3	8.33	16.61
31.11	186.37	55.91	11.41	20.23
31.87	182.01	54.6	12.06	22.09
30.91	176.06	52.82	11.62	20.88
32.39	180.41	54.12	12.09	21.7
32.13	185.77	55.73	11.96	21.99
30.82	181.82	54.55	10.6	19.96
30.69	181.41	54.42	9.23	18.41
26.83	169.3	50.79	7.54	14.7
31.67	188.34	56.5	11.05	20.07

2	6	3	2	3.14	1017236	1263140	748.76	2921.27
2	6	3	2	3.14	879406.4	1122809	659.49	2603.39
2	6	3	2	3.14	1112731	1371157	797.8	3115.53
2	6	3	2	3.14	1067973	1377816	811.89	3214.35
2	6	3	2	3.14	1148256	1479187	868.52	3427.07
2	6	3	2	3.14	679841.1	952575.3	522.55	2162.74
2	6	3	2	3.14	1065762	1428344	826.05	3342.36
2	6	3	2	3.14	1073679	1292818	740.58	2785.7
2	6	3	1	3.14	890883.6	1109865	635.41	2512.06
2	6	3	2	3.14	1044304	1444214	836.7	3434.12
2	6	3	2	3.14	837649.5	1099121	640.67	2566.46
2	6	3	1	3.14	1024288	1293919	748	2902.35
2	6	3	1	3.14	760529.3	1084062	576.29	2403.02
2	6	3	2	3.14	1068915	1433898	818.5	3362.53
2	6	3	1	3.14	1025489	1334938	756.93	3002.11
2	6	3	2	3.14	1143549	1505623	899.44	3648.78
2	6	3	2	3.14	1072346	1333127	771.66	2987.36
2	6	3	1	3.14	660361.2	855856.6	474.24	1896.04
2	6	3	2	3.14	941573.2	1168685	659.08	2544.68
2	6	3	1	3.14	783682.3	1087119	593.05	2473.99
2	6	3	1	3.14	512056.6	644039.8	323.98	1128.65
2	6	3	1	3.14	1002430	1273237	721.25	2821.85
2	6	3	2	3.14	1056371	1288608	779.04	3084.09
2	6	3	1	3.14	1026373	1245937	792.09	3084.78
2	6	3	1	3.14	831623.1	1083116	600.82	2411.07
2	6	3	2	3.14	985831.5	1324492	747.3	3074.03
2	6	3	1	3.14	823446	1049284	579.81	2298.17
2	6	3	2	3.14	1116849	1479426	833.91	3322.64
2	6	3	2	3.14	783682.3	1087119	593.05	2473.99
2	6	3	2	3.14	1013966	1424276	866.72	3601.68
2	6	3	2	3.14	1056371	1288608	779.04	3084.09
2	6	3	2	3.14	1026407	1411708	783.12	3241.86
2	6	3	2	3.14	1122471	1397031	864.97	3288.53
2	6	3	2	3.14	987014.2	1286600	738.76	2989.71
Erming=63.6%	Area 1							
3	7	1	1	3.14	29100	25103.52	25.65	85.49
3	7	1	1	3.14	16649.52	11762.4	13.19	43.96
3	7	1	1	3.14	23073.12	13734.42	15.2	50.65
3	7	1	2	3.14	28316.52	25284	23.06	76.86
3	7	1	1	3.14	21870	21578.4	20.14	67.14
3	7	1	2	3.14	25678.5	21865.2	21.1	70.35
3	7	1	2	3.14	25132.59	18739.05	18.11	60.38
3	7	1	2	3.14	22360.2	17069.4	16.86	56.2
3	7	1	1	3.14	16296.84	9598.89	10.8	36.01
3	7	1	2	3.14	23497.95	17147.88	18.02	60.06
3	7	1	2	3.14	16829.37	12398.7	12.35	41.17
3	7	1	2	3.14	25336.92	21680.52	21.1	70.32
3	7	1	1	3.14	14024.85	10653.72	10.71	35.72
3	7	1	1	3.14	13670.28	10573.92	10.11	33.71
3	7	1	1	3.14	16357.05	12664.08	12.17	40.56
3	7	1	2	3.14	18258.84	9402.12	10.86	36.2
3	7	1	2	3.14	17321.04	8585.28	11.04	36.79

260.28	135.19	62.63	54.14	77.77	36.53	57.46	28.73	65.31
250.21	130.81	57.41	51.06	73.3	35.64	55.28	27.64	62.88
258.31	139	63.08	58.8	77.73	41.65	57.39	28.7	65.88
260.03	153.13	59.63	59.7	76.93	46.49	57.05	28.53	64.68
258.01	147.44	63.15	60.61	81.35	41.67	60.34	30.17	67.95
261.03	149.41	54.54	41.55	76.42	41.54	55.31	27.66	64.66
257.93	145.72	59.14	60.07	79.26	37.17	57.33	28.67	66.07
273.82	145.45	63.4	56.45	76.34	39.92	58.96	29.48	63.42
237.48	135.16	54.8	54.19	68.27	37.35	51.47	25.74	60.22
268.45	135.53	61.21	56.87	84.65	39.71	60.08	30.04	69.61
237.85	128.32	53.5	52.19	70.2	37	52.11	26.06	59.81
251.95	136.98	59.68	57.21	75.39	37.06	56.79	28.4	62.62
228.88	122.59	48.26	52.53	68.79	33.84	48.08	24.04	56.35
273.07	144.17	60.36	59.03	80.97	42.26	57.72	28.86	69.11
258.19	139.68	59.75	57.21	77.78	40.49	57.7	28.85	65.12
256.79	145.44	60.64	62.86	79.84	41.93	57.83	28.92	68.29
251.71	138.65	63.12	56.63	78.47	37.91	57.36	28.68	63.92
248.03	135.71	55.6	39.59	72.06	39.18	52.53	26.27	60.75
251.3	133.27	57.42	54.66	71.27	36.11	54.83	27.42	60.81
235.36	127	50.13	52.11	69.54	35.28	48.42	24.21	58.38
227.1	118.6	53.54	31.88	67.34	30.65	49.51	24.76	43.11
258.6	140.16	58.56	57.06	74.38	39.77	57.35	28.68	64.16
249.66	142.07	59.36	59.32	72.41	42.77	55.87	27.94	66.98
256.88	141.77	61.05	56.04	74.11	39.13	58.37	29.19	67.57
239.09	125.55	53.9	51.43	70.2	38.23	50.89	25.45	59.11
263.95	146.64	57.55	57.1	77.32	41.48	53.77	26.89	64.5
238.43	125.56	54	50.83	68.81	36.67	50.66	25.33	58.32
255	145.49	60.99	61.04	80.79	42.63	58	29	65.06
235	127	50.13	52.11	69.54	35.28	48.42	24.21	58.38
245	139.38	57.53	58.75	80.81	41.64	58.17	29.09	68.55
246	142.07	59.36	59.32	72.41	42.77	55.87	27.94	66.98
268	146.63	57.94	59.05	79.69	42.32	57.3	28.65	68.27
262	144.06	63	59.39	78.41	42.6	63.64	31.82	67.88
255	137.24	60.39	54.48	78.72	40.82	57.96	28.98	68.71

45.46	25.95	9.7	10	13.41	6.24	10.83	5.42	12.6
38.17	20.52	6.92	8.02	10.4	3.77	8.46	4.23	10.54
42.55	23.2	8.82	8.72	12.34	3.71	8.93	4.47	11.65
45.08	26.31	9.42	10.02	14	6.02	10.24	5.12	12.26
42.27	23.96	8.1	9	13.32	5.4	9.85	4.93	10.86
45.28	25.75	9.01	9.5	13.7	5.32	9.96	4.98	12.25
44.39	24.41	8.61	9.73	13.85	4.51	9.1	4.55	11.39
44.47	24.65	8.3	8.98	13.08	4.35	10.05	5.03	11.48
38.07	21.24	6.69	8.12	10.63	3.01	8.18	4.09	9.42
43.03	23.7	8.05	9.73	13.11	4.36	9.7	4.85	11.59
40.31	21.06	7.11	7.89	11.17	3.7	8.3	4.15	10.02
46.13	25.58	8.68	9.73	14.06	5.14	10.84	5.42	12.32
39.51	19.78	7.03	6.65	11.53	3.08	8.14	4.07	9.62
35.14	19.28	5.98	7.62	10.49	3.36	6.81	3.41	9.09
36.96	20.8	6.69	8.15	10.66	3.96	7.4	3.7	9.41
39.36	21.27	7.57	8.04	11.48	2.73	7	3.5	10.29
37.55	21	7.29	7.92	10.84	2.64	7.65	3.83	10.7

32.66	188.24	56.47	11.22	21.61
31.44	180.77	54.23	10.4	19.9
32.94	193.27	57.98	12.06	22.41
32.34	184.81	55.44	12.36	20.99
33.98	195.5	58.65	13.28	23.24
32.33	189.83	56.95	8.29	14.48
33.03	188.21	56.46	12.96	22.94
31.71	196.19	58.86	10.17	19.15
30.11	177.35	53.21	10.58	18.59
34.81	195.14	58.54	12.79	25.34
29.91	170.74	51.22	10.79	20
31.31	186.09	55.83	11.52	21.19
28.18	169.45	50.83	10.5	19.6
34.56	196.45	58.93	12.31	23.32
32.56	193.02	57.91	11.63	21.49
34.15	187.84	56.35	14.21	25.09
31.96	190.14	57.04	11.87	21.55
30.38	182.78	54.83	7.64	13.97
30.41	186.16	55.85	10.13	19.09
29.19	171	51.3	10.51	19.48
21.56	163.95	49.18	4.97	9.52
32.08	192.97	57.89	10.91	20.13
33.49	186.55	55.97	12.35	21.71
33.78	181.92	54.58	12.01	21.76
29.56	177	53.1	10.08	19.2
32.25	185.25	55.58	11.65	20.96
29.16	177.49	53.25	9.64	18.3
32.53	193.1	57.93	13.03	22.84
29.19	171	51.3	10.53	19.48
34.28	180.7	54.21	14.7	25.84
33.49	186.55	55.97	12.54	21.71
34.14	198.17	59.45	12.1	22.11
33.94	192.22	57.67	12.55	22.83
34.35	197.1	59.13	11.72	21.78
6.3	24.62	7.39	1.88	3.29
5.27	20.08	6.02	1.15	2.14
5.83	24.09	7.23	1.19	2.18
6.13	26.02	7.81	1.7	2.92
5.43	22.33	6.7	1.59	2.8
6.13	24.81	7.44	1.55	2.73
5.7	24.41	7.32	1.36	2.47
5.74	24.95	7.49	1.26	2.28
4.71	20.71	6.21	0.95	1.7
5.8	23.68	7.1	1.4	2.53
5.01	21.37	6.41	1.02	1.95
6.16	25.68	7.7	1.52	2.75
4.81	20.22	6.07	0.9	1.81
4.55	18.71	5.61	0.96	1.75
4.71	19.74	5.92	1.1	1.95
5.15	20.68	6.2	0.92	1.7
5.35	20.33	6.1	0.98	1.75

3	7	1	2	3.14	14574.96	7111.47	8.63	28.76
3	7	1	2	3.14	15410.76	7764.48	9.14	30.48
3	7	1	1	3.14	15173.1	7925.4	9.38	31.28
3	7	1	1	3.14	12875.58	6029.1	7.66	25.53
3	7	1	1	3.14	12293.52	10118.4	8.76	29.21
3	7	1	1	3.14	18581.55	7660.62	10.88	36.28
3	7	1	2	3.14	27356.94	23034.24	23.46	78.18
3	7	1	2	3.14	26913.84	23256.72	21.54	71.81
3	7	1	1	3.14	20057.85	12420.84	14.21	47.38
3	7	1	2	3.14	27897.54	20036.28	21.71	72.35
3	7	1	2	3.14	24364.8	13176.24	16.38	54.62
3	7	1	2	3.14	22194	13722.3	15.81	52.69
3	7	1	2	3.14	28510.08	17092.02	18.81	62.71
3	7	1	2	3.14	23655.06	14463.36	17.86	59.54
3	7	1	2	3.14	25054.2	20914.08	20.82	69.41
3	7	1	2	3.14	24421.2	15102.36	16.99	56.64
3	7	1	1	3.14	19199.88	9100.08	12.43	41.44
3	7	1	2	3.14	23544.78	19858.44	18.49	61.64
Marten=49.0%		Area 3						
3	8	3	1	3.14	57418.2	49361.28	48.8	162.67
3	8	3	2	3.14	72432	66103.29	59.76	199.21
3	8	3	1	3.14	63010.8	63060.48	57.5	191.67
3	8	3	2	3.14	74016.45	67761.42	61.48	204.93
3	8	3	1	3.14	73989.42	74564.55	67.32	224.39
3	8	3	2	3.14	80046.54	73243.68	71.26	237.52
3	8	3	2	3.14	83400.12	81933.57	77.87	259.58
3	8	3	2	3.14	84671.25	77718.84	73.46	244.88
3	8	3	1	3.14	64468.8	57527.01	55.03	183.43
3	8	3	1	3.14	39236.85	33140.1	32.4	107.99
3	8	3	1	3.14	40106.55	30514.32	29.64	98.81
3	8	3	2	3.14	48960.36	35009.46	39.55	131.85
3	8	3	1	3.14	44386.5	31132.08	32.63	108.77
3	8	3	2	3.14	45145.44	32931.36	35.76	119.22
3	8	3	1	3.14	44942.28	34011.09	34.44	114.79
3	8	3	1	3.14	51738.03	40698	44.01	146.69
3	8	3	2	3.14	50716.32	35596.26	38.76	129.21
3	8	3	2	3.14	53164.08	38163.06	41.79	139.3
3	8	3	1	3.14	43126.95	31687.5	33.34	111.13
3	8	3	1	3.14	42625.98	33664.41	33.17	110.56
3	8	3	2	3.14	58808.88	60122.4	52.66	175.54
3	8	3	2	3.14	47624.28	42854.4	39.04	130.14
3	8	3	2	3.14	54190.08	43107.3	42.94	143.12
3	8	3	2	3.14	58484.46	50522.79	48.22	160.75
3	8	3	1	3.14	34777.59	22963.98	24.37	81.25
Mink=50.0%		Area 2						
3	9	2	1	3.14	90497.25	53049.36	58.82	196.06
3	9	2	2	3.14	126070.7	101110.1	98.42	328.06
3	9	2	1	3.14	90005.76	57025.98	59.67	198.89
3	9	2	1	3.14	104524	59785.95	66.33	221.11
3	9	2	2	3.14	116805.1	77355.9	79.76	265.86
3	9	2	1	3.14	86531.82	53437.92	53.67	178.89
3	9	2	2	3.14	147595.8	115007.9	113.74	379.13

37.23	21.44	6.53	7.44	10.63	2.23	6.85	3.43	9.32
35.4	20.43	6.68	7.69	10.11	2.56	7.1	3.55	9.52
34.88	19.12	6.9	7.33	10.36	2.55	6.53	3.27	9.2
34.35	19.59	6.14	6.99	9.9	2.03	6.2	3.1	9.74
32.94	19.08	5.66	7.24	9.92	3.4	6.01	3.01	8.28
39.37	20.6	7.33	8.45	11.66	2.19	7.52	3.76	11.11
43.1	26.49	8.66	10.53	13.76	5.58	9.41	4.71	11.99
41.16	25.44	8.83	10.16	13.32	5.82	9.08	4.54	11.53
38.82	21.87	7.95	8.41	11.63	3.56	7.88	3.94	10.62
43.26	25.51	9.46	9.83	14.12	4.73	9.69	4.85	10.98
41.85	24.63	8.64	9.4	13.64	3.22	8.01	4.01	12.62
43.06	23.39	8.22	9	11.85	3.86	9.68	4.84	11.38
45.23	23.82	9.92	9.58	13.63	4.18	9.57	4.79	10.96
43.85	24.39	8.58	9.19	12.96	3.72	9.7	4.85	11.65
45.2	24.36	8.98	9.3	14.96	4.66	10.62	5.31	11.54
44.57	22.98	9.4	8.66	13.83	3.64	9.93	4.97	11.06
39.64	20.8	8.02	7.98	11.49	2.64	8.55	4.28	10.61
45.71	25.74	8.54	9.19	13.16	5.03	9.42	4.71	11.73

62.51	36.21	13.72	13.95	21.88	7.52	15.75	7.88	19.06
67.59	40.51	16	15.09	24.73	8.91	16.07	8.04	20.1
64.38	37.79	13.8	15.22	23.46	8.96	16.04	8.02	19.57
67.5	41.22	16.35	15.09	25.58	8.83	17.1	8.55	20.19
66.18	41.6	15.58	15.83	25.65	9.69	16.01	8.01	21.57
69.07	40.83	17.17	15.54	26.48	9.22	17.95	8.98	21.74
70.11	43	16.44	16.91	26.49	10.31	17.41	8.71	21.56
70.34	41.78	16.75	16.85	26.68	9.71	18.49	9.24	21.56
60.6	36.18	14.8	14.52	22.91	8.37	14.17	7.09	18.7
54.67	29.74	11.15	11.73	18.35	6.02	12.91	6.46	15.43
55.97	29.81	11.99	11.15	16.62	6.12	12.89	6.45	14.97
60.96	33.17	13.29	12.28	20.19	5.78	14.86	7.43	17.7
53.69	30.36	12.7	11.65	17.04	6.09	12.65	6.33	15.19
58.22	33.8	12.84	11.72	18.48	5.94	14.91	7.46	17.3
55.94	31.37	12.14	12.34	17.91	6.33	13.56	6.78	15.88
56.32	30.84	13.83	12.47	19.38	7	13.94	6.97	16.87
54.29	31.44	13.28	12.73	18.06	6.57	12.99	6.5	15.73
59.04	34.3	13.04	13.59	18.33	6.94	14.27	7.14	17.34
55.66	30.36	12.05	11.93	16.9	6.25	13.54	6.77	15.67
58.29	32.88	11.58	12.27	18.07	6.21	14.11	7.06	16.42
61.63	38.1	13.39	14.64	21.32	9.4	14.07	7.04	18.48
58.56	33.55	11.99	13.24	19.2	7.44	13.37	6.69	16.7
61.23	33.91	13.44	13.44	21.1	6.81	15.63	7.82	18.19
59.81	36.12	13.19	14.78	22.13	7.61	14.37	7.19	17.26
52.24	28.27	10.51	11.03	15.34	4.99	11.42	5.71	14.59

78.65	40.87	18.45	16.35	27.76	6.37	18.73	9.37	23.64
88.54	50.79	20.38	20.62	33.14	10.17	21.27	10.64	28.28
78.51	42.27	18.03	16.64	27.39	6.94	18.36	9.18	23.64
84.57	44.98	19.26	18.09	29.35	6.79	19.67	9.84	27.09
87.78	46.4	21.44	18.16	30.3	8.51	21.3	10.65	28.67
79.52	40.21	17.62	16.37	26.08	6.83	17.71	8.86	22.53
88.97	52.53	21.4	22.99	32.85	11.67	22.16	11.08	28.12

4.66	19.25	5.78	0.77	1.34
4.76	20.05	6.02	0.86	1.49
4.6	18.33	5.5	0.9	1.64
4.87	18.09	5.43	0.74	1.3
4.14	17.99	5.4	0.89	1.53
5.56	20.66	6.2	0.92	1.76
6	22.75	6.83	1.81	2.95
5.77	23.79	7.14	1.74	2.82
5.31	20.4	6.12	1.22	2.17
5.49	22.59	6.78	1.67	2.84
6.31	22.06	6.62	1.31	2.22
5.69	23.47	7.04	1.22	2.25
5.48	24.46	7.34	1.39	2.63
5.83	22.28	6.68	1.36	2.44
5.77	24.37	7.31	1.54	2.85
5.53	24.1	7.23	1.27	2.46
5.31	20.97	6.29	1.05	1.99
5.87	24.59	7.38	1.35	2.39

9.53	37.81	11.34	2.6	4.49
10.05	41.71	12.51	2.95	4.92
9.79	39.04	11.71	2.98	5.07
10.1	42.84	12.85	3.04	4.97
10.79	41.49	12.45	3.39	5.39
10.87	42.51	12.75	3.44	5.82
10.78	41.33	12.4	3.7	6.04
10.78	44.12	13.24	3.48	5.86
9.35	36.15	10.85	3.03	5.07
7.72	31.42	9.43	1.98	3.63
7.49	32.85	9.86	1.77	3.31
8.85	34.06	10.22	2.16	3.97
7.6	31.7	9.51	2.03	3.58
8.65	34.75	10.43	2.05	3.53
7.94	33.38	10.01	2.05	3.66
8.44	31.99	9.6	2.6	4.76
7.87	31.44	9.43	2.38	4.11
8.67	33.99	10.2	2.36	4.06
7.84	32.41	9.72	2	3.66
8.21	34.8	10.44	1.9	3.36
9.24	36.81	11.04	2.85	4.61
8.35	34.64	10.39	2.22	3.88
9.1	37.99	11.4	2.34	4.22
8.63	35.51	10.65	2.69	4.45
7.3	30.04	9.01	1.56	2.87

11.82	50.14	15.04	2.49	4.8
14.14	56.3	16.89	3.71	6.46
11.82	50.29	15.09	2.53	4.71
13.55	55.41	16.62	2.61	4.92
14.34	59	17.7	3.03	5.73
11.27	50.99	15.3	2.25	4.45
14.06	57.19	17.16	4.26	7.22

3	9	2	1	3.14	91348.32	56820.42	62.66	208.86
3	9	2	1	3.14	98374.41	50444.1	62.2	207.34
3	9	2	1	3.14	99798.45	60329.43	64.9	216.32
3	9	2	2	3.14	114745	83263.32	81.87	272.89
3	9	2	1	3.14	107292.5	64611.84	69.14	230.48
3	9	2	2	3.14	140653.8	136702.8	116.6	388.68
3	9	2	2	3.14	135630.7	90762.75	97.13	323.76
3	9	2	1	3.14	91411.65	55242.72	62.07	206.89
3	9	2	1	3.14	84113.76	50213.25	54.94	183.12
3	9	2	1	3.14	114053.3	69184.08	77.35	257.85
3	9	2	2	3.14	121291.6	105912.2	95.67	318.9
3	9	2	2	3.14	142767	105999.4	103.64	345.46
3	9	2	1	3.14	101786.5	78013.86	75.31	251.02
3	9	2	2	3.14	140290.5	97580.07	101.57	338.56
3	9	2	2	3.14	147427.8	122982.2	124.38	414.61
3	9	2	2	3.14	117125.4	72547.86	78.61	262.04
3	9	2	1	3.14	103778.3	64728.9	69.35	231.16
3	9	2	1	3.14	96077.37	53531.73	63.29	210.97
3	9	2	1	3.14	92290.86	54139.68	60.06	200.22
3	9	2	2	3.14	126965.5	89333.37	91.02	303.39
3	9	2	2	3.14	133675.1	97956.75	99.7	332.34
3	9	2	1	3.14	98116.86	54714.96	63.96	213.2
3	9	2	2	3.14	121677.2	92604.42	95.03	316.76
3	9	2	1	3.14	98097.48	67895.52	68.13	227.1
Fisher=50.0%		Area 6						
3	10	6	1	3.14	264745.4	189571.5	189.46	631.53
3	10	6	1	3.14	303513	289558.6	266.48	888.27
3	10	6	1	3.14	265599.3	195761.9	200.48	668.26
Wolverine=72.2%		Area 1						
3	11	1	2	3.14	368339.6	356099.4	287.47	958.23
3	11	1	1	3.14	274324.3	223627	196.31	654.35
3	11	1	2	3.14	290196.6	407841.4	292.44	974.81
3	11	1	2	3.14	495725.7	442445.9	383.71	1279.04
3	11	1	1	3.14	332071.9	275957.2	247.87	826.23
3	11	1	2	3.14	542168.5	461549.4	419.13	1397.11
3	11	1	2	3.14	537899.9	479483.5	454.24	1514.12
3	11	1	1	3.14	397787	374998	317.57	1058.57
3	11	1	2	3.14	430448.6	412866.2	369.9	1232.99
3	11	1	2	3.14	586606.5	464245.2	398.22	1327.41
3	11	1	1	3.14	384273.4	315018.5	275.17	917.22
3	11	1	1	3.14	403834.8	351097.2	301.36	1004.53
3	11	1	1	3.14	403174.4	350000.2	308.86	1029.53
3	11	1	1	3.14	379974.2	351270.7	296.57	988.57
3	11	1	1	3.14	465352.6	430218.4	399.56	1331.85
3	11	1	2	3.14	498892.8	437702.2	387.28	1290.93
3	11	1	1	3.14	337477.3	290169.5	257.39	857.97
3	11	1	1	3.14	376468.8	373612.5	307.36	1024.53
3	11	1	2	3.14	571253.8	488023.2	436.96	1456.52
3	11	1	1	3.14	398902.6	357511.8	302.41	1008.02
3	11	1	2	3.14	384597.3	338882.4	288.49	961.64
3	11	1	2	3.14	545128.6	471739	401.94	1339.79
3	11	1	1	3.14	374129.6	355347	305.9	1019.67

76.49	42.26	17.54	17.36	25.02	7.57	17.59	8.8	23.33
77.9	41.69	19.21	17.07	26.69	6.3	19.53	9.77	23.63
79.05	43.18	18.43	18.05	27.51	7.31	19.06	9.53	24.45
86.1	47.91	20.41	18.74	31.08	8.93	20.78	10.39	26.7
80.95	44.84	19.49	18.35	28.64	7.52	18.78	9.39	24.74
91.98	53.48	21.35	21.96	33.02	13.8	22.67	11.34	27.12
88.74	49.57	22.56	20.04	31.03	9.75	21.33	10.67	27.39
77.99	40.2	19.47	15.65	27.04	6.81	18.89	9.45	24.75
76.04	40.03	17.48	16.04	25.95	6.45	17.78	8.89	23.88
83.25	45.95	20.19	18.83	25.97	8.88	20.39	10.2	25.22
88.94	50.36	20.67	19.56	32.78	10.77	20.75	10.38	28.05
91.87	51.68	21.75	21.88	32.96	10.72	22.27	11.14	28.59
80.35	45.37	18.33	18.51	27.46	9.47	18.33	9.16	24.04
90.36	51.34	21.7	21.55	31.61	10.29	21.36	10.68	27.59
90.25	54.33	23.05	21.32	33.41	12.27	24.21	12.11	29.79
89.04	45.66	22.12	17.65	31.57	7.66	21.59	10.8	27.97
80.15	44.44	18.42	18.78	27.14	7.95	18.78	9.39	24.98
76.03	41.56	18.29	17.51	27.41	6.51	19.44	9.72	24.13
78.41	41.59	18.51	16.62	27.51	6.56	18.49	9.24	24.13
85.55	50.28	20.91	20.24	30.17	9.87	20.53	10.27	27.47
89.74	51.22	20.89	21.33	30.95	10.55	22.58	11.29	28.2
78.85	42.18	18.19	17.98	27.76	6.57	18.77	9.39	25.28
87.22	49.61	20.31	19.97	30.93	9.98	21.62	10.81	27.98
78.74	45.3	17.81	18.36	26.72	8.47	17.99	8.99	24.33

116.11	63.19	32.54	27.12	43.67	14.47	32.71	16.36	37.64
128.42	72.23	33.95	29.8	47.57	20.29	33.7	16.85	42.69
122.26	64.13	33.83	26.17	44.27	14.74	33.94	16.97	39.72

140.78	93.73	36.39	33.74	54.3	21.86	31.79	15.9	44.72
130.4	77.72	31.23	29.28	48.31	15.43	30.07	15.04	39.44
163.43	101.77	43.3	22.34	61.71	22.03	37.44	18.72	50.45
157.81	106.48	40.71	40.59	62.15	23.73	37.12	18.56	49.09
143.95	87.26	33.84	32.71	51.94	17.71	31.15	15.58	42.69
168.46	108.83	41.97	43.06	61.1	25.18	38.5	19.25	50.87
168.57	107.98	42.03	42.66	60.91	26.24	42.01	21.01	50.6
151.15	96.39	35.34	37.52	52.17	23.96	34.79	17.4	44.14
156.06	99	39.68	36.16	59.68	23.06	35.48	17.74	50.03
165.94	108.01	45.59	42.89	59.98	25.8	34.28	17.14	49.78
148.39	95.29	34.35	37.29	53.96	19.46	31.05	15.53	44.11
149.46	93.42	36.49	36.89	52.2	22.42	33.71	16.86	44.76
141.52	93.06	35.79	37.55	51.08	22.84	33.05	16.52	45.25
148.42	95.39	35.33	35.85	53.03	22.08	32.94	16.47	44.6
143.8	98.31	39.44	39.33	53.43	26.84	36.07	18.04	46.26
163.11	104.83	40.96	40.6	60.59	24.08	36.51	18.26	52.06
139.77	87.85	35.11	32.04	52.17	18.54	31.84	15.92	45.1
149.51	96.49	34.24	36.65	55.35	22.5	31.31	15.66	46.25
168.66	108.96	44.16	43.12	63.15	25.76	36.23	18.11	52.15
146.6	95.85	36.32	36.61	53.13	22.43	31.45	15.73	44.75
146.95	93.36	37.54	34.15	54.1	20.88	32.72	16.36	45.57
156.83	106.67	43.87	41.42	58.96	26.67	36.11	18.06	50.13
148.21	94.99	35.09	35.54	53.5	22.14	31.52	15.76	45.16

11.67	46.8	14.04	2.73	4.94
11.82	50.05	15.01	2.66	4.97
12.23	52.04	15.61	2.74	5.01
13.35	56.28	16.88	3.17	5.7
12.37	52.26	15.68	2.85	5.14
13.56	59.14	17.74	4.23	7.27
13.7	55.38	16.61	3.65	6.53
12.38	49.85	14.96	2.65	5.15
11.94	49.05	14.71	2.41	4.57
12.61	52.62	15.79	3.1	5.61
14.03	57.36	17.21	3.59	6.33
14.3	59.92	17.98	3.76	6.68
12.02	49.68	14.9	3.12	5.53
13.8	56.01	16.8	3.75	6.59
14.9	58.15	17.45	4.59	7.63
13.99	57.98	17.39	2.94	5.74
12.49	51.42	15.43	2.88	5.2
12.07	49.92	14.98	2.77	5.08
12.07	50.16	15.05	2.55	4.81
13.74	55.6	16.68	3.55	6.03
14.1	57.98	17.39	3.7	6.49
12.64	50.42	15.13	2.7	5.05
13.99	54.95	16.49	3.63	6.38
12.17	50.15	15.04	2.88	5.01
18.82	83.37	25.01	5.44	9.99
21.35	84.77	25.43	6.92	12.3
19.86	83.75	25.13	5.47	10.42
22.36	96.13	28.84	6.81	10.22
19.72	86.95	26.09	5.02	8.42
25.23	107.51	32.25	5.96	9.58
24.55	104.56	31.37	8.1	12.01
21.35	89.26	26.78	5.74	9.47
25.44	105.82	31.75	8.29	12.84
25.3	103.16	30.95	8.98	14.02
22.07	95.7	28.71	7	10.98
25.02	97.13	29.14	7.9	12.45
24.89	108.53	32.56	8	12.29
22.06	93.86	28.16	6.18	9.63
22.38	97.32	29.2	6.72	10.75
22.63	94.42	28.33	7.27	11.06
22.3	95.03	28.51	6.66	10.36
23.13	91.82	27.55	9.26	13.55
26.03	105.87	31.76	7.91	12.31
22.55	92.59	27.78	6.14	9.77
23.13	94.57	28.37	6.85	10.62
26.08	105.61	31.68	8.64	13.37
22.38	94.39	28.32	6.88	10.52
22.79	97.15	29.15	6.54	10.3
25.07	107.81	32.34	8.54	12.56
22.58	91.01	27.3	6.88	10.73

3	11	1	1	3.14	419052.6	391782	336.12	1120.41
3	11	1	1	3.14	374645.9	273190.3	263.48	878.27
3	11	1	2	3.14	505113.8	486813	316.07	1053.56
3	11	1	2	3.14	465589.7	362391	309.09	1030.3
3	11	1	2	3.14	613419.2	481005.4	427.14	1423.8
3	11	1	2	3.14	505528.3	476125.7	389.37	1297.89
3	11	1	2	3.14	514305	446383.6	387.09	1290.29
3	11	1	1	3.14	391128	343806.1	296.04	986.79
3	11	1	1	3.14	380507.4	411096	324.51	1081.71
3	11	1	1	3.14	366862.6	309679.9	277.91	926.37
3	11	1	1	3.14	365170.1	311850	255.65	852.18
3	11	1	1	3.14	344762.7	311391	250.9	836.35
3	11	1	1	3.14	378560.9	310607.7	268.75	895.83
3	11	1	1	3.14	366482.1	338321.6	283.16	943.85
3	11	1	1	3.14	340058.3	303276.1	240.6	801.99
3	11	1	1	3.14	310851.2	293872.1	241.89	806.29
1	1	2	2	3.14	362138.4	305430.8	270.8	902.67
Black Bear=43.0%	Area 6&7							
4	12	6	1	3.14	909030.9	1119755	769.68	2565.61
4	12	6	1	3.14	552495.1	537999.2	401.68	1338.94
4	12	6	2	3.14	1167590	1482030	1111.25	3704.17
4	12	6	2	3.14	1740775	1960929	1549.84	5166.15
4	12	6	1	3.14	570648.6	702738.4	454.55	1515.16
4	12	6	1	3.14	799599.9	988794.6	716.59	2388.65
4	12	6	1	3.14	948150	1039487	789.22	2630.72
4	12	6	2	3.14	1415963	1575251	1197.95	3993.17
4	12	6	2	3.14	1673911	1834313	1444.86	4816.21
4	12	6	1	3.14	1264895	1383562	1047.64	3492.15
4	12	6	2	3.14	1575076	1708992	1407.78	4692.59
4	12	6	1	3.14	843770	805101.5	643.4	2144.68
4	12	6	1	3.14	623190.1	707804.3	506.86	1689.54
4	12	6	2	3.14	1064350	1401677	966.88	3222.93
4	12	6	1	3.14	704277.1	907949.1	610.99	2036.63
4	12	6	2	3.14	1119819	1426470	1002.92	3343.08
4	12	6	1	3.14	589100.4	484443	387.51	1291.7
4	12	6	2	3.14	844800.8	987553.1	722.53	2408.43
4	12	6	2	3.14	1408850	1954882	1484.27	4947.58
4	12	6	1	3.14	561275.6	588073.8	422.49	1408.29
4	12	6	2	3.14	674162.3	663413.3	488.82	1629.4
4	12	6	2	3.14	629911.6	729571.9	532.23	1774.1
4	12	6	2	3.14	1150326	878526	750.3	2501.01
4	12	7	1	3.14	696130.3	714454.7	517.93	1726.42
4	12	7	2	3.14	718158.2	711311.8	515.04	1716.8
4	12	7	2	3.14	922977.7	1028866	790.43	2634.77
4	12	7	1	3.14	979928.4	969651.6	784.2	2614.01
4	12	7	2	3.14	1898111	2213190	1703.68	5678.94
4	12	7	2	3.14	902090.9	960736.1	699.8	2332.68
4	12	7	2	3.14	1618711	1690382	1256.99	4189.98
4	12	7	1	3.14	1059983	1016345	802.26	2674.19
Racoon= 65.8%	Area 6							
5	13	6	2	3.14	214530	155600	142.96	476.53
5	13	6	1	3.14	217005.7	155294.2	140.32	467.72

152.21	97.58	36.73	38.03	56.78	23	32.84	16.42	47.03
140.76	85.71	35.65	35.03	48.88	18.63	33.2	16.6	40.78
164	110.43	37.93	44.39	61.7	26.3	38.89	19.45	27.08
159.3	100.61	39.41	39.38	56.5	21.38	31.23	15.62	49.1
171.92	109.19	44.47	45.98	61.81	25.94	34.96	17.48	52.13
167.02	106.16	41.14	40.96	62.83	25.26	35.97	17.99	51.92
166.37	105.61	41.25	41.56	62.44	23.83	36.18	18.09	53
142.21	93.82	34.4	37.9	50.22	22.82	32.33	16.17	42.36
151.41	97.61	35.35	35.88	56	24.47	32.5	16.25	46.22
150.42	92.89	35.13	34.81	53.68	19.23	33.67	16.84	46.04
151.19	93.49	35.17	34.61	55.44	18.75	31.48	15.74	45.47
147.97	94.02	33.87	33.93	54.63	19	30.12	15.06	45.35
149.3	93.34	35.92	35.13	54.55	18.98	32.04	16.02	44.61
148.52	96.55	35.45	34.46	53.83	20.95	32.41	16.2	44.72
141.92	92.46	34.91	32.47	52.19	19.37	32.04	16.02	40.44
139.72	86.25	32.03	32.35	54.15	18.09	31.14	15.57	42.91
131.04	85.52	35.04	34.45	41.88	24.31	35.19	17.6	37.15

249.06	152.94	59.73	50.73	92.07	40.54	61.48	30.74	72.62
218.45	121.35	48.49	37.98	72.87	24.61	52.33	26.17	57.88
283.51	173.35	66.1	58.88	98.33	50.24	74.16	37.08	82.03
314.87	194.58	78.53	73.89	110.45	59.18	80.1	40.05	91.17
226.16	120.81	47.4	40.13	77.08	30.39	51.28	25.64	58.5
227.04	146.25	53.51	49.81	82.01	40.19	56.87	28.44	67.27
262.55	143.92	63.21	50	86.95	39.85	63.48	31.74	69.68
290.66	176.38	73.29	64.4	103.71	50.63	69.32	34.66	83.17
302.58	185.11	82.54	67.6	104.43	58.55	75.6	37.8	90.47
278.04	167.79	68.06	61.95	102.01	45.21	69.01	34.51	79.37
305.36	188.89	74.44	70.53	110.55	51.53	76.27	38.14	92.94
238.81	136.28	61.45	45.77	77.72	34.53	61.54	30.77	66.95
237.05	132.27	50.14	41.43	74.17	31.81	55.1	27.55	64.66
277.95	162.68	64.6	54.92	92.63	50.44	66.92	33.46	81.02
246.92	136.71	53.98	43.49	79.54	38.05	60.42	30.21	64.47
273.49	172.12	68.29	54.66	92.06	51.65	69.32	34.66	74.33
224.74	120.41	48.2	40.74	64.67	24.97	52.36	26.18	60.97
250.04	140.2	58.23	48.36	83.89	39.24	61.37	30.69	68.55
299.61	188.23	73.55	63.85	102.2	63.76	74.95	37.48	92.69
217.06	120.28	49.17	38.05	74.79	26.21	54.49	27.25	58.35
229.75	123.51	50.59	44.42	75.81	29.17	55.1	27.55	60.61
226.04	129.24	47.58	44.13	74.69	32.56	55.99	28	65.71
245.95	142.5	59.81	64.11	86.13	34	63.02	31.51	68.35
232.78	129.93	54.33	42.71	76.65	31.07	56.76	28.38	61.8
239.02	128.54	57.16	41.88	77.79	30.48	57.85	28.93	61.21
260.41	156.7	58.68	52.43	83.04	41.3	62.46	31.23	74.08
266.91	142.19	67.1	48.68	83.67	38.63	65.9	32.95	73.97
308.14	210.68	78.47	80.63	113.34	65.09	76.23	38.12	91.42
260.65	145.22	62.96	47.76	85.65	37.39	63.94	31.97	71.52
303.28	186.43	76.6	70.44	102.28	55.09	70.6	35.3	79.54
264.75	148.62	70.3	50.26	87.79	38.59	65.37	32.69	75.32

115.35	65.62	30.81	23.21	38.62	13.43	28.96	14.48	33.83
117.61	70.41	30.19	23.96	40.19	12.88	29.12	14.56	34.8

23.52	95.76	28.73	7.36	11.48
20.39	89.49	26.85	6.24	10.25
13.54	103.86	31.16	6.42	9.54
24.55	104.61	31.38	6.47	10.24
26.07	108.91	32.67	8.28	13.04
25.96	110.19	33.06	7.77	12.23
26.5	109.19	32.76	7.76	12.22
21.18	91.91	27.57	6.94	10.52
23.11	96.66	29	7.14	11.08
23.02	95.75	28.73	6.16	9.97
22.74	100.43	30.13	5.64	9.12
22.68	97.67	29.3	5.65	8.9
22.31	96.69	29.01	6	9.6
22.36	95.38	28.61	6.36	9.78
20.22	96.26	28.88	5.65	8.67
21.46	92.15	27.65	5.77	9.35
18.58	88.96	26.69	6.89	10.56

36.31	178.26	53.48	10.3	16.78
28.94	149.5	44.85	6.13	11.03
41.02	187.32	56.2	13.07	21.37
45.59	205.32	61.6	16.41	26.55
29.25	154.82	46.45	6.7	12.54
33.64	156.28	46.88	10.52	16.33
34.84	168.04	50.41	10.02	18.28
41.59	191.3	57.39	13.74	22.64
45.24	202.44	60.73	15.92	26.02
39.69	188.14	56.44	12.56	20.81
46.47	198.16	59.45	15.37	24.84
33.48	164.48	49.34	8.98	15.74
32.33	158.04	47.41	7.13	12.77
40.51	191.12	57.34	11.6	19.81
32.24	165.45	49.64	8.25	14.9
37.17	183.12	54.94	12.22	19.42
30.49	155.82	46.75	5.75	10.73
34.28	165.45	49.64	9.63	17.18
46.35	193.22	57.97	16.51	26.28
29.18	153.61	46.08	6.49	11.71
30.31	158.25	47.48	7.09	13.19
32.85	156.34	46.9	7.85	13.73
34.17	176.65	53	10.17	17.55
30.9	161.54	48.46	7.42	13.29
30.61	165.2	49.56	7.18	13.36
37.04	169.36	50.81	10.12	16.81
36.99	173.81	52.14	9.79	18.38
45.71	203.69	61.11	18.43	26.96
35.76	180.61	54.18	8.95	16.06
39.77	197.88	59.36	13.82	22.47
37.66	181.79	54.54	10.1	17.99

16.92	80.28	24.08	4.13	7.26
17.4	83.55	25.07	3.98	6.64

5	13	6	1	3.14	245350.1	172490	159.89	532.96
5	13	6	1	3.14	232160.3	164241.2	163.3	544.34
5	13	6	1	3.14	185989	131308.6	122.15	407.18
5	13	6	2	3.14	251570.6	172716.6	168.47	561.58
5	13	6	1	3.14	213147.5	157193.6	149.97	499.9
5	13	6	2	3.14	174222.7	110507	107.29	357.64
5	13	6	1	3.14	191995.9	136694.3	121.64	405.46
5	13	6	2	3.14	155508.4	106095.8	100.44	334.8
5	13	6	1	3.14	132068.6	76079.52	74.65	248.84
5	13	6	2	3.14	325620	224789.9	223.91	746.36
5	13	6	2	3.14	267647.1	250996.5	203.29	677.64
5	13	6	1	3.14	205162.9	121888	122.03	406.77
5	13	6	1	3.14	172819.5	98098.74	100.44	334.79
5	13	6	2	3.14	293219.9	263293.4	224.21	747.36
5	13	6	2	3.14	165478.9	120178.4	107.8	359.32
5	13	6	2	3.14	207332.6	100723.7	115.35	384.51
5	13	6	2	3.14	177869.4	118581.8	112.33	374.42
5	13	6	2	3.14	284433.8	240093.7	218.62	728.73
5	13	6	2	3.14	139943.2	108720.5	97.06	323.55
5	13	6	1	3.14	196910.6	134345.8	128.2	427.35
5	13	6	2	3.14	217127	185672.3	168.37	561.24
5	13	6	1	3.14	145644.7	97198.29	86.43	288.08
5	13	6	2	3.14	227469.2	183215.4	167.85	559.51

110.85	73.39	31.12	26.28	39.14	14.69	29.26	14.63	33.24
113.61	72.29	29.81	25.96	43.21	12.67	28.99	14.5	37.44
109.02	64.89	27.12	22.86	39.22	11.16	28.11	14.06	32.7
117.28	69.67	32.68	25.66	41.3	13.94	31.04	15.52	35.76
110.34	66.63	29.79	23.85	38.67	13.55	29.64	14.82	34.54
108.17	60.58	27.84	20.86	34.62	10.64	26.55	13.28	31.26
104.17	66.76	27.55	23.23	36.22	12.58	26.71	13.36	30.95
110.05	60.62	25.97	19.96	36.61	9.66	25.61	12.81	30.54
103.23	56.53	24.43	18.02	32.02	7.92	23.32	11.66	30.04
116.63	81.12	32.4	33.5	43.87	17.08	31.67	15.84	38.99
115.32	75.34	32.62	27.35	48.25	17.34	31.51	15.76	37.44
111.4	63.79	27.02	25.31	40.67	9.99	27.49	13.75	31.87
108.77	63.12	27.25	21.14	39.54	8.27	27.33	13.67	31.17
122.01	80.3	33.53	29.15	45.83	19.15	32.13	16.07	40.27
111.13	62.52	28.94	19.06	40.18	9.97	27.6	13.8	34.13
112.41	64.86	29.21	23.66	37.14	9.04	28.43	14.22	32.64
106.31	63.38	26.05	22.76	37.08	10.66	26.58	13.29	31.78
116.87	78.05	32.75	28.95	43.59	18.36	31.23	15.62	39.18
105.37	61.56	24.22	19.26	38.39	9.44	25.78	12.89	33.9
110.28	68.2	28.11	23.35	40.49	11.06	26.98	13.49	34.46
112.3	74.1	28.02	25.83	42.42	14.59	28.92	14.46	35.19
106.17	59.77	23.59	20.58	37.63	8.61	24.61	12.31	30.38
115.42	69.36	28.01	27.07	41.83	14.6	28.4	14.2	35.21

16.62	80.76	24.23	4.81	7.26
18.72	78.87	23.66	4.79	7.53
16.35	77.95	23.39	3.73	6.27
17.88	83.01	24.9	4.79	8.06
17.27	78.33	23.5	4.53	7.5
15.63	75.31	22.59	3.31	5.9
15.48	76.94	23.08	3.89	6.07
15.27	71.91	21.57	3.04	5.52
15.02	71.87	21.56	2.41	4.4
19.5	85.2	25.56	6.4	9.2
18.72	87.71	26.31	5.88	8.99
15.94	78.05	23.42	3.65	6.38
15.59	77.47	23.24	3.08	5.3
20.14	89.31	26.79	6.13	9.31
17.07	80.42	24.13	3.23	5.75
16.32	79.6	23.88	3.42	5.93
15.89	75.64	22.69	3.52	5.91
19.59	83.66	25.1	6.24	9.34
16.95	75.14	22.54	3.07	5.26
17.23	77.55	23.26	3.88	6.27
17.6	76.1	22.83	5	7.57
15.19	75.64	22.69	2.71	4.82
17.61	76.92	23.08	4.85	8.07