

# **DIETARY VARIATION AMONG THE PREHISTORIC ASIATIC ESKIMO**

by

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## **ABSTRACT**

Prehistoric Asiatic Eskimo cultures flourished along the Chukotka coast of Northeast Asia, concentrated within the Bering Strait region. One such site is Ekwen, a village occupied between about two to one thousand years ago. Archaeological research on this and other Asiatic Eskimo sites indicates that the people were dependent upon marine resources, especially sea mammals such as walrus. We can test these archaeological conclusions with stable isotope analysis on the human remains found in the village cemetery at Ekwen. Further, dietary differences within the population can be examined with isotopic analyses. To conduct this study, stable carbon and nitrogen isotopic measurements were obtained for 19 faunal samples and 74 prehistoric Asiatic Eskimo individuals from the site. Both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  averages from the human dataset are unexpectedly heavy. The average  $\delta^{13}\text{C}$  of  $-11.81 \pm 0.38\text{‰}$  (for adults) indicates that this population was dependent upon marine protein, precluding terrestrial species such as reindeer from having been significant dietary sources. The heavy  $\delta^{13}\text{C}$  average may represent the end point value for populations exclusively sampling from the marine food chain in the North Pacific. The  $\delta^{15}\text{N}$  results point to a diet composed mostly of higher trophic level marine species like ringed seal, with a lesser amount of lower trophic level marine species such as walrus. Within the population, lactating infants have distinct isotopic values as a result of their milk diet. Otherwise, no significant dietary differences can be shown between other age groups or between adult males and females. Finally, some dietary changes appear to have occurred between the Old Bering Sea culture and later cultural periods.

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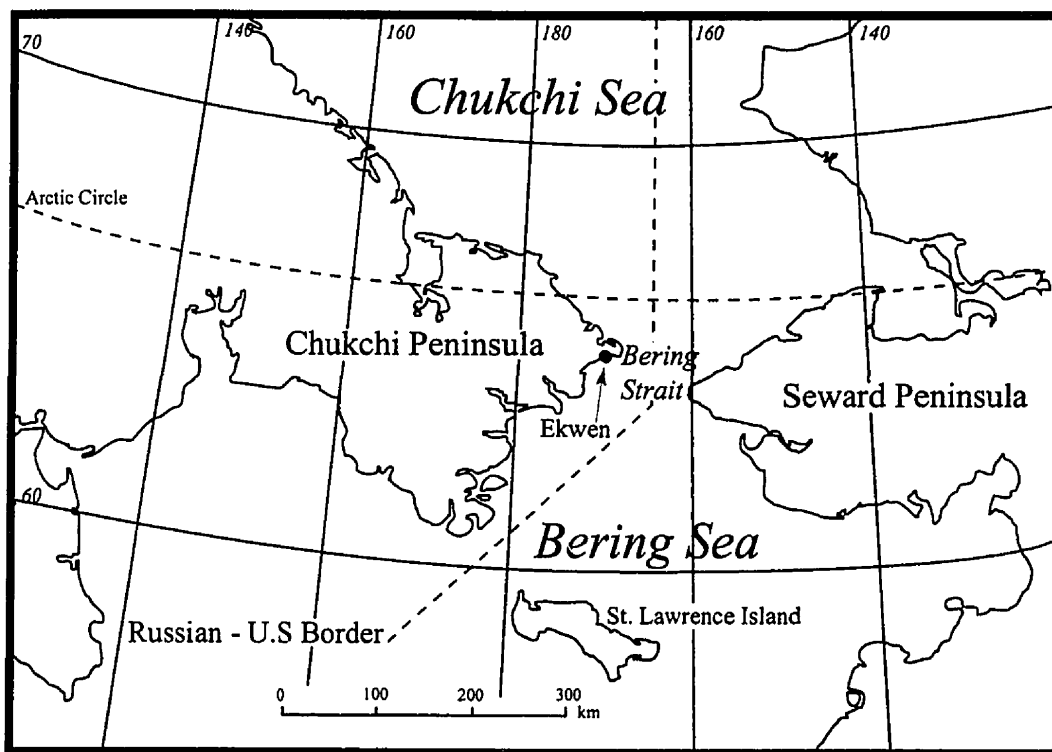
## **Chapter 1: Introduction**

For thousands of years, Eskimo groups have inhabited the Arctic, from Chukotka in Northeast Asia, through North America, to Greenland (*cf.* McGhee 1996). During this time and despite the hostile environment, Arctic groups not only survived, but flourished. This research focuses upon the isotopic examination of diet for a group of Asiatic Eskimos at Ekwen, a prehistoric coastal village located on the Chukchi Peninsula along the Bering Strait (Figure 1). Through stable carbon and nitrogen isotope analyses of faunal samples and 74 humans from the Ekwen cemetery, this study provides information on the isotopic method itself and on the diets of this group of people.

Stable carbon and nitrogen isotope analyses are excellent methods for studying diet (for a review, see van der Merwe 1980; Schoeninger and Moore 1992). By examining human tissues, information is obtained directly for that individual. In this study, bone collagen was measured which provides information on the sources of dietary protein. In circumstances such as this, it is possible to use stable carbon and nitrogen isotope analyses to distinguish marine and terrestrial sources of protein, and to identify the trophic level of food species.

In the Bering Strait region, the source of most human dietary protein is marine species, especially the abundant sea mammals. In contrast, the terrestrial environment provides only a limited amount of plant foods and few animal species. Indeed, archaeological studies of hunting artifacts, social organisation, faunal remains, as well as ethnographic works (for a review, see Ackerman 1984 and Krupnik 1993b) indicate that prehistoric Asiatic Eskimo groups based their food economies upon marine resources, as

Figure 1 Map of the Bering Strait region including the location of the Ekwen site



do their modern descendants. While this primary dependence on marine animals did not change, available information indicates that the principal resource for each cultural period has alternated between walrus, seal, and whale. It is thought that during some periods, there also was a greater emphasis on terrestrial resources.

Given the environmental and cultural information, we can expect isotopic measurements to reflect a primary dependence upon marine protein with perhaps a small amount of terrestrial protein. Further, the nitrogen isotope analysis should provide information on the trophic level of the species consumed because species of successive

trophic levels tend to have heavier nitrogen values. A cursory examination of this trophic level enrichment and of isotopic differences between marine and terrestrial species is obtained through analysis of 19 faunal samples measured in this study. Faunal results also can be compared to human measurements to better identify which species, or types of species were important to human diet.

While we expect human diet to be marine-based, this does not preclude the possibility that small dietary differences existed between segments of the population as predicated by ethnography. Isotopic data can identify potential dietary variation within this population if certain groups consistently consumed more terrestrial protein, or consumed protein from different trophic levels of the marine food chain.

To test for dietary differences, comparisons are made between age groups, and between males and females. Also, individuals from different cultural periods are examined. There are few dated individuals from the later cultural periods, making difficult the task of identifying dietary changes over time. However, this preliminary comparison may gauge the potential utility of isotopic analyses in addressing this question.

In this thesis, an overview of the Asiatic Eskimo is presented in Chapter 2, including information on pan-Arctic trends in subsistence and exploitation patterns, on their diet requirements, and on the Ekwen site itself. Chapter 3 reviews the applicability and limitations of both stable carbon and nitrogen isotopic analyses. The selection and sampling of Ekwen materials are described in Chapter 4, and the results are presented in Chapter 5. Discussion of results addresses both methodological and archaeological research questions.

## **Chapter 2: Archaeological Background**

### **2.1 Asiatic Eskimo Cultures**

The origins of the Asiatic Eskimo are not established, as Paleo-Eskimo sites are absent in the Bering region. The earliest Eskimo sites found on the Chukotka coast date to the Neo-Eskimo Stage, a period that began in the last few centuries BC (Ackerman 1984). The following is a synopsis of the culture sequence based on review of relevant literature (Dikov 1977; Krupnik 1993b; Rudenko 1961; Arutiunov and Sergeev 1968, 1975; Collins 1937; Rainey 1941; Alekseev *et al.* 1972; Ackerman 1962, 1984; Arutiunov and Fitzhugh 1988; Rousselot *et al.* 1988; Ford 1959; Giddings and Anderson 1986; Mason 1998). This sequence is summarised in Table 2.1.

The oldest known cultures, the Old Bering Sea (OBS) and Okvik cultures are closely related and roughly contemporaneous, dating from the last few centuries BC to the first few centuries AD (Ackerman 1984; Krupnik 1993b). The Old Bering Sea culture, which is divided into three periods (OBS I, II, III) based on artifact typology (Rudenko 1961), is generally considered to predate Okvik (Arutiunov and Sergeev 1968). The territories of both cultures are concentrated within the Bering Strait region (see Ackerman 1984:107, Figure 1). These groups were well-positioned to focus upon marine resources and in particular the abundant walrus stock, although a wide range of resources was exploited, including whales and seals (Collins 1937; Rainey 1941; Arutiunov and Sergeev 1968; Ackerman 1984; Arutiunov and Fitzhugh 1988; Rousselot *et al.* 1988).

The Birnirk and Punuk cultures follow, with Birnirk preceding the latter by a few centuries (Arutiunov and Sergeev 1969). Birnirk dates from AD 300 to AD 900 while Punuk spans the period AD 600 to 1200. Sealing was the primary focus of Birnirk economy, but also more terrestrial hunting occurred than in preceding periods. The territories occupied by the Birnirk and Punuk people overlapped in the Bering region (Ackerman 1962). Birnirk settlements stretched northwards along the Bering Strait to the Kolyma River, while Punuk territory extended southwards (Collins 1937; Rainey 1941; Ford 1959; Rudenko 1961; Ackerman 1962; Arutiunov and Sergeev 1969, 1975; Ackerman 1984; Mason 1998). The more southerly climate suited the large scale whaling practised by the Punuk (Rudenko 1961; Arutiunov and Sergeev 1968; Krupnik 1993b).

Table 2 Archaeological Culture Sequence of the Neo-Eskimo Stage

Culture	Date	Region	Economic Focus
Old Bering Sea (OBS)	200 BC - AD 500	Northeastern Siberia, St. Lawrence Island, Diomede Islands, Point Barrow	walrus
Okvik	100 BC - AD 500	Chukchi Peninsula, St. Lawrence Island, Diomede Islands, Punuk Islands	walrus
Birnirk	AD 300-900	Western Alaska, St. Lawrence Island, Northeastern Siberia along the Bering Strait coast north to Kolyma River	seals and wild reindeer
Punuk	AD 600-1200	St. Lawrence Island, Punuk Island, Diomede Islands, Chukchi Peninsula from the Bering Strait region and south, Point Hope	large whales
Western Thule	AD 800-1500	all previous regions (except Punuk dominated areas <i>i.e.</i> , St. Lawrence Island)	seals, walrus, whales
Late Prehistoric	AD 1600-1800	eastern reaches of Northeastern Siberia along the coast, islands	seals, walrus, whales

Western Thule is believed to have developed from Birnirk by approximately AD 800 and continued until AD 1500 (Collins 1937; Ford 1959; Giddings and Anderson 1986). Along the Chukchi Peninsula and nearby islands, Thule artifacts are intermingled with Birnirk and Punuk objects, indicating that preceding cultures were not simply replaced. For example, while whaling harpoons in Western Thule sites were unique innovations, the harpoons for walrus and seals remained Birnirk and Punuk in form (Ackerman 1984). On St. Lawrence Island, Punuk gradually developed into the culture of the late prehistoric-protolithic period (Collins 1937). In Northeast Asia, the Western Thule culture with Birnirk and Punuk features continued with little change until the historic period (Krupnik 1993b). Thule culture subsequently spread throughout the North American Arctic and Greenland, replacing previous cultures.

To the west of the Asiatic Eskimos, Chukchi tribes have long occupied the inland regions of the Chukchi Peninsula. In the late prehistoric and protohistoric periods (the sixteenth to seventeenth centuries AD), part of the Chukchi population moved to the coast, splitting the population into Maritime Chukchi and interior Reindeer Chukchi. This expansion pushed the Eskimo as far as the eastern reaches of Chukotka. By the nineteenth century, the Maritime Chukchi had taken over several Eskimo villages (Arutiunov and Sergeev 1968; Alekseev *et al.* 1972). The degree to which assimilation occurred is questionable, as early twentieth century censuses (in Krupnik 1993b) indicate that the communities of the Chukchi coast distinguished themselves as Chukchi or Eskimo, with the latter representing only a quarter of the coastal population.

## 2.2 Subsistence

All cultures from Old Bering Sea through to the Late Historic appear to have been largely sedentary, occupying clan-based villages from which they hunted sea mammals (Rainey 1941; Rudenko 1961; Fitzhugh 1988; Krupnik 1988; Gurvich 1994). This strategy focused upon the procurement of abundant local and migratory marine species of the Bering Strait. Migratory species included walrus (*Odobenus divergens*), bearded seal (*Erignathus barbatus*), bowhead (*Balaena mysticetus*), gray (*Eschrichtius robustus*), humpback (*Megaptera novaeangliae*), and beluga (*Delphinaptera leucas*) whales and sea birds. Ringed seal (*Phoca hispida*) populations were year-round residents (Freeman 1984). With these reliable food resources, sedentism was the optimal strategy (Eidlitz 1967).

The historic Asiatic Eskimo practised a subsistence cycle that reflects these ancient roots. Krupnik (1993b) describes how the year was divided into four seasons based on the exploitation of different food resources. The spring and autumn hunting seasons were most important, yielding ten times the quantity of food obtained during summer and winter. Spring, lasting from April until June, was very important because of the migrating sea mammals. In April and May, bearded seals migrated north, while walrus and whales passed through the Bering region from April to June. These large animals were hunted along the open coast. Migratory birds also appeared in coastal environments during the spring. Summer spanned July and August during which time intensive fishing, bird hunting, and egg and plant collecting occurred, most of which was performed by women. Male hunters occasionally traveled to open waters to hunt pinnipeds. In autumn the same migratory species now traveled through the Bering region and large scale boat hunts were organised. Walrus were hunted during September and



October, and the bowhead whale in October and November. Finally, winter lasted from December to early April, during which time seals were taken from their breathing holes. Fishing was also a year round activity.

In general, historic Asiatic Eskimo diet did not include significant quantities of terrestrial protein resources. In the tundra environment, the surface cover of vegetation is limited, therefore grazing animals would not be abundant (Freeman 1984). In historic times, the reindeer was virtually absent along the Chukchi coast (Bogoras 1904; Freeman 1984; Arutiunov and Fitzhugh 1988) and thus, the Eskimos needed to hunt further inland into the region occupied by the Chukchi tribes to find wild reindeer (Arutiunov 1988). Of interest, island populations existed without direct access to indigenous reindeer populations although reindeer antler has been found in sites (Rainey 1941). Instead, frequent trade with the Reindeer Chukchi supplied the Eskimo with terrestrial meat, hide, and antler (Bogoras 1904; Krupnik 1993b).

### **2.3 Ekwen**

The Ekwen site was an Asiatic Eskimo village, located on the southern coast of Cape Deznhev (or East Cape) on the Chukchi Peninsula (Figure 1). Its inhabitants were in a good position to exploit migrating marine species traversing the narrow Bering Strait, as well as species available year round. The location must have been advantageous, for this village was occupied for at least a thousand years, spanning the time from the Old Bering Sea through to Puduk culture (Arutiunov 1991, pers. comm. in Fedoseeva 1991).

While a site description is not available, historic coastal villages of the Chukchi Peninsula tend to follow a typical form as described by Krupnik (1993b). The

mountainous terrain of the peninsula produces many fjord-like bays, where freshwater streams or lagoons lie close to the sea. These locations allow access to both marine resources, birds, and anadromous fish stocks. Semi-subterranean houses were usually located on low terraces above the beach, where boats were launched and hauled out. Sea-mammal hunting occurred within sight of the village. Ethnographic studies have described that fish, bird, egg, and plant resources could be obtained within a 400 m radius of the houses (Krupnik 1993b:41).

In historic times, the territories of coastal villages extended only about 2 km inland. These borders were not strictly defined or guarded because the economies of maritime populations and inland Reindeer Chukchi were so different that competition did not exist (Krupnik 1993b). Instead, marine and inland groups traded, an activity which also likely occurred prehistorically (Bogoras 1904). Conversely, the sea-shore boundaries between the various coastal groups were more rigid and recognised. Promontories formed natural boundaries between coastal settlements (which may have been part of larger communities) spaced about 8 - 12 km apart (Krupnik 1993b:41).

Historic records indicate that abundant marine resources supported relatively dense human populations. Based on early censuses, the average population density for the coastline was 1.2 to 1.4 individuals/km<sup>2</sup> as compared to only 0.025 individuals/km<sup>2</sup> for the entire Chukchi Peninsula. Before the Chukchi and Eskimos were relocated under Russian rule, 30-40 sedentary Eskimo settlements dotted the south-western Chukchi coast (Krupnik 1993b:40). Occupation of villages was year-round, as the skin tents from the semi-subterranean winter houses were removed and pitched closer to the shore during the summer. Permanent cemeteries were located further uphill past the houses.

This degree of sedentism may have been greater in the historic period than in the prehistoric (Krupnik 1993b). However, available information on Ekwen suggests that it

was a 'typical' coastal Eskimo village. The habitation area of Ekwen lies close to the water's edge while further inland lies the cemetery which consists of two parts, the eastern and western hill (Bronshtain and Dneprovsky 1996, pers. comm.).

#### **2.4 Dietary Resources**

Both archaeological and ethnographic data provide information on the prehistoric diet of the Asiatic Eskimo. The ethnographic data are especially valuable since they describe both what and how resources were utilised for food by Arctic groups in general and specifically by the population studied here. A drawback is that ethnographic accounts may not necessarily pertain to prehistoric populations. However, after examination of archaeological and historic data of Eskimo groups across the Arctic, Krupnik (1993b) contends that the Asiatic Eskimo culture has changed the least from pre-contact times. The Asiatic Eskimos also were not as extensively documented as other groups, such as the Chukchi. However, information from Chukchi accounts are useful since the Maritime Chukchi occupied the same region as the Asiatic Eskimo, and practised similar subsistence strategies.

Subsistence related data also are provided by archaeological faunal analyses and artifact analyses of hunting technology. While these data exist for many Eskimo sites along the Chukotka coast (see Rudenko 1961 for description), detailed information from Ekwen was not available.

## 2.5 Marine Resources

### Walrus

The Asiatic Eskimo have been termed "walrus people" because of their dependence upon these large pinnipeds (*Odobenus divergens*), a reliance which seems to date to the beginning of the Neo-Eskimo phase (Krupnik 1993b). Krupnik (1993b:72, Figure 8) calculates that walrus usually provided most meat and fat in historic diets. However, because hunting larger animals like walrus was prestigious, ethnographies may over-emphasise the importance of this resource.

Walrus was also the favoured food for the inhabitants of St. Lawrence Island (Hughes 1960). This opinion was not universally held, as some people, such as the North Alaskan (Spencer 1959:33) and Southampton Island groups (Freeman 1969-1970) fed most of the meat to dogs. The Asiatic Eskimos both consumed walrus and fed more undesirable "waste" portions to their dogs (Krupnik 1993b:61).

Walrus also was important as a non-food resource. Ivory was used for the runners of sleds, and skins for water crafts (Rainey 1941; Rudenko 1961). Harpoon points were fashioned almost exclusively from ivory (Rainey 1941; Rudenko 1961). Furthermore, typological analysis of numerous harpoon heads from the Uelen and Ekwen cemeteries indicates that many were designed for hunting walrus (Arutiunov and Sergeev 1975).

### Whales

Whale species exploited include the bowhead (*Balaena mysticetus*), beluga (*Delphinaptera leucas*), gray (*Eschrichtius robustus*), humpback (*Megaptera novaeangliae*) and narwhal (*Monodon monoceros*). Bowhead whales are more commonly associated with Eskimo sites while the gray and humpback whale remains are

more prevalent in Chukchi sites (Krupnik 1987). The capture of the different whale species was accorded varying degrees of prestige. The bowhead whale was considered the most prestigious game, while gray and humpback whales were far less valued. Even so, hunting these lesser whales was more prestigious than hunting walrus, polar bear, and even the beluga whale.

This ranking is reflected in Eskimo oral tradition which gives detailed descriptions on the butchering and distribution of whale portions (Krupnik 1987; Bogoras 1907). Ceremonies of thanksgiving were performed each time a whale was caught (Bogoras 1907). While historic records reveal that few whales were captured yearly (Krupnik 1993b:60), because of the animal's size, each catch provided large quantities of meat and fat.

Krupnik (1987; 1993a) has noted the frequent occurrence of suckling or young whale remains in archaeological sites on the Chukchi Peninsula, a pattern similarly observed in Alaskan and Canadian Thule sites (Giddings and Anderson 1986). Accounts from Asiatic Eskimo elders (Krupnik 1993b) confirm that suckling whales were targeted as adult whales were considered too dangerous and too large. This pattern of exploiting calves may extend back to the Old Bering Sea culture, since some Ekwen graves were lined with jaw bones and scapulae from immature whales (Krupnik 1993b; Mason 1998).

The importance of whale species varied between different periods. During the Old Bering Sea/Okvik cultures, whaling occurred, but on a small scale (Rudenko 1961). Whalebone was used as house beams although wood was the predominant building material (Rudenko 1961). While Birnirk culture is not generally associated with whaling, remains of gray whales are found in archaeological deposits. It was with the Punuk culture that whaling, especially of large bowheads, proliferated (Krupnik 1993b). During this period, the number of large whaling harpoons increased as did the use of whalebone

in building ritual sites, such as in the Whale Alley site, and houses in which whalebones largely replaced wooden beams (Rudenko 1961; Arutiunov *et al.* 1979 in Krupnik 1993b:191).

## Seals

According to Birket-Smith (1959), the most important resources for Eskimo cultures across the Arctic were undoubtedly the ringed (*Phoca hispida*) and the bearded (*Erignathus barbatus*) seals. Other researchers examining particular regions do not arrive at the same conclusion; the Bering Strait Eskimo of Alaska (Lantis 1946:173), the coast Chukchi (Bogoras 1904), and the Asiatic Eskimo (Krupnik 1993b) exploited these species, but apparently were not heavily dependent upon them as a food resource. While Leechman (1945:73) describes the Eskimo's craving for seal when deprived of it for too long, Mathiassen (1928:206) reports that seal meat was considered the poorest quality food which was left for the dogs when other food was available. The early twentieth century Asiatic Eskimos apparently did not favour seal meat, however, large numbers were caught every year (Krupnik 1993b:59).

The historic Asiatic Eskimos hunted more ringed seal than any other marine mammal. However, this small pinniped yields only a quarter the meat and blubber of larger bearded seals, and only about 6% that of walrus (Krupnik 1993b:61). Thus despite the thousands of small seals caught yearly by some historic Eskimo communities, these seals were only the second most important resource after walrus for meat and fat contribution (Krupnik 1993b:72, Figure 8).

This intense exploitation of the ringed seal extends into antiquity as 97% (NISP) of all sea mammal remains at Ekwen are of ringed seal (Savinesky 1996, pers. comm.). Also, harpoon points for hunting small sea mammals were very abundant among Uelen

and Ekwen cemetery grave inclusions (Arutiunov and Sergeev 1975). Despite this evidence, archaeological interpretations do not identify these pinnipeds as primary resources. Because of its small size and year-round availability, their importance may have been overlooked in ethnographies and archaeological reconstructions (Eidlitz 1967).

## Fish

Fish was a year-round resource which supplemented the sea mammal diet. Eskimo sites tend to be located near rivers and fish was an alternative resource when sea mammal hunts were unsuccessful, especially in winter (Krupnik 1993b:37). However, the Chukchi considered fish to be poor food (Bogoras 1904:193). Eidlitz (1967:29) suggests that the common low regard for fish is related to their year-round availability, which led them to be viewed as a reserve food especially for the poor. Fishing was not prestigious and was considered a lower status activity mostly for the elderly, young, and female (Rudenko 1961; Freeman 1988).

Other reasons may exist to account for the relative unimportance of fish to the Asiatic Eskimo. Salmon was the most important fish species to Arctic groups because their spawning pattern brought them to the shore and rivers where they could be harvested in abundance (Freeman 1988). However, the inhabitants of the Chukotka coast were too far north to exploit these large schools (Bogoras 1904:146) and thus large quantities could not be caught easily. Finally, because of the lower fat content and mass compared to sea mammals, fish were considered only as supplemental meat (Spencer 1959:36).

Shellfish was regarded as either a delicacy or emergency food for most Arctic groups (Eidlitz 1967). Mussels and crabs were considered emergency food by the Asiatic Eskimo (Menowstwachikow 1963:465 in Eidlitz 1967) although numerous mussel shells

have been found at Ekwen (Savinesky 1996, pers. comm.). The overall contribution of these resources to protein diet was insignificant.

### Seaweed

Seaweed was gathered by Chukchi women when animal resources became scarce, and children were observed to eat it when playing along the beach (Bogoras 1904:197). The prehistoric Eskimo also utilised this resource. In a Punuk site, a device for collecting seaweed in open water was found. Also, seaweed washes ashore in summer and could have been gathered on the beaches without the use of tools (Rudenko 1961:114).

Seaweed may have provided an valuable supplement of vitamins, including vitamin C, and minerals (Eidlitz 1967). However, since it contains only trace amounts of protein, it would not have contributed significantly to the protein portion of diet.

## **2.6 Terrestrial Resources**

### Reindeer

In historic times, reindeer (*Rangifer tarandus*) meat was very much desired by the Eskimo, and was obtained through trade with the Reindeer Chukchi (Bogoras 1904:193). In late August or early September, large scale trade occurred between coastal hunters and inland herders at well-known places (Krupnik 1993b). According to Eskimo tradition, trade with inland groups was common and existed prehistorically as well (Bogoras 1904). Reindeer antler found in the cemeteries of Ekwen and Uelen (Arutiunov and Sergeev 1975) confirms the antiquity of this trade.



## Birds and Eggs

Many ethnographies describe the exploitation of sea birds and eggs (Murdoch 1892; Collins 1937; Spencer 1959; Krupnik 1993b). Within the Bering region, migratory bird stocks were abundant and were regularly harvested by western Alaskan groups (Murdoch 1892; Spencer 1959). Birds also constituted an important dietary supplement to island populations. On St. Lawrence Island, bird meat was desired to add variety to diet (Collins 1937). Bird eggs also were used by all groups of this region (Murdoch 1892; Krupnik 1993b). The exploitation of birds and eggs was so intense that the size of bird colonies around the Bering Strait region have been severely depleted in historic times (Krupnik 1993b:78).

Bird and egg utilisation also existed prehistorically. Many bird darts and bolas have been found in Asiatic Eskimo sites on the Chukchi Peninsula (Rudenko 1961). Also, recent excavations at Ekwen have turned up numerous bird remains (Savinesky 1996, pers. comm.).

## Bear

Polar bear (*Ursus maritimus*) meat was highly valued by the historic Asiatic Eskimos, but was generally scarce. Bears found as far south as the Bering Strait region were tracked and hunted (Krupnik 1993b:78). When a polar bear was taken, the Asiatic Eskimo would perform a ceremony of thanksgiving similar to that performed after a successful whale hunt (Bogoras 1907:406-408). These elaborate rituals could last several days.

Although the polar bear is grouped among terrestrial *species* here, it may be best described as a terrestrial *inhabitant*. Isotopically, polar bears have marine signatures reflecting their diet of fish and sea mammals (Ramsay and Hobson 1991; Schell 1992).

## Other Species

Other terrestrial species utilised by the Asian Eskimo included hare, fox, and dogs. These were supplemental resources, considered poor or emergency food possibly because of their low fat content (Bogoras 1904, 1929; Spencer 1959). Historically, dogs were eaten as emergency food, but were occasionally consumed in times of plenty. Dog intestines and brains, which have higher fat content than the rest of the animal, were particularly favoured. This practice declined or was hidden in the historic era due to European distaste (Bogoras 1904:101). When food was abundant, selected parts may have been consumed while the bulk of the animal (flesh), might not have been eaten. Thus, dog meat was unlikely to have formed a regular or substantial part of diet.

Dogs, like the polar bears, might best be considered terrestrial inhabitants as they were probably fed marine species (Krupnik 1993b) and should have marine isotopic signatures.

## Plants

Although plant resources were regarded as emergency rations by most Eskimo groups, plants probably were consumed in greater quantities than reported (Eidlitz 1967). Among the Chukchi and Asiatic Eskimos, females and children consumed more plants than did adult males who consumed more meat and 'high status' foods (Bogoras 1904:198; Krupnik 1993b).

Bulbs and roots obtained by robbing the winter stores of rodents (Bogoras 1904; Hughes 1960) were consumed mixed with meat or oil (Bogoras 1904:198). Given this common eating practice, plant protein contribution was insignificant compared to that from meat, although plants may have been a significant source of vitamins (Eidlitz 1967) and carbohydrates.

Some Arctic populations have resorted to eating bark as an emergency food. The Chukchi consumed the inner bark of the willow (Bogoras 1904), but there is no record that the Asiatic Eskimo used this resource. Mosses and lichens usually were not eaten other than as medicine and seasoning, and mushrooms were avoided by most Arctic groups (*cf.* Eidlitz 1967:64-65). The exception is vegetation found in animal entrails and stomach. For many groups across the Arctic, reindeer guts and contents including lichens, mosses, and plants were prized as delicacies (Eidlitz 1967:51-52). In general, plant resources could not contribute large quantities of protein to human diet.

## **2.7 Dietary Requirements and Shortages**

Krupnik (1993b:53) estimates that the Asiatic Eskimo required over 1 kg of fatty sea mammal meat per person daily. According to the World Health Organisation, the recommended daily protein intake for moderately active adults is under 40 grams, an amount contained in about 160 g of meat. Clearly, the Eskimos were burning surplus protein for energy, however, carbohydrates or lipids are required to metabolise protein. If this balance does not exist, starvation can occur despite an ample supply of dietary protein (Noli and Avery 1988). Further, the body can metabolise only a limited amount of protein for energy; energy requirements are met mostly by dietary carbohydrates and fats.

In the Arctic environment, the lack of carbohydrates meant that lipids from sea mammals were critical for energy and protein metabolism. Steffansson (1956) estimates that for seal eaters, 80% of energy requirements were met by dietary fat. More recent examinations place less emphasis on fat, and actual proportions may have varied

depending on the availability of different species (Krupnik 1993b:53). Clearly, marine mammals were important dietary resources which could not be easily replaced by other leaner species. However, Steffansson (1956) found seal meat to be quite lean among marine species. While Krupnik (1993b:53) does recognise that seal meat (1.8-4.6% fat) contains less fat than walrus meat (8% fat), the entire sea mammal provides much more fat than the fish, bird, and terrestrial species of this region.

Arutiunov (in Fedoseeva 1991:245) postulates that despite the favourable location of Ekwen for exploiting sea resources, the inhabitants may have experienced frequent food shortages, particularly in late winter/early spring when winter stores were depleted and the new hunting season had not yet begun. Food shortages may have had different effects on the population. For example, shortages may have resulted in deficiencies in specific nutrients.

In the Arctic, vitamin C and fat shortages are not uncommon (Eidlitz 1967). Vitamin C is available in fresh animal foods such as sea mammal skin and organs, and thus, should not be deficient in diets if basic energy requirements are met (Høygaard and Rasmussen 1939). Fat deficiency, which may have been common amongst inland groups, was unlikely to have afflicted the Asiatic Eskimos consuming sea mammals. For example, seals contain three times the required amount of fat needed to metabolise the amount of meat they provide (Steffansson 1956). Thus, the inhabitants of the Bering region would not suffer individual nutrient deficiencies so much as general food shortage.

The severity of food shortage varied considerably between insignificant to catastrophic and consequently, emergency foods are ranked. In examining eating habits of several Arctic groups during times of shortage, Eidlitz (1967:128) observed six levels of emergency food. First, when the primary resources failed, populations would eat more of those foods normally consumed in small quantities. Next, they would consume plants

and fish not normally eaten, followed by animals and parts of animals not normally eaten. Then domestic animals infrequently consumed, such as dogs, would be killed for food. During severe food shortages, skins from tents, clothing, and footwear, and ermine (considered very foul) would be eaten. Consuming corpses and earth were final measures that only arose in extreme conditions.

Although food shortages were commonly described in historic accounts, not all instances of shortage were serious. The absence of a preferred food was considered food shortage by informants. Also, if too much time passed without consuming a common resource or consuming only one resource, this too was a shortage (Eidlitz 1967:117). According to some accounts, famine occurred when fresh (and frozen) food ran out, leaving only preserved food (Holm 1914 in Eidlitz 1967:119). In these cases, nutrition and health may not have been impacted.

Catastrophic famines have certainly occurred in the Arctic, many of which are recorded historically or recounted by oral history (see Eidlitz 1967 for examples). The causes have been both natural, such as changes in weather (Stadling 1901; Holm 1914 in Eidlitz 1967) or the absence of certain staple animal stocks (Harrington 1952; Hughes 1960), as well as directly or indirectly the result of European contact (Bogoras 1904). Through consumption of European trade goods and spirits, some Arctic groups were kept in perpetual debt to merchants who then treated these individuals as slaves (Stadling 1901). Traditional subsistence cycles were disrupted by the pursuit of trade items and the consumption of trade goods such as liquor. Thus, while extreme famine surely occurred in prehistory, its frequency may have increased during the historic period.

## **2.8 Summary**

Examination of the archaeological, ethnographic, and environmental data clearly indicates that the economies of Asiatic Eskimos, past and present, relied primarily upon sea mammals. These species provided large quantities of meat and fat, as well as other materials necessary for subsistence. This diet was supplemented by other resources including fish, birds, eggs, plants, and terrestrial species, although the protein contribution from these foods was much smaller. When sea mammal stocks periodically diminished, exploitation of these minor resources increased. By themselves, these secondary resources were insufficient to meet the dietary requirements of the population for long periods of time (Krupnik 1993b).

Food shortages appear to have been common throughout the history of the Arctic. Emergency foods that were frequently relied upon may have made a noticeable contribution to total diet. However, the small amount of foods consumed during extreme famine was unlikely to have contributed significantly to the overall average diet.

## Chapter 3: Stable Isotope Analysis

### 3.1 Introduction

Stable isotope analysis identifies dietary components based on the fundamental premise that distinctive isotopic ratios define certain categories of food sources. Thus, by measuring these ratios in human tissue, isotopic analysis can identify the types of food consumed by that individual (see van der Merwe 1982 and Schoeninger and Moore 1992). Carbon and nitrogen isotopes are most commonly used in these analyses.

The natural abundance of carbon ( $^{12}\text{C}$  to  $^{13}\text{C}$ ) and nitrogen ( $^{14}\text{N}$  to  $^{15}\text{N}$ ) is 99:1 and 996:4 respectively although these ratios are not typically found in organic samples. Instead, isotopic ratios measured in samples are reported in relation to those found in international standards, Pee Dee Belemnite (PDB) for carbon and atmospheric nitrogen (AIR) for nitrogen. Measurements based on the comparison of isotopic ratios between the sample and standard are delta ( $\delta$ ) values and reported in parts per thousand, or permille (‰) as defined by the following equation:

$$\delta^{13}\text{C}_{(\text{PDB})} = \left[ \frac{^{13}\text{C}/^{12}\text{C}_{\text{sample}}}{^{13}\text{C}/^{12}\text{C}_{\text{PDB}}} - 1 \right] \times 1000\text{‰}$$

Measurements reported in relation to AIR are  $\delta^{15}\text{N}$  values and determined with an analogous equation. Samples that contain proportionately more  $^{13}\text{C}$  or  $^{15}\text{N}$  than the

standards have positive values while those with more of lighter isotopes are negative. Plant and animal tissues tend to have negative  $\delta^{13}\text{C}$  and positive  $\delta^{15}\text{N}$  values.

### **3.2 Carbon Isotope Analysis**

Stable carbon isotope analysis has been used to identify the introduction of maize to North America (*e.g.*, Larsen *et al.* 1992; Katzenberg 1988; Boutton *et al.* 1984), and to study the proportion of marine *versus* terrestrial foods consumed by coastal inhabitants (*e.g.*, Tauber 1981; Chisholm *et al.* 1982, 1983; Chisholm and Nelson 1983; Yesner 1988).

Carbon isotope analysis can distinguish three general dietary sources: those based on marine, terrestrial  $\text{C}_3$ , and terrestrial  $\text{C}_4$  plant food chains. Each of these three food chains has distinct isotopic signatures determined by the method by which plants photosynthesise, and the reservoir from which carbon is sampled.

Plants that follow the Calvin-Benson pathway, or  $\text{C}_3$  plants, are most common. These include most trees, shrubs, flowering plants, and temperate grasses. The  $\delta^{13}\text{C}$  values of  $\text{C}_3$  plants average  $\cong -26\text{‰}$ , ranging from  $-35$  to  $-20\text{‰}$  (Boutton 1991; Ehleringer 1991).  $\text{C}_4$  plants have evolved to survive harsh climatic conditions, such as excessive sun, a short growing season, saline conditions, and aridity, and follow the Hatch-Slack photosynthetic pathway. Some tropical plants and sub-tropical grasses are  $\text{C}_4$  plants, including important food species such as maize, sorghum, millet, and sugar cane. These plants have an average  $\delta^{13}\text{C}$  value of  $-12.5\text{‰}$ , ranging from  $-16$  to  $-9\text{‰}$  (Boutton 1991; Ehleringer 1991). Marine phytoplankton photosynthesise in a manner comparable to  $\text{C}_3$  plants. However, while atmospheric  $\text{CO}_2$  has  $\delta^{13}\text{C}$  values of  $\cong -7\text{‰}$ ,



bicarbonates in the ocean measure close to 0‰. (Pee Dee Belemnite is a marine bicarbonate.) Phytoplankton  $\delta^{13}\text{C}$  values are highly variable (from -31 to -7‰) but average around -18‰ (van der Merwe 1982).

The isotopic differences between  $\text{C}_3$ ,  $\text{C}_4$ , and phytoplankton primary producers are maintained up through the species which feed on them. Some researchers suggest that with each trophic level, or food chain level,  $\delta^{13}\text{C}$  values may be enriched by about  $0.8 \pm 1.1\%$  (Epstein and DeNiro 1979), however this increment is not usually discernible except in well-controlled systems (Schoeninger and Moore 1992).

A large enrichment of about 5‰ does exist between a consumer's diet and its bone collagen (see van der Merwe 1982 and Schoeninger and Moore 1992). Ambrose and Norr (1993) suggest that the enrichment value depends on the size of species, type of metabolism, and on diet, however an enrichment of 5‰ is appropriate for large mammals such as humans (Nelson 1997, pers. comm.; Vogel *et al.* 1991).

Assuming a 5‰ enrichment, individuals subsisting entirely on a  $\text{C}_3$  based-diet will have collagen  $\delta^{13}\text{C}$  values of about -22 to -20‰, while those with a pure  $\text{C}_4$  diet will measure about -7.5‰. Marine consumers should have  $\delta^{13}\text{C}$  values of -13 to -12‰. These 'end point values' represent total dietary dependence upon one food chain. Definitive end point values are difficult to establish, as few human populations are wholly dependent upon one food chain. Also, environmental conditions may cause variation in end point values, necessitating calibration to specific environments (van Klinken *et al.* 1995; Lidén and Nelson 1994; van der Merwe 1989). Finally, it has been shown that isotopic results also are influenced by differences in laboratory collagen extraction procedures (Lidén *et al.* 1995).

While isotopic values may differ due to external factors, variation between individuals due to metabolic effects between the sexes and age groups do not appear to

exist in populations with homogenous diets (Lovell *et al.* 1986; DeNiro and Schoeninger 1983). Lovell and colleagues (1986) found variation in  $\delta^{13}\text{C}$  values between individuals in a population to be small. Standard deviations within about  $\pm 0.3\text{‰}$  for a population likely indicate dietary homogeneity.

The variation in values for a human population with a similar diet is small compared to the wide range of values found among plants and some animals. The low human variation may be due to human selection of food, and to the large quantity of food consumed that is reflected by a collagen sample (Nelson 1997, pers. comm.). While short term isotopic fluctuations are recorded in individual plants, long term sampling of plants by herbivores and omnivores average out seasonal effects.

### **3.3 Nitrogen Isotope Analysis**

Nitrogen isotope analysis characterises dietary sources in three ways. Nitrogen-fixing and non-nitrogen-fixing plants have different  $\delta^{15}\text{N}$  values, as do aquatic and terrestrial species. Further, the  $\delta^{15}\text{N}$  values in all systems increase with trophic level.

Nitrogen fixation is the ability to derive nitrogen from air instead of from soil nitrogen alone. Therefore,  $\delta^{15}\text{N}$  values for nitrogen-fixing plants are closer to the atmospheric value (Schoeninger 1989; Delwiche *et al.* 1979; Rennie *et al.* 1976). Among food species, legumes are nitrogen-fixing, while most other plants are not. The  $\delta^{15}\text{N}$  of non-nitrogen fixers varies depending on the soil content (Delwiche *et al.* 1979; Rennie *et al.* 1976; Heaton *et al.* 1986; Ambrose 1991).

Terrestrial and marine resources can be distinguished, as oceanic  $\delta^{15}\text{N}$  values are significantly *heavier* than terrestrial ones (Schoeninger and DeNiro 1984). Individuals

consuming marine protein tend to have values of 14 to 20‰ (Schoeninger and DeNiro 1984; Yesner 1988) while those consuming terrestrial foods measure around 6‰ (Schoeninger and DeNiro 1984; Schoeninger 1985).

Nitrogen ratios also provide information on trophic levels since species at successive steps along the food chain are enriched by about 3‰ (Minagawa and Wada 1984; Schoeninger 1985, 1989; Vogel *et al.* 1990). For example, where terrestrial herbivores have values of approximately 6‰, carnivores measure around 9‰. Because food chains are longer in the ocean, the spread of values between lower and higher trophic level species is even wider. Thus, while carbon end point values may be discrete, end point values cannot be well defined for nitrogen isotope analysis.

The trophic enrichment value may vary between some species. This enrichment has been demonstrated to be larger among some grazing, water-conserving animals than water-dependent species in the African savanna. Also, greater enrichments may be characteristic of some species living in hot, arid ecosystems (Ambrose 1991). Consequently, different values may be needed when working in specific environments or with unique types of animal physiology. The enrichment value determined by Minagawa and Wada ( $+3.4 \pm 1.1$ ‰) was based upon marine species in the North Pacific near Japan. Thus, this value should be applicable to the marine species of the Bering Strait studied here.

### **3.4 Materials of Investigation**

Isotopic analyses are usually performed on archaeologically preserved hard tissues - bone and teeth. These hard tissues are composed mainly of minute crystals of apatite

bound by long fibrils of collagen, a large protein that makes up 90% of the organic material in bone (White 1991).

All protein, including collagen, is derived from protein recycled within the body as well as dietary protein. As bone remodels, collagen is formed incorporating these recycled and dietary amino acids. Given this process, collagen turnover can take up to 25-30 years (Stenhouse and Baxter 1979), and thus reflects a long-term average of dietary protein. However, the rate of bone remodeling varies within the body and between ages. During childhood, growth is fast and bones quickly reshape and remodel. Also, trauma and pathologies, such as bone lesions from fracture or infections can prompt bone growth. Bone growth is accelerated in those localised, weakened areas and thus repaired bone may reflect more recently consumed foods.

Mineral hydroxyapatite is a calcium phosphate crystal that does not contain carbon. However, carbonates in the blood stream exchange with phosphate radicals in the apatite. Carbonates in apatite reflect the individual's total diet, including dietary protein, carbohydrate, and lipid, whereas collagen mostly reflects dietary protein (Martin and Armelagos 1985; Ambrose and Norr 1993). This is especially the case in high protein diets, such as that of the Eskimo.

Despite its representation of total diet, stable isotope analysis of apatite is not common because samples may be diagenetically altered by the exchange of carbonates from ground water with phosphates in apatite (Lee-Thorpe and van der Merwe 1991). Although collagen will decompose, it is less likely to become contaminated, as the amino acids are tied by chemical bonds into long strands of polypeptides insoluble to groundwater.

While bone diagenesis is not well understood, there are quantitative and qualitative indicators to assess the integrity of a collagen sample. These include the

concentration of carbon and nitrogen in collagen, amino acid composition, and collagen yield. DeNiro (1985) has argued that archaeological collagen samples should have a carbon to nitrogen (C:N) ratio comparable to that found in modern bone. When measured by weight, C:N ratios should have a value close to 2.8:1, although a valid C:N ratio does not ensure that the sample is uncontaminated.

In this project, collagen is examined to determine the sources of *dietary protein*. The Asiatic Eskimos consumed large quantities of protein greatly in excess of that required daily. And while plant carbohydrates may have contributed to energy requirements, animal protein and lipids were the dominant sources of energy (Steffansson 1956; Krupnik 1993b). Since the same species that provided meat also likely provided fat, isotopic examination of collagen should identify most of the diet. Further, apatite does not contain nitrogen, and nitrogen isotope analysis is expected to provide valuable information on trophic level sampling. For both methodological and archaeological reasons, collagen was considered the best material for analysis.

## **Chapter 4: Samples**

In total, 74 individuals from the cemetery at Ekwen (see Appendix A) and 19 faunal samples (see Appendix B) were examined in this study. The human group includes individuals of all ages, both sexes, and from various cultural periods. This material comes from recent excavations at Ekwen, although the cemeteries have been excavated since 1967 by Sergeev and Arutiunov. The faunal material includes the five species likely to have been key dietary resources, and also the domesticated dog. Most of these faunal bones were recovered during recent excavations of the habitation area of the site and are not dated (Savinesky 1996, pers. comm.).

The Ekwen cemetery is divided into an eastern and a western section. Recent excavations have focused within the northeast region of the eastern cemetery where mostly early burials are found. Some Birnirk and Punuk burials have been recovered from the eastern lot (Bronshtain and Dneprovsky 1996, pers. comm.). Because the human material studied here was taken solely from these excavations, this collection is not a representative sample of the total cemetery.

Only a small number of individuals have been dated: 17 burials date to the Old Bering Sea phases and only four to the later Birnirk or Punuk periods. These relative dates were obtained through established typologies of associated grave goods which bear stylistic markers specific to a cultural period. The cultures represented by dated burials are the Old Bering Sea phase I, II, III, Birnirk, and Punuk (Bronshtain and Dneprovsky 1996, pers. comm.). Some graves have been given the same burial numbers (*i.e.*, 324-1, 324-2, 324-3), but may not be contemporaneous, as pits for new graves sometimes

disturbed existing, older burials. Thus, artifacts dating one individual do not necessarily date the other(s). While archaeologists have been able to distinguish between contemporaneous multiple burials and the intrusion of new graves upon existing burials, this information was unavailable.

The skeletons were sampled in March of 1996 at the Institute of Archaeology, Russian Academy of Sciences, where the human remains are housed. At the invitation of Dr. Marija Kozlovskaja, permission was granted for Anders Götherström (a Swedish colleague) and myself to visit and take samples. To every extent possible, each skeleton was sampled by drilling from the same bone element at the same location, however, most skeletons were incomplete. Thus, samples were taken from a number of cranial and limb bones. Also, the condition of the skeleton was considered when drilling, and thus, fragile and degraded bones or parts of the bone were avoided. These sampling procedures are described in detail in Appendix C.

From 10 of the more complete skeletons, two bone samples were taken, one from the skull and one from a long bone in order to examine potential differences between bones in the body. It is important to test for intra-skeletal variation because analysis of all 74 individuals will compare isotopic values measured from various bones in the skeleton.

Crania were sampled at the parietal bone, near the coronal and sagittal sutures to avoid osteological features and landmarks. However, where skulls were partly disarticulated, Russian researchers requested that we sample the smaller fragments. Thus, some cranial samples were taken from the temporal, occipital, and frontal bones. All long bones were drilled at the diaphyses near the epiphyses. The femur was preferred, due to its large size and frequency among burials, and was usually sampled on the anterior surface on the proximal end. In burials where the femur was not present, the tibia or the humerus was preferred over the smaller ulna, fibula, or radius. As much as

100 mg of bone were drilled from each sample depending on the size of the bone and the condition. Usually half that amount was sampled, especially from cranial and infant bones.

Due to time constraints, Dr. Kozlovskaja provided age and sex estimates for only half of the individuals sampled. Individuals of all ages and both sexes were identified. In total, 18 subadults and 22 adults were aged, but most subadults were not sexed. Sexed adults number 15 each of males and females. There was no available information on whether or not this burial collection was representative of the population, or even of the total cemetery.

Faunal material from Ekwen was also collected. The zooarchaeological material is being studied by Professor L. Denisman and Dr. Arkady Savinesky of the Institute of AEEMA, Russian Academy of Sciences. Dr. Savinesky provided walrus, ringed and bearded seal, dog, and reindeer bones from the Ekwen habitation area. These bones were selected with his assistance to ensure that each originated from a different individual.

Although a faunal report was not available, Dr. Savinesky commented upon the assemblage (1996, pers. comm.). In general, preservation was good, so that small bones survived. The assemblage included remains from sea mammals, birds, dogs, fish, and shellfish. Mussels were numerous and bird bones outnumbered sea mammal bones. Ringed seals comprised well over 90% of the sea mammal remains. Bearded seals, walrus, bowhead, gray, and beluga whales were present in much smaller numbers.

Neither fish, bird, nor whale bones from the site were available during our visit. Whale samples from elsewhere were sought. Two of the whales examined here, a minke whale and a gray whale, are from the Simon Fraser University zooarchaeological collections. The gray whale was measured by Keeling (1996) using the same extraction procedures outlined in Appendix C. Although these specimens are from British



Columbian sites, these species do migrate to the Arctic. A third whale measurement was taken from Schell's study (1992) on modern Alaskan bowhead whales. His extraction methods are not described and may differ from those used here.

Collagen extraction was performed in laboratories at Stockholm University and Simon Fraser University. Identical methods were used (as outlined in Appendix C) and all samples were measured with a Prism isotope ratio mass spectrometer with measurement reproducibility within about 0.05‰ for carbon and better than 0.2‰ for nitrogen (Nielsen 1997, pers. comm.). Measurements were performed at the Isotope Laboratory in the Department of Oceanography at the University of British Columbia.

## **Chapter 5: Results and Discussion**

### **5.1 Results**

The data obtained are presented in tables throughout this chapter and in Appendices A and B. Before isotopic examination of the Ekwen diet, methodological issues *must be considered*. Analysis of faunal isotopic measurements not only provides background isotopic signatures for the region, but also permits testing of trophic level enrichments. Results from the human dataset will indicate the amount of marine and terrestrial protein in the Asiatic Eskimo diet and on the trophic level of species consumed. Additionally, these data provide an excellent opportunity to examine variability between individuals (or groups of individuals) within the population. Comparison of subadult and adult values may identify unique diets or illustrate the difference between short-term and long-term dietary consumption. Finally, potential dietary differences between males and females and between cultural periods are examined.

### **5.2 Faunal Background**

Most faunal specimens analysed are archaeological remains from the Ekwen habitation area. The 18 faunal samples from Ekwen are of five species - reindeer (*Rangifer tarandus*), dog (*Canis familiaris*), walrus (*Odobenus divergens*), ringed seal (*Phoca hispida*), and bearded seal (*Erignathus barbatus*). Additionally, a North

American minke whale (*Balaenoptera acutorostrata*) was measured. The results are given in Table 5.2 (also see Appendix B). These results also include measurements made elsewhere of a gray (*Eschrichtius robustus*) and bowhead (*Balaena mysticetus*) whale.

Most samples were of bone, with a few of dentin. The walrus samples include one bone sample (mandible) and four ivory samples (dentition). In addition, one of the two reindeer samples was taken from a tooth and the other, a tarsal bone. Isotopic data from African elephant bone and ivory from the same individual show insignificant differences, and thus bone and dentin measurements should be comparable (Vogel *et al.* 1990; van der Merwe *et al.* 1990). The primary difference between bone collagen and dentin in this study is that dental collagen does not turn over or remodel, and thus only records dietary information during its period of formation.

The absence of collagen turnover in teeth explains the large discrepancy in isotopic values between the two reindeer samples. The dental sample has a  $\delta^{15}\text{N}$  value of 5.11‰ while the bone sample measures only 1.52‰. The heavier dental sample reflects a milk diet as its teeth were formed early in development (Bocherens *et al.* 1995; Bocherens *et al.* 1991). Despite differences between the two reindeer samples, both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  measurements fall within the range of values from Greenland reindeer which also display wide variation among individuals (Nelson 1997, pers. comm.). The mean  $\delta^{13}\text{C}$  value for the Ekwen reindeer is several permille lighter than average values for marine species. More significantly, the average  $\delta^{15}\text{N}$  of these two terrestrial animals (3.32‰) is almost 12‰ lighter than the lowest  $\delta^{15}\text{N}$  average for a marine mammal, indicating that they can be clearly distinguished. If reindeer meat provided even a small but consistent supplement to Eskimo diet, human measurements would be noticeably lighter than typical marine values.

Table 5.2 Faunal Results

Sample	Bone	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	Sample	Bone	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
Reindeer				Bearded seal			
24	tarsal	-18.39	1.52	2	mandible	-12.66	16.37
25	tooth	-17.33	5.11	3	tibia	-12.25	16.04
Average		-17.86	3.32	Average		-12.46	16.21
Walrus				Various			
19	ivory	-11.91	13.73	baleen			
20	ivory	-11.85	15.96	whales			
21	ivory	-12.97	14.88	27 <sup>1</sup>	vertebra	-14.01	16.08
22	ivory	-11.85	13.10	28 <sup>2</sup>	humerus	-14.10	12.10
23	mandible	-12.06	14.82	29 <sup>3</sup>	unspecified	-16.23	15.79
Average		-12.13	14.50	Average		-14.78	14.66
		$\pm 0.48$	$\pm 1.11$			$\pm 1.26$	$\pm 2.22$
Ringed Seal				Domestic			
				Dog			
11	r. radius	-13.31	17.16	5	r. tibia	-12.46	19.69
12	r. radius	-13.69	18.88	7	r. ulna	-12.60	18.15
13	r. radius	-13.73	17.63	8	r. ulna	-12.22	17.31
14	r. radius	-13.73	17.61	9	r. tibia	-13.14	16.88
15	r. femur	-14.57	14.38	Average		-12.61	18.01
Average		-13.81	17.13			$\pm 0.39$	$\pm 1.24$
		$\pm 0.46$	$\pm 1.67$				

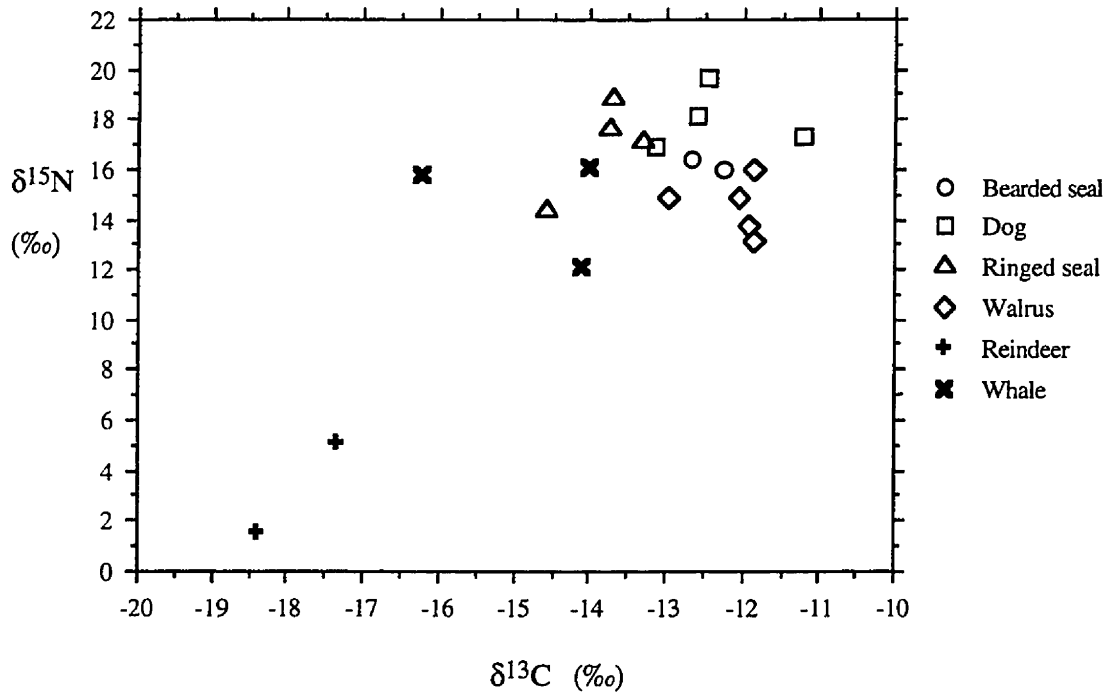
Averages reported with one standard deviation where applicable.

- 1 Minke whale (see Appendix B)
- 2 Gray whale (see Keeling 1996)
- 3 Bowhead whale (see Schell 1992)

The four marine mammal species have average isotopic values different from one another, reflecting their unique diets (Figure 5.2). Although average  $\delta^{13}\text{C}$  values between walrus and baleen whales differ by over 2.5‰, their  $\delta^{15}\text{N}$  averages are virtually identical

( $14.66 \pm 2.22\text{‰}$  and  $14.50 \pm 1.11\text{‰}$  for whales and walrus respectively). Compared to seals, these lower trophic-level species have lighter  $\delta^{15}\text{N}$  values.

Figure 5.2  $\delta^{15}\text{N}$  versus  $\delta^{13}\text{C}$  for Faunal Species



The bearded seals have a slightly higher average  $\delta^{15}\text{N}$  value of  $16.21\text{‰}$ . Like the walrus, these pinnipeds feed on molluscs, but also some fish (Antonelis *et al.* 1994). Fish-eating ringed seals have the heaviest  $\delta^{15}\text{N}$  values, averaging  $17.13\text{‰}$ . The true result may actually be higher considering that one of the five samples (#15) is a conspicuously light outlier whose C:N ratio is suspiciously high (C:N = 3.29).

Otherwise, its lighter measurement could reflect a different diet, or it is possible that the bone was mis-identified. Omission of this seal raises the average  $\delta^{15}\text{N}$  value to 17.82‰.

Results of the  $\delta^{15}\text{N}$  data for these four marine mammals are consistent with their positions on the food chain. Walrus and baleen whales have the lowest  $\delta^{15}\text{N}$  measurements of marine species. High values from ringed seals indicate that these fish-eating animals have a higher position on the food chain. The bearded seals are positioned appropriately with intermediate measurements.

For the  $\delta^{13}\text{C}$  results, trophic level enrichment does not provide a valid explanation for the pattern exhibited. If a 1‰ increment exists between food chain levels, the ringed seal measurements should be heaviest, followed by the bearded seal, and then the walrus and whale. Instead, walrus have the heaviest  $\delta^{13}\text{C}$  values, followed by bearded seals, ringed seals, and finally baleen whales. It is interesting to note that this order does correspond with the distance from shore of the species' respective feeding grounds. The limited data here are not sufficient to determine whether this is a fortuitous or a substantive observation.

Of the faunal samples available, the whales were least satisfactory. None were recovered from the Chukchi coast and all are modern. However, these migratory whales do spend time in the Bering region and were likely exploited by the Asiatic Eskimo. Measurements of modern and archaeological marine samples should not differ since the marine reservoir is not significantly affected by recent addition of carbon from fossil fuels. As well, the minke whale (#27) is a juvenile and its  $\delta^{15}\text{N}$  value may still reflect milk diet. The bowhead whale sample (#29) has a light  $\delta^{13}\text{C}$  value (-16.23‰) compared to the other whales and marine mammals. Because the bowhead whale sample was taken from a fresh kill, lipids were probably present in the bone. If these lipids were not extracted, then the  $\delta^{13}\text{C}$  for this sample may not be comparable to other faunal

measurements here. Finally, the gray whale (#28) has an unusual diet among baleen whales as they are primarily benthic feeders (Wolman 1985). Its low  $\delta^{15}\text{N}$  may be unique among baleen whales and thus, it is not clear if there are 'typical' isotopic signatures for baleen whales. The three whale samples suggest that a wide range of values likely exist. More detailed analyses will require a much better understanding of the isotopic signatures of whales.

Finally, bird and fish remains from Ekwen were not available for testing. Many marine and terrestrial species have been examined by Schoeninger and DeNiro (1984). Their results found marine fish to average  $-12.5\text{‰}$  for carbon and almost  $14\text{‰}$  for nitrogen, while marine birds had values of about  $-16\text{‰}$  ( $\delta^{13}\text{C}$ ) and  $13\text{‰}$  ( $\delta^{15}\text{N}$ ). However, these samples were from fresh bones and museum specimens, and may have contained lipids.

Despite some uncertainties, these results suggest that isotopic data can distinguish between the different potential food species. Thus, it should be possible to compare faunal and human  $\delta^{15}\text{N}$  values to determine what species were consumed by the human populations. If individuals have heavy  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  measurements, this would point to higher trophic level marine species in the diet. Heavy  $\delta^{13}\text{C}$  combined with slightly lighter  $\delta^{15}\text{N}$  values might indicate more lower trophic level marine species being consumed. Finally, if both  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values are light, this could indicate that reindeer meat was a significant dietary resource.

The diets of humans and associated domestic dogs are sometimes similar. This pattern has been demonstrated in isotopic studies (Noe-Nygaard 1988) and may be the case here. The Ekwen dogs have  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values indicating marine diets. The  $\delta^{15}\text{N}$  values range widely from  $16.88\text{‰}$ - $19.69\text{‰}$ , suggesting that dietary components were inconsistent and varied. When fed, dogs were given scrap food, consisting of fish, meat,

and "waste parts" from sea mammals, and even other dogs (Krupnik 1993b). Therefore, their measurements may exhibit more variation than humans, who had first choice of food.

### **5.3 Human Results**

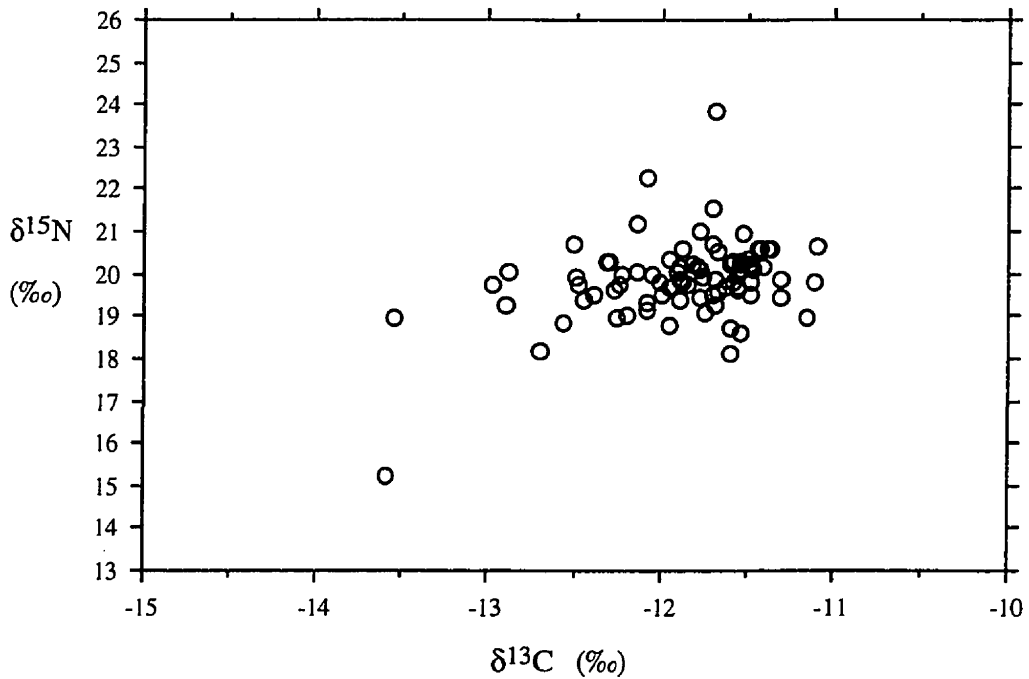
In total, 84 pairs of stable carbon and nitrogen isotopic measurements were obtained from 74 individuals (see Appendix A and Figure 5.3). From this burial group, 64 individuals are represented by one  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  value each, sampled from various skeletal elements. From the remaining 10 individuals, two collagen samples were taken from a cranial *and* a limb bone. By omitting the limb bone measurements from these 10 individuals, the average  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for the 74 individuals is  $-11.88\pm 0.49\text{‰}$  and  $19.89\pm 0.98\text{‰}$  (one standard deviation). These averages do not change significantly when the axial bone values of those 10 burials are used in the place of cranial measurements (the average values are  $-11.87\pm 0.47\text{‰}$  and  $19.98\pm 0.83\text{‰}$ ).

Lovell and colleagues (1986) have argued that for  $\delta^{13}\text{C}$  measurements, standard deviations  $\leq 0.3\text{‰}$  and lower indicate homogenous diets within a population. If this holds, the larger standard deviations of the Ekwen group suggest that some dietary differences existed. There is no analogous value established for  $\delta^{15}\text{N}$  measurements.

To examine this variation, I first consider differences within an individual (between cranial and axial bones) to establish that isotopic values are not significantly different within the skeleton. Measurements for separate bones of the skeleton should be generally similar.



Figure 5.3  $\delta^{15}\text{N}$  versus  $\delta^{13}\text{C}$  for All Individuals



The paired measurements of cranial and axial bones from ten individuals provide a test for this intra-skeletal variation (Table 5.3). Crania were sampled almost exclusively from the parietals with the exception of one undetermined cranial vault bone. Limb samples were taken from femoral, tibial, or humeral shafts. Both sexes and a range of ages are represented in this group. Of the ten individuals, four are subadult (13, 18, 5 years old, and 6 months old).

Table 5.3 Isotopic Measurements of Cranial and Axial Samples from the Same Individual

Burial	Bone Elements		$\delta^{13}\text{C}$ (‰)			$\delta^{15}\text{N}$ (‰)		
			(C)ranial	(A)xial	C - A	(C)ranial	(A)xial	C - A
<b>Subadults</b>								
280 <sup>1</sup>	l. parietal	l. femur	-11.60	-11.11	-0.49	18.72	19.81	-1.09
310 -2 <sup>2</sup>	r. parietal	r. femur	-11.95	-11.47	-0.48	18.76	20.13	-1.37
315 <sup>3</sup>	l. parietal	r. femur	-11.67	-12.98	1.31	19.59	19.72	-0.13
322 <sup>4</sup>	skull	l. femur	-13.58	-12.14	-1.44	15.22	21.18	-5.96
<b>Adults</b>								
285 - B	r. parietal	r. humerus	-11.48	-11.60	0.12	20.16	18.13	2.03
308	l. parietal	r. tibia	-11.55	-11.90	0.35	20.06	19.37	0.69
310 -1	r. parietal	r. femur	-11.56	-11.58	0.02	19.68	20.27	-0.59
312	parietal	l. femur	-12.40	-11.89	-0.51	19.53	20.19	-0.66
321	r. parietal	r. femur	-12.24	-12.45	0.21	20.01	19.39	0.62
323	r. parietal	r. femur	-11.62	-11.90	0.28	19.66	19.88	-0.22
<b>Total Average</b>	<b>n=10</b>		-11.97 ±0.65	-11.90 ±0.53	0.07* (0.48)	19.14 ±1.46	19.81 ±0.79	0.33* (1.34)
<b>Adult Average</b>	<b>n=6</b>		-11.81 ±0.40	-11.89 ±0.31	0.08* (0.28)	19.85 ±0.26	19.54 ±0.79	0.31* (0.80)
<b>Subadult Average</b>	<b>n=4</b>		-12.20 ±0.93	-11.93 ±0.82	0.27* (0.93)	18.07 ±1.94	20.21 ±0.67	2.14* (2.14)

1 Age 13 years

2 Age 18 years

3 Age 5 years

4 Age 6 months

\* indicates net difference  
(average absolute differences in brackets)

As expected, isotopic measurements do not differ greatly between cranial and axial bones for most individuals, especially adults (see Table 5.3 for average absolute differences). For the infant (burial #322) significant differences (>1‰) exist for both carbon and nitrogen values. Similar discrepancies between cranial and axial measurements greater than 1‰ is present in either the  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$  values of the other

three subadults. Some researchers note that children sometimes yield anomalous isotopic values (Nelson 1997, pers. comm.), perhaps due to a combination of different diets, changing metabolisms, and quick growth. Thus, separate averages were calculated for *all individuals, adults, and subadults*. For all three groups, differences  $\delta^{13}\text{C}$  between cranial and axial bones are less than 0.3‰. Although larger differences exist between  $\delta^{15}\text{N}$  values, especially among the subadults, t-test calculations indicate that cranial and post-cranial bone measurements cannot be distinguished.

Some consistent patterns do emerge between adults and subadults. For subadults, cranial measurements tend to be lighter than axial values. Three of the four subadults (Burial #315 being the exception) have lighter cranial  $\delta^{13}\text{C}$  measurements, and all four individuals have lighter cranial  $\delta^{15}\text{N}$  values than limb bone values. Among the adults, this pattern is reversed. Five of the six adults have heavier cranial  $\delta^{13}\text{C}$  values. While only half of the adults have heavier cranial  $\delta^{15}\text{N}$  values, the average cranial  $\delta^{15}\text{N}$  value is almost 0.3‰ heavier than the post-cranial average. Also, the differences between cranial and post-cranial averages are larger for subadults than for adults, indicating greater variation in isotopic values in younger skeletons. It is apparent that subadult and adult values behave differently and require separate treatment in the following analysis and discussion.

#### **5.4 Variability within the Subadult Population**

The Ekwen dataset includes 17 individuals with ages ranging from six months to 18 years old at death. To organise data and perform statistical analyses, individuals are grouped into three age categories (Table 5.4.1 and Appendix D). Although this

categorisation is somewhat arbitrary, effort was made to create meaningful divisions so that physiological events such as puberty, and culturally specific information such as weaning times were considered.

For some individuals, two measurements (*i.e.*, cranial and post-cranial) were obtained. Due to the variation in values from different bones in the skeleton in some subadults, both values are presented in the Table 5.4.2. Thus, two averages were calculated for each group, one of cranial and another of post-cranial values.

These results once again suggest that post-cranial measurements tend to be heavier, especially with  $\delta^{15}\text{N}$  values. For infants and adolescents, there is almost a 1‰ difference between the skull and limbs. However, if the lowest and highest infant  $\delta^{15}\text{N}$  values are removed, this difference disappears. Smaller variations exist between cranial and post-cranial  $\delta^{13}\text{C}$  values.

Table 5.4.1 Subadult Age Categories

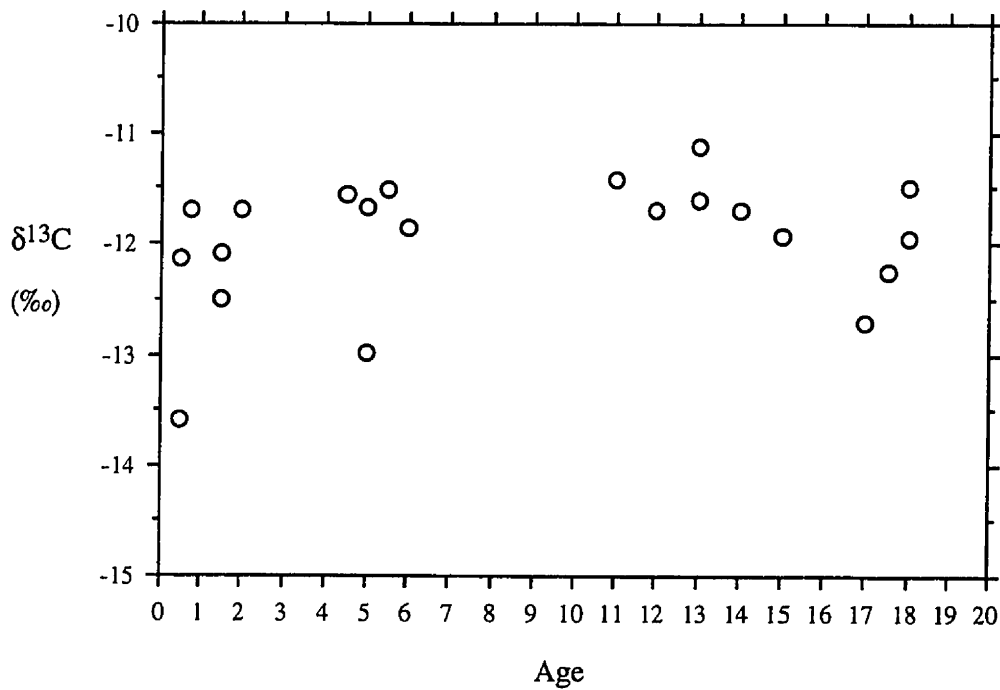
Categories	Age cut-off	Description	Number
Infant	0-3 yrs	breast-feeding, weaning, or weaned but still retaining the high nitrogen isotopic value associated with a breast-fed diet	5
Child	4-12 yrs	period after high breast milk signature has been turned over and prior to puberty	6
Adolescent	13-19 yrs	beginning at puberty and ends at approximate end of growth and beginning of the reproductive age	6

Table 5.4.2 Isotopic Measurements of Known-Age Subadults

Burial	Bone element	Age	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
Infant				
322	skull	6 mos	-13.58	15.22
	femur		-12.14	21.18
284 - 2	parietal	9±3mos	-11.69	23.86
294	parietal	1.5	-12.09	22.24
298 - 1	parietal	1-2	-12.51	20.72
279	humerus	<2	-11.70	21.55
Cranial Average		n=4	-12.47 ± 0.81	20.51 ± 3.75
Post-Cranial Average		n=2	-11.92	21.37
Child				
281	temporal	4-5	-11.54	20.21
315	parietal	5±2	-11.67	19.59
	femur		-12.98	19.72
327 - 2	radius	5-6	-11.50	20.33
220	parietal	6	-11.85	19.75
327 - 3	femur	10-12	-11.42	20.58
327 - 1	parietal	12	-11.70	20.68
Cranial Average		n=4	-11.69 ± 0.13	20.06 ± 0.49
Post-Cranial Average		n=3	-11.97 ± 0.88	20.21 ± 0.44
Adolescent				
280	parietal	13	-11.60	18.72
	femur		-11.11	19.81
292	fibula	<14	-11.69	19.88
326 - 2	tibia	15±2	-11.91	20.03
284 - 1	femur	17	-12.70	18.15
326 - 3	femur	17-18	-12.26	19.72
310 - 2	parietal	18	-11.95	18.76
	femur		-11.47	20.13
Cranial Average		n=2	-11.78	18.74
Post-Cranial Average		n=6	-11.86 ± 0.57	19.62 ± 0.74

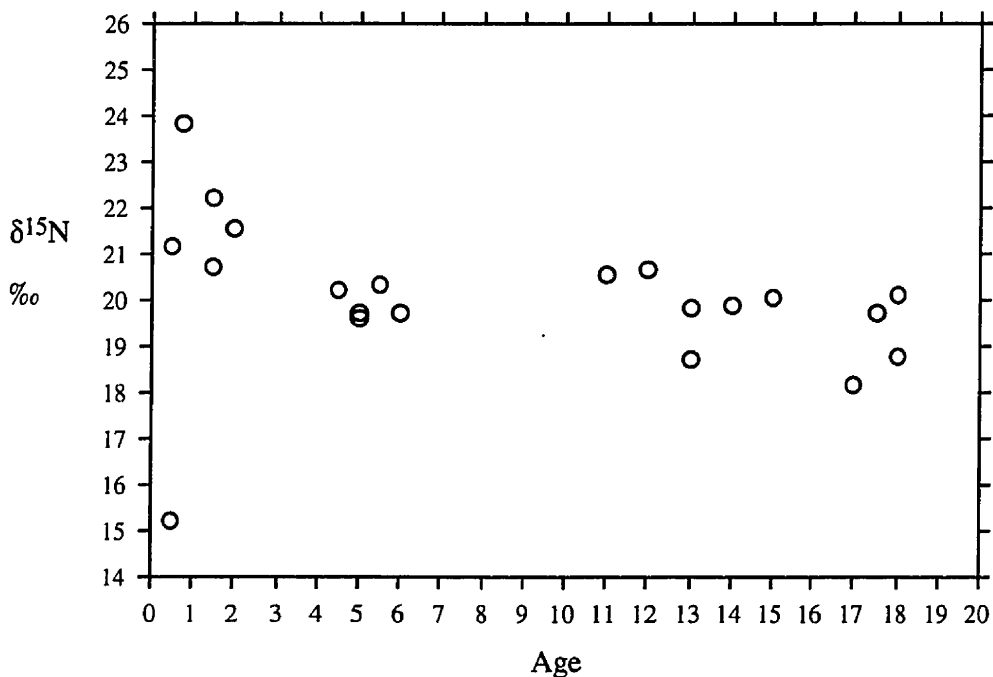
Metabolic effects associated with age and their influences on the isotopic composition of bones are not well understood (Schoeninger and Moore 1992). No significant differences have been found in  $\delta^{13}\text{C}$  values between humans of different ages (Lovell *et al.* 1986), and comparable data for  $\delta^{15}\text{N}$  variation are lacking. However, the data presented here does indicate isotopic differences between age groups (Figure 5.4.1 and 5.4.2). Infants tend to have the lightest  $\delta^{13}\text{C}$  and the heaviest  $\delta^{15}\text{N}$  measurements. As age increases,  $\delta^{13}\text{C}$  values tend to become heavier, while the opposite pattern is observed for  $\delta^{15}\text{N}$ .

Figure 5.4.1  $\delta^{13}\text{C}$  versus Age for Subadults



The pattern of rising  $\delta^{13}\text{C}$  values with age is similar to that found for fossil cave bears (Nelson *et al.* 1998). That study attributed the increase in bear  $\delta^{13}\text{C}$  values to metabolic effects associated with hibernation, obviously an explanation that cannot be applied to human populations. Isotopic data from a human population from Saskatchewan also indicate a small increase in  $\delta^{13}\text{C}$  values up to the age of 9 (Lovell *et al.* 1986). Although these data are consistent, the cause of the pattern cannot be determined. Some metabolic effects associated with pregnancy and growth may influence isotopic measurements. However, this pattern also may result from real dietary changes between the period of gestation and lactation on the part of the mother.

Figure 5.4.2  $\delta^{15}\text{N}$  versus Age for Subadults



For  $\delta^{15}\text{N}$  measurements, the pattern reflects not a metabolic effect but a real dietary shift, indicating infant weaning (Fogel *et al.* 1989; Katzenberg and Pfeiffer 1993). This weaning curve has two parts, an initial increase in  $\delta^{15}\text{N}$  values and then a drop. During gestation, the mother and fetus have similar  $\delta^{15}\text{N}$  values. After birth, infants being breastfed will develop higher values than their mothers. As they are weaned, their  $\delta^{15}\text{N}$  values slowly drop to adult signatures by the age of 3 or 4 (when the curve levels out, Figure 5.4.2). This leveling of  $\delta^{15}\text{N}$  values suggests that infant bone has been completely replaced.

It is not possible to determine the actual age at which these infants were weaned as it is a gradual process. First, isotopic measurement of bone cannot be used to determine weaning times because the rate of bone turnover is not well understood. Furthermore, age at weaning may have varied between individuals as seen in recent North Alaskan Eskimo groups (Chance 1966). In these populations, weaning was usually completed by the time the child reached three years old (Chance 1966). This weaning age fits the isotopic pattern presented in this dataset of Asiatic Eskimo infants.

The quick turnover in children's bones means that short term fluctuations in diet would have a dramatic effect on the isotopic make-up of a child's body. Indeed, we see that subadult values do tend to exhibit greater variation than those of adults, and that significant differences exist among bones in the subadult body. This is most notable for burial #322, the six month old infant. Even though the bone was brittle and crumbled into a fine powder on drilling, both cranial and femoral collagen yields (6.5 and 10.5% respectively), C:N ratios (2.99 and 2.85), and the carbon and nitrogen concentrations of the extracted collagen were acceptable. Furthermore, differences of over 1‰ in either  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$  values between cranial and axial measurements are present for the other subadults. The large differences likely result from ontological development. Throughout



infancy to the end of puberty, the skeleton grows quickly and episodically (Tanner 1978). Thus, if diet does change during this period of extensive bone formation, short term dietary differences may be recorded.

For infant #322, the difference in  $\delta^{15}\text{N}$  values is approximately 6‰, which is about two trophic levels apart. Two possible explanations related to growth patterns are considered. If the femoral bone was produced during an earlier stage in development, the high  $\delta^{15}\text{N}$  value may reflect a fetal value and/or breast-milk diet. The cranial value of 15.22‰ is lighter than any other measurement from this population by about one trophic level. A fish diet could have produced this isotopic ratio. Ethnographies of Maritime Chukchi have described that motherless infants were fed fish broth (Bogoras 1904). Thus, the low cranial  $\delta^{15}\text{N}$  measurement may reflect a later fish broth diet or a temporary diet by the mother.

It is more likely that the cranial bone developed earlier and reflects the *in utero* signature while the limb bone measurement reflects the infant's breast milk diet. Limb bones such as the femur are preferred over cranial bones for accurate aging of fetal and post-natal infants because growth of cranial bones is more irregular (Kósa 1989; Ubelaker 1989). If limb bones undergo quick and regular growth, the femoral  $\delta^{15}\text{N}$  value should reflect the more recent diet. Thus the two  $\delta^{15}\text{N}$  values from infant #322 illustrate the turnover from a fetal signature to one from a breast milk diet. However, since the difference is larger than one trophic level (*i.e.*, 3.4‰), other factors are likely involved. The mother's diet may have changed after delivering the infant or while she was lactating. It is possible that the mother was on a seasonal or an emergency diet.

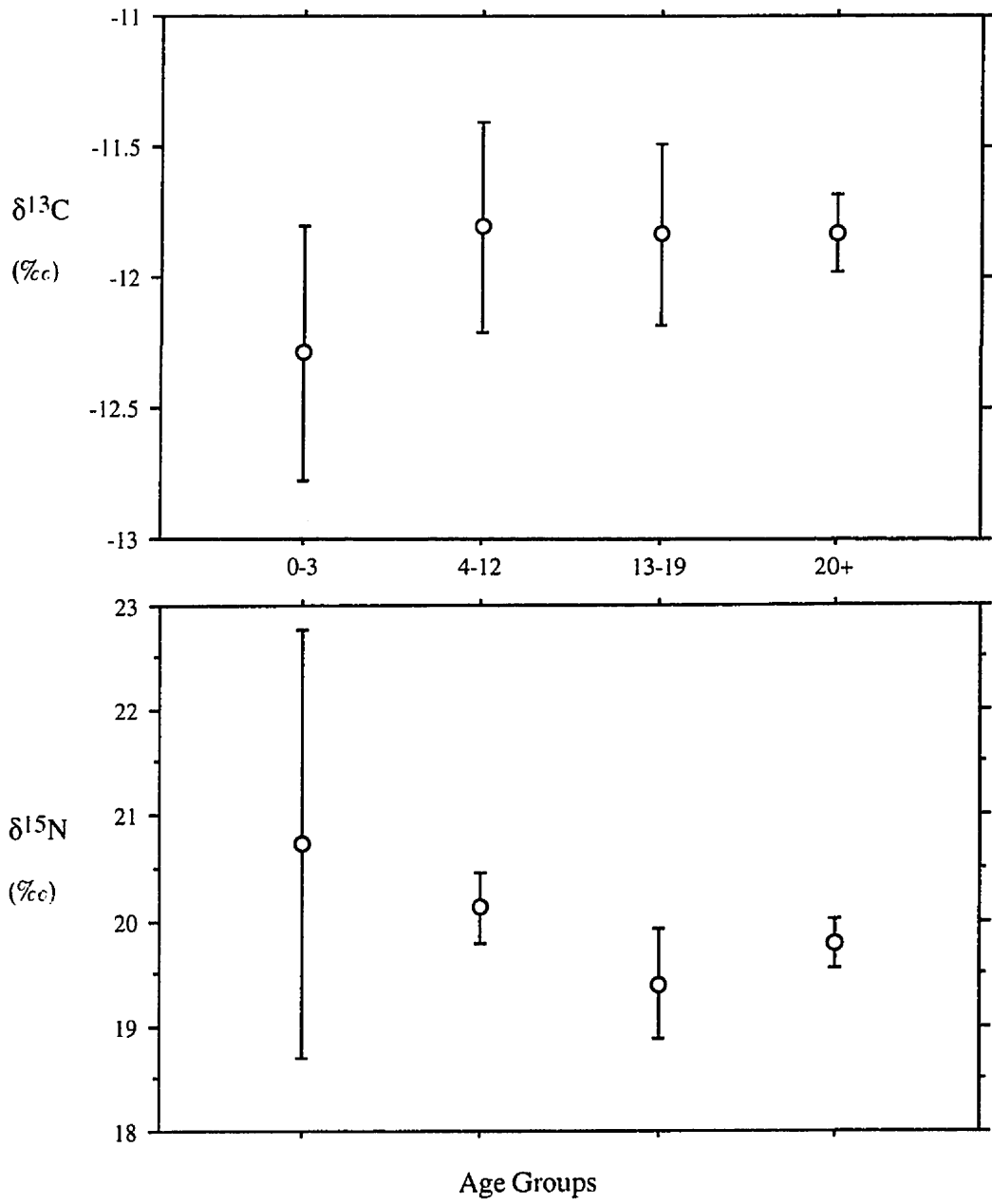
## 5.5 Variability within the Population

With the removal of subadult values, the remaining adult isotopic measurements vary less. The averages for all adults are  $-11.81 \pm 0.38\text{‰}$  for  $\delta^{13}\text{C}$  and  $19.76 \pm 0.61\text{‰}$  for  $\delta^{15}\text{N}$ . Dietary differences are examined for individuals of varying ages (Table 5.5), but t-tests show no significant differences between these adult age groups. The  $\delta^{13}\text{C}$  standard deviation of  $0.38\text{‰}$  suggests that little, if any, dietary variation existed within the population. Thus a standard deviation for  $\delta^{15}\text{N}$  of about  $0.6\text{‰}$  also may be a measure dietary homogeneity within a group for nitrogen isotope analysis.

Table 5.5 Isotopic Measurements of Known-Age Adults

Burial	Bone Element	Age (years)	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	Burial	Bone Element	Age (years)	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
311	parietal	20-25	-11.30	19.41	216	parietal	30-40	-11.70	19.50
316	femur	20-25	-12.58	18.86	320	temporal	30-40	-11.40	20.18
323	parietal	20-25	-11.62	19.66	324 - 2	tibia	30-40	-11.88	19.83
326 - 1	parietal	20-25	-11.68	19.23	324 - 3	frontal	30-40	-11.54	18.57
Average		22.5yrs	-11.80	19.29	Average		35yrs	-11.63	19.52
			$\pm 0.55$	$\pm 0.34$				$\pm 0.21$	$\pm 0.69$
309	parietal	25-35	-11.38	20.58	287	femur	35-40	-12.09	19.30
318	parietal	25-35	-11.48	19.53	310 - 1	parietal	35-40	-11.56	19.68
321	parietal	25-35	-12.24	20.01	307	temporal	35-40	-11.78	21.02
Average		27.5yrs	-11.70	20.04	Average		37.5yrs	-11.80	20.00
			$\pm 0.47$	$\pm 0.53$				$\pm 0.28$	$\pm 0.90$
319	femur	30-35	-12.27	18.96	312	parietal	>40	-12.40	19.53
325	parietal	30-35	-11.78	20.11	314	temporal	>40	-11.44	20.56
328 - 1	tibia	30-35	-11.88	20.59	317	parietal	>40	-11.48	20.21
328 - 2	femur	30-35	-11.96	19.70	324 - 1	parietal	>40	-12.48	19.75
Average		32.5yrs	-11.97	19.84	Average		>40yrs	-11.95	20.01
			$\pm 0.21$	$\pm 0.69$				$\pm 0.57$	$\pm 0.46$

Figure 5.5  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  Means *versus* Age Groups  
Error bar = 95% confidence interval (2 standard errors)



The  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  average values for all individuals (grouped by age) are plotted in Figure 5.5. With the possible exception of the very young, isotopic values do not differ significantly.

## **5.6 Dietary Interpretations and Discussion**

The  $\delta^{13}\text{C}$  values are consistent with expectations that the coastal Asiatic Eskimos obtained their dietary protein from marine species. In fact, the heavy  $\delta^{13}\text{C}$  average ( $-11.88 \pm 0.49\text{‰}$ ) for the Ekwen dataset likely defines the marine end point value for the North Pacific. The adult average  $\delta^{13}\text{C}$  value of  $-11.81 \pm 0.38\text{‰}$  indicates even less variation, and may be a more accurate measure of the average diet since it excludes the highly variable measurements from subadults, whose diets appear to have differed. This  $\delta^{13}\text{C}$  average is comparable to measurements for other coastal populations. Greenland Eskimos measure  $-12.8\text{‰}$  (Tauber 1981); closer to the Bering region but at lower latitudes, coastal populations from British Columbia average  $-13.4\text{‰}$  (Chisholm et al. 1982, 1983). However, since more terrestrial animals inhabit the British Columbian coast compared to the Bering coast, the Ekwen population were likely more dependent upon marine resources than groups further south along the Pacific Northwest.

The  $\delta^{15}\text{N}$  data also provide information on the species consumed by the inhabitants of Ekwen. The adult  $\delta^{15}\text{N}$  average of  $19.76 \pm 0.61\text{‰}$  indicates that higher trophic level species, such as seals, dominated the diet. Bearded seals may have contributed to the high values seen in the human population, however, the frequency of its remains at Ekwen is low (Savinesky 1996, pers. comm.). Instead, sea mammal remains from Ekwen were mostly composed of ringed seal bones (~97%). Though ringed

seals are much smaller than the other marine mammal species, large numbers were taken. Clearly they were a reliable and abundant resource. While ethnographic and archaeological reconstructions place a greater emphasis on walrus in diet, isotopic data suggest that walrus was of secondary importance for dietary protein.

The high  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  measurements also rule out reindeer, bird, fish, and whale meat (if present measurements provide reliable indicators) as significant sources of protein. However, ethnographic reports and archaeological remains indicate that mostly young whales were targeted by the Eskimos. Suckling whale calves should have heavier  $\delta^{15}\text{N}$  values due to their milk diet; the juvenile minke whale measured in this study has a  $\delta^{15}\text{N}$  value of about 16‰. However, the  $\delta^{13}\text{C}$  value obtained from this sample is much lighter compared to human measurements. The light  $\delta^{13}\text{C}$  values for whales may be due to migration patterns: the spring migration brings whale species to the  $^{13}\text{C}$  depleted waters of the East Beaufort and East Siberian Sea for the summer season. Suspension feeders from these seas are about 6‰ lighter than those from the Bering and Chukchi Seas (Dunton *et al.* 1989; Schell *et al.* 1989). Thus whales hunted during the spring migration, before reaching their summer habitat, should have heavier  $\delta^{13}\text{C}$  values for their soft tissue than reflected by measurements of bone collagen, in which seasonal variation is averaged. Conversely, whales hunted during the fall migration would have very light values for their soft tissue. Because of these seasonal effects, it is difficult to gauge the importance of whale meat in diet. However, it is hard to reconcile the human data with a large consumption of whale meat.

The human diet was different from that of domesticated dogs. Both groups have marine diets, but dogs exhibit much greater variation and have lighter values than humans. Dog isotopic values appear to reflect a variable diet of fish, and marine mammals. While researchers have found isotopic values from dogs to mirror those of

their human owners in some regions and cultural periods (Noe-Nygaard 1988), this close dietary relation does not exist among the prehistoric Asiatic Eskimo. The heavier and more homogenous isotopic values for humans suggest that humans selected a diet of higher trophic level species.

Having established the general diet of the entire population, isotopic data are examined in order to determine intra-population differences in diet. However, intensive utilisation of animals and altruistic sharing of food and resources likely minimised differences by homogenising individual diets within a community despite ethnographic record of rank differences between families groups and individuals. Some dietary differences have already been shown between age groups. The difference in  $\delta^{15}\text{N}$  values between infants and other subadult groups is caused by weaning. Possible differences related to sex is considered next.

### **5.7 Dietary Differences Based on Sex**

Even though food was communally shared, dietary differences between males and females are documented among Arctic groups. More plants were consumed by females while the 'best foods' were eaten by males (Bogoras 1904; Krupnik 1993b). The high status food among the Asiatic Eskimo was reindeer meat (Krupnik 1993b). Dietary differences also may have arisen due to activities practised by males and females. Male hunters on expeditions sometimes ate terrestrial species that were not brought back and eaten by the rest of the group (Eidlitz 1967). If males did consume more terrestrial meat, it should be reflected in lighter  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values. Although plants also have terrestrial signatures, isotopic analysis on bone collagen would not reflect inputs from

plant resources because of their relatively small protein contribution to this high protein diet.

Table 5.7 Isotopic Measurements of Known Males and Females

Individual	Bone Element	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	Individual	Bone Element	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
<b>Male</b>				<b>Female</b>			
216 - 1	parietal	-11.70	19.50	283 - A	femur	-12.08	19.15
283 - Д	parietal	-12.89	20.02	285 - Б	parietal	-11.48	20.16
285 - A	parietal	-11.76	19.90	289	femur	-11.77	19.42
287	femur	-12.09	19.30	291	parietal	-11.48	19.79
297	parietal	-11.82	20.23	304 - B	skull	-11.09	20.66
302	parietal	-11.60	20.25	309	parietal	-11.38	20.58
307	temporal	-11.78	21.02	312	parietal	-12.40	19.53
310 - 1	parietal	-11.56	19.68	314	temporal	-11.44	20.56
311	parietal	-11.30	19.41	317	parietal	-11.48	20.21
316	femur	-12.58	18.86	318	parietal	-11.48	19.53
319	femur	-12.27	18.96	323	parietal	-11.62	19.66
320	temporal	-11.40	20.18	325	parietal	-11.78	20.11
321	parietal	-12.24	20.01	326 - 1	parietal	-11.68	19.23
324 - 1	parietal	-12.48	19.75	328 - 1	tibia	-11.88	20.59
324 - 3	frontal	-11.54	18.57	328 - 2*	femur	-11.96	19.70
<b>Total</b>	<b>n=15</b>	<b>-11.93</b>	<b>19.71</b>	<b>Total</b>	<b>n=15</b>	<b>-11.67</b>	<b>19.93</b>
<b>Average</b>		<b>±0.47</b>	<b>±0.63</b>	<b>Average</b>		<b>±0.32</b>	<b>±0.52</b>

\* low collagen yield (<1%)

To examine male and female diets, adults of known sex are compared. Sex identification is available for 30 individuals, of which 15 are male and 15 female (Table 5.7). The average  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for males are  $-11.93 \pm 0.47\text{‰}$  and  $19.71 \pm 0.63\text{‰}$ ; average female measurements are  $-11.67 \pm 0.32\text{‰}$  and  $19.93 \pm 0.52\text{‰}$ .

The similar values between males and females indicate that individuals shared almost all the same sources of dietary protein. However, it is interesting to note that male  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values are both slightly more 'terrestrial' than those of the females, an observation consistent with ethnographic descriptions. It will take a much more detailed study to determine the validity of this observation. Generally, isotopic measurements do not differ between sexes.

### **5.8 Dietary Differences between Cultural Periods**

While the number of dated individuals are insufficient to properly compare dietary differences between cultural periods, a preliminary examination is possible. Only 21 adult burials are dated thus far (Table 5.8.1). No adults have been dated to the earliest Old Bering Sea culture phase I, while many are assigned to Old Bering Sea phase II and III. Only four burials contain Birnirk or Punuk period artifacts. Birnirk and Punuk individuals cannot be divided into separate groups because these cultural periods are represented by only one individual each (Burial #278 and #303). The two other graves can only be dated to the later period and not to a specific culture. This necessitates combining the four later period burials.

The average values for the Old Bering Sea group are  $-11.83 \pm 0.51\text{‰}$  and  $19.84 \pm 0.55\text{‰}$  for carbon and nitrogen. For later period individuals, the averages are  $-12.56 \pm 0.64\text{‰}$  and  $19.56 \pm 0.70\text{‰}$ . Individuals from Birnirk/Punuk have significantly lighter  $\delta^{13}\text{C}$  values than those found among Old Bering Sea individuals ( $p=0.022$ ). Only five of the 17 Old Bering Sea individuals have  $\delta^{13}\text{C}$  values lighter than  $-12\text{‰}$ , and of these five, two of the samples gave low collagen yields. The  $\delta^{13}\text{C}$  measurements for all four later



Table 5.8 Isotopic Measurements of Culturally Dated Individuals

Individual	Bone Element	Cultural Date	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
276	parietal	OBS II	-11.96	20.36
300	frontal	OBS II	-11.15	18.97
301	parietal	OBS II	-11.30	19.87
282	parietal	OBS II/III	-11.54	20.12
283 - Б	femur	OBS II/III	-11.74	19.05
283 - B	mandible	OBS II/III	-11.54	20.31
283 - Д	parietal	OBS II/III	-12.89	20.02
285 - Б	parietal	OBS II/III	-11.48	20.16
285 - B	parietal	OBS II/III	-11.67	20.53
285 - Г	parietal	OBS II/III	-11.79	20.19
286 *	femur	OBS II/III	-12.90	19.28
287	femur	OBS II/III	-12.09	19.30
290	parietal	OBS II/III	-12.20	19.00
293 *	femur	OBS II/III	-12.28	19.62
296	parietal	OBS II/III	-11.55	19.65
302	parietal	OBS II/III	-11.60	20.25
304 - A	parietal	OBS II/III	-11.36	20.59
Average		n=17	-11.83 ±0.51	19.84 ±0.55
278	femur	Birnirk	-12.14	20.02
212	parietal	Birnirk/Punuk	-12.31	20.30
319	femur	Birnirk/Punuk	-12.27	18.96
303 *	femur	Punuk	-13.52	18.97
Average		n=4	-12.56 ±0.64	19.56 ±0.70

\* low yield (under 1%)

period individuals are lighter than -12‰. Later period individuals also have a lighter  $\delta^{15}\text{N}$  average, however, this is not a statistically significant difference. All  $\delta^{15}\text{N}$  values from the later period individuals fall within the range of Old Bering Sea measurements, although lighter  $\delta^{15}\text{N}$  values of around 19‰ are uncommon for Old Bering Sea measurements.

The drop in  $\delta^{13}\text{C}$  values with time *may* suggest that species with heavier  $\delta^{13}\text{C}$  values, such as walrus, were being replaced in the later periods by species with lighter  $\delta^{13}\text{C}$  values, such as ringed seals and whales. This is consistent with existing archaeological interpretations (Krupnik 1993b) which indicate that ringed seals were more important in Birnirk culture and that whaling became more dominant during Punuk culture.

The grouping of the four Birnirk/Punuk individuals into one category is not ideal since different subsistence patterns have been proposed for Birnirk and Punuk cultures. Based on  $\delta^{15}\text{N}$  results, burial #278 (Birnirk) and #212 (Birnirk/Punuk) have similar values of over 20‰, and are more than 1‰ heavier than #319 (Birnirk/Punuk) and #303 (Punuk) which have values just under 19‰. Speculating that these differences distinguish Birnirk and Punuk individuals, some interesting patterns emerge. Old Bering Sea individuals would have heavier  $\delta^{13}\text{C}$  but lighter  $\delta^{15}\text{N}$  averages compared to the two Birnirk samples. Punuk individuals would have the lightest measurements in both categories.

This pattern would be consistent with archaeological reconstruction of subsistence. Punuk culture is associated with large scale whaling. Isotopic values from baleen whales are the lightest of marine mammals tested here, and these lighter values would be reflected in Punuk individuals. Birnirk is characterised by greater seal and reindeer hunting. Although the reindeer signature does not appear, the heavy  $\delta^{15}\text{N}$  value

from Birnirk individuals may reflect a ringed seal diet. Finally, if the Old Bering Sea culture is marked by walrus and seal hunting, then the people should have lower  $\delta^{15}\text{N}$  but heavier  $\delta^{13}\text{C}$  values compared to Birnirk as a result of consuming more walrus.

These patterns are speculative at best. At present, the available data do suggest some differences between cultural periods consistent with archaeological interpretations. More detailed isotopic studies are thus warranted.

## **Chapter 6: Conclusions**

The faunal and human samples from Ekwen provide a unique and interesting set of isotopic data from which both methodological and archaeological interpretations can be inferred. The  $\delta^{15}\text{N}$  results from the faunal data distinguish lower trophic level feeders (walrus and baleen whales) from those higher up the food chain (ringed seals). The differences are in the order of one trophic level ( $\sim 3$  to  $3.5\text{‰}$ ). Bearded seals, which consume both molluscs and fish, have intermediate  $\delta^{15}\text{N}$  values. The food-chain positions established by the isotopic data are as expected based on the known diets of these different species.

Conversely, the proposed trophic level enrichment (of about  $1\text{‰}$ ) for stable carbon isotope analysis is not evident here. High trophic level species, ringed seals, have lighter  $\delta^{13}\text{C}$  values than do lower level species, such as walrus. Instead, the pattern exhibited may be influenced by the migration of some marine mammals, but no conclusions can be drawn from this data.

Isotopic results from human samples are consistent with archaeological interpretations that the prehistoric Asiatic Eskimos (at Ekwen) were totally dependent upon marine protein. Both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values from the human group are extremely heavy. There is every reason to believe that all dietary protein was of marine origin and thus, the  $\delta^{13}\text{C}$  average of  $-11.88 \pm 0.49\text{‰}$  or  $-11.81 \pm 0.38\text{‰}$  (adult average) likely measures total sampling from the marine food chain, or the end point value for a marine diet.

Dependence upon marine resources is expected from a population located along the Arctic coastline and is by no means a new interpretation. However, the heavy  $\delta^{15}\text{N}$  values indicate that these people consumed mostly higher trophic level species. These results suggest that the prehistoric Asiatic Eskimo may not have been as dependent upon walrus as were their historic descendants. Often dubbed as "walrus people," this label apparently does not apply to the prehistoric population.

Dietary differences within the population also were examined. Adult isotopic values vary little, while subadult values tend to fluctuate more. This variation also exists between different bones of the juvenile skeleton. During child and adolescent growth, short term changes in diet may have been recorded in bone that is quickly formed. Without time for this bone to remodel (which would average out these dietary fluctuations), bones would record seasonal, emergency, or special diets.

For infants, a special diet was identified. Infant  $\delta^{15}\text{N}$  values are very high and decrease with age. This is caused by the lactation effect where lactating infants have  $\delta^{15}\text{N}$  values a trophic level higher than those of their mothers. Infants appear to have been weaned in the first few years of life such that by the age of 3 or 4, their  $\delta^{15}\text{N}$  values are in line with adult measurements.

Little variation exists between adult individuals suggesting that diet was homogenous. Adult isotopic values were compared to examine differences between male and female diets and between cultural periods. Ethnographies describe that males ate more reindeer meat and although both  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  averages for males are slightly lighter than those for females, no significant differences exist, suggesting a similar diet. Finally, some changes appear to have occurred between cultural periods as  $\delta^{13}\text{C}$  values become lighter in the later periods. The present data suggests that this line of investigation is promising and dietary changes may exist over time. Patterns

distinguishing the various Eskimo cultures may become apparent with larger sample sizes of later period individuals.

Generally, the diet of the prehistoric Asiatic Eskimos at Ekwen was fairly homogeneous and had changed little within many hundred years of occupation. While little heterogeneity in isotopic values can be expected in an environment where terrestrial protein resources are sparse and marine species abundant, the inhabitants also selectively consumed similar quantities of meat from species of various trophic levels.

## Appendix A: Ekwen Data

Burial <sup>1</sup> Number	Sex	Age (years)	Cultural Period	Bone	Bone Weight (mg)	Collagen Weight (mg)	Collagen Yield <sup>2</sup> (%)	Carbon (%) <sup>3</sup>	Nitrogen (%) <sup>3</sup>	C:N	δ <sup>13</sup> C (‰)	δ <sup>15</sup> N (‰)
212			Birnirk/Punuk	l. parietal	73.05	9.12	12.48	42.6	15.3	2.78	-12.31	20.30
216 - 1	male	30-40		r. parietal	93.56	17.30	18.49	43.1	16.0	2.69	-11.70	19.50
220		6	OBS I	r. parietal	106.14	11.01	10.37	43.4	15.8	2.75	-11.85	19.75
276			OBS II	l. parietal	46.43	3.96	8.53	43.7	15.2	2.88	-11.96	20.36
277				l. parietal	43.10	4.66	10.81	45.5	15.8	2.88	-11.58	19.79
278			Birnirk	l. femur	44.54	1.23	2.76	34.2	11.5	2.97	-12.14	20.02
279		< 2		r. humerus	63.45	6.96	10.97	42.7	15.0	2.85	-11.70	21.55
280		13	OBS II/III	l. parietal	91.80	15.57	16.96	43.7	16.0	2.73	-11.60	18.72
				l. femur	107.35	10.91	10.16	42.5	14.9	2.85	-11.11	19.81
281		4-5	OBS II	temporal	61.11	5.39	8.82	42.4	15.1	2.81	-11.54	20.21
282			OBS II/III	l. parietal	97.28	16.06	16.51	43.5	16.1	2.70	-11.54	20.12
283 - A	female			r. femur	54.37	5.43	9.99	43.6	14.4	3.03	-12.08	19.15
283 - B			OBS II/III	r. femur	44.55	6.03	13.54	46.7	16.3	2.87	-11.74	19.05
283 - B			OBS II/III	mandible	44.72	4.22	9.44	46.3	16.4	2.82	-11.54	20.31
283 - Γ				r. ulna	42.78	5.22	12.20	46.8	16.0	2.93	-11.54	20.25
283 - Д	male		OBS II/III	l. parietal	51.18	6.23	12.17	48.7	16.1	3.02	-12.89	20.02
284 - 1		17	OBS II	r. femur	33.39	0.85	2.55	38.3	12.5	3.06	-12.70	18.15
284 - 2		9±3 mos	OBS II	parietal	146.90	20.47	13.93	43.3	14.7	2.95	-11.69	23.86

Burial Number	Sex	Age (years)	Cultural Period	Bone	Bone Weight (mg)	Collagen Weight (mg)	Collagen Yield (%)	Carbon (%)	Nitrogen (%)	C:N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
285 - A	male			l. parietal	40.41	6.28	15.54	46.3	16.1	2.88	-11.76	19.90
285 - B	female		OBS II/III	r. parietal	86.65	13.58	15.67	43.2	15.2	2.84	-11.48	20.16
				r. humerus	61.19	7.49	12.24	41.8	14.7	2.84	-11.60	18.13
285 - B			OBS II/III	r. parietal	32.26	4.20	13.02	45.6	15.7	2.90	-11.67	20.53
285 - Γ			OBS II/III	r. parietal	32.31	0.85	2.63	46.2	16.3	2.83	-11.79	20.19
286			OBS II/III	l. femur	41.81	0.30	0.72	44.8	13.9	3.22	-12.90	19.28
287	male	35-40	OBS II/III	l. femur	36.83	2.79	7.58	43.9	15.7	2.80	-12.09	19.30
288				l. femur	32.36	1.45	4.48	44.8	14.7	3.05	-11.99	19.47
289	female			l. femur	33.97	4.13	12.16	45.0	15.8	2.85	-11.77	19.42
290			OBS II/III	l. parietal	75.60	8.73	11.55	43.1	14.6	2.95	-12.20	19.00
291	female			r. parietal	89.41	15.80	17.67	43.6	16.0	2.73	-11.48	19.79
292		< 14		fibula	32.28	4.76	14.75	41.9	14.9	2.81	-11.69	19.88
293			OBS II/III	r. femur	47.22	0.20	0.42	41.9	12.9	3.25	-12.28	19.62
294		1.5		l. parietal	45.46	7.17	15.77	42.5	15.1	2.81	-12.09	22.24
295				l. tibia	40.88	0.18	0.44	43.6	14.4	3.03	-12.06	19.97
296			OBS II/III	r. parietal	34.56	3.82	11.05	44.1	15.9	2.77	-11.55	19.65
297	male			r. parietal	30.51	3.80	12.45	45.7	16.1	2.84	-11.82	20.23
298 - 1		1-2		r. parietal	47.54	6.85	14.41	41.4	13.9	2.98	-12.51	20.72
298 - 2		(infant)		temporal	55.58	7.57	13.62	42.6	15.0	2.84	-12.32	20.28
299				r. femur	49.37	0.57	1.15	43.5	15.0	2.90	-12.50	19.94
300			OBS II	frontal	107.59	17.99	16.72	43.0	14.9	2.89	-11.15	18.97
301			OBS II	parietal	166.19	31.12	18.73	43.4	16.0	2.71	-11.30	19.87
302	male		OBS II/III	l. parietal	34.70	4.11	11.84	44.7	15.5	2.88	-11.60	20.25
303			Punuk	l. femur	90.47	0.79	0.87	36.0	11.3	3.19	-13.53	18.97



Burial Number	Sex	Age (years)	Cultural Period	Bone	Bone Weight (mg)	Collagen Weight (mg)	Collagen Yield (%)	Carbon (%)	Nitrogen (%)	C:N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
304 - A			OBS II/III	l. parietal	43.05	5.83	13.54	45.2	15.6	2.90	-11.36	20.59
304 - B				l. parietal	164.46	23.31	14.17	43.0	14.4	2.99	-11.56	19.98
304 - B	female			skull	124.39	9.57	7.69	42.8	15.6	2.74	-11.09	20.66
305				parietal	37.61	4.51	11.99	44.5	15.6	2.85	-11.52	20.96
307	male	35-40		r. temporal	37.88	5.73	15.13	43.9	15.4	2.85	-11.78	21.02
308				l. parietal	34.11	5.61	16.45	45.2	15.7	2.88	-11.55	20.06
				r. tibia	32.82	2.10	6.40	43.2	14.4	3.00	-11.90	19.37
309	female	25-35		parietal	129.12	24.77	19.18	43.8	15.7	2.79	-11.38	20.58
310 - 1	male	35-40		r. parietal	26.83	2.57	9.58	44.6	15.1	2.95	-11.56	19.68
				r. femur	32.92	3.79	11.51	43.5	14.8	2.94	-11.58	20.27
310 - 2	male	18		r. parietal	51.03	7.89	15.46	43.4	15.0	2.89	-11.95	18.76
				r. femur	27.26	3.25	11.92	44.2	15.6	2.83	-11.47	20.13
311	male	20-25		l. parietal	41.44	6.55	15.81	42.2	14.8	2.85	-11.30	19.41
312	female	> 40		parietal	26.40	3.18	12.05	41.5	14.0	2.96	-12.40	19.53
				l. femur	28.89	2.58	8.93	43.3	14.7	2.95	-11.89	20.19
313				r. parietal	27.52	2.15	7.81	44.6	15.8	2.82	-12.01	19.78
314	female	> 40		temporal	32.81	4.87	14.84	41.9	14.3	2.93	-11.44	20.56
315		5±2		l. parietal	36.15	3.24	8.96	41.2	14.5	2.84	-11.67	19.59
				r. femur	37.93	2.44	6.43	46.3	15.6	2.97	-12.98	19.72
316	male	20-25		r. femur	33.46	1.77	5.29	40.4	13.6	2.97	-12.58	18.86
317	female	> 40		l. parietal	36.33	3.00	8.26	43.4	15.3	2.84	-11.48	20.21
318	female	25-35		l. parietal	111.05	20.01	18.02	43.5	15.8	2.75	-11.48	19.53
319	male	30-35	Birnirk/Punuk	r. femur	41.93	2.60	6.20	40.1	14.1	2.84	-12.27	18.96
320	male	30-40		temporal	122.64	19.59	15.97	43.2	15.6	2.77	-11.40	20.18

Burial Number	Sex	Age (years)	Cultural Period	Bone	Bone Weight (mg)	Collagen Weight (mg)	Collagen Yield (%)	Carbon (%)	Nitrogen (%)	C:N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
321	male	25-35		r. parietal	25.59	4.70	18.37	42.6	14.8	2.88	-12.24	20.01
				r. femur	25.27	0.94	3.72	42.0	14.0	3.00	-12.45	19.39
322		6 mos		skull	65.30	4.25	6.51	41.3	13.8	2.99	-13.58	15.22
				l. femur	26.85	2.82	10.50	44.4	15.6	2.85	-12.14	21.18
323	female	20-25		r. parietal	26.10	4.75	18.20	42.1	15.1	2.79	-11.62	19.66
				r. femur	29.85	2.50	8.38	44.9	14.7	3.05	-11.90	19.88
324 - 1	male	> 40		parietal	128.09	17.41	13.59	44.4	15.6	2.85	-12.48	19.75
324 - 2		30-40		l. tibia	62.82	3.61	5.75	39.8	12.6	3.16	-11.88	19.83
324 - 3	male	30-40		frontal	67.53	7.61	11.27	42.8	15.2	2.82	-11.54	18.57
325	female	30-35		r. parietal	24.51	2.47	10.08	43.9	15.3	2.87	-11.78	20.11
326 - 1	female	20-25		r. parietal	36.37	6.45	17.73	47.8	16.3	2.93	-11.68	19.23
326 - 2	male	15±2		tibia	27.11	1.85	6.82	41.5	14.1	2.94	-11.91	20.03
326 - 3	male	17-18		l. femur	30.24	0.75	2.48	37.8	12.3	3.07	-12.25	19.72
327 - 1		12		r. parietal	29.63	5.25	17.72	41.8	15.3	2.73	-11.70	20.68
327 - 2		5-6		radius	25.71	4.64	18.05	41.5	14.0	2.96	-11.50	20.33
327 - 3		10-12		l. femur	33.94	6.03	17.77	42.4	14.9	2.85	-11.42	20.58
328 - 1	female	30-35		l. tibia	38.93	3.65	9.38	43.2	15.5	2.79	-11.88	20.59
328 - 2	female	30-35		l. femur	45.78	0.19	0.42	46.2	16.5	2.80	-11.96	19.70

- 1 Cyrillic letters: А - А      Б - В      В - В      Г - Г      Д - Д
- 2 Collagen Yield = Collagen Weight / Bone Weight × 100%. Given the collagen extraction procedures, only collagen fragments >30 kdaltons are present, and thus these collagen yields may be low compared to other studies.
- 3 Carbon % and Nitrogen % is based on weight.

## Appendix B: Faunal Data

Sample Number	Species (Common Name)	Bone	Bone Weight (mg)	Collagen Weight (mg)	Collagen Yield (%)	Carbon (%)	Nitrogen (%)	C:N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
2	bearded seal	mandible	187.97	31.74	16.89	43.4	15.9	2.73	-12.66	16.37
3	bearded seal	tibia	163.51	26.35	16.12	43.6	16.1	2.71	-12.25	16.04
5	dog	r. tibia	121.65	17.66	14.52	43.9	16.2	2.71	-12.46	19.69
7	dog	r. ulna	66.71	7.57	11.35	43.0	15.3	2.81	-12.60	18.15
8	dog	r. ulna	71.35	10.46	14.66	43.5	15.4	2.82	-11.22	17.31
9	dog	r tibia	59.04	4.96	7.40	41.5	14.3	2.90	-13.14	16.88
11	ringed seal	r. radius	129.88	20.46	15.75	44.0	15.9	2.77	-13.31	17.16
12	ringed seal	r. radius	75.23	5.01	6.66	41.5	14.5	2.86	-13.69	18.88
13	ringed seal (juvenile)	r. radius	100.45	11.04	10.99	42.9	15.3	2.80	-13.73	17.63
14	ringed seal	r. radius	31.85	2.78	8.73	39.8	13.8	2.88	-13.73	17.61
15	ringed seal	r. femur	79.75	3.60	4.51	41.1	12.5	3.29	14.57	14.38
19	walrus	ivory	148.52	15.05	10.13	43.8	15.5	2.83	-11.91	13.73
20	walrus	ivory	208.24	32.79	15.75	44.1	16.5	2.67	-11.85	15.96
21	walrus	ivory	85.25	12.10	14.19	42.9	14.9	2.88	-12.97	14.88
22	walrus	ivory	127.63	21.31	16.70	43.7	16.0	2.73	-11.85	13.10
23	walrus (juvenile)	mandible	305.73	31.20	10.21	44.8	16.1	2.78	-12.06	14.82
24	reindeer	tarsal	350.14	1.28	0.37	41.7	14.9	2.80	-18.39	1.52
25	reindeer	tooth	95.92	10.55	11.00	42.3	15.0	2.82	-17.33	5.11
27	minke whale (juvenile)	vertebra	59.04	4.96	7.40	41.5	14.3	2.90	-14.01	16.08

## **Appendix C: Procedures**

### **Sample Collection**

Bone samples were taken at the same location on the same skeletal element where possible. Most frequently, the parietal bone behind the coronal and sagittal sutures and the femur on the anterior surface at the proximal end of the diaphysis were sampled. Before drilling with small hand-held drills, the surface of the bone was scraped clean. Bone drillings were collected onto clean pieces of aluminum foil, then transferred into labeled eppendorf tubes for storage and transit. Between samples, the drill bit was cleaned by burning with ethanol and scouring with glass fibre wool.

### **Collagen Extraction**

Bone collagen was extracted following the procedures outlined by Longin (1971)(modified by Chisholm *et al.* 1983; Brown *et al.* 1988). About 30 mg of bone or dentin drillings were placed into each prepared extraction funnel. 1) Bone apatite was demineralised by adding 0.25 M HCl to the sample for two days. The acid was replaced after the first day, filtered away with a vacuum pump. 2) To dissolve the collagen, the remaining sediment was soaked in 0.01 M HCl and heated overnight at 58°C. 3) After cooling, the filtrate was transferred into ultrafilters (Amicon, Centriprep-30) and prepared following the manufacturer's instructions. This step removes smaller fragments of

collagen and concentrates the collagen into a few millilitres of solution. 4) The remaining collagen solution was lyophilized or freeze-dried. Lipid removal procedures were not performed for archaeological bone samples.

## Appendix D: Age Categories

In this study, subadults were defined as those individuals under 20 years and were divided into three groups. Infants included those who at the time of death were breast-feeding, weaning, or were weaned but still retained the high  $\delta^{15}\text{N}$  from a breast milk diet. Historically, children from North Alaskan groups were weaned when the next infant was born or as late as four years of age if no child succeeded (Chance 1966). In the Ekwen material, there was a natural gap in age between a two year old infant (#279) and a four year old child (#281). Thus, the cut-off age of three years was both relevant to weaning time and practical.

The next category, *children*, included subadults who had not yet reached puberty (*i.e.* those aged 4-12). Average age for the start of puberty is around 13 years. At this age, the adolescent growth curve begins, boys increase upper arm strength significantly, and girls reach menarche (Tanner 1978).

Finally, *adolescents* were those individuals not yet of the reproductive age (culturally determined) at the time of death (aged 13-19). During these teen years, individuals reached the working age (beginning at 16 years), learning and partaking in hunting and gathering (Krupnik 1993b:46). Historically, men and women did not conceive until the age of 20 years (Krupnik 1993b:46). There was also a gap in the data between an 18 year old and four adults aged 20-25.

Along with cultural and physiological considerations, the age categories were created with the Ekwen data in mind. Given time constraints, Dr. Marija Kozlovskaja determined age estimates quickly and not as thoroughly as would be ideal. Also, gaps in

the data influenced age cut-offs for the subadult categories. While age data was examined in forming these categories, isotopic *results* were not considered in creating these groups.

Many adults also were aged. However there was overlap in age estimates and thus, it was difficult to separate adults into different age categories. Adults are grouped together in one general category.

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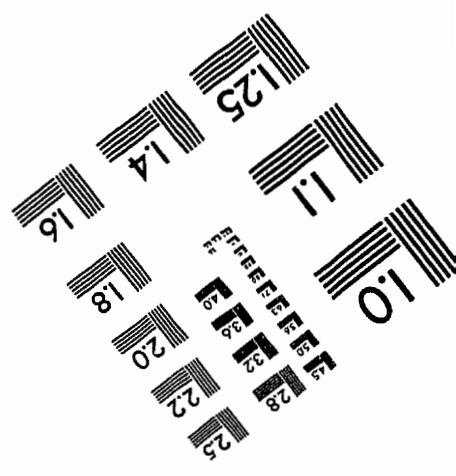
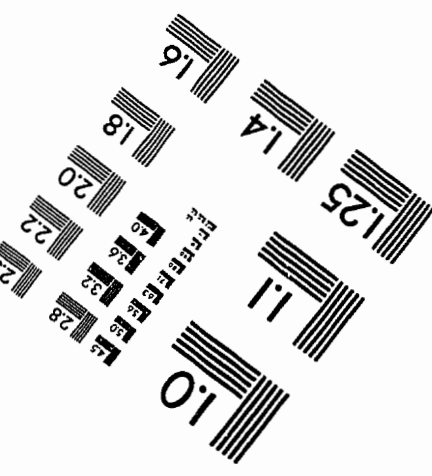
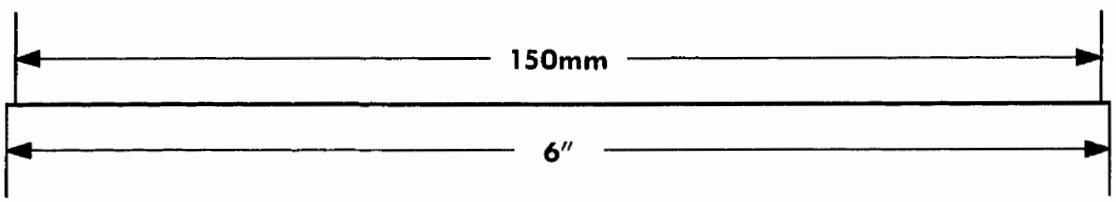
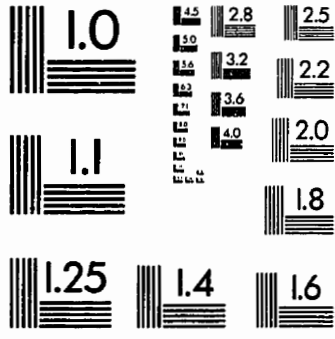
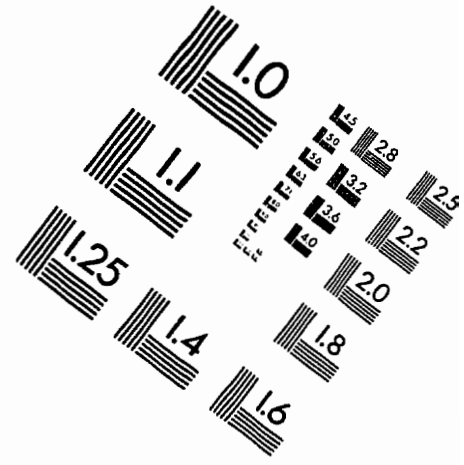
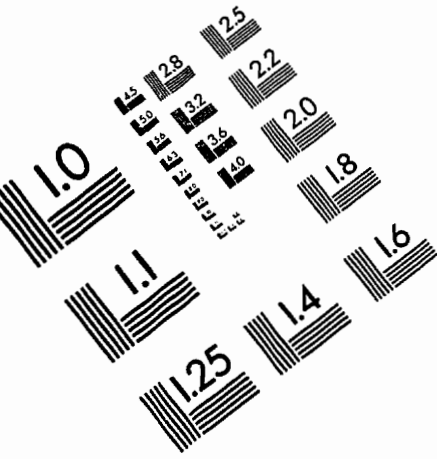
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