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Prehistoric human subsistence patterns in northern Patagonia, argentina: Isotopic evidence for reconstructing diet

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Prehistoric Human Subsistence Patterns in Northern Patagonia, Argentina:
Isotopic Evidence for Reconstructing Diet

by

Scott M. Grammer

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts Department of Anthropology College of Arts and Sciences University of South Florida

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# Table of Contents

LIST OF FIGURES ii

LIST OF TABLES iii

ABSTRACT iv

I. INTRODUCTION 1

II. ARCHAEOLOGY AND ETHNOLOGY OF NORTH-CENTRAL PATAGONIA 7
   Introduction 7
   Physical Environment of Patagonia 13
   Prehistory in Patagonia 16
   Tehuelche Indians of Patagonia 22
   South American Camelids and Stable Isotopes 33

III. METHODS 35
   Stable Isotope Analysis 35
   Natural Variations 44
   Linear Mixing Models and Isotope Routing 46
   Trophic Level Spacing 48
   Preservation and Diagenesis 49
   Isotope Analysis 50

IV. PATAGONIAN SAMPLE ANALYSIS 53
   Treatment of Skeletal Samples 53

V. DISCUSSION 58

VI. CONCLUSION 67
   Future Research 72

VII. REFERENCES 75
List of Figures

Figure 1: Patagonia, Argentina 2
Figure 2: Sites and Relative Location Samples were Recovered 3
Figure 3: Patagonian guanaco 6
Figure 4: Rhea 6
Figure 5: Previously Investigated Archaeological Sites 8
Figure 6: Penguin colony 11
Figure 7: Julieta Gomez-Otero excavating human skeletal remains 12
Figure 8: Valdés Peninsula 14
Figure 9: Nuevo Gulf Coast 14
Figure 10: Sea-lion colony 21
Figure 11: Penguin 21
Figure 12: Tehuelche hunting with bolas 31
Figure 13: Native Patagonians wearing their guanaco skin robes 32
Figure 14: Variation in stable nitrogen and carbon isotopes of food resources found in the Americas 40
Figure 15: Skeletal remains excavated on Valdés Peninsula 51
Figure 16: Scatterplot of carbon and nitrogen isotope data 61
Figure 17: Scatterplot nitrogen vs. carbon isotopes 64
List of Tables

Table 1: Cultural sequence for Argentina                          24
Table 2: Patagonian Human Skeletal Samples Recovered          54
Table 3: Isotopic Data for Patagonian Human Skeletal Remains    56
Table 4: Isotopic Data for Patagonian Human Skeletal Remains    57
Table 5: Carbon and Nitrogen isotope values for samples of grave goods from Pisagua, Chile 59
Table 6: Stable Isotope Data for Human Skeletal Samples, Tierra del Fuego and Cuyon 65
Table 7: Isotope Data on human bones from Fuego-Patagonia     71
Prehistoric Human Subsistence Patterns in Northern Patagonia, Argentina: Isotopic Evidence for Reconstructing Diet

Scott M. Grammer

ABSTRACT

This study investigates the isotopic signatures of human skeletal remains that were recovered from several sites along the coast and inland in the north-central Patagonian region of Argentina. Human skeletal remains, dating from 2500 BP through the early historic period, are examined to determine the relative significance of terrestrial and aquatic food resources and subsequently, the extent to which coastal food resources were exploited by indigenous Argentinians. Carbon and nitrogen isotopes contained within human bone collagen and apatite are measured quantitatively to determine the relative significance of marine and terrestrial foods. This study, one of the first isotopic studies of indigenous diet on the Atlantic coast of Argentina, is significant because it provides initial results to be used for the reconstruction of aboriginal subsistence patterns prior to and after European contact. Results of this study, based upon preliminary data, suggest that there are isotopic correlations that support archaeological evidence recovered from rock shelters in southern Patagonia. Archaeological remains and ethnohistoric accounts indicate that prehistoric hunter-gatherers (the Tehuleche), located inland or along the coast,
were primarily reliant upon terrestrial food sources such as the guanaco, rhea, and other terrestrial fauna. The isotopic evidence suggests that for coastal indigenous people, marine food resources were as important a food resource as terrestrial foods.
I. INTRODUCTION

The purpose of this pilot study is to examine fundamental assumptions about food procurement strategies employed by prehistoric and proto-historic hunter gatherers in Chubut, the north-central Patagonian region of Argentina (Figure 1). It has been designed only to begin the establishment of a ‘baseline’ of values for the region. As this region has received little attention archaeologically (Gomez-Otero 1993; Gomez-Otero et al. 2001), it is hoped that the combined use of archaeological and ethnographic evidence from southern Patagonia and stable isotope data will provide additional insight into food procurement strategies employed by prehistoric hunter-gatherers of north-central Patagonia. This study was initiated as a partnership between Julieta Gomez-Otero of the Centro Nacional Patagónico, Provincia del Chubut, Argentina, and Dr. Robert H. Tykot of the University of South Florida and was funded in part by the National Geographic Society.

Archaeological investigations within Patagonia have, until recently, been limited in depth and scope (e.g. Bird 1938; Steward and Faron 1959) and have relied heavily on comparisons of sites that are separated by great distances. In an effort to understand better the human occupation within the north-central region of Patagonia (Figure 2), this study incorporates isotopic data (derived from
Figure 1: Patagonia, Argentina
Figure 2: Sites and Relative Location
Samples were Recovered
human skeletal remains recovered from an inland and coastal sites) into current proposed models (e.g., Borrero 1997; Mena 1997; Gomez-Otero 1993; Gomez-Otero et al. 2001) of human occupation of both coastal and inland sites. Recent attention (e.g. McEwan, Borrero, and Prieto 1997) based on combined archaeological and ethnographic data has made clear that prehistoric and historic human occupation of Patagonia was diverse and cannot be adequately explained by large scale models as proposed by Bird and Steward. Recent studies (e.g. Gomez-Otero 2001) have begun to focus on local and regional cultural variations exhibited by inhabitants of Patagonia.

The use of stable isotopes within archaeological contexts is significant as it can be used independently to support or refute current understandings of human subsistence strategies that are based solely upon ethnohistoric or archaeological data, or a combination of both. More important, stable isotope analysis is testable and repeatable and can be used in archaeological sites where bone preservation is adequate for analysis. Stable isotope analysis is one more tool available to archaeologists and has become essential to all dietary and nutritional studies of past human cultures. The technique uses skeletal remains recovered from both coastal and inland sites to determine the relative significance of marine and terrestrial foods in the human diet. This is accomplished by examining both human skeletal remains and faunal remains recovered from archaeological contexts. Stable isotopes of both carbon and nitrogen that are ‘locked’ in skeletal remains are ‘unlocked’ and examined.
Isotopes are atoms that contain the same number of protons and electrons but have a different number of neutrons (Masterton and Hurley 1997). They are naturally occurring and can be used in a variety of archaeological applications, including carbon dating. Stable isotopes do not transmute into other elements as do radioactive isotopes. Isotopes of a given element behave similarly in chemical reactions but they react at different rates because of their different atomic weights (Katzenberg 1992:106). Once isotope ratios of a given skeletal population are determined, new insights such as migration patterns or seasonal habits can be gained about a given population. Combined with additional ethnohistoric and archaeological evidence, a more complete picture of past human behavior and adaptation can be proposed.

Archaeological and ethnohistorical evidence recovered from sites in Patagonia suggests that hunter-gatherers, ancestors of the Tehuelche Indians, were highly mobile and primarily dependent upon the guanaco (Lama guanacoe; Figure 3) and rhea (Rhea americana and Pterocnemia pennata; also locally known as the choique and ñandú; Figure 4) for food, clothing, tools, and shelter (Gomez-Otero 1993; Borrero 1997; Mena 1997; Steward and Faron 1959; Skottsberg 1913).
Figure 3: Patagonian guanaco (photo by Gomez-Otero)

Figure 4: Rhea (photo by Glasgow Zoo)
II. ARCHAEOLOGY AND ETHNOLOGY OF NORTH-CENTRAL PATAGONIA

Introduction

Archaeological investigations conducted by Junius Bird at two cave sites, Cueva Fell and Cueva Pali-aike (Figure 5) during the 1930s (Bird 1938; Borrero and McEwan 1997; Gomez-Otero 1993) established regional cultural and faunal sequences for the area spanning eleven thousand years. Bird established occupation sequences for five principal periods that are still employed by archaeologists today (Borrero and McEwan 1997). Following Bird, Osvaldo Menghin (1952; 1971) surveyed the Río Gallegos Basin and reported on lithic assemblages recovered archaeologically. Additional survey was conducted in western Patagonia, including the continuation of work at Cueva Fell by French archaeologists (Emperaire et al. 1963; Gomez-Otero 1993). As a result of archaeological investigations throughout the middle and latter half of the 20th century, cultural typologies have been developed for much of Patagonia and adjacent regions. Building on this foundation, archaeologists throughout the 1980s have developed interpretations that are heavily influenced by ecological models. Two such examples include work conducted by Borrero et al. (1985) and Nami (1984), where ecological factors such as availability of local fauna and
7stone for the manufacture of tools are put forth to explain adaptive strategies employed by prehistoric hunter-gatherers (Gomez-Otero 1993).

Figure 5: Previously Investigated Archaeological Sites
Archaeological evidence recovered from apparent year-round occupation sites such as Los Toldos, Cueva Fell and Cueva Pali-aike (Figure 5), as well as seasonal or “residential camp” (Gomez-Otero 1993:339) sites such as Potrok-aike, Juni-aike, El Volcán, and Peggy Bird (Mena 1997; Borrero 1997; Gomez-Otero 1993; Steward and Faron 1959) suggests that the Tehuelche preferred the guanaco over all other prey and were extremely thorough in the uses of all portions of the carcass. This tradition began with the well-known extinction of Pleistocene megafauna and continued through the proto- and historic periods in Patagonia. Mena (1997) points out that there is a clear difference in archaeological remains (e.g. tool assemblages) that suggests the development of hunting strategies and reliance on the guanaco as early as 8000 BP. Guanacos are ubiquitous in Patagonia and their behavior makes them a predictable and reliable resource for human exploitation. Guanaco are territorial and in rough terrain limit their range to less than 20 km (Borrero 1997:76; Franklin 1982) making their movements easily predicted and are always available for procurement (Borrero 1997). Questions arise, however as to the additional components of the hunter-gatherer diet and to what degree, if any, were non-terrestrial food resources consumed. Gomez-Otero (et al. 2001, 1993) report that inland rock shelter sites (e.g. Juni-aike and Potrok-aike) show that faunal remains are dominated by the guanaco and that all portions of the animal are represented. In the case of Potrok-aike, MNI based on the nearly 1700 specimens recovered suggests the butchering and consumption of 5 adult and 3
juvenile guanacos (or possibly reversed based on diaphyses recovered on site) with the presence of 10 birds of varying size, 32 coruros (small, rat-like rodents present in coastal scrub vegetation along the coast to elevations of 3500 m), 21 crecetids (rodents) and 3 unidentified carnivores (Gomez-Otero 1993). At Juni-aike, MNI based on the nearly 1400 specimens recovered include remains of 5 to 7 guanacos, 16 birds of varying size and 2 cricetids (Gomez-Otero 1993). What is most important to note is that guanaco comprised the bulk of the skeletal remains that were recovered, displayed butchering marks and have clearly undergone secondary and tertiary butchering. Additional faunal remains include migratory birds such as ducks, as well as ibis, birds of prey, hares, foxes, mice, and pumas (Figure 6; Gomez-Otero 1993:329). Evidence recovered from coastal sites suggest that locally available marine food resources contributed to the diet and include limpets, mussels, whelks, southern king crabs, whales (cetacaeans), and sea lions (pinnipeds; Gomez-Otero 1993:329). The presence of archaeological sites both inland and along the coast supports a model of nomadic, hunter-gather economy employed by the Tehuelche and their ancestors. Faunal remains recovered from inland archaeological sites in southern Patagonia (see Figure 2), such as those at Cueva Fell, Potrok-aike, and Juni-aike (Borrero and McEwan 1997; Gomez-Otero 1993; Bird 1938), clearly demonstrate a reliance on the guanaco for a variety of needs, including food, clothing, and shelter. Although there have been few reported archaeological investigations at coastal areas (Gomez-Otero et al. 2001), faunal evidence (e.g.
whale, sea lion) does suggest that the systematic exploitation of coastal marine resources was well established by 6000 B.P. (Mena 1997:51; Mena also suggests that coastal sites throughout the South American continent have been obliterated or covered by the rise in sea level following the last Ice Age). Faunal remains of marine shells at Las Buitreras (see Figure 5) support interpretations that there was at least seasonal exploitation of coastal marine resources and that these foods were used to supplement traditional terrestrial foods, particularly the guanaco (Mena 1997; see also Borrero 1997; Borrero and McEwan 1997).
Figure 7: Julieta Gomez-Otero excavating human skeletal remains (photo provided by Gomez-Otero)
Physical Environment of Patagonia

This study examines skeletal remains excavated by Julieta Gomez-Otero (seen here in Figure 7) from archaeological sites located in the north-central Chubut region of Patagonia, Argentina (see Figure 2). Patagonia is a region that includes Tierra del Fuego, located between 39° and 55° S latitude, and encompasses over 900,000 km² (McCulloch et al. 1997; Borrero and Franco 1997). Patagonia is bounded to the west by the Andes and to the east by the Atlantic ocean. The region is characterized by a steppe environment, with 40 to 100 meter terrace reliefs (Figures 8 and 9). There is ample evidence of extensive geologic activity, specifically volcanism and orogenesis (mountain building) resulting from the subduction of the Pacific plate under the South American plate (creating the Andean mountain range) and a strike-slip fault in the Magellan Straight and the Beagle Canal (McCulloch et al. 1997). The resultant heat and pressure has created the Andes and accounts for the large number of volcanos. Stone available for human use that is naturally formed, metamorphosed, and deposited includes basalt, quartz, quartzite, volcanic tufts and obsidian (McCulloch et al. 1997; Borrero Casiraghi, and Yacobaccio 1985). In some areas the ground is characterized as being covered with basalt, quartz, quartzite, and flint (Gomez-Otero 1993). Topographically, the region was heavily modified by the expansion and subsequent retreats of Andean glaciers prior to the Holocene. Glacial lakes, moraines, and steppe terrain were created following the final retreat of the glaciers. Vegetation patterns that have predominated during prehistory and the historic period are heavily influenced by topography,
Figure 8: Valdés Peninsula (photo by Gomez-Otero)

Figure 9: Nuevo Gulf Coast (photo by Gomez-Otero)
temperature, and rainfall (McCullogh et al. 1997). Annual rainfall measurements range from over 5000 mm near the Andean mountain range to less than 200 mm in the north-central and northeastern portions of the region (McCullogh et al. 1997; Gomez-Otero et al. 2001). Regional variations are extreme as they are affected by storm tracks that move in from the Andes. Patagonian vegetation includes the evergreen Magellanic forest, deciduous Magellanic forest, Patagonian steppe, and Magellanic tundra. Environmental zones include the Andean desert, the Magellanic Oceanic domain, and the steppe or grassy plain (Horowitz 1990:38). Where skeletal samples were recovered, the area is characterized by a semi-arid, grass plain that has likely continued to become progressively more arid since the end of the Pleistocene, particularly during the past 1000 years (Gomez-Otero et al. 2001; Gomez-Otero 1993).

Temperatures in Patagonia tend to be slightly milder as compared to those of similar latitudes in the northern hemisphere (due in large part to the fact that the land mass is surrounded by ocean; Horowitz 1990). Average annual temperatures range from 2.3°C to 7.4°C (36°F to 45°F; Gomez-Otero 1993) inland and 12°C to 14°C (54°F and 57°F; Gomez-Otero et al. 2001) along the coast. During fall and winter, the climate tends to be cold and dry with frequent frosts and light snow fall, while spring and summer tend to be cool with constant and sometimes gusty winds (Gomez-Otero 1993). Although the temperatures may be milder, it is clear that the Atlantic and Pacific oceans surrounding the southern tip of South America greatly impact overall weather conditions,
influencing vegetation patterns. This in turn determines migration patterns of
game, and subsequently, cultural adaptations by humans who depend on game.

Prehistory in Patagonia

The peopling of the southern end of South America is generally accepted
to have been as early as 11,500 BP (Borrero and McEwan 1997; Borrero and
Franco 1997; Nami 1995; Bruhns 1994). Dates from a variety of sites within
Patagonia and Tierra del Fuego are consistent and are quite acceptable when
considering recent dates from Monte Verde (12,500 BP; see Figure 5) reported
by Dillehay (1997). Otherwise, archaeological evidence for the whole of
Patagonia is scarce and this is particularly true of the northern reaches. In
addition, archaeological studies that have been completed are largely focused on
rock-shelter as opposed to open-air sites (Gomez-Otero et al. 2001; Borrero and
Franco 1997; Nami 1995; Gomez-Otero 1993). (Although it is unclear from the
literature available as to why rock-shelter sites have been the primary focus of
study, it is possible that since there is some protection from the environment,
these sites are better preserved than open-air sites). The overall lack of data
extends through all time periods, especially early sites, and may very well be
attributed to the lack of field work in the region (Borrero and McEwan 1997).
Another consideration is the flooding and possible destruction of coastal sites
that resulted from the rise in sea level following the retreat of the Pleistocene
glaciers (Borrero and Franco 1997).
Early hunter-gatherers in the region are believed to have relied on Pleistocene megafauna in much the same way as is documented for North America. However, when considering the two continents, there exists a fundamental difference in the availability and the diversity of animals available for procurement. Evidence recovered from sites such as Cueva Fell, Cueva Lago Sofia 1, Cueva del Milodon, and Tres Arroyos suggest a low species diversity during the late Pleistocene (McCullogh et al. 1997; Bruhns 1994). Low species diversity (as compared to the rest of the continent) is thought to be the result of arid conditions, particularly in the northern and eastern regions, as well as the overall landmass being too small to support large numbers of megafauna. Faunal evidence, or the lack of highly diverse faunal evidence, recovered in association with human remains excavated from Cueva del Milodon supports this conclusion. Typical megafauna assemblages include the remains of ground sloths (Mylodon darwinii), horses (Onohippidium saldiasi), a horse-like mammal (Macrauchenia sp.), a large cat (Panthera sp.), as well as guanaco (Lama guanacoe; McCullogh et al. 1997:28-29). McCullogh et al. (1997) suggest that these animals may well have been better suited for the climatic variation (e.g. rainfall amounts) that exists in the region. They postulate that Patagonian Pleistocene megafauna were generalists and could withstand periods of aridity as well as temperature extremes. As is the case in the northern hemisphere, the extinction of the Pleistocene megafauna in Patagonia seems to have been the result of a variety of factors, including changes in environmental conditions,
human predation, and destruction of habitats (McCullogh et al. 1997; Borrero and McEwan 1997).

The extinction of megafauna in Patagonia did not result in radical changes in lithic technology as is often believed to be the case in the northern hemisphere (e.g. Clovis technology is abandoned while Folsom is adopted). In the North American plains, for example, the use of the Clovis tool kit seemingly stops at approximately the same time as the mass extinctions of megafauna (Fagan 1995). From the discussion above, early Holocene hunter-gatherers in Patagonia relied on a variety of megafauna as well as medium-sized mammals such as the guanaco. It is arguable that the extinction of the megafauna simply resulted in a shift in procurement strategies that focused on the more predictable guanaco, without necessitating changing the lithic technology employed. Clearly, procurement and use of the guanaco was an early adaptation and one that continued throughout prehistory and the early historic period. Seemingly, guanaco was the primary food source between 12,500 and 500 years BP (Borrero 1985; Gradín 1980).

As is the case in many prehistoric populations (Fagan 1995), the dispersal of Patagonian hunter-gatherers tended to follow vegetation and game patterns, as well as areas of locally available raw materials for tools, food, etc. Movements of humans are not considered to have been uniform but more likely as the filling in of empty spaces or niches, with subsequent generational dispersion associated with band fission (Borrero and McEwan 1997:34). Archaeological evidence suggests that, as a result, humans adopted a
generalized diet that took advantage of nearly all of the resources available, albeit with a primary reliance upon the guanaco (Borrero and Franco 1997; Gomez-Otero 1993). Throughout much of Patagonian prehistory, there was little specialization in hunter-gatherer economies because of the wide dispersal of food resources. As mentioned above, the climate in the north-central region is cool and dry with highly variable topography. Constant spring and summer winds combined with arid conditions limit vegetation growth, thereby limiting areas at which grazing mammals congregated to feed. Borrero and Franco (1997) suggest that with the scarcity of ecological niches available for medium and large grazing mammals, human population increased and their dispersal was difficult because of the limited availability of game. Overall, Patagonian hunter-gatherers lived in a region with a fairly low productivity and a highly variable climate (Borrero and Franco 1997).

Through time (i.e., the Archaic period, roughly equivalent to North American sequences), there is a small, gradual increase in hunter-gatherer population. This interpretation is largely based on archaeological evidence, specifically a diversification in the tool kit where use of shell and bone augment stone (Castro and Tarrago 1992). Throughout the Archaic period there is the beginning of adaptive diversification, such as the adoption of the bola in the north and the use of canoes and harpoons in the south (Borrero and Prieta 1997; Gomez-Otero 1993). Change could be considered slow as small improvements were made to facilitate the hunter-gatherer way of life. Enough of them took place over the millennia that clear distinctions in food procurement strategies and
technologies can be discerned between the populations of the northern plains and Tierra del Fuego.

Gomez-Otero (1993) relates that two distinct adaptive strategies developed in the southern cordillera and the northern continental portions of Patagonia and were well in place at the time of European contact in the late 19th Century near Tierra del Fuego (and the Beagle Canal). The different adaptations employed by native Patagonians became sufficiently specialized that clear cultural differences are distinguishable in each region. Hunter-gatherers living in the southern (Magellan-Fuegan) channel appear to have adopted an economy based primarily upon maritime resources. Archaeological and ethnohistoric evidence (e.g. Pero 2002, Steward and Faron 1959 and Bird 1938) supports this conclusion. Faunal remains and tool remnants recovered from coastal sites offer direct evidence of the use of maritime food resources (e.g. sea lions, penguins, shell fish; Figures 10 and 11) as well as a change in technology better suited for maritime adaptation (Borrero 1997; Gomez-Otero 1993). Canoes and the presence of bone fish hooks and harpoons at southern archaeological sites suggest a culture that was becoming highly specialized to a maritime way of life at the time of European contact (Borrero 1997). Three groups of natives living in the Magellan-Fuegan channel, collectively called the Aónikenk by Europeans, were recognized as having adopted a maritime way of life. These include the Yámana of the Beagle canal region of Tierra del Fuego, the Kawéskar of western Tierra del Fuego, and the Chonos of the outlying islands of Tierra del Fuego (Borrero 1997).
Figure 10: Sea-lion colony (photo by Gomez-Otero)

Figure 11: Penguin (photo by Gomez-Otero)
In contrast, the continental hunter-gatherers of the central and northern portions of Patagonia developed an economy based primarily upon terrestrial resources. Inland archaeological sites such as guanaco processing sites (Borrero 1985) and rock shelter sites (cf. Gomez-Otero 1993) clearly indicate a primary reliance on guanaco and other terrestrial fauna. Coastal sites exist and, although there are clear indications that marine foods (shellfish, pinnipeds) were consumed, the sites tend to be small in size, suggesting seasonal exploitation of marine foods (e.g. at Las Buiteras). By some estimates, there was a clear, systematic seasonal exploitation of coastal resources as early as 6000 BP (Mena 1997). Combining archaeological evidence with ethnohistoric accounts, it seems clear that the terrestrial hunter gatherers of the continental Patagonia were highly mobile and, although primarily reliant on guanaco, exploited a number of resources from a variety of areas on a seasonal basis. Further, two groups of terrestrial hunter-gatherers had developed enough cultural differences to be distinguished from one another at the time of European contact. These groups include the Ona of northern Tierra del Fuego and the Patagones or Tehuelche of central and northern Patagonia.

Tehuelche Indians of Patagonia

Much of Patagonian prehistory can be considered to be continuous, albeit regionally diverse. As a result, for archaeologists, it is difficult if not impossible to assign cultural attributes to specific time periods or phases of prehistory (Mena 1997). What is clear is that the hunter-gatherer way of life was successful
enough in both the north and south that it remained largely unchanged until the arrival of Europeans.

One of the earliest attempts to assign cultural sequences based on artifact attributes was produced by Junius Bird (1938). Based on cultural deposits discovered at Cueva Fell and Pali-aike (see Figure 5), it has apparently lost favor with some archaeologists in the region because it does not account for the cultural diversity present throughout Patagonia and is dated. Mena (1997) offers the observation that Patagonian prehistory, although diverse, was continuous and therefore not easily subdivided into periods or phases. Bird's phases are, however, occasionally used to clarify time periods (cf. Gomez-Otero 1993). The phases Magellanes I through Magellanes V (as refined by Willey 1971; assigned to Paleo-Indian through Contact Period) were largely dependent upon point types, associated debitage, and faunal remains (e.g. the presence versus absence of megafauna or the presence versus absence of “fish tail” type projectile points - a style of point that tapers at the base as opposed to notched or shouldered). Though still employed by archaeologists in Patagonia, the Magellanes cultural sequences have largely fallen out of favor. For the purposes of this study, the specific attributes of the individual cultural sequences are largely unnecessary as the project is focused on the Magellanic Phase IV and V or late prehistoric and early historic periods (approximately 4500 BP to mid-19th century; Gomez-Otero 1993). A generalized sequence accepted for Argentinian archaeology (Bruhns 1994) is shown in Table 1.
Table 1: Cultural sequence for Argentina (from Bruhns 1994)

<table>
<thead>
<tr>
<th>Date Range</th>
<th>Cultural Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD 1450 - Contact</td>
<td>Imperial</td>
</tr>
<tr>
<td>AD 1100 - AD 1450</td>
<td>Regional Development</td>
</tr>
<tr>
<td>200 B.C. - AD 1100</td>
<td>Formative</td>
</tr>
<tr>
<td>500 B.C. - 200 B.C.</td>
<td>Archaic (pre-agricultural although some cultivation, continued nomadic hunter-gathering traditions)</td>
</tr>
<tr>
<td>5000 B.C. - 500 B.C.</td>
<td>Pre-agricultural (nomadic hunter-gatherers)</td>
</tr>
<tr>
<td>8000 B.C. - 5000 B.C.</td>
<td>Paleoindian</td>
</tr>
</tbody>
</table>

The Tehuelche have been characterized as highly mobile hunter-gatherers with a highly successful way of life with a rich oral tradition (McEwan, Borrero, and Prieto 1997). They clearly developed a way of life and technologies associated with their lifestyle, one that had very limited dependence on changing lithic technologies (McEwan, Borrero, and Prieto 1997; Mena 1997; Gomez-Otero 1993). From the turn of the Holocene, there is a continuation of their hunter-gatherer way of life with an ever broadening economic base and subsequent technological changes associated with economic changes (Mena 1997). Evidence from a number of archaeological sites (cf. Gomez-Otero 1993; Borrero 1985; Bird 1938) with the presence of flake tools, bola stones, as well as an increase in types of faunal remains suggests a possible diversification in faunal resources that were exploited. It has been postulated that specialized tool kits developed early on, particularly for guanaco hunting. Mena (1997) relates that blades, flakes, and scrapers associated with the Casapedrense lithic
tradition, dating from 7000 BP to 3000 BP, may be evidence for specialized tool kit development for guanaco hunting. However, given the overall lack of diagnostic projectile points associated with the Casapedrense, it is difficult to definitively say whether it is in fact a distinct tradition, much less evidence for an early specialized tool kit. Bows and arrows, although present and seemingly an independent invention in South America, were not a preferred hunting weapon and were virtually replaced by bolas when the horse was adopted (Pero 2002). Bolas and bola stones were apparently the preferred method of dropping guanaco and choique, particularly during the historic periods when horses were more available to the Tehuelche (Mena 1997; Bird 1938). At some rock shelter sites, lithics are generally comprised of locally available materials selected for their expediency. Evidence recovered from sites such as Los Toldos 3 supports this conclusion. Throughout the strata at Los Toldos, expedient tools were apparently used and discarded shortly thereafter. This is particularly true of recovered side and end scrapers that have not been retouched. In addition, there are hammerstones and cores that have been recovered from Los Toldos that show little use and few flake scars respectively. As has been previously discussed, locally available raw materials suitable for stone tool use includes basalt, quartz, and quartzite. Obsidian is also available and seems to have been highly prized by prehistoric hunter-gatherers throughout the region. Obsidian points seem to have been heavily curated and when evidence of obsidian is found, it is typically in the form of small pressure flakes (Borrero and Franco 1997). In sum, lithic evidence from Tehuelche archaeological sites continues to
suggest a highly mobile lifestyle (hundreds of miles over the course of a year; Pero 2002) and in conjunction with faunal remains, continues to suggest a generalized diet.

Faunal remains from archaeological sites give an indication of the variety of animals the Tehuelche used for food and raw material resources. In addition, the faunal remains show that the cultural adaptations and strategies in use changed very little throughout prehistory. The only real variability in faunal assemblages are seemingly associated with variability in locally available resources (e.g. pelagic fish and shellfish were used at sites near the coast and rivers as opposed to inland sites). Once again, the one main constant is the presence of guanaco at nearly all archaeological sites. Typical faunal assemblages (see Horowitz 1990; Gomez-Otero 1993, Borrero 1997; Mena 1997) throughout central and northern Patagonia may include gastropods (e.g., limpets, whelks), cetaceans, pinnipeds (particularly Otaria flavescens the South American sea lion), as well as pelagic and shore fish (e.g. silversides similar to mullet). Freshwater aquatic resources included mussels and a variety of fish (e.g. native trout such as Galaxias maculatus). Avifauna available for procurement included wild goose, ducks, seagulls, penguins, condors, nandu, choique, and a variety of birds of prey. In addition to guanaco, other mammals such as the gray and red fox, rats and mice could be utilized. Following European contact, sheep and rabbits were also taken by indigenous people (Mena 1997; Steward and Faron 1959). Ethnographic evidence (Mena 1997) suggests that certain cuts of meat and vital organs were consumed raw at the kill.
or processing site. Those cuts not consumed following the kill were transported back to the camp site where women roasted (over an open fire or by inserting heated stones into the carcass and roasting inside-out) or boiled the meat. Armadillos were also consumed after roasting whole in the shell (Pero 2002). Ethnographic accounts describe how the Tehuelche supplemented the meat in their diet by a “kind of spinach” (Pero 2002:109;) and a variety of tubers (said to have resembled beets and yams), fungi, and wild fruits. Tubers were also typically roasted, boiled, or ground into powder and consumed.

Ceramics have been determined to have entered into the Tehuelche territory by approximately 1000 BP and are presumed to have been influenced by either Andean cultures or the Mapuché speakers to the north (a group that was to play a large role in changing traditional lifeways of the Tehuelche after European contact), specifically near the Río de Plata. Supporters of the Andean influence on Tehuelche point to the presence of similar geometric motifs in ceramics, rock art, ceremonial stone axes, and feathered cloaks. Ceramics, although innovative, apparently did not affect the subsistence base of the Tehuelche as basket and other storage containers (e.g. shells) continued to be preferred. Mena (1997) suggests that ceramics were adopted for use as prestige items and only in some cases were recognized for their utility in the cooking of smaller game (e.g. rabbits). The selective use of pottery is apparent in the archaeological record as sites either contain some pottery or are completely devoid of pottery. Mena argues that the presence or absence of pottery from sites in north-central Patagonia could support seasonal use of sites. He also
suggests that there are issues of ceramic functionality (i.e. prestige versus utility) that may force the examination of just which animals (aside from the guanaco) and how intensively animal by-products were used (Mena 1997).

Housing and shelter employed by the Tehuelche apparently ranged so widely in style and size that there is no characteristic “dwelling” that can be described as exclusively Tehuelche. Borrero (1997) relates that Tehuelche shelter ranged from semi-permanent dome-shaped huts to temporary vertical windbreaks. In some instances, congregations of toldería or a collection of large, elaborate tents (toldos) made of guanaco skins were erected (Pero 2002). Tents, usually raised (and dropped) by women, were typically erected facing east (as the prevailing winds are from the west) upon entering or departing a camp site. Posts were usually set on the ground (and as a result, little trace is left of the posts in the form of molds or stains) in several rows, diminishing in height from front to back, and fastened with leather cords. Bone pegs or stakes were then inserted into the ground to help support the frame. (Although it is theoretically possible to find peg or stake molds, one would have to be extraordinarily lucky to uncover such evidence of occupation. In addition, it could be unlikely that more than one would survive, making it unlikely to reconstruct the dwelling or series of dwellings at a given site). Cover typically consisted of thirty to forty guanaco skins with the fur facing the elements (Pero 2002). Screens made of skin were then hung in the interior, employed for privacy. Clearly, these types of structures present a challenge to the archaeologist. Tents and vertical windbreaks that are set up temporarily would be difficult if not impossible to identify as very little
ground disturbance save for bone pins inserted in the ground would accompany such structures. Other activity areas such as hearth features or midden sites would be extremely difficult to identify as these sites were typically only temporary in nature.

The traditional lifeways of the Tehuelche remained largely unchanged until contact with Europeans. The European “Age of Exploration” is well documented and indigenous people of South America were adversely affected in much the same way as documented for indigenous people of the rest of the Americas. Some of the more notable European explorers, navigators, and scientists to have traveled to the region included Hernando de Magallanes (voyage from 1519-1521), Francis Drake (1578), Walter Raleigh (1586), James Cook (1769), and Charles Darwin (1831-1836). Although Europeans began sailing around Tierra del Fuego as early as the 16th century, impacts of European activity do not become obvious until the mid- to late-19th century (Horowitz 1990). There were no serious attempts at colonization in the region until the late 19th century. This is in large part due to the overall lack of interest in the area early on by the Spanish as it was viewed as unsuitable for navigation, poor for agriculture, and did not contain gold or silver. Sea traffic did become more regular during the 18th century as advances in navigational technologies made the voyage less dangerous, however, contact between Europeans and local inhabitants was relatively rare until missionaries began to colonize the region during the 19th century (McEwan et al. 1997).
The effects of European contact on indigenous populations in the Americas are widely documented. For the Tehuelche, the most notable, lasting effect on their culture was the introduction and subsequent adoption of the horse (Mena 1997; Bird 1938). The adoption of the horse and the accompanying changes in the Tehuelche way of life were viewed by Bird (1938) as closely paralleling that of the Plains Indians of North America. Although the base of the Plains Indian and Tehuelche economy was centered on different types of game, bison and guanaco, some behavioral characteristics of the Plains Indians and the Tehuelche were very similar. Both guanaco and bison grazing, herding, and mating practices are easily predicted. Because of this, hunters can easily procure these animals and rely on them as a resource in the future. With the adoption of the horse and the associated increase in mobility, the Tehuelche could move more rapidly over greater distances, haul more meat, and could thus more intensively hunt guanaco (Figure 12). The adoption of the horse changed all facets of life for the Tehuelche from technology and mobility to their economy and social organization. Changing priorities from a subsistence-based economy to one of creating surplus for the establishment of trade networks and commerce with the “outside world” (i.e. Europeans) was possible as the horse allowed for greater mobility and increased procurement of guanaco (Mena 1997; Bird 1938). Tehuelche adults typically only wore one garment, a robe made from guanaco skins like those seen in Figure 13 that measured approximately five and one half feet long by four and one half feet wide. This robe or mantle kai was draped over the shoulders and reached to the knees (Pero 2002).
Figure 12: Tehuelche hunting with bolas (George C. Musters *At Home with the Patagonians, 1871; adapted from Steward and Faron 1959)*
The robe was worn fur side in during the winter, fur side out during the summer and bundled around the body, leaving the chest exposed. The robes were typically constructed of skins obtained from young guanaco (they were softer), sewn together with sinew, and decorated with geometric designs with a variety of different colored pigments (Pero 2002).

The Tehuelche typically adorned themselves in a variety of ways (Pero 2002). These ranged from the use of horse hair extensions used by women, braiding of hair, head bands, strings of beads worn around the neck, and brooches. Children of both sexes usually had their ears pierced by the age of four. The Tehuelche also adorned themselves on special occasions with rhea
feathers and painted geometric designs on their skin using a variety of pigments and animal grease. These designs were often tattooed into the skin as well.

The basic unit of organization was the band which consisted of a number of family units (Pero 2002). Bands resided, traveled, hunted, and gathered together. They were not rigid constructs as individuals and families were free to leave and join other bands at any time. Bands recognized territory and “formalities” (i.e. social rituals) when coming into contact with neighboring bands (Pero 2002:112). Bands are reported to have moved seasonally to take advantage of game and the availability of fresh water and good grazing areas for their horses. Ethnographic accounts report that bands typically wintered near sea level and spent summers near the Andes (Pero 2002).

South American Camelids and Stable Isotopes

Given the above discussions concerning guanaco and the importance that it played in Tehuelche culture, it is worth considering the guanaco in greater detail. The guanaco has been a dietary mainstay and an important resource for a variety of purposes, including tools and skins for shelter. Guanaco are territorial and range over approximately the same areas throughout the year. In particularly difficult terrain, the guanaco range diminishes and is often less than 20 km². As a result, humans could depend on the predictability of the guanaco and travel to locations where hunting conditions were favorable to take guanaco (Borrero 1997).
Few studies have examined in detail the grazing behavior of guanaco. Those studies that have examined their feeding behavior have concluded that they spend as much as 84% of their lives grazing and feeding themselves (Amaya 1985). Specifically, this time is spent foraging for and consuming a variety of weeds, grasses, shrubs and in some cases, cacti. What is significant to this study is that the guanaco diet is highly variable in terms of the stable isotope signature that could in turn affect the human stable isotope signature contained within the skeletal samples discussed previously. Guanaco feed on a variety of plants (Gramineae) that use both the C\textsubscript{3} and C\textsubscript{4} photosynthetic pathways. C\textsubscript{3} plants available to guanaco include Festuda pallescens, Poa lanuginosa, Hordeum spp., Poa ligularis, Bromus spp., and Stipa spp. C\textsubscript{4} plants include Distichlis spp. and Sporabolus (Amaya 1985). Although this could pose a problem, differing contributions of both C\textsubscript{3} and C\textsubscript{4} plants consumed by guanacos and subsequently humans can be taken into account. The testing of the ratio of stable isotopes (\textsuperscript{13}C) alone in human skeletal remains will show a more positive value, showing contributions from both C\textsubscript{4} plants and guanaco consumers, as well as seafood. However, if one examines both collagen (using \textsuperscript{15}N) and apatite results, a comparison of dietary adaptations can be made from what becomes a picture of the whole diet that was consumed. This will be discussed in greater detail later.
III. METHODS

Stable Isotope Analysis

Simply stated, stable isotope analysis is a method of determining the overall significance of the variety of marine and terrestrial foods in a given organism’s diet. Stable isotope analysis as an analytical technique is well established and was originally “predicated on the assumption that all dietary macronutrients contribute equally to carbon in bone collagen” (Ambrose et al. 1997:344; Schwarcz 1991; Schoeninger 1989). Although all dietary macronutrients have been proven not to contribute equally to carbon in bone collagen, it has been shown that they do in bone apatite. In other words, you are what you eat. For archaeologists, this understanding of diet, as it pertains to human beings, can provide key insight into cultural adaptations exhibited by past peoples. Bone chemistry studies can provide an independent database that can augment interpretations based solely on ethnohistorical and archaeological data (Pate 1995).

Stable isotope analysis has provided archaeologists with a method of procuring data with which to make inferences concerning specific individuals or whole burial populations. Questions surrounding cultural attributes such as nutrition, mortality, morbidity, and differential access to food resources based
upon gender or age can be addressed and meaningful interpretations can be made (Lambert and Grupe 1993; Katzenberg 1992). Archaeological investigation and recovery of phytoliths and pollen can only specify the types of plants that were present in an archaeological site. Isotopic studies can identify and quantify the food resources that were consumed over an organism’s lifetime and, combined with AMS dating, issues of context between faunal remains and the people who consumed them are largely solved (Tykot and Staller 2002). This is due in part to the fact that bone collagen (the protein portion of bone) and apatite (the mineralized portion of bone or biological carbonates) are constantly absorbed and reformed over an organism’s lifetime. This fact ensures that isotopic studies of collagen and apatite can provide a picture of the organism’s diet over at least the last several years of its life. Preserved human bone in is approximately 70% inorganic and 30% organic by weight. Of this organic component, approximately 90% is collagen. In archaeological contexts, the prospect for the preservation of bone collagen is high as bone collagen has been found in fossils dating back to the Devonian period (Katzenberg 1992). Aside from bone collagen, apatite recovered from tooth enamel can also be examined and, as the isotopic ratios are locked at the time of tooth formation, can provide a snapshot of the individual’s diet at that time (e.g., human diet can be examined at periodic stages in life if the accompanying teeth are examined). As the technique is founded in fundamental principles of general chemistry and biology, methods are testable and data are repeatable.
Archaeologists and biological anthropologists recognized the potential for reconstructing past dietary pathways using stable isotopes of carbon and nitrogen during the late 1970’s. Two landmark studies paved the way for dietary reconstruction. Nier and Gulbransen (1939) demonstrated that land plants were depleted in $^{13}$C relative to CO$_2$ in the atmosphere and that the depletion was variable. This was based on the principle that carbon dioxide in the atmosphere is comprised of normal carbon ($^{12}$C) as well as other carbon isotopes (e.g., $^{13}$C and $^{14}$C), stemming from the well known carbon cycle (i.e., carbon dioxide in the atmosphere is used by plants). Photosynthesis is the process by which plants reduce atmospheric carbon dioxide (CO$_2$) into organic molecules (e.g., sugars such as glucose) using a C$_3$ or C$_4$ photosynthetic pathway (Calvin-Benson pathway or Hatch-Slack pathway, respectively). A third method, often employed by cacti, is referred to as CAM or Crassulacean Acid Metabolism (an alternative method of photosynthesis). Bender (1968) hypothesized that there was a relationship between photosynthetic pathways (i.e., how plants manufacture food) and carbon isotopic ($^{13}$C) values (Katzenberg 1992). In addition, it is well established that plants acquire necessary nutrients from the soil and air as they absorb (fixate) nitrogen and manufacture food during photosynthesis. Stable isotopes of nitrogen ($^{14}$N, $^{15}$N) and carbon ($^{12}$C, $^{13}$C) are deposited in plants, consumed by animals, and are passed to consumers in sequences known as a food chain or pyramid. A typical food chain is made up of three to five stages comprised of the producer (e.g., a photosynthetic plant), primary consumer (e.g., an herbivore), secondary consumer (e.g., a carnivore), followed by a tertiary
consumer (e.g., carnivore or human). Sequences in the food chain are referred to as trophic levels and it is the human component or, upper trophic level, which is of most importance to archaeologists. The differences in carbon and nitrogen ratios that are ultimately deposited in bone tissue can be measured using mass spectrometry conducted on samples less than one gram in size.

Recognizing the potential anthropological applications, Vogel and van der Merwe (1977); van der Merwe and Vogel (1978), pioneered the use of isotope analysis in archaeology when they demonstrated that stable isotope ratios could be used to detect maize consumption by prehistoric populations in North America. The significance of the van der Merwe and Vogel (1978) study is that it establishes the usefulness of carbon isotopic data in determining $C_3$ and $C_4$ plants (i.e., how the plant manufactured its food during photosynthesis) contributions in the human diet (Katzenberg 1992). These two pathways can be measured due to differential fractionation (i.e., the break-up of carbon dioxide molecules; Lee-Thorp et al. 1989) of carbon isotopes during CO$_2$ fixation. This fact is particularly useful to archaeologists when one examines and compares methods of photosynthesis employed by plants, particularly corn (zea mays). Corn is one of only a few $C_4$ plants in North America, whereas most other edible native species are of the $C_3$ variety (van der Merwe 1978). Additional $C_4$ plants of note include sugar cane and sorghum, whereas $C_3$ plants include rice, root crops, vegetables, fruits, and nuts, all of which are common plant resources available as food today and during prehistory (Ambrose et al. 1997). Additional early contributions to the development of stable isotope analysis to reconstruct
prehistoric diet include controlled animal feeding experiments that clearly showed the isotopic relationship between diet and animal tissue, particularly bone (DeNiro and Epstein 1978; Katzenberg 1992).

In the case of nitrogen isotopes, values are largely dependent on how plants obtain nitrogen. Plants usually obtain nitrogen through a symbiotic relationship with nitrogen-fixing bacteria or obtain nitrogen (in the form of nitrates) directly through the soil (DeNiro and Schoeninger 1983; Ambrose 1991). Nitrogen isotope ratios are more variable than those of carbon due to rainfall and other environmental factors. Nitrogen isotope ratios available for consumption within marine environments are also highly variable. This is due to the differential isotope ratios found within aquatic environments (also known as the reservoir effect; Little 1998).

Isotope analysis is accomplished by examining preserved bone collagen, bone apatite, or tooth enamel for ratios of nitrogen and carbon isotopes ($^{15}\text{N}$ and $^{13}\text{C}$), ratios are determined as follows:

\[
^{13}\text{C} = \frac{^{13}\text{C/}^{12}\text{C sample} - ^{13}\text{C/}^{12}\text{C PDB standard}}{^{13}\text{C/}^{12}\text{C PDB standard}} \times 1000
\]

Note: PDB is Peedee Belemnite standard for carbon

\[
^{15}\text{N} = \frac{^{15}\text{N/}^{14}\text{N sample} - ^{15}\text{N/}^{14}\text{N AIR standard}}{^{15}\text{N/}^{14}\text{N AIR standard}} \times 1000
\]

Note: AIR is standard of atmospheric nitrogen
Bone collagen is produced primarily from the protein portion of the diet, whereas apatite is produced from a combination of protein, carbohydrates, and dietary fat (Ambrose and Norr 1993; Tieszen and Fagre 1993). For this study, $^{15}\text{N}$ and $^{13}\text{C}$ from non-human consumers are established to account for natural variations of isotopic values that occur within food resources available for human consumption and so that comparisons can be made with human isotope values.

![Figure 14: Variation in stable nitrogen and carbon isotopes of food resources found in the Americas (Norr 1997:22 Figure 4)](image-url)
Figure 14, compiled by Norr (1997), shows isotopic variations contained in common plants and animals available for human consumption in the Americas. The $^{15}\text{N}$ in bone collagen is used to distinguish between terrestrial and aquatic protein sources. The $^{13}\text{C}$ in bone collagen distinguishes between terrestrial and marine protein sources and is particularly useful when trying to determine protein obtained from C$_3$ and C$_4$ food chains. The $^{13}\text{C}$ in bone apatite and tooth enamel provides isotopic values reflecting proportions of both protein and carbohydrates and fats in the diet (Magoon et al. 2001; Norr 1995; Little and Schoeninger 1995; Ambrose and Norr 1993).

Since van der Merwe’s early research, archaeologists and physical anthropologists have continued to employ the technique with increasing confidence that the data provide an accurate snapshot of prehistoric human diet. The technique has been employed world wide, particularly throughout the Americas (e.g., Tykot and Staller 2002, Little and Schoeninger 1995; Buikstra and Milner 1991; Schoeninger et al. 1983; and others). Today, many archaeological studies, particularly nutrition and coastal adaptation studies, are considered incomplete if stable isotope analysis is not included. This acceptance stems from the continued applications of stable isotope analysis throughout the 1980s and 1990s by Ambrose (1990, 1991, 1993), Ambrose and DeNiro (1987, 1989), Ambrose and Norr (1993), Chisolm et al. (1983), Parkington (1991), Schoeninger (1985), Sealy et al. (1987), Tauber (1981), Tieszen and Fagre (1993), Walker and DeNiro (1986). These authors have shown that stable isotope analysis has grown in significance from just determining the presence of
maize in the diet to contributing to the understanding of human reliance on marine and terrestrial food resources. This understanding has facilitated archaeologists’ ability to make interpretations about past environments as well as migration patterns of both humans and the game they pursued (Katzenberg 1989, 1992, 1993; Sealy and van der Merwe 1986; Ambrose and DeNiro 1987, 1989; Sealy et al.1987). Throughout the last two decades, the use of stable isotope analysis in archaeological studies has continued to grow. This growth and, more important, the acceptance of the technique and its applications in archaeology have ensured its place as another fundamental part of interpreting human skeletal remains. Current studies such as Magoon, et al. (2001) show that stable isotope analysis is now often included with visual (e.g., microscopic, x-ray) examinations of skeletal remains that previously only included studies of osteological and dental pathologies. Other research (e.g., Katzenberg 1993, Lee-Thorp et al. 1989, van der Merwe et al. 1993) demonstrates the usefulness of reconstructing dietary pathways using stable isotopes to make inferences about past resource procurement strategies.

These studies, however, could not have been possible without significant research surrounding the use of stable isotopes throughout the latter 1980s and early 1990s. Fundamental questions concerning the limitations of stable isotopes were raised and subsequently addressed through laboratory experiments. Early observations posed by DeNiro and Schoeninger (1983) included three issues surrounding sampling of preserved bone for analysis. They recognized that oftentimes in archaeological contexts the amount of human
skeletal remains available for destructive analysis is small. They also recognized that, in most burial contexts, it is rare to recover the same bones from different individuals (e.g., femur from individual one versus cuneiform from another individual). And last, DeNiro and Schoeninger recognized that skeletal remains are often mixed and represent different individuals of both sexes. Chisolm et al. (1983) recognized the need to account for variations in isotopic consumption from various food sources, as well as the need to account for physiological differences that may result in different ratios (if any). Chisolm et al. (1983) also recognized problems of diagenesis (the replacement of bone minerals with local minerals) and the need to establish standardized extraction techniques. Tieszen and Fagre (1993) recognized that in addition to the issue of diagenesis, stable isotope ratios could vary due to genetic and environmental variations in plants and the metabolic routing of dietary carbon to an organism’s tissues.

The most significant of these questions concerning the adoption and use of stable isotope analysis include analysis of natural variations of carbon isotopes, linear mixing models (LMM) and routing, effects of trophic level on isotope ratios, as well as bone preservation and diagenesis. In short, the past two decades have seen increasing attention paid to variability of both carbon and nitrogen isotope values as well as attempts to control and explain variations in values.
Natural Variations

A host of environmental and genetic factors have been recognized to impact \(^{13}\)C values and include the following: recycled and respired CO\(_2\), declining irradiance, water stress, osmotic stress, nutrient stress, and temperature stress (Tieszen 1991). It has been demonstrated (Smith and Epstein 1971) that the photosynthetic pathway is the source for \(^{13}\)C fractionation and the values result in a bimodal distribution with mean values between -28% and -26% for C\(_3\) plants and between -14% and -12% for C\(_4\) plants (Tieszen 1991). A given plant’s \(^{13}\)C value will fluctuate depending on the \(^{13}\)C value contained in ambient CO\(_2\) within a given ecological zone. This ambient value can be lowered as a result of the release of CO\(_2\) that results from respiration by organisms in a given ecological niche or from \(^{13}\)C-depleted organic matter. This factor becomes increasingly important when examining isotopic values recovered from plant or animal tissues in areas where free mixing of the atmosphere is restricted (e.g. rainforest; van der Merwe and Medina 1991; Tieszen 1991). Restriction of the free mixing of air results in increased depletion of \(^{13}\)C values. This is manifest in organic tissues with \(^{13}\)C values being more negative than those values determined from areas without restricted atmospheric mixing (Tieszen 1991). This trend can also be seen within a restricted free mixing environment (such as the Amazonian rainforest) where more negative values are recorded for plants that grow on the floor as compared to those that comprise the canopy of the Amazonian rainforest (van der Merwe and Medina 1991). This has been coined the “canopy effect.”

Estimates of the impact of the canopy effect or reassimilation of respired CO\(_2\)
are as high as an increased depletion value of 8‰ (Medina et al. 1986; Tieszen 1991). (For example, using the range of values previously mentioned, $^{13}$C values could thus be expected to range from -36% for C$_3$ plants and -22% for C$_4$ plants). These values can be further affected by irradiance as, in the case of rainforest environments, sunlight penetration is greatly reduced, minimizing photosynthesis. Although established as an independent environmental factor affecting $^{13}$C values in field experiments (Mulkey 1986; Tieszen 1991), irradiance and reassimilation of respired CO$_2$ often occur together in nature and can be expected to further decrease isotopic values (Tieszen 1991).

Water stress also affects $^{13}$C and $^{15}$N values, particularly in arid or semi-arid environments. For naturally occurring vegetation as well as domesticates, $^{13}$C values can be expected to be enriched and increase as much as 6% (Tieszen 1991). Osmotic stress (which can be related to water stress as lack of sufficient water will impact osmosis, the diffusion of water in plant cells) is manifest almost identically to water stress, though changes in $^{13}$C values are estimated to be as high as 10% (Tieszen 1991). For the case of nitrogen ratios, values often increase in regions that are hot and dry relative to conditions that are cool and moist. In addition, there is often an increase in values associated with the step-wise enrichment within the trophic ladder (see below; Ambrose 1991).

In locations where temperatures vary from the optimum, CO$_2$ uptake is reduced and is ultimately reflected with a decrease in $^{13}$C values. This is proposed by Tieszen (1991) to be of significance when assessing values for
plants (and their consumers) in high latitudes that may be growing at non-optimal temperatures. Tieszen is supported in this hypothesis by Stuiver and Braziunas (1987) when they report an increased fractionation with latitude for a group of tree species (Tieszen 1991:234).

This discussion of natural variations in $^{13}$C values is important to archaeologists because they must consider past environmental conditions that existed when the sample organism was alive. Factors discussed above, specifically heavily forested areas and water stress, could significantly alter $^{13}$C values. In addition, considering archaeological contexts, one must consider how ambient CO$_2$ values have changed with industrialization by western cultures during the 19$^{th}$ century. Evidence for global warming (greenhouse effect) is well documented and results in increased CO$_2$ in the atmosphere. Additional evidence from ice core data recovered from Antarctica (Tieszen and Fagre 1993; Friedli et al. 1986) and tree ring data (Keeling et al. 1979) support the conclusion that $^{13}$C values have decreased globally by 1.5‰. This decrease has become well recognized and is commonly taken into account when reporting on archaeological contexts (e.g. Gomez-Otero et al. 2001).

Linear Mixing Models and Isotope Routing

Although metabolic processes and how dietary components take part in the production of essential amino acids has been understood for some time, it was unclear as to what exact proportions of dietary components (carbon and nitrogen) were deposited in bone tissue. To examine further how dietary
components were deposited in tissue, a series of controlled feeding experiments (DeNiro and Epstein 1978; DeNiro and Schoeninger 1983; Ambrose and Norr 1993; Tieszen and Fagre 1993) have been conducted. DeNiro and Epstein’s (1978) work closely examined $^{13}$C values found in bone apatite in mice. DeNiro and Schoeninger (1983) conducted experiments with rabbits. They extracted bone collagen from different bones from the same individual and the same bones from several individuals. They concluded that $^{13}$C and $^{13}$N values in bone collagen were not significantly different, regardless of where the collagen was obtained.

Following Krueger and Sullivan’s (1984) work on mixing, Schwarz (1991) recognized isotopic variability in food sources and that fractionations must be determined. To explain better the ratios of dietary carbon deposited in collagen and bone apatite, a Linear Mixing Model (LMM) was proposed (Schwarz 1991). The basic premise of the LMM is that it assumes proportions of dietary components make uniform contributions to the isotope ratios found in bone. In contrast, Chisolm (1989) suggests that dietary protein was in fact routed towards the manufacture of protein in an organism’s tissues.

In response, Ambrose and Norr (1993) conducted a series of nine controlled feeding experiments on rats to determine if mixing or routing did indeed explain the presence of carbon in bone collagen and apatite. (Rats were selected as their digestive physiology is similar to human physiology). They determined that the LMM could not account for carbon ratios found in bone collagen but could explain values found in bone apatite. They determined that
routing does in fact occur and that bone collagen is formed primarily from the protein portion of the diet, whereas bone apatite is formed from components of the whole diet (proteins, fats, and carbohydrates).

Trophic Level Spacing

Primary consumers, secondary consumers, and tertiary consumers all ingest carbon and nitrogen that were originally found in soil or air. Through the trophic ladder, the ratio of stable isotopes (contained within soil and air) in foods consumed changes and becomes more concentrated in consumers' tissues. Experiments by DeNiro and Epstein (1981), Macko et al. (1982), and Minagawa and Wada (1984) show that $^{15}$N values of bone collagen are enriched by 3‰ relative to the controlled diet test subjects were fed. This supported the existence of a trophic level effect for nitrogen isotopes (Schoeninger 1985:516). This observation is thus 3‰ higher. $^{15}$N values for each subsequent trophic level with herbivore values 3‰ higher than plants consumed and carnivore values 3‰ higher than herbivores consumed. The case is similar for carbon isotopes. DeNiro and Epstein (1978) and Tieszen, Boutton, Tesdahl, and Slade (1983) demonstrated that $^{13}$C values in bone collagen are enriched between 3-5‰ (Schoeninger 1985). However, further investigations (Schoeninger and Deniro 1983; Little and Schoeninger 1995; Ambrose and Norr 1993; Ambrose et al. 1997) indicate that nitrogen isotopes are in fact enriched along the trophic ladder while carbon isotopes are not. A carbon isotope trophic level effect is only
documented to exist from animals found from a single food web as opposed to among food webs (Schoeninger 1985; Ambrose et al. 1997).

This trophic-level relationship also exists within the bone collagen and apatite of sub-adult humans who are being breast-fed. Evidence indicates that nitrogen enrichment takes place within individuals who are being breast fed and that the enrichment reverts back to a “normal” value when the individual is weaned (Katzenberg 1992).

Preservation and Diagenesis

In archaeological contexts, preservation is one of the foremost issues that an excavator can face. Although bone collagen can be preserved for millions of years, its preservation is dependent upon the burial environment (Katzenberg 1992). Some environments are not suitable for the preservation of organic remains. This must be taken into account when collecting human skeletal remains for isotopic studies (Pate 1995; Tieszen and Fagre 1993; Tieszen 1991; Ambrose and Norr 1993; Schwarz 1991; Chisolm et al. 1983; Lee-Thorp and van der Merwe 1991). It has been well established in geological contexts that elements and minerals contained in groundwater can replace those found in rock. The same holds true for skeletal remains. Bone collagen and apatite can be preserved for thousands of years if deposited in favorable areas such as seen in Figure 15 (Katzenberg 1992; Ambrose 1991). What is of particular concern to archaeologists conducting isotopic studies is whether there is enough bone collagen present to extract and whether there are contaminants (most common in
archaeological contexts are humic acids, consisting of decayed plant matter.) If ground water has facilitated the replacement of carbon atoms within the bone matrix, it is possible that the bone has essentially turned to rock, rendering it useless for analysis. Ground water contains carbonates (e.g., HCO$_3^-$) that are often deposited in bone tissue as calcite (CaCO$_3$; Lee-Thorp and van der merwe 1991; Ambrose 1991). It has been demonstrated that field observations and chemical treatment of the bone can largely nullify the effects of diagenesis (Katzenberg 1992; Ambrose 1990; Koch et al. 1997).

Isotope Analysis

The past twenty years have seen significant challenges to the credibility and usefulness of stable isotope analysis. Given the research discussed above, it is clear that questions about the variation in values and the mechanisms behind carbon and nitrogen deposition in bone tissue have been addressed. Questions surrounding sampling, preservation, and treatment of samples have also been widely addressed. In short, stable isotope analysis is widely accepted and is extremely useful in reconstructing diet and in some cases, reconstructing prehistoric environments.

First and foremost, $^{13}$C values recovered from bone collagen primarily reflect the protein portion of the diet. The $^{13}$C values recovered from bone apatite reflect the whole diet (protein, fats, and carbohydrates) and can account for the types of plants consumed in a given ecosystem (e.g., whether there is the presence of a C$_4$ plant such as maize). The $^{15}$N values can help ascertain the
presence of marine foods in the diet. Relative values of all three can help determine the significance of terrestrial foods versus marine and or freshwater aquatic foods in the diet, and in specific regions, can help determine whether maize or some other $C_4$ plant was a contributor to the overall diet.
To ensure that these values will stand up to scrutiny when employing this technique in any archaeological study, several fundamental issues must be understood or assumptions met. Environmental and genetic conditions, as well as a trophic level effect, can explain isotopic variability. Preservation of the sample is also a key element in ensuring enough material is available for analysis. These factors can be explained by establishing (when possible) a base-line of values that are representative of the ecosystem from which an archaeological sample was recovered. Given the possibility that that ecosystem is no longer in existence, modern analogues can be used if the industrialization effect ($1.5^{\circ}$‰ depletion of $^{13}C$) is taken into account. (Patagonia today is largely unaffected by industrialization, however pollutants are present worldwide that could affect values and subsequently, are taken into account) Sample preservation and the presence or absence of diagenesis, although significant, can be minimized through chemical treatment and selection of samples from the archaeological site. Comparisons can then be made as to which dietary components were included in a given organism’s diet.
IV. PATAGONIAN SAMPLE ANALYSIS

Treatment of Skeletal Samples

Samples representing eleven individuals were recovered by Gomez-Otero (Gomez-Otero et al. 2001) and submitted to Dr. Robert H. Tykot. The samples were prepared by this author according to well accepted treatments (Ambrose 1990; Lee-Thorp et al. 1989; Koch et al. 1997) to prepare bone samples for analysis in a stable isotope ratio mass spectrometer. Archaeological sites where the human skeletal remains were recovered are shown in Figure 2. Sex and age of the individuals were determined by Gomez-Otero’s research team prior to their submission to the University of South Florida. The samples were comprised of four males, from 20 to over 50 years of age, and five females, from 20 to 50 years of age. Two juveniles of indeterminate age were also recovered. The individuals, the location from which they were recovered, their sex, age, and antiquity are included in Table 2 (Gomez-Otero et al., 2001). The bone samples were well preserved and pieces of compact bone were cut from the whole bone (e.g. tarsal, clavicle, and rib–bones) as only 1-2 grams are needed for collagen extraction. Dry weights were recorded after the cleaning of the external surfaces of the bone. Each individual sample was then submerged in its own beaker of distilled water (to prevent possible cross-contamination) and placed in an
ultrasonic cleaner to remove any macro-contaminants missed during cleaning or present within the bone marrow matrix. Once free of visual contamination, samples were dried at 60°C.

Table 2: Patagonian Human Skeletal Samples Recovered

<table>
<thead>
<tr>
<th>Site</th>
<th>Location</th>
<th>AMS Date</th>
<th>Sex</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calle Tehuelches</td>
<td>Coast</td>
<td>2410 ± 50</td>
<td>F</td>
<td>20 - 34</td>
</tr>
<tr>
<td>El Elsa</td>
<td>Estuary</td>
<td>1990 ± 50</td>
<td>F</td>
<td>25 - 49</td>
</tr>
<tr>
<td>El Golfito #1</td>
<td>Coast</td>
<td>770 ± 50</td>
<td>M</td>
<td>20 - 34</td>
</tr>
<tr>
<td>El Golfito #2</td>
<td>Coast</td>
<td>770 ± 50</td>
<td>M</td>
<td>unknown</td>
</tr>
<tr>
<td>Gastre #1</td>
<td>Inland</td>
<td>350 ± 50</td>
<td>indeterminate</td>
<td>juvenile</td>
</tr>
<tr>
<td>Gastre #2</td>
<td>Inland</td>
<td>350 ± 50</td>
<td>indeterminate</td>
<td>juvenile</td>
</tr>
<tr>
<td>La Azucena #1</td>
<td>Coast</td>
<td>880 ± 50</td>
<td>F</td>
<td>20 - 34</td>
</tr>
<tr>
<td>La Azucena #2</td>
<td>Coast</td>
<td>880 ± 50</td>
<td>F</td>
<td>35 - 49</td>
</tr>
<tr>
<td>Playa del Pozo</td>
<td>Coast</td>
<td>1540 ± 50</td>
<td>M</td>
<td>50+</td>
</tr>
<tr>
<td>Punta León</td>
<td>Coast</td>
<td>1050 ± 50</td>
<td>F</td>
<td>20 - 34</td>
</tr>
<tr>
<td>Rawson (El Elsa)</td>
<td>Riverine</td>
<td>Modern</td>
<td>F</td>
<td>35 - 49</td>
</tr>
</tbody>
</table>

Following a twenty-four hour drying period, samples were weighed, and then immersed in 0.1 M NaOH (sodium hydroxide) to remove organic contaminants (i.e. humic acids) that may have been present followed by three days in a 2% HCl (hydrochloric acid) solution to demineralize the bone. After
repeating the NaOH treatment, fatty components of the bone samples were then dissolved using a 2:1:0.8 mixture of CH$_3$OH (methanol), CHCl$_3$ (chloroform), and water. Following each chemical treatment, samples were rinsed thoroughly with distilled water to ensure all chemicals were removed. Bone remnants (i.e. collagen pseudomorphs; Pseudomorph is defined where one mineral chemically replaces another mineral without changing the external form) were then freeze-dried for a period of twenty-four to forty-eight hours. High collagen yields verified the initial observation that the samples were in fact in a good state of preservation. Freeze dried pseudomorphs were analyzed using a Carlo Erba CHN analyzer coupled with a VG Prism II stable isotope ratio mass spectrometer. The spectrometer measures the abundances and masses of isotopes in the form of ions. The sample is vaporized and the resultant gas is ionized, ions are accelerated, and accelerated ions are separated according to their mass using a magnetic field, an electrostatic analyzer, or both. Separated ions are then counted by a detector within the spectrometer and these are subsequently reported by the machine (Katzenberg 1992:110). In this study, acceptable ratios of elemental C:N were produced during combustion in the mass spectrometer, confirming sample preservation.

Bone apatite samples were also prepared from whole bone. Cleaned whole bone (using methods previously discussed) was powdered using a Spex ball mill. Approximately 10 mg of powder were immersed in a 2% NaOCl (sodium hypochlorite) solution for 72 hours to dissolve organic components. Nonbiogenic carbonates were then removed using a 1.0 M buffered
CH₃OOH/NaOOH₃C (acetic acid/sodium acetate) solution for 24 hours. Purified apatite samples were analyzed using a multi-prep individual acid bath accessory coupled to the mass spectrometer.

Table 3 shows results for both collagen and apatite samples. Data are reported relative to the PDB and AIR standards, respectively. Precision is ± 0.1

Table 3: Isotopic Data for Patagonian Human Skeletal Remains

<table>
<thead>
<tr>
<th>Site</th>
<th>¹³C - Bone Collagen</th>
<th>¹³C - Bone Apatite</th>
<th>¹⁵N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calle Tehuelches</td>
<td>-15.8</td>
<td>-8.2</td>
<td>17.2</td>
</tr>
<tr>
<td>El Elsa</td>
<td>-17.6</td>
<td>-11.4</td>
<td>14.1</td>
</tr>
<tr>
<td></td>
<td>-17.8</td>
<td>-7.3</td>
<td>12.7</td>
</tr>
<tr>
<td>El Golfito #1</td>
<td>-16.4</td>
<td>-9.2</td>
<td>14.2</td>
</tr>
<tr>
<td>El Golfito #2</td>
<td>-16.0</td>
<td>-10.2</td>
<td>13.7</td>
</tr>
<tr>
<td>Gastre #1</td>
<td>-18.9</td>
<td>-9.4</td>
<td>12.0</td>
</tr>
<tr>
<td>Gastre #2</td>
<td>-17.6</td>
<td>-12.7</td>
<td>16.5</td>
</tr>
<tr>
<td>La Azucena #1</td>
<td>-13.2</td>
<td>-14.3</td>
<td>17.4</td>
</tr>
<tr>
<td></td>
<td>-13.8</td>
<td>-13.3</td>
<td>16.8</td>
</tr>
<tr>
<td>La Azucena #2</td>
<td>-14.1</td>
<td>-9.1</td>
<td>17.2</td>
</tr>
<tr>
<td>Playa del Pozo</td>
<td>-17.4</td>
<td>-9.2</td>
<td>13.5</td>
</tr>
<tr>
<td></td>
<td>-17.1</td>
<td>-7.0</td>
<td>12.3</td>
</tr>
<tr>
<td>Punta León</td>
<td>-15.4</td>
<td>-10.8</td>
<td>18.9</td>
</tr>
<tr>
<td>Rawson (El Elsa)</td>
<td>-14.2</td>
<td>-14.2</td>
<td>13.8</td>
</tr>
</tbody>
</table>
Table 4: Isotopic Data for Patagonian Human Skeletal Remains: $\mu$; $\sigma$

<table>
<thead>
<tr>
<th>Site</th>
<th>$^{13}$C - Collagen</th>
<th>$^{13}$C - Apatite</th>
<th>$^{15}$N</th>
</tr>
</thead>
<tbody>
<tr>
<td>coastal (8)</td>
<td>-15.6± 1.6</td>
<td>-10.4± 2.4</td>
<td>15.1± 2.1</td>
</tr>
<tr>
<td>inland (2)</td>
<td>-18.3</td>
<td>-11.1</td>
<td>14.3</td>
</tr>
</tbody>
</table>

$\mu$ - mean; $\sigma$ - standard deviation for $^{13}$C and ± 0.2 for $^{15}$N. (Individuals from El Elsa, La Azucena #1, and Playa de Pozo have two sets of data; Gomez-Otero et al. 2001). Table 4 shows mean and standard deviation for $^{13}$C in bone collagen and apatite, as well as for $^{15}$N.
V. DISCUSSION

This pilot study is designed to test fundamental assumptions about prehistoric and historic hunter-gatherer adaptation in the north-central region of Patagonia, Argentina. Current understanding based upon both archaeological and ethnographic data suggests that these highly mobile hunter-gatherers, ancestors of the Tehuelche, were primarily dependent upon the ubiquitous guanaco for food. Guanaco were a resource used for a variety of purposes and were supplemented as a food resource with locally available plants and animals. Current interpretations suggest that while camped along coastal sites, aboriginals would have taken advantage of and consumed locally available marine food resources in addition to the terrestrial staples. Conversely, aboriginals located farther inland would not have relied upon marine resources as they would not have been readily available.

Stable isotope analysis is one method that can help test these fundamental assumptions that archaeologists have made concerning inland and coastal archaeological sites in Patagonia. In this study, stable isotope analysis provides basic information about the humans recovered from the sites seen in Figure 2 and respective data are displayed in Table 3. It should be noted here that studies such as that by DeNiro and Schoeninger (1983) have demonstrated
through controlled feeding experiments that $^{13}$C and $^{15}$N ratio values varied with a standard deviation of less than one percent. They concluded that small sample sizes typically encountered in archaeological contexts are acceptable because of the small amount of variation within a group of animals eating the same diet (Katzenberg 1992). To ensure proper prehistoric and protohistoric dietary interpretation, a baseline of isotopic values based on a variety of faunal samples would ideally be established. In the case of this pilot study, only one faunal sample recovered from the Valdés Peninsula was available for the establishment of a baseline. The values determined for this sea lion ($^{13}$C value of -13.5‰, $^{15}$N value of 22.6‰) are however, consistent with those faunal values, specifically the sea-lion reported by Aufderhiede et al. (1994) for marine fauna recovered from Chile (Table 5). (Note that, although these values are obtained from the Pacific, they are useful for comparison for samples obtained from the Atlantic).

Table 5: Carbon and Nitrogen isotope values for samples of grave goods from Pisagua, Chile (Aufderhiede et al. 1994)

<table>
<thead>
<tr>
<th>Organism</th>
<th>$^{13}$C ‰</th>
<th>$^{15}$N ‰</th>
</tr>
</thead>
<tbody>
<tr>
<td>eel jay</td>
<td>-14.4</td>
<td>16.1</td>
</tr>
<tr>
<td>sea-lion</td>
<td>-13.1</td>
<td>22.1</td>
</tr>
<tr>
<td>fish vertebrae</td>
<td>-12.6</td>
<td>N/A</td>
</tr>
<tr>
<td>fish vertebrae</td>
<td>-11.3</td>
<td>20.3</td>
</tr>
<tr>
<td>fish vertebrae</td>
<td>-12.9</td>
<td>20.3</td>
</tr>
</tbody>
</table>
Given that maize was unlikely to have been present prior to the Inca period in Argentina (approximately 1450-1550; Bruhns 1994: 20), the only samples in this study that could have maize contributions to the diet come from Gastre, dating to 350 ± 50 BP (see Table 1).

The variation in isotopic ratio values based upon the distribution of carbon isotopes in the diet (carbohydrate, protein, and fat portions) are significant in reconstructing prehistoric diet (Magoon et al. 2001; Ambrose and Norr 1993; Klepinger and Mintel 1986; Norr 1995). The difference between carbon isotope values obtained from bone collagen and those from bone apatite in a skeletal sample represents the isotopic relationship of dietary protein compared to the total diet. If the difference between apatite carbonate and collagen is small (1-2%; Ambrose and Norr 1993), a marine protein and non-maize carbohydrate is indicated. If the difference is large (7-11%; Ambrose and Norr 1993), a terrestrial protein and C4 (e.g. maize) diet is indicated. If the value of the difference falls between these high and low values (intermediate 4-6%), then the isotopic values for the dietary proteins and carbohydrates are similar. If this is the case, then the diet could be all C₃-like, all C₄-like, or a mixture of C₃ and C₄ carbohydrates obtained from both terrestrial and marine protein sources (Ambrose and Norr 1995; Magoon et al. 2001:23).

Individuals who have eaten C₃ plants and/or animals who have consumed only C₃ plants typically have values around -20‰ (Katzenberg 1992). In this data set, the average ¹³C value of -15.6 ± 1.6‰ for bone collagen and the average ¹³C value of -10.4 ± 2.4‰ for bone apatite (see Table 2) obtained for the coastal
sites Calle Tehuelches, El Golfito, Playa del Pozo, La Azucena, Punta Leon, El Elsa, and Rawson, are intermediate (Figure 16) as compared to the average $^{13}$C value of -18.3‰ for bone collagen and $^{13}$C value of -11.1‰ obtained from the inland site, Gastre. This suggests that humans consumed a diet that was comprised of a mixture of both marine fauna (e.g. sea lion, penguin, fish, and shellfish) and terrestrial foods (e.g. guanaco, birds, rodents) at Calle Tehuelches, El Golfito, Playa del Pozo, La Azucena, Punta León, and Rawson.

This estimate for marine resource consumption is supported by the high nitrogen ratios obtained from coastal sites where the average $^{15}$N value found in human bone collagen was $15.1 \pm 2.0$‰. As discussed previously, $^{15}$N values in
plants (primary producers) can potentially be elevated as a result of water stress or low rainfall. Coastal areas with saline soils or soils exposed to sea spray can also elevate $^{15}$N values. However, the range of values seen here are most likely due to human consumption of upper trophic-level marine fauna such as sea lions and large fish. In addition, it is clear that terrestrial food resources remained an important part of the diet for individuals recovered from coastal sites.

At the same time, the range of variation of isotopic values from the individuals recovered from La Azucena compared with those recovered from Playa del Pozo and El Elsa suggests differing components of their respective diets (see Table 2). The high carbon and nitrogen isotope ratios of the La Azucena human remains suggests a greater contribution of marine resources, whereas the relatively lower carbon and nitrogen isotope ratios of the Playa del Pozo and El Elsa remains suggests lesser marine contributions to the diet. Nevertheless, it is clear that terrestrial food resources were important contributors to people’s diets at both inland and coastal sites. It is likely that this reflects the seasonal mobility of contact-period Tehuelche and that these sites happen to be where individuals died.

Some additional observations concern the range of variation of carbon and nitrogen isotope ratios through time. The earliest site tested, Calle Tehuelches, and the latest site tested, La Azucena, have the most positive isotopic values and thus, these individuals relied more heavily upon marine resources available to them relative to the individuals from other sites tested in this study. At Gastre, it is possible that non-$C_3$ foods were consumed. However,
given the date of the site and ethnohistoric accounts of the greater mobility of aboriginals, it is possible that these individuals may have had access to maize (C₄ plant) or additional marine or riverine resources. In addition, given that these two individuals were estimated to be juveniles by Gomez-Otero, it is possible that part of the isotopic enrichment is due to trophic fractionation from mother to child.

This study has been limited in scope due to the availability of skeletal samples. Guichón (2002) estimates that, prior to the recovery of human skeletal samples by Gomez-Otero and others during excavations in central and northern Patagonia during the mid-1990s, there were only 301 individuals recovered from southern Patagonian contexts available for bio-anthropological study. (This includes collections housed in museums throughout North and South America). Therefore, isotopic studies conducted upon skeletal remains recovered from Tierra del Fuego, south of this project’s recovery area (Valdes Peninsula, Chubut), and the Cuyon region (Mendoza), to the north-west of this project’s recovery area are briefly examined below.

Although the locations from which the skeletal samples were recovered are geographically distant from the locations in this study, the values determined are useful for comparison. This is particularly true given that, similar to this pilot study, Borrero et al. (2001), Guichón (2002), Novellino and Guichón (1999), Fernandez and Panarello (1994), Hedges et al. (1992) and Yesner et al. (1991) have all reported on the use of stable isotope analysis used to test fundamental assumptions based on archaeological evidence collected either at specific sites or geographically related sites. Of these studies, Novellino and Guichón report
isotopic values collected from skeletal samples recovered from the Cuyon region of Argentina (well northwest of this study's location near the Valdes Peninsula) whereas, the rest are restricted to Tierra del Fuego. The values from each of these studies are in Table 6. Figure 17 follows, showing the relative values ($^{13}$C versus $^{15}$N) obtained from samples recovered from Tierra del Fuego and the Valdes Peninsula (as no nitrogen data was available for the Cuyon region). (Radiocarbon dates are reported by the above authors. However, the dates range over several thousand years encompassing both prehistoric and historic samples. Because of the date range of samples, prehistoric and historic, reported here for this pilot study, radiocarbon dates are not further examined).

![Figure 17: Scatterplot nitrogen vs. carbon isotopes; Tierra del Fuego, Valdes Peninsula (Chubut, North-Central Patagonia); Hedges et al. (1992), Yesner (1991), and Cruz et al. (1996)](image)
Table 6: Stable Isotope Data for Human Skeletal Samples, Tierra del Fuego and Cuyon

<table>
<thead>
<tr>
<th>Tierra del Fuego</th>
<th>$^{13}\text{C} %$ Collagen</th>
<th>$^{15}\text{N} %$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruz et al. (1996; from Guichón 2002)</td>
<td>-12.6, -13.3, -16.8, -18.5</td>
<td>18.8, 17.2, 13.2, 10.6</td>
</tr>
<tr>
<td>Guichón et al. (1996)</td>
<td>-19.9, -16.8, -20.2, -16.0, -11.0</td>
<td>N/A</td>
</tr>
<tr>
<td>Fernández and Panarello (1994)</td>
<td>-18.6, -18.3</td>
<td>N/A</td>
</tr>
<tr>
<td>Yesner et al. (1991)</td>
<td>-21.1, -21.9, -20.3, -18.6</td>
<td>12.6, 9.9, 11.9, 10.8</td>
</tr>
<tr>
<td>Cuyon</td>
<td>$^{13}\text{C} \text{O/oo}$ Collagen</td>
<td>$^{15}\text{N} \text{O/oo}$</td>
</tr>
<tr>
<td>Novellino and Guichón (1999)</td>
<td>-20.1, -17.9, -15.3, -14.9, -14.1, -16.5, -19.8, -18.2, -17.7</td>
<td>N/A</td>
</tr>
</tbody>
</table>
As more isotopic data become available for Patagonia and Tierra del Fuego, it becomes evident that, in general, the hunter-gatherers throughout the region were in fact opportunists who took advantage of all food resources available to them. Upon examination of Figure 17, it is clear that the Valdes Peninsula falls within the range of data available for Tierra del Fuego. This is consistent with archaeological interpretations currently reported for Tierra del Fuego and Patagonia though may be counter-intuitive given the cultural adaptations of Tierra del Fuego inhabitants. One example is the extensive use of canoes by the Yamana and the presumption that fishing may have been a primary method of collecting food and subsequently reflect a dependence on aquatic food sources (Borrero and Prieto 1997; Horowitz 1990; Borrero et al. 1985).

Turning attention to the north, Novellino and Guichón (1999) report archaeological interpretations in conflict with carbon isotopic values for human bone collagen (specifically, expectations that this population were developing and relying on cultigens). The data reported for the Cuyon region turned out to be more positive than originally hypothesized, suggesting that interpretations based on excavations alone are incomplete. Less negative carbon isotope values suggest less of a reliance upon cultigens than originally suggested. Continued investigations of nitrogen isotope values would be valuable to help solidify the current interpretations for this area.
VI. CONCLUSION

The analysis of both carbon and nitrogen isotopes has grown significantly since first used by van der Merwe and others during the late 1970's. A technique that was initially implemented to differentiate the presence or absence of maize in the diet of indigenous North Americans, it has evolved to become an accepted and essential component of any archaeological study where human remains have been recovered. Bone chemistry studies have expanded beyond just the examination of bone collagen to differentiate the presence of $C_3$ or $C_4$ plants to include the examination of carbon isotopes in both bone collagen and carbonate, as well as the examination of nitrogen, oxygen, strontium, and sulfur isotopes.

In this examination of selected skeletal remains recovered from coastal and inland sites along the north-central area of Patagonia, Argentina, the purpose has been to test fundamental assumptions about the Tehuelche and their food procurement strategies. Archaeological investigations in the region have thus far been limited and have been primarily focused on inland cave and rock-shelter sites (Gomez-Otero 1993), though a growing number of studies are being published as more archaeologists strive to learn more about the aboriginals of Patagonia and subsequently report on their investigations (e.g. Briones and Lanata 2002, Gomez-Otero et al. 2001; McEwan et al. 1997). This
study is a part of the growing body of information about the Tehuelche and their way of life.

Archaeological and ethnographic studies have suggested that the Tehuelche were mobile hunter-gatherers who primarily depended upon the guanaco for food and other necessary raw materials (e.g. Pero 2002, Gomez-Otero et al. 2001, Borrero 1997). Archaeological evidence from sites such as Cueva Fell, Cueva Las Buitreras, Los Toldos, Juni-aike, and Potrok-aike suggests that guanaco was the backbone of the Tehuelche hunter-gatherer way of life. Although faunal evidence from these sites (e.g., Juni-aike and Potrok-aike) indicates a variety of animals were hunted and subsequently butchered (and presumably consumed), it is clear that the one animal that is almost always represented in Patagonian archaeological faunal remains is the guanaco.

Historical ethnographic evidence (Pero 2002; Steward and Faron 1959; Skottsberg 1913) supports archaeological interpretations that the Tehuelche primarily relied upon the guanaco for food, clothing, and shelter.

The examination of stable isotope ratios of $^{13}$C in both bone collagen and apatite and $^{15}$N in human skeletal remains recovered from both coastal and inland sites in Chubut provided the opportunity to compare the assumptions stated above as they pertained to coastal versus inland sites. In other words, did the Tehuelche significantly change their diet as a result of their seasonal movements that would have taken them into close proximity to coastal food resources? Archaeological and ethnographic evidence would suggest that the Tehuelche were opportunists who would exploit all available resources, albeit in
addition to certain mainstays such as the guanaco and possibly the rhea.

Archaeological evidence from sites such as Las Buitreras supports this conclusion as there was at least seasonal exploitation of coastal marine resources supplementing guanaco (Mena 1997; Borrero 1997; Borrero and McEwan 1997). In this study, $^{13}$C and $^{15}$N ratios obtained from human skeletal remains clearly indicate that individuals recovered from the inland site were primarily reliant upon terrestrial food resources and individuals recovered from the coastal sites relied upon a combination of marine and terrestrial foods. This observation is supported by stable isotope data that has been reported for southern Patagonia and Tierra del Fuego. The regional variability within Tierra del Fuego is seen in Table 7 (from Guichón 2002 with data from Yesner et al. 1991, Hedges et al. 1992, Cruz et al. 1996, Guichón et al. 1996, and Fernández and Panarello 1994). In addition, studies such as Novellino and Guichón’s (1999) work in Cuyon clearly show the value of isotopic data to supplement archaeological and ethnographic data.

As this has been designed as pilot study, intended to begin the process of establishing a “baseline” of data for the region, additional research can build on the data presented here and contribute to the overall knowledge of the Tehuelche. Future research should strive to obtain human skeletal samples that are similar in age. In this study there is a range of dates for the samples so no chronological inferences can be made. If additional samples that are relatively close in age to those presented here could be obtained, it is possible that inferences could be made about humans living in the same region at
approximately the same time. This could, for example, provide insight into localized geographical spheres that bands may or may not have maintained (i.e., coastal areas versus inland or along rivers).

Also worth noting is that for this study, there was only one sea-lion bone available for testing. This provided some information as to the baseline of isotopic values in the region however, it is not sufficient for complete understanding of regional variation among possible human food sources. Ideally, a range of samples would be tested to improve the baseline so that a more comprehensive understanding of human values can be determined. Specifically, two areas of research should be addressed. First, given the Tehuelche reliance upon guanaco and rhea, samples from these animals should be obtained, tested, and isotopic values determined. Second, so that a complete understanding of isotopic values in the region can be established, a range of samples representing the trophic ladder should be obtained and tested. Future research should include samples from indigenous plants as well as the variety of animals represented at archaeological sites in the region.

In addition to the development of a regional baseline based upon samples of represented archaeological faunal remains, an area of research could examine values obtained from pelagic plants, shellfish, and fish. These could then be used for comparisons among human skeletal values as well as those values obtained from riverine plants, shellfish, and fish. This would in turn provide a baseline of values that could provide local isotopic variation among Tehuelche bands who may have focused their geographic sphere along rivers for example, as
compared to those who may have minimized their movements along the coasts or rivers.

Table 7: Isotope Data on human bones from Fuego-Patagonia

<table>
<thead>
<tr>
<th>Region</th>
<th>Location</th>
<th>$^{13}$C Collagen</th>
<th>$^{13}$C Apatite</th>
<th>$^{15}$N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isla Grande</td>
<td>unknown</td>
<td>-21.1</td>
<td>-15.7</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>unknown</td>
<td>-21.9</td>
<td>-15.6</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>Río Grande</td>
<td>-20.3</td>
<td>-15.9</td>
<td>11.9</td>
</tr>
<tr>
<td></td>
<td>Punta María</td>
<td>-18.6</td>
<td>-14.8</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>Ea. Mariá Luisa</td>
<td>-14.2</td>
<td>-10.4</td>
<td>14.7</td>
</tr>
<tr>
<td></td>
<td>Caleta Falsa</td>
<td>-11.8</td>
<td>-9.7</td>
<td>18.5</td>
</tr>
<tr>
<td></td>
<td>Caleta Falsa</td>
<td>-11.6</td>
<td>-9.9</td>
<td>18.3</td>
</tr>
<tr>
<td></td>
<td>Caleta Falsa</td>
<td>-11.3</td>
<td>-10.6</td>
<td>15.1</td>
</tr>
<tr>
<td></td>
<td>Policarpo Bay</td>
<td>-11.6</td>
<td>-7.9</td>
<td>17.2</td>
</tr>
<tr>
<td>Beagle Channel</td>
<td>Ushuaia</td>
<td>-12.6</td>
<td>-10.6</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>Hoste Island</td>
<td>-13.3</td>
<td>-10.7</td>
<td>17.2</td>
</tr>
<tr>
<td>Beagle Channel</td>
<td>Isla Island</td>
<td>-16.8</td>
<td>-13.4</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>Navarino Island</td>
<td>-18.5</td>
<td>-13.9</td>
<td>10.6</td>
</tr>
<tr>
<td>San Gregorio</td>
<td>Cerro Sota</td>
<td>-19.9</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td></td>
<td>Río Gallegos</td>
<td>-16.8</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td></td>
<td>Daniel</td>
<td>-16.0</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td></td>
<td>C. Johnny, B. Norte</td>
<td>-20.2</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td>Ultima Esperanza</td>
<td>Est. Trinidad cave</td>
<td>-11.0</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td>Deseado</td>
<td>El Rodeo 1</td>
<td>-18.6</td>
<td>no data</td>
<td>no data</td>
</tr>
<tr>
<td></td>
<td>El Rodeo 2</td>
<td>-18.3</td>
<td>no data</td>
<td>no data</td>
</tr>
</tbody>
</table>
Future Research

Future bone chemistry studies should strive to sample and test human skeletal samples that are similar in age with multiple samples obtained from male and female skeletons. This would be ideal in order to determine if there was any difference in the diet based upon sex. Ethnographic evidence indicates that there was a clear division of labor among the Tehuelche (Pero 2002; Steward and Faron 1959) as well as differential “rights-of-passage” traditions based upon gender. Could sex differences extend to diet or access to food resources? Questions of diet and resource access based upon age differences could also be examined if samples were obtained from juveniles for comparisons with adult or aged individuals. Clearly, additional physical anthropological inspections would need to take place however, this could be part of an overall, comprehensive examination of Tehuelche diet and health.

It is also theoretically possible to examine potential changes in diet over a given individual’s lifetime. It has been well established that human bone reconstitutes itself over an approximately ten-year span (Katzenberg 2001). If molars and skeletal remains were found to be in context with one another, it is possible to test 6-year, 12-year, and 18-year molars and compare isotopic values with those obtained from skeletal tissues. In some cases, seasonality has been shown to be established within an individual tooth (Tykot pers. com.). Findings such as these could be invaluable in making inferences concerning seasonal movements or possible environmental changes limiting available food resources.
over a given individual’s lifetime. Additional inferences can be made about an individual’s overall health status if isotopic evidence is combined with a physical examination of well known dietary indicators such as Harris lines in tooth enamel.

One last area of research potential involves the examination of oxygen and strontium isotopes. This paper has limited its examination to just $^{13}\text{C}$ and $^{15}\text{N}$ isotopes in human skeletal tissue. If future research expands and examines oxygen and strontium, it is possible to gain specific insight as to the extent of Tehuelche migration patterns. In the case of strontium, there is no correlation or alteration of isotope ratios that result from trophic spacing or from metabolic processes. Because of this, strontium isotope ratios can be matched to specific environments. This could be tremendously helpful as the Tehuelche are reported to have been highly mobile. Since strontium isotopes are based upon the composition of local bedrock, it is possible to determine the distance from where an individual lived during their final ten years relative to where their skeletal remains were recovered (Katzenberg 2001). If tooth enamel is available for testing and depending upon which tooth is tested, it is possible to determine where that individual may have lived (during tooth formation) relative to where their skeletal remains were recovered. Oxygen isotopes can also be used to help establish the degree in which individuals moved during their respective lifetime. Oxygen isotope ratios are determined by ingested water and vary according to latitude, distance from the ocean, as well as altitude (Katzenberg 2001). Different ratios recovered from bone versus dentition could help determine in an individual has moved from an inland region to a more coastal region.
Finally, given today’s political climate within the United States, it would have been difficult if not impossible to conduct a study such as this one. It would be even more difficult to continue research as proposed. With the passing of NAGPRA in 1990, the use of human skeletal remains for destructive analysis has become more difficult. Current literature abounds with concerns expressed over the future of physical anthropological and bone chemistry studies of archaeological remains. Significant questions in North American archaeology may have trouble in being addressed adequately as a result of limitations placed upon the use of human skeletal remains for destructive analysis. Katzenberg (2001) suggests broad based questions such as the peopling of the New World could be more difficult in studying and will rely upon skeletal samples obtained from countries other than the United States. Given this reality, it is hoped that additional research can be done responsibly and that techniques such isotopic studies can become better understood in terms of their potential to gaining a better understanding of past human behaviors. As stated previously, isotopic studies are becoming more commonplace and many studies will be perceived as incomplete without them. Although human skeletal samples in the United States may be more difficult to obtain, perhaps continued research into similar questions that archaeologists may have about other prehistoric populations can help sway public and Native American concerns about destructive analysis in North American archaeology and result in samples that are more easily tested.
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79
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