Rethinking Binford's Utility Indices: Interpretive Problems in Northern Environments and Their Pleistocene Analogs

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submitted: 10 April 2022; revised: 10 June 2022; accepted: 10 June 2022

ABSTRACT

One of Binford's most influential contributions was his development of utility indices—rankings of ungulate body parts according to their meat, marrow, and grease value. Binford's immediate objective was to model the butchering and processing decisions made by Alaskan caribou-hunting Inuit. Ultimately, his goal was much broader—to use these models as a means to better understand the way Eurasian Middle and Upper Paleolithic hunters dealt with reindeer, caribou's Old World cousin. The development of utility indices had a huge and almost instantaneous impact on zooarchaeological research, and these indices have now become a standard component of work across the width and breadth of the discipline. Binford's original models were quite complex, and subsequent studies have simplified several of them. While these modifications make the derivation of the indices more transparent and straightforward, the improvements mostly address technical and methodological issues, and miss a fundamental interpretive problem. Both Binford's original Modified General Utility Index (MGUI) and its more streamlined derivative, the Food Utility Index (FUI), place the upper fore- and hindlimbs among the highest-ranking anatomical units, in large part because of the masses of muscle tissue associated with these areas of the carcass. But traditional northern foragers, including Binford's own Nunamiut informants, considered muscle meat as dog food or white man's food. What traditional northern foragers most valued in the limbs was their fatty marrow content, not the lean muscle. A more realistic ranking of body parts, though unfortunately far more difficult to operationalize in an archaeological context, would look more like the following (the details varying according to species, sex, season, and needs of the hunters): most highly ranked would be the backfat (in early accounts often called the fleece or dépouille), fat concentrated around the neck, hump, and on the rump, fatty tissue surrounding the intestines and internal organs (kidneys, liver, etc.), and marrow. Also highly ranked would be the fattiest meat cuts, especially the tongue, ribs, and brisket. The brain, though rich in polyunsaturated fatty acids, is less easily assigned a rank. It is clear that in many ethnographic and ethnohistoric contexts the head was considered a very desirable food. However, in a surprising number of accounts the brain was not eaten but was used instead to soften and tan hides. Hides for clothing, shelter, and equipment were also highly ranked, though their value fluctuated according to the hunting group's changing needs. Bone grease, like hides, at times was also very important, but because its extraction required considerable time and effort, it is difficult to assign an across-the-board valuation. And finally, the parts that most often occupied last place among Indigenous northern hunters were the naturally lean muscle masses of the upper limbs, their use limited by physiological constraints on the amount of protein an individual could safely consume and metabolize on a daily basis. That limit is less than about 300g or only about 1,200kcal's worth of protein per day, leaving northern foragers with a substantial energy deficit that could only be filled with additional non-protein calories. In the absence of reliable carbohydrate sources, northern foragers often resorted to surplus killing, sometimes on a prodigious scale, for the sole purpose of acquiring fat. Much of the lean meat that resulted from surplus killing was either used as dog food (if dogs were part of the calculus) or simply discarded. The limit to the amount of protein a forager could safely consume also has a direct bearing on the interpretation of cutmarks observed in Paleolithic faunal assemblages from sites in the colder reaches of northern Eurasia. An abundance of cutmarks on meaty upper limb elements such as the femur and humerus does not necessarily indicate that Paleolithic hunters were after the meat. Instead, the cutmarks may be the incidental byproduct of having to dismember the limbs and remove the muscle in order to get at the underlying marrow. Much of the meat may have been discarded. In support of this view, marrow indices are often better predictors of bone transport than heavily meat-based indices such as the MGUI and FUI.

INTRODUCTION

> *I found the Indians putting great emphasis upon the eating of the organs of the animals, including the wall of parts of the digestive tract. Much of the muscle meat of the animals was fed to the dogs.* (Price 1939: 260)

Probably a reflection of my own personal bias as a zooarchaeologist, I have always felt that Nunamiut Ethnoarchaeology, and particularly Binford's (1978) development of anatomically-based utility indices, stands as one of his most important contributions. The models he devel-

PaleoAnthropology 2022:2: 237–265. https://doi.org/10.48738/2022.iss2.113 ISSN 1545-0031

TABLE 1. MEAN RANK OF *PERCEIVED MEAT VALUE* OF 17 MAJOR CARIBOU CARCASS PARTS ASSIGNED BY BINFORD'S NUNAMIUT INFORMANTS (the major muscle-bearing parts of the upper fore- and hindlimb are shown in capital letters; data from Binford (1978: 41, his Table 1.14).

CARCASS PART	RANK (MEAN)
Sternum	1.2
Ribs	1.7
Thoracic vertebrae	3.2
Lumbar vertebrae	3.7
Sacrum–pelvis	5.0
Tongue	6.2
FEMUR	**6.7**
TIBIA	**6.7**
Skull	8.0
SCAPULA	**9.0**
HUMERUS	**9.0**
Atlas–axis	10.0
Cervical vertebrae	10.0
Phalanges	10.7
Metatarsal	11.0
Radius–ulna	12.0
Metacarpal	12.0

oped—most notably the Modified General Utility Index or MGUI—provide invaluable baseline expectations of what hunters should do at a kill—that is, which body parts they should keep and which they should discard—assuming, as Binford (1978: 252, 454) did, that the foragers' decisions were largely rational and nutritionally sound. Without such baseline models, there is no way to recognize assemblages that do not conform to expectations, and it is in those deviations from the expected that we find some of the most interesting new insights and avenues of research.

At the personal level, the MGUI played a critical role in the development of my own career. In analyzing the faunal remains from the 15th-century Garnsey Bison Kill in southeastern New Mexico, had I not used Binford's utility indices I might never have recognized the important role of fat in the processing and transport decisions made by the site's late prehistoric hunters (Speth 1983; Speth and Spielmann 1983).

However, as anyone familiar with *Nunamiut Ethnoarchaeology* well knows, Binford's original models were very complex, giving rise to a number of more recent attempts to clarify and simplify them without sacrificing their effectiveness as zooarchaeological tools (e.g., Emerson 1990; Jones and Metcalfe 1988; Metcalfe and Jones 1988; Morin 2007). These newer and more streamlined versions have become very popular and are now widely employed in the analysis of prehistoric faunal remains.

Binford's original indices and their derivatives, specifically those that involve meat weights in their formulation (e.g., MUI, GUI, MGUI, FUI), however, contain a serious interpretive flaw that has been there right from the beginning and, to my knowledge, has remained largely unrecognized as a potential problem ever since. These heavily meat-based indices assign high ranks to the upper limbs, and especially to the upper hind limbs or haunches (i.e., the femurs). In striking contrast, Binford's own Nunamiut informants gave the muscle masses of the haunches a much lower rank (see Binford 1978: 41, his Table 1.14; and Table 1 above), echoing the opinion of many 19th- and 20th-century explorers and ethnographers, including several who worked directly among the Nunamiut. Many of these earlier voices made it clear that northern Indigenous hunters commonly viewed muscle meat as "dog food" or "white man's food." This striking mismatch between Binford's meat-based indices and northern Indigenous body-part valuations makes it anything but clear how we should interpret patterning that emerges between these indices and measures of skeletal element abundance, particularly when we are dealing with archaeological faunal assemblages recovered from environmental contexts not unlike those of the modern arctic and subarctic.

MEAT-BASED UTILITY INDICES AND THE FEMUR

Let us begin this discussion by looking at the utility values that Binford assigned to the femur, the element representing an ungulate's haunches, hindquarters, hams, or thighs. The "standardized" Meat Utility Index (MUI) value assigned to the femur (i.e., the measured index value expressed as a percentage of the element with the highest value) is 100%, making it the top ranking anatomical unit in the carcass of the caribou, Binford's primary reference animal, but presumably the case in most other ungulates as well (Binford 1978: 21). This outcome is not surprising since the upper hindlimbs or thighs are clearly the meatiest part of most ungulates, accounting for some two-thirds of the total muscle in the legs (Brink 2001: 256).

The standardized Grease Index, a measure of the quantity of lipids distributed within the cancellous or spongy tissue of various elements such as the major epiphyses of the limbs is again highest (100%) in the (distal) femur (Binford 1978: 33; see Brink 1997 for an interesting look at shortcomings in the way Binford constructed and implemented this index).

The only index that deviates for the femur is the Marrow Index, which comes in with a lower standardized value (proximal=33.51, distal=49.41; Binford 1978: 27). However, when the various indices are combined, after making a few adjustments for "riders" (small, nutritionally unimportant bones such as carpals and tarsals), to form a single composite value—the Modified General Utility Index or MGUI (the index zooarchaeologists have relied most heavily upon)—the femur tops the list, again with a value of 100% (Binford 1978: 74). In other words, all other things being equal (which of course they seldom are), hunters should usually be expected to keep the haunches or thighs—especially because of their masses of associated muscle, but also because of their lower-ranked but nonetheless important marrow bones—when butchering an ungulate and deciding which body parts to discard at the kill and which to bring home.

Metcalfe and Jones (1988: 498, their Table 3) greatly simplified Binford's complicated MGUI, creating what they called a standardized Food Utility Index or (S)FUI. And while its derivation was much more straightforward than the MGUI, its values are similarly weighted in favor of the amount of muscle on the major elements, with the fully expectable result that the thighs (with the femurs included) maintain their position as the highest ranking anatomical units in the typical ungulate carcass. In short, the FUI leads to the same expectation as the MGUI—when faced with having to abandon portions of an ungulate carcass at a kill, foragers under most circumstances should be expected to bring home the haunches and, judging by the femur's middling rank as a marrow bone, the number one reason for doing so is because of the massive quantities of meat associated with that part of the ungulate carcass.

MUSCLE MEAT AND "RABBIT STARVATION" IN THE NORTH

As already indicated, the ethnohistoric record from the arctic and subarctic suggests a rather different picture regarding the thighs. Northern Indigenous peoples, whose diet over much of the year was based almost entirely on animal foods, were constantly concerned about getting an adequate amount of fat, and they did so by deliberately targeting animals in good overall condition, and body parts with lots of fat (Lyver and Łutsël K'é Dene First Nation 2005). Without sufficient *non-protein* calories (i.e., calories from either fat or carbohydrate), a diet—whether year-round or for an extended season—that is based heavily on the naturally lean meat of large wild game such as caribou, elk, moose, muskox, bison, mountain sheep, or deer, or smaller animals like rabbits and hares, can rapidly lead to a condition that has come to be known, both in the arctic and beyond, as "rabbit starvation."

> In this tract of country fish is at all seasons scarce, and in winter the sole dependance of the natives for subsistence is placed upon rabbits (the most wretched food upon which to exist for any time that can possibly be conceived); and when these fail, the most frightful tragedies at times take place. (Simpson 1845: 421)

> There is something peculiarly offensive in rabbit after continuous diet. I have lived at one time or another during my hunting experiences on one kind of game for periods of varying length, but nothing ever filled me with such loathing as rabbit. Indeed, it is commonly said by the Indians that they "starve on rabbit," and after my experience I can easily understand it; you may eat until you are surfeited, but after a couple of hours' hard travelling you feel as empty as though in the midst of a prolonged fast. There is neither nourishment nor strength in the meat, and yet the rabbit seems almost to be manna for the otherwise God-forsaken land. (Whitney 1896b: 124–125)

When a hunter's daily intake of protein from lean meat, consumed over a stretch of several weeks or longer, exceeds about 300g of protein (the precise limit depending on the body weight of the individual; see Bilsborough and Mann 2006: 132–133; Cordain et al. 2000: 688; Speth 2010: 77–79), serious health problems are likely to emerge, marked first by lethargy and overall weakness and, if continued unchecked, by death (Speth 2010, 2019, 2020; Speth and Spielmann 1983; Stefansson 1945, 1946, 1960).

> By this time the fat and marrow, of the animals we had killed, were exhausted, and our stock of salt had been long since expended. One who has never been deprived of bread and salt, nor known the absence of oleaginous substances in his food, cannot make a true estimate of the invaluable benefits of such ingredients, in the sustentation of the bodily frame; nor of the extremity of our corporeal debility. [...] Now we experienced the full extent of a new species of starving. Having neither bread, nor salt, nor fat of any kind, every day we remained here, we became more and more weak and emaciated. We had plenty of meat, both fresh and dried, of which we ate four, five and six times a day, in every shape we had the means of dressing it. Though we gorged the stomach, the appetite was unsatiated. Something like a diarrhoea ensued, which contributed to the imbecility of our bodies. Bears oil would have made our venision [sic] savoury, but such an animal as a bear, we had as yet not seen in all our wanderings. (Henry 1812: 46–48)

As a convenient shorthand, this upper protein limit is commonly expressed as a percentage of total calories, and typically placed somewhere between 25% and 35% of daily energy intake, although higher percentages are often reported in the literature (see Bilsborough and Mann 2006: 132–133). However, thinking in terms of percentages can be very misleading, as it implies that a forager will be fine so long as he or she keeps adding fat or carbohydrate to the diet in order to keep the proportion of protein below the critical threshold. But the limit, whatever the current uncertainties may be about its actual value, is an *absolute amount of protein*, expressed in grams per kilogram body weight, that an individual can safely metabolize within a 24-hour period. Once that amount has been exceeded, and allowing for a certain (but unknown) degree of adaptation, augmenting one's intake of fat or carbohydrate is not likely to result in a significant upward displacement of the protein limit. In other words, because of its protein content the maximum amount of lean meat that a forager can safely consume is finite, irrespective of how much fat the forager can glean from the carcass, or starchy plant foods happen to be at hand in the surrounding landscape or in storage.

Typically, meat is about 20% protein, give or take a few percent, and each gram of protein yields about 4kcal (Whitney and Rolfes 2011: 9). Thus, if the upper limit of one's daily protein intake is around 250g, a reasonable figure for a forager whose weight falls between 60kg and 70kg (see Bilsborough and Mann 2006), that would mean that he or she can safely consume roughly 1,000kcal's worth of protein per day (about 1.25kg of fresh, uncooked meat; see Speth 2010: 77–79). For a forager who burns 2,500kcal per day (Jenike 2001: 212), and assuming for the moment that there is no fat in the meat, he or she must obtain more than half of their daily energy from foods other than meat (e.g., plant oils or carbohydrates).

In order to make these calculations more realistic, let us add some fat to our hypothetical forager's all-meat diet. Because of seasonal fluctuations in food availability (i.e., winter–spring vs. summer–fall, or rainy season vs. dry season), and the demands of the animals' reproductive cycles (pregnancy and lactation in females, rutting in males), most wild ungulates seldom average more than 10%–12% total body fat when in peak condition, and much of the time their fat levels fall well below that value, typically closer to 5%–7% or lower (Speth and Spielmann 1983). Caribou/reindeer (*Rangifer tarandus*), arguably the most important terrestrial ungulate in the foodways of interior northern foragers, as well as during much of the Eurasian Late Pleistocene, are no exception (see, for example, Adamczewski et al. 1987b; Bartoň et al. 2014; Cook et al. 1989; Couturier et al. 2009; Gerhart et al. 1996; Huot 1989; Wiklund et al. 2005; 2019). Most African ungulates are even leaner throughout much of the year (Ledger 1968).

So, if an animal is in peak condition with a total fat content of 12%, and assuming that fat yields about 9kcal per gram (Whitney and Rolfes 2011: 9), the 1.25kg of fresh meat that our forager can safely consume would contain 150g of fat, which would yield about 1,350kcal. Adding in the 1,000kcal from the protein in the meat brings the forager's food intake to 2,350kcal. In other words, our hypothetical forager can more or less break even if he or she kills only animals in absolute peak condition and burns no more than 2,500kcal per day.

But for much of the year most animals are not in peak condition, and often far from it. Thus, in order to make these numbers more realistic, let us now assume the prey has only 7% body fat—still a very respectable amount—and the forager needs 3,000kcal per day, a reasonable figure for active hunting peoples in northern environments (Jenike 2001: 212). As before, if the forager is limited daily to 1.25kg of fresh meat, the yield would be 1,000kcal from protein and 87.5g of fat or 787.5kcal, bringing the total to 1,788kcal. That amount still leaves our hypothetical forager with a staggering energy deficit of 1,212kcal or some 60% of his or her total daily energy needs. If there are no (or insufficient) plant foods available, our hunter has little choice but to keep killing additional animals just to acquire the needed fat. Without the added fat, the outcome after a few weeks will be rabbit starvation. The inevitable excess of lean meat that would result from such "surplus killing" ends up being used as dog food (if dogs are, in fact, part of the picture), offered to others (e.g., Euroamericans) in barter or trade ("white man's food"), or simply left behind to be consumed by wolves and other predators and scavengers as the hunter moves on in search of additional fat-rich prey (Speth 2020).

The ethnohistoric literature from the North American arctic, subarctic, northern Great Plains, and Siberia contains countless examples of such surplus killing—that is, foragers killing caribou, reindeer, bison, elk, moose, muskox, deer, and other animals, sometimes in prodigious numbers, primarily to obtain the fattiest body parts, the remainder simply discarded and left behind (e.g., Banfield 1957: 17–19; Binnema 2001: 51; Dunn 1844: 85; Ellis 1748: 182–183; Henry 1992: 422; Odgaard 2018; Robson 1759: 51; Williams 1969: 154).

> <u>Nicholas Denys, Mi'kmaq (Micmac), Acadia, Eastern Canada</u>: The hunting by the Indians in old times was easy for them. They killed only in proportion as they had need; when they were tired of eating one sort, they killed some of another; if they no longer wished to eat meat, they caught some fish, they never made an accumulation of skins of moose, beavers, otters, or others but only so far as they needed them for personal use; they left the remainder where the animals had been killed, & didn't bother to bring them to their camps. (Denys 1672: 419–420; see also Denys 1908: 426 and 594 for an English translation)

> <u>Louis Hennepin's Captivity, Issati and Nadouessans (Dakota), Minnesota, 1680</u>: Sometimes they sent the swiftest amongst them by Land to seek for Prey, who would drive whole Droves of Wild Bulls [bison] before them, and force them to swim the River. Of these they sometimes kill'd forty or fifty, but took only the Tongues, and some other of the best Pieces: The rest they left, not to burden themselves, that they might make the more haste home. (Hennepin 1698: 198–199)

James Isham, Canadian Arctic, 1743: I have found frequently Indians to Kill some scores of Deer, and take only the tongues or heads, and Let the body or carcass go a Drift with the tide, therefore I think itt's no wonder that godalmighty shou'd fix his Judgemen't upon these Vile Reaches, and occation their being starvd. and in want of food, when they make such havock of what the Lord sent them plenty of,—their ignorance may perhap's Justifie them something…. (Rich and Johnson 1949: 81)

Samuel Hearne, Canadian Arctic, 1770: Having prepared as much dried flesh as we could transport, we proceeded to the Northward; and at our departure left a great quantity of meat behind us, which we could neither eat nor carry away. This was not the first time we had so done; and however wasteful it may appear, it is a practice so common among all the Indian tribes, as to be thought nothing of. On the twenty-second, we met several strangers, whom we joined in pursuit of the deer, &c. which were at this time so plentiful, that we got every day a sufficient number for our support, and indeed too frequently killed several merely for the tongues, marrow, and fat. (Hearne 1795: 39)

Charles McKenzie, 3rd Expedition to the Missouri, 1804–1805: The winter being far advanced and considerable Snow upon the ground thousands of Buffaloes resorted to the vicinity of the villages. We had great pleasure in Seeing the Indians go into the fields Surround and Kill whole droves of them—& so many to fall—one upon the other. The best parts only of the meat were taken home—and we lived like Kings. (Wood and Thiessen 1985: 265)

Charles McKenzie, 4th Expedition to the Missouri, 1806: I here witnessed greater slaughter upon Buffalo than I hade been accustom to see at the Missurie I have been with the Shawyens a hunting, or surround the cattle, with[in] 20 acres of their Camp, when they Killed…. 250 fat Cows which they left on the field as they fell; excepting the Tongues which they dried for a general feast they were to make for the Missurie Indians…. (Wood and Thiessen 1985: 282)

Isaac Cowie, "Buffalo Plains," 1867–1874: The supply of fat was always too small to enable us to convert all the lean pounded or powdered meat into pemmican, for which equal weights were required. Consequently we always had been obliged to buy, at low price, however, quantities of this "pelly" meat that no one except a very hungry person or animal would touch without being mixed with fat. (Cowie 1913: 415; see also Lytwyn 2002: 87)

Andrew Lawrie, Manitoba–Nunavut Border Area, Canadian Arctic: This need for fat while on a meat diet imposes apparently wasteful habits on the eskimo. Thus in late spring and summer caribou have little fat save in the tongue and marrow while its progressive deposition in the mesenteries and omenta, in the orbit of the eye, pharyngeal and laryngeal musculature, about the ribs and sternum, in the pelvis and ultimately in a suet-like pad over the back and rump occurs in the fall. In the late spring and summer eskimo were repeatedly observed to take only the tongue and the lower part of the limbs from their kills—the lean meat, unfortified with fat, being untouched. (Lawrie 1948: unpaginated, 43rd page of document)

Although a great deal of this behavior, especially from the 1700s onwards, can be brushed aside as an unfortunate consequence of Indigenous involvement in the fur trade, abundant evidence of surplus killing can already be found in the very earliest accounts from many different parts of the continent, describing peoples at or close to the time of first contact, and certainly well before they became deeply enmeshed in colonial trade systems (Speth 2020). In short, as counterintuitive as surplus killing may at first seem, northern foraging bands may have had little choice but to target the fat and discard the excess lean if they were to consistently stave off rabbit starvation. Friar Gabriel Sagard, unaware of the likely nutritional underpinnings of what he was observing, commented already early in the 1600s on what he considered the lamentable practice of surplus killing among Canadian First Nation peoples:

> Les Canadiens & Montagnais ont aussi ceste coustume de tuer tous les eslans qu'ils peuvent, attraper à la chasse, croyans que ceux qui eschappent vont advertir les autres de se cacher au loin peur de leurs ennemis, & ainsi en laissent ils par fois gaster sur la terre, quand ils en ont des-ja suffisamment pour leur provision, qui leur feroient bon besoin en autre temps, pour les grandes disettes qu'ils souffrent souvent, particulierement quand les neiges sont basses, auquel temps ils ne peuvent que tres-difficilement attraper la beste.... (Sagard 1636: 639; text converted to modern letter forms but preserving original orthography)
>
> [The Canadians & Montagnais also have this custom of killing all the moose they can catch while hunting, believing that those who escape will warn others to hide in the distance for fear of their enemies, & so they sometimes leave some to rot on the ground, when they already have enough for their provision, which they would really need at other times, for the great famines that they often suffer, especially when there is little snow, at which time they can hardly catch the beast.... (Google translation with minor wording changes by JDS)]

For illustrative purposes, one more calculation will be helpful. This time I will use the maximum figure for the upper protein limit—300g per day or approximately 1,200kcal—but stick with the 7% level of body fat. With these parameters, our hypothetical forager can consume 1.5kg of fresh meat, which would yield 105g of fat or 945kcal. Adding the energy from the protein and fat together, our forager can derive about 2,145kcal from the meat. If his or her daily energy needs remain on the order of 3,000 kcal, the meat would still leave an energy deficit of 855kcal or approximately 29%—that is, nearly one-third of the forager's total daily energy needs.

To put these calculations in broader perspective, let us consider some real-world nutritional data recorded among traditional coastal-dwelling Inuit within the first few decades of the 20th century. One of the earliest of these studies was conducted by August and Marie Krogh (1915; summarized in Rodahl 1954a: 71–73) in West Greenland. The Inuit observed by the Kroghs consumed, on average, about 1.8kg of meat, which yielded 280g of protein and a whopping 218g of fat, the latter coming mostly from marine mammals. These West Greenland Inuit therefore obtained about 1,120kcal from protein and 1,962kcal from fat, for a total daily intake of 3,082kcal, with approximately 36% of the calories coming from protein. Høygaard (1941: 56; see also Mullie et al. 2021) estimated that the Angmagssalik Inuit, also marine-based hunters in Greenland, consumed 2,800kcal per day, with protein contributing 299g (1,196kcal or 43% of calories) and fat contributing an additional 169g (1,521kcal). Comparing these early Inuit data (see also Rabinowitch 1936: 493) with our previous hypothetical calculations underscores just how difficult it is for interior-dwelling northern foragers, who do not have regular access to marine mammals, to eke out a living relying heavily on the limited amounts of fat they can obtain from terrestrial ungulates like caribou, reindeer, and bison, even when the animals are in good overall condition. The yield of fat from these animals simply pales by comparison to the masses of blubber the Inuit can obtain from seals, walruses, and whales. Thus, for interior foragers to survive for extended periods on a heavily meat-based diet, surplus killing for the purpose of acquiring fat may have been a recurrent necessity. Fulfilling specific hide needs may have accentuated this hunting pattern.

These calculations also raise an interesting question about our Middle Paleolithic forebears, the Neanderthals, who, at best, had only minimal access to marine mammals. I think it reasonable to assume that, unlike felids, wolves, and hyenas, Neanderthals were not hypercarnivores and hence were unable to survive on the high-protein intakes that many other carnivores can thrive on (anywhere from 50% to 70% of kcal or more; Van Valkenburgh 2007). How then did Neanderthals cope if their energy needs were as high as most estimates would seem to suggest? For example, Churchill (2008: 117, 128) believes that it took some 3,500–5,000kcal/day to feed an adult Neanderthal with an average body weight slightly over 80kg. The upper protein limit for an individual of that approximate weight would be around 300g/day (Speth 2010: 78). If Neanderthal physiology was anything like that of modern subarctic and arctic foragers (clearly a critical gap in our knowledge), they would have faced an ever-present shortage of dietary lipids (or carbohydrates). How they managed to fill that gap is unknown, but the considerable abundance of large and very large mammal remains typical of their occupations may be silent testimony to nutritionally-driven surplus killing on an impressive scale (Morin et al. 2016).

Regardless of habitat, most wild ungulate body fat levels vary widely over the year and, for most months, their yield of fat remains well below peak levels. Moreover, annual fluctuations in male and female body condition are usually not in synch with each other, their fat levels broadly tracking the demands of their reproductive state (Speth and Spielmann 1983). In addition, fat levels are generally greatest in prime adults, as old animals and juveniles often have considerably smaller reserves. Thus, the prime-age adult pattern that seems to be so characteristic of human hunting for at least the last 300,000–400,000 years, and perhaps all the way back to the early reaches of the Pleistocene, should not come as a surprise (Bunn and Gurtov 2014; Stiner 2009). It is also worth noting that, in general, larger mammals possess greater proportions of body fat than do smaller mammals, though the variability also tends to increase with body size (Calder 1984: 22, 50–51; Hallgrimsson and Maiorana 2000: 571, 589; Lindstedt and Boyce 1985: 873; Prothero 1995: 633, 639; Pitts and Bullard 1968; White and Kearney 2014).

Considering all of these factors together, one can see that it often pays for the northern hunter to target, not just prime adults, but prime adults of the largest taxa available, and to take them according to their seasonal and reproductive peaks in body condition. While this conclusion sounds much like the usual expectation of traditional diet breadth models, as well as conventional thinking in zooarchaeology more generally, it actually puts a slightly different spin on things—the largest animals may have been the preferred targets, but often specifically for their fat reserves, not their meat. In fact, a sizable fraction of the meat may have been discarded (i.e., surplus killing).

The situation during the spring may deviate somewhat from the pattern just described. Particularly after a long, harsh winter, many of the ungulates, regardless of their age or sex, may be in poor shape, making them less than ideal sources of food. At such times, northern hunters commonly turn to smaller animals that are normally well endowed with fat in the spring, most notably beaver (especially their tails) and migratory waterfowl (especially various species of geese, but also eiders and other ducks). These fat-rich animals provide the life-sustaining lipids that hunting peoples need in order to make it through the lean times (Belinsky and Kuhnlein 2000: 102; Berkes and Farkas 1978: 156–158; Berkes et al. 1994: 353–354; Feit 1973: 52; Honigmann 1961; Jenness 1922: 105; Klein 1966; Kuhnlein et al. 1994). It is also important to keep in mind that hide needs, not food, may dictate which animals become the top-ranked targets (this topic is discussed more fully later).

SELECTING SPECIFIC BODY PARTS

But there is another dimension of selectivity that is critical to understanding the hunting, culling, and transport decisions made by northern foragers. That dimension concerns the choice of specific body parts kept vs. those left behind at a kill, an aspect of selectivity that brings us full circle, back to our focus on utility indices. In the hypothetical calculations given earlier, I expressed the amount of fat on an animal as a percentage of total carcass weight (commonly based on the ingesta-free carcass). However, by presenting the data in this manner, one could come away with the mistaken impression that fat is more or less uniformly distributed throughout the animal's carcass, such that almost any cut of meat from the animal would yield roughly the same amount of fat as any other. But that is decidedly not the case—not even close. Meat from domestic animals like cattle, sheep, and pigs is strongly "marbled"—that is, there is a great deal of fat, not just between the muscles (*intermuscular fat*), but also dispersed as patches, stringers, and even layers within the muscle tissue itself (*intramuscular fat* or IMF). Not so in wild game (Bartoň et al. 2014; Bureš et al. 2015; Cordain et al. 2002; Crawford et al. 1970; Davidson et al. 2011; Soriano and Sánchez-García 2021). The meat of most wild ungulates has very little IMF. In other words, it is not "marbled" and is therefore far leaner than its domestic counterparts.

A few examples are sufficient to show just how limited the levels of IMF can be within the muscle meat of wild ungulates. Before doing so, however, it may be helpful to point out that many studies analyze the fat content in just a single muscle or subset of muscles and present these results as more or less representative of the values one would expect to find in most other muscles within the carcass. The muscle complex most commonly reported, in large part because it is easily accessible, is the *Longissimus dorsi*, a compound muscle unit comprised of the *L. thoracis* and *L. lumborum*, both of which lie along the spine, positioned so that they are atop the ribs. In the meat industry, these muscles are often referred to as the "backstrap," 'loin," or "ribeye" steaks. Though less often reported separately, another important muscle is the *Psoas major*, the "tenderloin" or "filet mignon" in the terminology of the meat industry. This muscle also lies along the spine but beneath the ribs. Two other muscles commonly analyzed are the *Semimembranosus* ("top round") and *Semitendinosus* ("eye of round"), both very lean muscles of the upper hind leg or thigh. Unfortunately, many nutritionally oriented studies, especially those most readily accessible to the general public, simply report a single value under the rubric "meat" or "venison" without specifying which muscle or muscles were analyzed (let alone the sex and age of the animal, whether it was range-fed or grain-fed, and whether it was "finished" in a feed lot before being slaughtered).

Let us look now at some actual data, beginning with the snowshoe hare (*Lepus americanus*), the animal whose extremely limited total body fat reserves and lean muscle meat gave rise to the term "rabbit starvation" in the first place (unspecified muscle, raw, fat=0.9%; see Appavoo et al. 1991: 110, their Table 1a). Turning to ungulates, Lorenzo et al. (2019: 1563) report IMF values of only 0.3% in adult wild Iberian red deer (*Cervus elaphus*), and as little as 0.05% in red deer under about two years of age. Similarly, Soriano et al. (2020: 4) found only 0.42% fat in *Longissimus* muscle of red deer stags and 0.56% in hinds. Volpelli et al. (2003: 559) observed comparably low IMF values (< 0.6%) in the meat of pastured Italian male fallow deer (*Dama dama*). Serrano et al. (2019: 240–241, their Table 9.4) provide a useful summary of data for a number of different cervid taxa (red deer, fallow deer, roe deer, and elk), and many of the IMF values fall well below 1%. Marchello et al. (1989: 178, their Table 1) observed an IMF value of 1.9% in the *Longissimus* muscle of American bison (*Bison bison*) and just 1.2% in the *Semimembranosus*. Janssen et al. (2021: 11, their Table 3) also reported a value of 1.9% for American bison (heifer) *Longissimus*. In European bison (*B. bonasus*), Haščík et al. (2011: 18, their Table 1) found that the IMF values for *Longissimus dorsi* muscles varied according to the age and overall condition of the animal, ranging between 1.26% and 2.11%. Similarly, Łozicki et al. (2017: 121, their Table 2) reported an IMF value of 1.13% for the *Semitendinosus* muscles of male European bison.

To underscore the striking contrast in fat content between the meat of domestic and wild bovids, Crawford (1968: 1330) already years ago noted that the fat content in butcher's beef sold in the UK (25.0%) was nearly ten times greater than the amount found in wild buffalo (2.8%). Though somewhat less dramatic, the IMF in *Longissimus iumborum* muscle of domestic cattle bulls (14.1%) was seven times greater than the level found in the same muscle of wild eland bulls (T*aurotragus oryx*) finished under similar conditions and diets (2.0%; Bartoň et al. 2014: 348). Similarly, Brittin et al. (1981: 1806) observed a nearly 5-fold difference in the amount of fat in rib roast of beef (11.2%) and wild mule deer (*Odocoileus hemionus*, 2.3%). The most extreme examples of marbling are found in Japanese Wagyu and Korean Hanwoo beef. Wagyu *Longissimus* can attain IMF values well in excess of 40% and top grade Hanwoo *Longissimus thoracis* may approach 30% (Gotoh and Joo 2016: 710).

Looking specifically at caribou and reindeer, almost all of the analyses of muscle meat that I have been able to find report IMF levels at or below about 3%, with the majority falling between 1% and 2%, and many under 1% (Adamczewski et al. 1987a: 370; Appavoo et al. 1991: 110; Chan-McLeod et al. 1995: 281; Cordain et al. 2000: 688–689; Farmer et al. 1971: 138–139; Hoppner et al. 1978: 257; Kuhnlein et al. 2009: 18; Kuhnlein and Soueida 1992: 119; Mann et al. 1962: 63, 72; Rincker et al. 2006: 72; Schaefer 1977: 24; Semenova et al. 2019: 72–73, 75; Wei Wo and Draper 1975: 811). In other words, as in most other wild ungulates, the IMF values in caribou and reindeer are very low, certainly far below the fat levels I used in the hypothetical calculations given earlier. That is, an animal in good overall condition with a total fat level of, say, 7% may have IMF values for most individual muscle units well below 2% and often under 1%. The reason for this striking difference is due largely to the lack of marbling within the muscles. Most of the fat in a wild ungulate carcass is concentrated elsewhere in the body, particularly beneath the skin as subcutaneous fat or adipose tissue, in the intercostal (rib) tissue, in the brisket (i.e., the muscles and associated fatty tissue at the front of the lower chest over the sternum and costal cartilage), around the intestines, kidneys, liver, and other internal organs, in the brain (much if it, however, not as triacylglycerols, but as non-esterified fatty acids or NEFA), within the eye sockets, in the tongue, bone marrow, and distributed within the cancellous tissue of the limb epiphyses and other spongy bones (see Adelson 1992: 174; Colpitts 2007: 69–70; King 1836: 151–152; Parker 1987: 53; Stefansson 1921: 231).

Among traditional northern hunting peoples, a few body parts stand out as particularly valued, in large part, not surprisingly, because of their fat content. Most noteworthy among these are the tongue, briskets, intercostal tissue (ribs), and reasonably often the brain as well. For example, Buffalo Bird Woman, an elder of the Northern Plains-dwelling Hidatsa, recalled the special value her people assigned to the tongue, internal organs, brisket, and ribs (while obliquely indicating that her people did not attribute comparable importance to the thigh meat, only to the marrow bones within):

> After the hunters had placed the hides and the greater part of the meat from the five cows on the stage, they returned to the camp, packing some of the choicer cuts on their backs. Usually, these were the tongues and kidneys and the meat on the breastplate bone. They brought in only the choicest pieces because we already had a good supply on hand. (Wilson 1924: 247)
>
> When they returned, each hunter packed a load of meat on his back.... Only the choice cuts were brought back in this fashion: the tongues, the kidneys, and the ham bones for the marrow; the rest of the meat was left behind on the meat pile. Some of the ribs with the meat clinging to them were also brought in. (Wilson 1924: 249–250)

Warburton Pike, a 19th-century English explorer of the Canadian west and arctic, provided an ordering of body parts very similar to Buffalo Bird Woman's ranking:

> Of the external parts the ribs and brisket rank highest, the haunches being generally reserved for dog's food; a roast head is not to be despised, and a well-smoked tongue is beyond all praise. (Pike 1892: 51)

In the ethnohistoric accounts of the 19th century and earlier, the tongue in particular is almost always singled out as a special culinary delight, and with good reason. Regardless of species, sex, age, or season, it is invariably one of the fattiest muscular tissues in an animal's body and, of particular note, it retains its fat no matter how stressed and otherwise fat-depleted the animal might be. The singular importance of the tongue to Indigenous bison hunters in the American Midwest was clearly underscored already in the 17th-century by Father Sebastien Rasles, a Jesuit missionary to the Illinois between 1691 and 1693. In a letter to his brother, penned in 1723, he observed that "When they have killed a buffalo which appears to them too lean, they content themselves with taking the tongue, and going in search of one which is fatter" (Rasles, in Kip 1847: 39).

During the 20th century, however, tongue as a food, at least in much of the West, "fell from grace," and one now has to look long and hard to find rigorous nutritional data on this particular part of ungulate anatomy. The meat industry in the USA and in many parts of Europe treats tongue, not as a commercially important cut of meat for sale at mainstream supermarkets, but as "variety meat," or "by-product," or, worse yet, as "offal"—the stuff that slaughterhouses commonly discard, export to non-Western countries, or sell to pet food manufacturers (Schaefer and Arp 2017).

Nevertheless, despite its current demotion to the status of offal, there is still enough data to see why hunters in the past would have found the tongue so irresistible. Rodahl (1954b: 35), for example, observed a fat level of 45.5% in boiled caribou tongue. This is the highest value I encountered in the literature and likely reflects a substantial loss of moisture during cooking. That seems borne out in a study of cooked and uncooked sheep (mutton) tongue carried out by Bester et al. (2018: 5–6). In their study, the uncooked tongue contained 21.7% fat, but jumped to 33.2% in the cooked samples. Other studies of uncooked tongue report quite a range of values, though always substantial by comparison to the paltry figures seen in most muscle meats. Thus, Kuhnlein and Soueida (1992: 119) provide a figure of 17% for raw caribou tongue. Grinkova et al. (2014: 13, their Table 3 [in Russian]) report a higher value—29.2%—for wild reindeer tongue, and van Heerden and Morey (2014: 249, 253) note a broadly similar level—23%—in fresh uncooked South African beef tongue. Jayawardena et al. (2022: 334) observed a somewhat lower value—16.1%—for beef tongue, a figure more in line with the one just noted for fresh caribou tongue (see also Ockerman et al. 2017: 685; Mustafa 1988: 270, his Table 1). Looking farther afield, Stanisz et al. (2015: 1061, their Table 6, 1065) report values between 15% and 18% for the uncooked tongues of farmed fallow deer (*Dama dama*).

Needless-to-say, the range of values one finds in the literature for the amount of fat in tongue is quite substantial, greater than one might expect simply from differences in analytical techniques. A recent paper by Warren et al. (2020: 3, 10, 13) might provide an important clue to the source of at least some of that variability. Their study is the only one I have found that analyzed the fat content of the tongue at different points along a longitudinal transect between tip (anterior) and base (posterior). These authors found that the values rose from a minimum of only 1.6% at the tip to 16.1% near the mid-point to 22.9% at the base. The tip also contained more polyunsaturated fatty acids and less saturated fatty acids than the base.

Data on the fat content of wild ungulate brain (specifically from the perspective of the brain as food), briskets, and intercostal tissue are surprisingly rare. Nevertheless, what limited information does exist shows that these particular body parts are far richer in fat than the muscle masses of the upper fore- and hindlimbs. The brain, an organ that, like the tongue, retains its fat content despite changes in the degree to which an animal is stressed, generally has values falling between about 8% and 10%. Thus, according to Kuhnlein and Soueida (1992: 119, their Table 2) uncooked caribou brain contains about 9.8% fat. Cordain et al. 2001: 152, their Table 2) offer a similar figure for the uncooked brain of African ruminants (9.3%). When cooked, the percentage of fat can be much higher (e.g., boiled caribou brain, 25.5%; Rodahl 1954b: 35, his Table 1). The fat content of the uncooked brain of domesticated animals (calf, beef, lamb, pig) is similar (8% to slightly over 9%) to the values reported for caribou (Chanted et al. 2021: 1, 5; Ockerman et al. 2017: 685, their Table 22.3; Mustafa 1988: 270, his Table 1).

Concrete values for the fat content of the brisket are very scarce but the two that I have been able to find also reflect the elevated levels in this part of the ungulate carcass. Thus, according to Rodahl (1954b: 34, his Table 1), uncooked caribou brisket contains 5.1% fat. Traveling farther afield, Szulc et al. (1971: 494, their Table 11) offer a value of 8.5% for the fat content of the brisket of European bison (*Bison bonasus*)–domestic cattle hybrids.

I have found only a single explicit value for the fat content of intercostal tissue in a wild ungulate, but if the figure, in this case for caribou, is in any way representative, it is clear why this particular tissue was also prized by hunters, both Indigenous and Euroamerican (7.0%; Adamczewski et al. 1987a: 370). Also of interest, Rodahl (1954b: 34, his Table 1) provides fat values for cooked caribou ribs—roasted (5.0%) and boiled (5.1%). Interestingly, despite the much lower total amount of body fat found in bison by comparison to the values typically observed in domestic cattle, a significantly greater proportion of that fat is concentrated over the ribs (Koch et al. 1995: 1271, 1278–1279). Thus, the fatty intercostal tissue, in combination with the concentrated fat deposits overlying the rib cage (i.e., the voyageur's "*dépouille*"), made this part of the bison particularly attractive to hunters of the past. I was unable to determine whether fat is concentrated in a similar fashion over the ribs in other northern ungulates but, if so, it would further underscore the value of this particular body part.

Aside from the tongue, brisket, and intercostal (rib) tissue, most other muscle meat from wild ungulates has very little intramuscular fat or IMF Thus, if northern hunters are limited to not more than about 1,200kcal's worth of protein per day (i.e., a maximum of 300g of protein x 4kcal/g), they must fulfill the remaining balance of their daily energy needs with fat. It is for this reason that they often are compelled to continue killing additional animals almost solely for their fatty tissues, while discarding the excess lean meat, or feeding it to their dogs, or offering it to Euroamericans in trade (e.g., Abe 2005: 100, footnote; Anderson 1918: 61; Banfield 1957: 13; Bessels 2016: 160; Flook 1952: 3; Gaede-Penner 2016: 124; Gubser 1965: 301; Hadleigh-West 1963: 180; Hanson 1973: 62–63, 119–121; Harper 1932: 30–31; Ingstad 1951: 102, 1992: 186; Kooyman 1981, 1988; Lawrie 1948: unpaginated, 43rd page of document; Pike 1892: 51; Price 1939: 260; Russell 1898: 90–91; Stefansson 1921: 232; Turner 1894: 278; United States Army, Chief of the Air Corps 1940: 231; Wheeler 1914: 58; Whitney 1896a: 722).

> When it is remembered that the ordinary meal for a dog-train—i. e., four dogs, that are travelling thirty or more miles a day—consists of a caribou hind and fore quarter, that we had twenty eight dogs, and that we never got more than a caribou or two at intervals of several days, the reader may understand why the dogs were like wild animals, and why we ate the intestines and grease and saved them the meat. (Whitney 1896a: 722; see also Whitney 1896b: 251, 273)

> The [late 19th-century American] whalers at Herschel Island [Yukon] one winter bought 40,000 pounds of caribou meat, and they bought hams only. (Stefansson 1909: 607)

> The Indian feeds his dog on tenderloin, sirloin, the meat of the legs and the heart, lungs, liver and kidneys. He confines his own activities to the head, bones, intercostal muscles, fat, intestines, unborn calf and afterbirth. […] Meat straight is an unsatisfactory diet unless the Indian custom is followed. If one is to keep in condition he should use a great deal of raw smoke-dried fat. Well cooked fat is more palatable but more cloying. (Wheeler 1914: 58)

> For themselves, the hams are either fed to the dogs, which must have their share, or cut up for drying. The white man's "choice cuts" are not the Eskimo's or the Indian's favorites, and as a rule are not the first choice of the out-door man who is cooking in the field with primitive appliances. (Anderson 1918: 61)

> It is seldom among the Alaska and Mackenzie River Eskimos that caribou hams are eaten when there is enough of other meat. The hams, some of the entrails, the lungs and liver, the outside meat from the neck and brisket, and the tenderloin are the food of the dogs (Stefansson 1921: 232)

> I found the Indians putting great emphasis upon the eating of the organs of the animals, including the wall of parts of the digestive tract. Much of the muscle meat of the animals was fed to the dogs. (Price 1939: 260)

> If a family of three Eskimos has a team of six dogs, then on the average the people eat half of each caribou, the team the other half. And the halves are always the same. The dogs, for instance, get all the livers and the people get all the heads; the dogs get all the tenderloins and most of the ham meat, the people get all the briskets and most of the rib meat. (Stefansson 1944: 2)

> In the late spring and summer eskimo [sic] were repeatedly observed to take only the tongue and the lower part of the limbs from their kills—the lean meat, unfortified with fat, being untouched. As the fall progressed the choice of cuts constantly widened until every part of the caribou was utilized save the viscera, neck, shoulders and thighs which were fed to the dogs, the first after removal of the mesenterial fat. (Lawrie 1948: unpaginated, 43rd page of document)

> In fact, once during the Norwegian–Russian summer expedition a moose hunt took place, and at least on the days that we were able to observe, the parts were put in cold storage and consumed as boiled meat and soup. Vasili referred to this moose hunt during our field season, noting that when he offered to share a part of the moose, we (the expedition members) asked for the femur which had the largest amount of meat. Vasili recalled that he (and the study group) considered this a poor choice as the part was the least tastiest, but did not say anything at that time. During his recollection he also noted that all Russians (by which he meant all non-Evenki) seemed to have this strange preference for meaty parts. (Abe 2005: 100)

I do not know why Binford did not tap into this rich corpus of ethnohistoric and ethnographic literature when he began formulating his ideas about utility and the likely role of lean muscle meat. Already in the late 19th century, more than 75 years before Binford began his studies in Anaktuvuk Pass, explorers had begun publishing about the limited value of muscle meat to northern foragers, and especially the meat from the upper hindlimbs (e.g., Pike 1892: 51; Whitney 1896b: 251, 273). I also do not know why Binford did not comment on the observations about the use of lean meat as dog food made by the Nunamiut's principal ethnographer, Helge Ingstad, who lived among them for nine months in 1949–1950, a period when these Inuit were still fully nomadic and heavily reliant on dog sleds for transport. By the time Binford began working in Anaktuvuk Pass in 1969, the community had switched over almost entirely to snowmobiles.

> The coarse meat, which in civilization is used for joints and steaks, is the least popular. In autumn and spring it is used to a certain extent for dried meat, otherwise it is given to the dogs. (Ingstad 1951: 102)

> During the winter of 1966 there were five snowmobiles in the community but dogteams were still the major means of transportation. [...] By the summer of 1969 the transition from dogteam to snowmobile was complete, as the last three families had purchased machines. Despite extensive wear and tear of running the machines over bare ground, nobody walked anywhere—it was too easy to jump on a machine and go after willows, water, to the permafrost cellar, or simply just go. The dependence of the hunting Eskimo upon his iron dog led to the neglect and disappearance of the living dogs. (Osburn 1974: 912–913; see also Hanson 1973)

Most curious of all, however, is the fact that Binford seems not to have been swayed by the rankings provided by his own Nunamiut informants (see Table 1). Their rankings, *concerned solely with meat, not marrow*, make it clear that the Nunamiut, just like other northern hunting peoples, did not consider muscle meat from the upper fore- and hindlimbs to be particularly desirable as human food. Binford attempted to explain this striking discrepancy by noting that:

> The lumbar vertebrae appear to be underrated by the informants, as do the femur, scapula, humerus, and cervical vertebrae. *It is interesting that these are the heavy muscled parts*. The negative bias is against lean meat in general with an anatomical bias against front legs and necks. These are the parts considered by the Eskimo to be most responsive to nutritional variability and are thus considered less "reliable" parts, particularly in spring. It is likely that this factor is built into the expressed preferences of the informants or that the informants all did not accurately accept the "fall" simulation since the interviews were conducted in spring! (Binford 1978: 40, emphasis added)

His explanation, however, ran counter to more than three-quarters of a century or more of prior arctic scholarship, as well as the findings of numerous wildlife studies. Why? Because there is hardly any fat (IMF) *at any time of year* in the muscle meat of wild ungulates. It is not "nutritionally variable," it is always lean. What fluctuates from season to season, often quite dramatically, are the deposits of fat that underlie the skin (adipose tissue), around the viscera, and within the marrow. The Nunamiut would certainly have known that, and their responses to Binford's meat survey show quite clearly that they did.

Although the quotes just given relate specifically to the arctic and subarctic, one sees similar undervaluation of the haunches in the northern Great Plains as well. One of the clearest examples is found in Buffalo Bird Woman's description of the Hidatsa's last great bison hunt, an event that occurred around 1870 (Wilson 1924: 201–202, 227–228, 235, 268; note the commentary in the figure captions). Brink (2004: 175) carefully examined Buffalo Bird Woman's account and summarized it thus: "...the femur was frequently taken from the kills, but...bone marrow rather than muscle tissue was often the desired product." Similarly, Kooyman (1981, 1988), examining bison-dominated faunal assemblages from historic period sites in the Canadian Plains, found that Indigenous and Métis populations tended to favor the fatty tissues from the head, hump, brisket, and ribs, as well as the marrow from the limb bones, while Europeans, though obviously also taking some of these same parts, opted far more often for the meaty but much leaner "steaks."

Evidence for the undervaluation of haunches by Indigenous foragers is actually quite widespread in the northern Great Plains, northern Rockies, and Columbia Plateau. However, the ranking is often implied, not explicitly stated; that is, when Euroamerican observers enumerated the parts that Indigenous peoples valued most highly, they seldom mentioned the thigh meat, or muscle meat more generally.

> When they reached the place where Drewyer had thrown out the intestines, they [Indigenous hunters encountered in western Montana by the expedition] all dismounted in confusion and ran tumbling over each other like famished dogs: each tore away whatever part he could and instantly began to eat it: some had the liver, some the kidneys, in short no part on which we are accustomed to look with disgust escaped them: one of them who had seized about nine feet of the entrails was chewing it at one end, while with his hand he was diligently clearing his way by discharging the contents at the other. It was indeed impossible to see these wretches ravenously feeding on the filth of animals, and the blood streaming from their mouths, without deploring how nearly the condition of savages approaches that of the brute creation: yet though suffering with hunger they did not attempt, as they might have done, to take by force the whole deer, but contented themselves with what had been thrown away by the [non-Indigenous] hunter. (Lewis and Clarke 1814: 274–275)

Typically, the only ethnohistoric accounts that routinely extolled the virtues of "savory steaks" were those that described the meat preferences of the expedition members themselves. And those individuals could afford to indulge in meals of lean meat because their expeditions were usually well supplied with flour, rice, potatoes, hardtack (biscuits), sugar, cooking oils, and bacon grease or lard. In other words, for those sorts of overland parties, rabbit starvation was seldom an issue. However, on those occasions when an expedition did run out of Western foods, and the tell-tale symptoms of rabbit starvation began to take hold, the accounts make it abundantly clear that lean muscle meat, no matter in what quantity, only exacerbated their suffering (see, for example, John J. Henry's [1812] poignant description, quoted earlier, of the acute rabbit starvation he and his compatriots experienced during their campaign against Quebec in 1775; see also the many examples cited in Speth 2010).

Contemporary Western meat preferences are not all that different from those expressed by Euroamericans in the 19th century, although nowadays such preferences are often couched in terms of their perceived healthfulness. Today's consumers generally prefer muscle meat over organs, and they commonly place a premium on cuts of meat that are "lean" (bearing in mind, of course, that meat from domestic animals is almost invariably marbled and hence anything but lean by comparison to muscle from wild ungulates). Nothing illustrates the Western perception of what constitutes "good" or "desirable" meat better than the goals expressed in a fairly recent market-oriented analysis of the emerging Alaskan reindeer meat industry (Renecker et al. 2005). These authors spell out in unambiguous terms the carcass qualities that are needed to meet the market demands created by today's Western consumer preferences. And, as the following quote so strikingly illustrates, these preferences are antithetical to those of traditional northern foragers precisely because they give top billing to lean muscle, not fat:

> Carcass value is influenced by the development of muscle, bone and fat with the most valuable cuts of meat coming from the loin and hindquarters of the carcass. The amount of external, internal and intermuscular fat effects the economic value of carcasses more than any other factor…*as the highest commercial returns are realized from carcasses possessing the highest amount of lean tissue in comparison to bone and fat*. (Renecker et al. (2005: 117, emphasis added)

I should also note here that, when it comes to opinions about the way "traditional" northern hunters ranked different body parts of their prey, the ethnohistoric literature can often present rather contradictory views. In order to make sense of these discrepancies, one has to keep in mind both the nature and context of the sources from which one draws such information. For example, as pointed out earlier, it makes a great deal of difference whether the rankings are faithful renderings of what Native peoples were actually doing, or instead are statements colored by the observer's (usually a Euroamerican) own food choices and preferences.

It is also important to note the timeframe of the observations. Prior to the widespread use of dog sleds, the demand for dog food would have been relatively small (if at all), and hence the need for lean muscle meat correspondingly limited as well. Interestingly, even though basic sled technology was introduced into the New World arctic during the Thule migrations sometime after about AD 900–1000, heavy reliance on dog sleds for travel and transport did not develop until much later, in fact probably not until the late 18th and 19th century, hand-in-hand with the growth of the European fur trade. Both archaeological and ethnohistoric data suggest that pre-Contact dog breeds in the north were relatively small and poorly suited for pulling heavily-laden sledges and sleds through deep snow (Ameen et al. 2019; Friesen 2020; McGhee 2009; Morey and Aaris-Sørensen 2002; Savelle and Dyke 2014; Savishinsky 1975; Sharp 1976: 26; Sheppard 2004; Simpson 1843: 311, footnote; Whitridge 2018: 24–25). As a consequence, most transport in the north, even as recently as the first half of the 19th century, was done, not by teams of dogs pulling sleds, but by women carrying heavy burdens on their backs or dragging loaded sleds or sledges (Allen 1887: 133; Anonymous 1710: 27–28; de Laguna 2000: 326; Dunn 1844: 105; Franklin 1824: 143; Glover 1962: 106, 125–126; Gookin 1792: 9 [originally written in 1675]; Hardisty 1867: 312; Hearne 1795: 55, 89–90; Latham 1851: 249; Lytwyn 2002: 97–98; Mackenzie 1801: 261; McCormack 2014; Perry 1979: 365; Robinson 1879: 326–327; Savishinsky 1975; Sharp 1976: 26; Smith 2022: 84; Swaine and Drage 1748: 211; Turner 1894: 271). In the Northern Plains that pattern only began to break down when groups acquired horses. In the north, where the use of horses was simply not viable, change came about as the Hudson's Bay Company began providing Indigenous hunters with larger Old World dog breeds that were capable of pulling loaded sleds through deep snow, and high-powered rifles that allowed them to kill enough game to keep a ravenous team of hard-working sled dogs adequately fed. Thus, if I had to guess, I would expect that the value to Indigenous hunters of lean muscle meat would have increased markedly during the 19th century, both because of its usefulness as dog food, and because of its value as an item of trade with European and American fur companies, as well as with missionaries, whalers, miners, military personnel, and other non-Indigenous settlers taking up residence in the north.

In the 20th century, as northern Indigenous peoples began living a more sedentary lifestyle in larger, permanent settlements, and as snowmobiles replaced dog sleds as the primary means of travel and transport, the need for dog food almost certainly declined. However, the value of lean meat as human food may have increased, at least in those contexts where hunters were able to acquire Western foods through trade, government provisioning, or purchase at local grocery stores. These Western introductions would have loosened the nutritional constraints that limited human consumption of lean body parts in the past.

By 1969, when Binford began working at Anaktuvuk Pass, the Nunamiut had already largely abandoned the use of dog sleds in favor of snowmobiles. They also obtained Western foods in substantial quantities from a community grocery store and through government food-assistance programs (Binford 1978: 138; Hanson 1973; and Osburn 1974). Nevertheless, like most other traditional foragers in the north, they clearly still viewed thighs and other lean muscle meat as undesirable human food, Binford's rankings of the upper fore- and hindlimbs not withstanding (see Table 1).

Finally, one has to consider the impact of Western concepts of conservation on the way contemporary Native informants describe the use of hunted resources. One can readily see reflections of this impact in the many interviews of tribal elders appearing in the literature over the past 30 years or so (see discussion in Krech 2005). Many of these testimonials emphasize that, in the old days, Indigenous hunters never "wasted" what they killed—*they killed only what they needed, and they used all parts of the animals*. Leaving aside the idealism and obvious ambiguities in statements of this sort (i.e., does using all parts of a prey type necessarily mean the hunters used *every part of every individual* of that prey type that they killed?), the "non-wasteful" image that these contemporary interviews portray often smacks more of the conservationist agendas of governmental agencies than traditional Indigenous ideologies regarding the relationship between humans and the "other-than-human persons" who inhabit the same landscape (see discussion on "waste" below). Moreover, as emphasized throughout this paper, it also runs counter to nutritional logic. And it runs counter to numerous early accounts that document surplus killing, often on a substantial scale, during the period before these northern hunters became deeply enmeshed in the European fur trade and global market economies.

By now it should be clear that Binford's original MGUI and its more recent derivative, the FUI, when applied to hunter–gatherers living in subarctic and arctic environments or in their Pleistocene analogs, significantly overvalue the food utility of the upper limbs because of the weight they assign to the masses of lean muscle tissue associated with these parts of the carcass. Thus, a critical issue that remains to be considered is how that overvaluation might affect the interpretations that zooarchaeologists make when they find correlations between these heavily meat-biased indices and measures of skeletal element abundance? I will return to this important issue shortly but, before doing so, there are a few others that we should look at briefly first.

PEMMICAN

It is important to point out that thigh meat was not always ranked toward the lower end of the utility hierarchy by northern foragers. In fact, in addition to its considerable value as dog food or as an item of trade, it was of great importance for one other specific purpose, precisely because it was so lean—the making of pemmican (Colpitts 2015; Ngapo et al. 2021; Speth 2020: 80–81; Stefansson 1960). For those unfamiliar with pemmican (sometimes spelled pemican, pimican, pimikan, pemikan, or pemekan), it was the mainstay of the North American fur trade, and a critical food for First Nation and Native North Americans on the Great Plains and throughout the northern forests and tundras. It was also an extremely important food source for fur trappers (voyageurs), as well as for explorers, military officers, and many others who needed a light weight, easily preserved food that, by itself, could sustain an individual for months on end without additional food supplements (Glover 1962: 312–313; Merk 1968: 346–347). Pemmican was widely traded, and wars were even fought over control of its production and trade (e.g., Martin 1994).

Pemmican was made by drying or "jerking" lean meat, most often the thigh meat of bison, moose, elk, or caribou, and then pounding it into a powder called "beat meat." In Patagonia, Native hunters treated the lean thigh meat of guanacos in much the same way, first drying it to produce "charqui," then pounding it, and finally mixing it with the fat obtained from ostrich-like rheas (see Musters 1871: 74–75). Fatty meat was avoided because it was difficult to thoroughly dry before the fat turned rancid. The pounded or "beat meat" was then mixed with hot rendered fat (marrow fat was the most highly prized) according to highly standardized and widely known recipes, typically about half lean and half fat by volume. When converted into calories, standard pemmican provided about 30% of its energy as protein (lean meat) and 70% as fat (see Speth 2020). During the height of the fur trade, pemmican was stored and transported in leather sacks called "pieces" or "*taureaux*," each about the size of a large pillow case and weighing roughly 90lb (40kg). So long as pemmican was kept dry, it could be stored for well over a year. And, as already noted, the ideal meat for making pemmican came from the thighs, precisely because those muscles were extremely lean and hence easily and quickly sliced into thin strips and dried. As James Isham, an observer at Hudson's Bay in 1743, put it:

> The Leg's and thigh's they cure other ways, they cutting all the flesh of the bones, and Cutt itt in slices, which is to be Dryd. in the same manner as aforemention'd, this meet when Dry'd they take and pound, or beat between two Stones, till some of itt is as small as Dust, which they styl (Ruhiggan) being Dryd. so much that their is Little moisture in itt;—when pounded they putt' itt into a bag and will Keep for several Years…. (Rich and Johnson 1949: 155–156)

Pemmican could only be made in quantity if there was a substantial surplus of fat on hand, since roughly half of the traditional mix by volume was fat. However, as already discussed at length, the ethnohistoric record makes it abundantly clear that fat was almost always in short supply relative to the amount of lean meat that was available. Thus, surplus killing for the acquisition of fat was almost a given whenever pemmican was to be made in quantity, and during the heyday of the fur trade its production achieved an almost industrial scale. However, in the context of routine daily subsistence, Indigenous hunters tended to limit their use of the thighs and other major muscle masses (except when they had dogs to feed or when they anticipated trading with Euroamericans) and, to the extent possible, opted instead for the fattier parts of their kills.

THE NOTION OF "WASTE"

Surplus killing, understandably, is a topic of considerable sensitivity among contemporary Indigenous peoples and, by raising it at all, I am treading onto rather thin ice (see, for example, Krech's 1999 book *The Ecological Indian: Myth and History*, and the many responses it triggered—some laudatory, some extremely negative; also see his 2005 retrospective). Just using these words makes it sound as though I'm suggesting that Indigenous northern peoples were highly wasteful of valuable food resources, a view that was repeated endlessly by early Euroamerican observers. So a few words of explanation are definitely in order here. Westerners, at least those who were not dedicated "sport" or "trophy" hunters, have typically viewed big-game animals like caribou, bison, elk, and others as "resources," as commodities to which one can assign a concrete monetary or exchange value of some sort. The Hudson's Bay Company (HBC) provides a case in point. In the early days of the fur trade, HBC used the "Made Beaver" or MB as their principal unit of value, each MB equivalent "to the value of a prime whole beaver skin on the London market" (Ray 1978: 116). The HBC then assigned each European trade good—e.g., guns, ammunition, clothing, traps, knives, and other sundry supplies and equipment—its worth in MB units, and these values served as the basis for subsequent bartering with northern hunting peoples. Thus, from the typical Western perspective any animal that is killed just for its fat, with most or all of the meat and even the hide simply left behind to rot or be devoured by wolves, would almost certainly qualify as "waste."

Not only is the Euroamerican predilection for "steaks" at odds with the very real threat of rabbit starvation faced by hunters who subsist on a largely meat-based diet, but the very notion of "waste" as Westerners generally conceive of it stands in stark contrast to the ideology of most traditional northern hunting peoples. From the Indigenous perspective the landscape is filled with "other-than-human persons" or "spirit-beings," sentient entities with "souls" who demand and deserve the hunter's respect, who possess important knowledge about the landscape that the hunter must observe and learn, who have a rightful place or "home" within that landscape and pathways to move about in it, and who have definite wants and needs, much like those of the hunters themselves (Anderson 2017; Brightman 1993; Brightman et al. 2012; Harrod 2000; Hill 2011; Kendrick et al. 2005: 185–189; Losey et al. 2011: 175; Nadasdy 2007; Ray 1975: 59–60; Reo and Whyte 2012: 20; Tanner 1979; Wax 1968: 235; Willerslev 2007). Thus, the connections between humans and their non-human prey are relational and ongoing into the future.

Contrast this embracing and all-encompassing Indigenous view of the natural and spiritual world, which places humankind squarely within it, not above it, with the Western view, starkly codified in the Old Testament of the Holy Bible (Genesis 1: 26–28), which places mankind outside of, and clearly superior to, the rest of the natural world, and with an explicit license to go forth and "subdue" it:

> And God said, Let us make man in our image, after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth. So God created man in his own image.... And God blessed them, and God said unto them, Be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that moveth upon the earth. (Anonymous 1900: 1)

Sahlins, with his characteristically incisive yet humorous take on things, in a single sweeping paragraph traces the evolution of the Western tradition from the original "Fall" to the present day:

> Still, God was merciful. He gave us Economics. By Adam Smith's time, human misery had been transformed into the positive science of how we make the best of our eternal insufficiencies, the most possible satisfaction from means that are always less than our wants. It was the same miserable condition envisioned in Christian cosmology, only bourgeoisified, an elevation of free will into rational choice, which afforded a more cheerful view of the material opportunities afforded by human suffering. The genesis of Economics was the economics of Genesis. (Sahlins 1996: 397)

Indigenous belief systems differ from Western conceptions in other ways as well. For example, it is the animal who offers itself to the appropriately respectful hunter to be killed; it is not solely a matter of the hunter's skill that brings the prey down. And once the animal has offered itself to the hunter, its remains not only feed the hunter and his family, but whatever the hunter does not require, *or cannot use*, provides for the needs of countless other "sentient beings" who also, both literally and spiritually, share the same landscape (Buckreus 2016; Campbell 2004: 164). Some of the more obvious of these other-than-human-persons include wolves, coyotes, wolverines, foxes, weasels, martens, porcupines, badgers, bobcats, numerous predatory and scavenging birds, rodents, countless insects and their larvae, fungi, and many other life forms. From the traditional Indigenous perspective, all of these "beings" have food needs, hence none of what the hunter leaves behind is "wasted" in the conventional Western sense of the word. So long as the hunter has treated the animal, and its remains, with the proper respect, and has shared what he does not need with the other beings who inhabit the same landscape, be they human or non-human, the prey will regenerate and present itself to the hunter again, thereby repeating a timeless cycle. Resource "conservation," as typically conceived of in Western thought, is not the issue; it is maintaining the proper respect and fulfilling the necessary obligations between hunter and prey that perpetuate the relationship into the future.

One additional thought may be useful here. I speak no Indigenous language and my training in anthropological linguistics is minimal at best, so I do not know how Indigenous peoples might actually express these ongoing relational and spiritual connections between hunter and prey. These are alien concepts to most Westerners, and English is ill-suited for describing them. I have already illustrated the problem with the word "waste." But its many synonyms fare no better. For example, we have lots of words to describe the act of leaving parts of an animal behind at a kill, but none of them, as far as I can tell, convey any sense that there might exist a spiritual connection between the hunter and what he leaves behind that serves to maintain and perpetuate that relationship into the future. Thus, we use words like abandon, discard, cull, throw away, toss aside, reject, dispose of, get rid of, eliminate, dispense with, chuck, dump, and many others, but all imply a complete and permanent severing of any such relationships. From a Western perspective what gets deliberately left behind becomes trash or garbage, words that carry connotations ranging anywhere from things having no value or use to things that are utterly disgusting. That is why, for example, Southwestern archaeologists in the old days had so much difficulty understanding why ancient Puebloan peoples often buried their dead in village "trash middens." To many a Westerner, that smacked of disrespect for the dead, which seemed unlikely, so archaeologists went to great lengths to explain such behavior in ways they could find comprehensible. One of the favorites was the idea that Pueblo peoples simply found it easier to dig grave pits in the soft deposits of the middens than elsewhere in the compact surroundings (e.g., Wormington 1947: 55–56). Non-Native archaeologists simply could not fathom the idea that scraps of animal bone, decaying maize cobs, and broken potsherds might possess important spiritual meanings. In any case, like the word "waste," the many other similar terms are probably equally alien to traditional Indigenous ways of relating to the natural and spiritual world, and all, as a result, would be seen as inappropriate, if not offensive. Finding the right words and ways of phrasing them, and anticipating how they will be understood, not only by Western audiences, but also by Indigenous audiences, has proven to be far more difficult than I had ever imagined, and I fear I will end up satisfying neither....

VITAMIN C AND SCURVY

There is another reason why thigh meat, and muscle meat more generally, might be discarded or used as dog food rather than as human food. Muscle contains almost no ascorbic acid or Vitamin C (Speth 2019; see also Hassan et al. 2012: 4, their Table 1). Humans cannot biosynthesize Vitamin C, whereas dogs can (Gordon et al. 2020); hence people heavily dependent on animal foods for their mainstay—whether year-round, as in the arctic and subarctic, or over the long months of winter and spring, as in many cool to cold temperate regions—face the ever-present threat of scurvy. In ungulates, most Vitamin C is contained in the organs and nervous tissue, not in the muscle. Nor is there any significant amount of Vitamin C in the stomach contents, despite the abundance of partly digested vegetal matter. At the high pH values characteristic of both ruminant and monogastric stomachs (pH≈6.0), Vitamin C rapidly degrades (Speth 2019). While traditional foragers may not have known about vitamins, they certainly knew about scurvy, and through long experience they knew full well how to deal with it (focus on internal organs, not muscle; eat meat raw, lightly cooked, or fermented). I suspect ancient hunting peoples were equally well informed on the topic and knew how to stave off scurvy.

> When I asked an old Indian [First Nation Athabaskan, Yukon], through an interpreter, why the Indians did not get scurvy he replied promptly that that was a white man's disease. I asked whether it was possible for the Indians to get scurvy. He replied that it was, but said that the Indians know how to prevent it and the white man does not. […] He then described how when the Indian kills a moose he opens it up and at the back of the moose just above the kidney there are what he described as two small balls in the fat. These he said the Indian would take and cut up into as many pieces as there were little and big Indians in the family and each one would eat his piece. [...] By eating these parts of the animal the Indians would keep free from scurvy, which is due to the lack of vitamin C. The Indians were getting vitamin C from the adrenal glands and organs. Modern science has very recently discovered that the adrenal glands are the richest sources of vitamin C in all animal or plant tissues. (Price 1939: 75)

Price's Native informant knew exactly what he was talking about (see also Campbell 1976: 398). The adrenal glands are, in fact, the most concentrated locus of Vitamin C in the mammalian body, whether terrestrial ungulate or marine mammal, while muscle tissues are notoriously poor (e.g., Hediger 2002: 445; St. Aubin and Geraci 1980: 606; Rodahl 1949: 36). Early Euroamerican explorers' zest for "savory" roasted steaks was often, quite literally, the kiss of death.

HIDES

Archaeologists have a long history of treating hides as an "also ran"—that is, when you kill an animal you automatically get a hide as well, a bit like the "two-for-one" or "buy one, get one free" sales pitches familiar to us all on TV infomercials. To the contrary, numerous examples from the ethnohistoric and ethnographic literature indicate that, for northern Indigenous hunting peoples, acquiring suitable hides often involved a trade-off between obtaining food and fulfilling their clothing, shelter, and equipment needs (see, for example, Taylor and Turner 1969: 157).

> …one of the deers [caribou] grand crossing seasons, consequently be they fatt or lean, are killed in great numbers, now as the weather is very fine and warm consequently the skins are not in season, and yet this inconveniency cannot be helped, for should we slip this opportunity or oppose the Indians hunting them, we should get no venison and the Indians be disgusted. (Humphrey Marten, Chief Factor at York Factory, unpublished manuscript dating to the late 1700s in the National Archives of Canada, B.239/a/73, fo. 3d., cited in Lytwyn 2002: 103)
>
> The processing of caribou killed in the summer was usually quite different from the pattern just described. In the first place, the primary goal of most summer hunts was the acquisition of hides for clothing, particularly those

> of fawns of the year. Furthermore, most hunters living in the study region had to walk dozens, and sometimes hundreds, of miles to find caribou at this time of year. Then, having made a successful hunt, they had to pack the harvest the whole way back home again. In some districts, they traveled by boat part of the way, the balance on foot. [….] The overwhelming emphasis on skins and the difficulties of transport imposed stringent limitations on just what could be accomplished. Skins, virtually all of which were destined to become clothing, were carefully removed and dried…. Fat, too, was removed and dried, as were some of the sinews. Some meat was dried and carried along as food, but most of the meat and all of the bones usually were abandoned. (Burch 2006: 139)

Hides vary markedly in their properties by species, age, sex, season, and anatomical location. Some have better insulating properties; some are more waterproof; some are easier to keep clean; some are softer and more pliable, others stiffer; some stand up better to wear and tear; some are easier to process and tan. If the hunter needed hides for making moccasins, the standard footwear of the subarctic, he would most likely go after moose, which might require searching habitats far removed from the places where he would normally expect to encounter caribou, elk, or bison.

> …the foot-covering must be of the best. Moccasins are made of smoked moose-skin, because of its thickness (though the thinner caribou-skin is equally durable), and are really the pride of the Indian wardrobe. They are the most, and very frequently the only, decorated piece of his apparel; in presentation they are the vehicle of regard from one Indian to another; they carry the first tidings of a more tender sentiment from the maiden to the young hunter, and are the surest indication not only of the degree of the woman's handiwork, but, if she be married, of the degree of her regard for the husband. An Indian's moccasins are a walking advertisement of his standing at home. (Whitney 1896b: 59–60)

And if the hunter required hides to prepare warm winter clothing, caribou would be the ideal choice, with skins of females and calves best suited for soft, warm inner garments or for baby garments, and thicker male hides for more durable outer wear. For teepee covers, tarps, parfleches, body armor, shields, and other equipment requiring thicker, tougher, or more moisture-resistant leather, moose, elk, or bison might be the targets of choice (e.g., Hough 1895; Jones 2004; LeBlanc 1999: 107–110, 297; Lowrey 1999; see also references in Speth 2018: 212–213).

In sum, the ethnohistoric accounts bring to the fore several interesting points regarding the prey choices made by northern foragers when they had to fulfill specific hide needs: (1) in many circumstances the value of an animal's hide outweighed the value of its meat, the rank of the former instead being more in line with that of the fatty tissues on the carcass—that is, the tongue, internal deposits of fat, and hide would be taken, while much of the meat would be abandoned at the kill; (2) fulfilling hide needs sometimes led to prey choices that deviated significantly from traditional body-size or encounter-rate expectations arising from classic diet breadth models—for example, beaver and rabbits were preferred over caribou, despite their much smaller body size, when hunters needed to fulfill specific winter clothing needs; and, as already noted, caribou calves at times were preferred over adults for much the same reason; and, (3) on many occasions the hunter's choice of prey must have been influenced by his wife's hide needs, since she was the one who presumably made virtually all of the family's clothing and leather equipment. Since such items of material culture would have been absolutely vital to the survival and well-being of the entire household in harsh northern climates, it seems likely that the hunter would have been well aware of, and sensitive to those household needs. If so, such needs at times must have influenced what animals he searched for and where on the landscape he would have concentrated his efforts. This communicative and cooperative aspect of the division of labor is one that is seldom addressed head-on by archaeologists and human behavioral ecologists who, for the most part, tend to model the hunter's decisions about what and where to hunt as though they were solely his prerogative. However, fulfilling his family's multifaceted hide needs almost certainly involved more than simply killing any (preferably big) ungulate that conveniently happened to come down the pike. Thus, gaining a satisfactory understanding of the hunter's decisions, especially in light of the trade-offs he may have to make between his family's food needs and the wife's many specific hide needs, may require models as complex as those typically used to understand the hunter's subsistence-related choices (e.g., Bettinger et al. 2015).

MEAT VS. MARROW

Now, returning to our discussion of utility indices, the low value often assigned by traditional northern hunting peoples to the meat on the thighs and on the upper limbs more generally, raises an interesting point that is well worth keeping in mind. Faunal specialists commonly find cutmarks on the major meat-bearing limb bones, especially the femurs, humeri, tibias, and to a lesser extent the radii. Not only do zooarchaeologists typically interpret these marks as evidence that hominins had early access to complete or nearly complete carcasses, either by power scavenging or by hunting, they also often take their presence as prima facie evidence that ancient hunters had deliberately targeted the large muscle masses *because of their presumed important value as human food*.

> Humans with early access to carcasses impose the most cutmarks on upper limb bones (humerus and femur) because these bones support some of the largest muscle masses, one of the edible resources in the ungulate body that is of most interest to a hungry consumer. (Domínguez-Rodrigo and Pickering 2003: 278)

But in cold, highly seasonal environments broadly analogous to those of the northern latitudes today, and especially in contexts where feeding dogs was not a significant part of the picture, such cutmark evidence does not necessarily mean that all or even most of the muscle meat was actually conserved and eaten. Hunters obviously had to remove the muscle masses to get at the marrow lying beneath, and doing so would probably leave cutmarks, both dismemberment and defleshing marks. In other words, as counterintuitive as this may seem, such cutmarks do not automatically reveal what the hunter's real goal was—retrieving meat *plus* the underlying marrow, or just the underlying marrow (see also Kuntz and Costamagno 2011: 14). The commonplace zooarchaeological assumption that one of the hunter's objectives was to retrieve the muscle meat, or at least some of it, may in many instances prove to be correct; but in many others there is reason to worry, because what we actually may be doing is projecting the modern Western predilection for lean (and presumably) healthy steaks into the past, as so clearly expressed in the passage quoted earlier by Renecker et al. (2005: 117), rather than revealing the reality of prehistoric northern hunter–gatherer foodways.

Ironically, by giving so much weight to the muscle tissue on the limbs, the MGUI and FUI are biased in somewhat the same way as Renecker et al.'s contemporary marketing goals. As a result, these two indices are probably relatively poor tools for revealing the real food needs that motivated traditional northern foragers to transport upper limbs back to a home base (see the interesting discussion in Brink 2001). As already indicated, the major reason may have been for their marrow content (and perhaps grease), not the meat, a likelihood that is being recognized with increasing frequency in Paleolithic faunal studies (see, for example, Blasco et al. 2019: 7; Brink 2001; Costamagno et al. 2006: 475; Díez et al. 1999: 644–645; Discamps and Lemeur 2020: 8; Kitagawa et al. 2018: 228; Marín et al. 2020: 16; Moclán et al. 2021: 7, 9, their Table 2; Morin and Ready 2013: 259; Niven 2003: 206; Rendu et al. 2019: 5; Smith 2015: 194; Terlato et al. 2021; Voormolen 2008: 104). The great importance of marrow is made most evident in Morin and Ready's (2013; see also Morin 2007) broad comparative evaluation of the predictive power of several different meat-based and marrow-based utility indices. Their study led them to conclude that:

> Our analysis of correlations between Western European Paleolithic assemblages and an expanded set of utility indices indicate that the UMI—which measures marrow utility—shows the highest percentages of significant positive correlations, while significant inverse relationships are sometimes common with the MDI, a proxy for dried meat utility. In contrast, significant correlations with the food utility indices, positive or negative, are rare irrespective of the type of site. This pattern persists for all the taxonomic groups considered: cervids, large bovines, caprines, and equids. (Morin and Ready 2013: 259)

A critical implication here is that there may be a mismatch between our analytical results and how we interpret them. Put somewhat differently, many zooarchaeologists have found statistically significant correlations between the MGUI or FUI and various measures of skeletal element abundance (e.g., MNE, MNI, MAU, etc.). In other words, the indices often do produce patterning; that is not in question. What is in question is how we interpret that patterning (see also Brink 2001). Correlation need not indicate causation. Are we seeing evidence that ancient hunters transported upper limb elements because they were the meatiest parts of the carcass, or did they remove and discard much of the meat and bring back mostly muscle-stripped limb bones for their valuable yield of fatty marrow? Therein lies the conundrum....

DISCUSSION AND CONCLUSIONS

Utility indices have become popular tools for exploring patterning in prehistoric faunal assemblages, and nowadays most zooarchaeologists, almost as a matter of course, examine their data for patterned relationships between skeletal element frequencies and various measures of utility (see Lyman 2012). As a result, terms like "bulk curve" and "reverse utility curve" have become commonplace in the literature, and the transport and processing of low-utility elements like mandibles and phalanges are now often considered likely proxies for resource stress (Binford 1978: 31).

In addition, over the years since Binford's pioneering efforts with caribou and sheep, zooarchaeologists have developed utility indices for many other animals, including non-mammalian taxa and even plants (Barlow and Metcalfe 1996; Belardi and Otero 1998; Diab 1998; Emerson 1993; Friesen 2001; Garvey 2010; Garvey et al. 2011; Giardina 2006; Jacobson 2000; Lyman 2012:61, his Table 1; Lyman et al. 1992; Madrigal 2004; Morin 2007; Outram and Rowley-Conwy 1998; Rowley-Conwy et al. 2002; Savelle et al. 1996). In short, Binford launched a powerful and productive approach to the study of prehistoric animal remains, one that has gained widespread acceptance and use across the width and breadth of the profession.

Not surprisingly, zooarchaeologists have also come to recognize a variety of problems with Binford's original indices, spawning a number of revisions to his early formulations (e.g., Brink 1997; Jones and Metcalfe 1988; Lyman 1992; Metcalfe and Jones 1988; Morin 2007). While these newer efforts are valuable, a number of them have been directed primarily at resolving technical and methodological issues rather than examining the interpretive assumptions that underlie the indices. Thus, much progress has been made toward eliminating unnecessary complexity in the design and formulation of the original versions and improving their overall transparency; correcting mathematical inconsistencies and errors; and addressing a variety of equifinality issues, such as distinguishing patterning that reflects human agency from similar results arising from density-mediated attrition or other taphonomic processes (see, for example, Lyman 1994).

But as I have pointed out in this paper, there are some serious problems in the interpretation of the indices that have not been addressed, especially with regard to the more meat-based ones such as the Meat Utility Index (MUI), General Utility Index (GUI), and its widely used offshoot, the Modified GUI or MGUI. And though significantly revised and simplified, these same interpretive issues persist in the FUI. These problems are likely to be most salient when dealing with foraging peoples, recent and prehistoric, living in cold, highly seasonal northern environments in which hunters are compelled to subsist for extended periods on a diet comprised largely, if not entirely, of animal foods. Given a fixed upper limit to the amount of protein a forager can safely consume per day (about 300g or 1,200kcal), the hunter faces a substantial daily energy deficit that can only be met by consuming fat (assuming that carbohydrates are largely or entirely unavailable). Since most muscle meat in wild ungulates is exceedingly lean, foragers can only utilize it to a limited extent. Instead, they have to obtain the needed non-protein calories by selectively targeting fat-rich prey and the fattiest body parts. In doing so, they may often have to keep killing additional prey until they acquire sufficient fat. Depending on the time period and cultural system of concern, the excess lean generated by such surplus killing may simply be discarded, fed to dogs, cached for later use, or traded to others who have more ready access to carbohydrates and oils.

Before continuing further, there is a critical point that I need to underscore here lest the reader come away with a serious misunderstanding of this paper's core message. *In no way do I mean to suggest that muscle meat, regardless of the quantity ingested, is without food value and actually hazardous, but rather that its consumption is limited by the amount of protein a forager can safely ingest on a daily basis. Consumption of protein beyond that limit can rapidly lead to a condition widely known as rabbit starvation.*

It is easy to show the significance of this limit with a calculation similar to the ones we did earlier. Thus, if we assume a very generous daily protein ceiling of 300g for a 60–70kg forager, he or she can consume roughly 1.5kg of fresh meat, which yields 1,200kcal's worth of protein. And if the muscle meat has a fat content of 2%, a generous value for most wild ungulates (see, for example, Adamczewski et al. 1987a: 370; Belardi and Otero 1998; Cook et al. 1949; Farmer et al. 1971; Marchello and Driskell 2001; Miller et al. 1986; Rule et al. 2002; Soriano and Sánchez-García 2021; Wei Wo and Draper 1975), it would yield only 30g of fat or an additional 270kcal. When added to the calories from the protein, the total daily energy yield of the meat would only be about 1,470kcal. And if we assume a modest energy expenditure of 2,500kcal per day, the forager would repeatedly face a deficit of some 1,030kcal or roughly 40% of his or her daily energy requirement. That's a whopping deficit to have to face on a recurrent basis! As a consequence, surplus killing is likely to be a frequent necessity and, once kills have been made, foragers are likely to select mostly the fattiest tissues and jettison the leanest. *In northern environments and in their Pleistocene analogs, discard of excess lean meat may have been the norm, not a rare and unusual event.*

Going a step further and generalizing from these considerations, one might expect the amount of muscle meat that foragers end up discarding to increase the bigger the prey, the larger the number of animals taken per hunting foray, the greater the distance between kill(s) and home, and at times of year when animals are at their leanest and the threat of "rabbit starvation" at its greatest. Obviously, these expectations will also vary according to the size and age-sex composition of the foraging group, and whether the group at the time of the kill(s) is living in a relatively fixed settlement or traveling from one locality to another. Also, if domestic dogs are part of the calculus, as could be the case as far back as the Upper Paleolithic, more of the lean is likely to be saved for use as dog food (Germonpré et al. 2012; Pionnier-Capitan et al. 2011).

I realize that the basic message here does not make the job of the zooarchaeologist any easier. Thus, we can no longer simply assume that an abundance of limb bones, especially those of the meaty upper limbs, even those displaying unambiguous defleshing marks, necessarily implies lots of meat in the forager's diet. This conclusion likely holds for cold-temperate, subarctic, and arctic habitats, but it may also prove to be the case in other highly seasonal environments in which foragers had to rely heavily on animal foods for extended periods of time. Many of the limb bones may have been brought home largely if not solely for their marrow fat content, not the meat, and the cutmarks they bear may reflect the forager's efforts to get rid of a fair amount of the lean muscle, not put it on the family table (e.g., Morin and Ready 2013; see also Stiner 2012: 134). At this point I have no clear idea how to tease these two possibilities apart, but this to me is an important interpretive conundrum in need of much more creative thought and research.

To make matters worse, foragers can easily get at many of the most highly ranked parts of the carcass—the adipose tissue, tongue, intestines, blood, and stomach contents—without leaving many traces that an archaeologist can readily identify. Fortunately, however, the targeting of marrow, one of the most desirable sources of fat, does leave tell-tale traces, and we are fortunate in already having some very effective tools for studying its role in prehistoric contexts (e.g., well-designed marrow utility indices, and distinctive bone surface modifications such as striations and impact fractures; see, for example, Binford 1981; Byers et al. 2020; Morin 2007; Morin and Ready 2013).

The rib cage is another highly ranked area of the carcass (see Binford 1978: 41, Table 1.14), in part because of the layer of subcutaneous fat along the base of the spine directly above the ribs (in early accounts often called the fleece, *dépouille*, or *depuyer*; see Hamilton [1905: 33] for a helpful description of this important fat deposit), and in part because of the fat distributed within the intercostal tissue itself. Rib units, because of their high surface-area-to-volume ratio and limited marrow content were also comparatively easy to dry with limited spoilage and transport (e.g., Binford 1978: 105, his Table 3.1, Column 6; Friesen 2001; Pasda 2013: 115–116). The brisket, a mass of fatty tissue surrounding the sternum, is also very highly ranked (e.g., Ewers 1958: 13; Flannery 1953: 58; Pike 1892: 51). Hence, these elements may also have considerable diagnostic potential not unlike marrow extraction. Moreover, gaining access to the viscera in the upper body cavity may leave diagnostic cutmarks on the internal surfaces of ribs as well as on adjacent thoracic centra (see Nilssen 2000: 46–47).

Ribs are frequently encountered in archaeological sites and cutmarks are common. However, ribs are also among the elements that zooarchaeologists most often ignore, though not without reason (see discussion in Ramsay and Lyman 2014). They are difficult to identify to species and even to specific element within the rib cage; in contexts where whole animals were not transported, the proximal ends may be underrepresented, presumably because hunters often found it more expedient to break off large segments of the rib cage than to disarticulate each individual bone where it joined the spine (see butchery descriptions in Wheat 1972: 98–103; see also O'Connell et al. 1988: 120; Tixier 1844: 171; Yellen 1977: 282–283); they are quite fragile and break or split into many fragments and splinters; and they are vulnerable to density-mediated attrition and loss to carnivores.

Nevertheless, because of their high food utility, I think ribs are worth a closer look (see Ramsay and Lyman 2014). Despite the problems just enumerated, if one is willing to work with broad size classes rather than individual species, and perhaps quantify the fragments in some relatively coarse-grained manner, such as observed versus expected total length of rib in the average rib cage of an animal of a particular size class, we might yet learn a lot about transport decisions based on an element that even Binford's Nunamiut informants uniformly assigned a much higher rank than either the femur or the humerus (again, look at Table 1.14 in Binford 1978: 41). The ribs are definitely a neglected category that is worth exploring further. For an example of their interpretive potential, though for a case far removed in both time and space from the Paleolithic, see Speth and Rautman's (2004: 103–106, 128) study of the ribs of pronghorn antelope (*Antilocapra americana*) and American bison (*Bison bison*). The authors were able to show that 14th-century AD hunters in southeastern New Mexico consumed the rib units of antelope locally, but increasingly used dried bison rib slabs as items of exchange with distant Pueblo farmers. Others have successfully used this same approach to quantify fragmentary ribs from archaeological sites (e.g., Driver 1990: 250–251; Grayson 1988: 66–67; Thomas and Mayer 1983: 358, 365–366).

Perhaps the most important message of this paper is the suggestion that northern foragers (including the Nunamiut in pre-snowmobile days) either fed much of the muscle meat to their dogs or left it behind at the kill. What often contributed most to the value of the limbs was their marrow content, not the lean muscle meat (see also Brink 2001). However, given the weight of limb bones relative to their yield in marrow, the hunters would very likely have processed many of these bones, particularly those from larger ungulates, at or near the kill rather than schlepping them home. Moreover, northern hunters may have had to continue killing animals long after they had reached their protein quota just in order to obtain sufficient quantities of fat to stave off rabbit starvation. For the archaeologist this implies that there may be a significant mismatch between the estimated number of animals found in a site and their actual consumable food yield. For the very same reason, I suspect surplus killing may also have been common in the Paleolithic, giving rise to the same mismatch between numbers of animals killed and the actual amount of meat that was transported and eaten.

Finally, given the arguments laid out in this paper, one can begin to appreciate a problem in the way the nitrogen stable isotope data for Neanderthals are generally interpreted. In study after study the 15N results place these hominins further up the trophic ladder than hypercarnivores like wolves, hyenas, and even lions and saber-toothed cats (Bocherens 2011; Bocherens and Drucker 2021; Bocherens et al. 2005), an outcome that, to me at least, makes little nutritional sense. Yet most scholars seem willing to accept these results at face value, I suppose in large part because they tend to affirm the level of carnivory most of us assume for Neanderthals on the basis of the abundant large-mammal bones found in Middle Paleolithic archaeological sites (see Morin et al. 2016).

I have no qualms about the actual isotope numbers, nor do I have problems with the suggestion that Neanderthal diet, at least during colder phases of the Late Pleistocene, was comprised almost entirely of animal foods. Traditional northern foragers such as the Inuit and many others were able to thrive that way, so why not Neanderthals? The problem lies in the fact that humans are not hypercarnivores, and I do not think they ever were. Even though they may consume a diet comprised entirely of foods of animal origin, some 70% of that intake (expressed in terms of energy) was provided by fat, not protein. Not so for the felids, hyenas, and wolves. Their fat needs were lower, and their protein tolerance much higher, allowing daily protein intakes as high as 50%–70% of calories (Bosch et al. 2015: S41, S47; Van Valkenburgh 2007). For hominins, sustained protein intakes that high would most assuredly have been lethal.

In order for these stable isotope results to make dietary sense for humans, something other than, or in addition to, total protein intake has to be responsible for pushing Neanderthal 15N values well beyond those of obligate carnivores and hypercarnivores. To be honest, I do not know what it was; but, if I had to guess, it likely had something to do with the surprising array of animal body parts that foragers, including Neanderthals, consumed and the way they prepared them—what Solomon Katz (1990) referred to as "cuisine." Traditional northern foragers ate meat and fat raw, frozen, dried, smoked, lightly boiled, simmered, roasted, stewed, and thoroughly putrefied (see Spray 2002). Moreover, they not only ate the meat and fat, they also consumed the stomach contents, maggots, warble fly larvae, amniotic fluid, bile, blood, antler velvet, soft inner parts of hooves, sometimes urine, and even excrement. Unfortunately, very little so far has been done to explore how such traditional "cuisines" might ultimately impact the 15N levels in bone collagen (but see Beasley 2020: 21; Beasley et al. 2019a: 14, 2019b: 47–48 for particularly tantalizing isotopic results for maggots). Moreover, meal preparation sometimes involved mixing in other ingredients as well, including a variety of mineral and vegetal flavorings, medicinal plants, and possibly even wood ash and special clays (Christensen et al. 1998; Ingstad 1951: 103; Nickerson et al. 1973: 15; Sorokowska et al. 2017). While the antiquity of "wet cooking" or "stewing" is unknown, it can easily be done in hide containers placed directly over hot coals without requiring heated stones (see Speth 2015). Altogether, such complex processing, mixing, putrefying, and cooking altered the food's pH, bacterial composition, fermentation and oxidation byproducts, Maillard reaction compounds, and polycyclic aromatic hydrocarbons derived from wood smoke and burning fat drippings (Farhadian et al. 2010; Speth 2017; Stumpe-Vīksna et al. 2008; Yu et al. 2017). How (if at all) such diverse and complex "cuisines," including the common if not routine consumption of maggots, might have impacted 15N levels remains largely unknown and under-explored.

To provide a concrete example of the potential complexity of northern "cuisine," a highly esteemed meal in the arctic and subarctic consisted of a caribou or reindeer stomach with its contents still within—preferably the stomach from an animal that had been feeding on lichens at the time it was killed—to which were added the animal's blood, liver, other internal organs, and fat. If maggots were present, they too were often included. The stomach was then sealed and either buried or hung from a tree branch for an extended period of time, in either case long enough to ferment, even thoroughly putrefy its contents. In many cases the stomach was then deliberately frozen so that it could be conveniently sliced before being served. Would such a complex "cuisine," a recurrent delight for the northern palate, affect 15N values in bone collagen and, if so, in what way and to what extent? Whatever the outcome, we need to find out. We will not resolve this isotopic conundrum by simply measuring more 15N values, while ignoring the way humans invariably transformed the unprocessed products of the hunt into culturally appropriate "cuisine."

The classic image of the intrepid Ice Age forager hungrily chomping on a juicy hunk of roasted lean reindeer or mammoth steak is in large part a Western myth, one that ended up becoming incorporated into the MGUI and FUI, and one perhaps similarly embedded in our meat-centered approach to nitrogen stable isotope analysis and interpretation. The absence of fat and Vitamin C in such "meaty" meals would have been a recipe for disaster—the surest way to guarantee a northern forager's untimely demise from both rabbit starvation and scurvy.

ACKNOWLEDGMENTS

This paper was originally prepared for the "2021 Fryxell Award Symposium: Papers in Honor of Mary C. Stiner" and presented at the 87th Annual Meeting of the Society for American Archaeology in Chicago, Illinois on March 31, 2022. It was an honor to have been invited to participate in the Fryxell Symposium honoring Mary Stiner for her many remarkable contributions to the study of human paleoecology and evolution. And to the same end I am delighted to dedicate the published version to the occasion of that well-deserved recognition as well. Mary's many insightful ideas and analyses over the years have had a huge impact on my career and on the evolution of my own ways of thinking about prehistoric faunal remains and zooarchaeology more generally. When in the mid-1980s I took my first fledgling steps into Paleolithic faunal analysis, I found myself instantly thrust into the midst of the contentious hunting–scavenging debate with no clear vision of how to proceed. It was Mary's pioneering work with the age structure of prey taken by cursorial and ambush predators, and her manner of presenting the carnivore and hominin zooarchaeological data by means of ternary diagrams, that offered me a clear path forward. Her subsequent contributions to the study of human population growth at the end of the Pleistocene, and its reflection in the types of prey targeted by hunters, also provided me with interesting and productive avenues of research to pursue in my own work, as have her many publications on modern human origins. In short, her work has always been a source of inspiration for me and for that, as well as her life-long friendship, I am eternally grateful. Thank you, Mary. I also wish to express my gratitude to Lee Lyman, who generously—and voluntarily—wrote detailed and extremely helpful comments on the manuscript. Thanks to his input I've been able to clarify some critical but ill-conceived arguments and flesh out others. The paper is much better as a result. I also thank my two anonymous reviewers, whose comments led to a better focused and far less strident final product. And in closing, I want to express my deepest gratitude to Loren Cordain, Professor Emeritus of Health and Exercise Science at Colorado State University, for the invaluable advice and help he has given me over the years concerning the role of protein and fat in human diet and nutrition. While he is in no way responsible for any blunders or misunderstandings I may have made along the way, or that I may have incorporated into the present endeavor, I simply could not have developed these ideas to the point where they are today without his invaluable input. That support has always meant a great deal to me. Thank you, Loren.

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