THULE SUBSISTENCE AND OPTIMAL DIET: A ZOOARCHAEOLOGICAL TEST OF A LINEAR PROGRAMMING MODEL

by

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ABSTRACT

Thule archaeological sites typically yield large quantities of well-preserved faunal remains. These remains represent a wealth of information on a wide range of activities related to Thule animal-based subsistence economies, but have only recently been subjected to the quantitative ecological analyses that have increasingly concerned archaeologists elsewhere. This thesis involves the development of a linear programming model of Thule resource scheduling, and an explicit test of its applicability. When compared to the results of a detailed zooarchaeological analysis of faunal material collected from a variety of seasonal site types on southeastern Somerset Island, the modelling procedure was found to offer moderately interesting insights not otherwise attainable.

RESUMÉ

Les sites archéologiques de la culture Thulé produisent fréquemment les vestiges fauniques en grande quantité et en bon etat de conservation. Ces restes représentent beacoup d'information qui a rapport à un grand nombre des activitées relatif aux economies basées sur les animaux. Ce thèse comprend le développement d'un genre de modèle quantitatif et écologique de la chasse Thulé qui devient de plus en plus important en archéologie, et un vérification de son utilité. En comparison avec des resultats d'un analyse detaillé fauniques des ossements retrouvé dans les camps saissonier préhistoriques sur l'Isle Somerset, le modèle s'est demontré moyennement intéressant.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

page

1. INTRODUCTION

One of the most distinctive features of archaeological theory during the 1970's and 1980's was the ever-increasing elaboration of ecological models of prehistoric behaviour. Inspired by the New Archaeology's respect for explicitly scientific formulations of archaeological problems, the "processual archaeology" which emerged in the mid-1970's adopted evolutionary ecology as one of its most important disciplinary paradigms. Although the backlash against ecological approaches in archaeology during the last few years has become at least as fervent as its promotion a decade ago (see, e.g., Shanks and Tilley 1987), it would be imprudent to discard a large body of potentially useful theory merely for the sake of intellectual fashion. In arctic archaeology in particular, which has consistently lagged far behind the theoretical avant garde, many of the most interesting ecological applications have only begun to be explored, and may yet prove worthwhile for understanding the prehistory of a region known for its environmental demands on human resourcefulness. The present research is an investigation of Thule Eskimo (ca. AD 1000 - 1600) subsistence on southeastern Somerset Island, NWT. The potentially rich zooarchaeological database suggested a formal ecological model might feasibly be tested here, while also providing the comparative framework that was lacking due to the absence of detailed zooarchaeological reporting for other sites in the immediate study area.

During the summers of 1989 and 1990 faunal samples were collected from a range of seasonal Thule feature types at Ditchburn Point (PaJs-3) and Mount Oliver (PaJs-4, PaJs-13), in the vicinity of Hazard Inlet (Figures 1 and 2), under the direction of James Savelle. In March and April 1991 ethnoarchaeological research into ringed seal butchery and transport was conducted at Clyde River, Baffin island, to provide a supplementary analytical tool for interpreting the faunal assemblages. The results of the faunal analyses are used to test a linear programming model based on one developed by Arthur Keene (1979) for historic Netsilik Inuit subsistence on Boothia Peninsula, just south of Somerset Island.

The specific objectives of the research are as follows:

1. to develop a linear programming model of resource-scheduling by Thule groups on southeast Somerset Island. This will involve the quantification of nutritional and essential non-food requirements and their availability in the environment, as well as the "costs" of procuring resources which satisfy these needs.

2) to reconstruct, as far as possible, the actual Thule subsistence round through the analysis of faunal remains excavated from a range of seasonally occupied sites.

3) to compare the results of these two lines of inquiry, and assess their implications for Thule decisions regarding resource-scheduling, and for the stability of the Thule adaptation to harvesting a particular suite of faunal resources.

4) to evaluate the appropriateness of this modelling procedure for understanding prehistoric subsistence economies in the arctic.

Chapter 2 provides an overview of the history of ecological approaches in archaeology, and the current state of prehistoric human ecology. Chapter 3 begins with a review of previous studies of Arctic subsistence economies, and particular zooarchaeological approaches to Thule prehistory. A model of resource scheduling for Somerset Island is then developed, from its roots in optimal foraging theory through the quantification of the parameters in a form appropriate to linear programming. Chapter 4 presents the results of the faunal analysis, discussions of taphonomy and site seasonality, and a synthetic account of Thule resource scheduling in the study area. In Chapter 5, the projections of the linear programming model are discussed, evaluated in light of the archaeological data, and the overall results of this research assessed against the above objectives. The conclusions are presented in Chapter 6.

Figure 1: Location of study areas

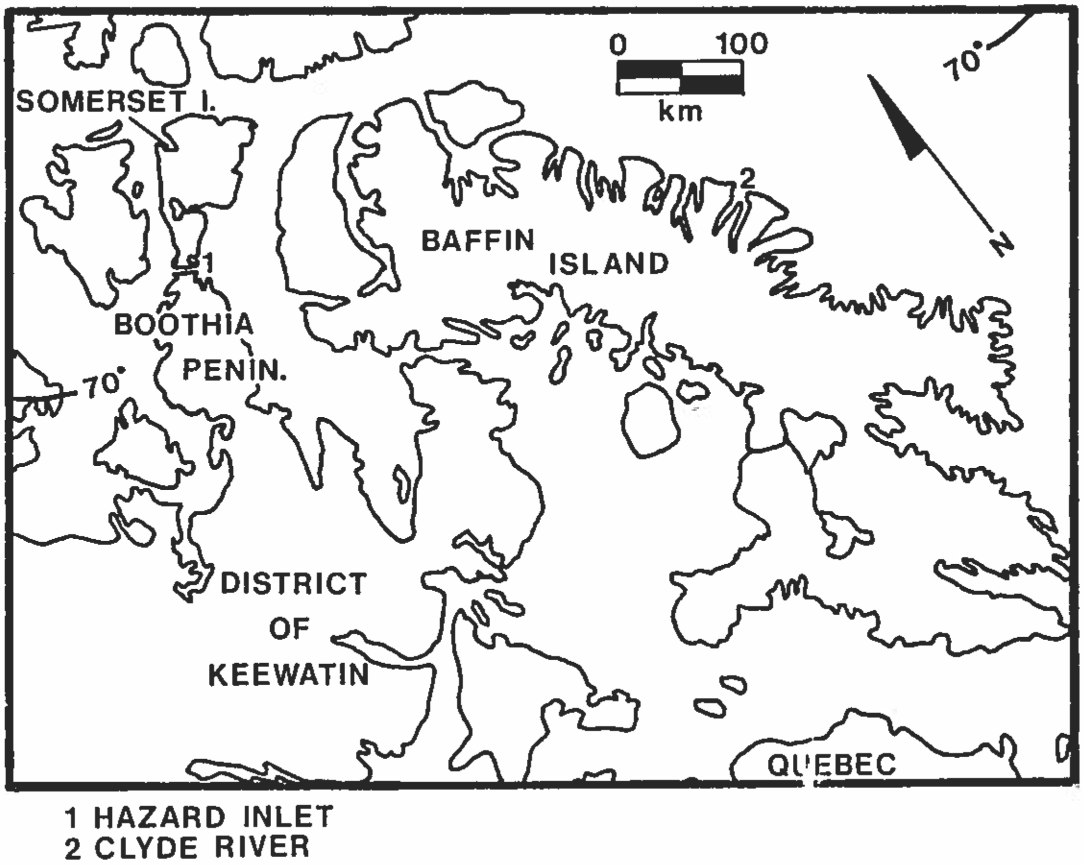
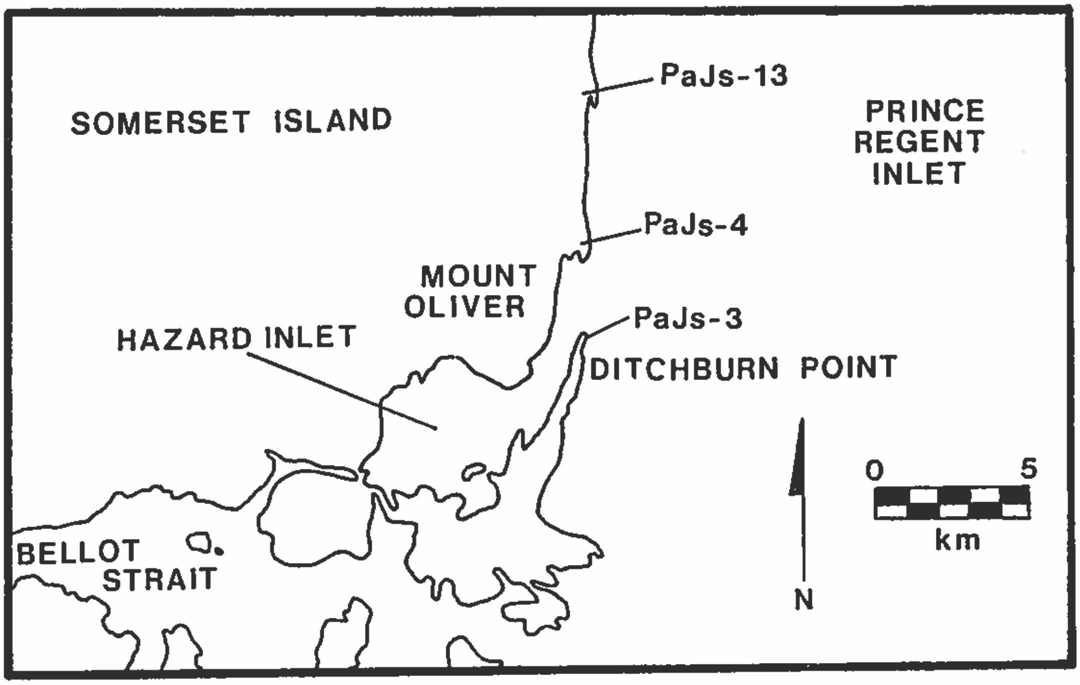


Figure 2: Location of sites



2. ARCHAEOLOGY AND HUMAN ECOLOGY

In one form or another, an ecological or environmental approach has been present within the discipline of archaeology for as long as it has existed as an academic discipline. If the genesis of this approach in archaeology can be traced back at least to the mid-nineteenth century (but ultimately to Aristotle [Ellen 1982:1]), it is only since the mid 1950's that ecology has risen to its current ascendance in the field, as a theoretical orientation largely congruent (but not synonymous) with first the New Archaeology, and more recently its incarnation as 'processualism'. Many of the current debates in archaeology centre around attacks on the wisdom of applying a branch of biological theory to the interpretation of human culture, which appears to be infinitely more complex. This debate, between advocates of 'processualist' and 'post-processualist' positions, is considered in greater detail in Chapter 6, after an assessment of the performance of the model developed here. Following is an overview of the development and, in some circles, crystallization of an ecological approach to the archaeological record.

The Development of an Ecological Approach in Archaeology

Studies of paleoenvironment and prehistoric subsistence emerged alongside scientific archaeology itself. In the mid-nineteenth century Jens Worsae directed interdisciplinary excavations of Danish shell middens (*Kjoekkenmoedding*), which were published with detailed contextual summaries of the floral, faunal and geological data (Morlot 1861:291-304). Japetus Steenstrup's paleobotanical investigations of peat bogs (ibid:304-310) not only lead to the refinement of chronologies based on artifact seriation, but produced hypotheses relating to prehistoric man-environment relationships. Although not fully incorporating the advances pioneered by Scandinavian archaeologists, an intimation of ecological relationships (albeit somewhat mechanistic) appears in the slightly later use of faunal type fossils to define successive epochs of the French and British Paleolithic (Trigger 1989:87, 96). These and other pioneering studies of ecological data (e.g. Dall 1877) had little influence on the course of prehistoric archaeology in the late nineteenth and early twentieth centuries. It appears rather that when environment was considered, archaeological interpretations were guided by broad theoretical trends which originated in cultural anthropology.

Ellen (1982) traces in detail the elaboration of environmental and ecological approaches in anthropology during the twentieth century, and provides a useful sequence of four important concepts which were also influential in archaeology: environmental determinism, possibilism, cultural ecology, and human ecology. This scheme forms the core of the discussion below.

Around the turn of the century, environmental determinism was common in both anthropology and geography, and was embodied in the works of German anthropogeographers such as Ratzel and Steensby. For them the forms of 'primitive' cultures were essentially determined by the operation of climatic, topographical, geological, vegetational and faunal variables which necessitated particular technological and economic adaptations. In archaeology, the geographically influenced work of Crawford and Fox in Britain, and Mason and Holmes in North America, reflected the search for broad correlations between cultural forms and environmental circumstances, often involving the normative definition of 'culture-areas' (Earle and Preucel 1987: 502-503, Ellen 1982, Trigger 1978:135). The inadequacy of such formulations rests in their inability to account for variations from the norm, variability which proved to be ubiquitous as more detailed archaeological work was carried out. Without an understanding of the functional relationship of particular adaptations to particular variables, it was impossible to generate anything but uni-causal explanations for the presence or absence of culture-environment correlations (Ellen 1982:3).

One response to this dilemna was an escape into a somewhat negative and vague possibilism or particularism. According to Boas and his followers cultures are constrained in a general way according to limits set by the environment, but "It is sufficient to see the fundamental differences of culture that thrive one after another in the same environment, to make us understand the limitations of environmental influences" (Boas 1940:256). The development of specific cultural features was seen as a product of such factors as diffusion, invention and cultural drift, and as particular to the history of that culture. The problem of environmental determinism is avoided by removing environment from the causality equation, such that ultimately culture determines culture in a closed circular argument. Ellen, however, shows that a possibilism which admits of any environmental restriction (e.g. Boas 1940:255-256) is logically reducible to an "inverted determinism" by the environment, for "in restricting the options it is also helping to determine the final outcome" (Ellen 1982:50).

Separate developments in Britain and North America offered alternative ways of accommodating the explanation of cross-cultural regularities and the occurrence of particular cultural traits, in the context of a broadly applicable *ecological*, rather than strictly environmental, approach. Grahame Clark (1953) outlined an approach to economic prehistory which viewed prehistoric societies in terms of the functional integration of the economic, social and religious spheres. While explicitly avoiding the reduction of society and ideology to ecological variables (Clark 1953:236), he maintained that the economic dimension of prehistoric life was particularly accessible to the archaeologist through the analysis of ecological data, and because of its interrelationship with other aspects of culture could potentially be used to reconstruct the entire system.

In North America, interest in an explicitly ecological approach in archaeology is primarily associated with the influential cultural ecology of Julian Steward (Earle and Preucel 1987), although the writings of Clark himself were also disseminated (Trigger 1989:274, 280). The acceptance of this approach was enabled by the emergence of a generally functionalist orientation in the United States by the early 1940's (ibid:275), especially as elaborated in the influential work of Taylor (1948). Like Clark's "economic prehistory", cultural ecology was essentially materialist, emphasizing the explanation of recurrent cultural types in terms of the active integrating role of technology and economic production, Steward's 'culture-core'. Ellen (1982:53) notes that this is in marked contrast to the possibilist assignment of a passive, contingent role to economic and ecological factors, and the environmental determinists' concern with correlation, rather than explanation.

The last major phase of ecological thinking in archaeology represents not so much a departure from cultural ecology or Clark's functionalism, as a refinement and elaboration of these convergent approaches, through the promulgation of an explicitly scientific paradigm and the adoption of a cybernetic analogy in archaeology. Whereas cultural ecology suffered from the lack of definition in the 'culture-core' (Halperin 1989), and Clark from the inability to account for cultural change (Trigger 1989), the concept of culture as part of a dynamic ecosystem allowed the interrelationships of particular elements (sub-systems) of a culture to be explicitly defined, and change in the entire system (through autocatalysis or externally stimulated self-amplifying feedback) to be modelled.

Anthropologists had been familiar with human ecology for some time (e.g. Bates 1953, Barth 1956), and even Clark (1953) had advocated the ecosystem concept at an early date. But it was the New Archaeology's wholesale endorsement of a more scientific approach to the past, and the adoption of a systems paradigm in everyday archaeological discourse (Flannery 1968), that ultimately were the source of a core of ecological and evolutionary thinking in "the emerging consensus" (Butzer 1982:3) of processual archaeology. While the idea of studying culture process advocated by Binford (1968) was assimilated into mainstream archaeology, the search for archaeological laws of past human behaviour was eventually dropped from the program (Shennan 1989:832). In its place appeared a general interest in formal, 'scientific', often ecological, techniques of analysis, but ones largely borrowed from outside the discipline. The nature of this recent ecological approach in archaeology is briefly outlined below.

Ecological Approaches in Archaeology

The importance of ecology to the New Archaeology is probably attributable to the great influence of Steward, and his students on New Archaeologists during the formative years of the late 1950's and early 1960's. In a seminal work of this period, Caldwell noted that archaeologists increasingly "have turned their attention to the interrelations between natural ecology and human populations and settlement patterns" (1959:304). Meighan *et al* (1958a, 1958b) provided an early, and detailed, inventory of ecological problems and the methodologies which could be used to address them, although even today few researchers have assimilated these arguments.

What connects this early work and contemporary ecological approaches is a core of fundamental concepts which have grown from casual, implicit guides to research, to a body of explicit, theoretically elaborated ecological concepts which are widely discussed in the literature. Numerous reviews of this body of theory have appeared since the late 1970's, which document the application of particular evolutionary, biological, geographical, and economic models in ecologically-oriented archaeology (e.g. Bettinger 1980, Borgerhoff Mulder 1987, Butzer 1982, Dunnel 1980, Ellen 1982, Jochim 1979, Kirch 1980, Smith 1983). Rather than cover this ground again, the following section concentrates primarily on the key theoretical positions, and the guiding assumptions which link all of the broadly ecological approaches, as it is these that are ultimately under attack.

Odum defined ecology as "the study of the structure and function of nature (it being understood that mankind is a part of nature)" (1959:4). The basic concept which integrates the studies of structure and function is the ecosystem. It is "the basic functional unit in ecology" (ibid:11), and at the same time defines the manner in which structure is to be conceptualized, namely as a system. While units more fundamental than the ecosystem can be recognized (e.g. community, population, individual), the identification of the ecosystem as the *basic* unit emphasizes the requirement that these smaller units not be divorced from a consideration of their characteristic systemic interaction with other organisms and with the physical environment: "Living organisms and their nonliving (abiotic) environment are inseparably interrelated and interact upon each other. Any area of nature that includes living organisms and nonliving substances interacting to produce an exchange of materials between the living and nonliving parts is an ecological system or ecosystem." (ibid:10).

Most archaeologists begin from the implicit premise that the ecosystem is too complex and unwieldy to serve as the basic unit of analysis, and attempt to define smaller, more manageable units. Practically, this is the only way that research can proceed. Problems emerge, however, in attempting to "reassemble" the system from heterogeneous analyses of subsystems or populations (Jochim 1979). Jochim notes the tendency to remedy this dilemma of synthesis by assigning causal priority in the operation of the system to particular subsystems, as Steward had done with the 'culture-core' (ibid:104). Jochim appears to reproduce the reductionism he criticizes, however, in defining problem-solving as an integrating explanatory framework, and thus loses sight of the point from which the analysis originated, namely the ecosystem.

Butzer (1982) conscientiously retains the ecosystem as a conceptual framework, producing an ambitious global synthesis for the archaeological study of human ecology which is able to move along the spatial scale from sites to continents, and along the temporal scale from decades to geological eras. The problems of size and complexity with the ecosystem concept alluded to above emerge when it is seriously applied in this way to the entirety of the human past. While Butzer's ecological analyses of relatively short term processes (a few centuries up to a few millenia in duration) do not strain belief, the explanations which attempt to encompass much larger blocks of prehistoric time verge on the implausible, and seem to require a leap of faith. On the other hand, such high order explanations reduce the richness and complexity of the past to an inevitable, mechanical progression which may possibly conform to some sort of evolutionary reality, but which ultimately tells us little about the diversity which appears to have characterized human societies, and which anthropology arose to explain (see for example the summary of human history and projections for the future in Butzer 1982:319-320). In taking the ecosystem to its logical conclusion in human ecology, Butzer reveals a fundamental difficulty in the full and systematic application of the concept.

Unlike the plant and animal communities that the concept was initially used to study, the ecosystem of which humans form a part cannot conveniently be defined by the boundaries of a pond, island, or even much larger communities on the scale of a biome. It is becoming increasingly apparent that human interactions have ultimately been played out on the scale of continents and hemispheres throughout prehistory, and on a global scale for approximately the past five hundred years (Wolf 1982). While it is convenient to ignore the full scope of such interrelationships, to truly consider the human species at the level of the ecosystem it is necessary to account for the full range of interactions which occurred during and since the colonization of the globe by human species. The scale and complexity of such an endeavor is so daunting that archaeologists have consistently avoided it by working with units smaller than the ecosystem, units which vary in scale and kind according to the theoretical predilections of the researcher.

In shifting from the ecosystem to more manageable units, the tendency has been to restrict both the range of environmental variables investigated, and the scale on which they are considered. Unfortunately the contraction of range has been fairly one-sided, and has resulted in inordinate attention to the natural environment, at the expense of the cultural environment. Interest in such things as subsistence, settlement and technology has been accompanied by neglect of the equally important social and symbolic dimensions of human activity.

The refinement of the concepts of ecology and system in the transition from cultural ecology to prehistoric human ecology is largely based on the adoption of evolution as a paradigm to account for change in the human ecosystem over time. The development of a processual, ecological archaeology is thus closely related to the synthesis of ecology and evolution which has produced the dominant paradigm in biology, namely evolutionary ecology. The privileging of subsistence, settlement and technology over the social and ideational appears to derive from differential success in the application of an evolutionary paradigm to human ecosystems. Those subsystems which relate directly and unequivocally to societal survival and reproduction can be studied and corroborated by observations and theory derived from biology, while those which are less apparently selective in the evolutionary sense must be studied on their own terms. Unfortunately, evolutionary terminology has been applied rather loosely to cultural and social 'evolution', generating confusion and theoretical laxness (Dunnel 1980). For example, it is unclear whether adaptation has the same sense in the phrases 'economic adaptation' and 'cultural adaptation'.

The most prominent attempt to rationalize an evolutionary approach to social and cultural behaviour is sociobiology, Wilson's (1975) "New

Synthesis" of biology and the social sciences. While sociobiology does have its archaeological proponents (Chapman 1986), it is better characterized by its dramatic failure to gain general acceptance in anthropology. Sahlins (1976) produced an impressively rapid, almost surgical, refutation of sociobiology from a general theoretical perspective, and by demonstrating the inadequacy of particular sociobiological mechanisms such as kin selection. While he thus succeeded in cutting off the possibility of any meaningful penetration of sociobiological thought into anthropology, his attack on its evolutionary basis is widely cited by cultural anthropologists and post-processual archaeologists as an indictment of <u>any</u> use of the evolutionary paradigm in anthropology and archaeology. In response, many archaeologists subsequently attempted to refine and rationalize the application of evolutionary concepts (e.g., Dunnel 1980, Kirch 1980).

The elevation of evolutionary ecological theory in archaeology from the 1960's level of the implicit and metaphorical, to the explicit and specific during the late 1970's and 1980's, seems to have satisfied criticisms from its relatively sympathetic processual adherents. The increasing use of optimization theory to generate quantitative ecological models is a particularly conspicuous example of the continued acceptance of such evolutionary concepts as selection and adaptive efficiency during the past decade (e.g. Winterhalder and Smith 1981, Smith 1983, Foley 1985). However, if Sahlins' critique of biology in anthropology spurred some ecological archaeologists to self-criticism and better theory-building, it also lead to the abandonment of the entire enterprise by others. The "emerging consensus" to which Butzer referred in 1982 (*op cit*) represents only one side of the coin. While many archaeologists did converge upon a more rational approach to evolution and ecology, an increasingly vocal contingent of dissenters was emerging, both in North America (Leone 1982) and in Britain (Hodder 1982), who heralded the demise of processualism at the very moment that Butzer heralded its victory.

3. MODELLING THULE SUBSISTENCE

The definition of Thule culture by Therkel Mathiassen was the product of "the first comprehensive and systematic archaeological work in northern North America" (Taylor 1958:93), carried out under the auspices of the Fifth Thule Expedition of 1921-24 (Mathiassen 1927). Although Mathiassen gained his first archaeological experience on sites of the Danish Maglemosian (de Laguna 1979), he did not bring the precocious Scandinavian concern with prehistoric human-environment relations to bear on the interpretation of his data, but rather produced a typology of Thule material culture that has not been significantly altered since its publication. Mathiassen did, however, describe the culture in what could now be considered ecological terms, as Eskimo groups "living at the coast in permanent winter houses [and] hunting the whale on a fairly large scale" (Mathiassen 1927:89). This formulation was eventually criticized for overestimating the extent of Thule whaling activities (Freeman 1979), at about the same time that systematic research into Thule whale procurement had begun (McCartney 1979, 1980). It is symptomatic of the twentieth century development of the sub-discipline of arctic archaeology that no attempt had previously been made to actually determine whether or not a fairly specific proposition about the economic basis of an enormously widespread archaeological culture was valid. Although it had been recognized that not all Thule groups necessarily engaged in whaling (Taylor 1968), the assumption that whaling was in some undefinable way an essential feature of Thule culture remained unanalyzed.

Subsistence Studies in the Arctic

The history of inquiry into arctic subsistence can be traced back before Mathiassen to the activities of anthropologically-minded geographers such as W.H. Dall (1877), and geographically-minded anthropologists of the anthropogeographical school (Steensby 1917). Dall rivals Mathiassen for the title of originator of "the first systematic archaeological research" (Laughlin 1985:777) in northern North America. His investigations of Aleutian shell middens in the early 1870's were not only exceptional from a methodological point of view (Griffin 1959:381), but represented a very early attempt to quantify the diet of a prehistoric population, and its change over time, from an imaginative analysis of organic refuse. The present study is a descendant of, if not a throwback to, Dall's original research.

Speculations on Eskimo origins were rampant before the widespread inception of archaeological field research in the 1920's and 1930's. Of passing interest are the anthropogeographical theories of Steensby (1917), who conceived of Eskimo material culture as a sort of technological overlay, adapted to coastal arctic conditions, on an inland Athapascan people from the Barrengrounds. His ideas were soon rejected, but the terms he applied to proposed evolutionary stages in Eskimo culture (Paleo-Eskimo and Neo-Eskimo) have ironically been retained. Although his work is characterized by the same extreme environmental determinism that pervaded much early twentieth century anthropological thought in North America, Steensby probably intuited the peculiar status of the Arctic's inhabitants, among non-Western peoples, in having forged a successful adaptation with mechanically simple (if intricate) technology to an environment that was essentially uninhabitable by any other means. The Eskimo example thus does not offer support to the currently popular hypothesis that culture somehow fashions itself independently of environmental constraints and opportunities.

Perhaps in reaction to the work of Steensby and others, growing interest in arctic culture history through the 1930's, and the explosive growth in archaeological research after WW II, were not accompanied by much attention to the economy and ecology of the north's prehistoric populations. Herbert Friedman, an ornithologist, published a series of papers on bird remains from archaeological sites in Alaska during the period of exploratory research (Friedman 1934a, 1934b, 1935, 1937, 1941), but these data do not appear to have been subjected to a proper archaeological analysis. With few exceptions (e.g. Taylor 1968), it was not until biological theory and explicitly "scientific" concerns entered the archaeological mainstream with New and processual archaeology in the 1960's and 1970's, that prehistoric Eskimo subsistence became even a marginal topic of interest. Binford's (1978, 1980) study of the organization of Nunamiut hunting and carcass processing marked a fresh engagement of theoretical archaeology with the rich arctic data base, and inspired subsequent archaeological research (e.g. Will 1985, Savelle 1987). Keene's (1979) test of a linear programming model against ethnographic data from Boothia Peninsula also emerged from this period, and is the basis of the Thule subsistence model presented below. At the peak of enthusiasm for processualist approaches Smith (1981) and Sabo (1991) developed explicitly ecological models for contemporary Inuit on eastern Hudson Bay and Thule on southern Baffin Island, respectively. Even Soviet researchers produced processual, ecological models during this period (Krupnik 1981).

Studies of Thule Subsistence

Arctic sites are typified by better than average organic preservation, primarily due to the frequent incorporation of buried remains into permafrost, and to the extreme cold and aridity, with concomitant low microbial and insect activity, which preserves even surface material for a much longer time than in warmer and moister environments. Later prehistoric, including Thule, sites often produce very large assemblages of organic artifacts and faunal remains, in very good states of preservation. This situation is compounded by a bias towards the excavation of large, permanent winter habitations, rather than ephemeral tent rings or the shallow Thule houses identified as *qarmat* which appear to have been the warm-season complement of winter houses. Most Thule archaeology, then, has focused on features which are probably among the richest anywhere in the world from a zooarchaeological standpoint. In spite of this fact, faunal remains were often not collected on Thule excavations, and site reports rarely provided more than a "laundry list" of faunal species present and subjective assessments of their relative frequencies (Savelle and McCartney 1988). Stanford's analysis of faunal material from the Walakpa site (Stanford 1976) stands out in this period for its systematic enumeration of species frequencies, skeletal part frequencies for the major prey species, and osteometric data. Although some of his terminology and presentation seems slightly idiosyncratic by current standards, this reflects the enormous growth and standardization in zooarchaeology since the publication of his report.

Staab's (1979) description of a large faunal assemblage from Silumiut was probably the first of its kind for a Canadian Thule site. She presented skeletal part data, and estimated the absolute and relative food value of the animals represented (in terms of meat consumption per day), but did not analyze this assembled data in any depth. Rick (1980) provided faunal data from Thule sites near the study area, including partial butchery data, and considered various methods of estimating usable meat. Hers is a good summary analysis of two moderately-sized winter house assemblages. Both Staab and Rick left open the question of the relative importance of bowhead whale use in the subsistence economy, and thus compromised their interpretations of the relative food yield of the non-cetacean fauna.

Morrison (1983a, 1983b) undertook a more detailed analysis of Thule sea mammal hunting, and considered his findings in the context of the settlement system, rather than merely diet. His was the first extensive presentation of age and seasonality determinations based on ringed seal dental annuli. McCullough (1988, 1989) analyzed a number of faunal assemblages from Ruin Island phase Thule sites on Ellesmere Island, but like Rick and Staab avoided the problem of assessing the importance of bowhead whales in the economy. She presents skeletal part frequencies for some species, but not in sufficient detail for comparison the present work. Park (1989) conducted an elaborate analysis of different dimensions of intrasite variability, especially covariation of faunal and artifact assemblages, at the Thule site of Porden Point. His presentation of element frequencies by feature for some species, including bowhead, is a refrehing addition to the literature. While the results are inconclusive, Park's dissertation is probably the most useful presentation of faunal data from any Thule site, when taken together with complementary data presented in Allison (1986).

Stenton (1989) has taken an interesting approach to Thule subsistence-settlement systems on Baffin island, exploring the relationship between essential requirements for terrestrial resources and the coastal-inland oscuillation of Eskimo settlement. As will be discussed below, his argument for the centrality of caribou hunting to Thule economies may be overstated, but his study exemplifies the recent trend towards increasingly systematic reporting of Thule subsistence data.

Savelle and McCartney have published extensively on Thule procurement of bowhead whales (McCartney 1979, 1980, McCartney and Savelle 1985, Savelle and McCartney 1990, 1991) and more generally on Thule subsistence-settlement systems (Savelle 1987, Savelle and McCartney 1988). As noted, whales have often been explicitly excluded from Thule subsistence analyses because of the difficulty of determining the relation between the skeletal elements present at a site and the actual number of whales consumed by its occupants. This is due to the likelihood that many of these massive bones were never transported from the beach to the habitation site (McCartney and Savelle 1985), the recycling of whale bone for house and artifact manufacture even centuries after the animal's death (McCartney 1979), and lingering scepticism about the ability of prehistoric hunters to reliably procure such huge animals (Freeman 1979). Savelle and McCartney's research represents an attempt to transcend the paralysis in Thule subsistence studies that derives from this inability to quantify the contribution of bowhead whales to diet by standard zooarchaeological methods. By approaching the problem as one of subsistence-settlement systems at the scale of regions and macro-regions, rather than localized subsistence practises at the level of a feature or site, they have demonstrated that whales were hunted rather than scavenged, that this hunting was selective with respect to size classes, and that selectivity and overall whaling success probably varied between regions (McCartney 1980, Savelle and McCartney 1990, 1991). By recording all features and whale bone located in surveys away from the primary residential sites

Savelle (1987) has identified the range of site types associated with particular settlement systems, including initial whale processing sites.

By calculating whale MNI (Minimum Number of Individuals) for discrete regions, and extrapolating down to the site level, rather than attempting to guess what proportion of total animals procured might be represented on a particular site, we can produce much more accurate estimates of whale harvesting, and its variability across space (Savelle and McCartney 1988). A problem that is left unresolved to some extent is variability in whale procurement over time. With no way of making a chronological assignment within the Thule period to off-site whale bone, let alone to the many Thule features without temporally diagnostic artifacts, we are left guessing as to the process of initial economic adaptation to a region by Thule colonists, and the ultimate abandonment of many regions and a "whaling mode of production" by the descendants of these same groups some centuries later. Until the Thule subsistence economy can be assessed at the level of diet (i.e. the relative dietary contribution of bowhead whales), it will be impossible to 1) ascertain the degree of economic "dependence" of Thule groups on whales, 2) the stability of this economic adaptation in the face of changing environmental parameters, and 3) the nature of the articulation between the Thule economy and social organization.

An alternative approach to the Thule whale problem is suggested by Keene's development of a linear programming model for Netsilik Inuit resource-scheduling in the pre-and post-rifle economy on Boothia Peninsula (Keene 1979, 1985). Such a model involves more or less warranted assumptions derived from optimal foraging theory about the logic of resource acquisition by human and non-human foragers, in the context of a given set of environmental opportunities and subsistence requirements. The background and development of a linear programming model of Thule subsistence in the study area are outlined below.

Optimal Foraging Theory

Optimal foraging theory is a set of concepts developed in evolutionary ecology, and based on the assumption that adaptive success is conferred on individuals (or species or human communities) who "*maximize the net rate of return (of energy or nutrients) per unit foraging time*" (Smith 1983:626). This is essentially a reformulation of the principle of natural selection, for over time those subsistence strategies will be selected which fulfill the basic nutritional (and for humans, non-food) needs with the minimum expenditure of labour and resources.

Optimal foraging models in anthropology closely parallel applications in ecology, expressing the ramifications of this basic principle in different forms (for biology see Pyke *et al* 1977, for anthropology see reviews in Winterhalder and Smith 1981, Jochim 1983, Keene 1983, Smith 1983). For instance, an early statement of the optimality principle concerned the exploitation of discontinuously and randomly distributed (patchy) resources (McArthur and Pianka 1966). In anthropology, this could be expressed in terms of the relationship between the spatial distribution of resources and the settlement locations (Heffley 1981) or group sizes (Smith 1981) most suited to their utilization. By considering patchy resource distribution in its temporal dimension, an optimal foraging model might focus on the efficient scheduling of extractive effort to best exploit seasonal fluctuations in resource availability (Keene 1981, Yesner 1981), or more generally on the range (diet breadth, Hames and Vickers 1981) and type (diet selection) of resources that should be exploited.

Maximization (or efficiency) is a broad concept, which is usually formulated in one of two ways. Most problems can be expressed either as the maximization of returns for a set expenditure (e.g. the number of animals procured in a day's labour), or the minimization of expenditure to achieve set returns (e.g. the least time and effort that can be expended in food procurement to satisfy a family's, or community's, nutritional requirements). In both cases the rate (returns per unit expenditure) is being optimized. Risk, rather than resource profits or labour costs, however, is sometimes the phenomenon that an optimality problem must address.

Thus all foragers (or human hunter-gatherers or even agriculturalists) will seek to minimize risk (maximize safety) to some degree, often at the cost of a loss of efficiency. Over the long term, however, risk minimization (reliance on stable, predictable resources) buffers the subject from more or less unpredictable fluctuations in the environment. Since a large proportion of environmental variability is predictable in the short term, projections based on risk-minimization tend to be very similar to those based on cost-minimization (Winterhalder 1986), although in the long term these two strategies may have different consequences (Mithen 1987). The determination of environmental constraints (nutritional and non-food requirements), returns on resource procurement (nutritional and non-food composition of resources), and the costs incurred in this activity are discussed below.

Optimal foraging concepts have been applied in a wide variety of ethnographic and archaeological contexts, ranging from hominid evolution (Kurkland and Beckerman 1985) to fishermen in modern state societies

(McCay 1981). Because of its ties to non-human ecology, optimal foraging theory has been most frequently used in anthropology to model the activities of hunter-gatherers, although it closely resembles some economic theory (McArthur and Pianka 1966:603) and so in other guises its basic principles have been applied to all classes of human economic activity. Linear programming, utilized in this study, was initially applied to solve problems of efficient resource allocation in economics, and won its pioneers the Nobel Prize in that field (Chvatal 1983).

Linear Programming

Linear programming is actually a branch of mathematics, created in the 1940's to solve a theoretical problem that happened to be expressed in terms of fulfilling a set of nutritional requirements from foods with a set price, at the least overall cost (Chvatal 1983): this is the so-called "diet problem", of which the present model is an example. For example, assume that the total nutritional requirements for a family for one month are 1400 mg of Vitamin B, 8000 g of protein, and 1400 mg of niacin (this example is adapted from Boyle and Wright 1988). One unit of food P contains 3 mg of Vitamin B, 27 g of protein, and 7 mg of niacin. One unit of food Q contains 4 mg, 14.4 g, and 2 mg of these nutrients, respectively. Food P is twice as costly to procure as food Q (whether relative cost is measured in dollars, calories expended in procurement, or time devoted to procurement).

	Vit B	Protein	Niacin	Cost
Food P	3 mg	27 g	7 mg	2
Food Q	4 mg	14.4 g	2 mg	1
needs	1400 mg	8000 g	1400 mg	

Thus the total cost of acquiring the requisite nutrients is equal to: 2 x no. of units of food P + 1 x no. of units of food Q. Total cost (C) can be expressed as C = 2P + Q, where P and Q are the costs of the respective foods. This total cost is referred to as the *objective function*. In this problem we are attempting to minimize the objective function, by arriving at the least costly combination of foods which satisfy the requirements. Using the mathematical technique referred to as the Simplex Method, a mathematician (or computer program) will examine possible combinations of P and Q that satisfy nutritional requirements until she (or it) arrives at this least costly, or optimal, combination. In this case, 89 units of food P and 390 units of food Q satisfy the requirements at the lowest possible cost, namely 2P + Q = 2(89) + 390 = 568 cost units. While this solution resulted in a surplus of Vitamin B, it only just satisfied the requirements for protein and niacin. Protein and niacin are thus said to be the *binding constraints* of this model, for it is in fulfilling these requirements that the cost value attained the level it did. In an ecological sense, protein and niacin are the limiting nutrients in the modelled environment. While Vitamin B can be acquired at a surplus, it is the availability of protein and niacin that will determine the effort that must be expended in satisfying overall metabolic requirements.

Keene's Model for the Netsilik

For most of the parameters of the present linear programming model I have relied on Keene's (1979, 1985a) estimates for the situation of a community of Netsilik Inuit on Boothia Peninsula (Figure 1) before the turn of the century, around the time of the introduction of firearms, and the reader is referred to these articles for some details and references. Conveniently, the Netsilik are the nearest historically (and ethnographically) documented Inuit group to the study area (Savelle 1981), so at least some of Keene's cost estimates for resources could be retained with slight modification. In fact, some Boothia Inuit still carry out harvesting activities on Somerset Island. Keene's collation of data on the nutritional composition of most of the foodstuffs used in this model, and his estimates of the demographic structure of an Inuit community and the particular nutritional requirements of Eskimos, were an invaluable source and guide in the development of a model of Thule resource selection on Somerset Island.

Keene, in turn, relied to a great extent on the wealth of data assembled in Foote (1965), who, among other things, developed a similar sort of model for Eskimo harvesting strategies in northwest Alaska during the early historic period. Foote's model was based primarily on caloric and non-food (hide) requirements. Where necessary, I have returned to Foote to recalculate some of the present model's parameters.

Arctic Nutritional Requirements

The age and sex structure, and annual nutritional requirements, of a community of 50 Inuit are shown in Table 1 reproduced from Keene (1985a). The population figure of 50 is a fairly arbitrary value, which is not intended to reflect the actual population of the Hazard Inlet region (Figures 1 and 2) in Thule times (which appears to have been higher). Few attempts have been made to estimate the population of Thule settlements (Park 1989:25-27), because of the difficult problem of determining feature contemporaneity. McGhee calculated an average winter population of 15 to 30 for each of three Thule "components" (1984:81), but the feature density in the Hazard Inlet region appears to be greater than McGhee observed at Brooman Point. Savelle (1987), in fact, suggests a local population in

Table 1: Demographic structure and nutritional requirements of an Eskimo community (after Keene 1985:166-167, Tables 6.3 and 6.4)

Demographic structure

age	% of population	number of persons	male	male or female	female
0-2	7.5	4	-	4	-
2-10	23.6	12	-	12	-
10-18	18.4	9	5	-	4
18-50	40.4	20	12	-	8
50+	10.1	5	3	-	2

Age- and sex-specific daily nutritional requirements

age	kcal		protein (g)		calcium (mg)	fat (g)	vitamin A (I.U.)	
	M	F	M	F			M	F
0-2	1200		28		550	25	2500	
2-10	2200		48		700	25	3000	
10-18	2800	2100	70	60	500	25	6000	5000
18-50	2800	2100	70	60	500	25	6000	5000
50+	2700	2000	70	60	500	25	6000	5000

age	thiamine (mg)		riboflavin (mg)		vitamin C (mg)	iron (mg)	
	M	F	M	F		M	F
0-2	0.7		0.8		30	15	
2-10	1.2		1.2		32	10	
10-18	1.5	1.2	1.8	1.4	36	18	18
18-50	1.5	1.2	1.6	1.2	36	10	18
50+	1.4	1.1	1.5	1.1	36	10	10

Annual requirements for a population of 50

44 840 300.0 kcal*
1 069 450.0 kg protein
456 250.0 g fat
10 074 000.0 mg calcium
86 140 000.0 I.U. vitamin A

23 177.5 mg thiamine
24 637.5 mg riboflavin
631 450.0 mg mg vitamin C
240 900.0 mg iron

* includes 1400 kcal/day/dog x 10 dogs x 365 days

the range of 150-250 persons for Hazard Inlet. In any case, the goal of the modelling process is to predict *relative* proportions of a suite of faunal resources, which can be compared to the *relative* proportions of archaeologically determined resources. Although the model will simulate the absolute needs of a group of 50, any attempt to determine the absolute quantities of food consumed prehistorically (as did Staab 1979) from a faunal analysis of food remains would be foolish, because of the large number of biasing factors which have deleted individual animals and whole species from the faunal record. The absolute populations of the sites around Hazard Inlet are thus irrelevant in this context.

Keene has estimated the requirements of this hypothetical group for nine essential nutrients, each of which constitutes a nutritional *constraint*. As far as has been determined, the human body actually requires one carbohydrate, one fat, nine amino acids, fifteen minerals, thirteen vitamins, water and fibre for the maintenance of metabolic processes and for growth and repair of tissue (Lieberman 1987:225). Keene's nine nutrients were selected somewhat arbitrarily for being those most frequently quantified in the literature on nutritional requirements (e.g. Draper 1977, Bang *et al* 1976, Bang and Dyerberg 1981, Freeman 1988) and nutritional composition of arctic foodstuffs (e.g. Mann 1962, Heller and Scott 1967, Stirling and McEwan 1975, Drury 1985). This at least represents a wide range of important nutrients, and proved superior to the more common restriction of optimal foraging models to requirements for calories, and occasionally protein (e.g. Hawkes *et al* 1982, Jones and Madsen 1989), in that it led to the recognition of a potential limiting mineral, namely calcium.

Arctic Non-Food Requirements

In his Netsilik (1979, 1985a) and Michigan Archaic (1981) models Keene defines one non-food constraint, namely an annual requirement for animal hides. In an environment as poor in plant fibres as the Arctic, animal skins are obviously of critical importance for clothing manufacture. The colonization of northern latitudes by hominids is believed to have been retarded by the lack of adequate clothing technology, and of the High Arctic in particular by the necessity for highly insulating, waterproof garments. Stenton (1989) devotes considerable space to a discussion of thermal requirements, and the importance of caribou hides as the ideal raw material for arctic winter clothing, although he neglects the necessity of waterproof clothing in warmer seasons for a maritime-adapted arctic population. Stenton suggests that the need for caribou skin clothing may have been a significant factor influencing and limiting arctic settlement and harvesting, and produces estimates of a substantial annual requirement for this resource. He calculates 40-70 skins would be required annually by a family of five (Stenton 1989:65) among caribou-oriented groups, and 28-36 among groups oriented towards coastal resources. Foote (1965:298) provides a breakdown of hide requirements by age and sex classes, including requirements other than clothing (bedding, tents, boats, rope, etc.), which are somewhat higher than Stenton's estimates, but could be manipulated in a systematic fashion to match the hypothetical age and sex structure of the modelled population. Foote provides similarly detailed estimates for the requirements for ringed seal and bearded seal skins, which are also substantial. It appears that his figures may be unrealistic ideals, which assume the annual replacement of 100% of all hide artifacts.

For this model, two classes of non-food requirements were calculated. A requirement for "light duty" hides was initially based on Foote's estimates for caribou and ringed seal skins for clothing and miscellaneous articles (e.g. bedding, skin bags, floats). Caribou skins were assigned a value of 1, and ringed seals a value of 0.56, by using weight as an index of hide size. Because the surface area of an animal (hide size) will increase as the square of its average dimensions, and weight will increase with volume (holding density constant) in cubic increments, this index was arbitrarily calculated as $\frac{\text{species weight}}{\text{caribou weight}} \times$ estimated hide utility (see below under non-food value of resources).

While not entirely satisfactory, in the absence of absolute measures this formulation allowed for consistent estimates of the hide size of animals which were intuitively more accurate than those based on a simple weight-size correlation, which tend to underestimate the value of hides of lighter animals, and overestimate the value of heavier animals. This produced a total "light duty" hide requirement of 485 for the hypothetical community, that could potentially be filled by species other than caribou and ringed seal, since the skins of polar bear, fox, dog, bird etc. may be used for clothing manufacture, bedding and other functions. Trial runs of the model indicated that Foote's estimates may indeed be unrealistic, so recycling was assumed to occur at a rate of 50% of the maximum requirements, reducing the "light duty" requirement (referred to as NFV2 in the tables) to 243 "caribou skin units".

In a similar fashion, "heavy duty" hide requirements (NFV1), principally for kayak and umiak coverings, boot soles, and rope, were calculated using bearded seal skins as the referent, and calculating the value of ringed seals as a function of bearded seal skin weight. Again, the Foote-derived estimate of 79 was reduced by half, to produce a "heavy duty" hide requirement of 40 "bearded seal skin units".

Nutritional Composition of Resources

Keene's estimates of the nutritional composition of resources per unit weight (100 g) were retained in most instances, but the particular array of available resources is different for Thule-era Somerset Island and historic Boothia Peninsula. In addition, some of Keene's estimates for the anatomical composition and distribution of usable tissue of some prey species were felt to be unsatisfactory. Keene's estimates were altered or supplemented as follows (see Tables 2 and 3).

Polar cod was probably mistakenly included in Keene's model, following Foote's data for northwest Alaska, as even in the rich marine environment of Creswell Bay cod are relatively uncommon (Sekerek *et al* 1976) and are much smaller than Foote calculated for the Western Arctic. Polar cod was not included among the resources feasibly available to groups possessing Thule technology. Arctic ground squirrel (which does not now occur in the study area [Banfield 1974]) and lemming (neither of which were included in Keene's optimal solution) were likewise excluded from the model.

Four resources not considered by Keene were added to this model, namely bowhead whale, beluga, narhwal, and walrus. The unit nutritional composition of these species is based on data in Mann (1962) and Heller and Scott (1967), as indicated in Table 2. Where not available, the nutritional composition of particular anatomical portions was extrapolated from the closest related species for which data were available, as for instance the composition of beluga blubber, which is based mostly on the composition of bowhead whale blubber, or the nutritional composition of

Table 2: Nutritional composition of arctic foods

species portion	kcal	protein	fat	Ca	Vit A	Thiam	Rib	C	Fe
arctic char (*Salvelinus alpinus*)									
meat	125.0	22.4	3.9	83	100	0.08	0.21	2	1
viscera	93.5	22.2	0.3	16	1500	0.02	0.08	3.4	0
roe	125.6	22.1	4.0	23	0	0.02	0.08	44.3	1.6
birds (*Aves sp*)									
meat	114.8	23.5	1.9	17.4	0.1	0.30	0.43	9.8	2.1
viscera	104.0	18.0	3.0	18	150	0.06	0.10	0	2
arctic hare (*Lepus arcticus*)									
total	144.0	24.2	8.0	20.7	0.2	0.08	0.21	5	2.2
beluga (*Delpinapteras leucas*)									
narwhal (*Monodon monoceros*)									
meat/viscera	110.5	26.5	0.5	7	340	0.14	0.44	8	25.9
blubber	831.3	1.6	90.9	7.5	278	0.24	0.01	1	0.5
muktuk	349.5	21.8	29.1	7	2160	0.22	0.08	2	1.0
liver	116.7	18.4	3.9	11	22100	0.12	1.41	1	0.5
bowhead whale (*Balaena mysticetus*)									
meat/viscera	114.9	24.9	1.7	17	330	0.14	0.44	8	14.1
blubber	831.3	1.6	90.9	7.5	278	0.24	0.01	1	0.5
muktuk	132.8	12.3	1.2	13	750	0.50	0	2	1.0
liver	116.7	18.4	3.9	11	22100	0.12	1.41	1	0.5
wolf (*Canis lupus*)									
arctic fox (*Alopex lagopus*)									
total	104.0	18.0	3.0	14	0.2	0.05	0.19	1	2.2
polar bear (*Thalarctos maritimus*)									
meat	135.0	25.6	3.1	17	1400	0.23	0.57	2	1
blubber	810.0	2.8	88.7	3.3	0	0	0	1	0
walrus (*Odobenus rosmarus*)									
meat	386.4	21.0	8.4	15	170	0.28	0.31	3	4.0
blubber	900.0	0	100.0	15	2520	0.03	0.01	1	9.4
liver	119.5	18.8	3.1	23	49500	0.12	1.41	19	14.4
heart	90.3	18.4	1.5	6.7	0	0	0	1.7	0
kidney	100.0	19.5	2.4	10.5	0	0	0	13.2	0
other visc.	149.0	21.0	7.0	38	1500	0.10	0.20	5	4
bearded seal (*Erignathus barbatus*)									
ringed seal (*Phoca hispida*)									
meat	137.0	22.0	5.0	13.7	1500	0.12	0.35	13	4
blubber	891.0	0	99.0	10	2400	0	0.25	1	0
liver	142.0	18.9	6.4	7.2	75000	0.15	0.30	18	4
heart	90.3	18.4	1.5	6.7	0	0	0	1.7	0
kidney	100.0	19.5	2.4	10.5	0	0	0	13.2	0
other visc.	149.0	21.0	7.0	38	1500	0.10	0.20	5	4
caribou (*Rangifer tarandus*)									
meat	119.0	26.7	1.2	28	0.1	0.17	0.50	2.0	1.9
fat	900.0	0	100.0	0	0	0	0	0	0
viscera	125.0	15.0	5.0	98	2000	0.10	0.20	15	8
muskox (*Ovibos moschatus*)									
total	365.0	10.8	34.2	9	200	0.08	0.19	0.5	1.9

Table 3: Anatomical compostion of prey species

species, average body weight, anatomical portion		% of total body weight	weight of average portion (kg)
arctic char (*Salvelinus alpinus*) average weight = 2.3 kg			
meat		74.8	1.72
viscera		13.2	0.30
roe		0.02	0.0005
	total useable	88.0	2.02
birds (*Aves sp*) average weight = 1.04 kg			
meat		61.6	0.64
viscera		18.4	0.19
	total useable	80.0	0.83
arctic hare (*Lepus arcticus*) average weight = 4.6 kg			
	total useable	55.0	2.53
beluga (*Delpinapteras leucas*) average weight = 454 kg			
meat		15.4	69.92
blubber		22.6	102.60
muktuk		15.4	69.92
liver		2.2	9.99
other viscera		18.6	84.44
	total useable	74.2	336.87
narwhal (*Monodon monoceros*) average weight = 700 kg			
meat		15.4	107.80
blubber		22.6	158.20
muktuk		15.4	107.80
liver		2.2	15.40
other viscera		18.6	130.20
	total useable	74.2	440.30

Table 3: Anatomical compostion of prey species (cont'd)

species, average body weight, anatomical portion		% of total body weight	weight of average portion (kg)
bowhead whale (*Balaena mysticetus*) average weight = 27 240 kg			
meat		14.8	4031.52
blubber		34.9	9506.76
muktuk		14.8	4031.52
liver		2.2	599.28
other viscera		8.3	2260.92
	total useable	75.0	20430.00
wolf (*Canis lupus*) average weight = 30 kg			
	total useable	55.0	16.50
arctic fox (*Alopex lagopus*) average weight = 3.2 kg			
	total useable	55.0	1.76
polar bear (*Thalarctos maritimus*) average weight = 410 kg			
meat		56.3	230.83
blubber		18.8	77.08
	total useable	75.1	307.91
walrus (*Odobenus rosmarus*) average weight = 665 kg			
meat		34.1	226.77
blubber		15.6	103.74
liver		2.2	14.63
heart		0.7	4.66
kidney		0.4	2.66
other viscera		22.0	146.30
	total useable	75.0	498.76

Table 3: Anatomical compostion of prey species (cont'd)

species, average body weight, anatomical portion	% of total body weight	weight of average portion (kg)
bearded seal (*Erignathus barbatus*)		
average weight = 215 kg		
meat	32.5	69.88
blubber	29.1	62.57
liver	2.2	4.73
heart	0.7	1.51
kidney	0.4	0.86
other viscera	5.6	12.04
total	70.5	151.59
ringed seal (*Phoca hispida*)		
average weight = 45.4 kg		
meat	32.5	14.76
blubber	35.9	16.30
liver	2.2	1.00
heart	0.7	0.32
kidney	0.4	0.18
other viscera	5.6	2.54
total	77.3	35.10
caribou (*Rangifer tarandus*)		
average weight = 81.3 kg		
meat	35.0	28.46
fat	10.0	8.13
viscera	20.0	16.26
total useable	65.0	52.85
muskox (*Ovibos moschatus*)		
average weight = 242 kg		
total useable	80.0	193.60

all portions of narwhal, which are identical to the estimates for beluga. While this procedure may introduce biases into the model, it is an unavoidable step in mathematical models such as this, which require precise quantification of all variables regardless of the availability of precise data. The average nutritional composition of birds was recalculated using Keene's own data, producing slightly different values.

To translate the unit composition of anatomical portions into absolute quantities of nutrients for each species, it is necessary to estimate the weight of these portions. Keene's figure of 75% usable tissue for marine mammals appeared to be reasonable, assuming slight wastage of total available tissue. His estimates for the composition of Pinniped species by anatomical portion are mostly derived from Foote (1965), since which time more accurate data have become available. Foote's and Keene's estimates were thus corrected according to data on meat, bone, sculp and viscera proportions of three harp seals and one hooded seal butchered by Lyman, Savelle and Whitridge (1992). The average proportion of body weight represented by viscera for these animals was quite compatible with Foote's estimates for whales, so these data were also used in the calculation of whale anatomical composition (i.e. to determine liver as a percentage of total body weight). Keene's butchery estimates were not altered for fish, birds, and terrestrial mammals. The estimates, by % total body weight and weight of average portion, are shown in Table 3.

With appropriate butchery data the absolute nutrient composition of each tissue type in an individual of each species can be estimated according to the following formula: (average weight in kg) x (tissue type as % of body weight) x (nutrient composition of tissue type per kg).

Average weights of species were recalculated, as indicated in Table 3. The absolute nutrient compositions of each tissue type were then summed, producing a grand total for each species (Table 4). These values, in addition to the annual requirement for each nutrient, constitute the nutritional constraints of the model. Returning to the example provided earlier in this chapter, if food P contains a total of 7 mg of niacin per animal, food Q contains 2 mg, and the stated requirement is 1400 mg, this can be expressed algebraically by the linear inequality: $3P + 4Q \geq 1400$, where P and Q represent the number of each animal procured. This procedure is repeated for each nutritional constraint, producing a series of inequalities:

$$\begin{aligned} 3P &+ 4Q \geq 1400 \\ 7P &+ 2Q \geq 1400 \\ 27P &+ 14.4Q \geq 8000 \end{aligned}$$

The qualification that the value of each resource cannot be a negative number must also be included, producing the additional constraints:

$$\begin{aligned} P &\geq 0 \\ Q &\geq 0 \end{aligned}$$

During the computer run of the model, the program is instructed to minimize the objective function (cost), subject to these constraints.

Non-Food Value of Resources

The final constraints to be calculated are the non-food values of each resource, which must sum or exceed the hide requirements established above in the final solution. As described in the section on non-food requirements, the light and heavy duty values for ringed seal were estimated as the square root of average weight divided by the weight of caribou and bearded seal respectively. In fact, not all hides are equal, even after factoring in their size. Some hides are considered here to be

Table 4: Nutritional composition of prey species

species portion	kcal	protein	fat	Calcium	Vit A	Thiamine	Riboflav	Vit C	Iron	NFV 1	NFV 2
arctic char (*Salvelinus alpinus*)											
meat	2150.0	385.3	67.1	1427.6	1720	1.38	3.61	34.4	17.2		
viscera	280.5	66.6	0.9	48.0	4500	0.06	0.24	10.2	0		
roe	0.6	0.1	trace	0.1	0	trace	trace	0.2	trace		
total	2431.1	452.0	68.0	1475.7	6220	1.44	3.85	44.8	17.2	0	0.001
birds (*Aves sp*)											
meat	734.7	150.4	12.1	111.4	0.6	1.92	2.75	62.7	13.4		
viscera	197.6	34.2	5.7	34.2	285	0.11	0.19	0	3.8		
total	932.3	184.6	17.8	145.6	285.6	2.03	2.94	62.7	17.2	0	0.003
arctic hare (*Lepus arcticus*)											
total	3643.2	612.3	202.4	523.7	5.1	2.02	5.31	126.5	55.7	0	0.02
beluga (*Delpinapterus leucas*)											
meat	7646.6	18528.8	349.6	4894.4	237728	97.89	307.65	5593.6	18109.3		
blubber	852913.8	1641.6	93263.4	7695.0	285228	246.24	10.26	1026.0	513.0		
muktuk	244370.4	15242.6	20346.7	4894.4	1510272	153.82	55.94	1398.4	699.2		
liver	11658.3	1838.2	389.6	1098.9	2207790	11.99	140.86	99.9	50.0		
other visc.	125815.6	17732.4	5910.8	32087.2	1266600	84.40	168.88	4222.0	3377.6		
total	1242404.7	54983.6	120260.1	50669.9	5507618	594.34	683.59	12339.9	22749.1	0	0
narwhal (*Monodon monoceros*)											
meat	119119.0	28567.0	539.0	7546.0	366520	150.92	474.32	8624.0	27920.2		
blubber	1315116.6	2531.2	143803.0	11865.0	439796	379.68	15.82	1582.0	791.0		
muktuk	376761.0	23500.4	31369.8	7546.0	2328480	237.16	86.24	2156.0	1078.0		
liver	17971.8	2833.6	600.6	1694.0	3403400	18.48	217.14	154.0	77.0		
other visc.	193998.0	27342.0	9114.0	49476.0	1953000	130.20	260.40	6510.0	5208.0		
total	2022966.4	84774.2	185426.4	78127.0	8491196	916.44	1053.92	19026.0	35074.2	0	0
bowhead whale (*Balaena mysticetus*)											
meat	4632216.4	1003848.4	68535.8	685358.4	13304016	5644.13	17738.69	322521.6	568444.3		
blubber	79029695.9	152108.2	8641644.8	713007.0	26428792	22816.22	950.68	95067.6	47533.8		
muktuk	5353858.5	495877.0	48378.2	524097.6	30236400	201576.00	0	806304.0	40315.2		
liver	699359.8	110267.5	23371.9	65920.8	132440880	719.14	8449.85	5992.8	2996.4		
other visc.	3368770.8	474793.2	158264.4	859149.6	33913800	2260.92	4521.84	113046.0	90436.8		
total	93083901.4	2236894.3	8940195.1	2847533.4	236323888	233016.41	31661.06	1342932.0	749726.5	0	0
wolf (*Canis lupus*)											
total	17160.0	2970.0	495.0	2310.0	33	8.25	31.35	165.0	363.0	0	0.2
arctic fox (*Alopex lagopus*)											
total	1830.4	316.8	52.8	246.4	3.5	0.88	3.34	17.6	38.7	0	0.02

Table 4: Nutritional composition of prey species

species portion	kcal	protein	fat	Calcium	Vit A	Thiamine	Riboflav	Vit C	Iron	NFV 1	NFV 2
polar bear (*Thalarctos maritimus*)											
meat	311620.5	59092.5	7155.7	39241.1	3231620	530.91	1315.73	4616.6	2308.3		
blubber	624348.0	2158.2	68370.0	2543.6	0	0	0	770.8	0		
total	935968.5	61250.7	75525.7	41784.7	3231620	530.91	1315.73	5387.4	2308.3	0	3.5
walrus (*Odobenus rosmarus*)											
meat	876239.3	47621.7	19048.7	34015.5	385509	634.96	702.99	6803.1	9070.8		
blubber	933660.0	0	103740.0	15561.0	2614248	31.12	10.37	1037.4	9751.6		
liver	17482.9	2750.4	453.5	3364.9	7241850	17.56	206.28	2779.7	2106.7		
heart	4208.0	857.4	69.9	312.2	0	0	0	79.2	0		
kidney	2660.0	518.7	63.8	279.3	0	0	0	351.1	0		
other visc.	217987.0	30723.0	10241.0	55594.0	2194500	146.30	292.60	7315.0	5852.0		
total	2052237.2	82471.2	133616.9	109126.9	12436107	829.94	1212.24	18365.5	26781.1	3.1	0
bearded seal (*Erignathus barbatus*)											
meat	95735.6	15373.6	3494.0	9573.6	1048200	83.86	244.58	9084.4	2795.2		
blubber	557498.7	0	61944.3	625.7	1501680	0	156.43	625.7	0		
liver	6716.6	894.0	302.7	340.6	3547500	7.10	14.19	851.4	189.2		
heart	1363.5	277.8	22.7	101.2	0	0	0	25.7	0		
kidney	860.0	167.7	20.6	90.3	0	0	0	113.5	0		
other visc.	17939.6	2528.4	842.8	4575.2	180600	12.04	24.08	602.0	481.6		
total	680114.0	19241.5	66627.1	15306.6	6277980	103.00	439.28	11302.7	3466.0	1	0
ringed seal (*Phoca hispida*)											
meat	20221.2	3247.2	738.0	2022.1	221400	17.71	51.66	1918.8	590.4		
blubber	145233.0	0	16137.0	1630.0	391200	0	40.75	163.0	0		
liver	1420.0	189.0	64.0	72.0	750000	1.50	3.00	180.0	40.0		
heart	289.0	58.9	4.8	21.4	0	0	0	5.4	0		
kidney	180.0	35.1	4.3	18.9	0	0	0	23.8	0		
other visc.	3784.6	533.4	177.8	965.2	38100	2.54	5.08	127.0	101.6		
total	171127.8	4063.6	17125.9	4729.6	1400700	21.75	100.49	2418.0	732.0	0.1	0.3
caribou (*Rangifer tarandus*)											
meat	33867.4	7598.8	341.5	7968.8	28	48.38	142.30	569.2	540.7		
fat	73170.0	0	8130.0	0	0	0	0	0	0		
viscera	20325.0	2439.0	813.0	15934.8	325200	16.26	32.52	2439.0	1300.8		
total	127362.4	10037.8	9284.5	23903.6	325228	64.64	174.82	3008.2	1841.5	0	1
muskox (*Ovibos moschatus*)											
total	706640.0	20908.8	66211.2	17424.0	387200	154.88	367.84	968.0	3678.4	0	1.8

essentially useless for some functions, while others are of marginal utility only. To produce reasonable estimates of hide value for all species, a subjective measure of relative utility was factored into the final value. These utility values range from a maximum of 1.0 for caribou (light duty) and bearded seal (heavy duty), to 0.05 for char skin, which has limited practical uses. To avoid duplicating the potential uses of a hide, all species were assigned to one of the heavy duty or light duty categories, or excluded alltogether (as with the three whale species, for which skin is considered edible tissue). The only exception to this procedure is ringed seal, which serves both types of uses in Foote's estimation. Ringed seal was thus assigned a utility value of 1.0, which was then divided between light and heavy duty utility, proportional to its relative importance in these categories. Thus 0.7 of each ringed seal skin is assigned to light duty, and 0.3 to heavy duty. The estimated values for each species are shown in Tables 5 and 6.

Resource Costs

The "cost" of resources in optimal foraging formulations take a variety of forms or "currencies". Some authors estimate the caloric expenditure involved in procuring a given resource, as a function of handling time and the strenuousness of particular activites (e.g. Hawkes *et al* 1982, Jones and Madsen 1989). In a consideration of time allocation, cost might simply be defined as the investment of time in hours (Smith 1983). In cost calculations such as these, which remain close to the techniques developed for non-human foragers, cost is often broken down into two main components: search and pursuit time. For hunters, search is the time required to actually locate prey, and pursuit is the time required to kill it once it has been located. Cost is

Table 5: "Heavy duty" hide value of prey species (NFV1)

species, average weight, utility value	non-food value: heavy duty uses (NFV1)
walrus (*Odobenus rosmarus*) average weight = 665 kg utility value = 1.0	NFV1 = 1.8
bearded seal (*Erignathus barbatus*) average weight = 215 kg utility value = 1.0	NFV1 = 1.0
ringed seal (*Phoca hispida*) average weight = 45.4 kg utility value = 0.3	NFV1 = 0.1

Table 6: "Light duty" hide value of prey species (NFV2)

species, average weight, utility value	non-food value: light duty uses (NFV2)
arctic char (*Salvelinus alpinus*) average weight = 2.3 kg utility value = 0.05	NFV2 = 0.008
birds (*Aves sp*) average weight = 1.04 kg utility value = 0.2	NFV2 = 0.02
arctic hare (*Lepus arcticus*) average weight = 4.6 kg utility value = 0.2	NFV2 = 0.05
wolf (*Canis lupus*) average weight = 30 kg utility value = 0.8	NFV2 = 0.5
arctic fox (*Alopex lagopus*) average weight = 3.2 kg utility value = 0.8	NFV2 = 0.2
polar bear (*Thalarctos maritimus*) average weight = 410 kg utility value = 0.8	NFV2 = 1.8
ringed seal (*Phoca hispida*) average weight = 45.4 kg utility value = 0.7	NFV2 = 0.5
caribou (*Rangifer tarandus*) average weight = 81.3 kg utility value = 1.0	NFV2 = 1.0
muskox (*Ovibos moschatus*) average weight = 242 kg utility value = 0.6	NFV2 = 1.4

calculated as the sum of search and pursuit time, often measured in hours or kilocalories. These costs are not static, but fluctuate in a predictable seasonal fashion according to prey ecology (calculated, in this study, following Keene), and unpredictably, when a chance encounter with a prey species that may otherwise be very difficult to locate drastically reduces the cost of procurement.

In Keene's (1979) calculations, search time is a function of prey mobility (indexed to the annual range of the prey species, up to a maximum of 100 square km) and density (no. of individuals per square km). Search time increases as prey mobility (M) increases, and decreases as prey density (D) increases, thus:

$$St = \frac{M}{D}$$

Pursuit time for human hunters generally involves stalking and then killing the prey, often from a distance with a projectile weapon. Keene estimates this value in terms of prey aggregation and critical distance. Critical distance refers here to the difference between the distance at which the prey may perceive a hunter (D1), and the distance from which a hunter can strike (D2), or: $CD = D1 - D2$. For animals which are normally trapped this value cannot be calculated, so Keene sets critical distance at the arbitrary value of 50. This value is also applied to the procurement of ringed seals during winter at their breathing holes, when pursuit is not really cost-free, but critical distance according to this formula would be effectively 0. Pursuit time increases as critical distance increases.

Aggregation refers to the number of individuals of a prey species that are likely to be found together at one time. Pursuit time decreases as aggregation increases, due to the greater likelihood of obtaining at least one individual when prey is grouped. Thus the following formula is obtained:

$$Pt = \frac{CD}{A}$$

A final cost factor to be considered is risk. This is a difficult variable to quantify, since risk is mostly a perception on the part of the hunter. Risk may vary seasonally according to ambient environmental conditions, as in the greater risk of hunting during mid-winter, when visibility and low temperature may unpredicatably produce substantial reductions in a hunter's effectiveness. Risk can also be a function of the overall difficulty of capturing a particular prey species, varying according to the danger of returning empty-handed from a hunt. More objectively, risk may vary with the stability of animal populations, increasing for species that are prone to extreme fluctuations in total population, and increasing again if the timing of these fluctuations are unpredictable. Keene made subjective assessments of risk (R) for each species based on these criteria, and assigned values of low (1.0), moderate (1.25), high (1.5) and very high (2.0) risk. These values were increased by 0.1 for all species during the season of maximum darkness. Resource cost (C) is calculated according to the following equation:

$$C = R \times \left(St + Pt \right)$$

$$\text{or} \quad C = R \times \left(\frac{M}{D} + \frac{CD}{A} \right)$$

Because of the significantly different characteristics of some Somerset Island resources from those on Boothia Peninsula, or at least from Keene's estimates of those characteristics, many of his cost calculations were altered to a greater or lesser degree, as outlined below for individual prey species. The only prey costs that were retained intact from Keene are those for bearded seal, wolf, and birds. The manner in which the others were altered is described below.

It is sometimes necessary to specify upper bounds on the availability of particular variables (resources) in linear programming models. This controls for situations in a diet problem where a resource is so nutritionally productive, and can be procured at such a low cost, that the optimal solution selects large quantities of this resource to the exclusion of all others. This can produce model situations where hunters would be harvesting tens of thousands of fish or thousands of seals in a couple of months, and nothing during the rest of the year. Upper bounds must be set at limits that reflect the realistic harvesting potential of the modelled community under the constraints of Thule technology (e.g. lack of fish nets). Many of Keene's upper bound constraints were altered for this model to reflect the ecology of the study area, and added where he did not specify an upper bound. These are listed in Table 7, and discussed below.

Arctic Char

Char are not as locally concentrated in the study area as on Boothia Peninsula, although anadramous individuals would have been available offshore (Sekerek *et al* 1976). Keene's mobility value is increased to 45 to reflect the estimated 45 km range of anadramous char from their home lake (ibid). Aggregation is reduced to 1 at all seasons to reflect the dispersion of fish populations in the ocean at some distance from their wintering site. Char could have been procured in the vicinity of Nudlukta Lake, some 30 km from the study area, and if so the changes in value will reflect the additional transportation costs. Keene's upper bounds were reduced by half, to a maximum of 200 fish per month. These values range

Table 7: Costs and bounds of resources

species	month	upper bound	cost
arctic char (*Salvelinus alpinus*)			
	Jan	17	10.4
	Feb-April	50	9.8
	May	100	8.2
	June	100	5.7
	July-Aug	200	5.1
	Sept	100	5.6
	Oct-Dec	133	8.1
birds (*Aves sp*)			
	Nov-Jan	20	135.9
	Feb-March	20	125.8
	April	10	110.0
	May	20	23.6
	June	60	13.5
	July	60	3.4
	Aug	60	12.1
	Sept	40	21.9
	Oct	20	118.8
arctic hare (*Lepus arcticus*)			
	Oct-Jan	40	40.6
	Feb-March	20	38.1
	April-Sept	60	37.9
beluga (*Delpinapteras leucas*)			
	Aug-Sept	5	407.1
narwhal (*Monodon monoceros*)			
	Aug-Sept	5	1159.0
bowhead whale (*Balaena mysticetus*)			
	Aug-Sept	2	
	r=50		21590.0
	r=100		43180.0
	r=200		86360.0
	r=315		136017.0
wolf (*Canis lupus*)			
	Nov-Jan	3	13763.8
	Feb-March	4	12512.5
	June-Sept	4	4179.1
	Oct	1	4597.0
arctic fox (*Alopex lagopus*)			
	Oct-Jan	40	33.4
	Feb-April	30	17.8
	May-Sept	50	30.3

Table 7: Costs and bounds of resources (cont'd)

species	month	upper bound	cost
polar bear (*Thalarctos maritimus*)			
	Jan	2	8820.0
	Feb	2	12240.0
	March	2	12200.0
	April	2	2600.0
	May	2	2640.0
	June-July	4	4400.0
	Aug-Sept	2	12300.0
	Oct-Dec	4	8400.0
walrus (*Odobenus rosmarus*)			
	Aug-Sept	1	20586.0
bearded seal (*Erignathus barbatus*)			
	Oct-Jan	5	514.8
	Feb-March	10	468.0
	April	5	468.0
	May	5	393.0
	June	5	333.0
	July-Sept	15	544.5
ringed seal (*Phoca hispida*)			
	Nov-Jan	75	63.9
	Feb-March	70	58.1
	April	35	54.0
	May-June	35	66.1
	July	30	149.0
	Aug-Sept	25	301.5
	Oct	25	173.8
caribou (*Rangifer tarandus*)			
	Nov-Jan	5	4624.8
	Feb-March	5	4282.3
	April	5	977.8
	May	10	946.5
	June-July	10	484.2
	Aug	10	742.8
	Sept	10	182.4
	Oct	10	1570.6
muskox (*Ovibos moschatus*)			
	Nov-Jan	3	1617.0
	Feb	1	1540.0
	March-April	2	1549.9
	May-June	2	2580.0
	July	1	1550.0
	Aug	1	1544.4
	Sept	1	1550.1
	Oct	1	2677.5

from 17/month in January to 100/month in summer and early fall.

Birds

In the absence of estimates by Keene, the upper bounds for birds of all species were subjectively set at 10 per month for late fall to early spring, 20/month for mid-spring and mid-fall, 40/month for late summer, and 60/month for late spring to mid-summer.

Arctic Hare

Keene's value of 4 for a typical aggregation of arctic hare appeared high, compared to descriptions of their behaviour in the southern part of their range (MacPherson and Manning 1959, Banfield 1974). This value was reduced to 2. The upper bound for hare was arbitrarily set at 10 per month.

Beluga

The parameters of beluga cost are based on estimates, and observations from the waters surrounding Somerset Island (Finley and Johnston 1977). Mobility is set at Keene's maximum of 100, as beluga are seasonal migrants in the study area. Average density, based on 6 transects in Peel Sound, is 1.4 animals/sq km (Finley and Johnston 1977:25). Critical distance was arbitrarily set at a higher value than any of Keene's species estimates, because of the greater pursuit costs of a fast-swimming, elusive prey. Average aggregation was estimated at 50 animals, based on personal observations. Risk was set at a value of 5, higher than for any of Keene's species, due to the difficulty of pursuit and the dangers of open-water hunting in skin boats. Beluga are considered only to be available in the months of August and September, and can be realistically harvested to a limit of 5 for this two month period.

Narwhal

The mobility, critical distance, and risk values for narwhal are considered to be the same as for beluga. Narwhal density, again based on transects in Peel Sound, is set at 0.55 (Finley and Johnston 1977:25). Average aggregation for 26 groups of narwhal observed near Bellot Strait is 10.0 (Finley and Johnston 1977:43). The upper bounds for narwhal, available only August to September, are the same as for beluga.

Bowhead Whale

Values estimated for bowhead whales are much more approximate than for beluga and narwhal, due to the extreme decimation of bowhead stocks in the early historic period and a consequent lack of comparable population data (Reeves and Leatherwood 1986). Mobility and critical distance were set at the same values as narwhal and beluga. Current density of narwhal, which also move through the study area for summer feeding, was adopted as an analogue for past densities of bowhead, and set at 0.55. Bowhead aggregations vary seasonally along age and sex lines (Reeves and Leatherwood 1986). Although bowhead are not particularly gregarious while on their feeding grounds, the population which occupied Prince Regent Inlet in late summer probably included substantial proportions of mother-calf pairs (Mitchell and Reeves 1982). The average aggregation was thus set at 2. The critical attribute of risk is exceedingly difficult to estimate in this case (see Spencer 1959, Vanstone 1962 for descriptions of Inupiat whaling). While bowhead are slow swimmers, and tend to float after death, the pursuit of such an enormous animal would have presented considerable danger to a group of Thule hunters. The danger to the survival of the community is even more important, and is compounded by the presence of 6-7 hunters in a single boat during this activity. In addition, bowhead whaling cannot be undertaken on an opportunistic basis with any great hopes for success. The requisite equipment is elaborate, and would involve major investments in artifact manufacture and repair in preparation for the whaling season. The mobilization of sufficient labour to man two or more whaling crews also carries with it a huge array of unquantifiable social costs (Cassell 1988, Ellanna 1988, Sheehan 1985). While admittedly these costs (which are not meant to be perceived as such within an egalitarian ideology) are also a critical factor in subsistence production among non-whaling groups (Wenzel 1981, 1991), the degree of effort (in time, labour, gifts, ritual activity etc.) involved in bringing several hunters together for a whaling crew must be considerable. For the sake of argument, this value has been set at 315, calculated according to the consequences of failure implied by the 15 hunters in our hypothetical community devoting 3 weeks (21 days) exclusively to whaling. In other words, each hunter is investing (or gambling) 21 days of productive activity on the potential returns from a successful whale hunt. This produces a total cost factor approximately 450 times that for ringed seal at this season (during which seal are at their most costly). The upper bound for bowhead procurement was set at 1 per month, or 2 for the period August to September. A community of the size modelled here would be hard-pressed to process and utilize more than this amount.

Wolf

The upper bounds for wolf were set at 1 per month for all months of the year.

Arctic Fox

Some manipulations of Keene's fox data were felt to be necessary, although his estimates of the ecological parameters were not altered. The standard critical distance value of 50 for trapped animals was reduced by half to reflect the efficiency of Thule fox-trapping technology, which involved an extensive scatter of fox traps across the landscape. Because the fox procurement strategy could be spatially extensive at relatively low cost, after the initial investment in construction of the traps, hunters would be somewhat buffered against local fluctuations in fox population. The generally greater efficiency of harvesting with permanent traps is thus also reflected in a reduction of risk value from high to low. It is even possible that foxes would be attracted to a settlement that produced a great deal of organic refuse, as garbage can be become an important supplement to fox diet (Fay and Stephenson 1989). Keene's upper bounds estimates were doubled, to 10 animals per month.

Polar Bear

Based on personal observations and reports of the recent concentrations of polar bears in the study area during summer (Savelle, personal communication), bear density has been increased to 0.05 per sq km for the months April to July. This is probably a conservative estimate. The critical distance for polar bears has been reduced by roughly half, to 200. This is intended to reflect the efficiency of polar bear hunting with dogs, apparently not considered by Keene. Because trained dogs can bring a bear to bay much faster than an unassisted hunter could approach to within striking range, pursuit time is greatly reduced. Keene did not set upper bounds on polar bears, so these were arbitrarily set at 2 per month, reflecting a low population level and low recruitment rate (an index of sustainable harvesting yield).

Walrus

Walrus are not included in Keene's model. In fact they very rarely stray into the study area at present, so few relevant ecological data are available (Davis *et al* 1978, Kemp *et al* 1977). They have been assigned a maximum mobility factor of 100, an arbitrary density figure of .01 to reflect their scarcity, a critical distance identical to bearded seal (293) and a high risk factor of 2. Only 1 walrus is allowed for the August-September open water hunting season.

Bearded Seal

Keene's estimates for bearded seal costs and upper bounds were not altered.

Ringed Seal

Keene's estimates for ringed seal have only been altered for the month of July, for which personal observations in the study area are relevant. His aggregation value has been increased from 1 to 2 (although this may still be conservative), and his mobility value reduced to 5, the same as for late spring, reflecting generally high concentrations of basking seals on Hazard Inlet and Prince Regent Inlet until the ice breaks up late in July. Ringed seal upper bounds were increased to 25 per month for the late fall and winter, 35/month for late winter to spring, 30/month for July, and decreased to 25 total for August and September. Although these estimates could realistically have been increased even more, it would have compromised the hide constraint estimates, for then low cost ringed seal could conceivably be selected to the exclusion of caribou and bearded seal to meet these requirements. To reflect the real necessity for acquiring hides of these species, ringed seal catches had to be restricted. The particularly low upper bound for the open water season reflects both the difficulty of procuring seal at this time, and the logistical constraints imposed by the availability of other important species, especially whales.

Caribou

Peary's caribou (*R.tarandus pearyi*), the subspecies which occurs on the arctic islands, is smaller, less abundant, and less gregarious than the Barren ground caribou (*R. tarandus groenlandicus*) that occurs on Boothia Peninsula (Banfield 1961, 1974). Keene's density estimates were thus reduced by half, and his aggregation estimates, which range from 5 in winter to 40 in early fall, were set at 4 for all months of the year. Upper bounds were correspondingly reduced substantially, and range from a low of 5 for a three month period in mid-winter, to a high of 10 in spring, late summer, and fall.

Muskox

The muskox population of Somerset Island is poorly understood. Although it was recently estimated at 100 (Fischer and Duncan 1976), muskox populations are notoriously variable on the arctic islands, as the animals periodically abandon particular habitats en masse (see Will 1985 for an account of muskox ecology from the perspective of Inuit harvesting). Based on this assessment, muskox density was reduced by half, to 0.04. Muskox aggregations in the study area, based on personal observations, were also reduced by half. Critical distance was also halved, in this case to reflect the effectiveness of hunting muskox with dogs (according to the same reasoning as for polar bears), as they are more likely to stop and form a defensive ring than flee when threatened in this manner. To reflect the dramatic fluctuations of muskox populations on the arctic islands, risk was increased from low to very high. Because of low recorded populations in the study area, the upper bounds were decreased from 5 per month to 1 per month.

4. ZOOARCHAEOLOGICAL ANALYSIS

During the summers of 1989 and 1990 all non-cetacean faunal remains were collected from a number of Thule features excavated on Ditchburn Point, and north of Mount Oliver, southeastern Somerset Island, under the direction of James Savelle. Due to their bulk, and potential value to Inuit carvers from nearby communities, bowhead whale bones were identified and measured, but very few were collected. A sample of the total faunal assemblage, its size dictated by time constraints, was analyzed for this report.

Methods - Faunal Analysis

Collection

Faunal remains were recovered by excavation unit, which in the case of four of the features reported here were one metre squares, while in the other four (all of which were ephemeral tent rings) faunal collections were not differentiated within the feature. One of the unanalyzed features was excavated in two by two metre squares. All features except tent rings were collected in natural stratigraphic units (e.g. surface, sod, house fill, below permafrost) but these were not consistently recorded, so for most of the purposes of this analysis the assemblage from each house has been lumped together (horizontal variability in the deposition of faunal remains is discussed in the section on taphonomy). The outside perimeter of most features was excavated, so the feature assemblages are not restricted merely to the remains which occurred within the walls of the house. Deposits were not screened or subjected to flotation, but judging from the large quantities of very small bones, such as fish and lemming, recovered from some features (e.g. Dorset features excavated at Nudlukta Inlet in 1990), it appears that recovery was not biased against particular faunal classes or species.

Preparation

The faunal remains were returned to McGill University and housed at the Archaeology Laboratory there. All specimens were cleaned with a dry brush and labelled by feature with provenience and a unique catalogue number. Wet cleaning may accelerate cracking and exfoliation of bone, so this was only resorted to for extremely dirty specimens. A small proportion of specimens, especially among the samples recovered from winter houses within the permafrost zone, still contained soft tissue (flesh, cartilage, tendon, feathers, skin etc.). Where this tissue could be removed without damaging the bone surface (and thus disguising butchery or carnivore gnawing marks), it was done so, but many of these specimens were simply air dried. Preliminary to identification, labelled specimens were bagged by gross categories (seal, bird, fox, large mammal, etc.).

Identification

Many faunal identifications require the physical comparison of the archaeological specimen with a prepared reference specimen of known species and, if possible, age, sex, body size, and health status. This necessitates use of a large comparative osteological collection with representatives of all species that might conceivably be encountered in the archaeological sample. Few institutions possess such an ideal comparative collection, but at the time this analysis was conducted, McGill did not possess any complete reference specimens. It was therefore necessary to use comparative collections found elsewhere. For ringed seal and arctic fox, archaeological specimens representing all skeletal elements were identified at the University of Toronto's Faunal Osteo-archaeology Laboratory. These specimens were then used as a reference collection in identifying other seal and fox remains. For all other species, identifications were physically conducted at the University of Toronto, Osteotheque de Montreal Inc. of the Universite de Quebec a Montreal, and the Zooarchaeological Identification Centre, Museum of Nature, Ottawa.

An attempt was made to identify all specimens to species, and to record skeletal element, element portion, side and age (Figure 3). Sex is difficult, if not impossible, to determine for most archaeological specimens, unless they possess sex-specific, discontinuous attributes, such as the presence of medullary bone in the limbs of nesting female birds. In addition, the presence of any cultural modifications was recorded, such as the location and number of cutmarks. The modification of bone surfaces by carnivores, such as punctures, furrowing or the erosion of cortical bone by digestive juices, was recorded as present or absent for each specimen. Other notable attributes of specimens were recorded as comments, such as the presence of osteophytes, healed fractures, or congenital abnormalities.

Thin Sections

Many animals create a record of their development in the deposition of alternating light and dark bands of dentine and cementum in their teeth. The technique of age determination was developed by R.M. Laws on teeth of the elephant seal (Laws 1952), and has since been extended to species as diverse as fox, bear, muskox, caribou, deer and gazelle, (refs) as well as a wide range of marine mammals. Although the actual causes of variability in dentine and cementum deposition are not fully understood

(Smith 1973), the technique has been refined for the determination of not just age, but season of death, and applied to seasonality analyses of archaeological fauna. The archaeological analysis of seal teeth appears, from the literature, to be more common than the analysis of any other non-domesticated species (e.g. Spiess 1976, 1978, Cox and Spiess 1980, Fletemeyer 1977, Morrison 1983a, McCullough 1988, Park 1989).

Examining unstained sections from the canines of ringed seals under transmitted light, a band of transluscent dentine can be observed which is deposited between the end of March and mid-to-late June, while an opaque band is deposited during the rest of the year (Smith 1973). Age is generally determined by simply counting the number of opaque bands, and season of death determined by observing what proportion of a transluscent or opaque band has been deposited next to the pulp cavity (Figure 4).

In an attempt to determine age and season of death of ringed seals in the sample, 50 canines were sectioned on a microtome. Specimens were selected from each feature so as to avoid making a determination on canines belonging to the same individual. For example, only canines actually present in left mandibles were selected from Sodhouse 2, and so on for the most frequent dental portion recovered in each feature (left maxillae, right mandibles etc.). Each specimen was cut to a thickness of 40 - 50 microns, examined under a microscope at 20x to 100x magnification, and the age and season of death recorded. This technique of preparation, involving undecalcified thin sections is similar to that described in Bourque *et al* (1978). The results of this analysis are discussed in the section on site seasonality.

Methods - Ethnoarchaeology

Background

Forty years ago White (1952) stressed the potential contribution of butchery studies to the interpretation of prehistoric subsistence, stimulating a moderate amount of actualistic research. With the publication of one detailed ethnoarchaeological and experimental study of caribou and sheep butchery (Binford 1978), however, interest in this aspect of economic behaviour grew tremendously. It has become apparent that a consideration of butchery practises should be an essential component of any zooarchaeological analysis, as a means of assessing the economic uses to which the prey carcass was put (see review and discussion in Lyman 1987a). Merely to reconstruct diet breadth from faunal remains requires an understanding of the biases introduced by butchery, transport and other taphonomic processes, that confound standard techniques of quantification such as NISP and MNI (cf. Grayson 1984).

Although qualitative and quantitative indices of skeletal part utility derived from butchery studies are available for species ranging from kangaroos to penguins, no comparable data has been reported for the economic anatomy of seals, which often comprise the vast majority of specimens from coastal Eskimo faunal assemblages. In February 1991 Lyman, Savelle and Whitridge butchered three harp seals and one hooded seal, in an effort to derive food utility indices for Pinniped skeletal elements (Lyman *et al* 1991). This is only one step, however, in the development of a complete set of analytical tools (so-called middle range theory) for interpreting Pinniped bone assemblages. The other major approaches are 1) the development of indices of element survival, usually measured as a function of bone density (Lyman 1984) and 2) ethnoarchaeological studies of butchery (e.g. Binford 1978)

Although the anatomical distribution of different types of tissue (including bone density) is a physiological characteristic of particular species, the *economic utilization* of these resources follows culturally determined practises. Where historical continuity can be inferred between modern and prehistoric cultural behaviour, as in much of the Arctic, the archaeologist can reasonably apply contemporary observations on carcass treatment to the interpretation of archaeological faunal remains. More cautiously, these applications may be extended to areas where a historical connection is not demonstrable, on the assumption that a large, but undetermined, proportion of subsistence behaviour represents the rational and efficient use of an environment's (or animal's) resources.

Towards this end, between March 12 and April 19, 1991 ethnoarchaeological research into Inuit breathing hole sealing and the economic anatomy of ringed seals and other key economic species was conducted in and around Clyde River, Baffin Island, NWT. Data were collected by participant observation of sealing, caribou hunting and associated butchery and transport practises on the sea ice and land, and by formal and informal interviews with Inuit hunters both in the community and while engaged in hunting.

Research Narrative

I arrived in Clyde River on March 13 and, as pre-arranged with the Hamlet Council, moved into the home of an Inuit family, with whom I resided for the course of the study. Consultations were made with the Hunters and Trappers Association, Hamlet Council, and Renewable Resources officer, in order to locate hunters willing to accompany me sealing. Announcements regarding my study were also made on the local radio station. Although working through this formal administrative network did generate some awareness of the project, and ensured the approval of the community leaders, it was through informal social connections, often facilitated by my host, that I made contact with most of the hunters who ultimately provided the core of my data. For the duration of my stay at Clyde my time was divided approximately equally between hunting and travelling on the land and sea and performing logistical tasks (buying fuel and supplies, meeting with officials, writing up fieldnotes, etc.), and visiting homes (to conduct interviews, establish hunting contacts, and socialize) within the community. In total, I spent three days in transit between Montreal and Clyde River, fifteen days hunting and travelling outside the community, and ten days working and visiting in the community itself.

The participant observation portion of the research involved arranging to travel with a hunter one or more days in advance. On the arranged day I would leave in early to mid morning with the hunter, riding behind him on the snowmobile or, more commonly, in tow on the *kamatik* which carried supplies and sometimes other passengers. We would then spend eight to twelve hours searching for seal breathing holes, waiting for seals to surface, killing them, butchering the carcasses, loading them on the *kamatik*, and transporting them back to town. While on the sea ice I took length and girth measurements of seals caught in my presence, from which weight can be estimated by means of a regression model (Usher and Church 1969), and recorded the precise butchery sequence where applicable. Initially, an attempt was made to record precise times spent at various activities throughout the day, but this tended to unsettle the hunters and interfere with other activities, so it was abandoned. A narrative of the days events and a record of pertinent observations by informants were kept in the evenings. On two occasions events varied from this format: I spent two days on an overnight caribou hunt west of Clyde Inlet, and four days on an extended hunt for denning seals along Sam Ford Fjord. Besides the ongoing process of learning from hunters while actually engaged in hunting, I conducted several one to three hour formal interviews with hunters ranging in age from 26 to mid-70's, in which I presented them with diagrams of the skeletal anatomy of major prey species and recorded their description of the butchering process, and other comments. Some of the results of this research are presented in the section on taphonomy.

Faunal Analysis

Following are brief descriptions of the archaeological features from which the analyzed faunal samples were recovered. The contents of those features are described in the sections organized by species. Results of particular aspects of the zooarchaeological analysis are elaborated in the sections on taphonomy, seasonality, and resource scheduling.

Feature Descriptions

The faunal assemblages from seven features were examined. From the Mount Oliver sites, the faunal assemblages recovered in 1990 from essentially complete excavation of Feature 2 (hereafter referred to as Sodhouse 2) at PaJs-13, and from Features 9 and 11 at PaJs-4, were analyzed (Figure 2). From the Ditchburn Point sites (PaJs-3), the assemblages recovered in 1989 from the complete excavation of Features 1, 2, 3, and 4, and from three one metre square test pits in Feature 25 were analyzed. The total non-cetacean samples, and identifiable fractions, are listed in Tables 8 to 15.

Table 8: Summary of faunal analysis of Sodhouse 2

Order	NISP	NISP%	MNI	MNI%
mollusc (*Mollusca*)	2	0.02	1	0.6
fish (*Osteicthyes*)	14	0.1	1	0.6
bird (*Aves*)	654	5.8	45	25.3
mammal (*Mammalia*)	10635	94.1	131	73.6
total identified	11305	100.0	178	100.0
identified	11305	78.8	177	100.0
unidentified	3041	21.2	0	0
total	14344	100.0	177	100.0

Table 9: Summary of faunal analysis of Feature 25

Order	NISP	NISP%	MNI	MNI%
mollusc (*Mollusca sp*)	5	0.7	1	5.0
fish (*Osteicthyes*)	7	1.0	1	5.0
bird (*Aves*)	120	16.4	6	30.0
mammal (*Mammalia*)	599	82.0	12	60.0
total identified	731	100.1	20	100.0
identified	731	90.6	20	100.0
unidentified	76	9.4	0	0
total	807	100.0	20	100.0

Table 10: Summary of faunal analysis of Feature 9

Order	NISP	NISP%	MNI	MNI%
fish (*Osteicthyes*)	11	1.5	1	2.8
bird (*Aves*)	210	28.2	10	27.8
mammal (*Mammalia*)	524	70.3	25	69.4
total identified	745	100.0	36	100.0
identified	745	62.3	36	100.0
unidentified	451	37.7	0	0
total	1196	100.0	36	100.0

Table 11: Summary of faunal analysis of Feature 11

Order	NISP	NISP%	MNI	MNI%
fish (*Osteicthyes*)	8	0.9	1	3.1
bird (*Aves*)	86	10.0	5	15.6
mammal (*Mammalia*)	763	89.0	26	81.3
total identified	857	99.9	32	100.0
identified	857	67.8	32	100.0
unidentified	407	32.2	0	0
total	1264	100.0	32	100.0

Table 12: Summary of faunal analysis of Feature 1

Order	NISP	NISP%	MNI	MNI%
bird (*Aves*)	1	5.9	1	33.3
mammal (*Mammalia*)	16	94.1	2	66.7
total identified	17	100.0	3	100.0
identified	17	89.5	3	100.0
unidentified	2	10.5	0	0
total	19	100.0	3	100.0

Table 13: Summary of faunal analysis of Feature 2

Order	NISP	NISP%	MNI	MNI%
bird (*Aves*)	95	29.8	7	35.0
mammal (*Mammalia*)	224	70.2	13	65.0
total identified	319	100.0	20	100.0
identified	319	27.1	20	100.0
unidentified	860	73.6	0	0
total	1179	100.0	20	100.0

Table 14: Summary of faunal analysis of Feature 3

Order	NISP	NISP%	MNI	MNI%
bird (*Aves*)	90	32.1	5	55.6
mammal (*Mammalia*)	190	67.9	4	44.4
total identified	280	100.0	9	100.0
identified	280	56.8	9	100.0
unidentified	213	43.2	0	0
total	493	100.0	20	100.0

Table 15: Summary of faunal analysis of Feature 4

Order	NISP	NISP%	MNI	MNI%
mammal (*Mammalia*)	1	100.0	1	100.0
total identified	1	100.0	1	100.0
identified	1	50.0	1	100.0
unidentified	1	50.0	0	0
total	2	100.0	0	100.0

PaJs-13, Sodhouse 2

This feature was a medium-sized semi-subterranean dwelling near the north end of a row of similar features. Its south wall was continuous with the north wall of Sodhouse 1 (PaJs-13, Feature 1). This house row was located at several metres above sea level, facing a small cove formed by a southward-projecting spit. A number of bowhead crania were structural members in the entrance tunnel. A total of 14 344 specimens of bone were recovered from 29 one metre square excavation units, of which 78.8 % were identified to order, family, genus or species. Most of the bones were in an excellent state of preservation, from being enclosed within permafrost.

PaJs-4, Feature 9

Feature 9 was identified from surface survey as a *qarmat*. It was a semi-subterranean structure, smaller than typical winter houses, lacking an entrance tunnel and a permanent roof. It contained a paved floor and a raised sand and gravel sleeping platform. It occurred within a large cluster of similar features on a grassy slope east of Mount Oliver, facing Prince Regent Inlet. It produced a total of 1196 faunal specimens, of which 62.3 % were identified to a phylogenetic category. The faunal remains from this feature were fairly well preserved, although not as well as those from Sodhouse 2. Many features on the bone surface, such as cutmarks, may have been erased by mechanical weathering processes (causing exfoliation) and rootlet action.

PaJs-4, Feature 11

This feature was similar to Feature 9 with respect to dwelling construction and bone preservation. Of 1264 recovered bone specimens, about two thirds were identifiable to Order or better.

PaJs-3, Feature 25

Feature 25 (initially designated sodhouse/qarmat A) is a semi-subterranean structure with an entrance tunnel and relatively thick sod cover located in a grassy area above a pond on the west side of Ditchburn Point, and facing across the pond toward Prince Regent Inlet. It was tested in 1989 in an effort to identify the feature type. One unit was placed along the south wall of the main living compartment, another in the middle of the entrance tunnel, and a third just outside the mouth of the entrance tunnel. From the internal test unit, it would appear that the house had low walls and a paved floor, but on the basis of architectural information alone one can only speculate that the feature had a sod roof and was utilized primarily in winter. Faunal material from the tunnel and inner compartment were very well preserved, 90.6 % of the 807 specimens being identifiable to order, family, genus or species.

PaJs-3, Feature 1

Features 1 through 4 are located in a line stretching for about 20 metres along the 3.5 m beach ridge on the east side of Ditchburn Point approximately 30 m from Prince Regent Inlet (preliminary results of the analysis of these features was presented in Whitridge 1990). Feature 1 (initially labelled Tent Ring A) consists of a circular emplacement of stones defining an area of beach gravel of about 8 sq m. Faunal remains from this and the other tent rings (Features 2-4) were generally poorly preserved, due to the lack of a protective mat of vegetation. Only 19 specimens were recovered, of which 17 were identified to genus or species.

PaJs-3, Feature 2

This second tent ring was larger than Feature 1 (about 10 sq m), and was adjacent to two external hearths and a lichen-encrusted inukshuk. Seventy-three percent of the 1179 specimens were identifiable to order or better.

PaJs-3, Feature 3

This feature was a somewhat larger tent ring than Feature 2, and was also associated with an external box hearth. Of the 493 poorly preserved faunal specimens only 56.8 % could be identified to order, family, genus or species.

PaJs-3, Feature 4

This was the smallest of the tent rings in this row, and was composed of a ring of stones loosely defining an area of about 6 m of beach gravel. It is associated with a possible external hearth which produced no faunal material, and the entire feature only produced 1 identifiable specimen and an unidentifiable fragment.

Fish Remains

Besides the remains of invertebrates, which are here considered to be unrelated to feature occupations, fish remains constituted the smallest proportion of individual and combined feature assemblages of any animal order (Tables 16 to 19). For those features which did produce fish bone, on average it made up only 0.9 % of the identified specimens and 2.9 % of the total MNI. Of a total of 40 fish bones, 52.5 % were identifiable to the Salmon family, and the rest were unidentified. Although there is an extremely remote possibility that lake trout were available near the study area in Thule times, it is fairly certain that the identified specimens

Table 16: Sodhouse 2 fish remains

species	NISP	NISP%	MNI	MNI%
char/trout (*Salmonidae sp*)	11	78.6	1	100.0
unidentified fish (*Osteicthyes sp*)	3	21.4	0	0
total fish	14	100.0	1	100.0

Table 17: Feature 25 fish remains

species	NISP	NISP%	MNI	MNI%
char/trout (*Salmonidae sp*)	3	42.9	1	100.0
unidentified fish (*Osteicthyes sp*)	4	57.1	0	0
total fish	7	100.0	1	100.0

Table 18: Feature 9 fish remains

species	NISP	NISP%	MNI	MNI%
char/trout (*Salmonidae sp*)	6	54.5	1	100.0
unidentified fish (*Osteicthyes sp*)	5	45.5	0	0
total fish	11	100.0	1	100.0

Table 19: Feature 11 fish remains

species	NISP	NISP%	MNI	MNI%
char/trout (*Salmonidae sp*)	1	12.5	1	100.0
unidentified fish (*Osteicthyes sp*)	7	87.5	0	0
total fish	8	100.0	1	100.0

Table 20: Sodhouse 2 bird remains

species	NISP	NISP%	MNI	MNI%
loon (*Gavia sp*)	3	1.5	1	2.2
northern fulmar (*Fulmarus glacialis*)	100	48.8	17	37.8
snow goose (*Chen caerulescens*)	17	8.3	5	11.1
brant (*Branta bernicla*)	4	2.0	1	2.2
unidentified eider (*Somateria sp*)	13	6.3	3	6.7
oldsquaw (*Clangula hyemalis*)	1	0.5	1	2.2
unidentified duck (*Anatinae sp*)	4	2.0	0	0
total duck	18	8.8	4	8.9
unidentified ptarmigan (*Lagopus sp*)	21	10.2	5	11.1
unidentified shorebird (*Scolopacidae sp*)	3	1.5	2	4.4
glaucous gull (*Larus hyperboreus*)	28	13.7	5	11.1
unidentified small gull (*Laridae sp*)	5	2.4	2	4.4
unidentified large gull (*Laridae sp*)	4	2.0	2	4.4
total gull	37	18.0	9	20.0
black guillemot (*Cepphus grylle*)	2	1.0	1	2.2
total identified	205	100.1	45	99.9
identified bird	205	31.3	45	100.0
unidentified bird	449	68.7	0	0
total bird	654	100.0	45	100.0

are arctic char, which is the prime arctic fish resource and is still harvested in considerable quantities on Somerset Island (Kemp *et al* 1977). When found in abundance, char are an excellent resource which could be procured fairly easily by Inuit with static traps (fish weirs), lures, leisters or (in modern times) nets. The benefits of char harvesting are reflected in the very high density of occupation and processing features along the river draining Nudlukta Lake, just outside the study area. The paucity of fish remains in the Somerset Island features, in spite of the presence of artifacts associated with fishing (cf. Sabo 1990:142), may indicate that char were procured and consumed elsewhere, although the absence of fish remains in the tent rings could be the result of poor preservation and small sample size. In any case, fish do not appear to have constituted much of the Hazard Inlet diet at the times of year these features were occupied.

Bird Remains

Birds remains were second in abundance to those of mammals (Tables 20 to 26). Only the miniscule assemblage from Feature 4 did not produce any bird remains. Of the other seven, birds constituted 18.3 % of the NISP on average, and 31.8 % of the total MNI. For the two winter houses, these figures are 11.1 % and 27.7 % respectively, for the *qarmat* 19.1 % and 21.7 %, and for the tent rings with bird, 22.6% and 41.3 %. The NISP figures indicate that birds were most important in economies associated with the tent rings, and least important in the winter houses, while the MNI values reverse the ranking of qarmat and winter houses.

A minimum of 13 species are represented in the combined sample, and an average of 7.5 per winter house, 5.5 per qarmat, and a minimum of only 1 species for the tent rings with bird. The high value for winter houses

Table 21: Feature 25 bird remains

species	NISP	NISP%	MNI	MNI%
northern fulmar (*Fulmarus glacialis*)	18	81.8	3	50.0
oldsquaw (*Clangula hyemalis*)	2	9.1	2	33.3
unidentified gull (*Laridae sp*)	2	9.1	1	16.7
total identified	22	100.0	6	100.0
identified bird	22	18.3	6	100.0
unidentified bird	98	81.7	0	0
total bird	120	100.0	6	100.0

Table 22: Feature 9 bird remains

species	NISP	NISP%	MNI	MNI%
loon (*Gavia sp*)	1	2.8	1	10.0
northern fulmar (*Fulmarus glacialis*)	3	8.3	2	20.0
unidentified eider (*Somateria sp*)	19	52.8	3	30.0
oldsquaw (*Clangula hyemalis*)	2	5.6	1	10.0
unidentified duck (*Anatinae sp*)	5	13.9	0	0
total duck	26	72.2	4	40.0
unidentified shorebird (*Scolopacidae sp*)	3	8.3	1	10.0
unidentified gull (*Laridae sp*)	2	5.6	1	10.0
snow bunting (*Plectrophenax nivalis*)	1	2.8	1	10.0
total identified	36	100.0	10	100.0
identified bird	36	17.1	10	100.0
unidentified bird	174	82.9	0	0
total bird	210	100.0	10	100.0

Table 23: Feature 11 bird remains

species	NISP	NISP%	MNI	MNI%
northern fulmar (*Fulmarus glacialis*)	1	14.3	1	20.0
unidentified eider (*Somateria sp*)	2	28.6	2	40.0
unidentified duck (*Anatinae sp*)	1	14.3	0	0
total duck	3	42.9	2	40.0
unidentified ptarmigan (*Lagopus sp*)	1	14.3	1	20.0
unidentified gull (*Laridae sp*)	2	28.6	1	20.0
total identified	7	100.0	5	100.0
identified bird	7	8.1	5	100.0
unidentified bird	79	91.9	0	0
total bird	86	100.0	5	100.0

Table 24: Feature 1 bird remains

species	NISP	NISP%	MNI	MNI%
unidentified eider (*Somateria sp*)	1	100.0	1	100.0
total identified	1	100.0	1	100.0
total bird	1	100.0	1	100.0

Table 25: Feature 2 bird remains

species	NISP	NISP%	MNI	MNI%
unidentified eider (*Somateria sp*)	57	100.0	7	100.0
total identified	57	100.0	7	100.0
identified bird	57	60.0	7	100.0
unidentified bird	38	40.0	0	0
total bird	95	100.0	7	100.0

Table 26: Feature 3 bird remains

species	NISP	NISP%	MNI	MNI%
unidentified eider (*Somateria sp*)	44	100.0	5	100.0
total identified	44	100.0	5	100.0
identified bird	44	48.9	5	100.0
unidentified bird	46	51.1	0	0
total bird	90	100.0	5	100.0

may, however, be misleading. In other contexts, number of species has been demonstrated to correlate with sample size (Grayson 1984). The proportions of particular species in the different feature types is probably a more revealing measure of harvesting variability. Both Sodhouse 2 and Feature 25 have their highest proportions of northern fulmar, with gulls and ducks comprising most of the remainder of the assemblage. On average, fulmars comprise 65.3 % of the identified avian assemblages from these features by NISP. These same three families of bird comprise substantial portions of the *qarmat* assemblages, but in both duck is the most common type of bird, while gull and fulmar occur in low to moderate frequencies. This trend reaches its extreme in the tent ring assemblages, where eider duck comprises 100 % of the identified bird remains.

Fulmars are concentrated in breeding colonies for much of the summer, the closest being at Prince Leopold Island (Alliston *et al* 1976:403). They disperse in August, after the breeding season, at which time they become very abundant at Creswell Bay and at Hazard Inlet (ibid:Figure 11b). Their abundance appears to increase in these areas into September, and they may continue to be abundant until mid-to late September (ibid:79). High frequencies of fulmar in a faunal assemblage would thus tend to suggest late summer/fall rather than spring/summer procurement. This is consistent with the assumptions from feature construction that the qarmat and tent rings were not occupied during winter.

Daniel Walker, the naturalist on McLintock's Franklin search expedition, observed the arrival of eiders at Port Kennedy, 8 km SW of Ditchburn Point, in early June (Walker 1860). Similar observations were made more recently on Adelaide Peninsula (MacPherson and Manning 1959).

King eiders were abundant there until mid July, when the populations began to drop off rapidly through to their final departure in September. The abundance of eiders in the tent ring and qarmat assemblages thus tends to indicate an occupation between early June and mid-July, although procurement during late summer cannot be ruled out. Seasonality can be defined even more precisely, however, due to the presence of medullary bone in eider remains from Features 2, 3 and 11. Medullary bone forms in breeding females one to two weeks before egg laying, and is resorbed over a period of one to three weeks after the last eggs have been laid (RIck 1975). Based on behavioural observations from Adelaide Peninsula, medullary bone should not be present in the eiders before mid-June nor after mid-July. Although these dates only bracket the deaths of three individuals, the presence of medullary bone in unfragmented elements cannot be ruled out, and of course would not be present in males and non-breeding females of the species at any season. Feature 9 produced 3 unidentified bird specimens with medullary bone, while Feature 2 and Sodhouse 2 each produced 1 specimen. Features 3 and 11 contained 6 (MNI=1) and 1 eider specimens with medullary bone, respectively. The Sodhouse 2 specimen is somewhat problematic, and may indicate some late activity at the feature, storage with delayed winter consumption of birds harvested in summer, or may merely be intrusive. In any case, it represents only 0.2 % of the avian assemblage, as opposed to 1.4 % for the specimens from Feature 9, 1.2 % for Feature 11, 1.1 % for Feature 2, and 6.7 % for Feature 3.

Mammalian Remains

Mammals constituted by far the majority of most assemblages, averaging 81.8 % by NISP and 64.9 % by MNI (for this and future calculations the negligible sample from Feature 4 is excluded unless otherwise indicated). The only exception is Feature 3, where birds are in slight majority by MNI. The trends by feature type are the inverse of those observed for bird frequencies, winter houses averaging 88.1 % mammalian NISP, qarmat 79.7 %, and tent rings 77.4 %.

Species representation varies between features (Tables 27 to 34), but again the size of the Sodhouse 2 assemblage makes interpretation of this sort of evidence tenuous. All of the tent rings except Feature 2 are represented by only one mammal, ringed seal. The Feature 2 mammalian fauna also includes a substantial proportion (19.2 % NISP) of non-food remains in the form of collared and brown lemming bone. When this is factored out, the overall composition of the tent ring mammalian assemblages is 97.9 % NISP ringed seal.

The qarmat assemblages are much more diverse, Feature 9 with 7 different species or genera, and Feature 11 with 8. When non-economic species are removed, these figures drop to 5 for both qarmat (the exclusion of lemming and dog/wolf from the category of economic species is discussed below in the sections on those animals). Interestingly, identical mammalian food species are represented at these two features, and in similar proportions.

The two winter houses are less similar. Sodhouse 2 has 12 mammalian species, and 9 food species, while feature 25 has 6 and 4 respectively. This is as likely due to the difference in sample size as differences in harvesting strategies at the two sites.

Grouped by feature type, there is a clear trend in diversity of mammalian species present. The tent rings produced 25 % of all mammalian

Table 27: Sodhouse 2 mammal remains

species	NISP	NISP%	MNI	MNI%
arctic hare (*Lepus arcticus*)	32	0.4	3	2.3
brown lemming (*Lemmus sibiricus*)	9	0.1	2	1.5
collared lemming (*Dicrostonyx torquatus*)	34	0.4	14	10.7
unidentified lemming	107	1.2	0	0
total lemming	150	1.7	16	12.2
dog (*Canis familiaris*)	7	0.08	3	2.3
dog/wolf (*Canis sp*)	111	1.3	1	0.8
total *Canis*	118	1.3	4	3.1
arctic fox (*Alopex lagopus*)	1071	12.2	20	15.3
beluga/narwhal (*Monodontidae sp*)	6	0.07	1	0.8
polar bear (*Ursus maritimus*)	13	0.1	2	1.5
walrus (*Odobenus rosmarus*)	1	0.01	1	0.8
bearded seal (*Erignathus barbatus*)	50	0.6	3	2.3
ringed seal (*Phoca hispida*)	7230	82.5	77	58.8
caribou (*Rangifer tarandus*)	93	1.1	3	2.3
muskox (*Ovibos moschatus*)	2	0.02	1	0.8
total identified	8766	100.0	131	100.2
identified mammal	8766	82.4	131	100.0
unidentified large mamm.	13	0.1	0	0
unidentified medium mamm.	157	1.5	0	0
unidentified small mamm.	158	1.5	0	0
other unidentified mamm.	1541	14.5	0	0
total mammal	10635	100.0	131	100.0

Table 28: Feature 25 mammal remains

species	NISP	NISP%	MNI	MNI%
unidentified lemming	1	0.2	1	8.3
dog/wolf (*Canis sp*)	2	0.4	1	8.3
arctic fox (*Alopex lagopus*)	2	0.4	1	8.3
polar bear (*Ursus maritimus*)	1	0.2	1	8.3
ringed seal (*Phoca hispida*)	549	98.6	7	58.3
caribou (*Rangifer tarandus*)	2	0.4	1	8.3
total identified	557	100.0	12	99.8
identified mammal	557	93.0	12	100.0
unidentified large mamm.	1	0.2	0	0
unidentified medium mamm.	12	2.0	0	0
other unidentified mamm.	29	4.8	0	0
total mammal	599	100.0	12	100.0

Table 29: Feature 9 mammal remains

species	NISP	NISP%	MNI	MNI%
collared lemming (*Dicrostonyx torquatus*)	1	0.3	1	4.0
unidentified lemming	10	3.2	1	4.0
total lemming	11	3.5	2	8.0
dog/wolf (*Canis sp*)	7	2.2	2	8.0
arctic fox (*Alopex lagopus*)	7	2.2	1	4.0
polar bear (*Ursus maritimus*)	5	1.6	1	4.0
bearded seal (*Erignathus barbatus*)	7	2.2	2	8.0
ringed seal (*Phoca hispida*)	275	87.9	16	64.0
caribou (*Rangifer tarandus*)	1	0.3	1	4.0
total identified	313	99.9	25	100.0
identified mammal	313	59.7	25	100.0
unidentified large mamm.	11	2.1	0	0
unidentified medium mamm.	10	1.9	0	0
other unidentified mamm.	190	36.3	0	0
total mammal	524	100.0	25	100.0

Table 30: Feature 11 mammal remains

species	NISP	NISP%	MNI	MNI%
brown lemming (*Lemmus sibiricus*)	1	0.2	1	3.8
collared lemming (*Dicrostonyx torquatus*)	17	3.3	5	19.2
unidentified lemming	27	5.3	0	0
total lemming	45	8.8	6	23.1
dog/wolf (*Canis sp*)	2	0.4	1	3.8
arctic fox (*Alopex lagopus*)	3	0.6	1	3.8
polar bear (*Ursus maritimus*)	5	1.0	1	3.8
bearded seal (*Erignathus barbatus*)	2	0.4	1	3.8
ringed seal (*Phoca hispida*)	454	88.5	15	57.7
caribou (*Rangifer tarandus*)	2	0.4	1	3.8
total identified	513	100.1	26	99.8
identified mammal	513	67.2	26	100.0
unidentified large mamm.	1	0.1	0	0
other unidentified mamm.	249	32.6	0	0
total mammal	763	99.9	26	100.0

Table 31: Feature 1 mammal remains

species	NISP	NISP%	MNI	MNI%
ringed seal (*Phoca hispida*)	16	100.0	2	100.0
total identified	16	100.0	2	100.0
total mammal	16	100.0	2	100.0

Table 32: Feature 2 mammal remains

species	NISP	NISP%	MNI	MNI%
brown lemming (*Lemmus sibiricus*)	2	0.9	1	7.7
collared lemming (*Dicrostonyx torquatus*)	9	4.0	6	46.2
unidentified lemming	32	14.3	0	0
total lemming	43	19.2	7	53.8
arctic fox (*Alopex lagopus*)	8	3.6	3	23.1
ringed seal (*Phoca hispida*)	103	46.0	3	23.1
unidentified Pinniped	70	31.3	0	0
total seal	173	77.2	3	23.1
total identified	224	100.0	13	100.0
total mammal	224	100.0	13	100.0

Table 33: Feature 3 mammal remains

species	NISP	NISP%	MNI	MNI%
ringed seal (*Phoca hispida*)	165	86.8	4	100.0
unidentified Pinniped	25	13.2	0	0
total seal	190	100.0		
total identified	190	100.0	4	100.0
total mammal	190	100.0	4	100.0

Table 34: Feature 4 mammal remains

species	NISP	NISP%	MNI	MNI%
ringed seal (*Phoca hispida*)	1	100.0	1	100.0
total identified	1	100.0	1	100.0
total mammal	1	100.0	1	100.0

species and 22.2 % of economic species, the qarmat 66.7 % and 55.6 % respectively, and the winter houses 100 % of both categories. Although it is tempting to argue from this trend, and that in the fish and avian frequencies, for a seasonal alternation between a specialized and a generalized harvesting strategy, it should be kept in mind that the tent rings were likely occupied for a very short period of time, and the qarmat somewhat longer, but for a shorter period than the winter houses. Each feature type is thus probably exhibiting smaller or larger slices of the annual subsistence round. The remains of particular species and genera are discussed further below.

Arctic Hare

Hare was one of the least commonly occurring species in the overall mammalian assemblage, and is found only in the Sodhouse 2 sample. It is represented by 32 elements, namely an atlas, two teeth, a femur, and the rest hind extremity bones, on which the MNI determination of 3 is based. Sample size is small, but the skeletal element representation hints that only skins of two of the individuals may have been returned to the site, or that the hare's feet had served as hunting amulets. Hare may have been snared at any time of year.

Lemming

One or both species of lemming occurs in five of the seven samples: brown lemming in three and collared lemming in four. During excavation, many lemmings were observed to have died in their burrows, for they were recovered in association with quantities of lemming droppings. In addition, lemmings were observed to be active in and around the excavations during the 1990 season. In the case of Feature 2, many of the lemming bones were recovered from owl regurgitation pellets. The case can thus be made that all the lemming bone derives from Thule-era or post-occupational use of the features by nesting lemmings, and/or from the introduction of predator feces and regurgitation pellets. In subsequent discussions of the mammalian assemblages, lemmings are excluded from the NISP and MNI counts as "non-economic" species.

Beluga/Narhwal

Two phalanges and portions of four ribs from Sodhouse 2 were identified to the family *Monodontidae*, which includes only these two species. Although only accounting for 0.07 % of the NISP for economic species in this feature, and 0.06 % of the combined feature economic NISP, one beluga has the usable caloric value of over seven ringed seals, and one narwhal the value of almost thirteen. Although beluga/ narwhal procurement is essentially limited by these species' local ecology to the months of August and September, portions of such large animals would likely have been cached for future use (Savelle, personal communication, Whitridge 1991 -Clyde River field notes), so their presence in a winter house assemblage is not unusual. A consideration of butchery and transport of these and other large mammals is presented in the section on taphonomy.

Dog/Wolf

It is cautiously assumed that the specimens identified as *Canis sp.* are dog rather than wolf, due to the recognition of three individual dogs in the Sodhouse 2 sample, and no wolf in any of the samples. Of the 118 specimens of *Canis* from Sodhouse 2, 18 (15.3 %) were pathological, including 7 examples of healed fractures and 6 with osteophyte development. Judging from other species in the sample, most animals in the wild do not survive long enough with such serious health problems to be harvested by hunters. One each of the *Canis* specimens from Sodhouse 2 and Feature 9 were juveniles, again an unlikely occurrence if the individuals were wolves procured for their skins. One tibia specimen from Sodhouse 2 did exhibit probable skinning marks, but it is not unusual for Inuit to use dog fur to trim parkas. The presence of a cutmark on a juvenile *Canis* rib in the Feature 9 sample may indicate butchery for consumption. In sum, these specimens are probably all assignable to dog.

Dog/wolf was represented in all of the qarmat and winter house assemblages, and none of the tent ring assemblages. Certainly, a dog trained to pull a komatik, locate breathing holes, and bring bears to bay would be of no help in harvesting eider or basking ringed seals. Its presence in the qarmat assemblages, occupied, it is argued here, during a warm season as well, suggests relatively longer term occupation of these features (as indeed their construction suggests), in that dogs were maintained there although their labour may not have been utilized.

Although dogs may have been both consumed and their skins used at these sites, their primary functions were likely for traction and hunting. They are thus a quintessentially "economic" species, but more as an elaborate piece of edible technology, than as a staple food stuff. Since wolf was not identified, all *Canis* are excluded from further considerations of harvesting, along with lemmings.

Arctic Fox

Next to ringed seal, fox was the most abundant of any animal species in the total sample. Its remains occur in five of the seven assemblages under consideration, at frequencies ranging up to 12.6 % (Sodhouse 2) of a feature's economic mammal NISP, but averaging only 3.6 % in the samples where it occurs. Its presence in one of the tent ring samples is somewhat odd, as fox pelts (the major benefit in procuring fox) are at their worst condition during spring and early summer, when they lose their winter coat. The anomalous representation of three individuals by only eight metatarsals (but no phalanges) also suggests that fox were not processed at this site. Jenness (1916) illustrates a necklace of 60 drilled fox metatarsals collected among the Copper Inuit. Although the Ditchburn Point specimens were not drilled, they may have been collected for this purpose, or were used in a different manner as amulets.

The qarmat fox assemblages are also unusual. In Feature 9 only teeth are present, while in Feature 11 fox is represented by two ulnae and a bacculum. The latter may represent fox trapping in early fall, while the Feature 9 specimens may have only have been collected for the ubiquitous Thule fox tooth pendants.

Feature 25 produced a canine and a thoracic vertebra, the latter probably indicating on-site carcass processing. The assemblage from Sodhouse 2 was large, with high % MNI values for all major skeletal portions except vertebrae and ribs. This seems to indicate the return of whole fox carcasses to the site, with differential deposition or preservation of ribs and vertebrae. Only one unidentifiable fox vertebra fragment was found, so fragmentation of these portions is unlikely. The high overall NISP and MNI values for fox from this feature suggest it was a major resource, and perhaps a substitute for scarce caribou hides. Cut marks occur on 5 specimens (0.5%), including three distal humeri, a proximal radius, and a dorsal scapula, all of which could have resulted from skinning rather than butchering for consumption.

Polar Bear

Polar bear was recovered in low frequencies (no more than one individual per feature) from all features except tent rings. The value for both winter houses was 0.2 % of economic mammal NISP, and for the qarmat averaged 1.4 %. The consistency between the winter houses is striking, given the difference in sample size, as is the difference between these and the qarmat. An interpretation of greater harvesting emphasis on polar bears at the qarmat sites seems warranted. As discussed in the previous chapter under cost estimates, polar bears have been frequently observed in the study area during the June to August archaeology field season.

Walrus

Walrus was represented by a single post-canine tooth from Sodhouse 2, accounting for barely 0.01 % of both the combined and Sodhouse 2 mammalian fauna. Given the rarity of walrus in southern Prince Regent Inlet, this is not suprising. More specimens may, however, be represented by tusks in the artifact assemblages for these features, which have not been examined for this analysis. Walrus represents a caloric package equivalent to a narwhal, so the contribution to diet of even a single individual should not be underestimated. A single tooth, however, may have been acquired through trade and conserved for years for some small carving task, and not represent any contribution to the local diet.

Bearded Seal

Bearded seal bone occurs in Sodhouse 2, and Features 9 and 11, averaging 1.1 % of the mammalian NISP for these features. It is the most frequently occurring and most abundant sea mammal after ringed seal, which might be expected given the status in Inuit culture of bearded seal skin for the "heavy duty" uses discussed in the previous chapter. Bearded seals may be harvested in late spring or early summer along with basking ringed seals (Wenzel 1991), but may also be taken by chance at breathing holes in winter (Whitridge 1991 - Clyde River field notes), and generally in the same situations in which ringed seal are hunted, but at much lower frequencies. Bones of this animal are not unlikely to turn up in situations outside the season in which they were procured, due to the large quantity of usable meat they represent, and the common Inuit practise of fermenting the flippers. As with other large mammals, the frequencies of bearded seal are better discussed in the context of butchery, carcass transport, and bone deposition.

Ringed Seal

Ringed seal constitutes the great bulk of the economic mammalian fauna for all seven assemblages, averaging 96.4 % NISP and 84.9 % MNI. Frequencies range from a low of 85.1 % NISP for Sodhouse 2, to 100 % for the tent ring samples. These values are consistent with those obtained from some other coastal Thule sites (e.g. Morrison 1983a), but are considerably higher than those for the reported faunal assemblages closest to the study area, at Cape Garry and Creswell Bay (Rick 1980). Ringed seal can be exploited at all times of year, although they are relatively difficult to pursue during the open water season, and tend to sink when killed because of their lowered blubber content at this season. The data certainly indicate that ringed seal was a focal resource in the subsistence economy of all feature types. Aspects of seal taphonomy, age structure, and seasonality of procurement are elaborated below.

Caribou

Caribou elements comprised 0.6 % NISP and 5.7 % MNI of the overall mammalian assemblage, and were recorded for both qarmat and both winter houses. Sodhouse 2 produced the highest % NISP value, while that for Feature 25 was comparable to the low values from Features 9 and 11. The averages for the two feature types are 0.8 % NISP and 0.4 % NISP. Caribou are most attractive as a resource during late fall, when their hides are in prime condition for winter clothing manufacture, but they may have been scarce in the study area at this time of year (Fischer and Duncan 1976). Their generally low levels of local availability, relative to their importance as a source of hides, probably meant they were procured opportunistically at all seasons whenever they were encountered in the immediate site vicinity, and may have been harvested from adjacent regions by task groups. Caribou bones are subject to a different set of preservational biases than sea mammal bones, due to the presence of nutritionally rich marrow within long bones, and the utility of caribou bone and antler for artifact manufacture. Caribou were observed intermittently near the sites during field work.

Muskox

Only two muskox teeth were recorded for the entire faunal assemblage, both from Sodhouse 2. Like caribou, muskox might be expected to have been procured opportunistically at all seasons, although their lesser utility probably precluded major investments in harvesting away from the study area. Muskox are subject to some of the same preservational biases as caribou, discussed below.

Taphonomy

The elaboration of taphonomy, the science of the transformations undergone by biotic assemblages from their formation to their recovery, is perhaps the single most important contributing factor to the current heightened interest in zooarchaeology. Taphonomy provides both a model for the study of archaeological site formation processes generally, and the basis for any scientific study of faunal assemblages (Gifford 1981, Lyman 1987). A major portion of the zooarchaeological literature is devoted specifically to the analysis of cultural and natural processes which add, delete, and modify archaeologically recovered bone, but *any* reconstruction of subsistence practises from faunal data must take the operation of taphonomic agents into account.

Besides the actual availability of faunal resources in a site catchment (Appendix A), given its occupants' technology and cultural preferences, the most important factors shaping the faunal assemblage of residential sites, such as those under consideration here, are butchery and transport practises. The manner in which a carcass is initially processed, and the portions which are transported back to the living site, determine what elements of what species are likely to be deposited and ultimately recovered by the archaeologist.

Butchery practises are best inferred from the frequency and placement of cut marks on bone. Cut marks, however, are not always produced when a carcass is butchered, varying according to such factors as prey species anatomy, prey condition, technology (e.g. metal versus stone, expedient versus curated), the skill of the butcher, and the conditions under which butchery occurred (e.g. time limitations, climatic conditions). Such direct evidence of prehistoric behaviour may also be supplemented by actualistic studies of carcass processing by modern hunters.

The differential transport of carcass portions may be inferred from the frequency of various skeletal elements in an assemblage, in light of observed butchering marks and ethnoarchaeological observations. It will vary primarily according to cultural perceptions of the economic utility of different portions of a carcass of a particular species (which in turn will vary according to such things as the age, sex and condition of particular animals), and to situational factors relating to logistical constraints and the perceived needs of the hunter.

Interpretations of butchery and transport are complicated, however, by a set of factors which may subsequently alter a transported assemblage. Differential destruction or modification of bone by cultural and natural processes, differential disposal of bone refuse, and differential preservation of deposited assemblages may all interfere with a sample before it is recovered by the archaeologist. Even recovery techniques, and the analyst's skill at identification, may severely bias the data. Some of these biasing factors are considered below, following discussions of butchery and transport.

Butchery

Butchering marks were observed on two species of bird and seven species of mammal. The frequency of cut marks, expressed as the percentage of the combined NISP for each species, are displayed in Table 35, along with the average number of cut marks present on elements where any cut marks were observed. The average number of cut marks probably reflects primarily the difficulty of severing connective tissue, and is as variable within as between species. The overall frequency of cut marks, however, varies *predictably* between species, as a function of average animal

Table 35: Frequency of cut marks by species for combined assemblages *

species **	%NISP with cut marks	average no. of cut marks	average weight (kg)
snow goose	5.8	3.0	2.5
ptarmigan	4.5	1.0	0.6
dog/wolf	1.6	1.0	30.0
arctic fox	0.5	3.4	3.2
beluga/narwhal	50.0	4.0	577.0
polar bear	4.2	10.0	410.0
bearded seal	13.6	9.1	215.0
ringed seal	3.2	2.4	45.4
caribou	13.3	3.2	81.3
average	10.7	4.1	

* excluding tent ring samples

** all other species have cut mark frequencies of 0 weight. A simple linear correlation of cut mark frequency (for those species with any cut marks) with average weight produced significant results (r = .779, p = .013), although part of the overall strength of this correlation may derive from the strength of the outlying correlation for beluga/narwhal. It *suggests*, in any case, that the difficulty and/or intensity of carcass processing varies directly with carcass size. The small size of the cut-marked sample for most species precludes more detailed analysis. The large sample of ringed seal elements with cut marks, however, warrants greater consideration.

The frequencies of cut marks on specific ringed seal elements by feature are presented in Figures 5 to 16, and are calculated on the basis of feature MNE for each element. The tent ring assemblages have been excluded because the lack of observed cut marks on any specimens in those samples is likely due to poor preservation of the bone surfaces. The distribution of cut marks across the axial skeleton is shown in Figures 5 to 7. No axial elements from Feature 9 exhibited cut marks. The results for Sodhouse 2, Feature 25 and Feature 11 are fairly congruent, with greatest frequencies generally noted on the lower cervical, lower thoracic, and lumbar vertebrae, other variability reflecting sample size or, perhaps, seasonal differences in butchery practises. The largest sample, Sodhouse 2, reveals the most distinct patterning.

Different elements within a class are more or less equally as likely to receive cut marks during secondary processing (i.e. food preparation). Furthermore, cut marks are less likely to be produced at this stage, when the tissue will often be softened by cooking, processing occurs indoors, and there is less urgency to the activity, than during primary field butchery, if this occurs. *The relative proportions of butchered elements*

Figure 3: Form for recording faunal data

Site: PaSs-4 Feature: 9

cat #	taxon	element	portion	sd	age	cultural modificat.	natural modificat.	comments
10-894	P. hisp.	tibia dist. ep.	comp.	L	i	cm. lat.		
10-013	"	radius	diaph 2/3	R	it		cg	
15-034	eider	tibiotars.	prox. 4/5	R	it			
13-031	E. barb.	femur	prox 1/2	L	i	2 cm lat	cg	- prox ep
10-018	Salmonid	branchiostegal	comp.	U	it			
9-896	Canis	astragalus	comp.	R	j	calcined		
4-378	P. hisp.	metatarsal II	9/10	L	sa		cg	ep. part fused

Figure 4: Longtitudinal section of ringed seal canine

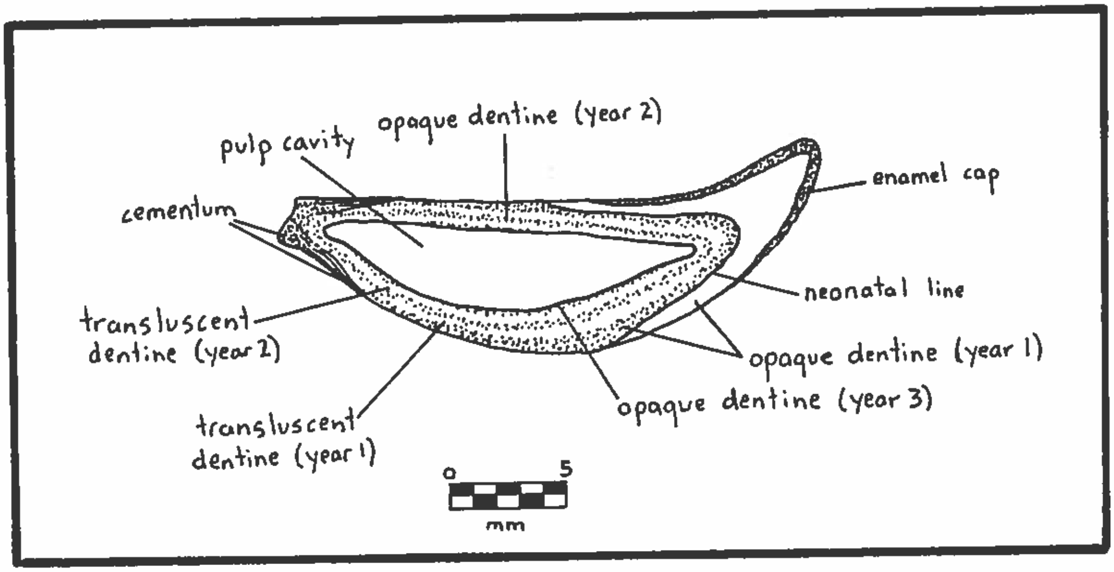
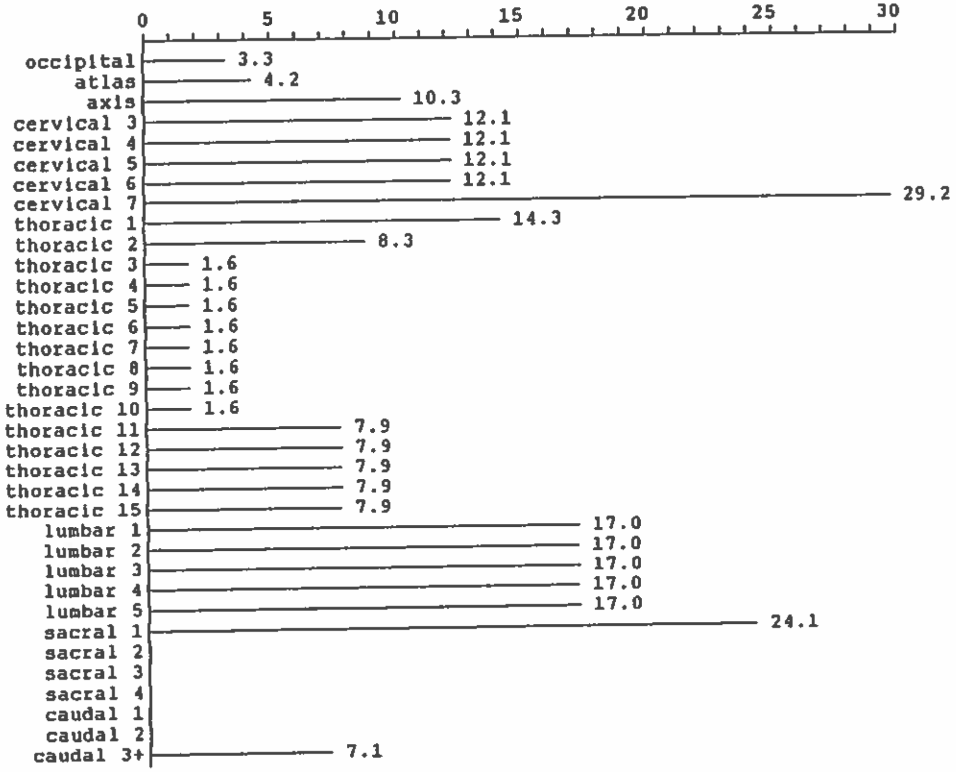
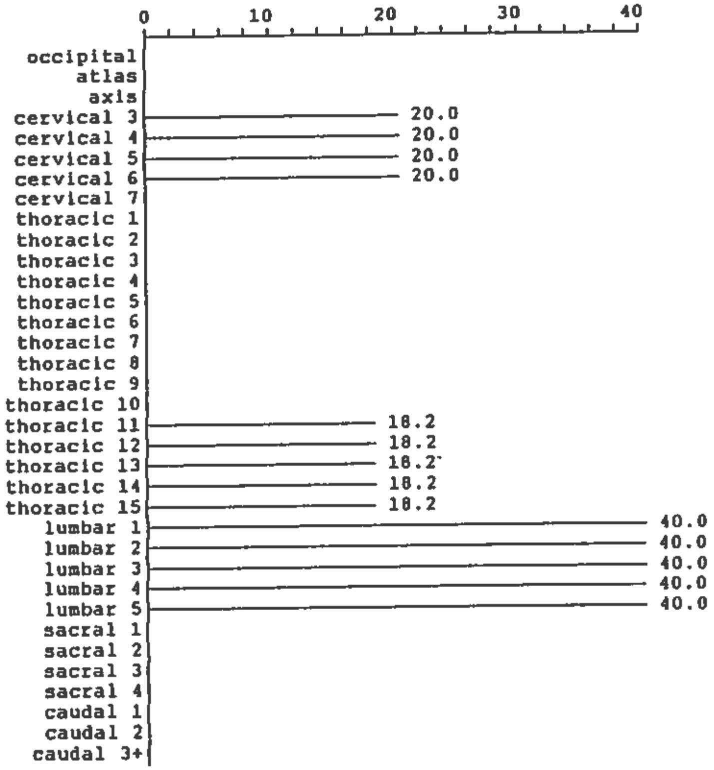


Figure 5: Sodhouse 2 frequencies of ringed seal axial elements with cut marks (%)*



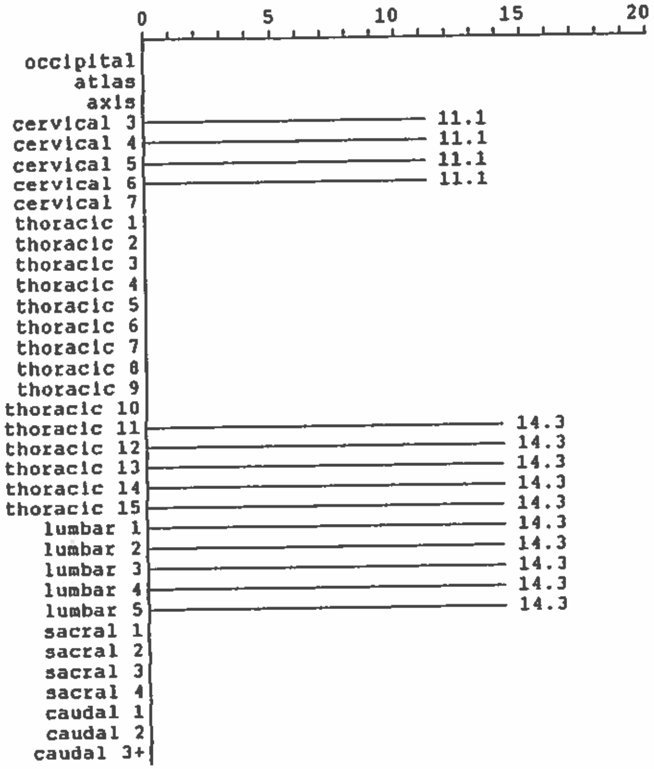
* where identification was to a class of elements (e.g. cervical 3-6), the frequency of cut marked elements for the class was taken as that for individual elements within the class

Figure 6: Feature 25 frequencies of ringed seal axial elements with cut marks (%)*



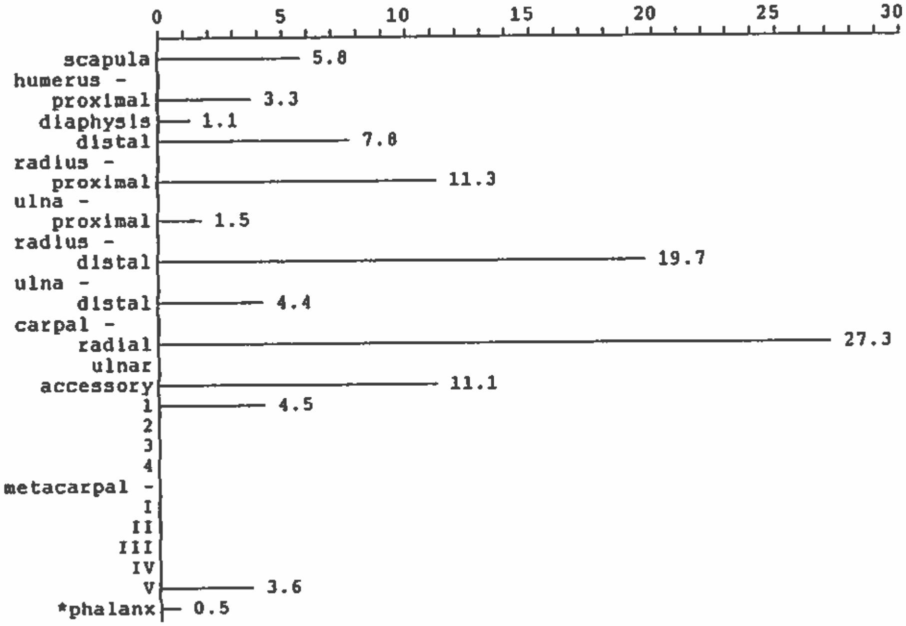
* where identification was to a class of elements (e.g. cervical 3-6), the frequency of cut marked elements for the class was taken as that for individual elements within the class

Figure 7: Feature 11 frequencies of ringed seal axial elements with cut marks (%)*



* where identification was to a class of elements (e.g. cervical 3-6), the frequency of cut marked elements for the class was taken as that for individual elements within the class

Figure 8: Sodhouse 2 frequencies of ringed seal front limb elements with cut marks (%)



* front and hind phalanges were not distinguished; this value represents that for all phalanges

Figure 9: Feature 9 frequencies of ringed seal front limb elements with cut marks (%)

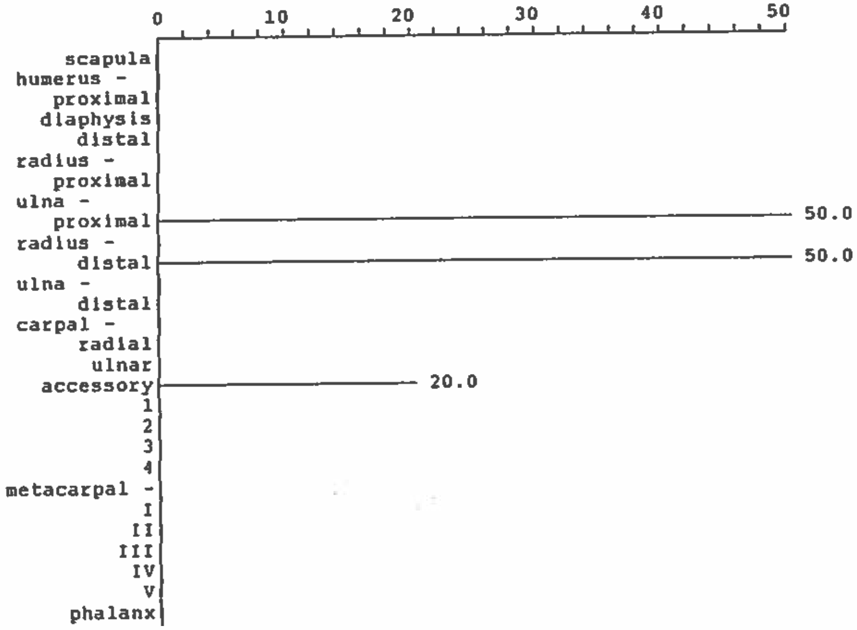
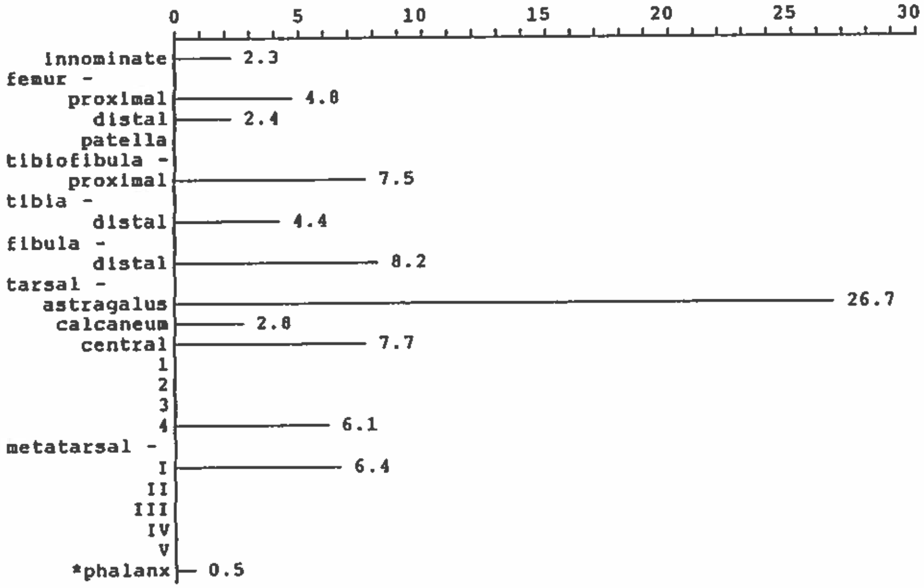


Figure 10: Sodhouse 2 frequencies of ringed seal hind limb elements with cut marks (%)



* front and hind phalanges were not distinguished; this value represents that for all phalanges

Figure 11: Feature 25 frequencies of ringed seal hind limb elements with cut marks (%)

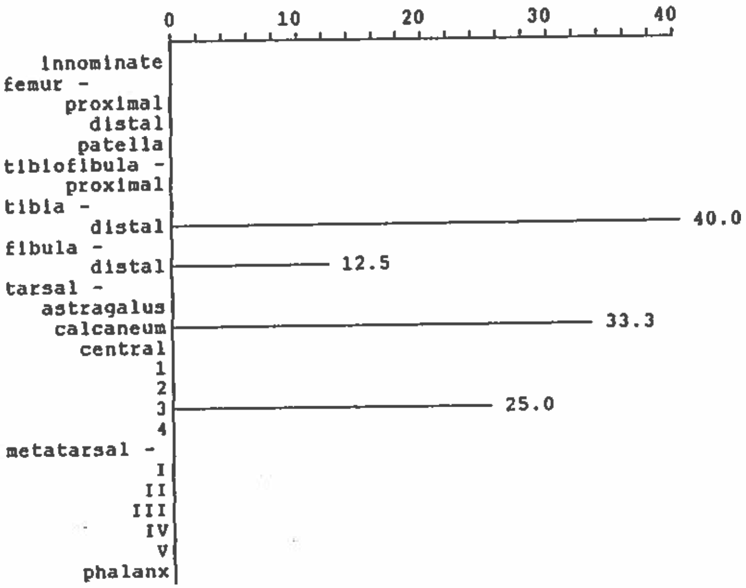


Figure 12: Feature 9 frequencies of ringed seal hind limb elements with cut marks (%)

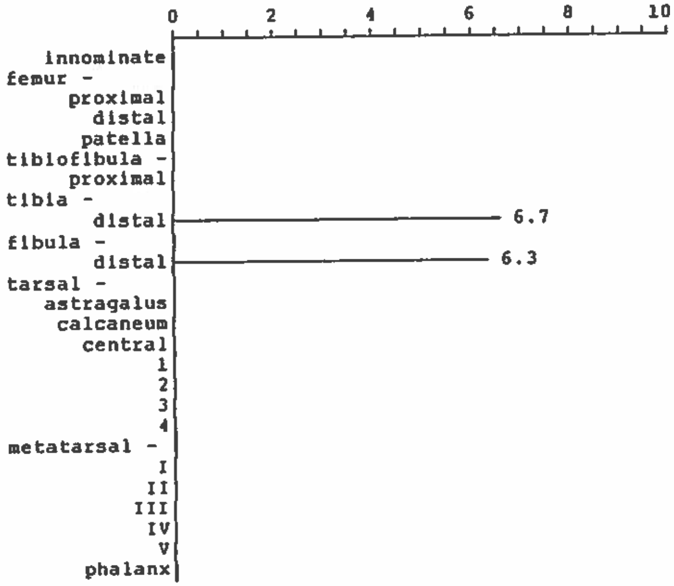


Figure 13: Sodhouse 2 frequencies of ringed seal ventral elements with cut marks (%)

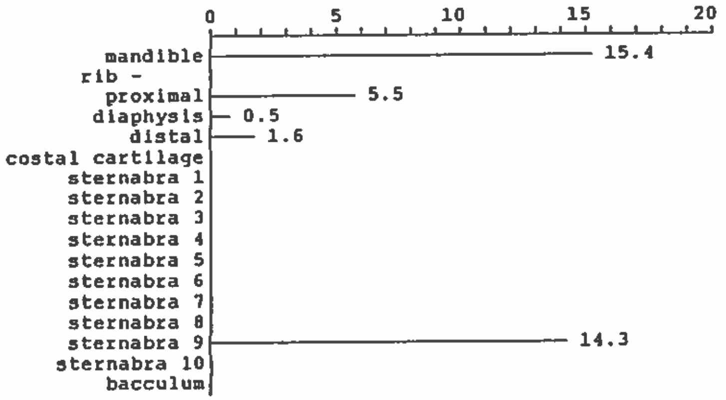


Figure 14: Feature 25 frequencies of ringed seal ventral elements with cut marks (%)

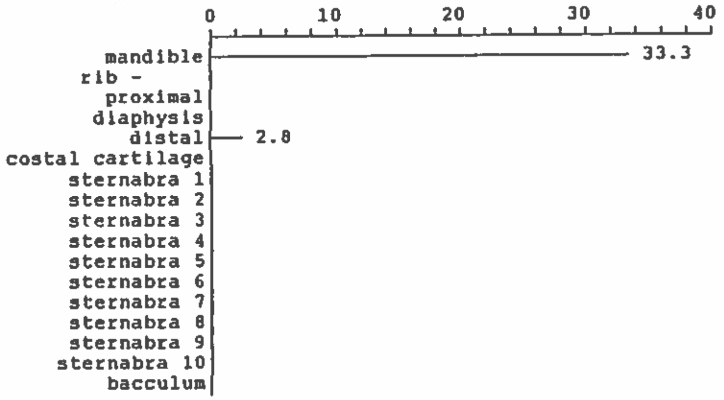


Figure 15: Feature 9 frequencies of ringed seal ventral elements with cut marks (%)

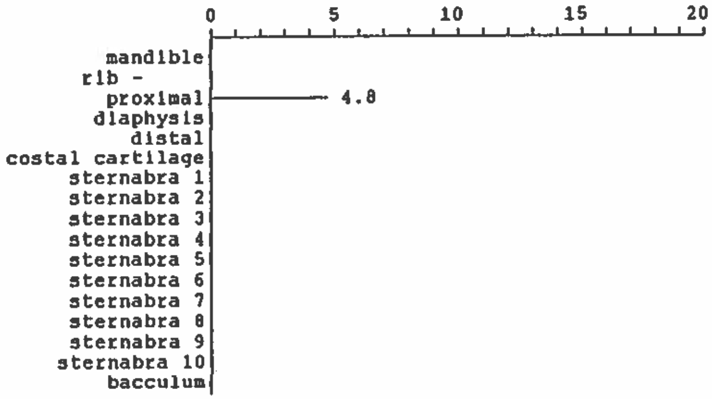
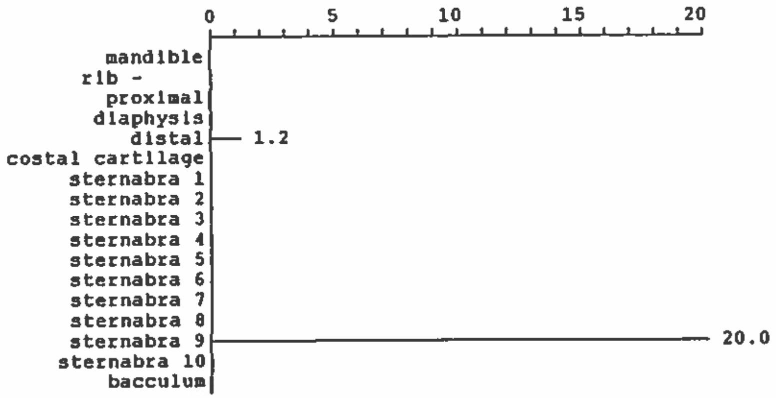


Figure 16: Feature 11 frequencies of ringed seal ventral elements with cut marks (%)



of each type are therefore tentatively assumed to reflect the differential likelihood that primary processing directly affects a particular element. Thus if the cranial region was separated from the cervical region during initial butchery, this appears to have occurred most often posterior to the atlas, as both the occipital and atlas have low frequencies of butchery marks. Other peaks and troughs in Figure 5 can be interpreted along similar lines. The frequency of marks on cervical 7 implies that the axial skeleton was often divided at this point, and with declining regularity at thoracic 1 and 2, while the trough for the middle thoracic vertebrae implies that thoracic 3-10 were normally kept as a unit. The relatively high values for cervical 3-6 and lumbar vertebrae suggest these sections were often the site of a division of the axial skeleton, but the precise location of this division (or divisions) cannot be defined because identification was not possible to particular elements within these groups. The pelvis appears to have been regularly separated as a unit, between the anterior sacrum and lumbar 5, while caudal 1 and 2 were regularly left with the pelvic unit. The tail was severed at an undetermined point posterior of caudal 3.

Cut mark frequencies for front limb elements from Sodhouse 2 and Feature 9 are presented in Figures 8 and 9. Only a single carpal ulnar from Feature 25 was marked, and no front limb elements from Feature 11. The 3 cut-marked elements from Feature 9 are an insignificant sample, so the discussion below is confined to Sodhouse 2. Interestingly, proximal scapulae have a low frequency of cut marks, supporting the observation from Clyde River (Whitridge 1991 -field notes) that upper front limbs were generally left attached to the rib units of each side. Cut mark frequency generally increases proceeding towards the proximal portion of the carpal region, suggesting that more distal front limb elements were increasingly likely to incur primary butchery (and possibly culling), while most carpals, metacarpals and phalanges were treated as a unit. In many instances, the upper front limb may only have been severed between the radius-ulna and the carpals during initial processing.

Cut marks on ringed seal hind limb elements were restricted to 5 specimens from Feature 25 (Figure 11), 3 from Feature 9 (Figure 12), none from Feature 11, and 61 from Sodhouse 2 (Figure 10). The pattern exhibited in Sodhouse 2, and suggested in Features 25 and 9, is similar to that for front limbs. Cut mark frequency increases towards the proximal portion of the tarsal region, then drops off, indicating that proximal elements were more likely to be retained within primary butchery units than distal elements, and most divisions of the hind limb occurred between the tibia-fibula and the tarsals.

Other carcass portions have been grouped here in the category "ventral elements", as they articulate with the axial skeleton not as appendages, but in supporting or protecting ventrally placed organs and other tissue (Figures 13 to 16). Again, Sodhouse 2 produced the most complete sample. The results are more difficult to interpret than those for limb and axial elements. Ribs may have been separated more frequently proximally from thoracic vertebrae than distally from costal cartilage. Based on experience in the lab, and observations from Clyde River, ribs may often be broken proximally when separated from the vertebral column, or severed through the cartilage at the articulation of their proximal epiphyses, and thus not preserve cut marks. Separation of the ribs and costal cartilage may also more often damage connective cartilage than the bones themselves. The incidence of cut marks on sternabra 9 suggests the sternum was removed by cuts proceeding from posterior to anterior, rather than the reverse. Mandibles may have been removed fairly frequently during butchery at the kill site.

Element Frequencies

While butchery marks provide evidence for the intensity and location of primary divisions of the carcass, skeletal element frequencies may indicate whether the particular carcass portions were discarded at the kill site or returned to a residential site. The skeletal element frequencies of species which produced very small samples (beluga/narwhal, walrus, muskox) have already been described. Lemming is not discussed here because it is not considered to have been a utilized species. Because bird remains are differentially identifiable to element, and bird identifiability was generally poor, bird skeletal element frequencies cannot be considered representative of the actual proportions in the assemblage, and are not discussed further. To ameliorate the effects of small sample size, the skeletal element frequencies of major mammalian species (except ringed seal), shown in Figures 17 to 22, are based on the combined samples from all features. The data were not felt to be sufficiently robust to examine seasonal variability in carcass processing. Hare element frequencies (Figure 17) exhibit a low incidence of most parts except hind extremities. At least one individual may have been transported whole to the site, but two others are only represented by hind feet. This may reflect the preferential transport of skins incorporating foot bones, or the curation of hare's feet as hunting amulets.

A similar pattern occurs with fox (Figure 18), which are best represented by hind extremity bones in the combined sample. This is mostly due to the high frequency of these parts in Feature 2 (Whitridge

Figure 17: Frequency of arctic hare elements from Sodhouse 2 (%MNI)

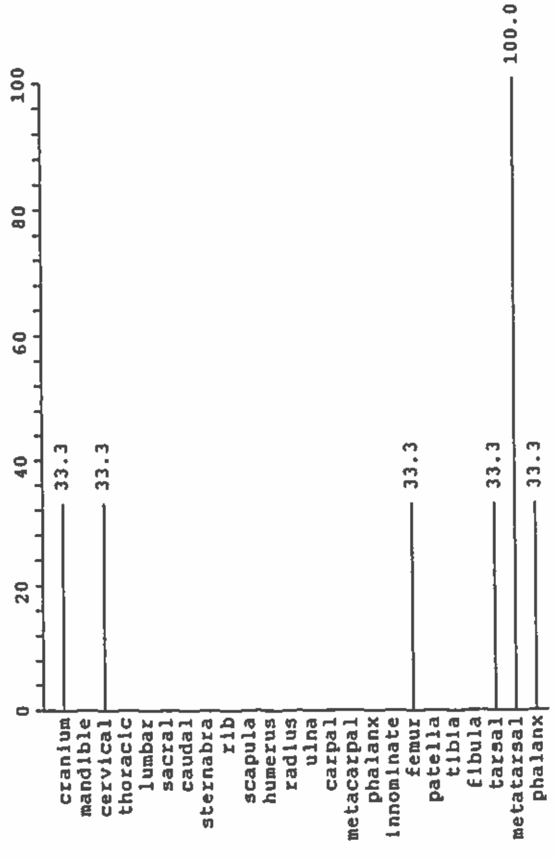


Figure 18: Frequency of arctic fox elements for combined assemblages (%MNI)

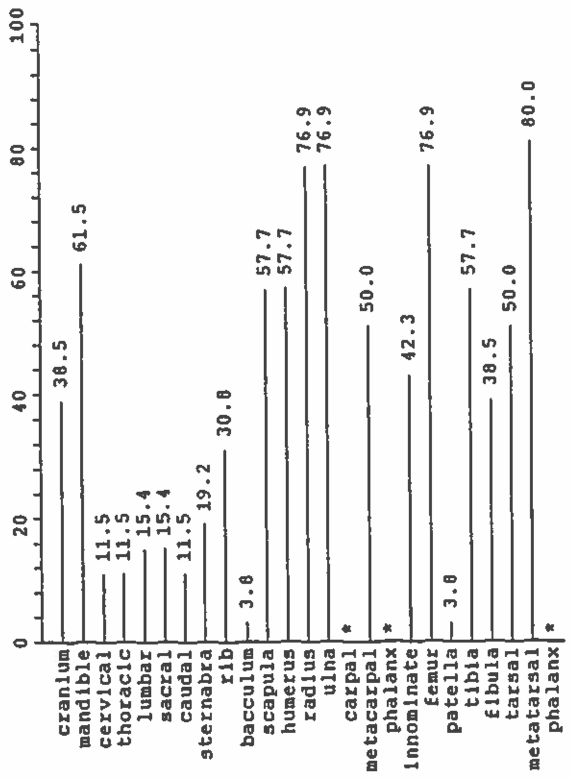
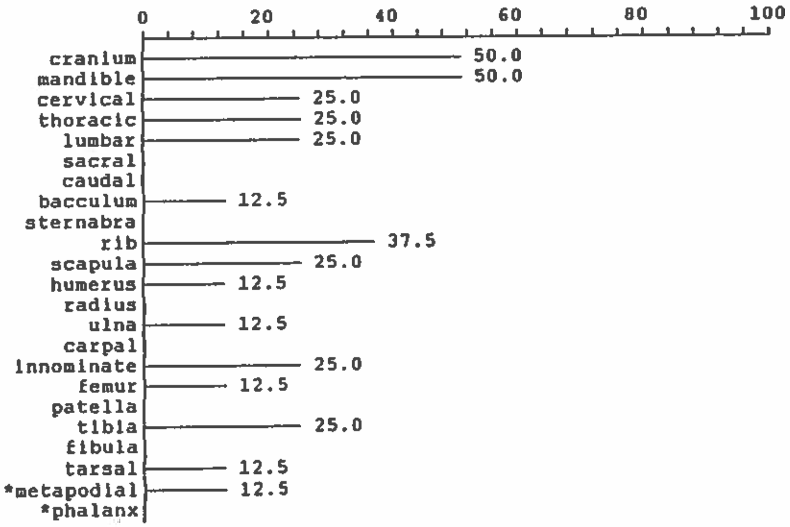
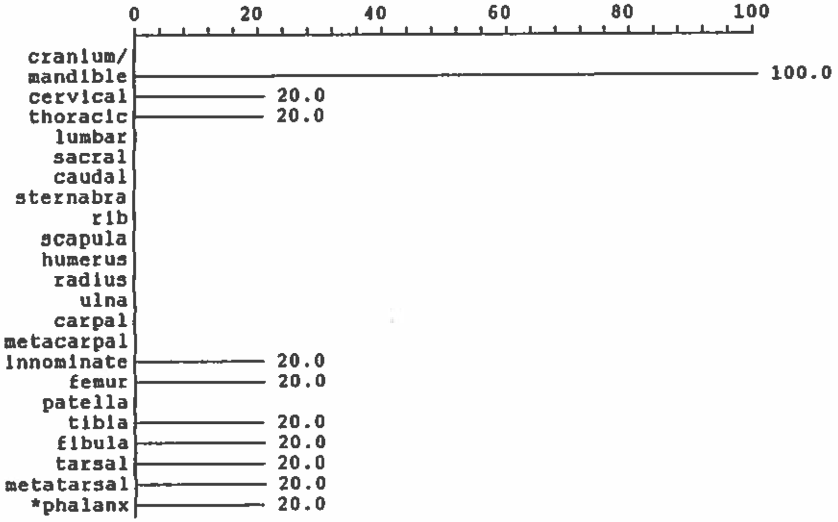


Figure 19: Frequency of dog/wolf elements for combined assemblages (%MNI)



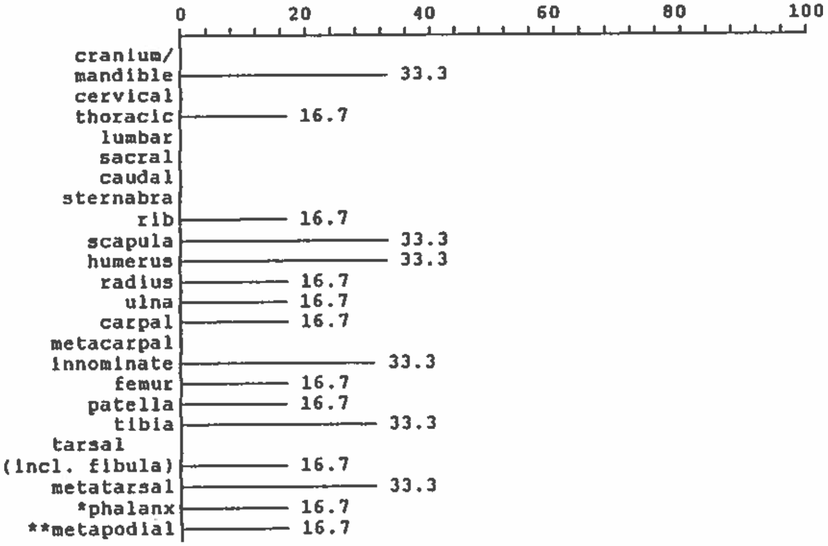
* front and hind metapodials and phalanges were not distinguished

Figure 20: Frequency of polar bear elements for combined assemblages (%MNI)



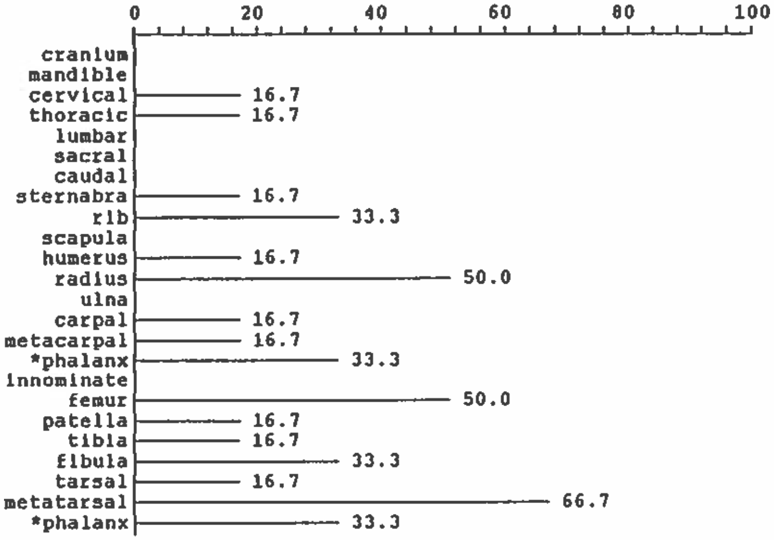
* front and hind phalanges were not distinguished

Figure 21: Frequency of caribou elements for combined assemblages (%MNI)



* front and hind phalanges were not distinguished
** an additional individual is represented by an unidentified metapodial

Figure 22: Frequency of bearded seal elements for combined assemblages (%MNI)



* front and hind phalanges were not distinguished; this is the value for all phalanges

1990). Otherwise, all fox elements occur in relatively high frequencies, except for vertebrae and ribs. The bulk of most fox carcasses (the thorax and abdomen) may have been preferentially discarded away from residential features, while limbs may have tended to travel as riders with the hide. The high frequency of crania and mandibles may reflect the extraction of fox teeth for pendants, which are abundant on most Thule sites.

The situation for dogs (Figure 19) is quite different, with high %MNI values for crania, mandibles, ribs and vertebrae. These animals are expected to have died at the site, element frequencies thus representing subsequent transport away from features, or differential bone destruction, perhaps by carnivores (other dogs) seeking marrow in long bones.

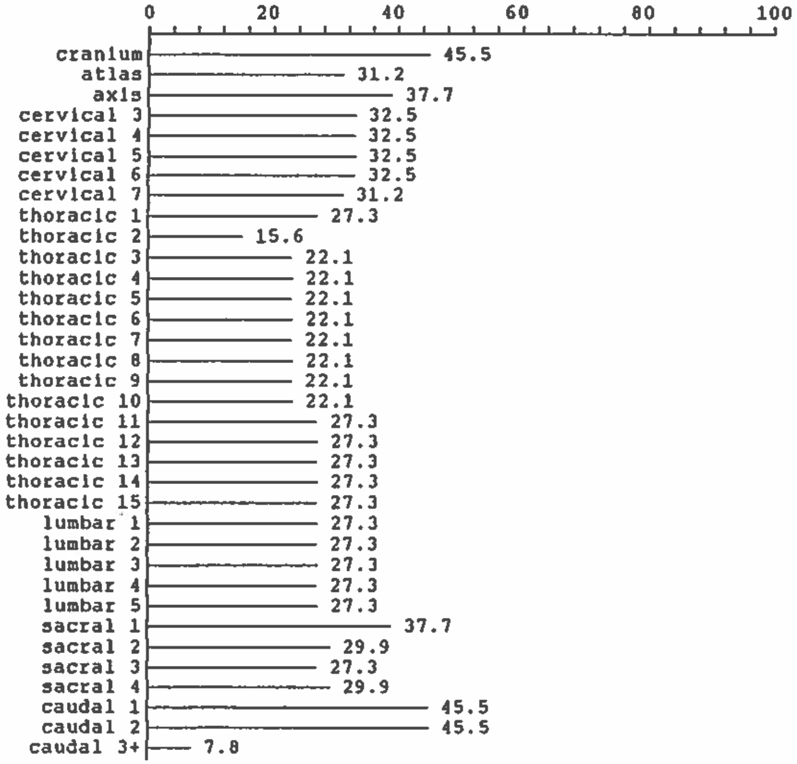
Polar bear (Figure 20) is best represented by dental remains, a comparable situation to that noted by Rick for a Thule winter house at Creswell Bay (1980:103). However, every analyzed feature with bear bone at Hazard Inlet contained some postcranial material, indicating active hunting and consumption rather than merely curation of bear teeth. The overall polar bear NISP is very low (24), and the MNI no greater than 2 for any feature, so the high %MNI values for some elements are misleading. Generally, a very small proportion of the skeleton was deposited in any one feature, as would be predicted by the "Schlepp effect" (Daly 1969) for such a large animal.

Most caribou element types (Figure 21), except vertebrae, contributed moderately to the total MNI count, but the great variability between features is reflected in the fact that no skeletal portion accounted for more than 2 of the 6 individuals in the combined assemblage. The deletion of vertebrae from most samples may reflect differential transport to the site, subsequent processing for grease and marrow, or transport away from the feature of dried vertebral units (Binford 1978), but the small sample precludes a firmer determination.

Bearded seal (Figure 22) are represented by high frequencies for some limb elements and ribs. This is the situation with another large marine mammal(s), beluga/ narwhal, and is probably due to the Schlepp effect. The particularly high value for metatarsals may reflect a preference for bearded seal flippers for the production of *igunaaq* (fermented meat).

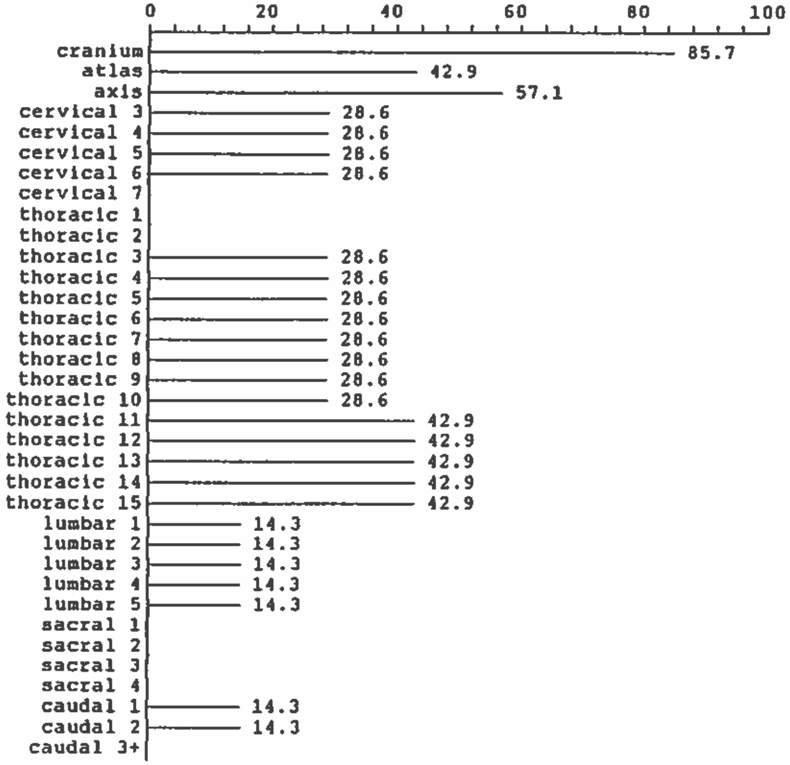
Ringed seal element frequencies are presented for each feature (the 4 tent rings are combined) according to the divisions described above: axial skeleton, hind limbs, front limbs, ventral elements. The patterns of axial element representation (Figures 23 to 27) are comparable for Sodhouse 2 and Feature 11, with generally high values for cervical 2-6, declining values from cervical 7 - thoracic 2, moderate to high values for thoracic 3-15, and high values for lumbar vertebrae. Feature 25 is similar, but has lower values for lumbar vertebrae, while Feature 9 has lower values for both lumbar and thoracic 11-15, and no cervical vertebrae. Even by combining Features 1 to 4, the tent ring assemblage was still too small, and poorly preserved, to demonstrate much patterning beyond generally low frequencies for all vertebrae. For Sodhouse 2, the trough between cervical 6 and thoracic 3 is particularly interesting, and may indicate a tendency for these elements to be destroyed, or rendered unidentifiable, by the severing of the cervical and thoracic regions (see Figure 5), or during the difficult separation of the anterior ribs from the upper thoracic vertebrae. Caudal 1-2 are more abundant than sacral vertebrae in all five assemblages, in seeming contradiction to the inference from cut mark data that the anterior caudal vertebrae were kept within a pelvic butchery unit. It may have been the case that the sacrum

Figure 23: Sodhouse 2 frequencies of ringed seal axial elements (%MNI)



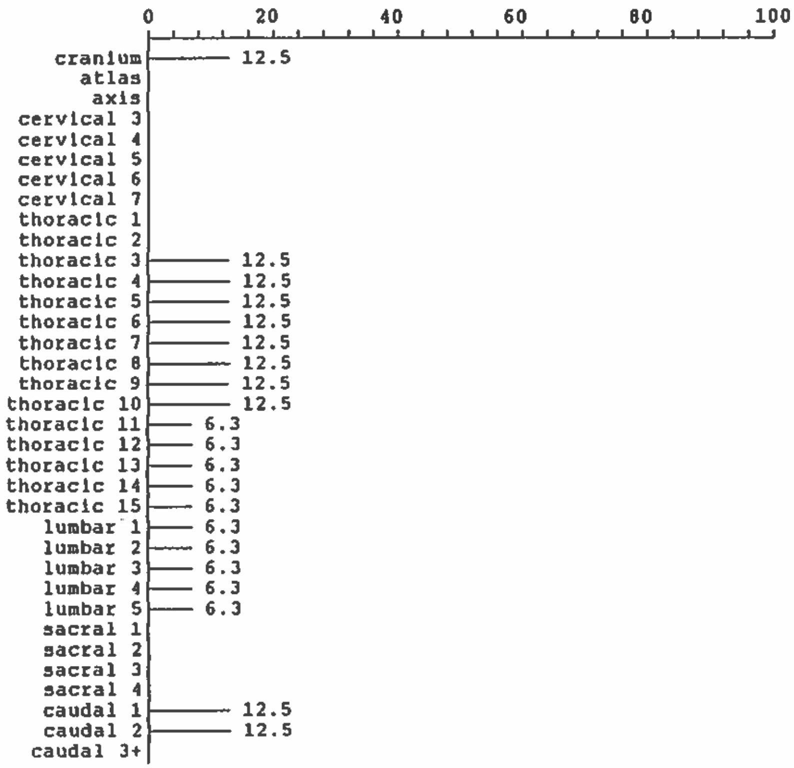
* where identification was to a class of elements (e.g. cervical 3-6), the frequency of elements for the class was taken as that for individual elements within the class

Figure 24: Feature 25 frequencies of ringed seal axial elements (%MNI)



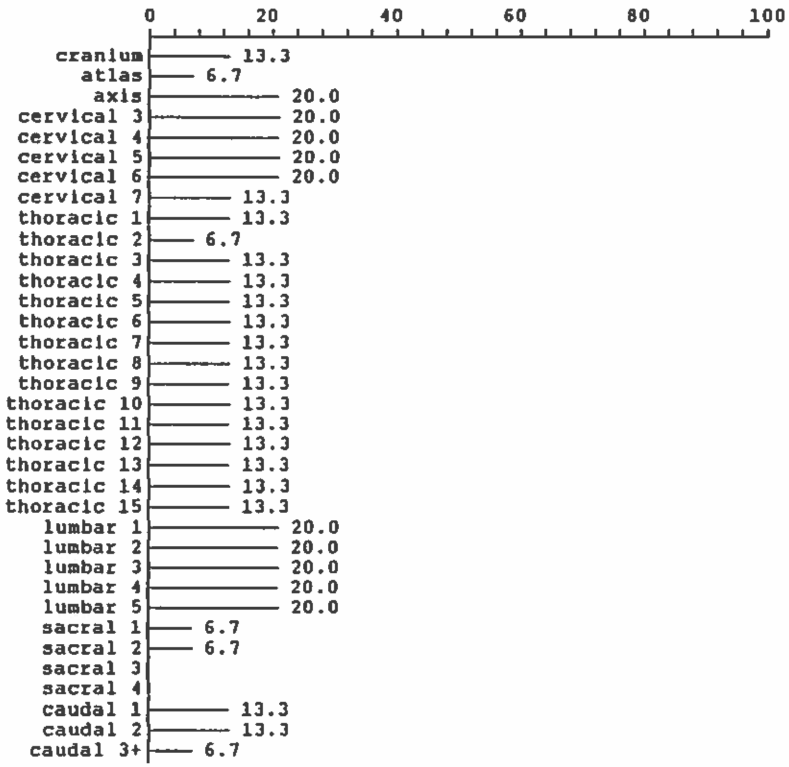
* where identification was to a class of elements (e.g. cervical 3-6), the frequency of elements for the class was taken as that for individual elements within the class

Figure 25: Feature 9 frequencies of ringed seal axial elements (%MNI)



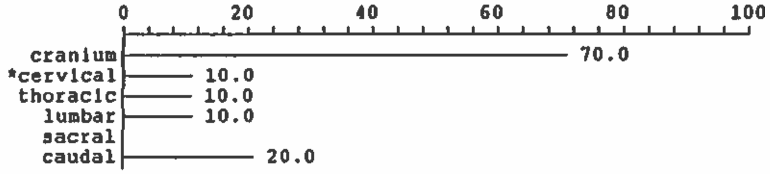
* where identification was to a class of elements (e.g. cervical 3-6), the frequency of elements for the class was taken as that for individual elements within the class

Figure 26: Feature 11 frequencies of ringed seal axial elements (%MNI)



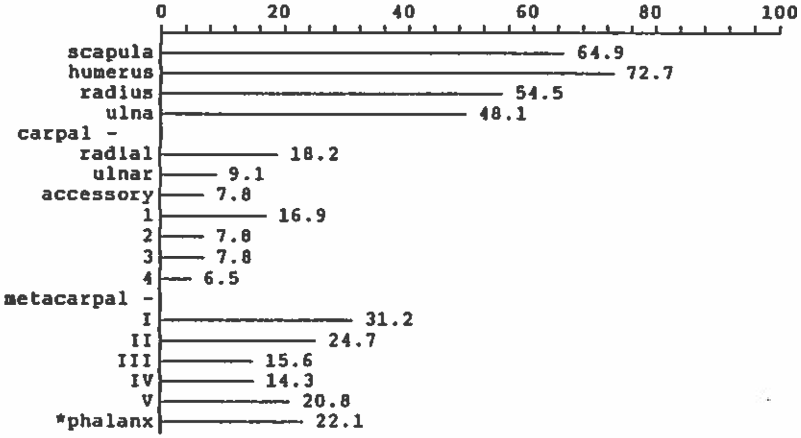
* where identification was to a class of elements (e.g. cervical 3-6), the frequency of elements for the class was taken as that for individual elements within the class

Figure 27: Tent rings' frequencies of ringed seal axial elements (%MNI)



* vertebrae were only identified to class for the tent ring assemblages

Figure 28: Sodhouse 2 frequencies of ringed seal front limb elements (%MNI)



* front and hind phalanges were not distinguished; this value represents the average for all phalanges

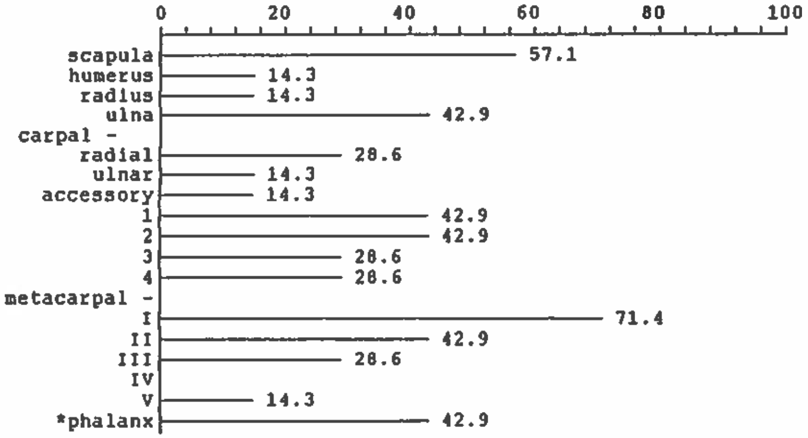
was heavily processed, or perhaps often fed to dogs. The anterior caudal vertebrae, which are highly unlikely to have been returned to camp more often than sacra, may simply be abundant from having escaped house cleanings due to their small size.

The values for front limb elements are shown in Figures 28 to 32. Again, only Sodhouse 2 produced specimens of each different element, as well as the clearest patterning. As suggested by the cut mark evidence, element frequency generally decreases proceeding distally along the front limb from the scapula to the distal carpal region. This appears to reflect the increasing likelihood that more distal elements would be culled during primary butchery. The greater frequency of distal extremity (flipper) elements can be interpreted in light of Clyde River butchery practises. There, front flippers were usually left attached to the hide, and thus were transported back to the residential site in spite of their low food yield (see below).

The sample from Sodhouse 2 is again the most robust for considering hind limb element frequencies (Figures 33 to 37). The patterning in these elements is partially reversed from that in front limbs, however, with higher frequencies of tibiae and fibulae than innominates and femora in most assemblages. In several samples (Features 25, 9 and 11) %MNI values for extremity bones (tarsals, metatarsals, phalanges) approach or actually exceed those for the most proximal elements. Processes other than initial butchery and transport appear to be shaping these assemblages. Differential destruction or secondary transport (of food or refuse) must have played a great role in determining the hind limb frequencies.

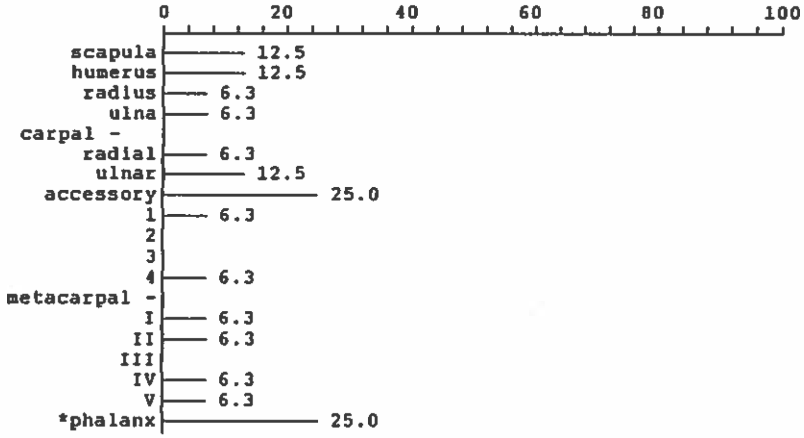
There is a great deal of variability in the representation of "ventral" elements between features (Figures 38 to 42). Mandibles vary

Figure 29: Feature 25 frequencies of
ringed seal front limb elements (%MNI)



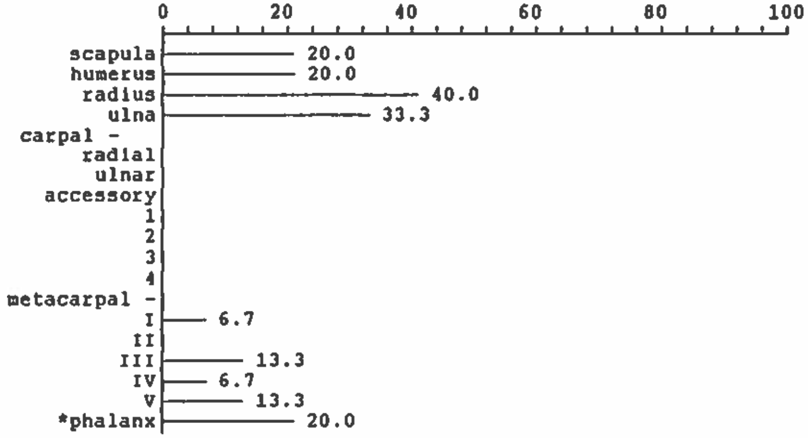
* front and hind phalanges were not distinguished;
this value represents the average for all phalanges

Figure 30: Feature 9 frequencies of
ringed seal front limb elements (%MNI)



* front and hind phalanges were not distinguished;
this value represents that for all phalanges

Figure 31: Feature 11 frequencies of ringed seal front limb elements (%MNI)



* front and hind phalanges were not distinguished; this value represents the average for all phalanges

Figure 32: Tent rings' frequencies of ringed seal front limb elements (%MNI)

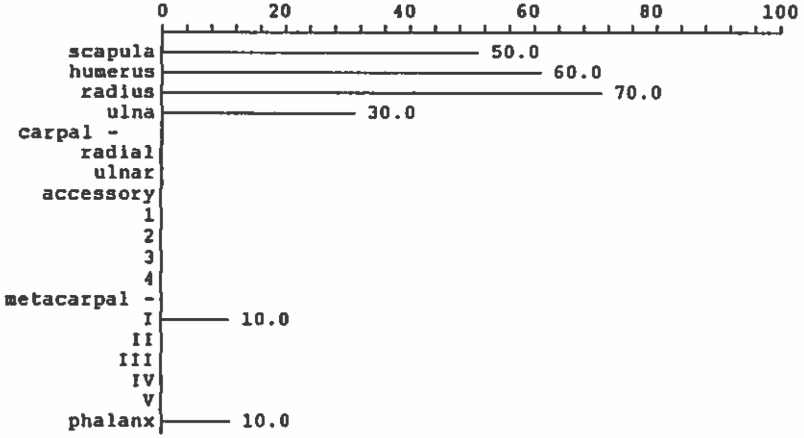
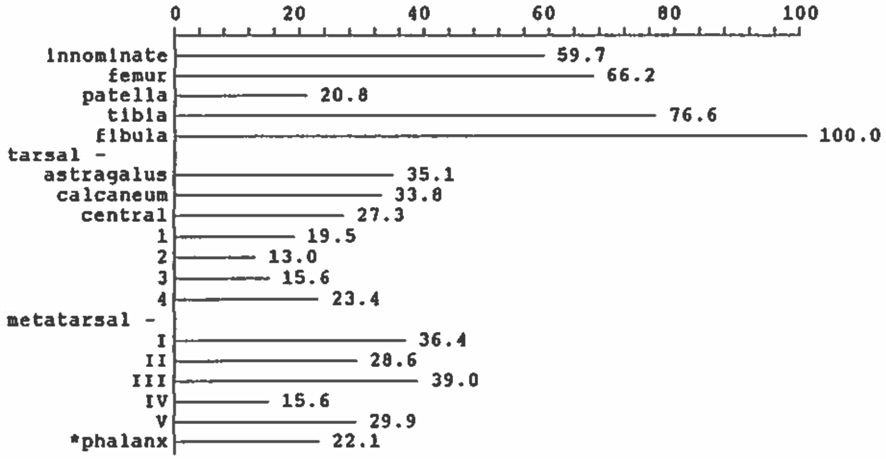
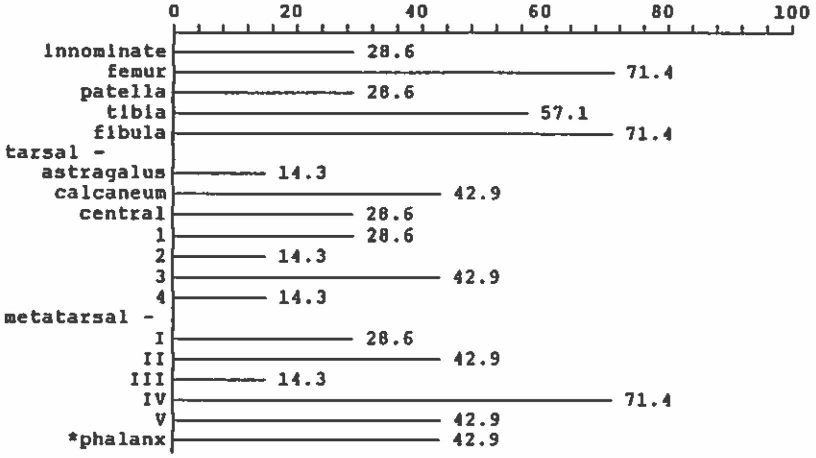


Figure 33: Sodhouse 2 frequencies of ringed seal hind limb elements (%MNI)



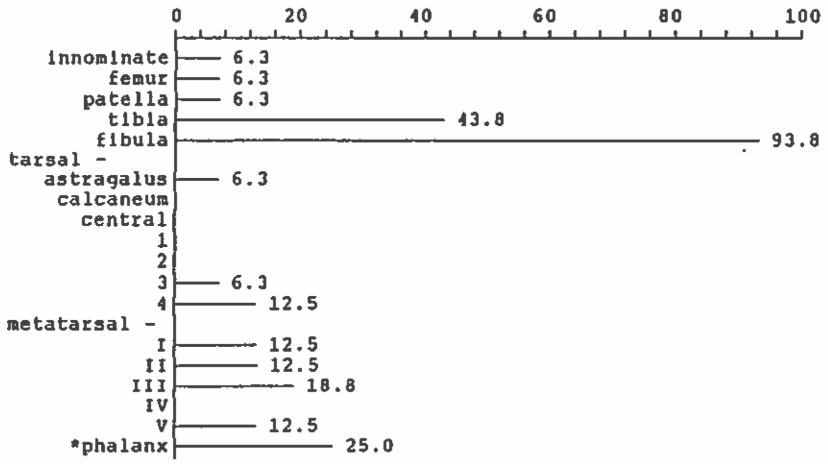
* front and hind phalanges were not distinguished; this value represents the average for all phalanges

Figure 34: Feature 25 frequencies of ringed seal hind limb elements (%MNI)



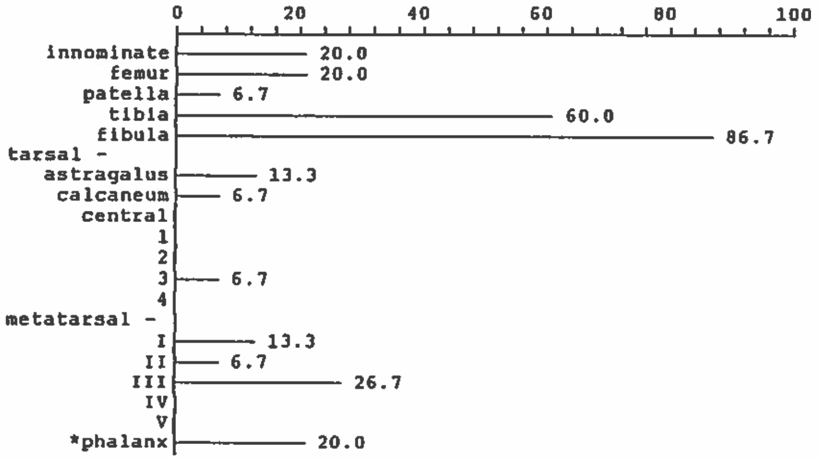
* front and hind phalanges were not distinguished; this value represents the average for all phalanges

Figure 35: Feature 9 frequencies of ringed seal hind limb elements (%MNI)



* front and hind phalanges were not distinguished; this value represents the average for all phalanges

Figure 36: Feature 11 frequencies of ringed seal hind limb elements (%MNI)



* front and hind phalanges were not distinguished; this value represents the average for all phalanges

Figure 37: Tent rings' frequencies of ringed seal hind limb elements (%MNI)

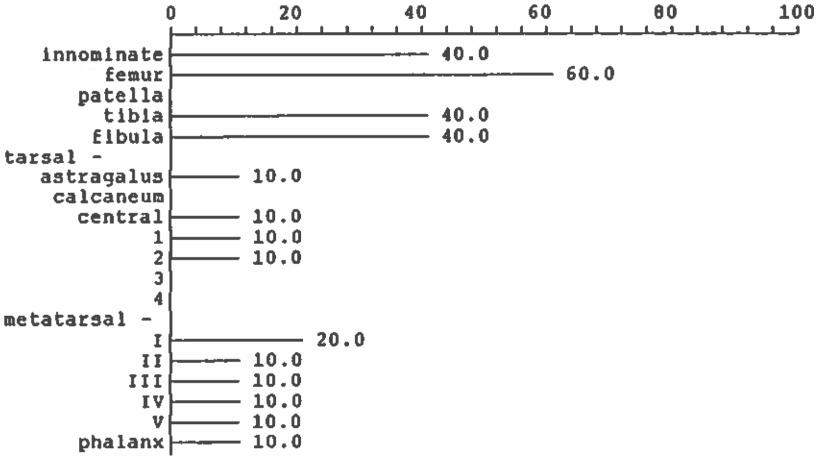


Figure 38: Sodhouse 2 frequencies of ringed seal ventral elements (%MNI)

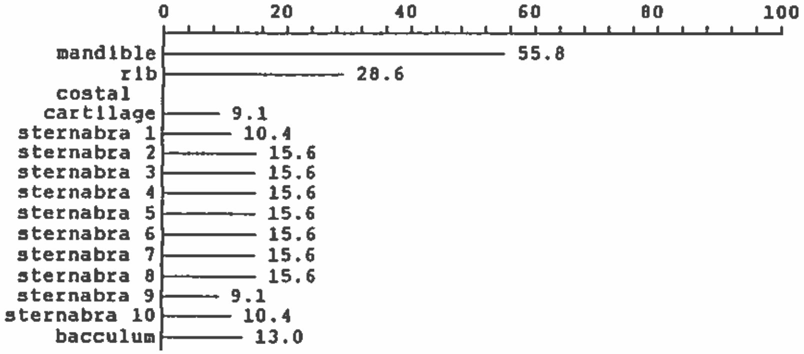


Figure 39: Feature 25 frequencies of ringed seal ventral elements (%MNI)

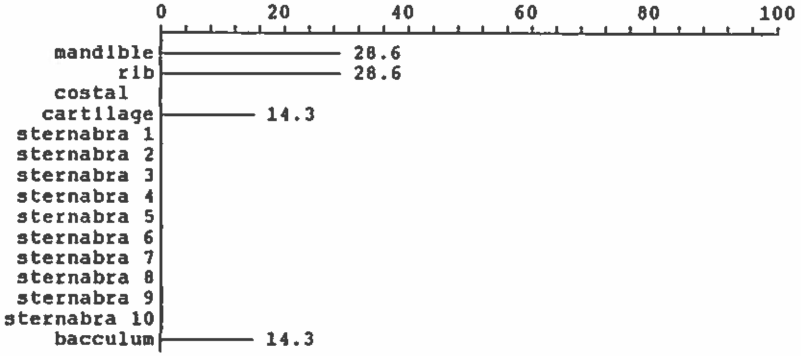


Figure 40: Feature 9 frequencies of ringed seal ventral elements (%MNI)

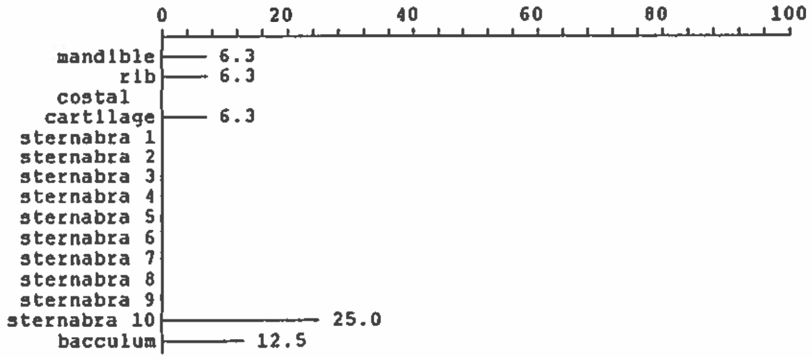


Figure 41: Feature 11 frequencies of ringed seal ventral elements (%MNI)

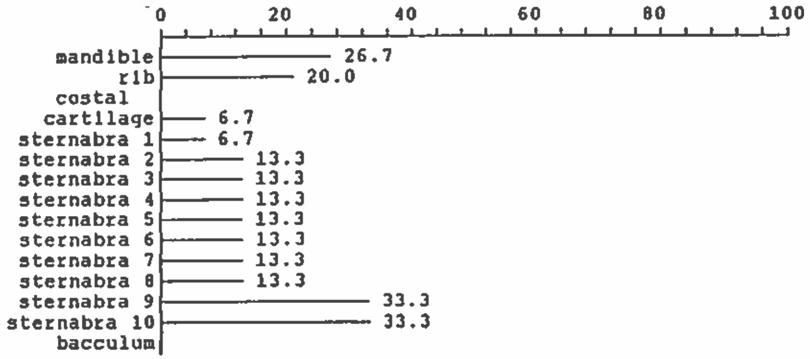
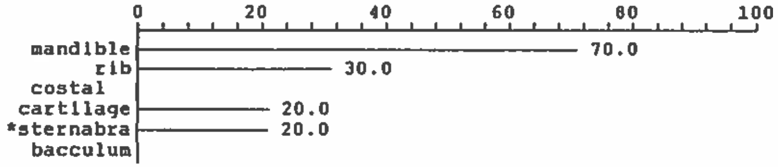


Figure 42: Tent rings' frequencies of ringed seal ventral elements (%MNI)



*sternabrae were not identified to sternal segment from 70 to 6.3 %MNI, while ribs are moderately frequent, and almost always more abundant than less dense costal cartilage. The most interesting feature of the sternabrae frequencies is the slightly lower value for sternabra 9 in the large Sodhouse 2 sample, complementing the high incidence of cut marks to this bone in the same assemblage. This tends to confirm the hypothesis (suggested for cervical 7 - thoracic 2) that the location of major carcass divisions during primary processing may artificially lower certain element frequencies by destroying or disfiguring the bones. The occurrence of baccula is uneven between features, but the frequency consistent where they occur. There is some discrimination against the procurement of male seals at certain times of year, especially near the pupping season when they emit a disagreeable scent which can be detected at breathing holes and dens (personal observations). For this reason, and the poor ossification of this element in immature individuals, baccula are predictably underrepresented in the sample.

To get beyond the reliance on basic element frequency tabulations, the frequencies of ringed seal anatomical portions were plotted against two different standards of reference. The first is an experimental meat utility index (MUI; Binford 1978) which reflects the quantity of meat associated with particular carcass portions. The derivation of the basic MUI for Pinnipeds is described in Lyman *et al* (1991). A log transform of the MUI produced slightly more interpretable results, and is utilized here (see Whitridge 1992). The second is a quantification of the likelihood that a particular butchery unit would be transported from the kill site to the residence by Clyde River hunters. Since the MUI was originally tested against zooarchaeological data calculated in terms of Minimum Animal Units (MAU's; Binford 1984), the Clyde River data has been quantified in similar terms, and the ringed seal MAU's from Ditchburn Point and Mount Oliver plotted against both (see Appendix B).

The correlations of ringed seal MAU's and log%MUI are shown in Table 36, and the graphic results in Figures 43 to 49, by feature and feature type. The linear regression analyses are striking for the lack of any significant correlations. An examination of the plots, however, indicates a repeated underrepresentation of vertebrae and ribs. This situation was noted in the initial tests of the MUI (ibid). If unknown taphonomic factors significantly bias the frequency of these elements, otherwise strong correlations of the MAU and MUI might be obscured. Vertebrae and ribs were thus removed from consideration and linear correlations recalculated (Table 37). Here the situation has improved slightly. While only two of the tests produced a significant correlation, all of the correlations are now positive, and much stronger than when ribs and vertebrae were included. Moreover, the correlation of Sodhouse 2 MAU's and log%MUI is very strong and, as noted in the earlier discussions, Sodhouse 2 was the only assemblage to produce large, presumably representative, samples of all elements. This test can thus be interpreted as moderate support for the accuracy and utility of the Pinniped MUI, as *the log%MUI was a significant predicter of MAU frequencies for all carcass portions except vertebrae and ribs in a very large sample*. The implication of the test is that ringed seal element frequencies appear to reflect preferential transport of carcass portions with high meat yield to Sodhouse 2 and, to a lesser degree, the tent rings. If such preferential transport occurred with the assemblages from Features 25, 9 and 11, this effect has been obscured by other taphonomic processes.

A second approach to the interpretation of element frequencies is to

Table 36: Correlation of ringed seal MAUs with log%MUI

assemblage	*r*	*p*
Sodhouse 2	0.147	0.616
Feature 25	-0.116	0.693
combined sodhouses	0.128	0.662
Feature 9	-0.014	0.963
Feature 11	0.110	0.708
combined qarmat	0.035	0.905
combined tent rings	0.006	0.982
Clyde River*	-0.181	0.536

*transported assemblage, calculated in %MAU

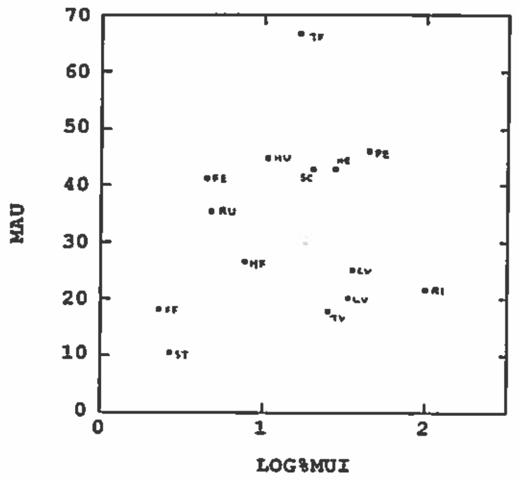
Table 37: Correlation of ringed seal MAUs
with log%MUI excluding vertebrae and ribs

assemblage	*r*	*p*
Sodhouse 2	0.712	0.021
Feature 25	0.212	0.557
combined sodhouses	0.709	0.022
Feature 9	0.253	0.481
Feature 11	0.327	0.356
combined qarmat	0.286	0.424
combined tent rings	0.547	0.102

Table 38: Correlation of ringed seal MAUs with Clyde %MAU

assemblage	*r*	*p*
Sodhouse 2	-0.197	0.500
Feature 25	-0.653	0.011
combined sodhouses	-0.254	0.382
Feature 9	-0.240	0.408
Feature 11	-0.204	0.484
combined qarmat	-0.230	0.430
combined tent rings	-0.243	0.402

Figure 43: Sodhouse 2 MAU vs. log%MUI



HE - head (cranium, mandible, hyoid)
CV - cervical vertebra
TV - thoracic vertebra
LV - lumbar vertebra
RI - rib
ST - sternabra
SC - scapula
HU - humerus
RU - radius and ulna
FF - front flipper (carpal, metacarpal, phalanx)
PE - pelvis (sacrum, innominate, bacculum, caudal vertebra)
FE - femur
TF - tibia and fibula
HF - hind flipper (tarsal, metatarsal, phalanx)

Figure 45: Sodhouse MAU vs. log%MUI

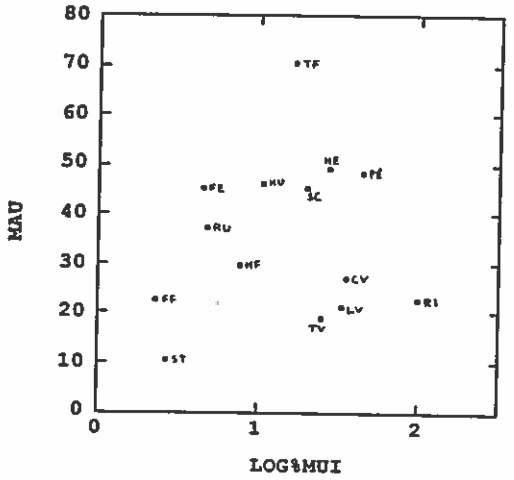


Figure 44: Feature 25 MAU vs. log%MUI

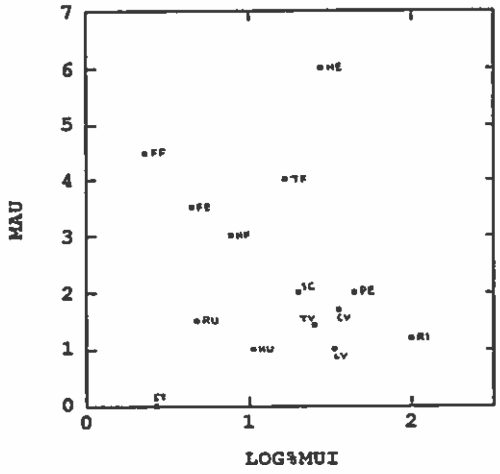


Figure 46: Feature 9 MAU vs. log%MUI

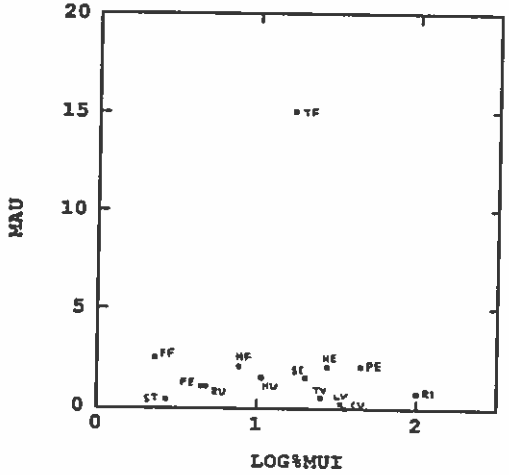


Figure 47: Feature 11 MAU vs. log%MUI

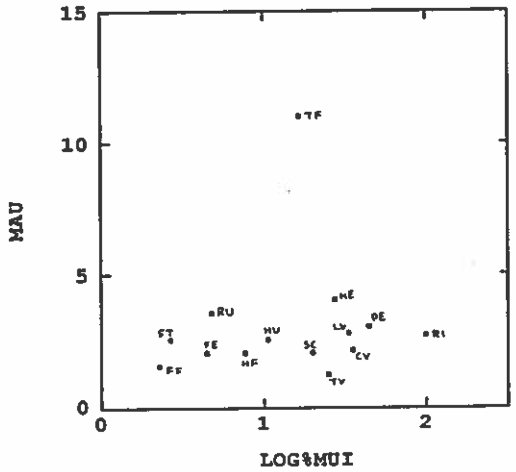
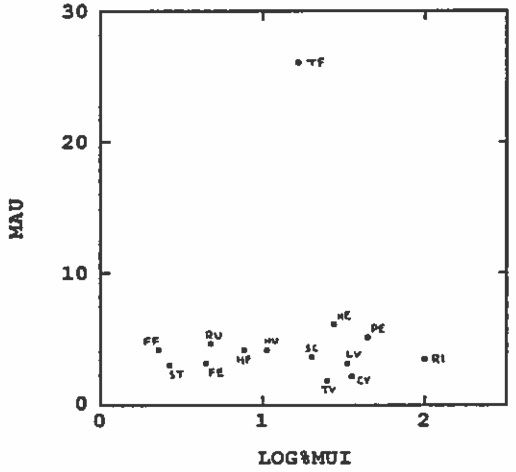


Figure 48: Qarmat MAU vs. log%MUI



HE - head (cranium, mandible, hyoid)
CV - cervical vertebra
TV - thoracic vertebra
LV - lumbar vertebra
RI - rib
ST - sternabra
SC - scapula
HU - humerus
RU - radius and ulna
FF - front flipper (carpal, metacarpal, phalanx)
PE - pelvis (sacrum, innominate, bacculum, caudal vertebra)
FE - femur
TF - tibia and fibula
HF - hind flipper (tarsal, metatarsal, phalanx)

Figure 49: Tent ring MAU vs. log%MUI

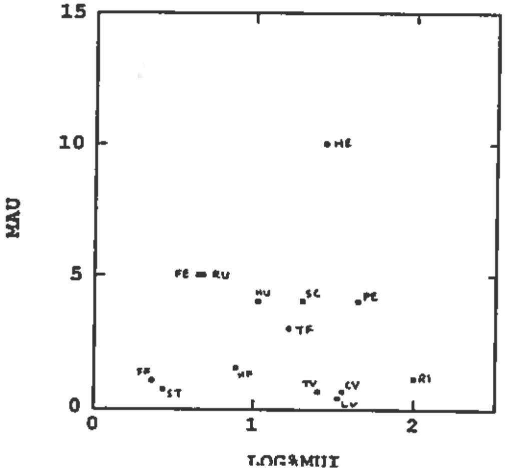
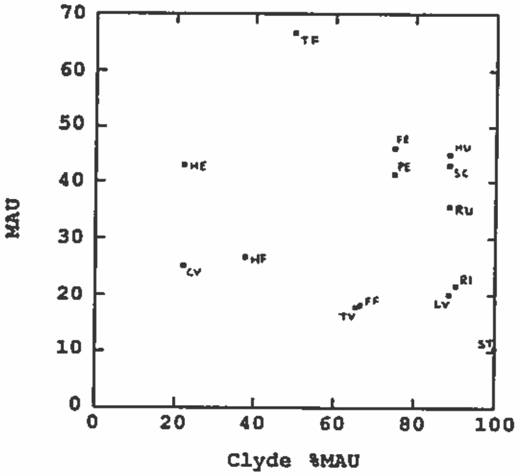


Figure 50: Sodhouse 2 MAU vs. Clyde%MAU



compare observed MAU's with those predicted by transport practises at Clyde River. A summary of linear regression analyses for features and feature types is presented in Table 38, and plots of observed versus expected frequencies in Figures 50 to 56. The results of this test are extremely negative. Most of the samples produced a weak negative correlation with the transported Clyde River assemblage, and Feature 25 even exhibits a *significant* negative correlation. Unlike the log%MUI regressions, clusters of repeatedly outlying values cannot easily be distinguished, to salvage more interpretable results.

This situation could have been predicted from a comparison of log%MUI and Clyde %MAU values, as a linear regression of these data sets produced a weak negative correlation (Table 36). The situation is more complex than simple incongruence, however. The relationship between Clyde %MAU and log%MUI (Figure 57) is actually highly patterned. Most of the overrepresented elements (those which were transported more often than their meat yield would indicate) travelled as riders with parts of higher value, in major butchery units. Thus the scapula, humerus, radius-ulna, and sternum were left attached to the high value ribs, while the femur was commonly left articulated with the innominate. These phenomena can be observed by reading horizontally from right to left on Figure 57. Front flippers are a special case. They were never included with the rib-front limb unit, but were either discarded or, more often, transported while attached to the hide. The underrepresentation of the cranial region and cervical vertebrae also deserves comment. While obviously associated with a great deal of edible tissue, they are not considered choice sources of food by Clyde River hunters and so were often discarded at the butchery site. This practise contradicts statements made at other times that all

Figure 51: Feature 25 MAU vs. Clyde %MAU

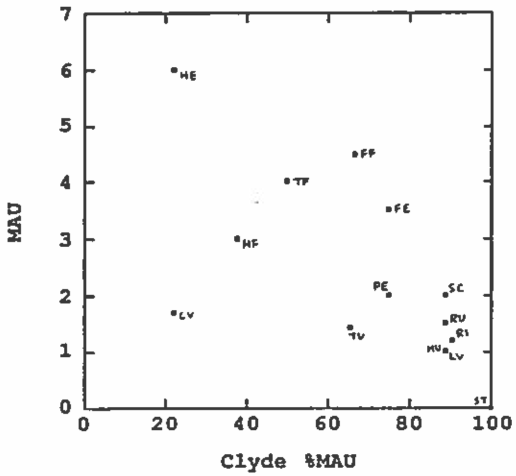
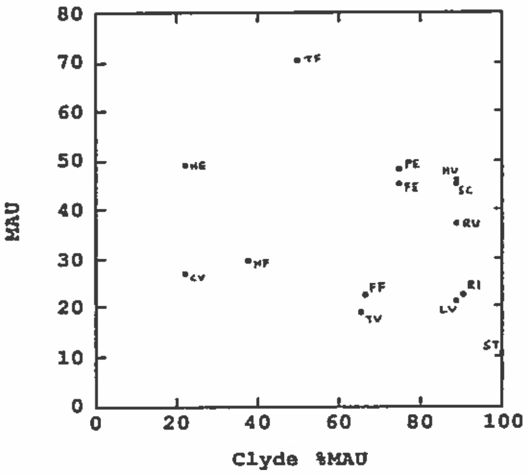


Figure 52: Sodhouse MAU vs. Clyde %MAU



HE - head (cranium, mandible, hyoid)
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SC - scapula
HU - humerus
RU - radius and ulna
FF - front flipper (carpal, metacarpal, phalanx)
PE - pelvis (sacrum, innominate, bacculum, caudal vertebra)
FE - femur
TF - tibia and fibula
HF - hind flipper (tarsal, metatarsal, phalanx)

Figure 53: Feature 9 MAU vs. Clyde %MAU

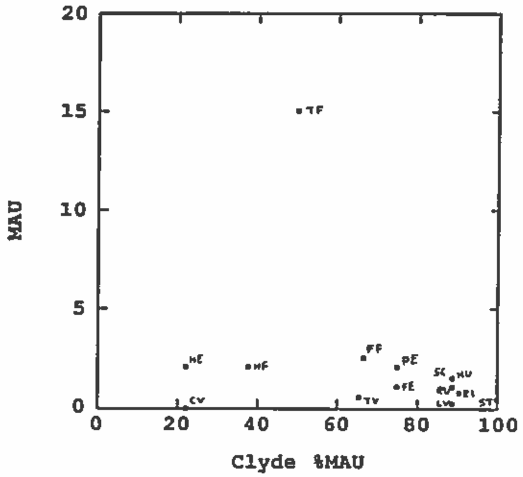


Figure 54: Feature 11 MAU vs. Clyde %MAU

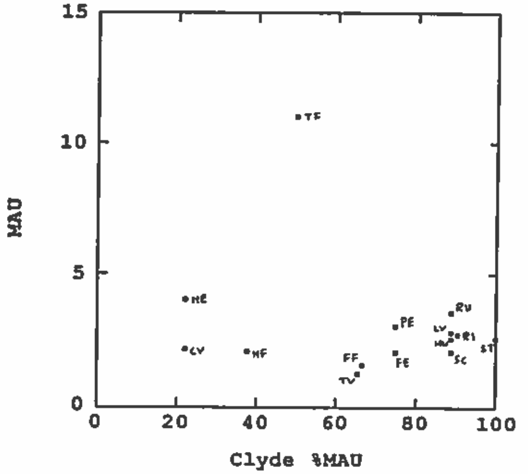


Figure 55: Qarmat MAU vs. Clyde %MAU

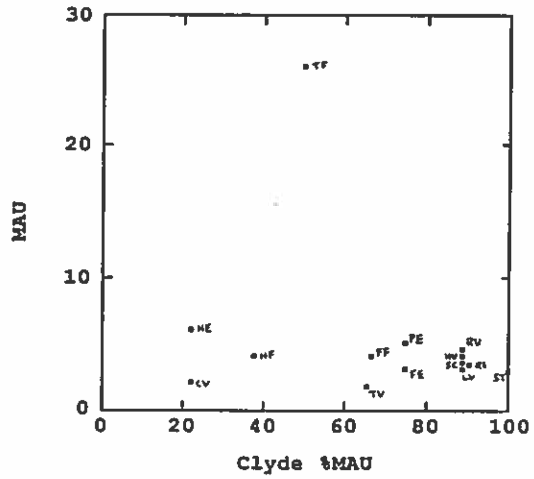
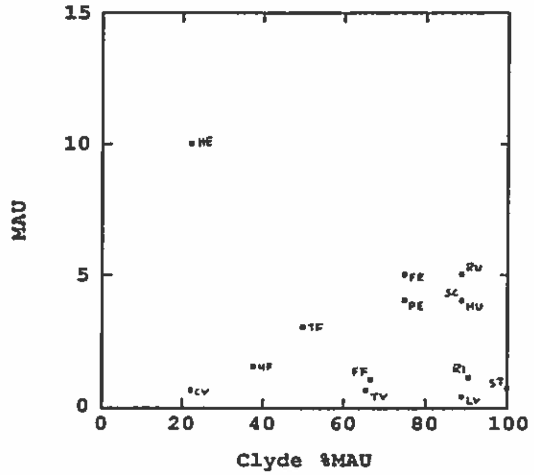
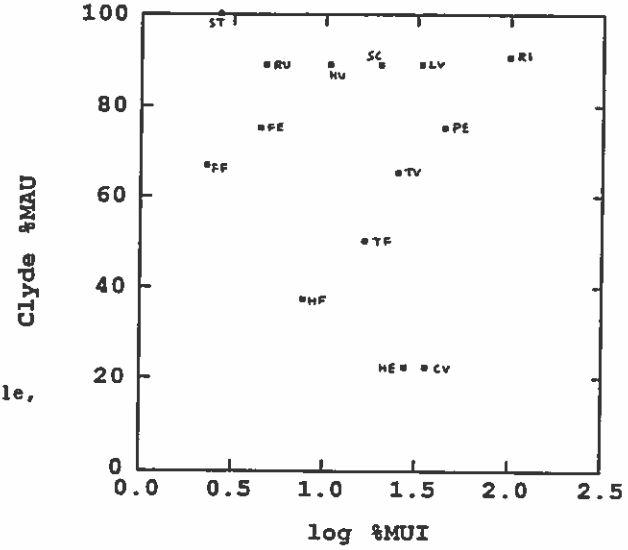


Figure 56: Tent ring MAU vs. Clyde %MAU



HE - head (cranium, mandible, hyoid)
CV - cervical vertebra
TV - thoracic vertebra
LV - lumbar vertebra
RI - rib
ST - sternabra
SC - scapula
HU - humerus
RU - radius and ulna
FF - front flipper (carpal, metacarpal, phalanx)
PE - pelvis (sacrum, innominate, bacculum, caudal vertebra)
FE - femur
TF - tibia and fibula
HF - hind flipper (tarsal, metatarsal, phalanx)

Figure 57: Clyde River %MAU vs. log %MUI



of a seal's meat was good to eat, and that under normal circumstances no parts were wasted. The low frequency of transport of the anterior axial skeleton at Clyde River probably does not reflect practises in the past, when seals were obtained with more difficulty than at present. The Clyde River data will have to be explored in greater detail, and probably manipulated to take riders into account, before they can be meaningfully applied to archaeological assemblages. If taken at face value, they weakly suggest that most feature samples reflect transport of valuable carcass portions away from the residential site. In view of the stronger results of the log%MUI regressions, this scenario seems improbable. Ringed seal skeletal element frequencies are best interpreted as a reflection of preferential transport to living sites of carcass portions with high meat yields, combined with the operation of undetermined taphonomic biases.

A final perspective on the differential transport of species is provided by a consideration of the relationship between NISP and MNI. Table 39 shows the ratio of NISP to MNI by species (fish and bird are considered by order, to compensate for low identifiability) for each feature and for combined feature types. Although MNI is largely a function of sample size (a linear regression of MNI on NISP was highly significant: $r = .987$, $p = .00001$, see also Grayson 1984), the expression of these two measurements as a ratio should be sensitive to differential transport of carcass parts. In effect, it is an index of degree of carcass transport; species with a high ratio were transported whole, or nearly whole, to the features, while species with a low ratio were intensively culled away from the feature. The value of these ratios as indices may be compromised in some cases, however, by differential

Table 39: Ratio of NISP to MNI by species and feature

species	SH2	F25	winter houses	F9	F11	*qarmat*	F1	F2	F3	F4	tent rings
fish	14.0	7.0	10.5	11.0	8.0	9.5	-	-	-	-	-
bird	14.5	20.0	15.2	21.0	17.2	19.7	1.0	13.6	18.0	-	14.3
arctic hare	10.7	-	10.7	-	-	-	-	-	-	-	-
lemming	9.4	1.0	8.9	5.5	7.5	7.0	-	6.1	-	-	6.1
dog/wolf	29.5	2.0	24.0	3.5	2.0	3.0	-	-	-	-	-
arctic fox	53.6	2.0	51.1	7.0	3.0	5.0	-	2.7	-	-	2.7
beluga/narwhal	6.0	-	6.0	-	-	-	-	-	-	-	-
polar bear	6.5	1.0	4.7	5.0	5.0	5.0	-	-	-	-	-
walrus	1.0	-	1.0	-	-	-	-	-	-	-	-
bearded seal	16.7	-	16.7	3.5	2.0	3.0	-	-	-	-	-
ringed seal	93.9	78.4	92.6	17.2	30.3	23.5	8.0	34.3	41.3	1.0	28.5
caribou	31.0	2.0	23.8	1.0	2.0	1.5	-	-	-	-	-
muskox	2.0	-	2.0	-	-	-	-	-	-	-	-
average	22.2	14.2	20.6	8.3	8.6	8.6	4.5	14.2	29.7	1.0	12.9
NISP	9434	684	10118	534	607	1221	17	249	255	1	522

destruction, or differential deposition of certain species' elements away from the features (considered below). Although the ratio of NISP to MNI is not significantly correlated with sample size ($r = .416$, $p = .305$), an examination of Table 39 reveals a great deal of variability for species between features. At low sample sizes, the ratio may monitor chance deposition of elements in a feature that does not truly reflect overall carcass transport practises. This is especially evident in the variability in the ratio for ringed seal among the tent ring samples. The moderate to large samples from the *qarmat* and sodhouses, however, appear to reveal significant differences in the pattern of carcass treatment. *Qarmat* produced lower ratios for most species when compared to the sodhouse samples, implying more intensive culling before transport to these features. This could reflect the greater constraints on field butchery during the winter (reduced light and temperature, freezing of carcass), with correspondingly higher transport of prey. Alternatively, it may reflect deposition of refuse on the rooves of sodhouses, which was ultimately incorporated in the feature samples.

Besides apparent seasonal variability in degree of carcass transport, a large proportion of the inter-species patterning in these ratios is a function of prey anatomy. A reciprocal regression (of the form $1/Y = a + bX$) best describes the negative relationship between species weight and NISP:MNI for Sodhouse 2, where transport was highest. It reveals that this ratio and, by extension, the degree of transport, is significantly correlated with carcass size ($r = .714$, $p = .006$). The Schlepp effect is thus demonstrably operative in the formation of the faunal assemblage.

Bone Destruction

An important taphonomic factor which may alter the species and element proportions of skeletal assemblages transported to a residential site is the differential destruction of bone. Bone density is often highly correlated with element survival (Lyman 1984), reducing the representation of species with fragile bone (e.g. fish, bird, hare, fox) and/or the frequency of less dense elements for a particular species (e.g. calvaria, costal cartilage). Bone density data is not available for any of the species in this sample, but strong correlations of bone frequency and density are only likely to occur where preservation is moderate to poor. While this is the situation with the heavily weathered tent ring assemblages, density-mediated bone destruction is less likely to have been a major factor in the other samples. A possible exception to this assumption is the destruction of less dense elements which were subject to intense carnivore gnawing. While the relationship of density to survivorship cannot be determined, it is at least possible to examine the frequency of gnawed elements of each type to assess the likelihood that certain bones were preferentially consumed by carnivores, regardless of density.

The breakdown of frequency of carnivore modifications (including furrowing, punctures, erosion by digestive juices) by mammalian species is provided in Table 40, based on the combined NISP for all samples. It is immediately apparent that elements of larger species appear to have suffered more frequent carnivore gnawing and consumption than those of smaller animals. In fact, a linear correlation of %NISP with modifications against average weight produced very significant results ($r = 0.812$, $p = 0.014$). The precise cause of this correlation is difficult to determine. It may be more difficult or inefficient to remove all edible tissue from large mammal bones, than for smaller ones, thus

Table 40: Frequency of carnivore modification by mammalian species* for combined assemblages

species	%NISP with modifications	average weight (kg)
arctic hare	0	4.6
dog/wolf	9.3	30.0
arctic fox	4.1	3.2
beluga/narwhal	33.3	577.0
polar bear	20.8	410.0
bearded seal	30.5	215.0
ringed seal	11.7	45.4
caribou	19.4	81.3
average	16.1	

* excluding lemming, walrus and muskox; walrus and muskox were not represented by any post-cranial elements

Table 41: Frequency of carnivore modification to mammalian elements* by feature

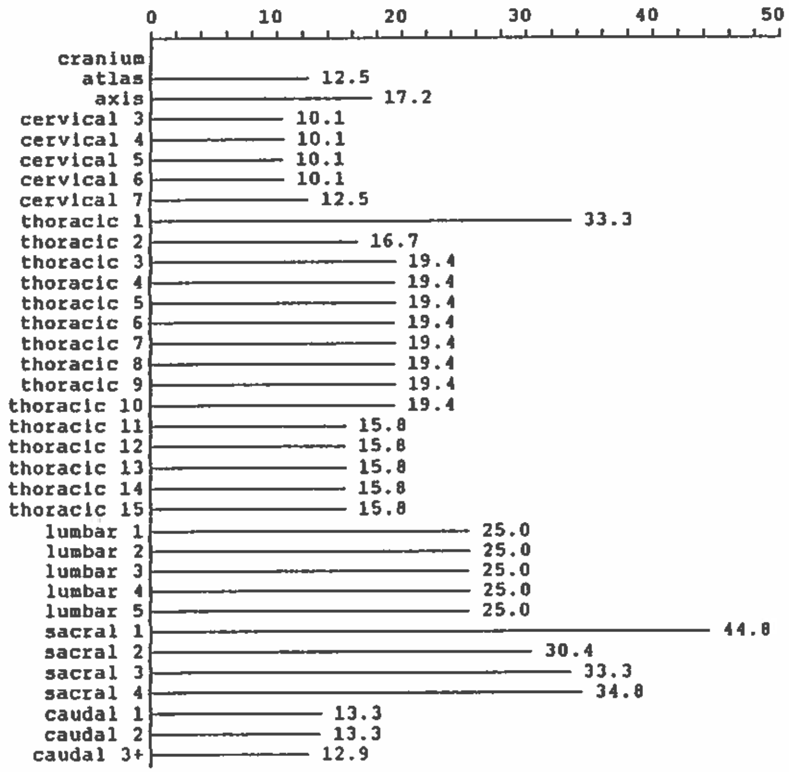
feature	%NISP with modifications
Sodhouse 2	10.7
Feature 25	5.8
Feature 9	24.8
Feature 11	14.3
Tent Rings	12.9
average	13.7

* excluding lemming, walrus and muskox; walrus and muskox were not represented by any post-cranial elements

providing a more attractive food source to dogs or other carnivores. Alternatively, large elements may simply preserve evidence of gnawing more often than small bones, which might be consumed whole, or tend to fracture rather than sustain surficial damage.

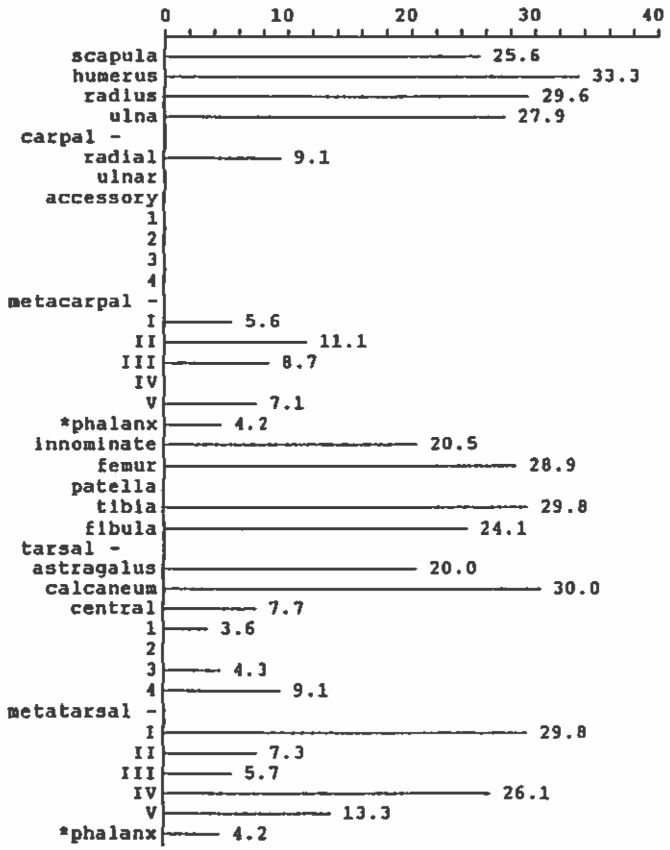
The frequency of carnivore modification to ringed seal bone is considered in more detail for the Sodhouse 2 assemblage (Figures 58 to 60). The incidence of carnivore modification to particular elements probably reflects butchering and the overall degree of processing of butchery units. For example, an element which was regularly stripped entirely of soft tissue might be less attractive to a scavenger than one with remaining edible soft tissue. This is particularly the case with marine mammals, the elements of which tend to contain a dense meshwork of cancellous bone rather than cavities filled with nutrient-rich marrow. Another factor could be the location of a particular element within a larger butchery unit. Thus if most cervical vertebrae regularly constituted a transported unit, and were discarded or intentionally fed to dogs in this form, then the first and last vertebrae in the unit would be more exposed to initial gnawing than those within the unit. This situation may account for the higher frequency of gnawing to cervical 1 (atlas), cervical 2 (axis), cervical 7, and thoracic 1, than for middle cervicals. Thoracic 1 and sacral 1 in particular appear from butchery evidence to have been points of division of the axial skeleton, and thus would have been exposed in this manner. Front and hind limbs generally exhibit higher frequencies of gnawing on proximal than distal elements. This may, however, be a reflection of the potential for small extremity bones to be entirely consumed. Most of the ventral elements have low to moderate frequencies of gnawing, although unexplained patterning is

Figure 58: Sodhouse 2 frequencies of ringed seal axial elements with carnivore modification (%)*



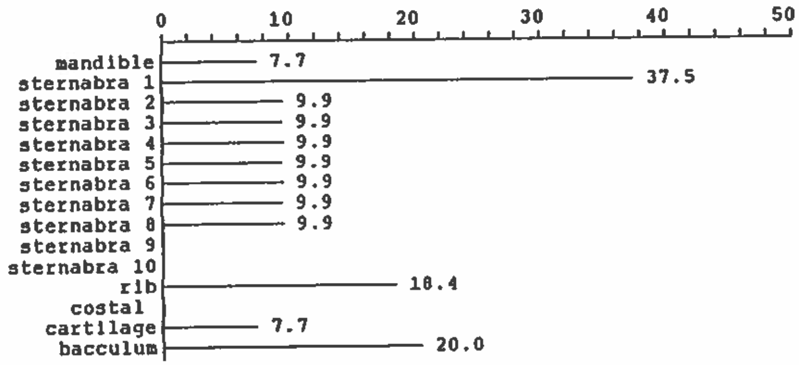
* where identification was to a class of elements (e.g. cervical 3-6), the frequency of modified elements for the class was taken as that for individual elements within the class

Figure 59: Sodhouse 2 frequencies of ringed seal front and hind limb elements with carnivore modifications (%)



* front and hind phalanges were not distinguished; this represents the average value for all phalanges

Figure 60: Sodhouse 2 frequencies of ringed seal ventral elements with carnivore modification (%)*



* where identification was to a class of elements (e.g. sternabra 3-8), the frequency of modified elements for the class was taken as that for individual elements within the class

evident for the sternabrae.

There is a great deal of variability in overall frequency of carnivore gnawing to mammalian elements between features, ranging from 5.8 % for Feature 25 to 24.8 % for Feature 9 (Table 41). The winter houses had the two lowest values, followed by the combined tent ring assemblage, while the highest values occurred within the two *qarmat*. Bones discarded in winter might be buried rapidly under snow, and so incur less gnawing than those deposited in summer at tent rings or *qarmat*. The higher frequencies at *qarmat* than tent rings can probably be attributed to the different lengths of occupation of these features. By extension, element frequencies are more likely to be biased by differential destruction of meaty, or less dense, bones at the warm weather dwellings than at the winter houses.

Spatial Distribution

As a case study in the differential deposition of the bones of different species within an excavated feature, the spatial distributions of faunal remains by unit are presented for Sodhouse 2 (Figure 61) in Figures 62 to 67. Figure 62 shows the density of all bone recovered from the 29 one metre square excavation units. Concentrations of bone are found south of the entrance tunnel in Unit 21, in a large swath extending along the north side of the tunnel (Unit 4) to south of the exterior entrance (Unit 24), and on the floor of the main compartment, in front of the tunnel (Units 11 and 19; cf. Savelle 1984:514, Figure 7). Faunal remains are noticeably scarcer at the back of the main compartment (Units 2, 9, 10, 17 and 18), the probable location of the sleeping platform, than in the eastern portion near the entrance. Much of the tunnel itself is also largely free of bone concentrations (Units 12, 13 and 14). If in

Figure 61.

Sodhouse 2 excavation units

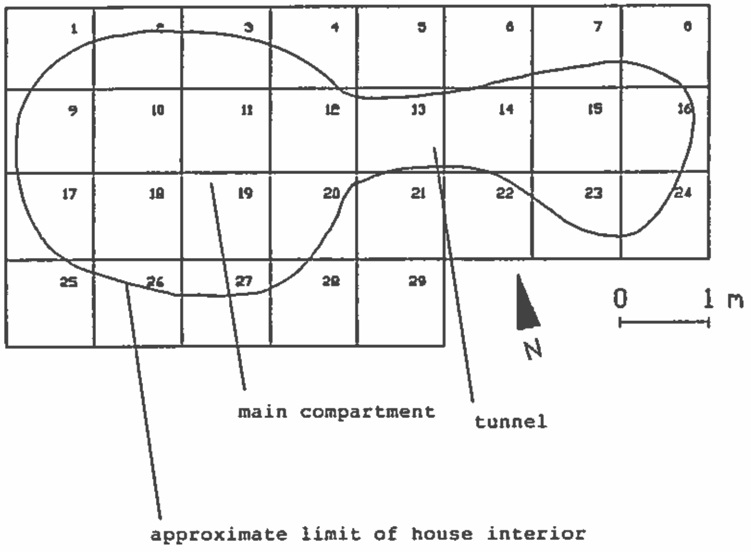


Figure 62.

Spatial distribution of all recovered bone in Sodhouse 2

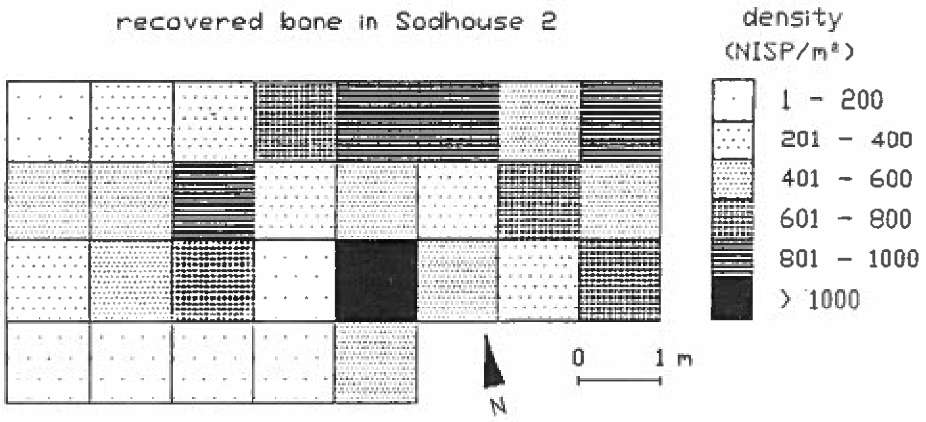


Figure 63.

Spatial distribution of ringed seal bone in Sodhouse 2

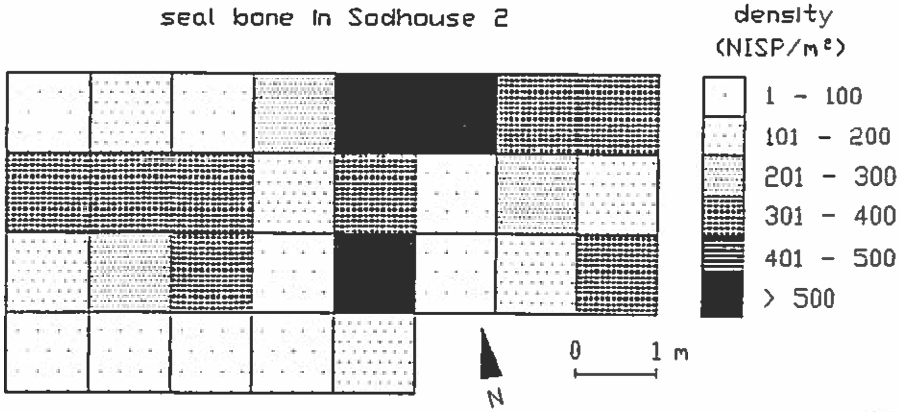


Figure 64.

Spatial distribution of large mammal bone in Sodhouse 2

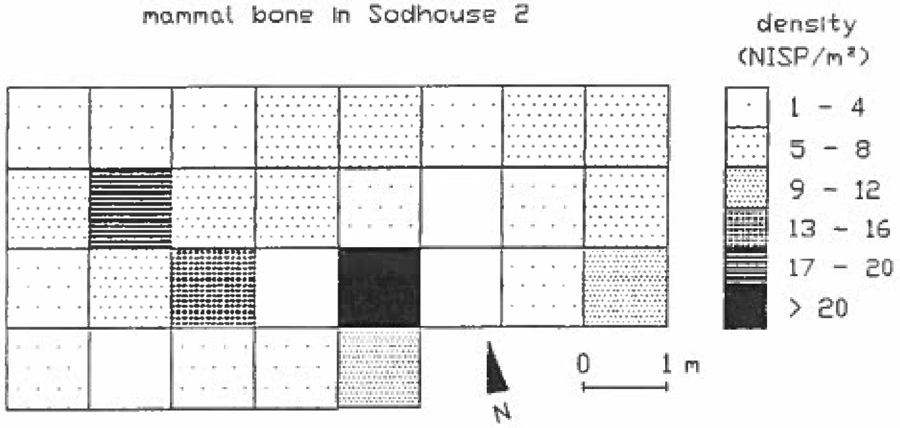


Figure 65.

Spatial distribution of arctic fox bone in Sodhouse 2

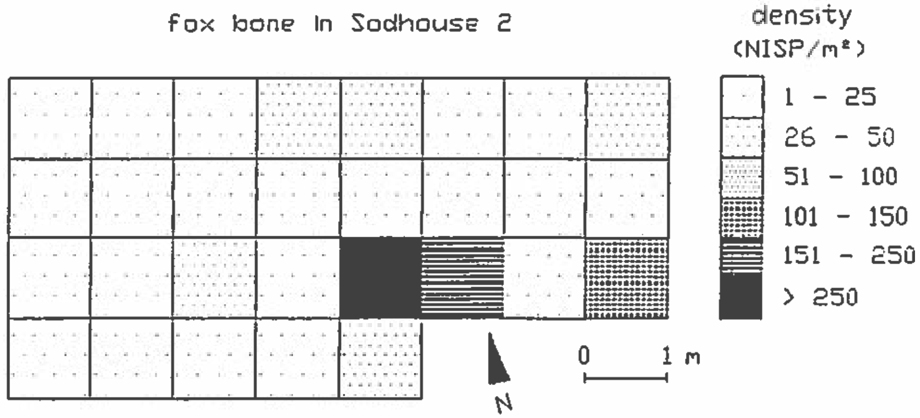


Figure 66.

Spatial distribution of arctic hare bone in Sodhouse 2

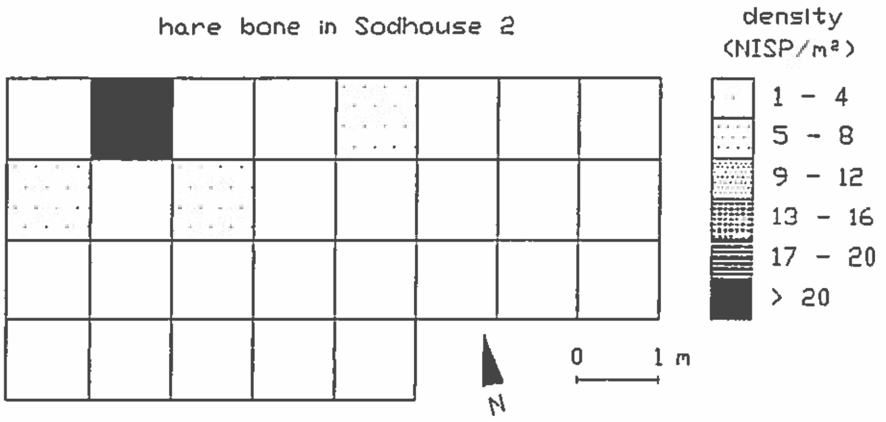
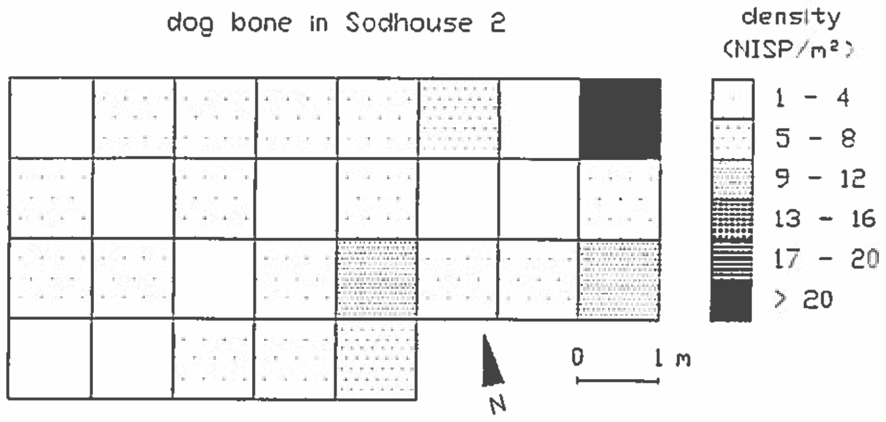


Figure 67.

Spatial distribution of dog bone in Sodhouse 2



fact the recovered bone is all associated with the occupation of Sodhouse 2, most refuse appears to have been deposited on either side of the tunnel, while the tunnel mouth was kept relatively free of debris. The unusually high density of bone in Unit 21 is somewhat problematic, but may represent a single depositional episode, such as the cleaning of the structure's interior before it was re-occupied for the winter. The possibility remains open, however, that some undetermined proportion of the Sodhouse 2 faunal (and artifactual) assemblage derives from the occupation of adjacent Sodhouse 1 to the south. While this could compromise an assessment of inter-feature variability, it does not present a significant problem for reconstructing the subsistence economy of the site occupants, as for the purposes of this analysis only a hypothetical norm, or mean, of subsistence behaviour is at issue.

The distribution of ringed seal bone (Figure 63) closely resembles that for all bone, as might be expected from the overwhelming predominance of this species in the faunal assemblage. Differences include the relatively higher density of ringed seal bone in the presumed sleeping platform area, and the generally smoother (less discontinuous) overall distribution.

It was expected that large mammal bone (beluga/narwhal, walrus, bearded seal, polar bear, caribou, muskox) might be differentially distributed towards the margins of the feature, but this was not the case (Figure 64). It is lightly distributed over most of the excavated area, with concentrations in the centre of the main compartment, and in the "bone dump" of Unit 21. The cluster in Unit 10 is produced by the abundance of several species (bearded seal, small whale, caribou and polar bear), and so is not easily dismissed as an anomaly. It may represent a cache of relatively rare (high value?) foods or, more likely, bone suitable for artifact manufacture.

Fox bone (Figure 65) is very evenly spread across Sodhouse 2, except for dense concentrations south of the entrance tunnel. A similar pattern, in which fox is *preferentially* deposited in dumps, was observed in another Thule winter house, Feature 2 at Port Leopold (Whitridge 1991 - Port Leopold field notes). This distribution is only unusual given the large number of fox bones recovered, and the correlative expectation that their distribution would parallel that for all bone.

Hare bone was recovered in four excavation units, but 88 % came from a single unit (Figure 66). This distribution is notable for its lack of correspondence with the overall bone distribution, but the three hare's feet this deposit represents may have been associated with skins or hunting amulets, rather than food.

Dog (or wolf) elements are also distributed differently than other bone (Figure 67). Like fox, it is thinly spread over most of the feature, but with a single high density concentration in Unit 8. Because the sample is moderately large (118 specimens, 4 individuals), the unusual distribution may be a real reflection of dog bone disposal practises. It appears that dog (like fox) bone was not considered in the same category with the bone of food animals such as ringed seal. While it seems to have been relatively appropriate to deposit seal bone within the living area, canid carcasses were somehow more definitively "garbage", and so were kept out of the domestic zone.

At least three different factors appear to be influencing the spatial distribution of bone in and around Sodhouse 2. The first reflects the deposition of bone where most food was processed and consumed, in front of the sleeping platform of the main compartment, and accounts for reduced densities in the sleeping platform area and entrance tunnel. The second, and strongest tendency, is the redeposition of refuse outside of the enclosed domestic space, especially around the exterior margins of the entrance tunnel. Lastly, differential treatment of the remains of some species, especially canids, resulted in their extreme concentration in "dumps", while the remains of other species were spread across the excavated area more homogeneously.

Summary

The combined results of these different lines of taphonomic analysis lead to certain conclusions about the formation and representativeness of the faunal assemblages. Primary butchery practises, which determine the carcass segments available for transport back to the residential sites, were most intense for larger species, presumably reflecting a higher degree of initial processing than for smaller species. In some cases, destructive butchery may have artificially lowered the frequencies of certain elements (e.g. ringed seal cervical 7 - thoracic 2), but probably did not result in the deletion of whole species or carcass portions from the assemblage.

Transport subsequent to butchery probably had a major effect on the observed representation of species and anatomical parts. Both MNI and NISP may be artificially low for large marine and terrestrial mammals, due to generally lesser transport to the residential site of elements from large carcasses. While ringed seal were frequently transported to the features, parts of relatively low food utility may have been regularly culled at the kill site. Smaller species (with the possible exception of hare) may have been regularly transported whole from the kill site.

Bone destruction due to carnivore gnawing appears to have been substantial, and may have deleted small species from the assemblage, and generally reduced the element frequencies and NISP of species smaller than ringed seal. Particular elements of some larger species, such as those exposed in butchery units or those more difficult to completely deflesh, may have also been deleted, or their frequencies reduced. While the bones of larger species were especially likely to be modified by carnivores, their bulk would have prevented them from being completely consumed. The main exceptions to this are the marrow-rich bones of terrestrial mammals, which may have been frequently consumed by dogs. Bone destruction, by weathering and carnivore attention, appears to have been more intensive at the *qarmat* and tent rings, while bone deposited at the sodhouses may have been rapidly frozen and buried under snow.

Spatial distributions suggest that the remains of some species (hare, fox, dog) were preferentially concentrated in dumps, and so may be underrepresented or absent if these dumps fell outside of the excavated area for a particular feature. The major food species, including large mammals, however, are well represented within the perimeter of structures.

Seasonality

The results of the thin section analysis are presented in Figures 68 to 76. Some researchers have presented seal season of death data in one month increments (McCullough 1989:Figures 61, 62), and the claim has also been made that even shorter term depositional events may be observable (George Hiseler, personal communication). The margin of error involved in determinations of age at death, while not prohibitive (Albright 1990), suggests that extreme caution should be used in interpreting the much less accurate determinations of season of death, for which comparable quality

Figure 68: Sodhouse 2 ringed seal season of death based on dental annuli

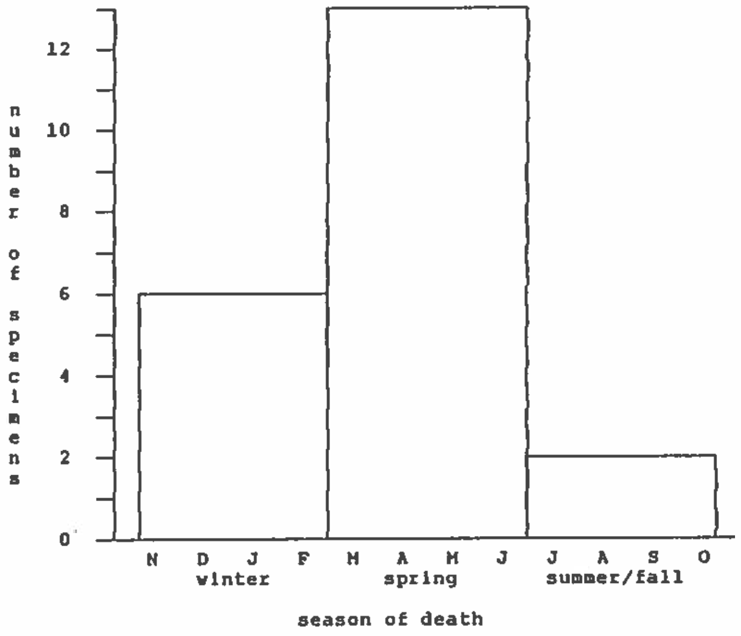


Figure 69: Feature 25 ringed seal season of death based on dental annuli

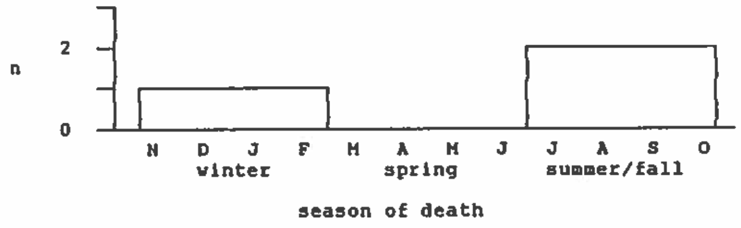


Figure 70: Combined sodhouse assemblages' ringed seal season of death based on dental annuli

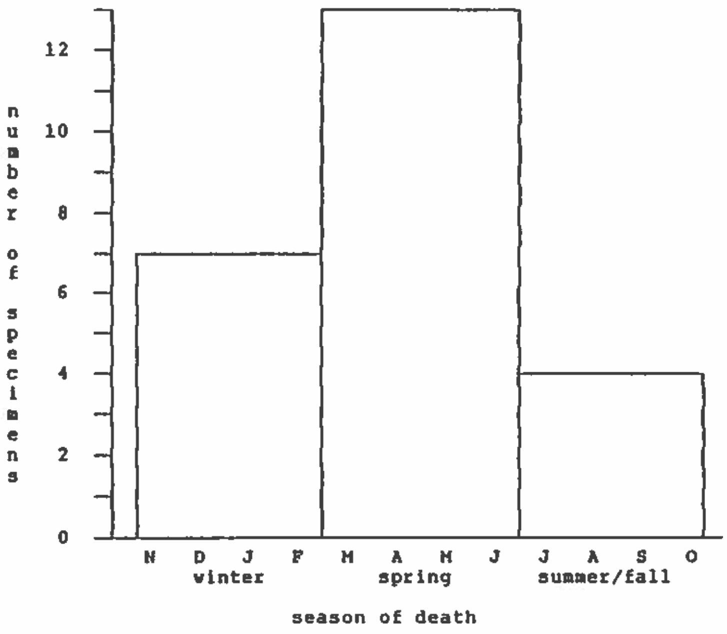


Figure 71: Feature 9 ringed seal season of death based on dental annuli

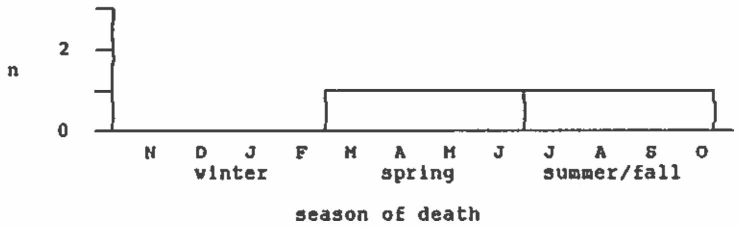


Figure 72: Feature 11 ringed seal season of death based on dental annuli

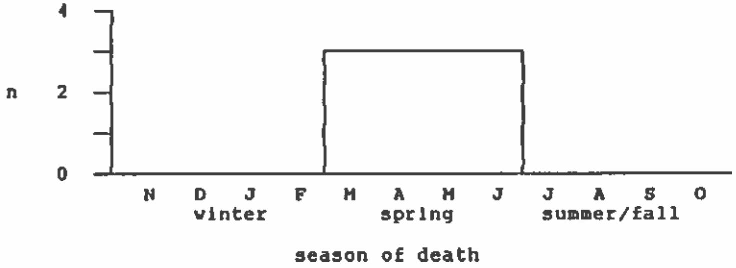


Figure 73: Combined qarmat assemblages' ringed seal season of death based on dental annuli

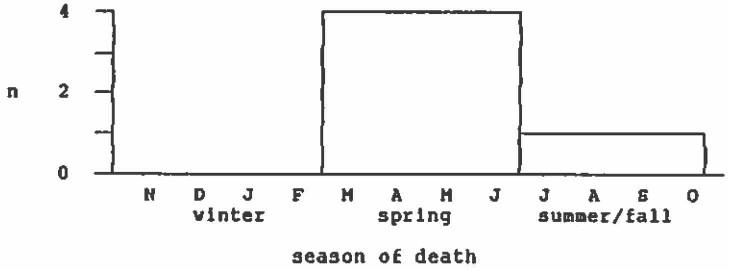


Figure 74: Feature 2 ringed seal season of death based on dental annuli

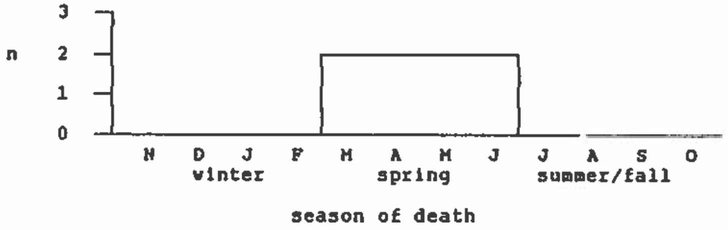


Figure 75: Feature 3 ringed seal season of death based on dental annuli

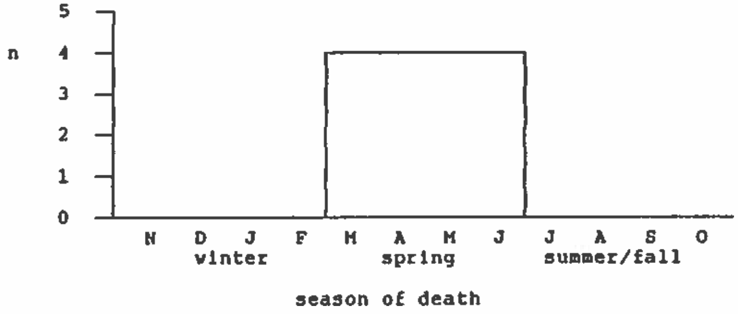


Figure 76: Combined tent ring assemblages' ringed seal season of death based on dental annuli

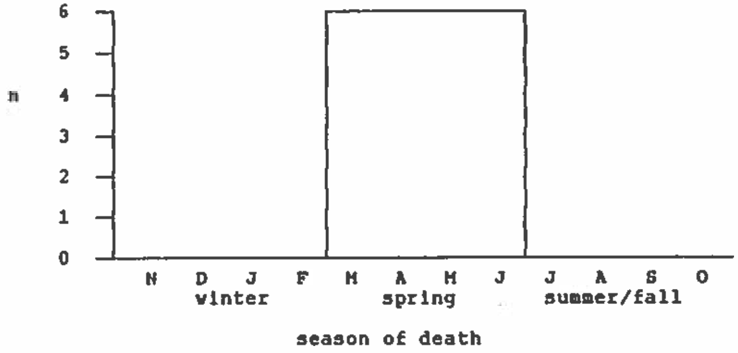


Figure 77: Sodhouse 2 ringed seal age of death based on dental annuli

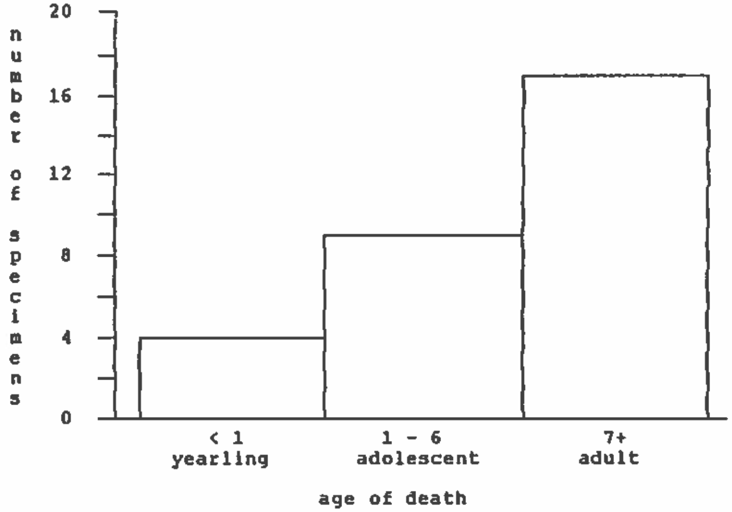


Figure 78: Feature 25 ringed seal age of death based on dental annuli

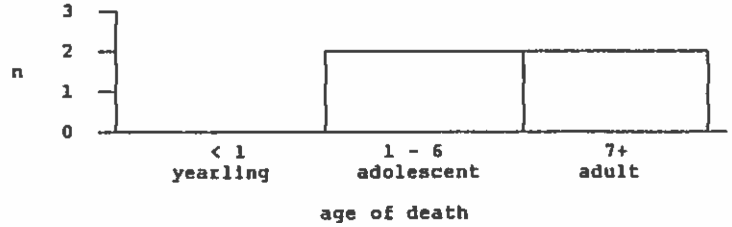


Figure 79: Combined sodhouse assemblages ringed seal age of death based on dental annuli

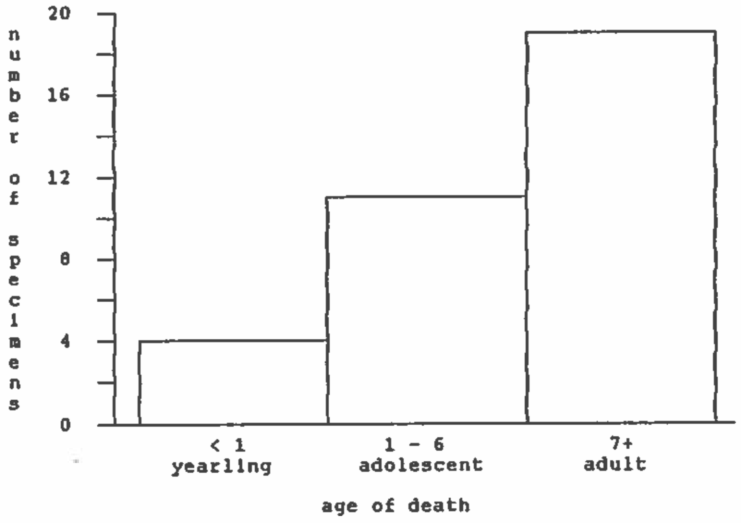


Figure 80: Feature 9 ringed seal age of death based on dental annuli

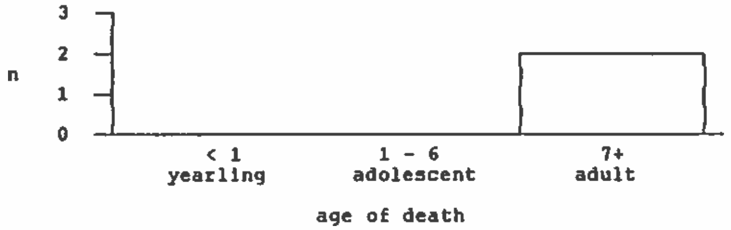


Figure 81: Feature 11 ringed seal age of death based on dental annuli

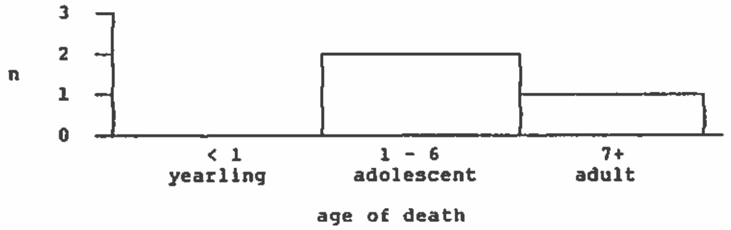


Figure 82: Combined qarmat assemblages ringed seal age of death based on dental annuli

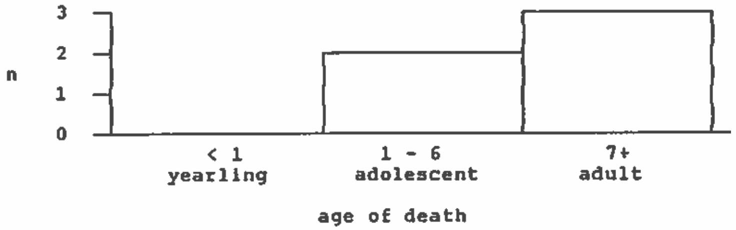


Figure 83: Feature 2 ringed seal age of death based on dental annuli

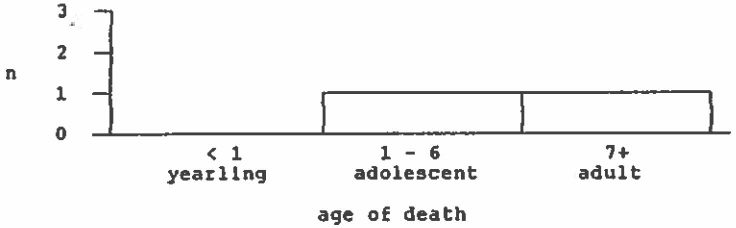


Figure 84: Feature 3 ringed seal age of death based on dental annuli

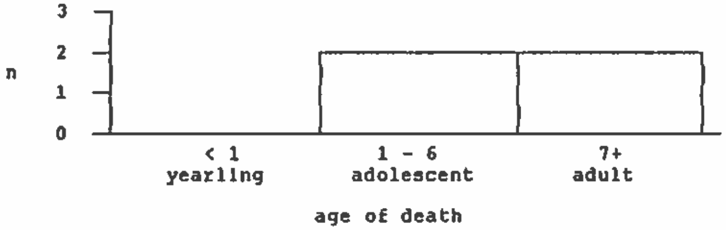
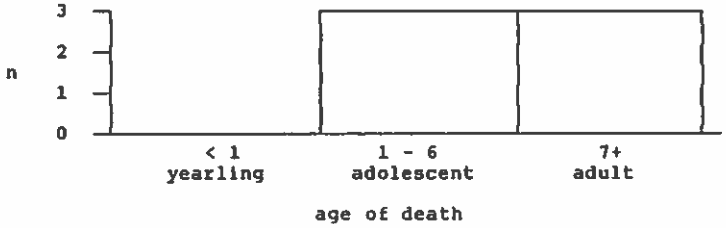


Figure 85: Combined tent ring assemblages ringed seal age of death based on dental annuli



control studies are not available. Beyond the problem of assessing normal variability in seasonality of annuli deposition, there appears to be disagreement over its actual timing. McCullough, for example, stated that the period during which the transluscent band is laid down changes to between March and August after the first year of life (1989:283, cf. Smith 1973). The data are thus presented in four month blocks, a manner appropriate to the reliability of the method. The three "seasons" utilized here do not necessarily correspond to harvesting seasons, but reflect the constraints on season of death estimates of the method itself. Thus the frequency of March/April determinations precluded a sufficiently secure distinction of specimens to allow the inclusion of March in a "winter season" and April in a "spring season". Admittedly, if different judgements had been made with respect to this tripartite division of the year, the seasonality plots may have looked quite different, but the breakdown utilized here was felt to be the most secure.

Of the 50 ringed seal canines sectioned, only 35 produced good seasonality observations, resulting in very low samples for most features. The determinations on specimens from Sodhouse 2 and Feature 25 are presented in Figures 68 to 70. For Sodhouse 2 the results indicate that the majority of seals were procured between March and June, about half as many during the winter, and the smallest proportion during late summer or early fall. If all of the animals were procured during the likely period of feature occupation, then relatively little sealing occurred between October and February, while intensive procurement took place in March, April, May and possibly June. Sample size is very low for Feature 25, so the divergent pattern (greatest activity in summer/fall, some in winter, and none in spring) may not be representative. However, Feature 25 belongs to a different settlement system than Sodhouse 2, and could also be temporally removed. Without larger samples from several winter houses at each site, it is impossible to determine whether the difference in seal seasonality is produced by sampling error, or reflects changes in either harvesting practises or seasonality of feature occupation.

The *qarmat*, Features 9 and 11, produced a different seasonal pattern (Figures 71 to 73). Again, sample size is small, but the harvesting activity represented at these features is different from that at the winter houses. Spring is still the season of most intensive harvesting, but summer/fall deaths account for the remaining 20 %, and winter deaths are lacking. A late spring to early fall period of site occupation is suggested for these features. The two tent rings produced readable sections (Figures 74 to 76), and are consistent in indicating a probable occupation of these features during late spring and/or early summer.

A second approach to the seasonality of seal harvesting (and feature occupation) is through a consideration of mortality profiles (Figures 77 to 85). Morrison (1983a:261-262) discusses problems in interpreting ringed seal age of death data with respect to the seasonal segregation of age cohorts, the major difficulties being substantial variability in population structure between regions, and in a given region over time. In addition, he notes the likelihood that seal behaviour will reflect local or regional ice conditions, particularly the presence or absence of an accessible winter floe edge. Thus data which show adolescents concentrated at the flow edge from winter to late spring (e.g. Smith 1973) may be irrelevant to some study areas. However, Hammil and Smith indicate that even within the fast ice "immature animals are excluded to areas of instability or little snow cover" (1989:2218). For the Hazard Inlet region, this implies greater winter and early spring concentrations of yearlings and adults on Hazard Inlet itself, and closer to shore on Prince Regent Inlet to the east. Adolescents might be expected to predominate in the unstable ice of Bellot Strait at these times. Depending on harvesting intensity, however, seal populations close to the site may be hunted out early in the season, at which time hunting activities are extended to more distant areas (Whitridge 1991 - Clyde River field notes). Thus it is possible that age selection may vary through the winter, even if age segregation is occurring. Given that breathing hole sealing should randomly sample the seal population (except close to the pupping season), it seems as likely that archaeological samples would be of interest to paleoecologists for revealing the *actual* age structure of the population, as that normative ecological data could be used to infer the precise seasonality of prehistoric harvesting. Nevertheless, differences in mortality profiles between some of the features in the sample are worth considering.

Although age at death can be estimated to within one or two years from dental annuli readings, the resultant spread of yearly age classes is of little interpretive value, since studies of living populations are concerned mainly with the sexual maturity or immaturity of animals. By collapsing the age estimates into the three categories illustrated, small errors in age determination are minimized, and the data can be more easily compared to biological census information. An average age at sexual maturity of 7 years, utilized by Smith (1987), is adopted here.

The mortality profile produced by the 30 ageable specimens from Sodhouse 2 (Figure 77) conforms to expectations for a winter to mid spring kill (note that age could be determined more frequently than season of death). Adolescents are significantly underrepresented in the sample, and yearlings also occur in low frequencies. This was the only feature which exhibited a significant predominance of adult seals. There does appear to have been selection for adult over adolescent seals, and this is tentatively explained as a result of age segregation of ringed seals by habitat, particularly during early to mid spring when they can be harvested while basking on the sea ice. Feature 25 (Figure 78) produced equal numbers of adolescents and adults and, interestingly, season of death data indicated more procurement during late fall and winter than spring.

Features 9 and 11 (Figures 80 to 82) produced variable results. The higher proportion of adolescents from Feature 11 seems to confirm the suggestion from season of death readings of greater harvesting activity during the spring, in this case presumably during June when adolescents move closer to shore just prior to breakup (Smith 1973, 1987). The exclusive occurrence of adults in Feature 9 may reflect the extensions of harvesting into the fall open water hunting season here (Figure 71), when adults tend to be more accessible.

Features 2 and 3 both produced equal proportions of adolescents and adults (Figures 83 to 85). As suggested above, such a combination might be expected from the procurement of basking seals during late spring and early summer.

Although sample sizes are small, and mortality profiles should be used cautiously for interpreting seasonality, the results are consonant with the season of death determinations, and further, suggest a de-emphasis on open-water hunting of ringed seals, even during the occupation of tent rings and *qarmat*. Together with other seasonal indicators (species ecology, discussed under the sections on bird and mammal remains) it is possible to make reasonably secure determinations of the seasonality of feature occupation and resource procurement.

Animals whose remains were deposited at the sodhouses were mostly procured between late fall and late spring, although some were probably harvested in late summer and early fall, and cached for winter use. Remains from the *qarmat* indicate spring to early fall procurement, but a substantial proportion of these animals appear to have been harvested in late spring. Occupation of the tent rings appears to overlap with *qarmat* use, with the majority of harvesting activity in mid to late spring, and possibly extending into early summer.

Resource Scheduling

The major results of the faunal analysis are summarized in Figure 86. This model of resource scheduling is based on combined seasonality determinations and species identifications for the three components of the settlement system: sodhouses, tent rings, and *qarmat*. Harvesting intensity at each season is expressed as %NISP for each combined feature type.

Sodhouses appear to have been occupied from mid fall (approximately October) to mid spring (end of April), tent rings from mid spring to early summer, and *qarmat* from mid spring to early fall, but the annual settlement round can be divided into two primary phases. When winter houses became uninhabitable due to increasing dampness and warmth, *qarmat* were occupied until the weather deteriorated. Qarmat were thus essentially permanent warm weather dwellings. Roughly simultaneous with the shift to qarmat, harvesting began to be practised from special purpose tent camps. For at least the period late spring to early summer, however, some harvesting appears to have been carried out from both tents <u>and</u>

Figure 86.

Summary of resource scheduling for combined feature types

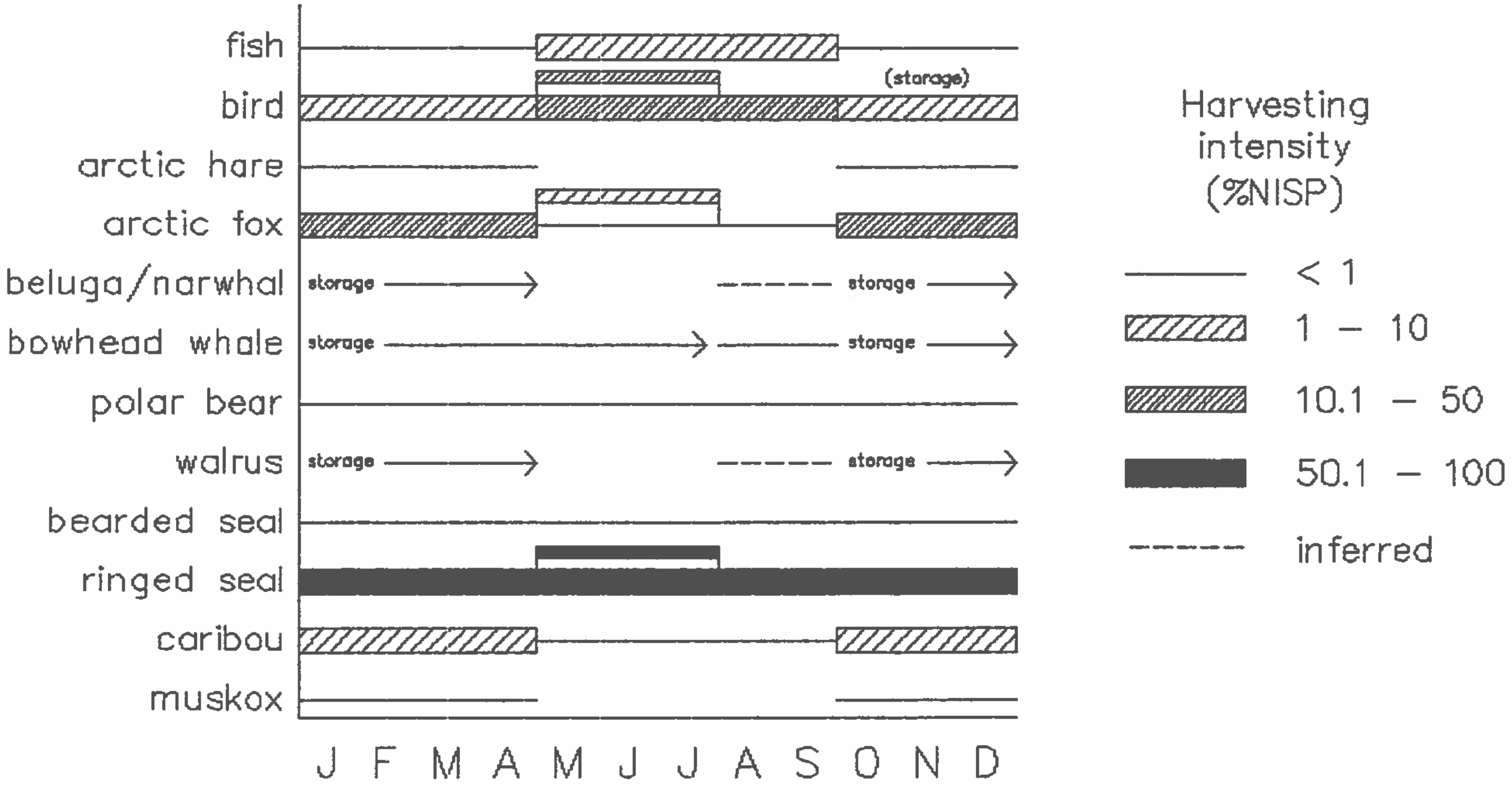
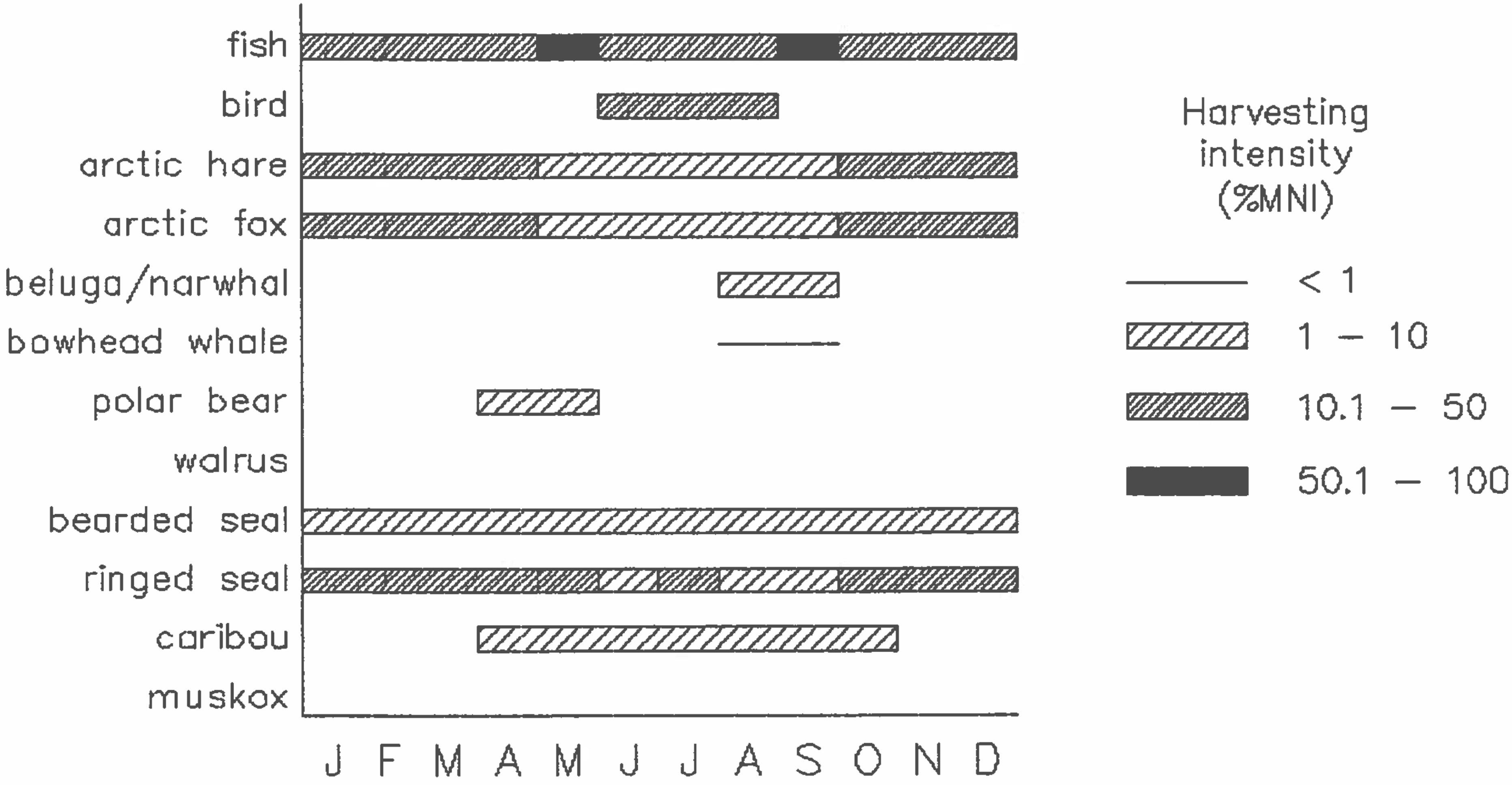


Figure 87.

Model of resource scheduling



qarmat. It is also possible that logistical hunting parties operated throughout the period of sunlight and warm weather, but that these expeditions left their remains outside the site area. Fish, which are abundant elsewhere during August and September, and caribou, the hides of which are coming in to prime condition at this time, would have been obvious target resources. This would have presented a scheduling conflict for groups dependent on bowhead whales and other large marine mammals which are only available during the open water season, so the procurement of fish and caribou may have been neglected (proportional to the dependence on whales). Only the coastal portion of such a logistical settlement component is represented in the sample (approximately May to July, illustrated in the small upper bar), at which time harvesting concentrated on nesting waterfowl, basking ringed seal, and possibly fox (see above).

At the main warm weather residential sites, ringed seal, bird and fish predominate (in terms of NISP). Fox, bear, caribou and bearded seal were harvested in lower frequencies, but large mammals may be significantly underrepresented due to intensive culling. Some species appear in "out of season" winter features (certain birds, beluga/narwhal, bowhead whale, walrus), and are assumed to have been stores put up during summer and fall, as indicated in Figure 86. Two of these did not also occur in the appropriate seasonal features, but must have been harvested at this time. Bowhead whales have not been considered in this faunal analysis, but their presence in sodhouses and *qarmat* is indicated, although "harvesting intensity" was not estimated because their NISP was not available.

The portion of the graph from October to April represents harvested and stored food remains recovered from the winter houses. Proportional harvesting activity within this period has not been broken down further. In spite of the fact that most ringed seals were procured in late winter and spring, seals probably constituted the focal resource throughout the period. Similarly, some birds would have been available throughout the winter, although in greatest abundance at the beginning and end of sodhouse occupation. Data to assess the precise seasonality of other species were not available. Most of these secondary species could have been harvested opportunistically at any point during the winter.

5. ASSESSING THE MODEL

Having developed an idea of the probable organization of Thule resource scheduling in the study area based on the zooarchaeological analysis, it is now possible to examine the results of the model constructed in Chapter 3 and assess the degree of fit between the simulated and prehistoric situations. The optimal solution to the linear programming model is presented below, followed by an analysis of binding constraints and post-optimality data, a test of the model against the zoooarchaeological data through a comparison of the two sets of results, and a discussion of the overall utility of the exercise.

Model Predictions

The objective function (minimizing the stated costs of the suite of resources selected in the optimal solution) and model constraints (nutritional composition and non-food value of resources subject to minimal requirements) were entered on SAS in the linear equation (or inequation) form demonstrated in Chapter 3. A problem with the linear programming package on SAS, and another that was tried initially but could not handle a problem of this magnitude (LINDO PC), is that the solution may select variables (resources) in fractional amounts. Thus the first optimal solution, presented in Table 42, poses presents some interpretive problems for the archaeologist. The left hand column lists the resource, followed by season, the "column activity", the upper bound on the amount of that resource that was allowed for that season, the seasonal cost of the resource, the "reduced cost", "+ range", and "- range". Column activity here refers to the number of the resource that were actually selected in the optimal solution. Reduced cost, + range, and - range are discussed in

Table 42: Linear programming model of resource scheduling (bowhead<2)

species	month	column activity	upper bound	cost	reduced cost	+ range (%)	- range (%)
arctic char (*Salvelinus alpinus*)							
	Jan	17	17	10.4	-63.5	610.8	
	Feb-April	50	50	9.8	-64.1	654.3	
	May	100	100	8.2	-65.7	801.5	
	June	100	100	5.7	-68.2	1196.8	
	July-Aug	200	200	5.1	-68.8	1349.4	
	Sept	100	100	5.6	-68.3	1220.0	
	Oct-Dec	133	133	8.1	-65.8	812.6	
birds (*Aves sp*)							
	Nov-Jan	0	20	135.9	120.4		88.6
	Feb-March	0	20	125.8	110.3		87.7
	April	0	10	110.0	94.5		85.9
	May	0	20	23.6	8.1		34.2
	June	60	60	13.5	-2.0	15.0	
	July	60	60	3.4	-12.1	356.8	
	Aug	60	60	12.1	-3.4	28.4	
	Sept	0	40	21.9	6.4		29.1
	Oct	0	20	118.8	103.3		86.9
arctic hare (*Lepus arcticus*)							
	Oct-Jan	40	40	40.6	-5.9	14.4	
	Feb-March	20	20	38.1	-8.4	21.9	
	April-Sept	60	60	37.9	-8.6	22.6	
beluga (*Delpinapteras leucas*)							
	Aug-Sept	5	5	407.1	-2013.2	494.5	
narwhal (*Monodon monoceros*)							
	Aug-Sept	5	5	1159.0	-2572.9	222.0	
bowhead whale (*Balaena mysticetus*)							
	Aug-Sept	1.7	2	136017.0	0	0	0
wolf (*Canis lupus*)							
	Nov-Jan	0	3	13763.8	13439.1		97.6
	Feb-March	0	4	12512.5	12187.8		97.4
	June-Sept	0	4	4179.1	3854.4		92.2
	Oct	0	1	4597.0	4272.3		92.9
arctic fox (*Alopex lagopus*)							
	Oct-Jan	40	40	33.4	-64.1	192.0	
	Feb-April	30	30	17.8	-79.7	447.9	
	May-Sept	50	50	30.3	-67.2	221.9	

Table 42: Linear programming model of resource scheduling (bowhead<2) - cont'd

species	month	column activity	upper bound	cost	reduced cost	+ range (%)	- range (%)
polar bear (*Thalarctos maritimus*)							
	Jan	0	2	8820.0	6052.2		68.6
	Feb	0	2	12240.0	9472.2		77.4
	March	0	2	12200.0	9432.2		77.3
	April	2	2	2600.0	-167.8	6.5	
	May	2	2	2640.0	-127.8	4.8	
	June-July	0	4	4400.0	1632.2		37.1
	Aug-Sept	0	2	12300.0	9532.2		77.5
	Oct-Dec	0	4	8400.0	5632.2		67.1
walrus (*Odobenus rosmarus*)							
	Aug-Sept	0	1	20586.0	15373.4		74.7
bearded seal (*Erignathus barbatus*)							
	Oct-Jan	5	5	514.8	-216.3	42.0	
	Feb-April	15	15	468.0	-263.1	56.2	
	May	5	5	393.0	-338.1	86.0	
	June	5	5	333.0	-398.1	119.6	
	July-Sept	15	15	544.5	-186.6	34.3	
ringed seal (*Phoca hispida*)							
	Nov-Jan	75	75	63.9	-376.4	589.1	
	Feb-March	70	70	58.1	-382.2	657.9	
	April	35	35	54.0	-386.3	715.4	
	May-June	35	35	66.1	-374.2	566.1	
	July	30	30	149.0	-291.3	195.5	
	Aug-Sept	25	25	301.5	-138.8	46.0	
	Oct	25	25	173.8	-266.5	153.4	
caribou (*Rangifer tarandus*)							
	Nov-Jan	0	5	4624.8	3054.2		66.0
	Feb-March	0	5	4282.3	2711.7		63.3
	April	5	5	977.8	-592.8	60.6	
	May	10	10	946.5	-624.1	65.9	
	June-July	10	10	484.2	-1086.4	224.4	
	Aug	10	10	742.8	-827.8	111.4	
	Sept	10	10	182.4	-1388.2	761.1	
	Oct	4.1	10	1570.6	0	0	0
muskox (*Ovibos moschatus*)							
	Nov-Jan	0	3	1617.0	184.4		11.4
	Feb	0	1	1540.0	107.4		7.0
	March-April	0	2	1550.0	117.4		7.6
	May-June	0	2	2580.0	1147.4		44.5
	July	0	1	1550.0	117.4		7.6
	Aug	0	1	1544.4	111.8		7.2
	Sept	0	1	1550.0	117.4		7.6
	Oct	0	1	2677.5	1244.9		46.5

the post-optimality analysis.

The solution calls for char to be procured to its upper limits at all times of the year (17 in January, 50 for the period February-April, etc.). Birds are only predicted to their upper bounds in June-August, and not at all in fall, winter and early spring. Arctic hare are predicted to their upper bounds for every period, as are beluga and narwhal. Bowhead whale, however, is the resource on which the solution hinges, for it was selected at a rate of 1.7 animals. While this figure could be simply rounded up to 2 animals, this actually would represent a more costly, non-optimal solution, for the objective function (total cost) would increase accordingly, as would surpluses of the required nutrients. This situation also pertains to the harvesting of caribou in October, when activity is 4.1. If this figure were rounded down to four animals, the objective function and the nutrients actually acquired would change very little, and it would still represent essentially an optimal solution. Bowhead, however, represents a much larger, more costly, nutritional package, so the 0.3 animals that are added by rounding up to 2 represent a cost of almost 41 000, equivalent to 11.6 % of the total cost of the solution.

There are two ways around this problem. One approach is to accept the fractional value for what it is, a relative value and an approximation. The nutritional requirements as described are for a hypothetical community of arbitrary size. If population and total requirements were increased moderately, it is easy to imagine a situation in which a combination of resources including two whales exactly fulfilled annual requirements. Alternatively, one could consider this figure as an average annual harvest prediction. The surplus put up in years when two or more whales were acquired could see the community through years when the hunt was less successful. This seems to be a more realistic scenario than one in which the community is constrained to take two, and only two, whales each year. Population structure would have varied year to year, with correlative changes in the number of experienced hunters, and total site population, so requirements and harvesting potential would have been greater in some years and less in others. The cost value for whales (and all other resources) is an approximate, average value. Harvesting strategies would have mapped year to year fluctuations in the costs and opportunities provided by the environment. This approach to interpreting the optimal solution is felt to be most satisfactory, and is adopted below, but not before an alternative pair of models is considered.

The second approach is to reformulate the model by setting a precise figure for the number of bowheads which must be procured, and letting other resources vary around this constraint. Rounding off the original activity figure for bowhead to 2, the model was run again with the constraint that 2 bowheads must be procured. The results are presented in Table 43. This did not solve the problem completely, for now narwhal, February-April bearded seal, and winter muskox occur as fractional values, of 2.6, 0.5, and less than 2.1, respectively. Now, however, the objective function would not be so drastically altered if narwhal were rounded up, muskox rounded down to 2, and bearded seal rounded down to 0 for this season (although we end up short half a bearded seal skin on the NFV1 requirements).

Resetting the bounds of bowhead whale in this manner had effects on the column activity of a number of other resources. Char, hare, beluga, fox and ringed seal are still harvested at their limits in every season, and bird only in the late spring and summer. The nutritional value that

Table 43: Linear programming model
of resource scheduling (bowhead=2)

species	month	column activity	upper bound	cost	reduced cost	+ range (%)	- range (%)
arctic char (*Salvelinus alpinus*)							
	Jan	17	17	10.4	-19.3	185.6	
	Feb-April	50	50	9.8	-19.9	203.1	
	May	100	100	8.2	-21.5	262.2	
	June	100	100	5.7	-24.0	421.1	
	July-Aug	200	200	5.1	-24.6	482.4	
	Sept	100	100	5.6	-24.1	430.4	
	Oct-Dec	133	133	8.1	-21.6	266.7	
birds (*Aves sp*)							
	Nov-Jan	0	20	135.9	114.3		84.1
	Feb-March	0	20	125.8	104.2		82.8
	April	0	10	110.0	88.4		80.4
	May	0	20	23.6	2.0		8.5
	June	60	60	13.5	-8.1	60.0	
	July	60	60	3.4	-18.2	535.3	
	Aug	60	60	12.1	-9.5	78.5	
	Sept	0	40	21.9	0.3		1.4
	Oct	0	20	118.8	97.2		81.8
arctic hare (*Lepus arcticus*)							
	Oct-Jan	40	40	40.6	-15.7	38.7	
	Feb-March	20	20	38.1	-18.2	47.8	
	April-Sept	60	60	37.9	-18.4	48.5	
beluga (*Delpinapteras leucas*)							
	Aug-Sept	5	5	407.1	-344.6	84.6	
narwhal (*Monodon monoceros*)							
	Aug-Sept	2.6	5	1159.0	0	0	
bowhead whale (*Balaena mysticetus*)							
	Aug-Sept	2	2	136017.0	93774.4		68.9
wolf (*Canis lupus*)							
	Nov-Jan	0	3	13763.8	13244.3		96.2
	Feb-March	0	4	12512.5	11993.0		95.8
	June-Sept	0	4	4179.1	3659.6		87.6
	Oct	0	1	4597.0	4077.5		88.7
arctic fox (*Alopex lagopus*)							
	Oct-Jan	40	40	33.4	-164.3	491.9	
	Feb-April	30	30	17.8	-179.9	1010.7	
	May-Sept	50	50	30.3	-167.4	552.5	

Table 43: Linear programming model of resource scheduling (bowhead=2) - cont'd

species	month	column activity	upper bound	cost	reduced cost	+ range (%)	- range (%)
polar bear (*Thalarctos maritimus*)							
	Jan	0	2	8820.0	6453.5		73.2
	Feb	0	2	12240.0	9873.5		80.7
	March	0	2	12200.0	9833.5		80.6
	April	0	2	2600.0	233.5		9.0
	May	0	2	2640.0	273.5		10.4
	June-July	0	4	4400.0	2033.5		46.2
	Aug-Sept	0	2	12300.0	9933.5		80.8
	Oct-Dec	0	4	8400.0	6033.5		71.8
walrus (*Odobenus rosmarus*)							
	Aug-Sept	0	1	20586.0	15333.4		74.5
bearded seal (*Erignathus barbatus*)							
	Oct-Jan	0	5	514.8	46.8		9.1
	Feb-April	0.5	15	468.0	0	0	0
	May	5	5	393.0	-75.0	19.1	
	June	5	5	333.0	-135.0	40.5	
	July-Sept	0	15	544.5	76.5		14.0
ringed seal (*Phoca hispida*)							
	Nov-Jan	75	75	63.9	-515.5	806.7	
	Feb-March	70	70	58.1	-521.3	897.2	
	April	35	35	54.0	-525.4	973.0	
	May-June	35	35	66.1	-513.3	776.6	
	July	30	30	149.0	-430.4	288.9	
	Aug-Sept	25	25	301.5	-277.9	92.2	
	Oct	25	25	173.8	-405.6	233.4	
caribou (*Rangifer tarandus*)							
	Nov-Jan	0	5	4624.8	3299.8		71.4
	Feb-March	0	5	4282.3	2957.3		69.1
	April	5	5	977.8	-347.2	35.5	
	May	10	10	946.5	-378.5	40.0	
	June-July	10	10	484.2	-840.8	173.6	
	Aug	10	10	742.8	-582.2	78.4	
	Sept	10	10	182.4	-1142.6	626.4	
	Oct	0	10	1570.6	245.6		15.6
muskox (*Ovibos moschatus*)							
	Nov-Jan	2.1	3	1617.0	0	0	
	Feb	1	1	1540.0	-77.0	5.0	
	March-April	2	2	1550.0	-67.0	4.3	
	May-June	0	2	2580.0	963.0		37.3
	July	1	1	1550.0	-67.0	4.3	
	Aug	1	1	1544.4	-72.6	4.7	
	Sept	1	1	1550.0	-67.0	4.3	
	Oct	0	1	2677.5	1060.5		39.6

was being sought in narwhal, however, is now reduced, so this resource is not exploited at its upper bound. Similarly, bearded seals are no longer so important for food, and are only harvested in sufficient numbers to fulfill non-food requirements. Polar bear, two of which were procured in each of April and May in the first solution, are excluded from the "2-bowhead" solution. Caribou procurement is reduced to nil in October, but occurs at the same levels as before in other seasons. Muskox are now added to the solution in all seasons except May-June and October, replacing the skins lost by the reduction in caribou and polar bear. Overall, this rescheduling of harvesting activity only resulted in an increase in the objective function of 4.4 %, rather than the 11.6 % that would have resulted from simply increasing bowhead to 2 in the first solution, due to the payoffs from reducing the nutritional emphasis placed on other resources.

A second version of this approach was also investigated, which produced even more interesting results. The model was reset with the requirement that exactly one bowhead be included in the solution. The result of this run was an infeasible solution. All resources were procured at their upper bounds at all seasons (at tremendous "cost") without fulfilling the nutritional requirements of the hypothetical community.

In other words, given the environmental parameters laid out in the original formulation, a community of the modelled size could not fulfill its nutritional requirements by harvesting only one bowhead per year. *Assuming all constraints were accurately set*, this implies that *a Thule whaling community which failed to procure more than one whale in each of several successive seasons would be forced to place such heavy demands on* *other foodstuffs that it would soon deplete local resource populations and be forced to abandon the Hazard Inlet region.* The qualification "assuming all constraints were accurately set" is the operative phrase here. These results may actually point in the other direction, to inaccuracies and inadequacies in the model's parameters, discussed below. For the purposes of subsequent discussion, the original "unbounded-bowhead" solution is considered the optimal solution to the problem as initially conceived. The proportions of resources it indicates are those which are compared with the zooarchaeological evidence.

Binding Constraints

The nutrients and hides actually acquired in the original and 2-bowhead versions of the model are shown in Tables 44 and 45. In the former version a surplus was acquired of all constraints except calcium and NFV2 (light-duty hides), and in the latter version calcium, NFV1 and NFV2 were acquired at exactly the required levels. These constraints constitute the *binding constraints* in the respective solutions. If the requirements for these variables were reduced, the objective function (cost) would also be reduced. The overall shape of the solutions is determined by the optimization of these, the most costly, requirements. The infeasible 1-bowhead solution must be understood to be dependent on the reality of the requirements and availabilities set for only one of these constraints, namely calcium.

Calcium also emerged as a binding constraint in Keene's models for Boothia Peninsula and the Michigan Archaic. Although it is possible that calcium requirements have been set too high, he notes that only an extreme reduction in calcium needs would remove it from the list of binding constraints (1981:166). In fact, calcium is considered by southern health

Table 44: Summary of linear programming constraints (bowhead<2)

constraint	requirement	activity	surplus (%)
cost	MINIMIZE	350 342.7	n/a
kilocalories	44 840 300.0	268 598 354.3	599.0
protein (g)	1 069 450.0	7 775 144.5	727.0
fat (g)	456 250.0	25 656 598.6	5623.4
calcium (mg)	10 074 000.0	10 074 000.0	0
vitamin A (I.U.)	86 140 000.0	1 201 821 223.8	1395.2
thiamine (mg)	23 177.5	422 796.4	1824.2
riboflavin (mg)	24 637.5	130 174.2	528.4
vitamin C (mg)	631 450.0	3 896 955.4	617.1
iron (mg)	240 900.0	2 065 037.1	857.2
heavy duty hides	40.0	74.5	186.3
light duty hides	243.0	243.0	0

Table 45: Summary of linear programming constraints (bowhead=2)

constraint	requirement	activity	surplus (%)
cost	MINIMIZE	365 922.5	n/a
kilocalories	44 840 300.0	269 188 339.5	600.3
protein (g)	1 069 450.0	7 449 976.1	696.6
fat (g)	456 250.0	25 745 836.0	5642.9
calcium (mg)	10 074 000.0	10 074 000.0	0
vitamin A (I.U.)	86 140 000.0	1 023 402 371.9	1188.1
thiamine (mg)	23 177.5	484 748.8	2091.5
riboflavin (mg)	24 637.5	118 816.4	482.3
vitamin C (mg)	631 450.0	3 831 797.1	606.8
iron (mg)	240 900.0	2 095 114.5	869.7
heavy duty hides	40.0	40.0	0
light duty hides	243.0	243.0	0

workers in the arctic to be a critically scarce nutrient at the present (Draper 1977, Kuhnlein 1990).

Alternatively, calcium availability in foodstuffs may have been underestimated. For instance, hunters at Clyde River indicated that traditionally most of the bones of ptarmigan were actually consumed along with soft tissue (Whitridge 1991 - Clyde River field notes). The consumption of fish bones, and perhaps the leaching of calcium from bones in broths should also increase calcium intake. Michelle Dupuis (personal communication) indicated that women at Lake Harbour encouraged gnawing on bones during meals, which might also supplement calcium intake. Some combination of reduced requirements and increased calcium content of foods may alter the degree to which calcium constrains the solution, but the relative difficulty of fulfilling calcium needs appears to be a fact of arctic subsistence.

The other constraining variables were light-duty hides in the first version, and both kinds of hides in the 2-bowhead solution. This also replicates Keene's results for the arctic and midwest, although in his model for Boothia Peninsula the total hide requirement was lower than for this model (300 hides). From our ethnographic knowledge of Inuit clothing needs, it does appear that hides, and caribou hides in particular, are a critical resource, although not a constraining one in some environments. The practises of, for instance, the Polar Eskimo, who relied on polar bear skin for winter clothing, are more striking for their uniqueness than anything else. It should be considered, however, that there is a difference between perceived needs for a commodity such as caribou hides, and physically inescapable requirements. Polar bear skins were used as a caribou substitute in at least one case, and could have done so in the past, as could other resources such as fox. The extremely high frequencies of fox in the Somerset Island Thule assemblages examined by Rick (1980), and low frequencies of caribou, may be such an instance of one substituting for the other (Savelle and McCartney 1988:27-28). The importance of adequate clothing in the arctic should not be minimized, however. If caribou skins were perceived to be essential for winter clothing, then they would have been acquired at any cost, whether by trade or long distance hunting expeditions.

Postoptimal Analysis

The "reduced cost" (Keene's shadow price) figures in Tables 42 and 43 provide postoptimal data which are useful for assessing the stability of the modelled predictions. Simply put, for resources which were not included in the optimal solution, the reduced cost represents the amount of reduction necessary in the resource cost before a hypothetical hunter would be willing to acquire one of those resources. Thus the cost of one bird in the period October-December would have to decrease by at least 6.4 for bird to be included in the optimal solution at this season.

Where a resource was included in the optimal solution, the reduced price will be zero or a negative value. If it was zero, as for bowhead whale and October caribou, then any increase in resource cost will reduce utilization of this resource or increase the objective function, and any decrease in cost will increase its utilization and decrease the objective function. The implication for bowhead whale procurement is that this species is at the cost limit hunters are willing to pay, but they are constrained to harvest more than one animal to satisfy their nutritional requirements. For those resources with a negative reduced cost, the value indicates the maximum increase in cost a resource could undergo, and still be included in the optimal solution at a net benefit for the objective function. Thus ringed seal could increase in cost by 386.3 in April, and a hunter would still be willing to acquire an additional individual, and including it in the optimal solution would lower the objective function.

Reduced cost is often translated into the percentage increase or decrease a resource must undergo to alter the objective function. These values are listed in Tables 42 and 43 under the headings "- range" for resources which must decrease in cost to be included in the optimal solution, and "+ range" for those which would be added to the solution (if their upper bounds were increased) even at greater costs. The results for the unbounded-bowhead model indicate great variation in the sensitivity of the cost estimates for different species. Fish produced uniformly high + ranges, indicating that even extremely large increases in the cost estimates (on the order of 650 to 1350 %) would not alter the inclusion of this species in the optimal solution. Bird, on the other hand, alternates between + and - ranges, some of which are fairly low. Thus fairly small cost decreases would lead to the incorporation of bird in the solution for May and September. Hare produced uniformly low + ranges, which suggests errors in cost estimation may have severely effected the occurrence of this species in the solution. Beluga, narwhal, wolf, fox, walrus and ringed seal all produced large + or - ranges, and are unlikely to change with slight alterations to the model parameters. Bowhead, polar bear, bearded seal, caribou and muskox, as well as bird and hare, all had low range values at one or more seasons, and are thus most sensitive to slight fluctuations in costs or requirements. Indeed, in the "2-bowhead" version of the model (Table 43), all except hare were selected in different amounts. In a real harvesting scenario, procurement of these resources would be most likely to fluctuate according to such situational variables as chance encounters, or the immediate food requirements of the community.

Zooarchaeological Test

The linear programming predictions are fairly congruent with the zooarchaeological data, although they differ in several respects (cf. Figures 86 and 87). Note that the graphic summary of the model in Figure 87 illustrates "harvesting intensity" in %MNI. Since the linear programming model does not incorporate assumptions about carcass transport, MNI can be considered equivalent to NISP under the ideal conditions of the model. For the zooarchaeological summary (Figure 86), NISP was felt to be a more accurate indicator of the proportions of species harvested than MNI. The wide range of amounts of edible tissue represented by one individual of each species should be kept in mind when considering the %MNI values depicted in Figure 87.

The model's predictions of as intensive fish harvesting as possible at all seasons is not matched by an abundance of fish remains in any of the assemblages. As several researchers have noted, however, abundant evidence for fishing technology at Thule sites may not be matched by abundant fish remains (Savelle and McCartney 1988:30, Sabo 1991). If fish were procured in large quantities, they were not returned to the features at Hazard Inlet. Conceivably, fish procurement and consumption were contemporaneous, and occurred elsewhere. The modelled predictions indicate the degree to which Thule groups may have been willing to adapt their seasonal positioning strategy to exploit char runs. The numbers of available char modelled for the immediate study area, however, are probably too high.

Although the model indicates bird harvesting <u>only</u> during the spring and summer, the generally greater frequency of birds in the tent ring and qarmat assemblages than in the winter houses is not inconsistent with the predictions. At least part of the avian assemblage from the winter houses must have been procured in summer or fall and cached, as several species would have been unavailable in winter. The model failed to take into account the apparent abundance of some species, such as fulmar, in the study area late in the season (i.e. until at least early fall)

Hare were predicted to occur at much greater frequencies during all seasons than was actually the case, although the relatively greater importance of this species in winter than other seasons was predicted. However, the precise seasonality of hare harvesting cannot definitely be established from the faunal analysis, because this species' occurrence in the very large Sodhouse 2 assemblage does not preclude its deletion from the other much smaller samples by various taphonomic processes. The abundance estimates for hare do, however, appear to be too high.

Beluga and narwhal were predicted at greater frequencies than they actually occurred. That any of these animals should be taken at all was an interesting implication of the model, as both of these species are rare or absent in most Eastern Arctic Thule faunal assemblages (although narwhal ivory is fairly common in artifact assemblages, ivory was not a requirement of this model). The skeletal elements represented in the Sodhouse 2 sample are congruent with maximum culling of these animals' carcasses, which would tend to depress their frequency in all samples.

Wolf was not selected in the optimal solution and does not appear to be represented in the faunal assemblages.

Fox are predicted at their upper bounds in all seasons. Fox were, in fact, the second most common mammalian species in the samples, and appear to have been more frequently harvested from the winter houses than the qarmat or tent rings. The zooarchaeological and modelled results were very similar for this species.

Bear was present in low frequencies in both the qarmat and winter houses, and not at all in the tent rings. The model's predictions of preferential harvesting in early spring appears to underestimate the availability, or overestimate the cost, of bears during the mid spring to early fall occupation of the qarmat.

Walrus was not selected in the optimal solution, and its unique occurrence in Sodhouse 2 is not conclusive evidence of regular harvesting, although walrus would certainly have been hunted if and when they were encountered.

Bearded seal is selected at its upper bounds in all seasons, matching the occurrence of this species in both qarmat, and one winter house assemblage. The very low NISP:MNI ratio in the *qarmat* indicates intensive culling of skeletal elements, while somewhat greater transport and/or deposition occurred at the sodhouses. The low level and ubiquity of bearded seal harvesting predicted by the model is not dissimilar to the zooarchaeological results.

Ringed seal was selected at its upper bounds for all seasons, which is closely paralleled by its abundance in all of the faunal samples. The extremely high frequencies of late winter and early spring kills indicated by the dental annuli data were not specifically incorporated in the modelled upper bounds, but are suggested by a consideration of the extreme insensitivity of seal procurement at this season to increase in cost, indicated by the postoptimal analysis. The relatively low "intensity" (%MNI) of modelled ringed seal harvesting is mostly due to the effects of a high MNI for fish during most of the year, and birds as well in summer.

Caribou frequencies in the faunal assemblages are somewhat ambiguous, but seem to indicate slightly higher emphasis on this species at the winter houses than the qarmat. The model predicts most harvesting would occur from late spring to early fall, but caching of caribou could account for the reversal of this phenomenon in the faunal assemblages.

Muskox was very rare in the faunal sample, ambiguously represented by only teeth, and were not selected in the optimal solution. These results are not incongruent.

Discussion

The question of whether this application of linear programming to an archaeological case was "successful" can now be addressed. In a detailed discussion of the benefits and liabilities of archaeological modelling generally, and linear programming in particular, Keene points out that "The validity of a particular model is determined by the purpose of that model and must be evaluated relative to that purpose." (1985b:241). This test application of linear programming was designed to explore the usefulness of the technique for understanding Thule resource scheduling on Somerset Island, and more generally the feasibility of implementing similar quantitative models of Eskimo subsistence economies. In light of these broadly framed goals, the exercise had both positive and negative results. These can be broken down into two categories: explanatory and heuristic.

One way in which the explanatory potential of linear programming would have been realized is if the model had provided a very close match with the zooarchaeological data, after taking into account taphonomic biases and possible inadequate sampling. In this instance, the basic premise of the model would have been supported, and could be tentatively assumed to hold true until subsequent research disproved it. The Thule subsistence economy could thus be explained as an efficient (cost-minimizing) solution to a nutritional problem posed by the environment. This premise might then be extended to other geographic regions and other time periods, as a means of predicting resource scheduling under changing circumstances.

In this respect, the model was not entirely successful. Although there were some points of congruence between the zooarchaeological results and the optimal solution, important differences between them would seem to preclude unequivocal acceptance of the dietary cost-minimizing premise. One might then conclude that socially regulated cultural practises not identified in the model's parameters appear to have played a significant role in determining Thule resource scheduling in the area. In other words, if the procedure was satisfactorily operationalized, then the optimization hypothesis is at least partially refuted. Even this result has explanatory value, in that it demonstrates the inadequacy of at least one possible (and widely advocated) explanation of prehistoric subsistence behaviour.

This conclusion is rendered problematic, however, by the likelihood of errors in the formulation of the model's constraints. The most important of these is the estimation of resource cost, which was compromised by the inadequacy for the purposes of the model of the ecological database. In addition, incomplete data on the nutritional content of foods, and the availability of particular nutrients (especially calcium) from these foods, may have introduced biases into these estimates. Beyond these technical problems, the cost formula itself suffers from an "implausibility effect". Even if a perfect data set were available, and the results were perfectly congruent (or significantly incongruent) with zooarchaeological data, would most researchers agree that nutritional optimization (or lack of optimization) had been demonstrated? This assessment ultimately devolves upon fundamental beliefs (often elaborated by high level theory) about the degree of constraint placed on human activity by the environment. Undoubtedly, any number of objections could be raised, and the problem left basically unsolved.

The essentially ambiguous results of this hypothesis test tend to suggest that linear programming is probably not appropriate in an explanatory or predictive framework. An enormous effort would be required to generate the data necessary to derive relatively unambiguous cost estimates. Some researchers have incorporated determinations of the time and physical effort, expressed in caloric expenditure, required by particular extractive tasks into optimality models (Johnson and Behrens 1982, Jones and Madsen 1989). But even if someone accomplished the probably impossible task of conducting experimental time allocation studies on the procurement of all local resources at all seasons with Thule technology, other variables would remain unquantified, such as various dimensions of risk, and the accuracy of paleoecological reconstructions.

In effect, the specific results generated by this type of linear programming problem are too fine-grained for the data on which it is built. Nevertheless, if the results are conscientiously interpreted in a broad, rather than literal, fashion, valuable implications may be derived from the postoptimality analyses of reduced cost. The general relationship of costs and benefits in a given harvesting strategy may be revealed, but in many cases not the precise costs or efficiency of these strategies. The approach thus appears to be useful for generating insights and hypotheses, which might then be explored through other avenues.

This last point leads to a consideration of the second category of results of this exercise, namely its heuristic value. Much is made by archaeological practitioners of linear programming of the original interpretive insights that derive from the modelling process, in spite of mediocre explanatory/predictive results:

> ...it is often stated that the optimal solution to a linear programming problem is not as important to decision makers as the marginal data provided through postoptimality analysis, and this holds true for archaeological applications. The question of whether or not people optimize is not, perhaps, as important to analysis as the analytical statement of the total set of relations among resources, needs, and costs in the subsistence system. (Reidhead 1980:179).
>
> Perhaps the value of such models is not best seen in a purely hypothetico-deductive framework, but as heuristic devices. They do not necessarily prove anything or make predictions to specific degrees of accuracy. Their major value is that they force us to recognize the actual complexities inherent in the societies we study and to focus on important interrelationships between variables. (Keene 1985a:180).

These statements, while apologies for the overextension of data inherent in archaeological linear programming, aptly encapsulate the major results of the test conducted here. While it is not difficult for the modeller to accept the "predictions" which match the zooarchaeological data, and rationalize those which do not, such an approach sacrifices replicability of results, the major strength of the method for its intended applications in other disciplines.

The rationale for the use of models in archaeology is avoidance of precisely this sort of *post hoc* accommodation of explanations to data.

What Keene and Reidhead suggest, however, is that the modelling process itself may be beneficial, as a means of exploring an overly complex amalgamation of data (ethnographic, nutritional, zooarchaeological, ecological, etc.) which intuitively seems as though it should demonstrate significant cross-correlations, but which we lack the tools to analyze by traditional methods. Linear programming may thus be less useful for testing hypotheses, than for generating hypotheses, indicating problematic areas for future study, or revealing weaknesses in our data (Reidhead 1979). From this perspective, the Thule test did generate positive results.

First, It tends to confirm Keene's conclusions, and modern nutritional observations, that calcium is a scarce, and possibly limiting, nutrient for arctic groups dependent on hunted game. That in spite of this observation much of the arctic has been continuously occupied for over 4000 years suggests either a physiological adaptation on the part of Eskimos to low calcium intakes (by lowered requirements or more efficient metabolic uptake), or inattention by nutritionists to alternative sources of calcium in arctic foodstuffs, such as through complete or partial consumption of some animal bones.

Secondly, granted that our knowledge of calcium intake is imperfect, the unique status of fish as a relatively cheap source of concentrated calcium suggests the degree of effort Thule groups may have been willing to expend to procure this resource, even from some distance. In light of abundant evidence for fishing technology at sites in the Hazard Inlet region, this conclusion implies that the relative scarcity of fish remains should be viewed sceptically, and the possibility of logistical fish procurement camps explored more closely.

Thirdly, again cautioning against uncritical acceptance of calcium as a binding constraint on Thule subsistence, the infeasibility of the "1-bowhead" version of the model suggests further investigation is warranted of the viability of Thule harvesting strategies in those regions, such as southeastern Somerset Island, that were vacated at about the time whaling appears to have been abandoned. It is possible that relatively scarce nutrients (not necessarily restricted to calcium) available in concentrated form in whale viscera, for example, were essential to the entire community's diet.

Fourthly, interpretation of the other binding constraint in the optimal solution, "light duty" hides, is less dependent on ambiguous nutritional data. Adequate warm and waterproof clothing is crucial to arctic survival. Polar bear, favoured by the Polar Eskimo and Sadlermiut as a substitute for the preferred skin of fall-killed caribou, was not abundant in the samples. Fox was fairly common and, as at other Thule sites, seems generally to vary inversely with caribou abundance (Savelle and McCartney 1988). The overall frequency of fox, however, is substantially lower than at other Thule sites on Somerset Island (Rick 1980). At Thule sites in the High Arctic, fox frequencies are also often higher, or are balanced by higher frequencies of polar bear, than was observed in the Hazard Inlet samples (McCullough 1989, Park 1989). The linear programming model thus successfully identified a problematic area in our understanding of Thule resource procurement, and points to clothing technology, and the satisfaction of clothing needs in caribou-poor regions, as areas worthy of further investigation. Specifically, the relative insulating qualities and durability of fox skins, the potential for trade in caribou skins between Hazard Inlet and Boothia Peninsula or

Prince of Wales Island, and the possibility of direct logistical procurement of caribou from one of these regions by Hazard Inlet Thule, are possible avenues of research.

These problems and hypotheses are all interesting and valuable products of the linear programming exercise, as is the conclusion that specific resource scheduling predictions are probably beyond the scope of this sort of archaeological application. The question remains, however, whether these results are consonant with the effort that was involved in formulating the model. In this instance a major portion of the groundwork had already been laid by Keene, in estimating ecological, demographic and nutritional parameters. Because his study area was so close to the present one, it was possible to adapt his model by relatively minor additions of species, some adjustments of his estimates, and conversion of his raw published data into an appropriate form for the computer to process. Nevertheless, this involved substantial time and research, in addition to becoming familiar with the linear programming technique, simple as Keene claimed it to be. If it had been necessary to derive every estimate from scratch, in addition to conducting a detailed zooarchaeological analysis, this test would probably not have been feasible within the framework of an MA thesis.

Herein lies a paradox in the notion of the "heuristic value" of linear programming. An explicit goal of this application of the method was to test its accuracy in a situation where rich zooarchaeological and contextual data were available. For this purpose, it could not be considered a failure if the exercise produced ambiguous results, since the issue is precisely the presence, or degree, of ambiguity in the results. Because these results could be compared to fairly secure zooarchaeological data, areas of strength and weakness in the model could be recognized.

If such comparative data were <u>not</u> available, however, the researcher would be left wondering how to interpret the model's "predictions". He or she might accept Keene's and Reidhead's assurances that the true value lies in the postoptimality analysis, but here as well some standard is needed to gauge the strength of even apparently clear postoptimal tendencies. Given the ambiguous results of this test case, and Keene's disclaimer of the predictive value of linear programming, can the approach seriously be recommended for other case studies? Would someone really devote so much time and energy to an "educational experience", when the results are almost certain to be tendentious? For most purposes of subsistence modelling, the answer is probably no. An area which has not been thoroughly explored, however, is the place of this sort of modelling within the general methodology of scientific research.

Although a great deal of the theoretical literature since the advent of the New Archaeology has been devoted to epistemological issues of validity and inference in hypothesis-testing, the equally important problem of hypothesis generation has tended to be underplayed. For all the precision and explicitly formulated research designs advocated by New and processual archaeologists, the development of ideas has been more or less relegated to some obscure black box. If the generation of useful hypotheses ("good ideas") is ignored, then the circle of scientific inquiry (hypothesis -test - evaluation - new hypothesis) is left open, lacking guidelines with which to initiate the cycle. The origination of scientific research thus appears to be solely a matter of creative insight and virtuosity, and potentially inaccessible to some. The use of linear programming, or similar models that require the consideration of a wide range of variables and types of data against which they must be tested, by their nature draw connections, and indicate problem areas, which may not have been intuitively apparent. Thus in spite of the shortcomings of linear programming, and allied quantitative approaches, it harbours an unexplored potential for explicit use in the generation of hypotheses, beyond a vaguely construed, and tenuous, "heuristic value". Ultimately, one could imagine the explicit incorporation of an abstracted version of this sort of quantitative modelling in a "hypothesis generation phase" of every research design.

6. CONCLUSIONS

The research presented here is essentially a continuation and elaboration of recent efforts to understand the Thule occupation of the Eastern Arctic through an examination of the ecological context of Thule subsistence economies (e.g. Savelle 1987, Savelle and McCartney 1988, Park 1989, Stenton 1989). Thule studies seem particularly amenable to this kind of approach for a number of reasons: 1) Conceptually, "Thule culture" is partly an ecological construct to begin with, due to Mathiassen's identification of it with a maritime adaptation. 2) Mathiassen's definition has engendered the core debate in Thule studies, most often honoured in the breach, over the role of bowhead whaling as an impetus for the initial migration, and in subsequent regional adaptations. 3) The average state of preservation, and abundance, of faunal remains on Thule sites is probably the best for any known archaeological culture. 4) Because the overwhelming majority of Thule diet, and material culture, was derived from animal products, faunal remains represent essentially the entire subsistence economy. 5) The arctic environment places greater physical constraints on human adaptation than more temperate environments (e.g. agriculture and pastoralism are severely limited). 6) Ecological models based on animal behaviour can be more directly applied to hunter-gatherer subsistence, than that of pastoralists or agriculturalists. 7) There is a detailed ethnographic record for Inuit and other Eskimo groups, which provides close analogues for some aspects of Thule society. Because sustained contact with Europeans occurred relatively late, these accounts are relatively more detailed than for "early contact" periods elsewhere, and thus offer the potential for testing archaeological models. 8) Many economic practises have continued from Thule times to the present, and so can be studied, and models tested, using ethnoarchaeological and direct historical approaches.

Recent postprocessual attacks on ecological archaeology notwithstanding, it is incontrovertible that ecological theory generally affords a perspective on Thule prehistory consonant with the available database. It is further argued that the Thule archaeological record is an ideal arena for testing such ecological models, for the reasons outlined above. It is crucial that new approaches be tested, both for Thule archaeology to progress along the ecological avenues now being opened up, and to refine ecological applications elsewhere. The research reported here represents such a test of the particular merits of linear programming for elucidating Thule diet and resource scheduling.

The results of the exercise indicate that the benefits of linear programming may be too little to justify its widescale application to other regions and time periods in the arctic. Although it stimulated several hypotheses concerning Thule subsistence, the data available for estimating model parameters are probably inadequate for the fine grained simulation that is generated, and the assumption of optimizing behaviour too equivocal to be resolved in a reasonable test of the model's results. What became apparent in the course of analysis, is that this sort of linear programmming problem cannot accommodate the wealth of zooarchaeological data actually available, while it depends on other sorts of data which are unreliable or essentially unavailable. The implications of the zooarchaeological analysis, hardly explored here, extend in numerous interesting directions, while the hypotheses generated by the linear programming model would tend to shackle further research to the narrow problem of "binding constraints".

The basic conclusion from this research then, is that detailed zooarchaeological analysis, even with the maligned goal of simply reconstructing the subsistence economy, appears to offer a much more fertile approach to Thule archaeology than the formal model that was tested against it. This is not to advocate a sort of historical zooarchaeology. Subsistence reconstruction should only be the first step in more penetrating investigations of Thule society in its entirety. Given the aptness of an ecological approach to Thule prehistory, and the demonstrably intimate articulation of Eskimo ecology, social organization, and ideology (Wenzel 1991), it is argued that zooarchaeological analyses grounded in ecological theory could provide a springboard to the social-symbolic core of Thule culture.

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APPENDIX B: RINGED SEAL ELEMENT FREQUENCIES, MEAT UTILITY INDEX, AND TRANSPORT INDEX

RINGED SEAL MNEs

	MNE by feature							
element class (number in skeleton)	SH2	F25	F9	F11	F1	F2	F3	F4
cranium (1)	35	7	1	1	1	3	2	-
mandible (2)	78	3	1	6	3	2	8	1
hyoid (9)	17	6	-	-	-	-	-	-
atlas (1)	24	3	-	1	-	-	-	-
axis (1)	29	4	-	3	-	-	-	-
cervical 3-6 (4)	99	5	-	9	-	-	-	-
cervical 7 (1)	24	-	-	2	-	-	-	-
unident. cervical (7)	-	-	-	-	-	-	4	-
thoracic 1 (1)	21	-	-	2	-	-	-	-
thoracic 2 (1)	12	-	-	1	-	-	-	-
thoracic 3-10 (8)	124	10	6	8	-	-	-	-
thoracic 11-15 (5)	101	11	1	7	-	-	-	-
unident. thoracic (15)	4	-	-	-	-	5	4	-
lumbar vertebra (5)	100	5	1	14	-	1	1	-
sacral vertebra 1 (1)	29	-	-	1	-	-	-	-
sacral vertebra 2 (1)	23	-	-	1	-	-	-	-
sacral vertebra 3 (1)	21	-	-	-	-	-	-	-
sacral vertebra 4 (1)	23	-	-	-	-	-	-	-
unident. sacral (4)	-	-	-	-	-	-	1	-
caudal vertebra 1-2 (2)	60	1	2	3	-	-	-	-
caudal vertebra 3+ (10)	70	-	-	2	-	-	-	-
unident. caudal (12+)	-	-	-	-	-	2	1	-
scapula (2)	86	4	3	4	2	2	4	-
humerus (2)	90	2	3	5	1	4	3	-
radius (2)	71	2	2	7	2	4	3	-
ulna (2)	68	3	2	7	-	2	4	-
carpal accessory (2)	9	1	5	-	-	-	-	-
carpal radial (2)	22	2	1	-	-	-	-	-
carpal ulnar (2)	13	1	2	-	-	-	-	-
carpal 1 (2)	22	3	2	-	-	-	-	-
carpal 2 (2)	7	4	-	-	-	-	-	-
carpal 3 (2)	11	4	-	-	-	-	-	-
carpal 4 (2)	10	3	1	-	-	-	-	-
metacarpal I (2)	36	9	1	2	-	-	2	-
metacarpal II (2)	36	3	1	-	-	-	-	-
metacarpal III (2)	23	3	-	3	-	-	-	-
metacarpal IV (2)	19	-	1	1	-	-	-	-
metacarpal V (2)	28	1	1	2	-	-	-	-
front/hind phalanx (56)	862	63	29	41	-	-	8	-

RINGED SEAL MNEs (cont'd)

	MNE by feature							
element class (number in skeleton)	SH2	F25	F9	F11	F1	F2	F3	F4
rib (30)	642	36	21	81	1	10	21	-
costal cartilage (30)	209	20	4	11	-	4	2	-
sternabra 1 (1)	8	-	-	1	-	-	-	-
sternabra 2-8 (7)	81	-	-	14	-	-	-	-
sternabra 9 (1)	7	-	-	5	-	-	-	-
sternabra 10 (1)	8	-	4	5	-	-	-	-
unident. sternabra (10)	-	-	-	-	-	3	2	-
innominate (2)	88	4	1	3	1	2	3	-
bacculum (1)	10	1	2	-	-	-	-	-
femur (2)	83	7	2	4	2	4	4	-
patella (2)	31	4	2	1	-	-	-	-
tibia (2)	114	5	15	14	-	2	3	-
fibula (2)	133	8	32	25	-	2	4	-
astragalus (2)	45	2	1	2	-	-	1	-
calcaneum (2)	36	3	-	1	-	-	-	-
tarsal central (2)	39	2	-	-	-	-	1	-
tarsal 1 (2)	28	2	-	-	-	-	1	-
tarsal 2 (2)	18	1	-	-	-	-	1	-
tarsal 3 (2)	23	4	1	1	-	-	-	-
tarsal 4 (2)	33	1	3	-	-	-	-	-
metatarsal I (2)	47	3	3	2	-	1	1	-
metatarsal II (2)	41	4	3	1	-	-	2	-
metatarsal III (2)	53	1	4	4	-	-	1	-
metatarsal IV (2)	23	6	-	-	-	-	1	-
metatarsal V (2)	45	3	3	-	-	-	1	-
front/hind phalanx (56)	862	63	29	41	-	-	8	-

RINGED SEAL MAUs *

element class (number in skeleton)	MAU by feature SH2	F25	F9	F11	F1	F2	F3	F4
head (1)	43.0	6.0	2.0	4.0	2.0	3.0	4.0	1.0
cervical vertebra (7)	25.1	1.7	-	2.1	-	-	0.6	-
thoracic vertebra (15)	17.5	1.4	0.5	1.2	-	0.3	0.3	-
lumbar vertebra (5)	20.0	1.0	0.2	2.8	-	0.2	0.2	-
pelvis (1)	46.0	2.0	2.0	3.0	1.0	1.0	2.0	-
rib/cost. cart. (30)	21.4	1.2	0.7	2.7	0.03	0.3	0.7	-
sternabra (10)	10.4	-	0.4	2.5	-	0.3	0.2	-
scapula (2)	43.0	2.0	1.5	2.0	1.0	1.0	2.0	-
humerus (2)	45.0	1.0	1.5	2.5	0.5	2.0	1.5	-
radius/ulna (2)	35.5	1.5	1.0	3.5	1.0	2.0	2.0	-
front flipper (2)	18.0	4.5	2.5	1.5	-	-	1.0	-
femur/patella (2)	41.5	3.5	1.0	2.0	1.0	2.0	2.0	-
tibia/fibula (2)	66.5	4.0	15.0	11.0	-	1.0	2.0	-
hind flipper (2)	26.5	3.0	2.0	2.0	-	0.5	1.0	-

* calculated for the carcass portions utilized
in the scatterplots with log %MUI and Clyde %MAU

MEAT UTILITY AND TRANSPORT INDICES *

element class (number in skeleton)	key	log %MUI	Clyde %MAU
head (1)	HE	1.44	22.2
cervical vertebra (7)	CV	1.55	22.2
thoracic vertebra (15)	TV	1.40	65.2
lumbar vertebra (5)	LV	1.52	88.9
pelvis (1)	PE	1.65	75.0
rib/cost. cart. (30)	RI	2.00	90.4
sternabra (10)	ST	0.43	100.0
scapula (2)	SC	1.30	85.7
humerus (2)	HU	1.03	85.7
radius/ulna (2)	RU	0.68	85.7
front flipper (2)	FF	0.36	66.7
femur/patella (2)	FE	0.65	75.0
tibia/fibula (2)	TF	1.22	62.5
hind flipper (2)	HF	0.89	37.5

* calculated for the carcass portions utilized
in the scatterplots with ringed seal MAUs

Aves continued

Alcidae: alcids

Uria lomvia thick-billed murre
Cepphus grylle black guillemot

Strigidae: owls

Nyctea scandiaca snowy owl

Alaudidae: larks

Eremophila alpestris horned lark

Corvidae: ravens and allies

Corvus corax raven

Motacillidae: pipits

Anthus spinoletta water pipit

Fringillidae: finches

Carduelis hornemanni hoary redpoll

Emberizidae: sparrows, buntings and allies

Calcarius lapponicus lapland longspur
Plectrophenax nivalis snow bunting

Mammalia mammals (Banfield 1974)

Leporidae: rabbits and hares

Lepus arcticus andersoni arctic hare

Muridae: rats, mice, voles and lemmings

Lemmus sibiricus trimucronatus brown lemming
Dicrostonyx torquatus clarus collared lemming

Monodontidae: beluga and narwhal

Delphinapterus leucas beluga
Monodon monoceros narwhal

Delphinidae: dolphins and porpoises

Orcinus orca killer whale

Mammalia continued

Balaenidae: right and bowhead whales

Balaena mysticetus bowhead whale

Canidae: dogs and allies

Canis lupus arctos arctic wolf
Alopex (Vulpes) lagopus innuitus arctic fox

Ursidae: bears

Ursus (Thalarctos) maritimus polar bear

Mustelidae: weasels and allies

Mustela erminea arctica ermine
Gulo gulo wolverine

Odobenidae: walrus

Odobenus rosmarus walrus

Phocidae: true (earless) seals

Erignathus barbatus barbatus bearded seal
Phoca hispida ringed seal

Cervidae: deer and allies

Rangifer tarandus pearyi Peary's caribou

Bovidae: cattle, sheep, goats and allies

Ovibos moschatus muskox

APPENDIX A: SOMERSET ISLAND FAUNA

Osteicthyes bony fishes (Sekerek et al 1976)

Salmonidae: salmon and allies

Salvelinus alpinus arctic char

Cottidae: sculpins

Gymnocanthus tricuspis arctic staghorn sculpin
Myoxocephalus quadricornis fourhorn sculpin
Myoxocephalus scorpioides arctic sculpin
Myoxocephalus scorpius shorthorn sculpin

Gadidae: cod

Boreogadus saida polar cod

Aves birds (Robbins et al 1983)

Gaviidae: loons

Gavia arctica arctic loon
Gavia stellata red-throated loon

Procellariidae: tubenoses

Fulmarus glacialis northern fulmar

Anatidae: waterfowl

Anserinae: swans, geese and allies
Cygnus columbianus tundra swan
Branta canadensis Canada goose
Branta bernicla brant
Anser albifrons greater white-fronted goose
Chen (Anser) caerulescens snow goose

Anatinae: ducks
Somateria mollissima common eider
Somateria spectabilis king eider
Clangula hyemalis oldsquaw
Melanitta nigra black scoter

Acciptridae: hawks, eagles and allies

Buteo lagopus rough-legged hawk
Aquila chrysaetos golden eagle

Aves continued

Falconidae: falcons and allies

Falco rusticolus gyrfalcon
Falco peregrinus peregrine falcon

Phasiande: ptarmigans and allies

Lagopus lagopus willow ptarmigan
Lagopus mutus rock ptarmigan

Gruidae: cranes

Grus canadensis sandhill crane

Charadriidae: plovers

Pluvialis dominica lesser golden-plover
Pluvialis squatarola black-bellied plover
Charadrius semipalmatus semipalmated plover

Scolopacidae: sandpipers, surfbirds, plovers and allies

Phalaropus fulicaria red phalarope
Arenaria interpres ruddy turnstone
Calidris maritima purple sandpiper
Calidris melanatos pectoral sandpiper
Calidris canutus red knot
Calidris alpina dunlin
Calidris alba sanderling
Calidris fuscicollis white-rumped sandpiper
Calidris bairdii Baird's sandpiper
Calidris minutilla least sandpiper
Calidirs pusilla semipalmated sandpiper

Laridae: jaegers, gulls, terns and allies

Stercorariinae: jaegers and allies
Stercorarius parasiticus parasitic jaeger
Stercorarius pomarinus pomarine jaeger
Stercorarius longicaudus long-tailed jaeger

Larinae: gulls
Larus hyperboreus glaucous gull
Larus thayeri Thayer's gull
Rissa tridactyla black-legged kittiwake
Xema sabini Sabine's gull

Sterninae: terns
Sterna paradisaea arctic tern