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Regional Zooarchaeology and Global Change: Problems and Potentials

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Abstract

Zooarchaeology is a potentially critical tool for the reconstruction of past regional landscapes. The subfield is increasingly being asked to contribute to long-term studies of human interaction with the environment associated with national and international investigations of past and future global change. Intersite comparison of animal bone collections (archaeofaunas) is central to such regional approaches. However , zooarchaeologists have identified many factors of deposition, attrition, recovery, and analysis that might appear to make such comparisons problematic. Using selected examples drawn from the North Atlantic and Eastern Arctic, this paper suggests that, while intersite comparison is not a trivial problem, it may be possible to compare animal bone collections effectively if we carefully match our research questions to our data resources.

Keywords: Eastern Arctic, historical ecology, North Atlantic, North Atlantic Bio-cultural Organization (NABO), zooarchaeology

Introduction: new opportunities for zooarchaeology

Zooarchaeology (or archaeozoology) has many disciplinary goals articulated in standard textbooks and review publications (Bogan and Robinson 1987; Casteel 1976b; Davis 1987; Hesse and Wapnish 1985; Klein and Cruz-Uribe 1984; Luff 1984; Rackham 1994; Wheeler and Jones 1989). Animal bone collections have been employed in biogeographic searches for rare species identifications, quantification and data management experiments, the investigation of Quaternary taphonomic processes, the reconstruction of paleoenvironments, and the reconstruction of past human decisions (interacting with the behavior and biology of past animal populations). These are all inherently worthwhile pursuits, and all engage the time and interest of most practicing zooarchaeologists to a greater or lesser degree.

However, in recent years zooarchaeologists have been increasingly asked to use their data and expertise to contribute to large-scale integrative projects and national or international initiatives that go beyond the normal confines of the discipline. With the proliferation of international programs investigating past, present, and possible future environmental change on the global scale, zooarchaeologists (as well as archaeologists, paleoecologists, historians, and geographers) are now being invited to contribute to the creation of plans for long-term sustainable development of resources by agencies and managers on the national and international level (McCauley and Meier 1991: 23–26). At the same time, many theoretical thinkers, dissatisfied with the increasingly sterile debates between processual and post-processual perspectives, are proposing new attempts to integrate the rich data resources of the former with the cognitive sophistication of the latter. Within anthropology this evolving movement is variously called *Historical Ecology* (Crumley 1994; Balee in press) or *Political Ecology* (Park and Greenberg 1994). Clear parallels exist in the environmental history movement (Cronon 1983, 1991; Crosby 1986, 1994), and extensive cross-fertilization between anthropology, history, geography, archaeology, evolutionary ecology, and paleoecology is a central part of the movement's agenda. This broad intellectual movement has been explicitly linked to a widely perceived need for a more effective social science contribution to environmental management (Crumley 1994: 243). The development of political/historical ecology and the increasing involvement of social scientists in global environment change initiatives are thus directly and explicitly connected (McGovern 1995). Arctic and North Atlantic zooarchaeology has already played a key role in the evolving agenda of historical and political ecology, and forms a core of a series of funded circumpolar interdisciplinary programs (Amorosi 1992, 1995; Amorosi et al. 1994, in press; Buckland et al. 1996; Ingimundarson 1995; McGovern 1994; Serjeant 1991).

Problems for discussion

In attempting to respond to requests for practical information relating to long-term human resource use, zooarchaeologists need to consider together whether their basic data and analytical tools can really sustain the demands of the regional and temporal synthesis required. If there is now a prospect that our common research may be used to inform decisions that may potentially affect a great many living human beings, then we have an obligation to work together to ensure that the interpretative accounts we contribute are the best our discipline can provide. This debate should transcend existing regional and temporal specializations, as the issue of the productive use of zooarchaeological data by environmental planners is too important to be restricted to the few research groups who have thus far found themselves involved in global change programs. While northern research teams have played a formative role in such work thus far, we are very conscious that we represent only a portion of the zooarchaeological community, and one normally considered well out of the mainstream of the discipline. This paper represents an attempt to widen the discussion of the appropriate use of zooarchaeological data in the context of dynamic landscape reconstruction and to use a series of examples drawn from northern research projects to illustrate points that may be of general interest.

Given all that we have learned in the past three decades about the effects of different attritional pathways, depositional contexts, excavation and recovery methods, identification and recording methods, the meaningful comparison of two or more archaeofaunas (i.e., excavated archaeological bone collections; see Grayson 1984; Lyman 1987, 1994) may appear problematic. The industriousness of the taphonomists has tended to emphasize many factors of differential attrition and recovery that make every site collection unique in one respect or another (Behrensmeyer 1993; Behrensmeyer and Hill 1980; Binford 1978, 1981; Bonnichsen and Sorg 1989; Brain 1981; Gifford 1981; Hudson 1993; Jones 1991; Koch 1989; Lyman 1994; Schafer 1972; Shipman 1981). Each site, and each locality within a site will inevitably experience somewhat different taphonomic processes at some scale. Perfect similarity between different archaeological contexts (or between recovery or analytic techniques) is unrealistic to expect in any area or time period. We must find workable, real-world approaches to the comparison of inevitably uneven and disparate collections, or abandon altogether the effort of regional and temporal synthesis. It may be that we will find that it is possible to develop data protocols and collection comparability measures similar to those recently adopted by northern palynologists and sedimentologists (Anderson et al. 1993) and gain the scientific credibility properly associated with such practical, community-based standards. It may also be that some skeptical assessments (e.g., Jones 1991) are correct, and that we will be forced to admit that our basic data are so inadequate and fragile that valid intersite or intercontext comparisons are rarely possible. If animal bone collections cannot be reasonably employed in intersite comparisons, or even in the comparison of different localities within a single site, then there would appear to be little justification for participation by zooarchaeologists in any multidisciplinary endeavor that requires a regional perspective, and we should retire from ambitious interdisciplinary co-operation.

This research group has been deeply involved in interdisciplinary research through its affiliation with the North Atlantic Biocultural Organization (NABO 1992, 1993, 1994). We take the deliberately hopeful position that such multicontext comparisons arc both feasible and productive—if they are carried out with an informed understanding of the limitations as well as the potentials of the basic zooarchaeological data. This short paper explores some of the factors affecting the reasonable use of zooarchaeological data in a regional perspective and seeks to provoke a wider debate on problems of practical approaches to the comparison of excavated bone collections.

All archaeofaunas are not equal

No zooarchaeologist would now be willing to assume that all site collections that arrive at their lab are equally useful or interesting, and many now routinely take steps to flag both "good" and "bad" bone collections during analysis. Most large-scale research or commercial zooarchaeology laboratories now employ increasingly explicit screening procedures designed to identify contexts that may be mixed or otherwise compromised. As many of us have discovered, it is all too possible to invest a great amount of scarce time and resources on the analysis of collections lacking proper stratigraphic control, temporal resolution, or adequate sampling and recovery in excavation. Most zooarchaeological data management packages now regularly include a battery of taphonomic indicators (such as percentage of whole bones, ratios of very dense to less dense elements, burning, carnivore chewing, mean fragment size; for example, see McGovern and Amorosi 1989). These procedures and indicators are designed to identify collections that are not likely to repay intensive analytical effort and those already processed collections whose characteristics suggest extreme attrition (such as collections composed almost entirely of teeth and very dense skeletal elements). Without determining the nature of taphonomic variability, it is too easy to assume that observed species or element distributions entirely reflect human activity (for discussion, see Klein and Cruz-Uribe 1984; Marean 1991; Maltby 1985; Rackham 1994). It might be useful systematically to compile and compare these existing practical (generally unpublished) screening protocols and attritional indicators built into different zooarchaeological quantification packages.

However, not all types of archaeological sites are equally useful for zooarchaeologists attempting regional comparison or landscape analyses, even if they are equally rich in bone and equally well excavated. This is not just a problem of sample size or recovery but a fundamental issue of depositional context and site type. Urban archaeological contexts have generated some of the world's largest archaeofaunas, but their interpretation in the context of a regional landscape presents some challenges. As the excellent papers edited by Hall and Kenward (1994) demonstrate, rural production strategies and urban provisioning needs interact in complex ways, making the interpretation of rural farming patterns based on urban pit-fill contexts a hazardous enterprise (see also Biddick 1989; O'Connor 1996). On the other end of the scale are very small, low-intensity sites formed by a long series of brief occupations (each producing a very small bone residue). These types of sites likewise create serious problems in quantification and interpretation for the analyst. While these very small sites have the potential for combination into a general regional perspective, in practice they have often been treated individually, with resulting problems of interpretative equifinality that can depress expectations for zooarchaeology as a whole (cf. Winters 1969).

However, many sites are between these two (influential) extremes. Many excavated archaeofaunas come from rural production sites (villages, individual farms, or long-term base camps) that have generated substantial collections far smaller than the urban archaeofauna but far larger than the sparse low-intensity sites. These sorts of rural production and consumption centers have a better chance of retaining some record of a larger range of past economic behaviors with less of the skewing effects of either high residential mobility or intensive craft specialization. This is of course the sort of site context that dominates the North Atlantic and to a smaller degree the Eastern Arctic, and this prevalence may indeed affect our optimism about zooarchaeological comparison just as the urban and low-intensity site contexts have fostered pessimism among other equally (but differently) experienced workers. It may be that some types of archaeological site produce collections that are inherently difficult to work with, despite the skills and ingenuity of the zooarchaeologist. We need to develop better ways of matching site type with research question. It is unrealistic to assume that urban pit fills, farm or village middens, or briefly occupied rock-shelters will all produce directly comparable data suitable for the same range of research problems.

Recovery concerns

In the past two decades the standards of recovery for animal bone have improved dramatically. Where sieving was once rare (Casteel 1972; Payne 1972, 1975; Thomas 1969, 1972), it is now standard, and debates now tend to center on the efficiency of particular mesh sizes and sampling strategies rather than simply repeating demonstrations that some sieving is good for recovery (Casteel 1976a, 1976b; Clermont 1994; Goldberg 1989; Jones 1991; Levitan 1983, 1984; Mantle et al. 1984; Turner 1984). While it may be tempting simply to exclude from all comparative studies any unsieved collection, or any collection not sieved to a particularly high standard (e.g., 4 mm mesh dry sieve versus 50 micron mesh wet sieve), this sort of methodological purity has significant practical drawbacks. Fine-mesh sieving may be simply impossible on some sites (e.g., clay soils and no practical local water source), and in every case every reduction in sieve mesh size is associated with dramatic increases in the time and labor allocated to sieving. For the site director invariably faced with a short season, limited funding, and a very finite pool of labor for all excavation tasks, this forces a choice between finer mesh sieving of a small excavation area and coarser mesh sieving of a much larger excavation area (or a radically stratified sampling program that leaves major portions of the site effectively unsieved). Since all modern excavators are aware of the multiple dangers of sampling by narrow, dark, and restrictive pits, and most excavators have adopted some variant of an open area approach as a preferred excavation strategy, any sieving program not prepared to handle large soil volumes will rapidly generate significant backlogs despite a major allocation of site labor. In our experience, when hard-pressed excavators discover that 40–50 percent of their workforce is occupied by sieving, and that bags of deposit continue to mound around the sieving station, they will tend to take precipitate action to recover control—usually involving direct dumps to the backdirt pile or spoil heap. An overly ambitious sieving strategy has the potential to cripple excavation and may well produce a tiny archaeofauna derived from a small (and possibly very unrepresentative) portion of the site. Such outcomes serve neither excavator nor zooarchaeologist, and we should anticipate that excavators will continue to adapt recovery programs to specific local problems and resources. Sieving strategies are thus not likely ever to reach some uniform standard, and we might better consider ways of creatively using zooarchaeological data sets generated by somewhat different recovery strategies (Smith 1976).

Integrating older collections

The integration of data from collections created by previous generations of excavators with those from more recent work likewise requires careful thought. While some excavations prior to 1960 expended considerable effort to recover very small fragments of unmodified animal bone (for example, Vebaek 1992), most employed no systematic sieving program whatever and often assigned animal bone recovery a low priority. If we simply exclude all older collections, we not only jettison work that would usually be prohibitively expensive to repeat today (even assuming the sites have survived), but we also may endanger a valid regional perspective. In the case of Norse Greenland, an approach that rigorously excluded all archaeofaunas that were collected prior to systematic sieving would reduce a potential pool of nearly fifty collections to only four. These four recently excavated collections derive from one corner of what was probably a single parish, and include one of the richest and one of the poorest farms in the district. Without the background provided by older collections (some excavated 1932–34), these collections would give a profoundly misleading impression of regional settlement and subsistence patterns (McGovern 1992b). If we are to attempt a regional perspective, we will have to work with the inevitably uneven data as it exists and try to develop strategies that help us match research questions with collection characteristics.

Different questions, different samples, different applications

If all sites are not equal, then neither are all research questions. Some questions are inherently easier to address than others, regardless of the skills or resources of the analyst. Large, well-excavated, and meticulously documented bone collections are always more desirable than small, poorly excavated, and inadequately recorded collections. However, in a particular research context, the immediate value of an archaeofauna is directly connected to the nature and difficulty of the research questions being asked. Even small, poorly documented collections can to some degree answer simple biogeographic present/absent questions. After all, one unicorn bone in a collection would be interesting, even in a small "bad" collection! Even very large collections may not fully support questions like "how many breeds of sheep were present in level Via, and which of them were domestic?" Research questions can thus rank archaeofaunas as effectively as any internal characteristic. Perhaps rather than focusing upon a search for a few "ideal" collections capable of addressing all possible research questions, we might explore means for identifying and ranking the research questions of immediate concern and then matching different archaeofaunas to different types of questions.

Table 1 presents a draft of one such approach. This matrix explicitly uses sheer sample size, here the number of identified specimens per taxon (or NISP; Grayson 1984) as a measure of the general utility of archaeofaunas for addressing different types of stated research questions. Similar tables might be constructed using sieving quality, temporal resolution, or abundance of particular taxa as the major variable and a different list of research questions down the lefthand column. Particular collections could be rated (ideally by their analysts) not for their universal value but for their applicability to a particular research problem. While sample size and recovery quality may be important ranking variables, they will not be the only ones. For example, if the stated research questions are related to the investigation of the interaction of sea-bird hunting and sealing, very large, well-documented inland sites might score very low in the matrix if they do not contain bones of the relevant taxa.

Table 1. Rural production consumption site midden deposits (assumes roughly comparable excavation and recovery): ranking scores 0–10

Sample size	Small (< 300 NISP)	Medium (300–1000 NISP)	Large (1–10,000 NISP)	Huge (10–100,000+)
Species present list	1	5	10	10
Major taxa relative %	0	10	10	10
Age at death: harvest profile	0	1	5	10
Metrical analysis: sex, breed, nutrition	0	1	5	10
Paleodiet: Kcal produced for human consumption	0	0	0	0

Note: While sample size is not the only measure of the relative value of an archaeofauna, it is one of the most easily (and nonconfrontationally) assessed characters. Sample size can provide one axis of a possible site assessment matrix, and research questions can form another. Other things being equal, "big is better" for most research topics, but at a certain point a huge sample may be no more efficient for answering a particular research question than a merely large collection. The last research question is essentially impossible: as many have demonstrated, any attempt to reconstruct paleodiet (in Kcal or other measures) from these sorts of secondary or tertiary deposits will be futile no matter what the sample size. It should be possible to create analogous scoring matrices, for which region-specific research questions are matched with graded site and archaeofauna characteristics (sieving mesh and proportion, column vs. open area excavation, etc.).

Sample size issues

While sample size is far from the only issue affecting the general utility of an archaeofauna, it is certainly a central and important issue. Sample size per layer, per site, or other unit of comparison may be the single most important factor in overcoming the taphonomic "noise" created by all the agents of differential attrition and deposition. Collections below some minimum sample size may be inherently so "noisy" as to be useful only for generating species lists, and then only the most common taxa. All other factors being equal, the larger the collection, the greater the range of research questions it can address. What are less clear are the approximate cut-off points for comparability in the context of a particular research problem. How large must an archaeofauna be to provide a reasonably accurate assessment of the relative importance of the major taxa (those together making up 60–80 percent of the total)?

Figure 1 presents one approach to this problem. Stratified middens of the small Greenlandic Norse site W 48 Niaquusat generated a large archaeofauna that may be divided into four phases (Arneborg 1991b; McGovern et al. 1983). The collection from the latest phase (dated to AD 1300–1350) from the main excavation units (total 12 sq. meters, average thickness of these layers was 20–40 cm) was mainly composed of the bones of cattle, caprines, caribou, and seals. The major taxa from the phase totaled just over 3,600 fragments that could be identified as deriving from one of the four major taxa, and the relative percentages (derived from the NISP counts) came to about 1 percent cattle, 9 percent caprine, 5 percent caribou, and 85 percent seal for the whole unit. However, smaller subsamples of the total excavated collection give different relative percentages, despite the relatively homogeneous nature of the midden deposit (a variety of tests fail to demonstrate marked clustering in the horizontal depositional patterning of these major taxa). An attractively simple graphical approach to the investigation of the effect of subsamples on overall sample patterning may be borrowed from forestry practices (Hardesty 1977). If we calculate the relative percentages for a single square meter, then add the bones from a second square meter and recalculate percentages, then repeat the process until we reach the total excavated area, we can produce a graph of the changes in calculated relative frequency of the four major taxa (Fig. 1). Note that while relative percentages initially change dramatically as additional sample squares are added to the growing collection total, a point is reached (around 5 sq. meters of area and c. 300–400 NISP) where new bags of bones no longer change the calculated relative frequency much. After a level of approximately 300–400 bone NISP is reached, adding additional samples of bones does not seem to affect what has become a stable, essentially "flat" pattern of relative abundance.

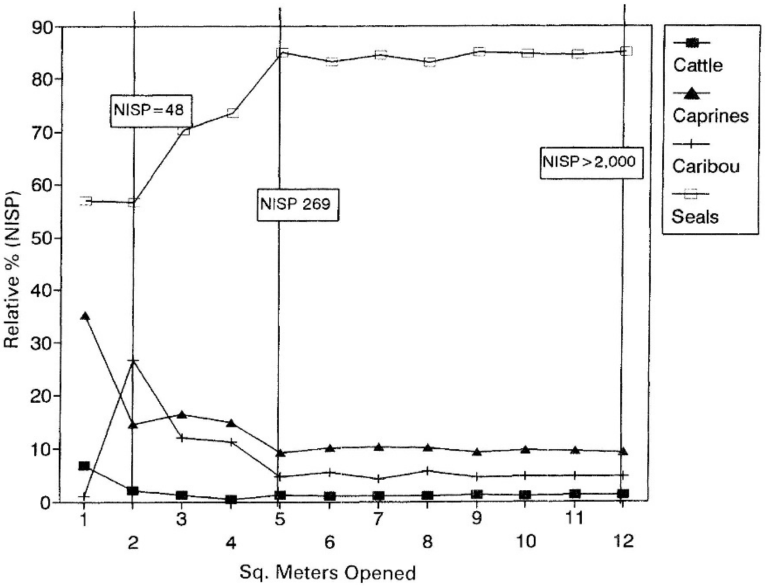

Figure 1. W48 Phase 4. The uppermost layers from the deeply stratified midden associated with the small farm site W48 Niaquusat in the Western Settlement in Greenland were excavated in separate 1-meter squares. By adding the bone counts for the major taxa from each square together and successively recalculating the relative percentages, we can get a visual impression of the point at which an expansion of the sample size ceases to alter the relative percentages of these major taxa significantly.

A second example drawn from the nearby Greenlandic Western Settlement site W51 Sandnes, a high-status manor farm approximately 8 km from W48 (McGovern et al. 1996) may provide another illustration of this approach (Fig. 2). Similar midden deposits provided a similar range of major taxa but in a different mix. In phase 4 (c. AD 1200–1250), cattle composed about 13 percent of major taxa, caprines 19 percent, caribou 23 percent, and seals 45 percent (all calculated on NISP, total NISP for phase = 1,627, major taxa = 884). As Figure 2 indicates, these relative percentages also stabilize around 5–6 square meters of excavated deposit, again around 300–400 NISP. In both these cases, sample characteristics appear to have neared population characteristics for these most common taxa around 300–400 NISP. While these experimental results may not transfer directly to other types of deposits in other regions, they provide some basis for a decision by this research team to set a lower minimum limit of c. 300 NISP for sample sizes of archaeofaunas to be used in intersite comparisons of major taxa. Note that this exercise has focused entirely upon the most common taxa within these collections. Less common taxa (such as the single arctic fox bone recovered from this phase) would require a much larger total sample size to match sample with putative population, and this may not be feasible in most situations. Very low-frequency taxa will always be inherently hard to quantify, except as "rare."

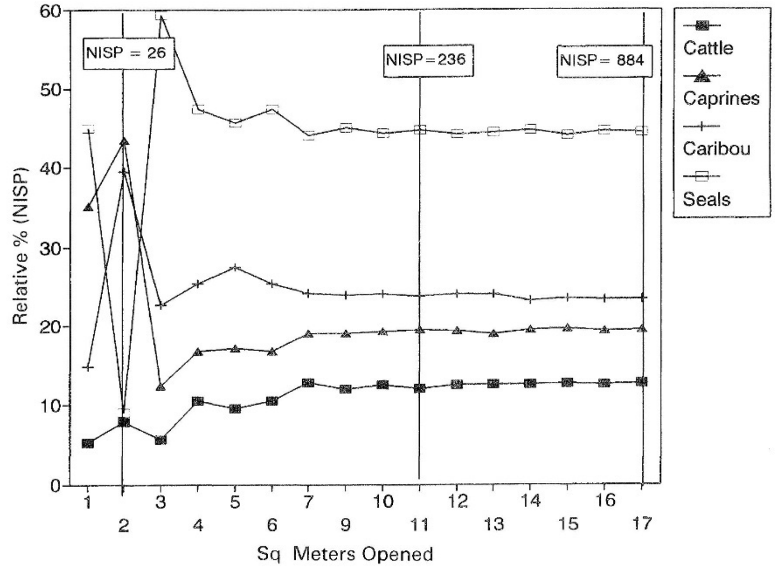

Figure 2. W51 Phase 4. Layers dating to c. AD 1200–1250 from the stratified midden associated with the large manor farm W51 Sandnes in the Western Settlement of Greenland were excavated in a similar manner to those of W48 in Figure 1. The same procedure of adding bone counts for successive excavation units produces a profile similar to that produced for the Phase 4 collection from the smaller site, despite the somewhat different proportions of the same major taxa.

For this research question (relative abundance of major taxa as a measure), and these types of midden deposit, it seems to make little difference if we use the total collection or a 300–500 NISP subset. Other areas and other types of deposits will certainly require different approaches and will probably suggest different minimum sample size points for major taxa comparison. Other workers will undoubtedly devise tests more directly relevant to their particular collections and research problems. There is no single "magic number" for intersite comparability, but we feel that such numbers do exist—we just need to be very clear about what magic we intend to work with them.

Quantification forever?

The last two decades have seen an argument to mutual exhaustion over the issue of the best measure for quantifying archaeofaunas (Casteel 1976/1977, 1978; Casteel and Grayson 1977; Crabtree 1990; Gilbert and Singer 1982; Grayson 1984; Klein and Cruz-Uribe 1984; Lie 1980; McGovern 1985; Speth 1983). Specialist and nonspecialist alike have been swamped by increasingly abstruse numerical arguments over proliferating acronyms, and it is not clear who (if anyone) has ended the game with the highest score. Many practicing zooarchaeologists now suspect that there may be no single measure that does everything for every research question on every site. If one is excavating a bison kill, fossil tar pit, or other context that concentrates nearly complete skeletons of many individuals, then one should be concerned about skeletal interdependence, and MNI is a basic indicator of choice. If one is working with midden deposits containing the heavily processed bones of skeletons that may well have entered the record as cuts of meat (not whole animals), and which are now in secondary or tertiary context, then one can probably turn to NISP counts. Other more unusual methods may also have part of the truth in them in particular contexts: but none hold the whole "Truth."

Many workers with very large collections (e.g., Crabtree 1990) are demonstrating that, when sample sizes are high enough, all the basic methods of quantification provide versions of the same overall pattern. This phenomenon can be seen in far more modest-sized archaeofaunas as well. Figure 3 presents data from the Icelandic site of Granastaðir (Einarsson 1994), a briefly occupied tenth-century farmstead. The figure illustrates the effect of sample size on a basic ratio of caprine to cattle bones (the two most common domesticates) as calculated using the NISP, MNI, and RF approaches (Amorosi and McGovern 1994). When the overall sample size was small (< 300 bones), the calculated ratios in the different contexts (site areas) bounce from 7:1 down to 0.5:1. When sample sizes are this small, none of the different basic indicators work well. When sample size rises above 1,000 identified fragments (as in the R15 unit, Total), all three measures converge convincingly on a 2:1 ratio (this is similar to other Viking Age sites in Scandinavia, cf. McGovern et al. 1993).

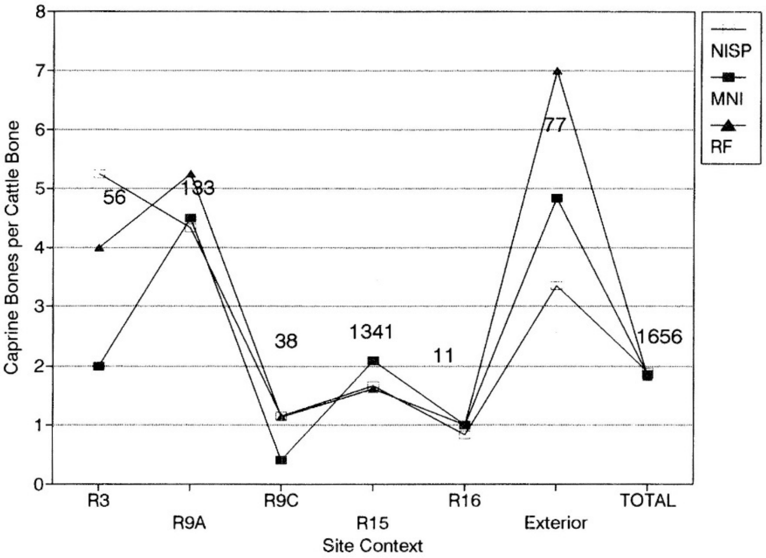

Figure 3. Granastaðir. Three different basic quantitative indicators regularly used for archaeofauna (NISP = Number of Identified Specimens, MNI = Minimum Number of Individuals, RF= Relative Frequency; terminology follows Grayson 1984) have been used to generate a ratio of caprine (both *Ovis aries* and *Capra hircus*) bones per cattle (*Bos taurus*) bone for the single phase, mid-tenth-century site of Granastaðir in northern Iceland (Einarsson 1994). Each of the different locations within the excavated area (R3-16, plus exterior) generated different numbers of identified fragments (listed above the data points). Where sample sizes were small (less than 300 NISP), the different indicators tended to give very different results. Where sample size increased above 1,000 identified fragments (R15, total) the three basic indicators converge on a predicted ratio of caprine to cattle of about two to one. This ratio is similar to other tenth-century sites in Atlantic Scandinavia (see McGovern et al. 1993). Sample size of the archacofauna may be more important than the zooarchaeological quantitative indicator chosen for many types of analyses.

Similar observations can be made on deeply stratified midden deposits. Figure 4 presents the relative percentages of the major taxa (cattle, caprines, seals, caribou) based upon the simple NISP count from the stratified midden deposit at the Norse site of Sandnes (W51) in West Greenland (McGovern 1992a, 1992b; McGovern et al. 1996). The basic pattern of change through time (Phase 1 is c. AD 1025–1150, Phase 5 is c. AD 1250–1350) appears to involve an increase in the relative proportion of caribou between Phase 1 and Phase 3 (c. AD 1125–1150), effective stability in the proportion of cattle through all the phases and a relative decline in the caprines (both sheep and goat). Numbers above the bars indicate the (fairly modest) bone count of major taxa behind the relative percentages. Figure 5 presents the same bone data but quantified using a simple MNI approach. The major difference in the patterning is in the greater relative percentage of caribou produced by the MNI in comparison with the NISP count. We have known for some time that the transport of selected cuts of meat into a site can inflate MNI scores (Binford 1978), and there is evidence that this elite manor farm was successful in collecting meat of caribou killed offsite. Figure 6 illustrates the pattern produced by calculating a ratio between meat-rich upper limb bone (humerus, radius/ulna, femur, tibia) and comparatively meat-poor lower limb and foot bones (metapodials, phalanges) for the three major ungulate taxa across the four archaeological phases. Despite the tendency to over-count caribou metapodials (shafts can be recognized even on small fragments) relative to cattle and caprines, and a certain amount of stochastic noise evident in the indicator, there is a clear difference between the pattern of limb deposition for caribou and for the domestic ungulates at Sandnes (for further discussion see McGovern et al. 1996). It appears that MNT is diverging from NISP in just the direction that prior experimental and observational research suggests it should: differential transport of caribou skeletal elements appears to have skewed the taxon's MNI scores upward (Grayson 1984). Mean values of RF were developed as an additional quantification measure and act to normalize the effect of different skeletal element frequencies in different taxa (Hesse and Wapnish 1985; McGovern 1985; Perkins and Daly 1968). RF scores are not counts but means of elements summed after they had been divided by the number of times they appear in the animal's skeleton. Seals, with five full-sized digits per limb, have a great many more bones in their skeleton than do cattle, caprines, or caribou (with two full-sized digits per limb). In the case of the Greenlandic bone collections, the RF measure should reduce the effects of such disparities in skeletal configuration between the pinnipeds (seals and walrus) and the hoofed mammals (cattle, caprines, and caribou). Figure 7 presents the relative percentages for the same bone collection based upon this RF mean. The major difference in this pattern is the reduced importance of seal bones, as would be expected from the correcting effects of the RF indicator.

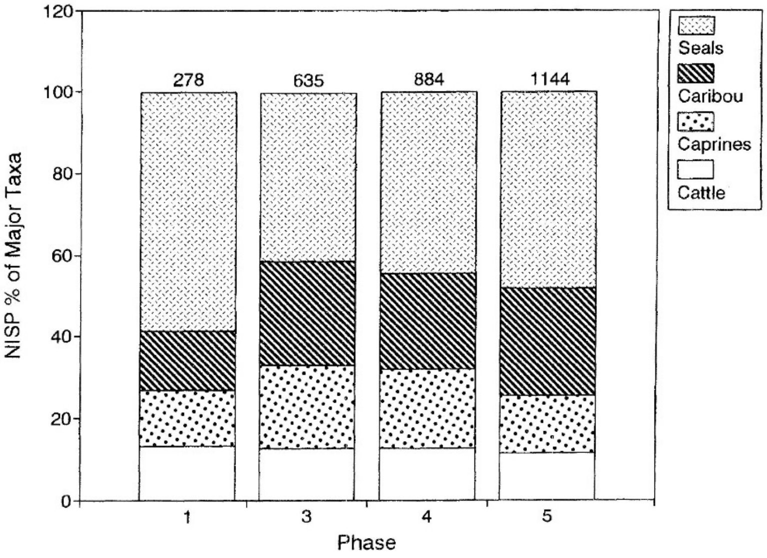

Figure 4. The deeply stratified midden associated with the elite Norse site W51 Sandnes in the former Western Settlement area in Greenland (modern Nuuk District) was sampled in 1984. The deposit can be divided into four major phases (1,3,4,5) dating to approximately AD 1050–1350, collections were sieved (4 mm and 1 mm mesh). The majority of the collection (as in other Greenlandic archaeofaunas) is composed of four major taxonomic groups: domestic cattle and caprines, caribou and seals (mainly harp and common seals). The number of identified fragments for these four groups rests above the stacked bar presenting their relative proportions expressed as percentage of NISP—a simple fragment count.

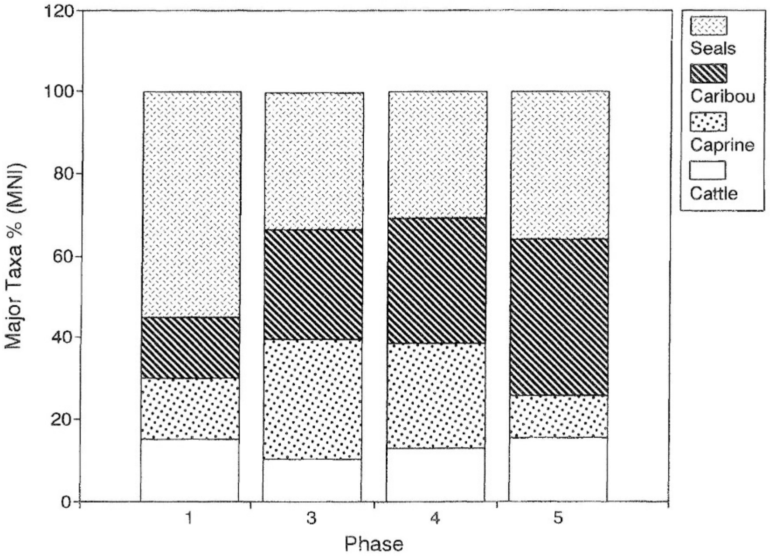

Figure 5. The bone collections from the midden at Sandnes in Greenland illustrated in Figure 4 can also be quantified using a simple MNI (minimum number of individuals) analysis (not taking into account fusion state, wear, or muscle markings) as the basis for relative percentage calculations. This simple MNI shows an overall pattern similar to the NISP percentage but with an indication of a higher relative percentage of caribou bone for all the phases. Note that whatever factor is elevating caribou MNI relative to the other major taxa seems to be operating fairly uniformly across phases.

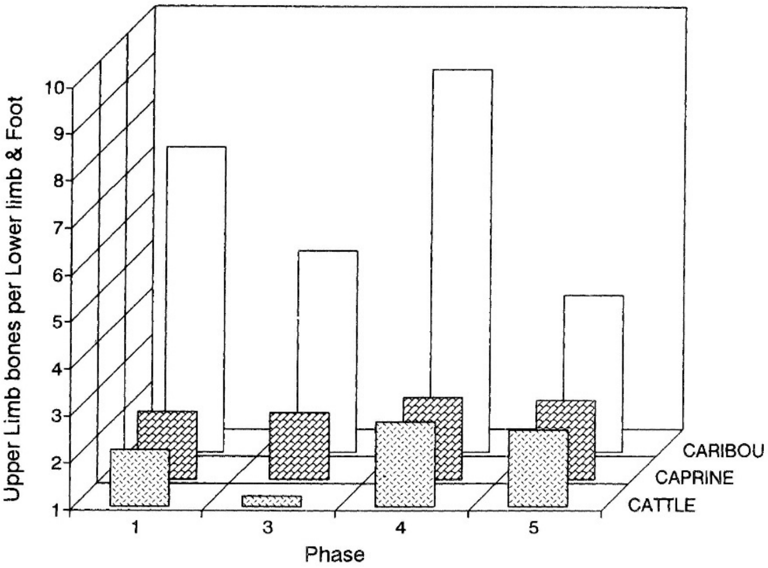

Figure 6. The bone collections from the midden at Sandnes in Greenland (illustrated in Figures 4 and 5) can also be broken down by skeletal element. This figure compares the distribution of skeletal elements for the three major ungulate taxa (caribou, caprines, cattle) as a ratio of upper limb bones (humerus, radius/ulna, femur, tibia) to lower limb bones (metapodials, phalanges). A higher bar thus indicates relatively more meat-rich upper limb bones present. While this indicator is probably inherently "noisy" (subject to stochastic variability from many sources), it does indicate a fairly consistent pattern among the domesticates and a variable but distinct pattern in the deposition of caribou bone. In all phases, caribou upper limbs seem to have been entering the midden deposit at a markedly higher rate than lower limbs. A parallel quantification using MGUI (Modified General Utility Index, Binford 1978; sec also Lyman 1994) produces consistently higher scores for caribou than for cattle or caprines—likewise suggesting differential transport and concentration of upper limb elements. Such differential transport has often been cited as a potential factor in inflating MNI counts relative to other measures (Grayson 1984) and is a probable explanation for the divergence of the relative percentages illustrated in Figures 4 and 5.

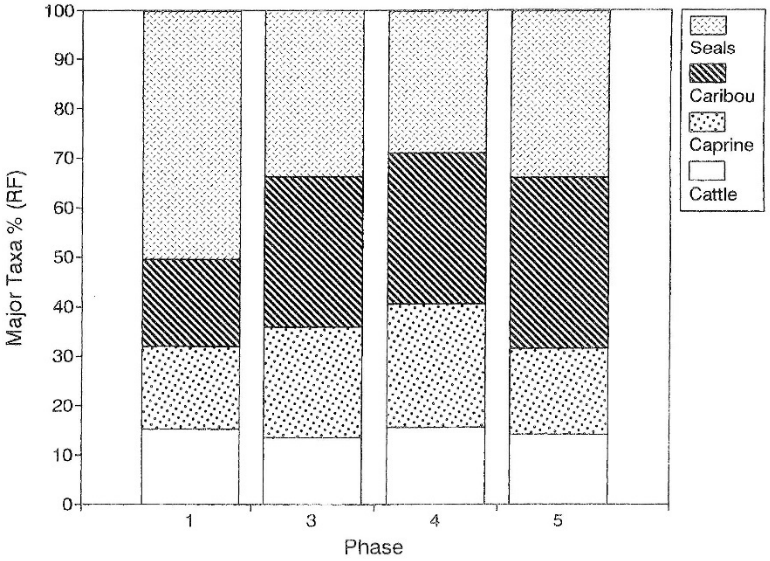

Figure 7. The RF (Relative Frequency) method invented by Perkins and Daly (see Gilbert and Singer 1982; Hesse and Wapnish 1985) attempts to avoid some of the biasing inherent in both NISP and MNI counts by dividing all skeletal elements identified by their frequency in the taxon's skeleton (thus normalizing for skeletons with different numbers of bones in them) and then taking the mean of the scores produced. This mean can then be used to produce relative percentages, as with the NISP and MNI approaches (Figs. 4 and 5). Here, the same data from Sandnes in Greenland have been quantified using the RF method and relative percentages calculated for the same four major taxa . The same overall pattern is produced as by the MNI and NISP approaches, except that the relative percentage of seals is reduced in all phases. This is a predictable result of the RF method, as seals have many more bone elements in their skeleton than do ungulates, and any correction for skeletal element frequency would be expected to reduce the importance of seals relative to cattle, caprine, and caribou. Note again that the reduction seems to affect all phases equally.

Proxy data and indirect evidence

Which of these zooarchaeological indicators is "True" in the case of the Sandnes collection? All three indicators produce broadly the same pattern of change through time, all three seem to be responding to underlying characteristics of the archaeofauna as a whole, and all three are surely *proxy indicators* of relative proportions of bones entering a midden (not counts of live animals in a barnyard). If none is True (in an absolute sense), which is then the most useful in this particular research context? In practice, we normally make use of the basic NISP count for most comparisons, as it is the least mathematically transformed, the least idiosyncratic (there are at least a dozen different ways of calculating MNI), and the most suitable statistically (Gilbert and Singer 1982) for manipulating small collections (thus a least common denominator for widespread comparisons). Most zooarchaeologists now use one or more of a wide variety of microcomputer-based zooarchaeological data management packages capable of calculating different quantitative indicators simultaneously. It has become practical to work with many different indicators for the same sample of bones, and we need not restrict ourselves to a single approach.

Many longstanding problems of quantification may be traced to the persistent illusion that somehow a skeletal fragment could stand for an entire animal, and that we could somehow reason back to a direct count of living animals (and their caloric content). Given what we now know of attrition and the multiple agencies that afflict our basic data before we ever see it, it is clear that in most deposits *most* animals alive in the past farmyard leave no bone remains whatsoever. We cannot reconstruct direct counts of ancient stock whatever our method of quantification. Palynologists have long realized that a preserved pollen rain in a lake or bog core is not an ancient forest, but a very altered *proxy* indicator of past vegetation. If we can accept that we too are dealing with proxy indications of past economic and environmental conditions, then we may stop worrying about getting “exact” counts of dead animals and spend more time considering the patterns formed by their transformed fragments. The particular method of quantification employed in this search for patterns in proxy data appears to be less important than other characteristics of the archaeofaunas under study. There are surely more interesting issues to concern zooarchaeologists than endlessly refighting the basic quantification battle—and certainly issues more critical to the question of site comparability.

Differences between investigators

Far less subject to discussion (at least in print) is the effect of different analysts and different analytical approaches on the resulting zooarchaeological numbers. Will two analysts produce the same count of species from the same pile of bones? Are consistent results possible in zooarchaeology, given the wide range of skills and the wide range of recording forms and data management strategies used by different laboratories? These are actually two very different questions. Any working zooarchaeologist would be astounded to produce precisely the same count of bones from the same site collection in two blind tests. Many sorting decisions (large terrestrial mammal or scrap?) are inevitably subjective, and while a good lab will provide standard reference pieces and elaborately annotated reference keys, there will always be some variation in how a particular bag is sorted and recorded. Recording systems may also impose differences—less in the manipulations by different computer packages than in the basic recording form. Some forms break down skeletons differently, some require an extraordinary number of choices per bone (e.g., six burning states, four weathering states, percentage of element remaining—the list can expand dramatically as categories and possible states are added) and some are simply hard to fill out accurately and consistently. This all means that it is unlikely that two analysts will produce exactly the same numbers from the same pile of bones. Instead of expecting exact correspondence between the results of different investigators, we might instead look for correspondences between overall patterns rather than in specific numbers.

Figure 8 presents a comparison of two archaeofaunas excavated from the Western Settlement of Greenland from two farm ruins, W54 Nipaatsoq and GUS (Gaarden under Sandet). The two farms are of the same general size and are on opposite sides of a glacial river. Nipaatsoq was excavated in 1976–77, and the ongoing GUS excavations began in 1991, fifteen years apart. The 1976–77 W54 collections (approx. NISP 1,400) were analyzed by McGovern and Bigelow (McGovern et al. 1983), and the 1992 collections from GUS (approx. NISP 700) were analyzed by Georg Nyegaard (Nyegaard 1992), who kindly shared preliminary data. As Nyegaard (1992) notes, the two analyses are strikingly similar in their results. In this case, it would appear that any individual differences, or differences in recording system, were overwhelmed by the patterning inherent in the data.

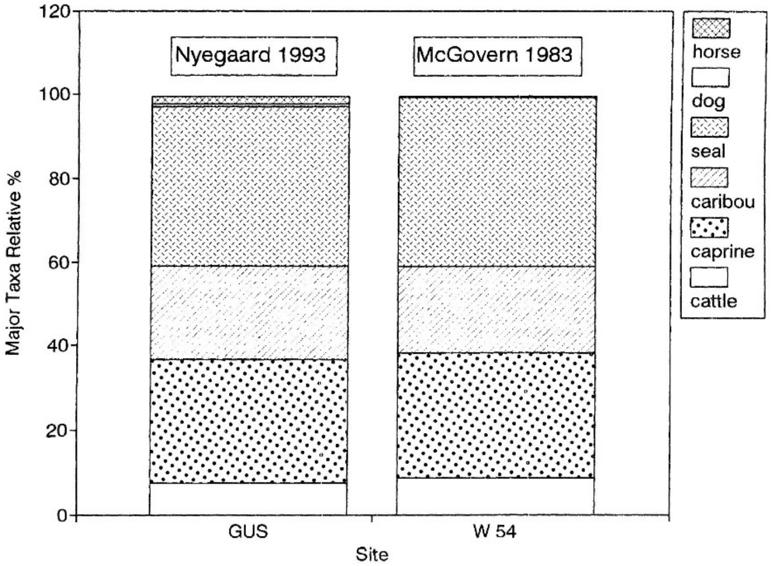

Figure 8. This figure compares results of analyses carried out over a decade apart by different analysts using slightly different methods for recording and identification (although both were able to draw on the long Greenlandic expertise of Ulrik and Jeppe Møhl of the Zoologiske Museum in Copenhagen, and both made use of the excellent comparative collections of the Zoologiske Museum) on two archaeofaunas from neighboring sites in the former Norse Western Settlement in Greenland. Both sites were of similar size and apparent economic and social rank, and both collections derive from terminal interior collections (mainly dating c. AD 1300–1350). The two sites were nearest neighbors and would have been within sight of each other's hearth smoke. This example does not support any assertion that analytical idiosyncrasy regularly obscures underlying regularities in the zooarchaeological record—we do appear to be measuring something besides ourselves. Thanks are due to Georg Nyegaard for generously sharing his data.

The nature of inter-observer problems can be further discussed in a case study in which two analysts examined the same collection. In 1978 McGovern, while a graduate student, carried out initial examinations of samples of archaeofaunas from four historic Inuit winter sod houses from Eskimo Island , Labrador, excavated in 1974–75 by the late Dick Jordan. In 1993–95, Jim Woollett reanalyzed the entire collection as part of a general view of Labrador archaeofaunas (Woollett 1995). The samples examined by McGovern range from 32 percent to 53 percent of the whole collections examined by Woollett in terms of NISP

(Woollett's NISP counts ranged from 300 to over 3,000 specimens). It is beyond the scope of this paper to examine the precise differences of percentage NISP profiles from these sites, which are reported in McGovern (1979) and Woollett (1995). Some notable differences in analytical methods and means should be noted, however. The analysts had different training backgrounds and used somewhat different modes of quantification in order to follow precedents established by previous regional work. Woollett had access to a far more comprehensive comparative collection than did McGovern. Woollett also employed a more conservative approach in identification, leaving comparatively more specimens in generic taxonomic categories. The difference in sample sizes between McGovern's and Woollett's analyses would accentuate the somewhat different identification and quantification procedures, increasing identification rates of particular species and their percentage NISP scores in McGovern's analysis.

Intuitively, there would seem to be many sources of bias which could make these analyses unrecognizable as portrayals of the same collection. However, McGovern's and Woollett's analyses are remarkably similar. Table 2 presents Kolmogorov-Smirnov two sample test statistics for each pair of analyses of the Eskimo Island collections, based on percentage NISP scores reported in McGovern (1979) and Woollett (1995). No significant difference between these analyses could be demonstrated. Again, it seems apparent that inherent assemblage characteristics can be robust despite analytical differences between different workers. While it would be premature to conclude that observer error plays no significant role in the patterning of reported archaeofaunas , such *ad hoc* tests suggest that it may be less of a problem than one might fear.

Table 2. Kolmogorov-Smirnov two-sample tests of % NISP scores in samples of Eskimo Island archaeofaunas. This chart presents test statistics comparing the cumulative distributions of two independent analyses of samples of the same faunal collections for each of four sites on Eskimo Island, Labrador (McGovern 1979; Woollett 1995). The analysis is based on % NISP scores for twelve taxonomic categories and follows the format for two samples of small size outlined by Siegel (1965: 127–36). In all cases, the maximum difference (K_D) fell well below the values required for acceptance of the hypothesis that the two samples were drawn from independent populations at the .01 level of significance.

Bone collection	Maximum difference (K_D)	*N*	α
Eskimo Island 1 House 2	0.083	12	0.01
Eskimo Island 2 House 5	0.083	12	0.01
Eskimo Island 2 House 6	0.083	12	0.01
Eskimo Island 3 House 1	0.167	12	0.01

Archaeology in zooarchaeology

Animal bone collections of quite modest size thus appear to generate patterns that may not be largely the result of quantification method chosen by the analyst or the analyst's error. If we accept that we are not counting whole sheep and cows but rather distant and derived proxy indicators of sheep and cows, then we should look for corroboration in other proxy indicators of past economic activity: the rest of the archaeological data. Thanks to more than a century of archaeological scholarship in Greenland, we have several types of such data available (McGovern 1985, 1992b). These data include farm-building architecture and pasture-plant-community distribution (Fig. 9). The size of farm buildings should logically have something to do with the number of animals housed within, and there is indeed a positive correlation between the floor area of excavated cattle byres and the ratio of caprine to cattle bones in the Greenlandic samples (Fig. 10). Pasture area also correlates positively with both byre size and barn size and the relative percentage of cattle bones. Where the Norse Greenlanders had large rich pastures they built comparatively spacious byres and filled them with cattle. Where they lacked extensive pastures, the byres are smaller and the ratio of caprines to cattle bones goes up significantly. It is possible to rank farms in Greenland by architecture, pasture area, and archaeofauna, and patterning is fairly consistent across categories of evidence (Table 3). This patterning is seen despite the spread in excavation dates for the sites in Table 3 from 1930 to 1992.

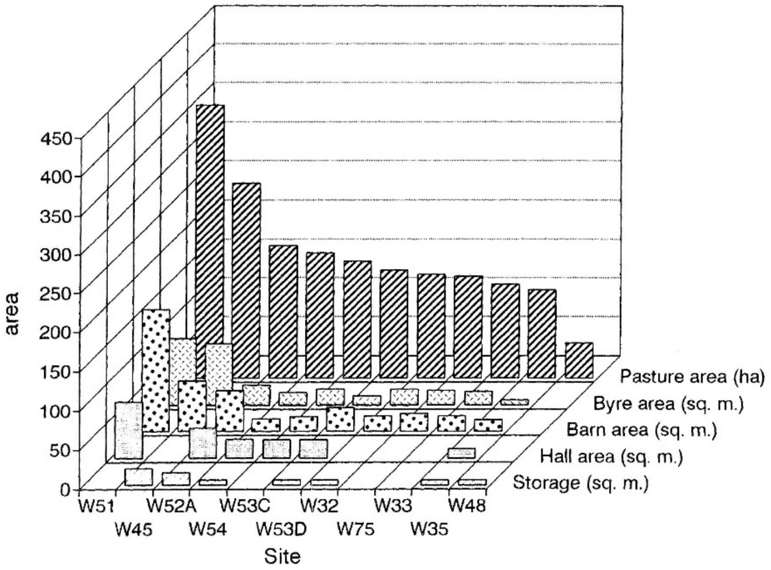

Figure 9. Architectural data on farm buildings from Greenland provide some cross-checking on patterns produced by other economic indicators, including animal bones. This figure graphs the floor area (in square meters) of hay barns, cattle byres, storage buildings, (*skemmur*) and halls against the calculated pasture area (in hectares) for the same sites (see McGovern 1992b for discussion). The Western Settlement sites listed here may all have been part of the same community centered on W51 Sandnes.

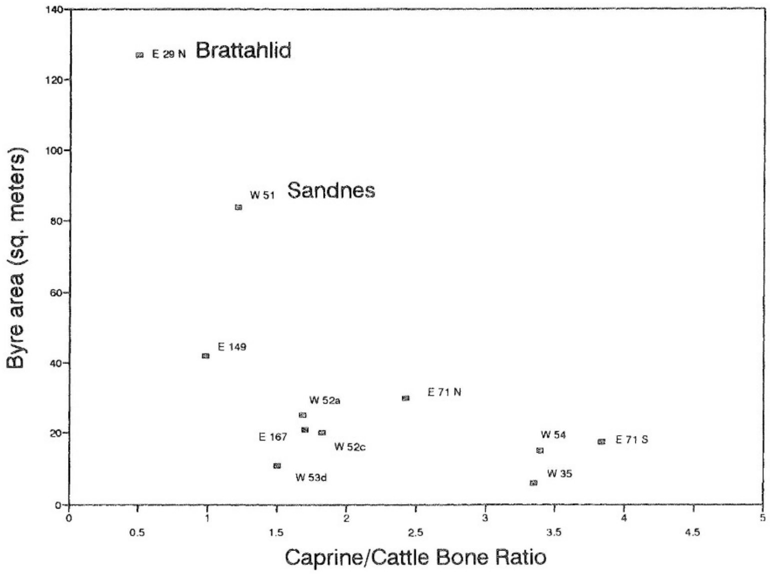

Figure 10. The byre area of excavated sites from both settlement areas in Greenland is plotted against a ratio of caprine bones per cattle bone (thus the lower right corner contains sites with relatively fewer cattle bones and relatively smaller byres). Farms emphasizing cattle production over caprine production would logically need larger cattle byres. It would appear that there is a logical relationship between bone counts and other classes of archaeological evidence, though many questions remain about the placement of individual sites on this graph and the real shape of the distribution: graphs like this should be understood as discovery tools rather than statistical "proofs." Comparisons of patterning in farm buildings , site territory, and excavated archaeofaunas can be exploited further in most world areas.

The questions being asked of the archaeofaunas in Table 3 are simple ones according to our division in Table 1: "What is the relative percentage of major taxa?" Most of these same collections can shed little light on herding strategy or metrical analysis, and none are much use for direct assessment of caloric intake. The convention (Table 3) of presenting percentage data carried to two decimal places does not imply great (and spurious) precision—large manor farms had a *lot* of cattle and *big* byres, medium-sized ones had *some* cattle and *middling* byres, and tiny farms had *very few* cattle and *small* byres. The numbers mean less than the patterns.

Table 3. This table summarizes available data for the Eastern and Western Settlements of the Norse colony in Greenland. Where stratified bone collections are available, only the terminal phases (c. AD 1300–1450) have been used here, as these provide the best match with the structural data. Pasture area data are currently available only for portions of the Western Settlement. Note that it is possible to rank the sites into at least four to five levels, with the episcopal manor of Gardar at the top, by using any of the data sets listed. While these data are in need of expansion and refinement, they may serve to indicate the role of social ranking in household economy. For more complete discussion of these data see McGovern (1985, 1992b).

Floor areas in square meters (final phases)							Pasture area in hectares	Animal bone data NISP % major taxa				Ratio caprine/ cattle
Site	Site rank	Hall	Byre	Barn	Storage	Church		Cattle	Caprines	Caribou	Seals	
Eastern Settlement												
E47	1 Gardar	131	389	353	361	154						
E83	2 Hvalsey	82	53	107		68						
E29N	2 Brattahlid	66	127	105	118	59						0.5
E111	2 Herjolfsnes	66	48	43	59	86						
El7a	2 Narsaq (10th c.)	66						16.56	23.53	4.8	55.12	1.91
E149	2 Nunnery?		42	40		62		16.84	16.5	3.87	62.79	0.98
E105	3		20	20		53						
E29R	3	35	77	56	51							
E167	3	38	21	18	16			22.96	38.98	1.72	36.34	1.7
E71N	3	36	30		17			15.48	37.47	0.25	46.81	2.42
E71S	3	26	18	16				11.48	44.08	1.67	42.78	3.84
E20	3	32										
E66	3		44	36								
E64c	4	19	18	25	7							
E64A	4	14	10	18	8							
E78A	4				5							

***Table 3** continued next page*

Table 3. *continued*

Floor areas in square meters (final phases)							Pasture area in hectares	Animal bone data NISP % major taxa				Ratio caprine/ cattle
Site	Site rank	Hall	Byre	Barn	Storage	Church		Cattle	Caprines	Caribou	Seals	
W51	2 Sandnes	72	84	155		40	350	11.54	13.99	26.22	48.25	1.21
W7	2 Anavik		50	54	38	58						
W45	2		77	64	21		250					
W52a	3	38	25	52	15		170	10.75	18.02	27.28	43.94	1.68
W54	3	24	15	15	6		160	8.77	29.77	20.79	40.67	3.39
W53c	3	23	20	19			150	7.82	14.21	10.79	67.18	1.82
W53d	3	23	11	30	6		138	8.78	13.17	18.81	59.25	1.5
W8	3	21	12	14								
W16	4	14	14	11	12							
W35	4	11	6	14	6		113	6.7	22.47	13.51	57.32	3.35
W32	4		20	20	6		133					
W33	4		16	20			120					
W75	4		18	23			131					
W44	4		14	13								
W48	5				6		44	1.15	9.11	4.75	84.99	7.92

While these collected archaeofaunas mainly address very basic zooarchaeological questions, they do appear to reflect a hierarchial division of land and resources and have stimulated and supported a vigorous and interesting debate on the nature of Norse society in Greenland (Arneborg 1991a; Berglund 1991; Keller 1991; McGovern 1992a, 1992b). These Greenlandic animal bone data also indicate a strong contrast with contemporary diets in Iceland and other parts of the Norse North Atlantic (Buckland et al. 1996). Analyses of human skeletal remains appear to support the patterning observed in the animal bone remains. The Norse Greenlanders' skeletons developed special characteristics of the teeth and bone around the teeth, suggesting a diet very different from their close relatives in Iceland and mainland Scandinavia (Scott et al. 1992). Lynnerup's (1995) isotopic analyses of the human bones from Greenland indicate an increasing reliance upon species within the marine food web in later periods of occupation, a pattern also suggested by the few stratified animal bone collections.

The Greenlandic Norse archaeofaunas are thus useful in a number of research contexts, even though they are uneven in size and were excavated over a long time period. Some of the larger collections in this sample exceed 10,000 NISP, others barely reach our group's 300 NISP minimum (nearly twenty more archaeofaunas are too small to include in the regional comparison; see McGovern 1985 for full listing). If we rejected all archaeofaunas deriving from pre-1970s excavations, our sample size would shrink to four sites, and our opportunity to observe regional patterning would be lost. If we add nonzooarchaeological evidence (the rest of the archaeology), then the mutual reinforcement of the multiple data patterning lends credibility to the whole enterprise. In Greenland, we have tried to expand our zooarchaeological sample as far as seems reasonable, to search out independent supporting evidence, and to look for patterns in the expanded data set. Zooarchaeologists working in many other areas and periods are doing similar things with their regional data sets (not without controversy: see Jones and Hildebrandt 1995; Lyman 1995). The North Atlantic is only one area where the existence of multiple, quantifiable archaeofaunas is stimulating pattern-searching activities.

Seals, cod fish, and global change

Global change research has many dimensions, but most initiatives center upon the connected problems of climatic impact and human impact on landscape and resources. In attempting to understand environmental change of the recent past and build predictive models of possible future changes, environmental managers and biologists have become increasingly aware of the shortage of biogeographic data prior to the mid-nineteenth century. Many studies have suffered from what has been called the "1850 effect"—the beginning of systematic written and instrumental scientific records is allowed to artificially bound the study universe (McGovern 1995). Zooarchaeology on a regional scale can provide assistance in lengthening this record, and may correct the distortions produced by a needlessly shortened observational record. Climate change is one topic where historical approaches are already increasingly well developed to extend the record beyond the limits of instrumental observation (e.g., Ogilvie 1991). Changing patterns in North Atlantic drift ice associated with the cooling events of the fourteenth to eighteenth centuries (documented in written sources from Iceland and other parts of the Eastern Arctic and North Atlantic) should have affected distributions of migratory and nonmigratory seal populations. Such changes appear to be reflected in zooarchaeological collections from the region (Fig. 11). Changing seal bone distributions in NE Iceland (Amorosi 1991, 1992), W. Greenland (McGovern et al. 1993), and Labrador (Woollett 1995; Serjeant 1991) show several interrelated correlations with drift ice patterns recorded in documents and sea cores (Jennings and Weiner 1996). Patterning in seal species presence and abundance in these bone collections thus appears to provide a proxy indicator of wider changes in historic and prehistoric North Atlantic sea ice distribution of great interest to global climate modelers. Other world areas certainly contain equally important climatic "sign posts" and equally relevant archaeofaunas.

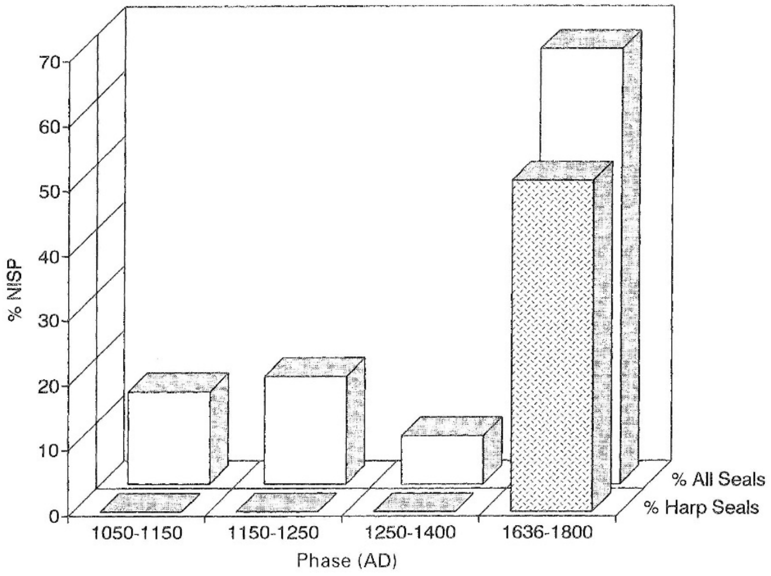

Figure 11. Seal distributions from the Svalbarð (6706-60) farm site in northeast Iceland. The deeply stratified midden deposits at the church farm of Svalbarð in pistilfjórð in northeast Iceland produced a substantial archaeofauna that can be dated by radiocarbon, tephra, and artifacts to c. AD 1050–1850. Seals increase as a percentage of the whole archaeofauna (rear bars), and harp seals are responsible for most of the increase (front bars). Although common seals (*Phoca vitulina*) were taken throughout the occupation, bones of harp seals (*Pagophilus groendlandicus*), especially new born neonates which are closely associated with the drift ice just offshore, appear only in the upper layers dated to the seventeenth to nineteenth centuries. The bones of these neonatal harp seals also confirm documentary accounts of sealing on the spring sea drift ice during one of the worst climatic cooling periods known for Iceland (Amorosi 1992). Other northern archaeofaunas from west Greenland (McGovern et al. 1993) and Labrador (Woollett 1995) also appear to reflect regional sea drift ice conditions.

Human impact on environment and the unintended consequences of changing resource exploitation strategies are also areas for potential zooarchaeological contribution. One of the great natural and social disasters of the last half of the twentieth century has been the near destruction of formerly abundant stocks of North Atlantic cod fish. Presently a number of countries and agencies are struggling with management plans for the remaining Atlantic cod stocks and there is also growing concern over collapsing stocks of North Pacific salmon and halibut (Beckmann 1995). Much management debate has centered on the age/size structure of different cod stocks and the implications for maximum sustainable yield. While interpretative problems are considerable, it appears that zooarchaeology may make some contribution to these debates. Table 4 presents Icelandic data indicating that medieval Icelanders were regularly landing cod whose live length can be reconstructed to 100–120 cm and longer. Similar patterns were also observed for medieval–early modern North Norwegian data (Amorosi, McGovern and Perdikaris 1994) and have been noted for other zooarchaeological collections from prehistoric maritime Canada (Rojo 1990), Norse Shetland (Bigelow 1984), and Norse Caithness (Barrett 1992, 1995; Jones 1991). Table 4 also presents the results of a systematic fine-mesh research trawling effort carried out by Icelandic fisheries scientists over a three-year period. The patterning of the archaeological specimens and the landed research trawls are clearly different.

Technological, attritional, and recovery biases have certainly skewed the archaeological sample distribution. Baited hand lines used by the Scandinavian medieval–early modern fishers (and probably by prehistoric Native Americans as well) select for larger, older age classes of fish which feed higher in the food web. The shortage of smaller cod in the archaeological collections is certainly a reflection of this technological factor as well as a bias towards the survival and archaeological recovery of large specimens (for discussion see Barrett 1995). For these and other reasons, a direct comparison of the size *distribution* of the archaeological and modern fish collections is highly problematic. The important difference in pattern of Table 4 may be in the comparison of the *absolute numbers* of large cod (> 100 cm) between a few excavated Icelandic sites and the very comprehensive modern research trawling effort. While the fine-mesh research trawl took over 10,000 individual cod, only 102 were as long as 100 cm. The archaeological samples from partial excavations of four sites generated more individual specimens that could be reconstructed to 100 cm and longer than did the comprehensive research trawl in *absolute numbers.* None of the sites reported was totally excavated, and each represents but one of literally thousands of comparable sites in Iceland alone. In absolute numbers, the modern research trawling effort could not duplicate the number of large cod indicated by a small sample of sites from the south (Stóraborg), southwest (Viðey), northwest (Miðbaer), and northeast (Svalbarð) of Iceland. Such large cod appear to be extremely rare in modern Icelandic waters, but were common enough in the past to be regularly landed all around the island and to enter into the archaeological record in substantial quantities. Unlike modern pelagic industrialized fishers, it appears that both Scandinavian and Native American small-scale (and often inshore) fishers were able regularly to land substantial numbers of such large cod right across the North Atlantic. The zooarchaeological data would thus indicate that several cod stocks formerly held far more older individuals than have been observed in modern times.

Table 4. Modern and medieval Atlantic cod length distributions in Iceland. Cod measured during systematic fisheries trawls during 1976–79 (trawls from the north, northeast, east, and south coasts of Iceland, data from Palsson 1983) are compared to reconstructed cod length distributions from the archaeological sites of Stóraborg (south coast), Viðey (Reykjavik harbor), Miðbaer (Breiðafjórð, northwest Iceland), and Svalbarð (pistilfjórð, northeast coast). Note the absence of cod reconstructed as less than 40 cm in length, except at Miðbaer on the island of Flatey. Medieval fishing gear, unlike modern fisheries trawls, seems to have selected against smaller-sized fish. There are a substantial number of remains (both the dentary and premaxillary) from the archaeological sites that were derived from fish 100 cm and longer. Fish of this size have become very rare in absolute numbers around Iceland and throughout the North Atlantic.

Length groups (in cm)	Iceland Icelandic fisheries trawl 1976–79 total measured fish	Iceland Stóraborg 15th–18th C. total	Iceland Stóraborg 15th–18th C. total	Iceland Viðey 13th–18th C. total	Iceland Viðey 13th–18th C. total	Iceland Miðbaer 13th–18th C. total	Iceland Miðbaer 13th–18th C. total	Iceland Svalbarð 11th–18th C. total	Iceland Svalbarð 11th–18th C.
		Archaeological reconstructions							
		Premax.	Dentaries	Premax.	Dentaries	Premax.	Dentaries	Premax.	Dentaries
5–9	83	0	0	0	0	0	0	0	0
10–19	632	0	0	0	0	0	0	0	0
20–29	1220	0	0	0	0	0	0	0	0
30–39	1489	0	0	0	0	0	0	0	0
40–49	1622	0	0	0	0	2	4	0	0
50–59	1765	0	0	1	0	10	11	0	0
60–69	1669	2	0	1	2	4	8	3	5
70–79	1133	8	10	0	4	15	4	12	8
80–89	538	52	66	9	12	6	2	23	16
90–99	223	64	97	13	12	3	1	21	11

***Table 4** continued next page*

Table 4. *Continued*

Length groups (in cm)	Iceland Icelandic fisheries trawl 1976–79 total measured fish	Iceland Stóraborg 15th–18th C. total	Iceland Stóraborg 15th–18th C. total	Iceland Viðey 13th–18th C. total	Iceland Viðey 13th–18th C. total	Iceland Miðbaer 13th–18th C. total	Iceland Miðbaer 13th–18th C. total	Iceland Svalbarð 11th–18th C. total	Iceland Svalbarð 11th–18th C.
		Archaeological reconstructions							
		Premax.	Dentaries	Premax.	Dentaries	Premax.	Dentaries	Premax.	Dentaries
100–109	62	37	57	15	8	6	0	18	11
110–119	28	13	12	2	1	0	0	7	6
120–129	4	6	10	2	0	0	0	2	1
130–139	8	0	1	0	0	1	0	1	0
140–149	0	1	0	0	0	0	0	0	0
150–l59	0	3	1	0	0	0	0	0	0
160–169	0	0	0	0	0	1	0	0	0
Total individuals	10476								
Fish =/> 100cm	102								
Fish =/> 120cm	12								
Fish =/> 140cm	0								
Total fragments		186	254	43	39	48	30	87	58
NISP =/> 100cm		60	81	19	9	8	0	28	18
NISP =/> 120cm		10	12	2	0	2	0	3	1
NISP =/> 140cm		4	1	0	0	1	0	0	0

Source: Palsson (1983)

Most fisheries management models are based upon modern research and commercial catches similar to the major Icelandic effort of the 1970s partially documented in Table 4, and most understandably assume as "natural" a population structure with extremely few large cod as old as 20–30 years. These modern fisheries data were all collected after 1900, after several generations of intensive industrial fishing effort may have already altered cod population characteristics. The archaeological data suggest that such population structures composed overwhelmingly of immature and 3–10-year-old fish are probably historically unusual and may not represent a valid profile of *most* natural cod stocks of the past 2,000 years in the North Atlantic. The shortage of very large old cod fish in the first half of the twentieth century may in fact have represented a warning that biological thresholds for exploitation were being reached. Because managers lacked the long-term perspective potentially provided by a regional synthesis of zooarchaeological fisheries evidence, they had no means of recognizing this warning signal in their own data.

While the collapse of the North Atlantic cod stocks in this decade is a complex event with many contributing causes, a short scientific observational series of less than a century is certainly one root cause of this human and environmental disaster. Short observational series are one of the fundamental limitations on any attempt to anticipate and mitigate the sudden threshold-crossing crashes that have the potential to devastate both natural resource and dependent human communities. Cod fish are not the only species in need of a longer and better understood history. Zooarchaeology, for all its faults and imprecisions, would appear to have an important role in lengthening the observational series of environmental managers, perhaps warning of critical threshold discontinuities before the resource crash (rather than after, as in the case of the Atlantic cod). Without systematic intersite comparison, zooarchaeology will be unable to differentiate site-specific variability from regional patterning and will be hard put to offer any such long-term insights.

Some practical protocols

Practical experience in working with animal bone collections on a regional basis has persuaded our research group that such exercises in intersite comparison are both feasible and productive. One bone collection is a curiosity, two are a controversy, but ten or more may form patterns that can *either* signal some plausible connection to other evidence *or* indicate that there is more noise than signal in the data set. If we expect that most archaeofaunas are indeed hopelessly abused by multiple pre- and post-depositional insults, then we should find many cases of the latter situation and few of the former. If we believe that even badly treated archaeofaunas can still answer questions of potential interest (if these are kept simple), then we should see some sense in our patterns not entirely due to wishful thinking.

Such regional perspective and cooperative pattern searching is at the core of the research initiative formally begun in 1992 by the North Atlantic Biocultural Organization (NABO 1992, 1993, 1994). NABO works to coordinate multidisciplinary approaches to common problems across the North Atlantic, and the comparability of bioarchaeological data is a key element in a developing research strategy. Other formal and informal bioarchaeological groups are pooling data on a regional scale and also finding useful patterns in their collected evidence. These groups may be regional in their organization such as the PALE (Paleoclimates of Arctic Lakes and Estuaries) initiative, or taxonomic in focus such as the International Congress of Archaeozoologists' (ICAZ) Bird Remains Working Group and Fish Remains Working Group. Cooperation across national and disciplinary boundaries will be vital to any attempt to put zooarchaeological evidence to work for sustainable resource management or investigation of global change (Barlow et al. 1995).

There is no reason to accept every bone collection as equally valuable, but there is even less reason to assert that sites are inherently incomparable, or that nothing can be done with low- to medium-quality zooarchaeological evidence. Rather than prolonging debates about numbers, we believe it is time to focus on patterns. Zooarchaeologists around the world need to cooperate broadly in working out practical research protocols that can allow us to assess realistically what sorts of questions different sorts of collections can be reasonably asked. While a coordinated effort is needed, we suspect that a series of regional, site-type, specific (urban, rockshelter, farmstead, village) working groups with specific research problems firmly in mind will prove more productive than a grand attempt to provide protocols for all zooarchaeology. Even such closely focused regional cooperation is difficult, but it is not impossible, as the northern palynological and limnological community has demonstrated with their new set of PALE[1] collective research protocols (Anderson et al. 1993). Our data are just as critical to any global change program, and we should not be reluctant to synthesize them for more general use.

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Note

1. Paleoclimates of Arctic Lakes & Estuaries, a subgroup of Past Global Changes (PAGES), International Geosphere-Biosphere Programme (IGBP), and the US National Science Foundation's Arctic System Science (ARCSS) Program. Protocol booklet is available from PAGES Barenplatz 2, CH 3011, Bern, Switzerland.

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