Too Many Bones: Data Management and the NABONE Experience

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Abstract: Management of Zooarchaeological data became a growing problem during the career of Brian Hesse and his early engagement with attempts to digitize recording systems needs recognition. This paper presents an account of attempts to respond to problems identified by Brian in the 1970's, extending through multiple levels of technology and responding to the increasing volume and importance of zooarchaeological data in the past four decades. Brian's influence on the NABONE data management system developed for the North Atlantic region is gratefully acknowledged.

Keywords: Zooarchaeology, Data Management, North Atlantic, NABO

In the mid-1970's Tom McGovern had the opportunity of working with Brian Hesse at Columbia University's Anthropology Department, volunteering to help sort Neolithic animal bones from Brian's collections and learning a great deal in the process about zooarchaeology and scholarship. In a good graduate program, you tend to learn as much or more about the profession from senior grad students as from the professors, and Brian was an excellent mentor brimming with ideas and enthusiasm. Importantly he was generous with timely purchases of beer and pizza, which surely fueled discussion and enthusiasm for what could otherwise be pretty tedious jobs like numbering bones and sorting bags of dauntingly tiny fragments. In later years it became apparent that this mentoring was part of the ongoing process of separating the lucky few who really enjoy sorting bags of often highly fragmented bone and thus become zooarchaeologists from the far larger majority of people who sadly do not. Brian was generous with his time and with his ideas and opinions, and his encouragement had a real impact in increasing the number and sophistication of the lucky minority for whom zooarchaeology has been a rewarding mission in life.

One area of interest to Brian (and to so many other zooarchaeologists in the same decade) was how to cope with the embarrassment of archaeofaunal riches resulting from the methodological impact of what was then still "new archaeology". Around the world senior archaeologists who had cheerfully dumped unmodified animal bones into the spoil heap under the old paradigm had converted to the new religion and were bringing back more and more animal bones each summer. The sheer volume of collections resulting from the re-definition of animal bones as artifacts worthy of recording and recovery immediately produced practical challenges at all levels. In the field, the increased volume of ecofactual finds combined (at least sometimes) with increase in at least partially sieved recovery led to a range of often *ad hoc* sampling strategies ("This is Tuesday, we only collect animal bones on Monday and Wednesday"). As museums discovered, suddenly the volume of finds to be stored had increased overnight to an exponential degree, and zooarchaeology rapidly gained the "problem child" status it enjoys to the present in the eyes of collections managers and curators. And of course the processes of analysis, recording, quantification, and data management encountered by the growing number of zooarchaeological/ archaeozoological practitioners was increasingly affected by sheer sample size.

Early workers were grappling with problems of basic osteological identification, often alone and with little comparative literature at hand (no ICAZ or Alexandria archive for them; http://www.alexandriaarchive.org/icaz/), and usually were working in nearly complete isolation from the processes of excavation and recovery in the field. Zoologists by training and profession, they tended to look for new species and flag up specimens that might be exceptional or at least out of their recorded modern range. The job of recording massively repetitive collections of (often largely domestic) animal bone fragments from the same range of species over and over again was alien to their training and processes of recording and quantification were initially not a high priority. Data management issues were far down these early practitioners' list of concerns.

As example, Magnus Degerbøl (1929, 1934, 1936, 1939, 1940, and 1941), based at the *University Zoological Museum* in Copenhagen, was an early leader in North Atlantic zooarchaeology, and is rightly given distinguished culture-hero status by his successors in the region. However, Degerbøl (as most of his contemporaries) recorded his observations as semi-quantitative lists of bones by taxon ("*Capra hircus dom*. Distal Humerus 6, Proximal 9, other fragments 11, whole Tibia 2,….."). In his reports (appearing as appendices to site reports in most cases) he discussed relative abundances fairly casually ("very common" or "fairly rarely seen") and normally did not produce a summary table or graph. While his work remains fundamental to the zooarchaeology of Greenland and Iceland, the record created required a huge amount of work (and some serious historical source-critical analysis) to convert into a quantifiable record that could be used for inter-site comparison. This sort of casual approach to data recording and management was then widespread, and modern critics should consider that pencil and paper aided by the occasional hand cranked adding machine were the best data management tools at hand for these early pioneers.

As many have noted, the transformations of the processual revolution were associated with early attempts to apply simple statistics and early digital technology to many aspects of archaeology, and zooarchaeologists facing growing piles of ecofactual riches were early adopters. With Brian's help, McGovern made use of the Columbia mainframe computer and early SPSS packages to have a go at quantifying and recording the archaeofaunal collections made in collaborative international excavations in Greenland in 1976-77. These were the first sieved archaeofauna from Norse Greenland, and while modest in size by modern standards (two sites with collective NISP of about 4,000) they presented challenges of recording and data management an order of magnitude beyond that faced by Degerbøl a generation before. Early attempts to use edge-punch cards which could be pulled from a deck by a set of needles pushed along the edges proved not very durable (the needles worked fine, once) and in practice resulted in a fragile paper card data set often unattractively spotted with blood stains (the needles were sharp). Brian arranged introductions with the enthusiastic but typically somewhat incoherently intense specialists at the mainframe in the basement (computers then dwelled mainly in basements) and they kindly got the project on the road to digital recording and data management.

As it turned out, the mainframe and 80-column punch card data entry format then cutting edge provided their own set of challenges. Each bone was represented by one card, each of which had to be punched using a special console in the basement of the computer lab where time on console was strictly limited by white coated priests we had not yet learned to call geeks. This meant that a paper coding form that mirrored as far as possible the layout of the punch card was a necessary bridge between bones lab and computer center, and that entries needed to be all-numeric codes. This resulted in some soul searching about how much data to record on each bone fragment and imposed some very un-transparent coding approaches. Given that locational data would eat up 20 or so of the available 80 columns, the basic question of how much to record about each individual specimen became pressing. As eager readers of *Nunamiut Ethnoarchaeology* and the growing spate of reports on taphonomy and bone modification we all had a great many things we would like recorded for later analysis – but how to get this into 60 spaces?

In the 1976-77 Norse Greenland archaeofauna this resulted in a record that looked like this (omitting the locational data): "657412725304412180008900500623004211002345000895641". This could be translated to a "Harp seal left distal humerus fragment that was fused but with fusion line still visible, had a heavy chop mark from butchery, had no evidence of burning, no evidence of hand polish or tool use, no evidence of animal tooth marks, a moderate degree of weathering on surface, no evidence of bone exfoliation, and a fragment size in the 2-5 cm maximum dimensions range". Without the coding manual this is of course a meaningless string of numbers, and converting observations on bones in the lab to codes on the record form was a lengthy process that even after much practice could introduce errors. One site appeared to be dominated by swan bones until we realized a systematic transposition of 6 and 5 had taken place (even mild dyslexia is fatal to a coding system like this). Both the paper recording sheets and the 80 column punch cards created a dauntingly heavy pile of vulnerable paper, and the work of transporting the punch cards across campus required borrowing of increasingly large carts from buildings and grounds. Much of the actual quantification from the print-outs was in practice done with a then brand new HP pocket calculator, and overall it seems likely that this attempt at cutting edge digital data management easily added an extra half year to the doctoral thesis (and some recurring lower back issues from boosting punch card boxes). The digital cutting edge turns out to be a painful work area, and this experience was widely shared by contemporaries working with the same mainframe restrictions.

Then the PC revolution hit, we all got our own computers and experimentation with programming was widespread in zooarchaeology, as was controversy around methods of quantification (NISP vs. MNI debates then spoiled many good friendships). Many of us spent many hours developing often remarkably clever if idiosyncratic programs for bone data recording and manipulation, some in early DOS and some in other early languages, none of which are today accessible to a modern computer. Early attempts at "one grand standard" for all foundered on a combination of rapid technological progress (several excellent potential grand standards were rapidly orphaned by the pace of change) and the realization that different world areas had different zooarchaeological requirements and different research projects had different data needs and possible data products. Proliferation of bone recording systems continued, increasingly using spreadsheets and early database programs commercially available (and increasingly dominated by

Microsoft). By the early 1990's most of us had some PC or Mac compatible digital recording system up and running, with or without an associated paper form package. Many were and remain excellent systems that now contain major data resources; others fell by the wayside or remained idiosyncratic.

The 1990's also saw the rise of regional-scale archaeological projects in many parts of the world, and these certainly had impacts on zooarchaeological recording systems. Recognizing that explaining the Neolithic revolution or any such complex interaction of humans, animals, plants, and landscapes through time is not likely to be achieved by comparing a half-dozen sites scattered across hundreds of kilometers, many teams pooled resources and committed time to regionally focused projects aimed at building up a systematic record of multiple indicators (with zooarchaeology in the first rank) on the finer scale of lake basins, islands, or other local ecosystems. The late 20th century theoretical turn towards *Historical Ecology* was particularly attractive to zooarchaeologists, and this approach focused attention on landscapes changing through time and complex interactions of people, animals, plants, and place particularly suitable to the comparison of multiple well-excavated, well-dated, and consistently-recorded archaeofauna from a selected region (Crumley 1994).

Within zooarchaeology, many practitioners were also coming to believe that sample size was the key variable for the utility of archaeofauna in comparisons, and that "bigger is better" was a clear take away message of early statistical experiments comparing quantification methods. Small collections (NISP in the low hundreds), no matter how well described in painstaking detail by the analyst, simply were usually too small and noisy to be useful in comparative work. It also appeared that the best remedy for the increasingly well documented bad news coming out of experimental and ethno-archaeological studies of bone attrition was to both pump up site sample sizes and to multiply sampling sites to try to recognize cultural signal vs. taphonomic noise (more or less the same remedy applied by other users of paleoecological proxy evidence in archaeobotany and geoarchaeology). From all sides, the push for more and larger archaeofauna put pressure on field and laboratory workers to work faster and more efficiently while producing records that could be reasonably compared across and between regions.

How to achieve these goals with the zooarchaeological recording and data management tools we had available? How to really directly compare different site reports and databases to move towards more effective Historical Ecology on a regional scale? A first step had to be communication, and it is no accident that the 1990's saw rapid growth of ICAZ and allied groups with proliferating workshops and interest groups formed around particular taxa, regions, and research problems.

In 1992, a group of archaeologists, zooarchaeologists, biologists, historians, climatologists and ethnographers met at Hunter College CUNY for an NSF-funded attempt to create what became a regional research cooperative called the "North Atlantic Biocultural Organization" (NABO, www.nabohome.org). The acronym means "neighbor" in several Scandinavian languages, and the concept of neighborly collaboration on projects and problems too big for any single scholar, research team, or national effort remains a core of the NABO research and education cooperative. The NABO foundational meeting in 1992 itself built upon a highly successful 1988 meeting at Bowdoin College hosted by Gerry Bigelow and Susan Kaplan. This brought together a core of field and lab workers mainly from UK, US, Canada, and Scandinavia united by their interest in bringing science and the more rigorous methods of prehistoric archaeology to the fascinating cultural and ecological issues resulting from the colonization of the islands of the North Atlantic following the Scandinavian spread in the early Viking Age. These teams rapidly recognized common interests and the need to coordinate projects and analyses across a broad area once unified by a common language and culture but now divided among multiple national traditions and without a natural scholarly meeting place. Initially NABO was very much about bringing science to Viking Age and Medieval Archaeology, and its membership still tends to remain on the "green" end of the scholarly spectrum. In the past few years, however, much NABO research has also become more fully engaged with saga scholars and environmental humanists in what is now described as "long term human ecodynamics".

Twenty years of collaborative work in the field, lab, and classroom followed, and the role played by the international Icelandic field school hosted since 1996 by the Archaeological Institute Iceland (*Fornleifastofnun Íslands*, FSÍ, http://www.instarch.is/english/) deserves special mention for its role in developing a growing cadre of North Atlantic field workers all trained to a comparable standard and all raised to see interdisciplinary and international research cooperation as natural rather than exceptional. A closely allied field school (now located on Rousay in Orkney) led by Julie Bond and Steve Dockrill of Bradford University strongly supports this process of hands-on introduction to science and archaeology in the cold and wet, and like the FSÍ field school the Rousay project has become a center piece for extensive collaboration with local schools and extensive public outreach and engagement. Many of the NABO students participate in both these field schools, and field school graduates are now early-career professionals with their own students and research teams working across the region. More about current NABO cross-disciplinary and international collaborations and a great deal of data are available at the NABO website (www.nabohome.org) maintained by Anthony Newton at the *School of GeoSciences of the University of Edinburgh* and now at the IHOPE Circumpolar Networks section of the *Integrated History and Future of People on Earth* website (http://www.ihopenet.org/circumpolarnetworks/).

The NABO teams are very diverse, often *ad hoc*, and low on organizational superstructure and high on heterachical energy – but everyone early on recognized the need for some common standards and shared approaches to data collection and management as key elements in the collaborative effort. There has also always been a strong representation of animal bones people who identify on the "zooarchaeologist" end of the ICAZ spectrum: people who see themselves primarily as archaeologists making use of animal bone evidence and who are ready to act as project directors in the field as well as sorting bones in the lab. This connection between field and lab meant that when the NABO zooarchaeology working group came together in 1995 to consider the common problems faced by the larger field by then represented by the international ICAZ community – problems centered around identification, recovery standards, and data recording and management – there was a recurring concern for practicality and robust-but-flexible systems that could be consistently implemented under the often demanding field conditions of the north. Comparison of experiences and combination of different national and local archaeological traditions across the region has proved a lasting source of strength and mutual inspiration.

Experimentation and close communication between field site and bones lab has also been key. In the evolving common NABO fieldwork strategies promoted within the network (typified by the now-widely applied Archaeological Institute Iceland's *Field Manual 3.0*, available for download from the NABO website). As an example of these interactions there was an initial interest in whole-site flotation to promote “total recovery”. Communication between field and lab rapidly revealed the problem with whole-site flotation in either creating massive backlogs of bags awaiting flotation (often discreetly used as backfill at end of season rather than being expensively transported elsewhere), or in limiting excavation unit sizes to column samples only. In North Atlantic contexts, the problem of laboratory analysis posed by a flotated collection also proved daunting – one bag might contain several thousand tiny fragments, nearly all dandruff-flake sized bits of communited fish bone. Sorting in the lab became genuinely soul destroying, and the sense that we were counting the same fish a nearly infinite number of times (and all the 100% flotated archaeofauna tended to produce relative percentages that were 99.99% “Fish Sp. Unident.”) suggested significant fundamental analytical issues as well.

Given that our non-zooarchaeological field partners were committed to large-scale open-area excavation of both structures and middens (both often containing well-preserved animal bone) and that many of us were interested in detecting potential activity areas and spatial refuse accumulation patterns, combined with the growing recognition that more and bigger archaeofauna had to be the way forward, the NABO teams rapidly recognized that whole-site flotation was a non-starter. On site, the outcome of a death match between proponents of open-area excavation strategies and of flotation-based recovery strategies was clearly going to be a total defeat for any program of sieving or flotation on site in the contexts of North Atlantic archaeology (small crews, short seasons, endangered sites, limited funding). Experimentation in field and lab fortunately indicated that there were no major changes in species diversity (with the exception of herring and small rodent bones) in most N Atlantic archaeofauna between flotation residue and the results of fairly coarse-mesh dry sieving (ca. 4mm mesh). This mesh size did a good job in the field of recovering bone fragments down to the 1-2 cm range in practice, and was also quite efficient in recovering beads and other small artifacts – and importantly this mesh size remained usable in normal North Atlantic weather and soil conditions. The eventual compromise was to standardize on 100% 4 mm dry sieve of all bone-bearing deposits (when stratified), sub-sampling (systematically and *ad hoc*) at 1 mm wet sieve, and maintaining a substantial sub-sample for whole-soil flotation (either in field or lab) for archaeobotany and entomology. This still has resulted in the occasional ugly sieving backlog on wet days (often associated with a rather nasty “gribble bag” arriving in the lab with the contents of a muddy sieve dumped in more or less whole by stressed field workers). There is no question that some small bones and bones of small taxa are certainly being lost, but the tradeoff was a practical working strategy that could be implemented in a wide range of sites (Labrador to North Cape) that has proven feasible as a compromise for comparability. Individual projects in practice often alter the proportions of the different recovery approaches to allow for local conditions and project objectives, but at least everyone is aware of the default standard for broad comparability in bone and artifact recovery.

As collaboration on field schools and research and rescue field projects promoted the development of a “messy but effective” approach to common recovery strategies, the NABO zooarchaeology working group met at Hunter College in New York for a week in 1997 to take on the issue of common or at least comparable bone recording methods. The gathering included 27 zooarchaeologists from the US, UK, Canada and Scandinavia with over a collective century of laboratory experience often including massive archaeofauna coming from both within and outside the North Atlantic region. A very productive set of discussions took place about the practical issues of balancing the need to record sufficient observations per bone fragment (element, side, end, burning, gnawing, cut marks, etc.) and enough possible states per observation (how many categories of burning?) with the need to process large collections and keep comparability among workers (including students and lab volunteers). We all had brought coding manuals and software (then mainly on 3.5" disks) and there was a great deal of fun in seeing many common solutions to problems independently discovered (the famous case of multiple discoveries of the light bulb in the early 20th century was replicated repeatedly). Significantly, by 1997 Microsoft products (Excel and Access) had achieved market dominance and most of us had reluctantly given up earlier home-programmed software. This standardization meant that we were mainly dealing with early versions of Excel spreadsheets (for specialist analysis, report tables, and graphics) and Access databases (then mainly just for raw data storage and extraction given the comparatively limited and user-hostile graphics package then available). James Rackham's coding system and database was clearly ahead of the rest of the pack, and was backed by extensive use in both research and contract work. The CUNY-developed set of supporting Excel spreadsheets aimed at providing forms for calculating MNI, NISP, DD, and illustrating skeletal element distribution patterns for mammals and fish (important for investigations of early artisanal vs. commercial fisheries research) were also seen as useful and worth further development, and it is fair to say that everyone made significant contribution to the "consensus package" that resulted, which perhaps inevitably was called NABONE.

The CUNY Zooarchaeology lab (then as now staffed by a mix of senior and entry-level grad students with multiple bones-focused doctoral projects in process) was selected for further NABONE development and testing against a real-world combination of large archaeofauna and student helpers. Lab testing revealed some need to opt for "simple but robust" vs. "precise but fragile" coding approaches. We initially had six graded degrees of burning as possible scores for a fragment, but experience showed that even with photos and actual example specimens mounted on cards it proved impossible to get consistent assessments between recorders or in many cases between pre-lunch and post-lunch sessions of the same analyst. We collapsed categories into three, provided better written descriptions (as below), and continued to provide photo type examples, and as a result consistency improved dramatically.

BURNING

B – Black burned
W – White-grey burned
S – Scorched (black & dark brown patches on unburned background)

The NABONE package has been torture tested through multiple generations of PhD projects and lab volunteers and is now in its 9th edition. Revisions have been evolutionary, with concern to maintain compatibility with earlier versions while fixing problems that became apparent with multiple users and multiple projects, but the package at core has remained a simple coding system that is fairly transparent (a "BOS, PH1, DIS, FUS, Chop, no chew, no burn, fragsize 5-10 cm" record we hope will remain comprehensible even if the manual is lost). The manual and the rest of the package including sample data sets and a teaching component has been circulated freely through the NABO working group of ICAZ in several formats (CD is still available) and is currently available for download through the NABO website (www.nabohome.org/products/manuals/.../NABONE9thEdition.pdf).

This coding and recording manual connects to a printed record form (that has 25 bones per page plus locational data and has scope for metrics and tooth eruption/wear and multiple examples of the same element) and thence to an MS Access database. The retention of a paper record provides both an ultimate hardcopy backup and an opportunity for supervision of recording by different individuals, and as bones labs remain dusty and gritty places this also reduces laptop mortality. The Access database is the key digital record, but a set of taxon-specific Excel spreadsheets (for cattle, caprine, deer, seals, birds, fish) are included which allow easy and consistent calculation of NISP, simple MNI, and bones/excavated volume, ranked element frequency, and (when possible) the comparison of ranked observed element frequency and ranked bone density scores (pooled by quartile to allow for different author's estimates of bone density). These spreadsheets allow for production of tables and graphs for reports and publications, and they have greatly eased the production of lab reports owed to colleagues (and posted on the NABO website) as well as consistent comparisons across NABO archaeofauna.

As example, Figure 1 is generated from the "all gadid fish" NABONE Excel file from Phase II at the Viking Age Icelandic site of Hofstaðir. It highlights through MAU % comparisons the high representation of pectoral girdle fish bones, in this case virtually all cliethra (dense bones around the gill area), which often travel with gutted and dried large cod-family fish in modern and historic dried products. A hypothesis that this site, located over 50 km inland, may have been provisioned by prepared (largely headless) marine fish (McGovern et al 2006, 2007, 2009) can be further investigated by zooming into the MAU % for the vertebral column for this same sample (Figure 2). Again, MAU % normalizes for skeletal element frequency (dividing recorded NISP by the number of times the bone appears in the whole skeleton), so the disproportionate number of caudal vertebra in the sample represents a clear under-representation of thoracic and pre-caudal vertebrae. These upper-body vertebrae were left in preserved fish products dried in the round (classic "stockfish"), but in flat-dried products were filleted out and left at the landing/processing point on the coast. It is the latter flat- dried product that seems to have been consumed regularly at this Viking age inland center. Similar pre-formatted graphs are generated from the other major taxa spreadsheets, making possible the generation of directly-comparable figures and graphs with a common "look and feel," as evident in the 63 NABO CUNY archaeofauna reports posted on the NABO website at present (http://www.nabohome.org/publications/labreports/labreports.html).

Figure 3 presents a larger scale comparison of early settlement phase archaeofauna from Norway, Scotland, Faroes, Iceland and Greenland based on the common NABONE recording system. The same system has been applied to medieval and early modern sites across the region, allowing for both broad inter-regional comparisons and what Crumley has called the "longitudinal perspective" of change through time in a particular region or landscape. The potential for addressing some of the big questions in our region, centering on human impact on island ecosystems through time, climate impacts on humans and landscapes, and the impact of culture contact and early globalization, is now being fully realized by a new generation of North Atlantic researchers (Brewington et al. 2014, Dugmore et al 2012, 2013, Harrison & Maher 2014, Hicks et al. 2014, Smiarowski et al. 2014). The NABONE record is also being curated and made widely available through archiving at tDAR (Digital Antiquity Program at Arizona State University, http://www.tdar.org/) and via a digital map -based NABO Project Management System on the main NABO website housed at University of Edinburgh. The NABONE record is also now playing a role in a new NSF-supported international North Atlantic Cyberinfrastructure project led by Colleen Strawhacker of the National Snow and Ice Data Center in Boulder Colorado, and will contribute to efforts to better curate, integrate, and visualize "big data" sets for promoting the ambitious goals of mobilizing the past to better serve attempts to secure future sustainability (Fiske et al. 2014). There is current work going forward to make the NABONE system more friendly to global searches and to enhance data discoverability, with new NSF proposals in review to provide support for major upgrades. For more updates on the NABONE story and downloads of all the current Hunter Zooarchaeology laboratory reports (currently 63 are available) please visit the NABO websites (http://www.nabohome.org/publications/labreports/labreports.html).

NABONE and the North Atlantic island ecodynamics projects drawing on it are only one example of the response of the international zooarchaeological community now so well organized and so well served by digital resources of all kinds to respond to the challenge of "too many bones". Brian's help with all those punch cards back in the beginning of the bone surge was much appreciated at the time, and has born good fruit since then.

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Figures

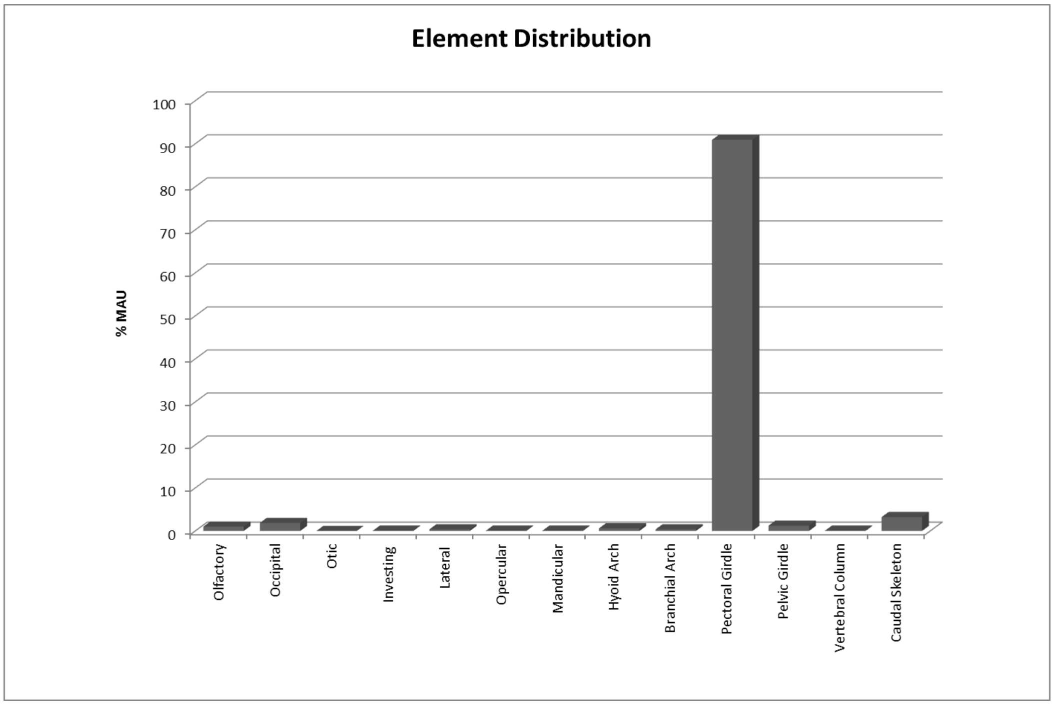

Figure 1. Comparison of fish bone (cod family) distribution across the major element groups of the cod skeleton. MAU % normalizes for different numbers of bones in the skeleton, so a whole fish would display here as a series of equal height bars.

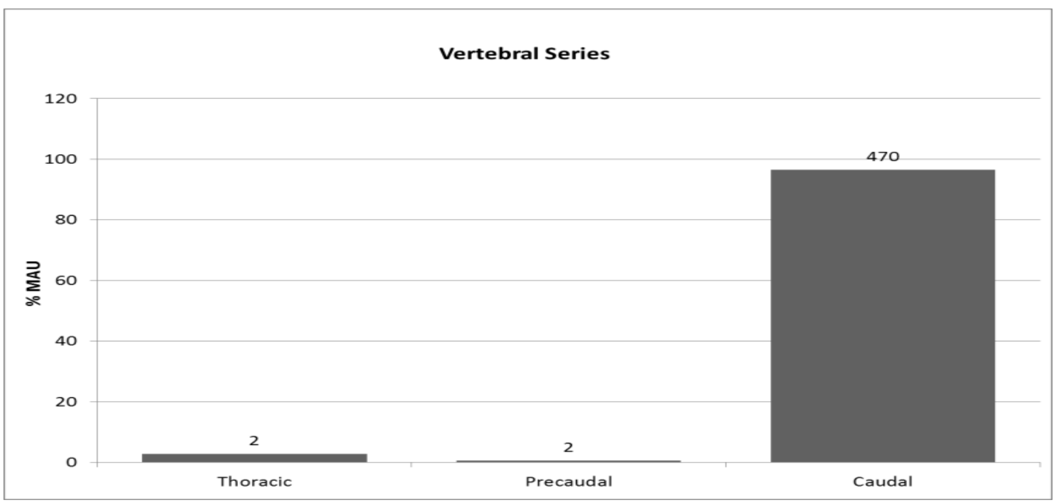

Figure 2. The same sub-sample of cod-family fish bones from the inland Viking Age site of Hofstaðir in Northern Iceland, showing the relative abundance of thoracic (upper body), pre-caudal, and caudal vertebrae from this taxon

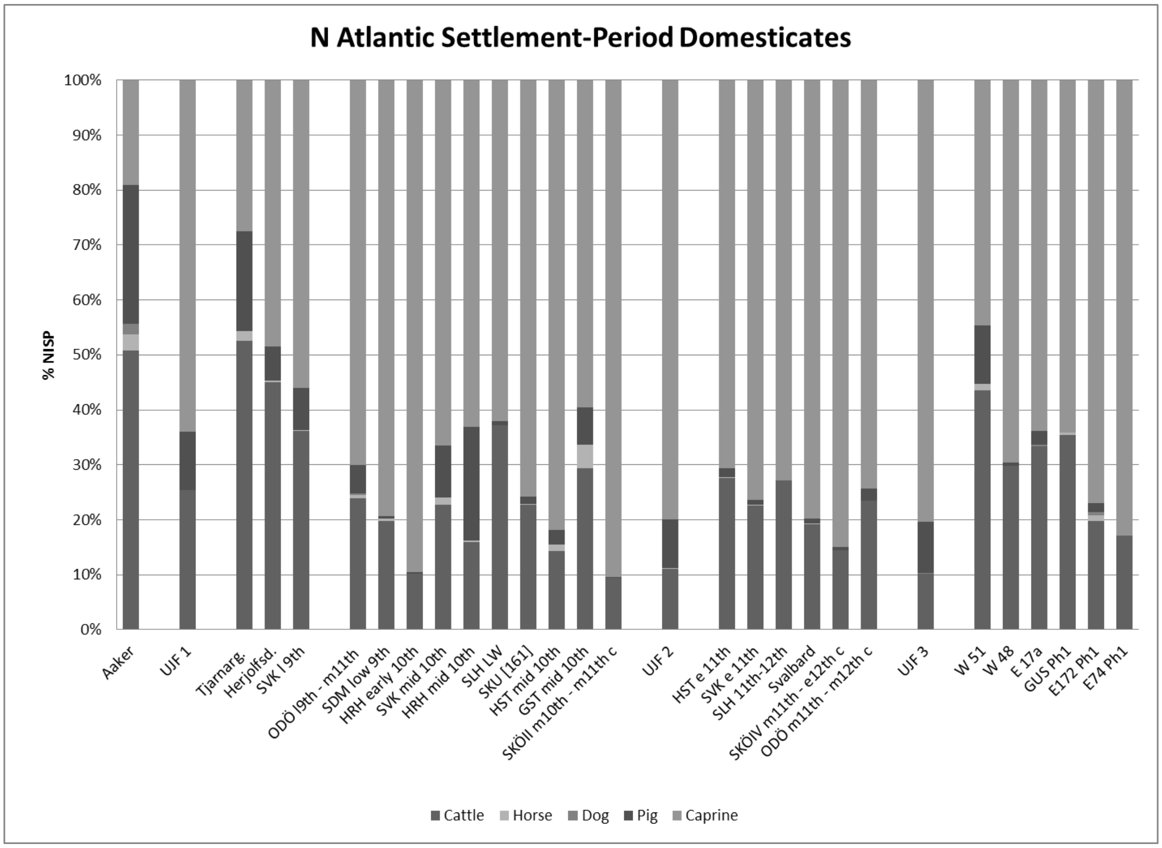

Figure 3. Comparison of multiple settlement age archaeofauna from Norway, Faroes, Iceland and Greenland in domestic mammal relative percentages (NISP). All were recorded in NABONE.

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