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REVIEW

The Ertebølle Zooarchaeological Dataset from Southern Scandinavia

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Interdisciplinary archaeological research in southern Scandinavia has a long history of practice, beginning in the mid-19th century. In particular, research concerning the late Mesolithic hunter-gatherer-fisher Ertebølle culture (5400-3950 cal BC) has resulted in a large zooarchaeological dataset useable in large-scale comparative or meta-analyses. In this paper, we review this dataset, and the quantity and character of the data is described. We then address particularities of the published data that may affect comparative analyses. By focusing on fragmentation and bone condition as major influencing factors on published quantitative statistics, we demonstrate that caution is warranted in comparisons between these types of data deriving from Ertebølle assemblages. Nevertheless, we focus on the dataset as a valuable resource for understanding variability in hunter-gatherer-fisher food economies and how to best mitigate potential issues in selection and use of the data in comparative studies. We do so by discussing types of comparative analyses that are most likely to provide valuable information about the human past. Lastly, we propose a series of recommendations that should inform and ensure the comparability of future Ertebølle research, and present our review as a case study in zooarchaeological meta-analyses.

Keywords: Ertebølle; Zooarchaeology; meta-analyses; fauna; Mesolithic

Introduction

Few traditions of archaeological inquiry can equal the history of archaeological and zooarchaeological research in southern Scandinavia (Fischer & Kristiansen 2002). Since the middle of the 19th century (Forchhammer, Steenstrup & Worsaae 1851), excavation reports of prehistoric archaeological sites in the region have included at least some analysis or description of faunal remains, scholarship which has continued until the present day. As the first Danish Kitchen Midden Commission (formed 1848) included archaeologists and zoologists (Fischer & Kristiansen 2002) in their investigations of the now-famous Danish shell middens, research in the region represents one of the longest legacies of interdisciplinary zooarchaeological research in the world.

The Ertebølle culture of southern Scandinavia (5400–3950 cal BC, hereafter EBK) represented the last phase of the Mesolithic, ending with the introduction of an agricultural way of life with the Funnel Beaker (hereafter TRB) culture, around the start of the fourth millennium BC. EBK groups were fully capable of exploiting a broad range of animal resources from various environments (Price & Gebauer 2005; Ritchie, Gron & Price 2013), and additionally a wide variety of plant foods (Göransson 1988; Kubiak-Martens 1999; Price & Gebauer 2005; Regnell *et al.* 1995). Thus, as an example of what may have been complex maritime hunter-gatherer-fishers, the EBK is particularly useful in terms of understanding forager and collector economies (Binford 1980).

Agriculture had nearly finished its march across continental Europe from the Near East, but stalled for much of the fifth millennium BC just south of the EBK culture area (Hartz, Lübke & Terberger 2007). When agriculture *did* arrive in southern Scandinavia, the reasons and explanations behind this sudden change can at least in part be attributed to processes starting in the preceding Mesolithic. This situation also raises questions as to why agriculture did not spread to southern Scandinavia for such a long time and then why it did and when it did, as EBK groups and farmers to the south were almost certainly aware of, and in at least sporadic contact with, each other (Hartz *et al.* 2007; Rowley-Conwy 2014). Therefore, the period is also of utmost interest in terms of the introduction of agriculture in northern Europe.

It is for these reasons that a detailed and useable understanding of the food economy of the EBK is desirable. Given the general paucity (but not absence) of organic plant remains (see Göransson 1988; Kubiak-Martens 1999; Price and Gebauer 2005; Rasmussen 1998; Regnell *et al.* 1995), faunal remains provide some of the best opportunities for

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understanding how EBK groups exploited the resources available to them. However, given that hunter-gatherers have varying patterns of mobility (Binford 1980), such investigations must in and of themselves encompass multiple sites for testing culture-wide hypotheses.

This paper aims to explore the potential for large-scale comparative studies (or meta-analyses) of EBK faunal exploitation using the existing dataset. It provides a much-needed review of the majority of the available published research for such applications. To do this, we work backwards; that is, we outline the data and its character, and then discuss its potential in a comparative sense. We will first review the available research detailing non-human bones in EBK contexts to outline what is available for such studies. We will then briefly outline the large number of particularities to EBK zooarchaeological research that have relevance for comparative studies of the published literature. In lieu of addressing every issue with the dataset, of which there are many, we instead focus on the most problematic: differential bone fragmentation among assemblages. Using indirect indicators, we illustrate the enormous degree of variability in the available published bone material that has measurable and profound impact on relative abundance values most common in the literature. Last, we will assess the potential for large-scale zooarchaeological meta-analyses and make some recommendations in an effort to increase future comparability, a move towards a more standardized EBK zooarchaeology.

The Dataset

As of the end of 2014, there are 121 published sites with reported faunal assemblages (**Table 1**) that have yielded bone material that dates, at least in part, to the EBK. This number may be larger or smaller depending on one's definition of a site (e.g. the Vedbæk sites) and whether assemblages of mixed date and/or culture are included. We are certainly aware of more analyses that have occurred and more bone material that remains unconventionally reported, but we focus here on data readily available in print. Given the history and disparate description and publication of these data, we fully acknowledge that we have missed some. Furthermore, there is a corpus of unpublished literature and there are sure to be new analyses to add to the existing dataset. This is not a comprehensive sample, but it is an excellent one as it represents most of what is available and serves to illustrate the potential for comparative analyses.

The sites in **Table 1** have been published in varying degrees of completeness, at least 169 times, indicating a significant amount of dual, piecemeal, or compilation publication compared with the number of sites reported. Some sites only reported the fish component to the exclusion of the mammals and birds, or vice-versa (e.g. Enghoff 1994). These reports range from simple lists of species (e.g. Andersen 2004), to partial quantification (e.g. Nobis 1962), to comprehensive analyses (e.g. Richter & Noe-Nygaard 2003). Of these reports, the primary language of publication is English, Danish, German, Polish, or Swedish, and publication dates range from the 19th century to the end of 2014.

One-hundred ten sites have reported Number of Identified Specimens (NISP) data in some capacity; often using different terms or descriptive methods that predate the term (see Lyman 1994a). Of this sample, only 24 possess similar Minimum Number of Individuals (MNI) data, subject to the same limitations and historic methodological and semantic limitations as the NISP data. In no instances are MNI values provided without NISP values. Sample sizes are widely variable, from a few dozen specimens to over several thousand. Twenty-two publications (**Table 1**) report a total number of specimens and either the number of unidentified or the number of identified specimens, or both. Qualitative treatments are widely varied.

Considerations

EBK zooarchaeology has a number of particularities that have the potential to influence the data, and therefore comparative study of the existing dataset. Some are related to geographical and natural factors, some are historical research concerns, while others concern human behaviors particular to Mesolithic culture in southern Scandinavia. In all cases, such considerations must be recognized to assess large-scale analytical potential.

Southern Scandinavia during the Mesolithic was a region of rich faunal diversity that is reflected in EBK assemblages. Therefore, species-rich assemblages exist, depending on site location, sample size, and recovery methods. Nearly the entire range of fauna present in a local environment may be found at a given site. Asnæs Havnemark, a coastal beach deposit, and Havnø, a transitional EBK-TRB kitchen midden, are primary examples. At these sites, 23 and 35 fish taxa and 13 and 34 bird taxa, respectively, were identified, as well as 16 mammal taxa each (Gron 2015; Ritchie 2010; Ritchie, Gron & Price 2013; Robson 2015). These numbers included marine, freshwater and diadromous fish, terrestrial, marine, and fur-bearing mammals, and waterfowl, raptors, and passerines. While useful in environmental understanding, this richness can be problematic. High species richness in southern Scandinavia can and will affect relative abundance values, as a number of closely related species may be present. This may include numerous species of fish, seals, canids, and waterfowl, all of which may not be identifiable to the species level, affecting relative abundance values and classification by the zooarchaeologist. Seals are a prime example, where only particular elements may permit specific determination among the four taxa present during the EBK (Storå & Ericson 2004). In this case, most species are easily identified as seals, but it is up to the zooarchaeologist whether a general class of "seal" is included in reporting for those specimens not determinable to a particular species. Furthermore, a decision must also be made whether to include general classes in NISP and MNI values, and how this is divided between, or included with, those specimens determined to species of seal. These decisions, coupled with chance findings of diagnostic elements, influence quantitative values in a way unrelated to past human behavior.

Site	LIST	NISP	MNI	Fragmentation Data	Percent Identifiable	Citation	Language
Agernæs	X	X	X		X	Richter and Noe-Nygaard 2003	English
Aggersund	X	X	X		X	Enghoff 2011; Møhl 1978	Danish, English
Alby	X	X				Königsson et al. 1971	Swedish
Arlöv I	X	X				Lepiksaar 1983	Swedish
Asnæs Havnemark	X	X	X	X	X	Ritchie et al. 2013	English
Bermansdal	X					Enghoff 2011	English
Bjørnsholm	X	X	X	X		Bratlund 1993; Enghoff 1993; Rosenlund 1976	English
Bloksbjerg	X	X				Enghoff 2011; Rosenlund 1976; Westerby 1927	Danish, English
Brabrand Sø	X	X				Enghoff 2011; Thompsen and Jessen 1906	Danish, English
Bredasten	X	X				Jonsson 1986	English
Bregentwedt	X					Nobis 1962	German
Brovst (upper levels)	X	X				Rowley-Conwy 1980	English
Bøgebjerg	X	X				Ritchie 2010	English
Bökeberg III	X	X	X	X		Eriksson and Magnell 2001	Swedish
Bønvig	X	X				Johansson 1999	Danish
Dąbki	X	X	X			Ilkiewicz 1989; Zabilska 2013	English, Polish
Dragsholm	X	X				Ritchie 2010	English
Drigge	X	X				Terberger 1999	German
Drøsselholm	X	X				Degerbøl 1943	Danish
Dyngby III	X					Andersen 2004	Danish
Dyrholmen	X	X				Degerbøl 1942; Rowley-Conwy 1980	Danish, English
Egsminde	X	X				Enghoff 2011	English
Ertebølle	X	X			X	Enghoff 1987, 2011; Madsen et al. 1900	Danish, English
Even Øst	X	X				Johansson 1999	Danish
Fiskerhuset	X	X				Johansson 1999	Danish
Flynderhage	X	X				Rowley-Conwy 1980	English
Frederiks Odde	X	X				Enghoff 2011	English
Fårevejle	X	X	X	X	X	Gron 2013; Madsen et al. 1900; Ritchie 2010	Danish, English
Förstermoor	X					Nobis 1962	German
Godsted	X	X				Degerbøl 1945; Rosenlund 1976	Danish, English
Grisby	X	X				Enghoff 1994; Petersen 2001	Danish, English
Grube-Rosenfelde	X					Schmölcke 2005	German
Grube-Rosenhof	X					Goldhammer 2008; Schmölcke 2005	German
Gudumlund	X					Forchhammer et al. 1852	Danish
Hallbygaard	X	X				Degerbol 1943	Danish
Havelse	X	X				Forchhammer et al. 1851, 1852; Winge 1903	Danish

Contd.

Site	LIST	NISP	MNI	Fragmentation Data	Percent Identifiable	Citation	Language
Havnø	X	X	X	X	X	Gron 2013; Madsen et al. 1900; Ritchie 2010; Robson 2011	Danish, English
Hjerk Nor	X	X	X		X	Hatting et al. 1973	Danish
Holme Skanse	X	X				Rowley-Conwy 1980	English
Humlebakke Syd	X	X				Johansson 1999	Danish
Jesholm I	X	X				Ritchie 2010	English
Jordløse By	X	X				Rosenlund 1976	English
Jäckelberg–Nord	X					Heinrich and Schmölcke 2009, Lübke et al. 2011	English
Karlsgab	X	X				Johansson 1999	Danish
Kassemose	X	X				Degerbøl 1945	Danish
Kildegaard	X					Degerbøl 1943	Danish
Klintesø	X	X				Madsen et al. 1900	Danish
Kolding Fjord	X	X				Degerbøl 1945	Danish
Kolind	X	X				Degerbøl 1942	Danish
Krabbesholm II	X	X			X	Enghoff 2011	English
Langø	X	X				Degerbøl 1928	Danish
Lietzow-Buddelin	X	X	X			Schmölcke 2005; Teichert 1989	German
Lillerøn	X	X				Johansson 1999	Danish
Lollikhuse	X	X	X		X	Magnussen 2007; Ritchie 2010	Danish, English
Lundbakke Syd	X	X				Johansson 1999	Danish
Lystrup Enge	X	X			X	Enghoff 2011	English
Löddesborg	X	X				Hallström 1984; Jennbert 1984; Jonsson 2005	Swedish
Lønned Vest	X	X				Johansson 1999	Danish
Magleø	X	X				Degerbøl 1943	Danish
Mejlgård	X	X				Møhl 1960; Petersen et al. 1888; Rosenlund 1976	Danish, English
Mellemste Sandhuk	X	X				Johansson 1999	Danish
Moesgården X	X	X				Rosenlund 1976	English
Møllegabet II	X	X	X		X	Cardell 2004; Hodgetts and Rowley-Conwy 2002	English
Møllekrog Vest	X	X				Johansson 1999	Danish
Nederst (midden I)	X	X				Ritchie 2010	English
Nederst (midden II)	X	X				Enghoff 1994	English
Neustadt	X	X	X		X	Glykou 2011; Schmölcke et al. 2006	German
Nivå 10	X	X				Enghoff 2011	English
Nivågård	X	X				Degerbøl 1926; Enghoff 2011	Danish, English
Norslund	X	X				Andersen and Malmros 1966	Danish
Norsminde	X	X				Enghoff 1991; Rowley-Conwy 1980	English

Site	LIST	NISP	MNI	Fragmentation Data	Percent Identifiable	Citation	Language
Nøddekonge	X	X	X		X	Gotfredsen 1998	Danish
Nørremarksgård II	X	X				Johansson 1999	Danish
Nørremarksgård III	X	X				Johansson 1999	Danish
Ordrup Næs	X	X				Becker 1939; Degerbøl 1939	Danish
Præstelyng	X	X	X		X	Noe-Nygaard 1995	English
Ralswiek-Augustenhof	X	X	X			Gramsch 2002; Teichert 1989	German
Ringkloster	X	X	X			Enghoff 1998; Rowley-Conwy 1980, 1998	English
Ronæs Skov	X	X				Enghoff 2009	Danish
Rønnen Syd II	X	X				Johansson 1999	Danish
Rüde	X	X				Feulner 2012; Lüttschwager 1967; Nobis 1962	English, German
Saltpetermosen	X	X				Rosenlund 1976	English
Satrup LA 2	X	X				Feulner 2012	English
Satrup LA 71 (Förstermoor)	X	X				Feulner 2012; Nobis 1962	German, English
Schlamersdorf (Travenbruck)	X	X	X		X	Heinrich 1993	German
Skateholm I	X	X		X		Jonsson 1988	English
Skateholm II	X	X		X		Jonsson 1988	English
Skjutbanorna	X	X				Jonsson 2005	Swedish
Slotstenen	X	X				Johansson 1999	Danish
Slotstenen II	X	X				Johansson 1999	Danish
Sludegårds Sømose	X	X				Albrechtsen 1954; Noe-Nygaard and Ricther 1990	Danish, English
Smakkerup Huse	X	X	X		X	Hede 2005; Larsen 2005	English
Soldattorpet	X	X				Althin 1954	English
Sparregård	X	X				Rosenlund 1976	English
Strandgaard	X	X				Mathiassen 1940	Danish
Sølager	X	X			X	Skaarup 1973	German
Timmendorf-Nordmole I	X					Schmölcke 2003, 2005	German
Tingbjerggard	X	X				Degerbøl 1943	Danish
Trustrup	X	X	X	X	X	Gron 2013	English
Tybrind Vig	X	X	X			Trolle 2013	English
Tågerup	X	X	X			Eriksson and Magnell 2001	Swedish
Vedbæk Boldbaner	X	X				Degerbøl 1946	Danish
Vedbæk Magleholm	X	X				Enghoff 1994	English
Vedbæk Maglemosegård	X	X				Enghoff 1983, 1994; Noe-Nygaard 1971	English

Contd.

Site	LIST	NISP	MNI	Fragmentation Data	Percent Identifiable	Citation	Language
Vedbæk Maglemosegårds Vænge	X	X				Enghoff 1994	English
Vedbæk-Henriksholm Bøgebakken	X	X				Albrethsen and Petersen 1977; Enghoff 1994; Rosenlund 1976	English
Vejkonge	X	X	X		X	Gotfredsen 1998	Danish
Vinkelhage	X					Enghoff 2011	English
Visborg	X	X			X	Enghoff 2011	English
Vængesø I	X	X				Rowley-Conwy 1980	English
Vængesø II	X	X				Enghoff 2011; Rowley-Conwy 1980	English
Vængesø III	X	X			X	Enghoff 2011	English
Wangels	X	X				Heinrich 1999	German
Yderhede	X	X			X	Enghoff 2011	English
Yngsjö	X	X				Jonsson 1997	Swedish
Åkonge	X	X	X		X	Enghoff 1994; Gotfredsen 1998	Danish, English
Åle	X	X				Enghoff 2011	English
Åmølle	X	X				Madsen et al. 1900	Danish
Øgaarde	X	X				Degerbøl 1943	Danish
Ølby Lyng	X	X				Møhl 1971; Petersen 1971	Danish
Østenkær	X	X			X	Enghoff 2011	English

Table 1: The EBK sample from southern Scandinavia listing which data are included in the literature.

Another consideration is at what number an archaeological assemblage's overall size is likely to represent the character of the death assemblage from which it derives, as there is a broad range of identified NISP values in the literature. To a certain extent, this is largely a function of the recovery techniques employed, especially sieving, that was only routinely undertaken from the late 1960s onwards. However, sample size is also a reflection of the intensity of exploitation, fragmentation, and other factors. Looking to the literature since 1880 (**Figure 1**), historical sample sizes immediately become larger once sieving is introduced for both mammals and fish, so inclusion of older assemblages in comparisons must consider that published relative abundances may be highly biased in this regard. While sieving can be a more significant influencing factor than fragmentation, the only option in comparing historical analyses is to quantify the present condition of the bone, which in non-sieved assemblages means that in effect, this is yet another taphonomic actor on the assemblages in question.

The background, training, and number of analysts (**Table 1**) are also inherently problematic. Different analysts apply different qualitative and quantitative methods and are partly a reflection of their academic training, his or her research questions, and the historical context of the work. Simply put, a geologist will ask different questions than a zoologist or an archaeologist, and therefore data generated will inherently differ and may be methodologically incompatible. Given the long and varied history of research, zooarchaeological practitioners are similarly varied, from early zoologists, Herluf Winge (Winge 1900; Winge 1903) and Magnus Degerbøl (Degerbøl 1928; Degerbøl 1942), to the present authors, both archaeologists. Aside from inherent inter-observer variation (Lyman & VanPool 2009), even among similarly trained researchers, this potentially can be problematic in comparative work.

Lastly, a particularity of EBK faunal exploitation is that there is strong evidence that the same species were sometimes used for different purposes. This warrants caution in comparing even the most abundant and objectively quantitative data, NISP values, as well as all other methods of quantification. An extreme example of this is the red deer (*Cervus elaphus*) from Agernæs (Richter & Noe-Nygaard 2003) and Åkonge (Gotfredsen 1998). At these sites, the relative abundance values look similar, at 55.3% and 65.3% of NISP respectively. However, the individual circumstances at each site vary considerably, with almost the entire Agernæs sample being represented by immature individuals probably killed for their spotted skins, whilst at Åkonge hunting of adults for food was probably the main focus. Simply comparing NISP values for

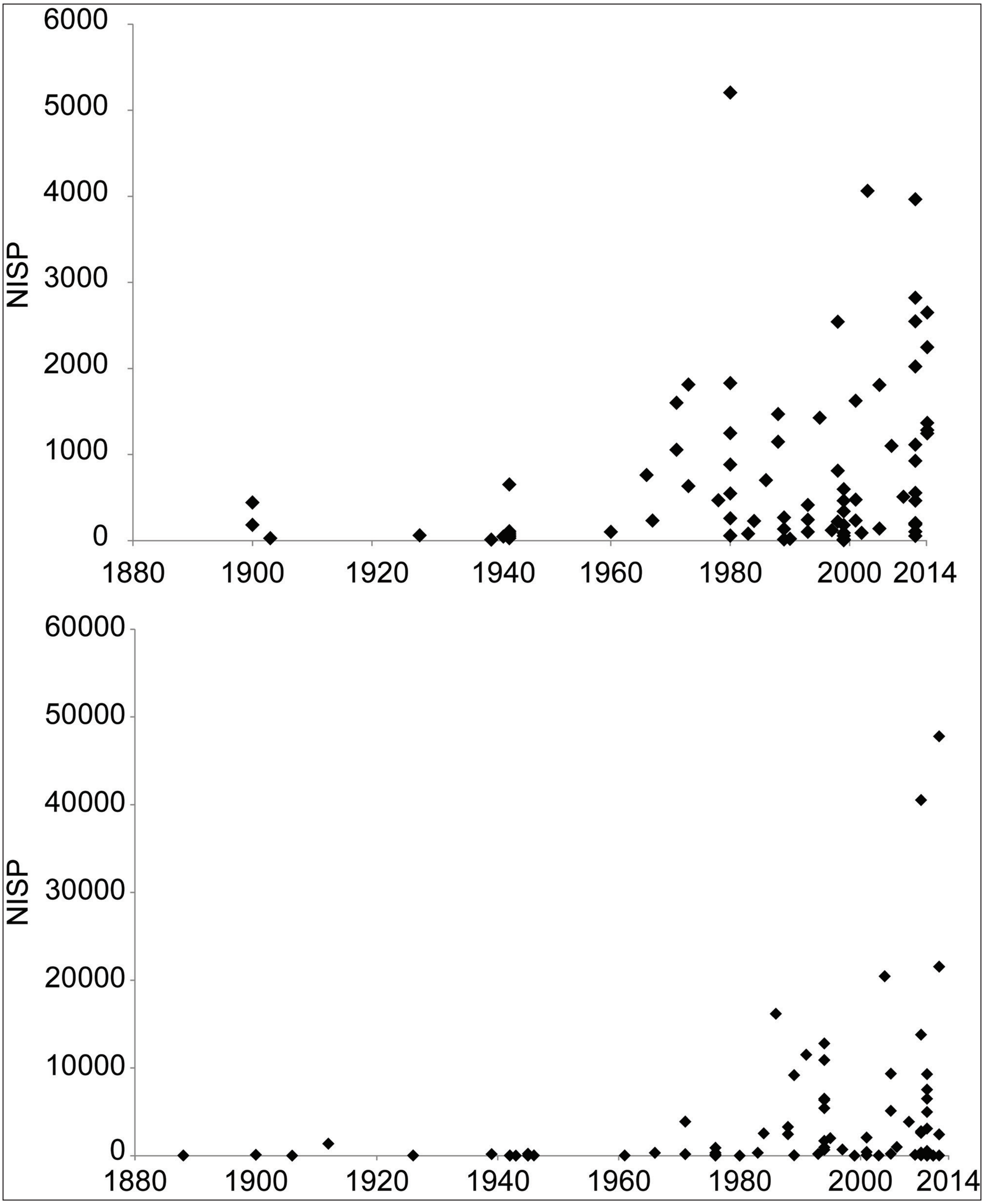

Figure 1: EBK sample size (NISP) by date for mammals and birds (top) and fish (bottom). Data from sites listed in Table 1.

red deer at the sites ignores significant variability in the motivations for the human behavior behind the observed faunal sample.

Fragmentation and Taphonomy

All other aspects of the dataset aside, the most concerning for comparative large-scale analyses is the overwhelming lack of quantification of overall assemblage character and the size of its fragments, with a few notable exceptions (Bratlund 1993; Eriksson & Magnell 2001; Jonsson 1988; Ritchie, Gron & Price 2013). Such cases of direct quantification of bone fragments in any capacity comprise only eight of 96 (8.3%) of the published reports and even in these cases the methods are not uniform. Several analyses report through measurement of every bone, identifiable or not, the taphonomic character of an assemblage

(Bratlund 1993; Gron 2015), while others employ a weight and counting method to determine the average weight of bone fragments (Jonsson 1988). In both cases, the number of applications is too small to be largely meaningful in a multi-site comparative sense.

This dearth is especially problematic as the degree of bone fragmentation has the potential to affect nearly every method of zooarchaeological quantification of potential use. There are a number of ways of quantifying fragmentation (Outram 2004). Some methods are simple ratios and can be retroactively applied to published data (Gifford-Gonzalez 1989; Lyman 1994b), while others require a modest time investment upon initial sorting (Outram 2004). While each method has its drawbacks, it is not difficult to apply multiple applications to any single faunal assemblage as these data can inform multiple interpretations, including studies of relative abundance, taphonomic effects, and sample size.

Most important are the potential effects of unidentified taphonomic actors on the most commonly reported relative abundance statistics, NISP and MNI (Marshall & Pilgram 1993), and on body-part representational data (Gron 2015). In the absence of information about the condition of the bone material, it is difficult to effectively compare relative abundances among individual sites, even though the same quantitative statistics may have been used. An alternative approach is to use a MNE-based quantitative analysis which largely circumvents differential fragmentation (Lyman 1994b). In most cases these data are simply not available with some exceptions (Rowley-Conwy 1980; Rowley-Conwy 1998) and comparative applications are not reasonable to expect in the near future until the dataset is expanded.

Bone fragmentation is a function of the taphonomic processes applied at a number of stages in a bone assemblage's history (Marean, Domínguez-Rodrigo & Pickering 2004). As published, EBK bone material is derived from a large number of different depositional contexts including peat bogs, submerged sites, beach ridges and shell middens (Bratlund 1993; Enghoff 2011; Gron 2015; Hatting, Holm & Rosenlund 1973; Hodgetts & Rowley-Conwy 2004; Noe-Nygaard 1995; Noe-Nygaard & Richter 2003; Ritchie, Gron & Price 2013; Trolle 2013), it stands to reason that the taphonomic history and therefore condition of the bone is also as variable.

Twenty-two assemblages report what percentage of the assemblage was identified, an indirect and imperfect measure of fragmentation, but an indicator nevertheless (Gifford-Gonzales 1989; Outram 2004). In the literature, this is sometimes expressed as the ratio between NISP and number of specimens (NSP) (Lyman 2008). To present this data, the publications in question list the numbers of bones that were "identifiable" or "unidentifiable" and a count of the total numbers of bones analyzed (**Table 1**). These data are important in that they allow at least a basic understanding of the degree of fragmentation (Gifford-Gonzalez 1989), the general character of the bone material, and the interplay of these factors on derived quantitative statistics. Several more publications pool these data for materials dating to the EBK and other periods (**Table 1**), but these are omitted in this part of the discussion to focus on the EBK.

The degree of fragmentation as calculated in this manner shows a broad range of variation (**Figure 2**). For example, Agernæs and Møllegabet II, respectively, are nearly completely identified and nearly completely unidentified. This method is not unproblematic, and may also indicate other factors in addition to bone fragmentation, including weathering and other means by which identifiable landmarks may have been obscured or removed from the bone surface. Regardless, the variation underscores the need for quantification of factors that affect this trait, which to a large degree includes bone fragmentation.

Another simple method of quantifying bone fragmentation is to calculate an NISP to MNI ratio (Klein & Cruz-Uribe 1984; Lyman 1994b). Despite its drawbacks, this method is one of the few that can be applied to the previously published data to quantitatively compare bone fragmentation between assemblages. Eighteen sites presented both MNI and NISP data, allowing the calculation of this measure. While there are 24 EBK assemblages that report NISP and MNI data (**Table 1**), five of them date to other periods in addition to the EBK, or present some ambiguous data. Therefore, we calculated the ratio for the 19 EBK assemblages in **Figure 3**.

NISP to MNI ratios range from a low of 2.23 identified fragments per individual to 47.52 identified fragments. While these values include a wide breadth of taxa with various numbers of bones and highly variable potential for being successfully identified to species, the general impression is of significant assemblage variation, which in turn reflects significant differences in the reasons behind observed quantitative statistics.

Discussion and Conclusions

It is not our aim to address the interpretations made in the aggregate literature, nor is it our aim to make interpretations of our own. While we have opinions in this regard, we instead choose to focus on particular methodological issues affecting comparability in quantitative data and on which grounds comparative analyses can be undertaken. This is done because the most informative interpretive data is oftentimes site-specific, that is, applicable only in consideration of the broader archaeological context of the bone remains and ancillary analyses (Gron 2015; Rowley-Conwy 1998). In the literature (**Table 1** and references therein), there are a number of primary data available for large-scale comparative meta-analyses. These include biometrics, as well as data concerning relative abundance, body-part representation, sample size, age and sex, and taphonomy. As outlined above, the quantity and character of these data are variable.

From these primary data and from outside information such as geographic and environmental data concerning the find location, some secondary analyses can be performed. These include geographical comparisons between areas of the EBK (Petersen 1990), indices based approaches drawn from population ecology (such as evenness, diversity, etc., Magurran 2004), and diachronic approaches. Such primary and secondary-data based approaches do

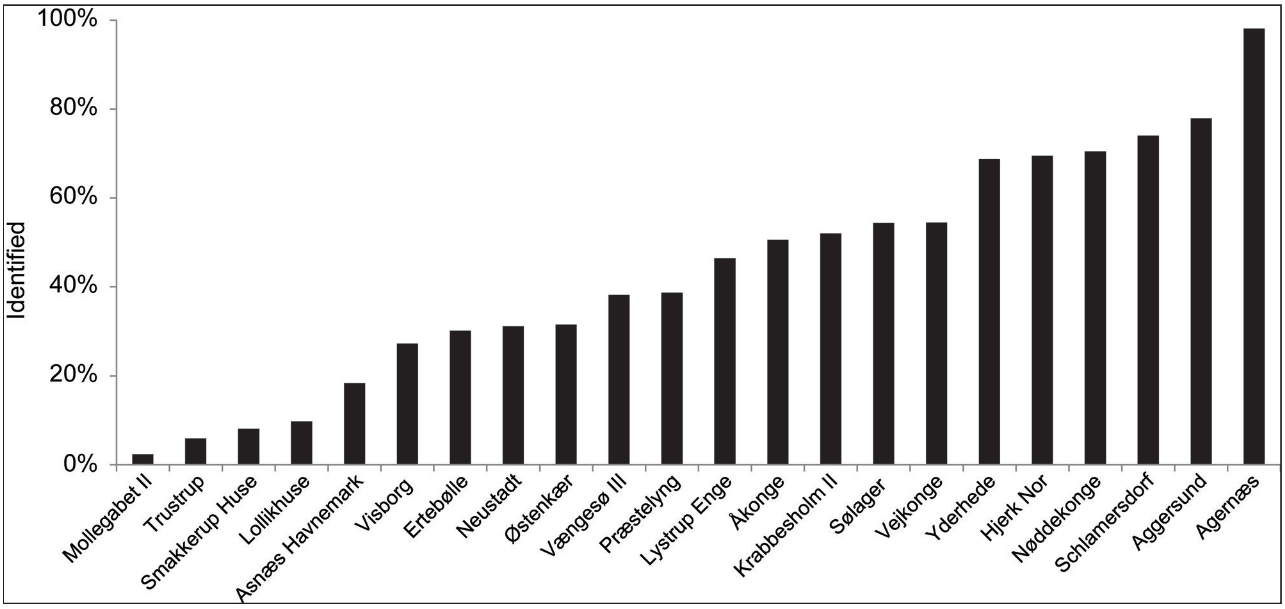

Figure 2: Percent identifiability.

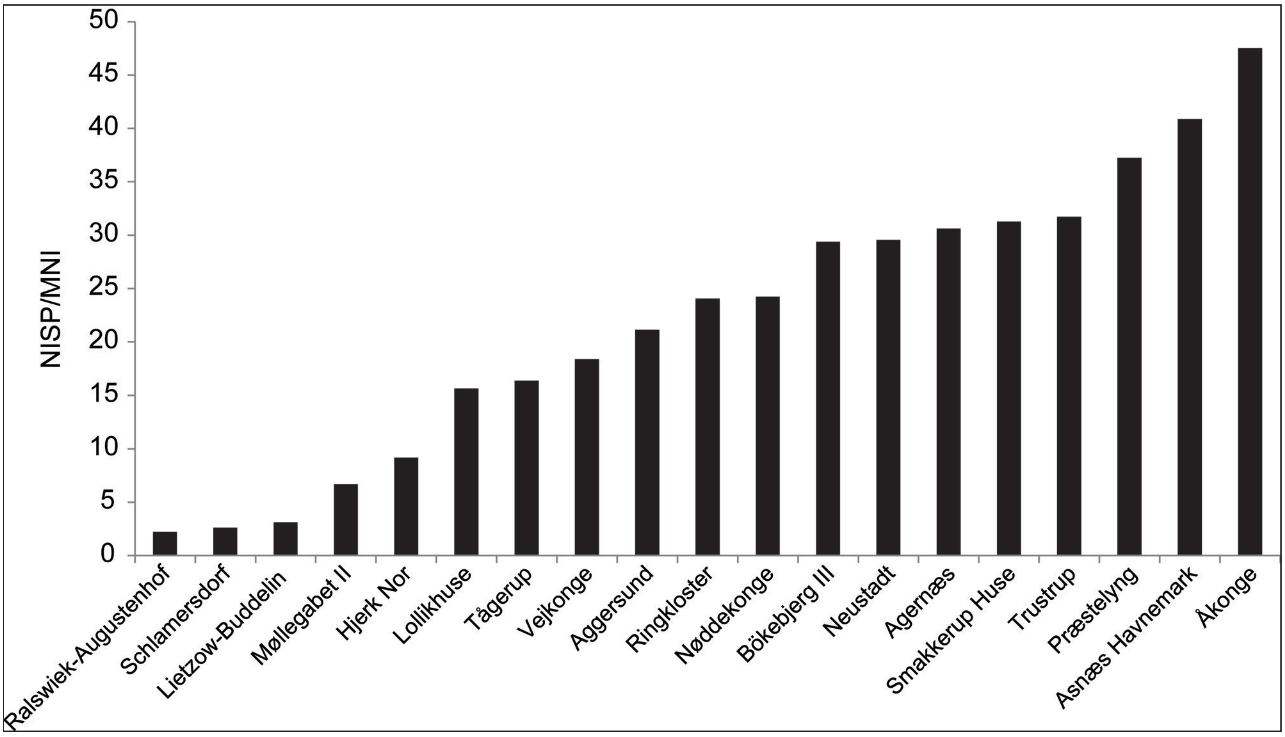

Figure 3: NISP to MNI ratio (all classes of taxa, fish excepted).

not have equal potential in large-scale analyses, and some have little potential awaiting further research.

Least-potential approaches are those that simply are not supported by the extant data at this time or are incompatible with EBK resource exploitation. These include work addressing broad-scale change over time, most taphonomic studies, and indices-based approaches. The first two are not supported by enough data at present, and await further chronological resolution and taphonomic study to be workable. Indices-based approaches, relying on particular taxonomic categories (Magurran 2004) are incompatible with what we know about differential use of the same species, as discussed above.

Medium-potential approaches are those for which the data are present in the dataset, but must be undertaken cognizant of the fact that some comparisons may be more useful than others and that sites' data may be more or less comparable depending on individual circumstances. Relative abundance data and body-part representational data are available from sites in numbers that may indicate broad-scale trends in EBK exploitative strategies but only with the caveat that reporting of these data are dependent on what we have shown to be highly variable bone fragmentation. It must be ascertained if patterns are real, that is, if they reflect human behavior or if they reflect factors unrelated to human activities and choices (Gron 2015). If the goal is to understand human societies in the past, then the potential for such obfuscating factors needs to be minimized. As we have demonstrated elsewhere (Gron 2015; Gron, Andersen & Robson 2015), similar depositional contexts, such as shell middens, yield bone material that is highly similar in overall condition, indicating that in such cases, comparative bias originating from various taphonomic processes may be minimized insofar as the equifinal condition of the material will more equally affect quantitative statistics. Therefore, it may be more productive to compare quantitative data from similar depositional contexts and sampling strategies (**Figure 1**) first, before focusing on other factors such as sample size, or location.

As might be expected, we see the highest potential for large-scale comparison between data that are standardized or discrete. This means, effectively, approaches using standardized biometrics (von den Driesch 1976), comparisons of sample size with relative abundances and species richness and similar assemblage traits, and geographical approaches using areas known to have been separate during the Atlantic Period. Approaches of this type, in relying on standardized data are those least likely to be influenced by taphonomic factors or historical research bias, but are not bias-free. Highly fragmented assemblages, for example, may not permit any measurements to be taken, but this is not to say that the animals in the assemblage were not of a particular size that could have been compared with other regions, but that it simply cannot be conventionally quantified.

In addition to assessing the potential for comparative or large-scale meta-analyses using these data, this review has also served to identify the primary characteristics of the dataset. In so doing, factors that may need mitigation for productive comparisons in this regard have become apparent. While the 121 assemblages containing some quantitative data do not represent an enormous sample, they represent a highly useful record that can, if considered appropriately, be used to understand prehistoric human behavior. However, applying the quantitative data to research questions is no easy task, and is impossible without the application of certain parameters to make the data comparable. It is this necessity that informs our recommendations for future research in an effort to maximize future comparability.

It is clear that the consistent application of standardized methods is required. There are a number of ways to quantify relative abundance of specimens, including, but not limited to, NISP, MNI, MNE, and their various permutations and synonyms (Lyman 1994a; Reitz & Wing 2008). Not quantifying MNI separately by stratigraphic layer can also be a source of error (Payne 1985), but when reported in from EBK sites, total numbers are often pooled (Gotfredsen 1998; Madsen *et al.* 1900; Ritchie, Gron & Price 2013), with some exceptions (Eriksson and Magnell 2001; Skaarup 1973), and it is only sometimes justified as to why this pooling is performed (Ritchie, Gron & Price 2013). Also, in highly fragmented assemblages, MNI tends to overestimate the abundance of infrequent species, and the two metrics behave differently with the degree of fragmentation (Grayson 1984; Marshall & Pilgram 1993; Payne 1985). To use NISP values as relative abundance values, the assumption is that recovery, analysis, taphonomic influences, and anatomical element abundances are uniform (Reitz & Wing 2008), which we know not to be the case. Lastly, percentages of different species quantified using the above metrics cannot be directly used to represent food value and particularly not their importance (White 1953). Methodologically, NISP and MNI can also be calculated differently (Casteel & Grayson 1977; Marean *et al.* 2001; Noe-Nygaard 1977; Payne 1975) and there is some variation present even in very consistent applications of these measures, partly owing to the skill of the analyst, which cannot be controlled for in comparisons.

As per both common sense and sound scholarly practice, methods should be made explicit and standardized terms should be employed consistently in publication. Zooarchaeology has largely self-policed itself through in-depth academic discussions of the various merits of particular approaches to quantitative statistics (Reitz & Wing 2008). However, quantification statistics, in and of themselves, do not necessarily describe how they were obtained or what particular method was used for their ascertainment in all cases. While singular terms are not necessarily synonymous and can be highly varied (Casteel & Grayson 1977; Lyman 1994a), in most cases, the reader is able, if necessary, to work through methods and determine what was done. While there are a rather large number of methods for establishing MNI counts (Reitz & Wing 2008), the individual procedure applied at best needs to be standardized in EBK research and at the very least needs to be explicitly stated in publication. This issue is easily remedied, and in most cases would be simply addressed with a single sentence and citation. It is for this reason that all analyses of faunal material dating to the EBK, and indeed in general, *must* have an explicit methodological discussion so that even if terminological changes occur in the future (which has happened looking back at the published data), the data will still be useable in comparative studies. In this way then, standardization of terms is less important than an explicit discussion of methods that absolutely has to be included in all publications.

The study of prehistoric subsistence economies by necessity must rely on faunal data from more than one site. This means that data resulting from varying research strategies and methods must be compiled. To productively study previous research, methodological differences must be controlled for. It is easy to criticize past approaches, but it is also paramount to recognize that work is done in the context of the science of the time and the methodological concerns of the discipline under which it was performed, and as EBK research spans essentially the entire development of zooarchaeology as a sub-discipline of archaeology, zoology, or geology, there is no real point in criticism except to inform future work.

In this review we have considered that the most pressing issues in comparative analyses can be rectified in the future through two major, but rather simple adjustments in procedure. These two issues are the inconsistent reporting of quantitative statistics and a lack of quantification of bone quality and fragmentation. Foremost of these, we have argued that bone fragmentation must be quantified in all assemblages. While certain fragmentation indices can be retroactively performed on some assemblages as we have done here, ideally every bone should be measured and weighed before analysis, regardless of its ability to be identified. Doing so provides a frame of reference for nearly every comparative analysis, regardless of method. Additionally, it is vital that other traits of the bone are also recorded, inclusive of a qualitative description (Enghoff 2011; Noe-Nygaard 1995), quantification of weathering (e.g. Behrensmeyer 1978), and perhaps simply a high-resolution image of the bone material on the analytical table (see Magnussen 2007). Secondly, all publication should, in addition to applying the most common quantitative statistics (NISP and MNI), explicitly state how these statistics were determined. So doing provides the comparative analyst important methodological background to inform comparability.

It is our hope that this compilation is of use to students of the prehistory of southern Scandinavia and will serve as both a bibliographic reference and a useful starting point for understanding what is available for those interested in prehistoric economies. The available dataset is varied in its composition, but represents a vital and unparalleled resource for understanding northern temperate hunter-gatherer-fishers just before agricultural origins in southern Scandinavia.

Competing Interests

The authors declare that they have no competing interests.

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