A cold case closed. New light on the life and death of the Lateglacial elk from Poulton-le-Fylde (Lancashire, UK)

Neue Erkenntnisse zu einem bisher ungelösten Fall: Das Leben und Sterben des spätglazialen Elchs von Poulton-le-Fylde (Lancashire, GB)

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Abstract - Since its excavation in the 1970s the Allerød, period adult male elk from Poulton-le-Fylde, Lancashire (UK) has been interpreted as a Lateglacial hunting episode, presumably by Federmessergruppen hunter-gatherers, albeit in the absence of typologically diagnostic artefacts. Lesions on several bones of the front body have been interpreted as evidence of lithic armatures (usually assumed to be arrowheads) and two uniserial bone harpoons closely associated with the elk's corpse provide the only human association with the kill. Here, we report on reanalyses of the elk's lesions and harpoons, arguing that they derive from the method of excavation rather than the death of the elk, and interpret the harpoons as evidence of a failed hunting episode probably deploying a two-pronged leister javelin. The first isotope analyses of the elk's teeth and bone reveal a restricted movement pattern entirely in keeping with modern elk, and a diet of lush aquatic vegetation that provides seasonal context for the kill.

Zusammenfassung - *Das in den 1970er Jahren bei Poulton-le-Fylde, Lancashire (Großbritannien) in den 1970er Jahren ausge- grabene Skelett eines Allerødzeitlichen männlichen erwachsenen Elchs wurde lange als Spätglaziale Jagdepisode, vermutlich von Jägern der Federmessergruppen, interpretiert. Diese Einordnung geschah, obwohl keine diagnostischen Artefakte gefunden wurden.*
Verletzungen an mehreren Knochen des Vorderkörpers des Elchs wurden als Schussverletzungen durch lithische Bewehrung (möglicherweise Pfeilspitzen) angesehen. Zwei einreihige Harpunen aufgefunden in der räumlichen Nachbarschaft zum Elchskelett sind die einzigen Belege für eine mögliche Beteiligung des Menschen an der Tötung des Elchs. In dem vorliegenden Beitrag werden die Verletzungen des Elchs und die zwei Harpunen neu bewertet. Daraus ergab sich, dass die Verletzungen an den Knochen nichts mit dem Tod des Tieres zu tun haben, sondern vielmehr Relikte der Ausgrabungstechnik sind. Die Harpunen wiederum dokumen- tieren eine glücklose Jagdepisode mit einem zweizinkigen Fischspeer. Erste Isotopenanalysen der Zähne und Knochen des Elchs zeigen einen eingeschränkten Bewegungsradius der dem Verhalten des heutigen Elchs vollkommen entspricht. Das Tier ernährte sich von verschiedenen aquatischen Pflanzen, die Hinweise auf die Saison des Todeszeitpunkts geben können.

Keywords - Allerød, Elk, Late Upper Palaeolithic, Stable isotopes,
    Allerød, Elch, Spätpaläolithikum, stabile Isotopen

Introduction

Nearly half a century ago the complete skeleton of an adult male elk (*Alces alces*) was discovered in Allerød period deposits in the High Furlong area of Poulton-le-Fylde near Blackpool, Lancashire, UK (Hallam et al. 1973). Usually known as either the Poulton or High Furlong Elk, its remains were recovered from proglacial pond deposits in association with two Late Upper Palaeolithic barbed bone points (Fig. 1). The recovery of these points, and the identification of several marks on its bones as lesions apparently produced by flint

tipped armatures that were not recovered from the site, lead to the interpretation of the elk as a kill, presumably by Lateglacial Federmessergruppen hunters. Given the apparent variety of weapon systems associated with the elk (the bone points, hypothetical flint tipped arrows and a hypothetical axe seen to 'imply hand-to-hand fighting'), Hallam et al. (1973: 125) concluded that *'the elk was attacked by hunters on at least two separate occasions, the first one or two weeks before death [evidenced by the bone points and one lesion clearly caused by one of these] and the second about the time of death [evidenced by the remaining lesions interpreted as arrows and an axe wound]'*. The distribution of lesions

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Fig. 1. The Poulton Elk articulated for display. Photo courtesy of the Preston Harris Museum.
Abb. 1. Der museal montierte Poulton Elch. Foto Preston Harris Museum.

on its skeleton suggested that *'the legs were deliberately aimed at, resulting in two or three successful shots, no mean feat of marksmanship even at short range. It is possible that the bone points may have been attached to drag lines for restraining the animal whilst the hunters took it into captivity or killed it outright by shooting missiles at close range. The latter could well have been the intention of the second attack'* (Hallam et al. 1973: 126).

Despite the apparent severity of the elk's wounds (Hallam et al. 1973: 126) it came not to be butchered and consumed but to rest, intact, at the bottom of a proglacial pond. If the purpose of its killing was to 'capture' it (Hallam et al. 1973: 126) then this clearly failed. If, alternatively, it represents a 'lake sacrifice' (Hallam et al. 1973: 126) we cannot demonstrate this unambiguously. Most discussion of the elk subsequently has perpetuated the 'hail of fire' interpretation.

The elk is curated at the Harris Museum in Preston, Lancashire. Renovation and renewal of its archaeological galleries in 2013 allowed us access to the elk and harpoons for fresh analysis, and the removal of samples of a tooth, rib and antler for isotopic (Sr, C, N, O) measurement. Nearly half a century on since its discovery, we offer here a revised interpretation of

the manner of the elk's death and its archaeological significance, as well as new information on its development and age at death, diet, and mobility.

Stratigraphy, chronology, environmental context
The elk was discovered during the excavation of a foundation trench for two new houses (Hallam et al. 1973: 104). One antler and the skull were uncovered by a mechanical digger, and spotted by a neighbour, who had the foresight to stall the digger and recover further bones. This initiated the first phase of recovery. Digging further into the trench he recovered more of the skeleton, including some of its ribs and barbed bone point number 1. At this point further digging was halted for some two weeks, after which archaeological excavations commenced. This second phase was aimed at recovering the elk's hind skeleton, which it did successfully, in addition to barbed bone point 2. As we shall see below, the markedly different methods of the two phases of recovery have a direct bearing on our interpretation of the elk's death.

Multiple coring established that the elk skeleton lay towards the eastern side of a local depression in the glacial till, measuring some 40 m across. Figure 2 (top) shows a transect across the basin (redrawn after Hallam et al. 1973: fig. 3). The depression would have formed a small water pool during the late glacial. The position of the elk is noted in Figure 2. It was found in a layer of coarse detritus mud overlying a thicker layer of calcareous gyttja; this mud contained leaves and twigs of birch (*Betula* sp.), in addition to fruitstones of pondweed (*Potamogeton* sp.) (Hallam et al. 1973: 106). The immediate environment thus appears to have comprised a small open-water pool surrounded by a thicket of birch. Dating of sediments and the bones of the elk itself are consistent with its biostratigraphic position. Initial bulk sample radiocarbon dating of the detritus muds in which the elk came to rest indicated an age of 11'665 ± 140 BP (St-3836), which was subsequently supported by ultrafiltrated AMS radiocarbon measurements of 11'660 ± 60 BP (OxA-11151) and 11'715 ± 50 BP (OxA-13075) on the elk itself, that is to ~13.8 – 14 ka calBP, i.e. the earlier part of the Allerød (Jacobi et al. 2009).

Pollen analysis revealed that there was a rise in birch pollen in the mud layer that contained the elk bones (Fig. 2, bottom). In Britain this increase in birch at the expense of juniper marks the transition from the Older Dryas into the Allerød, reflected, for example, in the Vale of Pickering (240 km east of Poulton) where juniper scrub was replaced by open birch woodland in response to declining temperatures ~14 ka calBP (Day 1995) and at the typesite for the British Lateglacial (Windermere) Interstadial, Lake Windermere (93 km north of Poulton) the earlier Allerød was dominated by birch and juniper woodlands (Coope & Pennington 1977). Overall, the picture at this time is one of decreasing dry land herbs and increasing birch as the landscape became more wooded, prior to a

return to the cold, open conditions of the Younger Dryas. The high totals of grasses (*Gramineae*) and sedges (*Cyperaceae*) during the Allerød reveal, however, that environments were still relatively open; this environment was nothing like the full deciduous forests that were to follow in the post-glacial.

Life and behaviour of the elk
The faunal (and archaeological) record for Allerød Britain is poor and lacks a single large faunal assemblage (Currant & Jacobi 2011: 176). Elk is represented, albeit very rarely, among the typically cool temperate species dated to the period. At Coniston Dib cave in the Yorkshire Dales, some 100 km to the east of Poulton, it has been dated to 11'210 ± 90 BP (OxA-2847) (13 – 13.2 ka calBP) (Hedges et al. 1992) (see below for a possible barbed bone point on elk bone from Sproughton). In almost all cases, however, undated remains of elk in Britain are likely to be of early Holocene Age (e.g. Bradshaw et al. 2003).

Elk remains are rare generally in Lateglacial northern Europe (see, for example, Bridault 1992; Bratlund 1996; Bodu 1998). Its sporadic appearance west of its main distribution in the East Baltic and Belarus was clearly very patchy in time and space, with few examples dating to the Allerød and far fewer to the Younger Dryas (Bridault 1992). In Denmark, the earliest examples date to the Allerød, at the site of Bromme (Degerbøl, in Mathiassen 1946), but become more common in the Preboreal Maglemosian culture (Leduc 2014). Rare examples are known from Allerød France (Leduc 2014: 154) yet they are remarkably rare prior to the Boreal/Atlantic (F. Audouze pers. comm. to PP). The amber carving of an elk cow dated to the Allerød from the *Federmessergruppen* site of Weitsch, Lower Saxony (Veil et al. 2012) shows that the animal had attracted artistic interest by this time, although it is possible that this was due to its rarity rather than ubiquity. The Rhineland's Neuwied Basin appears to be an exceptional pocket, wherein elk were relatively common in the Allerød (Street & Baales 1999). It possibly appeared locally towards the end of the Meiendorf/Bölling at sites such as at Gönnersdorf and Andernach-Martinsberg (Stephens et al. 2009), but elk are elsewhere rare in the region. Their appearance is consistent with an environmental context of open woodland (significantly, birch and willow), as suggested by stable isotope analyses (Stephens et al. 2009: 144) included - as very rare, and regionally patchy.

Age and season of death
Today, elk are born in late May and early June in both North America (Peterson 1955: 62) and Sweden (Skuncke 1949: 127), thus it seems safe to adopt this as the likely timespan for the birth of the Poulton elk. Elk erupt their teeth rapidly in comparison with, for example, red deer. M1 emerges behind the milk premolars during August (Skuncke 1949: 127), or at the age of 10-14 weeks (Peterson 1955: 87). Both these
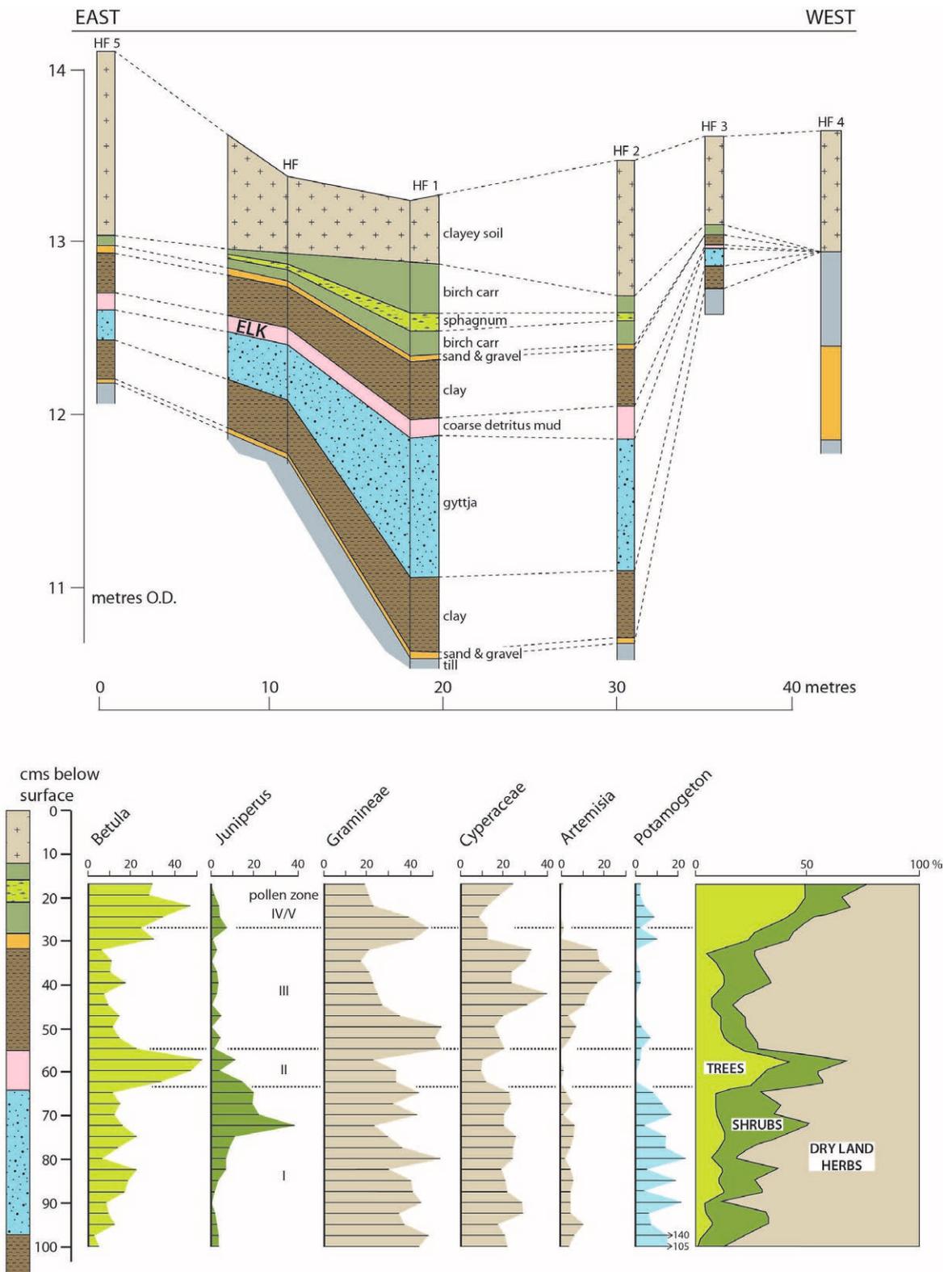
Fig. 2. Stratigraphy, palaeoenvironment and palynology of the Poulton Elk. The position of the elk is noted. Redrawn after Hallam et al. (1973: Fig. 3).
Abb. 2. Stratigraphie, Paläoumwelt und Pollenprofil des Poulton Elchs. Die genaue Position des Elchs ist markiert. Nachzeichnung nach Hallam et al. (1973: Fig. 3).

authorities agree that M2 starts to appear in about December of the animal's first year, and M3 at around 13-14 months of age. The permanent premolars start to displace the milk teeth at 13-16 months, but Markgren (1964) states that many individuals of this age retain some of their deciduous teeth – dental development can vary between the left and right mandibles of the same animal.

Animals that have all of their permanent teeth in place are much more difficult to age precisely. We were not able to examine the teeth of the Poulton specimen in detail because, while the skeleton was removed from display it is still mounted in articulation with teeth in occlusion. However, Hallam et al. (1973: plate VIIIA) present pre-display photographs of its dentition: from these it is clear that all permanent teeth are present and would have been functional, and they concluded that the animal was probably 3.5-6 years old at death (Hallam et al. 1973: 113). Their photograph reveals that the buccal tips of cusp 3 of M3 is worn, but this wear does not extend to the lingual tip. A sample of mandibles from modern animals of known death (shooting) date and probable age was recorded by one of us (PR-C) in Newfoundland, and the details of M3 cusp 3 are presented in Figure 3. This shows that animals at the same stage as the Poulton elk, with one tip worn, were most common in the 27-29 and 39-41 month categories, although some were present in the 51-53 month category. Wear is highly variable (some left and right mandibles of the same animal were indeed in different stages) and this method is unlikely to be particularly accurate, but it might suggest that by 6 years of age (Hallam et al.'s maximum age estimate) tooth wear is likely to be

Age	both tips unworn	one tip worn	both tips worn
51-53 months	0	6	51
39-41 months	0	17	32
27-29 months	14	34	19
15-17 months	67	1	0

Fig. 3. Frequency of wear on tips of the third cusp of lower M3 of a sample of moose from Newfoundland, recorded by PR-C. Both left and right mandibles are included where available because wear may vary between the two sides. The animals were all shot between mid-September and mid-November. Absolute ages were determined through incisor cementum banding carried out by staff of the Newfoundland and Labrador Wildlife Division, who cautioned that this technique may not always be accurate.

Abb. 3. Anzahl der Abnutzungsspuren auf den Spitzen der Zahnhöcker des unteren M3 aus einer Probe von amerikanischen Elchen aus Neufundland, aufgenommen von PR-C. Sowohl rechte als auch linke Seiten der Unterkiefer sind, soweit vorhanden, mit eingeschlossen, da die Benutzung zwischen beiden Seiten sehr stark variieren kann. Die Tiere wurden zwischen Mitte September und Mitte November geschossen. Absolute Sterbealter wurden anhand der Bänderung des Wurzelzements der Schneidezähne durch Mitarbeiter der Newfoundland und Labrador Wildlife Division bestimmt, wobei sie anmerken, dass diese Methode nicht immer zu präzisen Ergebnissen führt.

further ahead. A tentative age range based on the Newfoundland comparison might be 2.5-4.5 years.

Antler development, however, suggests that the Poulton elk cannot be as young as 2.5 years. There is a general tendency for elk antlers to add more points until the animal is in the prime of life, and then to decrease, but this varies considerably. Child et al. (2010) found that in a population in British Columbia, left antlers possessed significantly more points than right antlers – and we observe that, remarkably, the Poulton elk's left antler has 8 points and its right 6. In a study of 378 animals of known age, Skuncke (1949, table 2) shows that there is considerable variability in antler development: animals with 6 point antlers are mainly at least 3 years old, but a few may be as old as 8 years; while animals with 8 point antlers are usually 4 years or older. Most animals with antlers of 5 points or fewer are aged 4 years or less. Thus antlers of animals in their first couple of years are in general smaller than those of adults, but the number of antler points cannot be used for precise ageing. Furthermore, antler development may vary between populations due to nutritional factors (Skuncke 1949: 54), latitude (Saether & Haagenrud 1985), population density (Mills & Peterson 2013) and hunting intensity (Tiilikainen et al. 2010). Since the Poulton elk's smaller antler has 6 points, we can conclude on the basis of Skuncke's antler data is that it is likely to have been 3.5 years or older – but greater precision is not possible.

Thus the Poulton elk's antlers suggest an age of 3.5 years or greater, while the teeth suggest 4.5 years or under. We stress that both of these estimates are imprecise and open to question, but they lead us to a tentative mean estimate that the animal was around 3.5-4.5 years old at death.

The Poulton elk was likely killed during the winter. Hallam et al. (1973: 111) state that although attached, its antlers were about to be shed. Today, the date of elk antler shedding varies with age. Prime and elderly animals shed their antlers as early as late December or early January, while yearlings and two-year-olds may retain their small antlers until April. As juveniles age, so they shed their antlers progressively earlier (Peterson 1955: 91-93; Skuncke 1949: 54). If our age estimate of 3.5-4.5 years is at all accurate, the Poulton elk would have shed its antlers at a point between the shedding ages of old bulls and of young calves. A tentative estimate is that it might have been ready to shed its antlers around January or February.

Seasonal movement and diet: modern analogies, stable isotope analyses

Elk are the most northerly distributed of all the deer species, and their diet reflects this. In some areas their range overlaps that of red deer, but although sympatric the two species occupy very different ecological niches, and their diets hardly overlap. Figure 4 shows the winter diets of elk and red deer in Hunneberg in
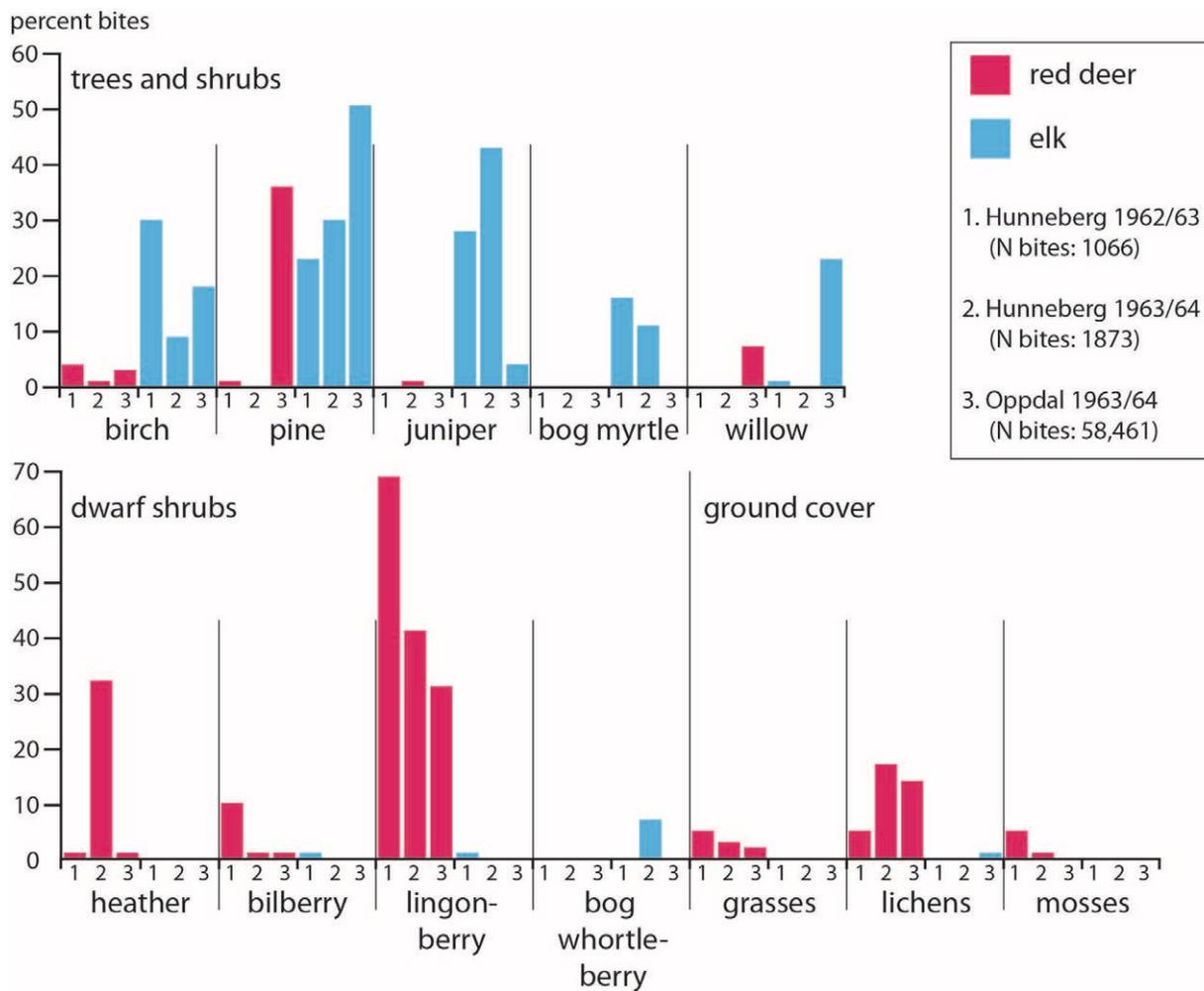
Fig. 4. Winter diets of elk and red deer in Hunneberg in Sweden over a period of two years, and for one year in Oppdal in Norway. Data from Ahlén (1965).

Abb. 4. Winternahrung von Elchen und Rothirschen in Hunneberg in Schweden über einen Zeitraum von zwei Jahren, und in Oppdal in Norwegen über ein Jahr. Daten aus Ahlén (1965).

Sweden over a period of two years, and for one year in Oppdal in Norway. The data are actual bites of vegetation of the different types, Figure 4 being based on over 60'000 counted bites (data from Ahlén 1965). There are differences between the two areas, and also between the two years at Hunneberg (the winter of 1962/3 was unusually cold). But the winter diets hardly overlap, with the elk concentrating on trees and shrubs, the red deer on the dwarf shrubs and ground layer. Figure 4 makes the important point that while birch and juniper are important winter foods of elk, pine is also very important. Birch and juniper were both present at Poulton during the Allerød (Fig. 2), but pine was not, so the relative importance of birch and juniper as winter foods would presumably have been even greater.

Elk diets vary massively between summer and winter, however. The trees and shrubs that dominated their winter diets give way in spring to a more varied range of low shrubs, waterplants, and more. Figure 5 presents an example from Grimsö in Sweden. Pine, and to a lesser extent, birch bark and twigs dominate during the winter. These are replaced by successive peaks of bilberry, rosebay willow herb, birch leaves, bilberry again, and finally heather in October before the winter diet reasserts itself (data from Cederlund et al. 1980). Grimsö is an area with rather few lakes and ponds, so waterplants do not constitute a major part of the diet. When waterplants are available, however, elk preferentially target them. Peterson (1955: 108) states that they swim well and may dive to depths of up to 5.5 metres in search of aquatic vegetation, and can remain submerged for over 30 seconds. Pondweed (*Potamogeton* sp.) forms the bulk of such food (Peterson 1955: 118).

Both birch and pondweed macrofossils were present in the mud layer in which the Poulton elk's bones lay (Hallam et al. 1973: 106). If we are correct that the animal died in January or February, however, its last meals would have been birch bark and twigs, not pondweed.

Elk are typically a territorial species (e.g. Peterson 1955; Skuncke 1949; Leduc 2012). Strontium ($^{87}Sr/^{86}Sr$), oxygen ($\delta^{18}O$) and carbon ($\delta^{13}C$) isotope
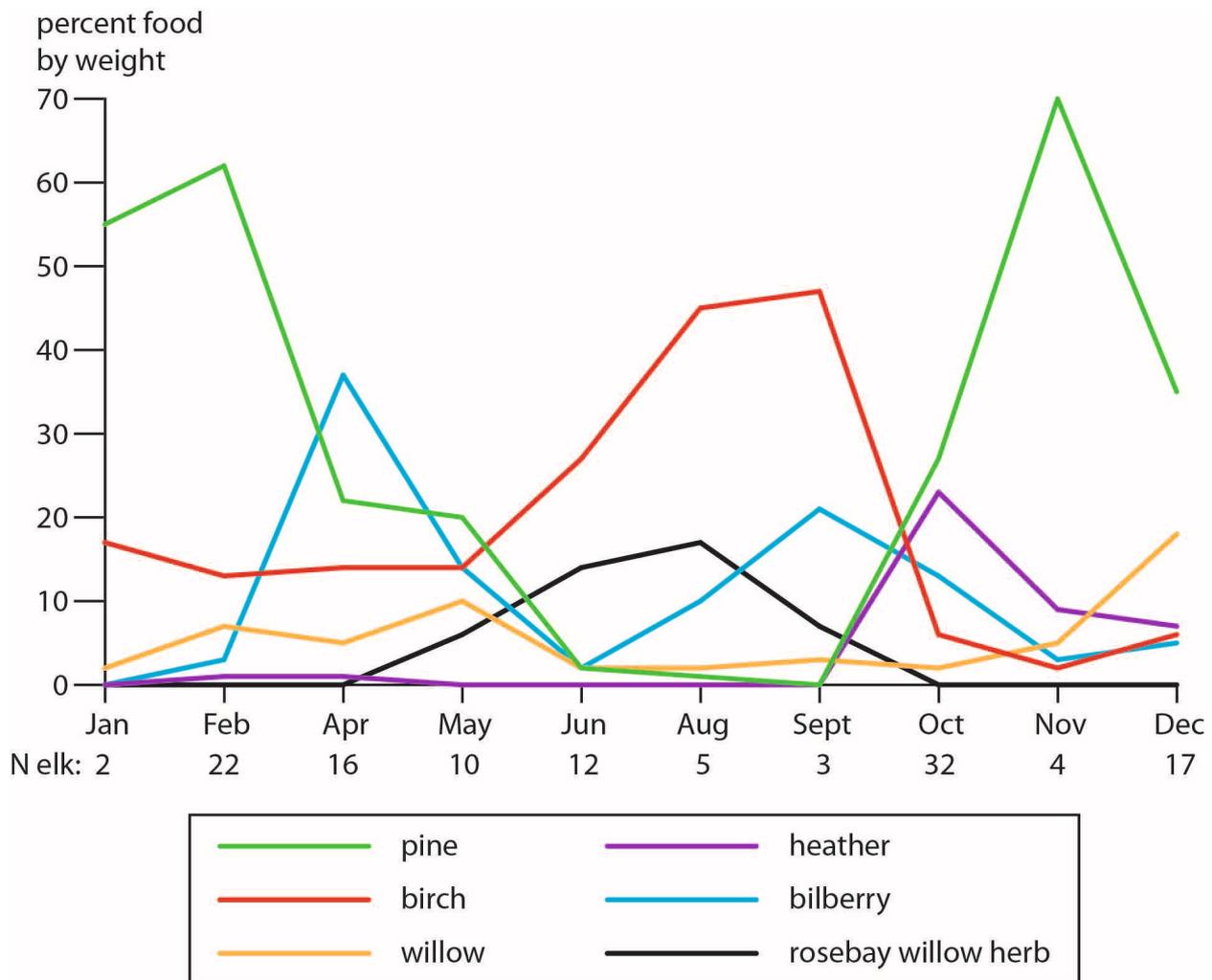
Fig. 5. Elk diets from Grimsö in Sweden. Data from Cederlund et al. (1980).
Abb. 5. Elchnahrung aus Grimsö in Schweden. Daten aus Cederlund et al. (1980).

analysis of the elk was undertaken to establish if the isotope ratios obtained were consistent with this – i.e. that the elk was territorial within the Poulton-le-Fylde region - or if they provided evidence of origins elsewhere and at what time of year any geographical movement or change in diet had occurred. Sequential ^{87}Sr/^{86}Sr values of herbivore tooth enamel can provide evidence of the geological terrain in which an animal was feeding and if this changed during the period the tooth was mineralising (Bentley & Knipper 2005; Montgomery et al. 2010; Towers et al. 2010). δ^{18}O sequential profiles within herbivore teeth have been shown to document seasonal changes in temperature (Fricke et al. 1998) and coupled with δ^{13}C, can document seasonal changes in diet, i.e. changes in either environment or type of food consumed (Balasse et al. 2006; Cerling & Harris 1999).

It was not possible to choose and extract a whole tooth for this purpose but upon close inspection it was noticed that the lingual enamel of the permanent lower left fourth premolar (P4) was fractured and loose, and thus it was carefully removed (Fig. 6). This

provided a slice of enamel from the occlusal cusp to the enamel-root cervix. This sample was large enough to be sub-divided transversely in order to produce five sub-samples representing a sequential chronological series from the time the tooth crown was mineralising. For the permanent P4 this mineralisation commences around four months of age (Magnell n.d.) which, given the well established seasonal birthing of the species, suggests the tooth would start forming in October of the first year. However, although there is a temporal record within the teeth of large herbivores, it is recognised that enamel matures slowly and in a species such as domestic cattle (*Bos taurus*), continues to incorporate environmental evidence such as stable and radiogenic isotopes for a period of 6-7 months at any specific point in a tooth (Balasse 2002; Montgomery et al. 2010). This may vary between species and currently there is no comparable developmental data available for elk.

In addition to the enamel, a sample of cortical rib bone and antler were removed from the elk for carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope analysis of extracted

Fig. 6. Detail of the mandible and maxilla of the Poulton elk with the sampled P4 (circled in red) shown following removal of the lingual enamel fragment. Photo JM and courtesy Preston Harris Museum.
Abb. 6. *Detail des Unter- und Oberkiefers des Poulton Elchs mit dem beprobten P4 (rote Markierung) nach Entnahme des äußeren Zahnschmelzes. Foto JM und Preston Harris Museum.*

collagen to provide additional evidence of the elk's diet. In contrast to the $\delta^{13}C$ values of enamel which are derived from the whole diet, those of collagen are predominantly routed from ingested dietary protein (Ambrose & Norr 1993). We anticipated that the antler would primarily provide a snapshot of evidence from the last year of the elk's life when the antlers were growing, i.e. predominantly during Spring and Summer, whilst the cortical rib would provide a longer term year-round averaged value derived from the elk's diet over the last years of life. It has been proposed that $\delta^{13}C$ and $\delta^{15}N$ values in modern British red deer (*Cervus elaphus*) bone and antler collagen cannot be directly compared as any differences may be due to different tissue formation processes rather than to changes in diet, and values are variable within a single antler (Stevens & O'Connell 2016) but there is no comparable study on elk from Britain.

Methods
The enamel fragment was mechanically cleaned of adhering dentine, dirt and varnish using dental burs and then sectioned transversely with a dental saw into five sections from the occlusal surface (PELK-1) to the enamel-root cervix (PELK-5). Each transverse section was then sectioned longitudinally to provide a sample for: 1) strontium isotope and concentration analysis; and 2)

oxygen and carbon isotope analysis. Sample 2 was powdered and subjected to pre-treatment following a protocol modified after Sponheimer (1999) incorporating a 30 minute leach in 1.7 % NaOCl solution to remove organic matter, a rinse with distilled water, and finally a leach in 0.1 M acetic acid for 10 minutes to remove exogenous carbonate. After further rinsing and freeze-drying the samples were weighed into septa-capped vials and loaded into a *Finnigan Gasbench II* connected directly to a *Thermo Delta V Advantage* continuous flow isotope ratio mass spectrometer. The enamel carbonate of each sample reacted with phosphoric acid (103 %) at 70°C to release CO_2, which was analysed with CO_2 from a reference supply. Values of $\delta^{18}O_{VSMOW}$ and $\delta^{13}C_{VPDB}$ were calibrated to the measured and accepted values of two internal standards and one international standard. Analytical precision determined through repeated analysis of the standards was +/-0.2 ‰ (1sd) or better for both $\delta^{18}O_{VSMOW}$ and $\delta^{13}C_{VPDB}$.

Collagen was extracted from a rib and antler samples for carbon and nitrogen isotope analysis at the Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology (MPI-EVA), in Leipzig, Germany. Extraction procedures followed the standard methods outlined in Richards and Hedges (1999), with the addition of an ultrafiltration step

(Brown et al. 1988) to filter out the >30 kDa fraction, which was the fraction that was used for the isotope measurements. Carbon and nitrogen isotope ratios were measured on a continuous flow mass spectrometer (ThermoFinnigan Delta V) coupled to an elemental analyser (Thermo Flash EA). Errors on the carbon isotope measurements are +/- 0.1, and are +/- 0.2 for the nitrogen isotope measurements.

Strontium isotope measurements on the teeth were also undertaken at the Department of Human Evolution, MPI-EVA. Powdered samples were drilled from the enamel and then prepared following standard procedures involving acid digestion of the enamel and subsequent strontium separation using an ion exchange column. Strontium isotope ratios were measured on a ThermoFinnigan Neptune MC-ICP-MS and compared and calibrated using reference standards SRM 1468 and SRM 987. Full detailed methods are provided most recently in Kinaston et al. (2014).

Results

The isotope results can be found in Figure 7. The oxygen isotope ratio of the sequential samples increases from c. 23 ‰ at the cusp to c. 25 ‰ at the cervix (Fig. 8). This 2 ‰ increase indicates a progressive shift during the formation of the P4 crown from a colder to a warmer environment, which would be consistent with the enamel representing a ~6 month time-frame from autumn/winter to spring/summer. With the one exception of -9.3 ‰ (PELK-4), the carbon isotope ratios are consistently ~ -12.4 ‰ suggesting no significant change in the elk's food source. A single data point which is so significantly different to the points either side and out of kilter with the rib and antler results (Fig. 7) is difficult to explain and interpret given the expected minimum of c. 6 month herbivore enamel maturation (Balasse 2002; Montgomery et al. 2010). It may indeed represent a short-term change in diet recorded in rapidly mineralising enamel but we cannot conclusively rule out other explanations such as incomplete removal of surface contaminants (for example from any varnish that may be present; see below) or an

anomalous measurement. Unfortunately given the limited material available we were unable to re-prepare the sample and replicate the analysis. We are therefore reluctant to assign significance to the value until more intra-enamel analyses are undertaken on elk teeth to establish temporal resolution of the isotope profile.

Today, Poulton-le-Fylde is located c. 5km from the western seaboard of Britain on the Fylde coastal plain, in a region of Triassic mudstones, siltstones and sandstones overlain by Quaternary glacial diamicton till (British Geological Survey 1977, 2001). From the underlying geology, proximity to the coast, rainfall and measured plant values in Triassic regions, biosphere $^{87}Sr/^{86}Sr$ and thus that of animals inhabiting the region is estimated to lie between 0.7092 and 0.7100 (Evans et al. 2010). The five $^{87}Sr/^{86}Sr$ measurements from the elk's tooth are 0.7096, essentially identical and consistent with the Fylde coastal plain. They therefore provide no evidence that the elk originated elsewhere or had moved between different geological regions when this tooth was mineralising during the first year of life.

By contrast, the amount of strontium reduces from 128 ppm at the cusp to 97 ppm at the cervix and whilst this is within the expected range and not a large difference in the context of mammalian strontium (Underwood 1977; Montgomery et al. 2010), the reduction within the tooth is consistent and incremental. Strontium is a non-nutrient trace element and is primarily routed with calcium in geological and biological systems (Price et al. 1986) but there are multiple factors controlling the level of strontium in mammalian skeletal tissues. There is evidence that bioavailable strontium in food webs varies geographically with geology and increases with proximity to the coast and aridity (Underwood 1977; Burton et al. 2003; Montgomery et al. 2010). For example, the concentration of strontium in grass appears to be negatively correlated with soil moisture (Ehlken & Kirchner 1996) suggesting that foliage growing in wet conditions will have lower strontium concentrations. It is therefore also possible that the strontium

Sample No.	Skeletal element	Tissue	$^{87}Sr/^{86}Sr$	Sr ppm	$\delta^{18}O_{VSMOW}$‰	$\delta^{13}C_{VPDB}$‰	$\delta^{13}C_{diet}$‰	$\delta^{15}N_{AIR}$‰
PELK-1	Lower right P4	enamel cusp	0.709588	128	23.7	-12.4	-26.5	
PELK-2	Lower right P4	enamel	0.709591	115	23.2	-12.5	-26.6	
PELK-3	Lower right P4	enamel	0.709591	106	24.3	-12.2	-26.3	
PELK-4	Lower right P4	enamel	0.709574	98	24.1	-9.3	-23.4	
PELK-5	Lower right P4	enamel cervix	0.709563	97	25.3	-12.2	-26.3	
PELK-6	rib	collagen				-20.5	-25.6	3.3
PELK-7	antler	collagen				-22.8	-27.9	5.7

Fig. 7. Isotope data for tooth, bone and antler samples from the Poulton elk. The permanent lower right P4 was sampled incrementally from the occlusal cusp (PELK-1) to the enamel root cervix (PELK-5). Values for $\delta^{13}C_{diet}$ were calculated assuming a diet-apatite increase of +14.1‰ (Cerling & Harris 1999) and a diet-collagen increase of +5.1‰ (Drucker et al. 2008).

Abb. 7. *Ergebnisse der Isotopenanalyse der verschiedenen Proben (Zahn, Knochen und Geweih) des Poulton Elchs. Der dauerhafte rechte P4 wurde schrittweise von der Kaufläche (PELK-1) zum Schmelz des Wurzelhalses (PELK-5) beprobt. Die Werte der $\delta^{13}C_{diet}$ wurden unter der Annahme berechnet, dass der Apatitanteil in der Nahrung um +14.1‰ (Cerling & Harris 1999) und der des Kollagen um +5.1‰ (Drucker et al. 2008) zunehmen.*
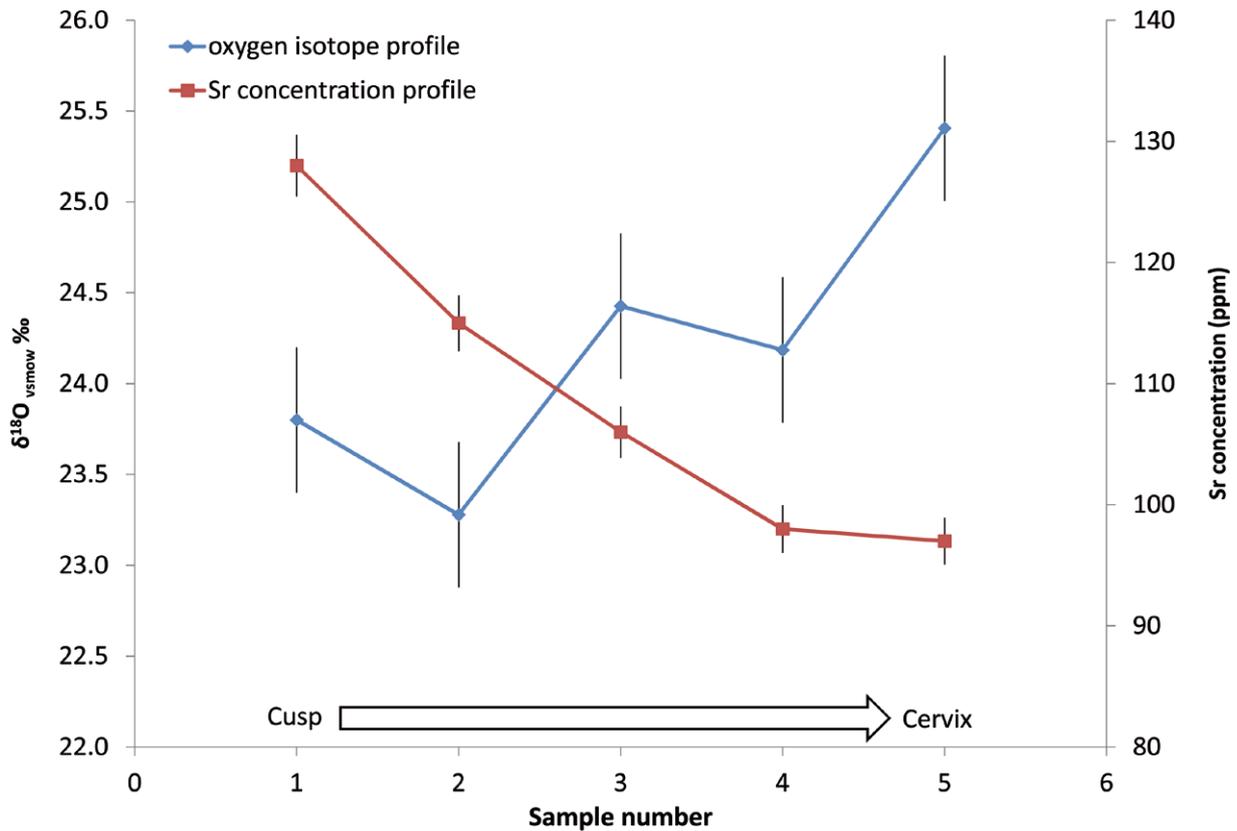
Fig. 8. Oxygen isotopes and Sr concentrations in five sequential samples of the Poulton elk's P4 from earliest forming cuspal enamel (Sample 1) to later forming cervical enamel (Sample 5). Oxygen isotopes exhibit an overall rising trend suggesting a shift from colder to warmer temperatures whilst Sr concentrations fall. Analytical errors are estimated at +/- 0.4‰ (2sd) for δ18O and +/- 2 % (2sd) for strontium concentrations.

Abb. 8. *Anteile der Sauerstoff-Isotopen und Sr Konzentrationen in fünf aufeinanderfolgenden Proben des P4 des Poulton Elchs vom sich früh bildenden Höcker-Schmelz (Probe 1) bis zu sich später bildenden Hals-Schmelz (Probe 5). Sauerstoff-Isotopen zeigen einen ansteigenden Trend, der auf Veränderungen der Temperaturen von kalt zu warm zurückzuführen ist. Die Sr Konzentrationen nehmen demgegenüber ab. Die Rechenfehler werden mit +/- 0.4‰ (2sd) für δ18O und +/- 2 % (2sd) für Strontium Konzentration angenommen.*

concentration in plants may vary seasonally and between different species and plant parts, e.g. fresh green leaves versus dry wood or grass. Strontium concentrations are also closely linked to dietary calcium, i.e. higher dietary calcium produces lower levels of strontium, but also trophic level, i.e. herbivores will have more skeletal strontium than carnivores within the same food web (Burton & Wright 1995). As a consequence, less strontium may have been deposited in the enamel of the elk in spring/summer as a result of an increase in dietary calcium and the consumption of fresh, lush, green vegetation.

Such a change in diet during the spring and summer is also suggested by the difference in both δ13C and δ15N values between the rib bone and antler collagen which are significantly different (Fig. 7). The rib has ~ 2 ‰ higher δ13C value than the antler but ~ 2 ‰ lower δ15N value (Fig. 9). As the antler samples a much shorter period of time (during spring and summer only) rather than the annual diet represented by the rib, this difference suggests in at least during its last year the elk's spring/summer diet deviated considerably from its longer term average diet recorded in its rib

collagen. This is consistent with the major seasonal differences in diet recorded for modern elk discussed above (Fig. 5). Carbon and nitrogen isotope ratios of plants can change with plant species, climate and environment (Drucker et al. 2008; Richard & Hedges, 2003). In animals, therefore, they vary geographically, seasonally and with species due to different trophic level, diet and behaviour. There are no directly comparable data for elk in western Britain during the Allerød period but it is generally accepted that the δ13C value of the diet of prehistoric large herbivores from northern Europe decreases by ~ 3 ‰ during the Late-Glacial/Early Holocene transition as forest cover increases (Richards & Hedges 2003; Noe-Nygaard et al. 2005; Drucker et al. 2008). The elk's rib values are consistent with those for other large herbivores from the Allerød in Northwestern Europe (Fig. 6) and, despite probable environmental change and the increasing amount of forest habitats, they are not significantly different from either pre-Boreal elk in Denmark (Bocherens et al. 2015) or elk from the Federmessergruppen site of Andernach-Martinsberg, Germany which were also found to be isotopically
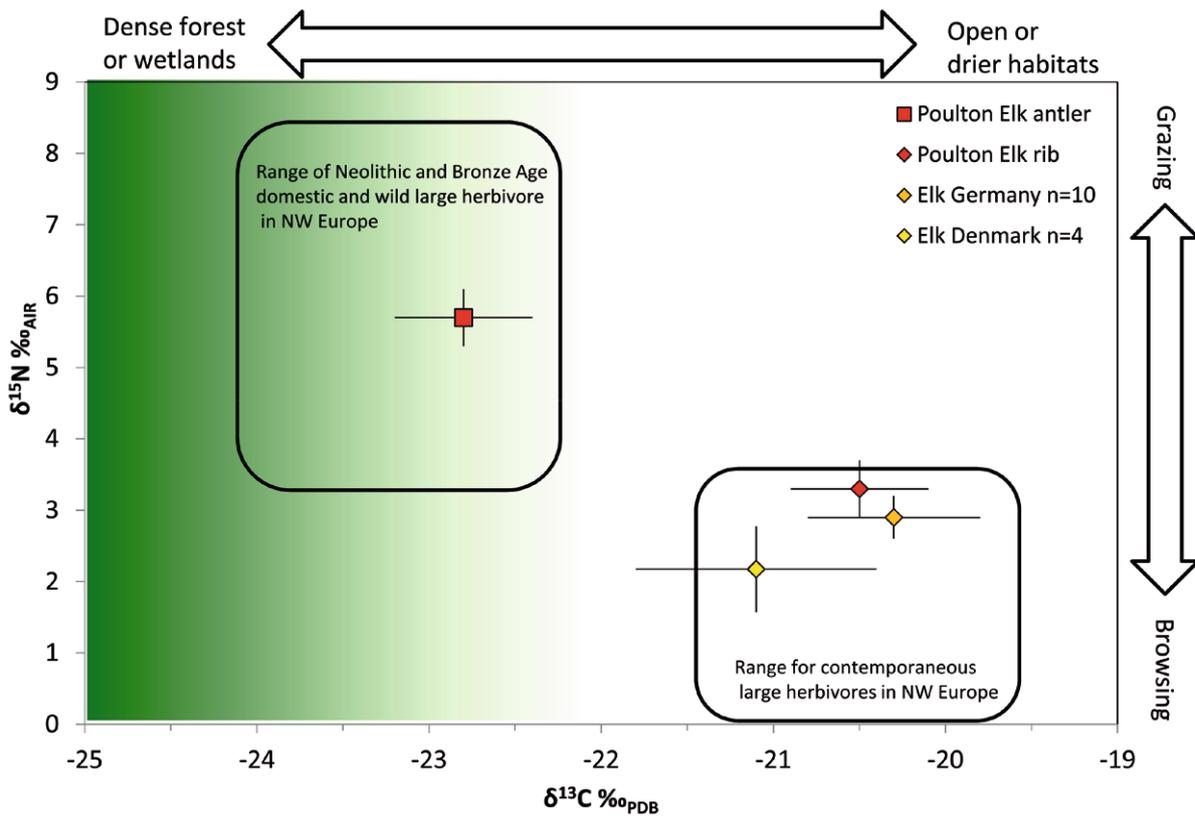
Fig. 9. Carbon and nitrogen isotope biplot redrawn after Bocherens et al. (2015) comparing the Poulton elk with: elk from the Federmesser-gruppen of Germany (Stevens et al. 2009); Preboreal elk from Denmark (Bocherens et al. 2015); large herbivores dating to the Allerød in Northwestern Europe (Richards & Hedges 2003); large herbivores dating to the Neolithic and Bronze Age in northwestern Europe (Lynch et al. 2008; Noe-Nygaard et al. 2005). Analytical errors are estimated at +/- 0.4‰ (2sd) for the Poulton Elk rib and antler. Mean values for comparative elk are shown with +/- 1sd.

Abb. 9. *Carbon und Nitrogen Isotopen Biplot nach Bocherens et al. (2015) im Vergleich mit dem Poulton Elch: Elch der deutschen Federmesser-gruppen (Stevens et al. 2009); Präborealer Elch aus Dänemark (Bocherens et al. 2015); große allerødzeitliche Herbivoren in Nordwest Europa (Richards & Hedges 2003); große neolithische und bronzezeitliche Herbivoren aus Nordwest Europa (Lynch et al. 2008; Noe-Nygaard et al. 2005). Die Rechenfehler werden mit +/- 0.4‰ (2sd) für die Rippe und das Geweih des Poulton Elchs angenommen. Mittelwerte für die zum Vergleich herangezogenen Elche sind mit +/- 1sd angegeben.*

comparable with other contemporaneous faunal taxa from Britain (Stevens et al. 2009).

The elk's rib values are therefore consistent with browsing in open habitats such as those that existed in early Holocene Northern Europe (Bocherens et al. 2015). By contrast, the antler has significantly lower $\delta^{13}C$ and higher $\delta^{15}N$ which are not found in domestic or wild large herbivores until c. 4'000 years later (Richards & Hedges, 2003; Noe-Nygaard et al., 2005; Drucker et al. 2008). Nonetheless, the isotopic difference between the rib and antler is difficult to explain solely as the metabolic difference found between red deer bone and antler by Stevens and O'Connell (2016) because in the case of the animals in their study, bone was usually found to be higher than antler for both $\delta^{13}C$ and $\delta^{15}N$: an alternative expla-nation may therefore be needed for the higher $\delta^{15}N$ in the elk's antler. As shown in Figure 9, lower $\delta^{13}C$ and higher $\delta^{15}N$ may indicate a shift towards increased grazing under canopy (Drucker et al. 2008; Bocherens et al. 2015) but it may alternatively record a shift from drier, woody browse to grazing in wetland

environments in spring/summer because the $\delta^{13}C$ values of plants have been shown to increase with decreasing moisture availability at mid- to high latitudes (Stewart et al. 1995; Lynch et al. 2008; Kohn 2010). If so, it would support the observation we proposed from the enamel strontium concentrations of a drier, woody, diet in autumn/winter and a lusher diet in spring/summer, although the tooth values derive from the first year of life and the antler from the last year of life.

The lesions

The (original) 'two hunting episodes' hypothesis

The published account of the death of the elk (Hallam et al. 1973) listed a large number of lesions on its skeleton, which despite the shiny nature of the bones (it is unknown if this reflects the presence of a preserv-ative/varnish or postdepositional alteration) remain clearly visible. They divided these into two groups: those that exhibited some signs of healing, and those that did not. The lesions are scattered liberally about
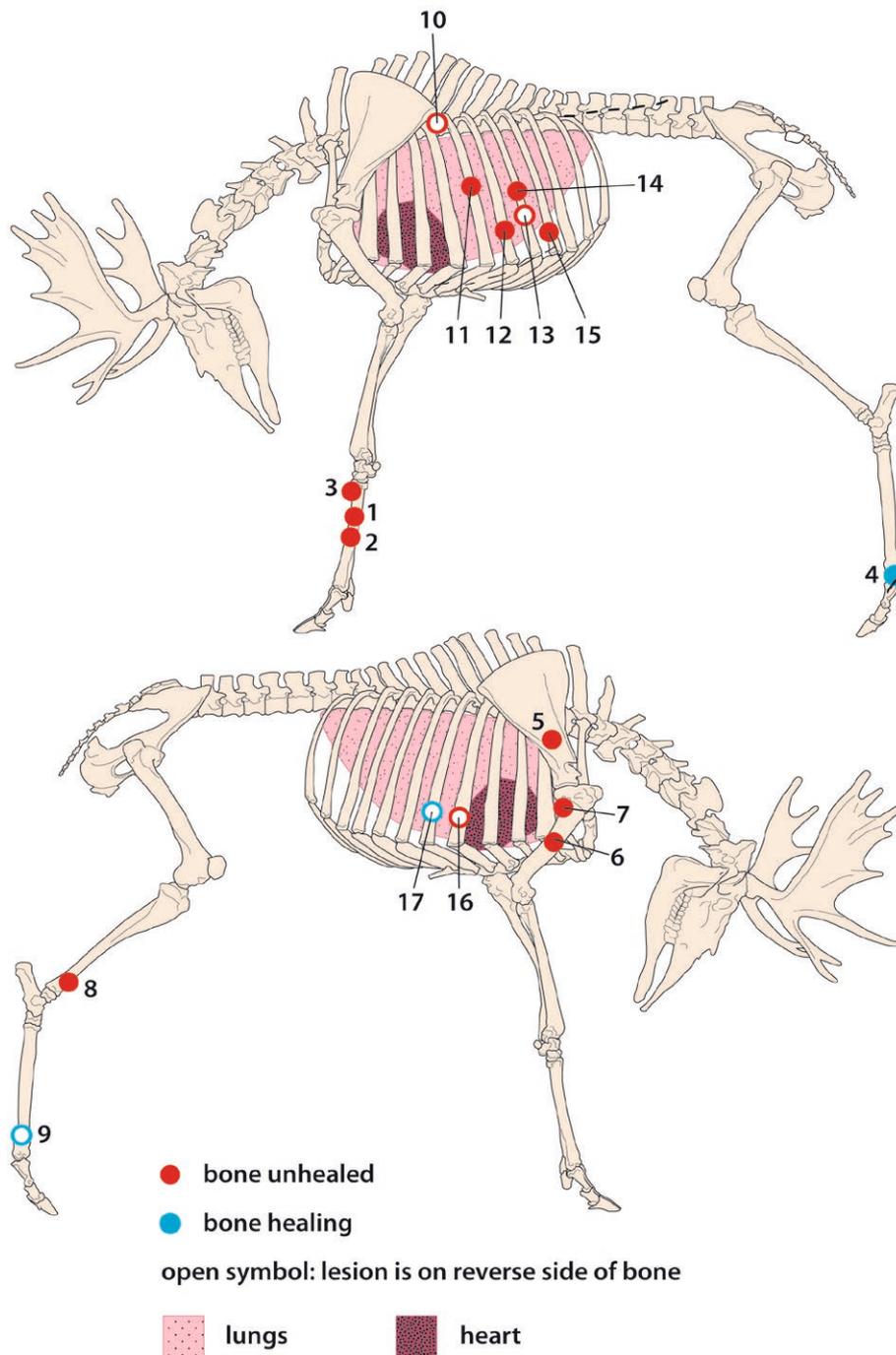
Fig. 10. Location and type of lesions on the Poulton elk's skeleton. Own data.
Abb. 10. Lokalisierung und Art der Verletzungen am Skelett des Poulton Elchs. Eigene Daten.

the skeleton. Figure 10 shows the locations of the two types of lesion. It is immediately noteworthy that the distributions of the two types are quite different: almost all the unhealed lesions are on the forward end of the thorax, while two of the three showing signs of healing are on the rear feet of the animal.

Hallam et al. (1973) interpreted these lesions as showing two distinct hunting episodes. Barbed point 2 (the shorter example) had evidently been lodged in the mass of tendons in the animal's rear left foot (Fig. 11). Lesion 4 beneath it was caused by the

pressure of the point on the bone; in the opinion of Dr. R. Popham of the Bury General Hospital the creation of this lesion would have taken about one to two weeks to form (Hallam et al. 1973: 118). Lesion 9 on the right metatarsal comprised '*two shallow smooth scars on the medial distal part of the shaft*' (Hallam et al. 1973: 116), which were also formed '*some time before the death of the animal*' (Hallam et al. 1973: 118). One hypothetical possibility was that two further barbed points had lodged in the tendons of this foot, but had dropped out before the animal's death and were thus

Fig. 11. Poulton elk lesion 4 (outlined in inset). Courtesy Preston Harris Museum.
Abb. 11. *Verletzung 4 am Poulton Elch (Markierung in kleinem Foto). Foto Preston Harris Museum.*

not recovered (Hallam et al. 1973: 125). Lesion 17 was the third showing healing; this comprised '*a number of very poorly defined grooves on the medial [i.e. inner] surface associated with a thin layer of secondary bony spicules*' (Hallam et al. 1973: 116). This injury was also thought to have been inflicted one to two weeks before death, by flint-tipped weapons (Hallam et al. 1973: 119). These injuries were seen to derive from the first hunting episode.

All of the remaining lesions were identified as deriving from the second hunting episode, Lesions 5 and 8 from direct impacts of 'flint-tipped weapons', and lesions 6, 7, 10, 11, 12, 13, 14 and 16 from 'oblique impacts'. Lesions 1, 2 and 15 were thought to have probably been inflicted by stone axes, while lesion 3 was caused by '*the impact of a stone club or similar instrument*' (Hallam et al. 1973: 119). This second hunting episode was clearly envisaged as a veritable hail of projectile strikes, but the animal nevertheless escaped its hunters, to die a short time later:

'*[The elk] drowned in the lake attempting to escape from the hunters…. Weakened by its wounds, it would have little chance of extricating itself. Its body, being trapped under the ice, would drift towards the edge [of the lake/pool]. There, concealed under the ice rim, it would be protected from hunters, wolves and scavengers until it was eventually entombed by the lake sediments*' (Hallam et al. 1973: 126).

This scenario was challenged almost immediately. N. Noe-Nygaard argued that almost all the lesions were of modern date, inflicted during the recovery and excavation of the elk. Lesion 9 she accepted as probably ancient; lesion 4 could have been caused by the sediments pressing the barbed point against the metatarsal; but all the rest '*can be interpreted most convincingly as results of damage caused during the excavation*' (Noe-Nygaard 1975: 15). She pointed out – rightly so – that it was curious that none of the injuries retained any part of flint points, which were common in such injuries in Denmark (Noe-Nygaard 1974). A rapid reply came from the palaeontological member of the original team, A.J. Stuart, who stated that the bones were not soft enough to have been damaged during the recovery/excavation. There was in any case an identical lesion on the rear limb (lesion 8, on the tibia), which had been excavated by archaeologists. Since this lesion must have been caused by a projectile impact – his argument went – those in the thorax would have been too. Lesion 4 could not have been caused by the pressure of the barbed point, since both the point and the metatarsal were made of bone (Stuart 1976).

The Poulton elk has, despite Noe-Nygaard's objections, largely gone into the literature according to the original scenario of two hunting episodes, the second one involving many flint-tipped projectiles. Ultimately,

this derives from a casual link to the Final Pleistocene reindeer hunting site of Stellmoor, Germany, as referred to in the original elk publication. Campbell (1977: I, 168) mentioned stone-tipped arrows and axes even if he expressed some scepticism about the interpretation. Megaw and Simpson (1984: 47, 50) followed this, as did Smith (1992: 105) and Huntley and Stallibrass (1995: 89), and one finds even recently opinions that *'the elk's skeleton had many injuries caused by flint-tipped weapons and bone projectile points from human hunters, and two barbed projectile points were found with the skeleton'* (Kitchener 2010: 37).

We now turn to the hypothesis that the Poulton elk was hunted twice, escaping from its hunters on both occasions. We concur with the original authors that the animal had not been butchered: if it had, the skeleton would not have remained in articulation, and the bones would likely not remain unbroken had the hunters gained access to it. Barbed point 2 has not been directly dated, but it is highly likely that it is indeed associated with the skeleton as Hallam et al. (1973) suggested. The point was identified as bone rather than antler by radiological examination (Popham, in Hallam et al. 1973: 123). Large-barbed uniserial points are in the early Holocene most usually made from the metapodials of elk or red deer (Andersen & Petersen 2009: fig. 2). Stuart (1976) was therefore likely correct to argue that the point would not have caused lesion 4 solely due to the weight of the overlying sediments: since the point and the elk's metatarsal were made of the same material, they should have had an equal effect on each other, and the point has not been pressed flat. It would also require a major coincidence for a point that had nothing to do with the elk to come to rest on the skeleton's foot.

There are, however, two major problems with the scenario of the proposed second hunting episode. The first is the position of some of the postulated projectile strikes. Four of the lesions (10, 13, 16 and 17) occur on the *inside* of the rib cage. To cause these, projectiles would have to have travelled right through the elk's thorax, whilst doing so without breaking any ribs on the side of entry. Lesion 10 extends across the heads of two ribs. It is described as 'probably cut by a flint-tipped projectile which pierced the rib-cage from a posterior direction at a low angle' (Hallam et al. 1973: 119). Any such impact, however, would involve the projectile passing through the elk's lungs, and hence the injury which caused lesion 10 would probably have led to the elk drowning in its own blood in a very short time. The projectiles causing lesions 13, 16 and 17 might have passed below the lungs, but would still have caused massive internal damage and blood loss. It is very difficult to envisage the elk surviving long enough to escape the hunters when transfixed through and through by four projectiles in such a way. The escape scenario is thus highly questionable.

The second problem is the claim that lesions 1, 2 and 15 were inflicted with a stone axe, and lesion 3 with a 'stone club'. Axes and clubs would presumably have functioned as butchery implements (or at least to deliver a *coup de grace*), not hunting weapons. The suggestion, therefore, that axe impacts 'imply 'hand-to-hand' fighting' (Hallam et al. 1973: 126) is deeply unrealistic: no ethnographic instances known to us involve such close-quarter hunting, and once again it is most unlikely that an elk hit a number of times with an axe (in addition to all the other injuries) would survive to escape its pursuers. Notwithstanding their hardiness, any elk that had suffered the injuries proposed for the Poulton specimen would surely have died on the spot and been butchered.

Elk hunting and butchery: the European context
Work subsequent to the discovery of the Poulton elk has done much to reveal aspects of the hunting and butchery of large mammals. There are hardly any archaeological instances of wounded elk escaping their hunters, only to die later and be recovered by archaeologists. The only serious contender is the male elk from Taaderup in Denmark, found in 1919. The skeleton has no lesions, but a possible fragment of a bone point was found near its humerus (Ødum 1920: fig. 3). Furthermore, a uniserial harpoon was found in the same area in 1941 (Andersen & Petersen 2009: fig. 10 no. 10). The elk has however been dated both by pollen and by radiocarbon accelerator to the Early Atlantic period, < 7'000 calBC, and it is doubtful whether uniserial harpoons of the relevant kind were still being produced this late in the Mesolithic (Andersen & Petersen 2009: catalogue no. 10). No association between elk and harpoon can therefore be demonstrated.

The other large animal hunted in the late glacial and early postglacial was the aurochs (*Bos primigenius*), and for this species we do have several wounded individuals that had escaped from their hunters. The best known are two from Denmark: Vig and Prejlerup. The animal from Vig was involved in two hunting episodes. Fragments of flint were embedded in its 9th right rib, but this injury was old and had healed. Just before its death the aurochs was hunted again, a broken flint armature remaining in an unhealed injury in its 7th right rib; three microliths were also found near its chest, probably indicating an arrow strike into soft tissue during the same hunting episode (Hartz & Winge 1906). The animal from Prejlerup had no flints embedded in its bones, but was surrounded by 16 microliths from about nine arrows, evidently lodged in the animal's soft tissues (Aaris-Sørensen & Petersen 1986a, 1986b). Both these aurochsen had evaded their pursuers but died shortly afterwards, since they comprised complete unbutchered skeletons – no axe impacts were visible on either specimen.

Aurochs kill-butchery sites, resulting from successful hunts, are also known. These are very

different to the escaped animals just described. The Late Mesolithic female from Balkweg in the Netherlands is represented by some vertebrae, the sacrum, and all four feet (Prummel & Niekus 2011). The early Mesolithic male from Seamer Carr B also has some vertebrae, but in addition has the right mandible and maxilla, the pelvis, and the proximal right radius (Rowley-Conwy 2017; Uchiyama et al. in press). In both these cases the meat-rich portions of the skeleton have been removed, and both are associated with stone tools. These are evidently primary kill-butchery locations.

We suspect that elk would have been dealt with in a similar manner to aurochs; both species are far too large for hunters to move the entire carcass very far overland. The Early Mesolithic site of Friesack 4 is a major settlement, and shows the other end of this transport process. Elk are relatively uncommon at the site, but it is striking that the thoracic and lumbar vertebrae, the ribs, and the metapodials are markedly under-represented. Friesack 4 is the kind of place where the meat-rich skeletal portions were taken for consumption (Schmölcke 2016: 88).

The situation is, however, more complex than just a bipolar separation into kill-butchery sites and settlements. Three early post-glacial sites in Denmark appear to be locations where elk carcasses were processed so the meat could be removed for onward transport – but they are not actual kill sites, nor are they regular settlement sites. At Skottemarke there were six elk, at Favro two (Møhl 1978), and at Lundby Mose about twelve, in six separate concentrations (Hansen et al. 2004). They were all dumped into the waters of small lakes. The bones of some of the Lundby Mose skeletons are so concentrated that they may have been wrapped in hides (Leduc 2012, 2014). The numerous cutmarks and the marrow fracturing reveal that the carcasses were intensively processed, and some portions were removed (Leduc 2012, 2014). It is unclear how so many carcasses came to be processed in these places, since elk are usually solitary and would probably have been killed singly, in various places. There are no precise analogues for aurochs, but sites with the intensive processing of groups of animals on the edges of low-lying valleys are known at La Montagne (Helmer & Monchot 2006) and Bedburg-Königshoven (Street 1999). In Britain, the Mesolithic site of Star Carr has been argued to be a processing site from where meaty elements of several species, including aurochs and elk, were removed (Legge & Rowley-Conwy 1988, Rowley-Conwy 2017).

In the broader context, it is therefore reasonably clear that elk and aurochs may occur archaeologically in four ways: as injured animals that escaped from the hunters but soon died; at kill-butchery locations; on mass processing sites; and at residential settlements. The Poulton elk is, however, anomalous: its unbutchered state suggests that it escaped from its hunters, but the extensive injuries it is claimed to have suffered should have left it dead on the spot and thus available for butchery. We must now pay attention to the lesions on its skeleton and their significance.

The lesions on the Poulton elk reconsidered

We consider the lesions in two main groups. The first comprises solely lesions 4 and 9, i.e. those on its metatarsals. Lesion 4 is the one argued by Hallam et al. (1973) to have been caused by pressure from the barbed bone point. The second group comprises all the rest.

Lesion 4 is illustrated in Figure 11. It is a shallow indentation with a smooth surface. Dr. Tina Jakob (Department of Archaeology, Durham University), has examined the photograph and believes that the lesion was inflicted ante-mortem, and is consistent with pressure being applied by the bone point. Popham's estimate that this could have occurred in one or two weeks (see above) may, however, be a little too low: three weeks or longer might be a more accurate estimate of the time involved. Lesion 9 on the right metatarsal is illustrated in Figure 12 (right). This is in fact formed of two adjacent lesions, both shallow and smooth. Dr. Jakob believes that these too were inflicted ante-mortem. Hallam et al. (1973: 125) speculate that a pair of bone points might also have caused these, lying embedded between the tendons and the bone for some time but falling out before the death of the animal. This remains plausible; we certainly have no better suggestions to advance.

The second group of lesions comprise those argued by Hallam et al. to have been the result of numerous projectile strikes. Not a single one of these is, however, convincing. A great deal of research has been undertaken on projectile impacts onto bone since the Poulton elk was excavated. Pioneering experimental work was carried out by Morel (1991, 2000), who evolved the first working typology of different types of impact marks (Morel 2000: 55). Subsequent work has modified this typology. Letourneux and Pétillon (2008) used bone and antler points, and grouped impact lesions into three main types: notches (*éraflures*) caused by glancing impacts; punctures (*percements*) that impact directly on the bone but do not penetrate it; and perforations (*transpercements*) that do penetrate right through the bone. Gaudzinski-Windheuser (2016) adopted these categories, and added a fourth: fragmentation. The experiments most relevant to the Poulton elk are those based on stone projectile points. Castel (2008) examined over 300 such experimental impacts. Notches may take the form of single or multiple irregular splintered grooves across the edge of a bone (Castel 2008: planche 1 photos 1a & 1b), or may remove a chip or flake of bone, while leaving a clear impact point (Castel 2008: planche 2 photo 6). Punctures and perforations involve crushing and splintering, and leave irregular and variable holes in the bone wall (Castel 2008: planche 1 photos 3a-c; planche 2 photos 4, 5, 8, 9 for example). Fragments of flint commonly remain in

Fig. 12. Poulton elk lesions: three lesions on the ribs (left) and lesion 9 on the right metatarsal (right). Courtesy Preston Harris Museum.
Abb. 12. Verletzungen des Poulton Elchs: drei an Rippen (links) und Verletzung 9 am rechten Metatarsus (rechts). Foto Preston Harris Museum.

notches, punctures and perforations (Castel 2008: 106; Gaudzinski-Windheuser 2016: 83; also Smith et al. 2007: 546).

None of the Poulton elk lesions looks anything like those from these experimental studies. Figure 12 (left) shows three of the lesions on the ribs, while Figure 11 shows those on the limb bones. They are without exception smooth-edged and lacking any of the splintering characteristic of Castel's experiments. Morel (2000: fig. 1) illustrates a lesion caused by a glancing impact which has produced a straight cut in the bone,

but with extensive cracking along each side; it is quite different from the Poulton examples. They may be quite deep, resulting from a direct impact (Fig. 12 left, lesion 15), or shallow and asymmetrical, resulting from an oblique impact. Lesions 1 and 2 on the left metacarpal are clear examples of this type (Fig. 13). Lesion 3 on the proximal anterior surface of this metacarpal is apparently the result of an even more oblique impact, the implement skating irregularly over the surface of the bone. None contain any fragments of flint.

Lesions 4 and possibly 9 are the only ones we may with any confidence relate to human activity in the Allerød. Lesion 4 was caused by pressure (see above), not by an impact; it therefore does not resemble any of the impact types discussed by Letourneux and Pétillon (2008). There can be virtually no doubt whatsoever that all of the remaining lesions on the Poulton elk's skeleton were inflicted by the tools of the
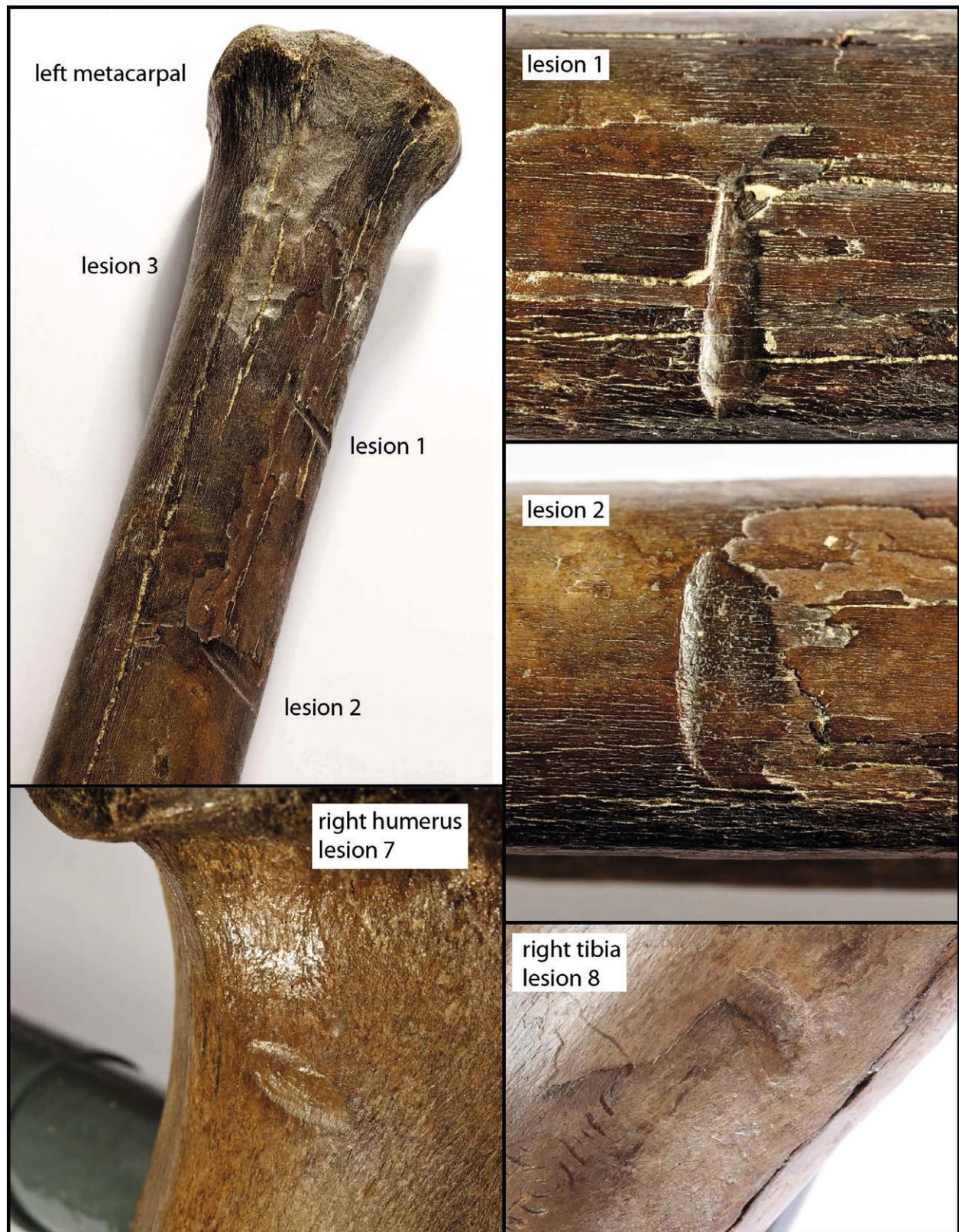

Fig. 13. Poulton elk lesions: lesions on the limb bones. Courtesy Preston Harris Museum.
Abb. 13. *Verletzungen des Poulton Elchs: Verletzungen an Extremitäten-Knochen. Foto Preston Harris Museum.*

workmen and/or amateur archaeologists responsible for finding and excavating the head, forelimbs and thorax of the elk. Lesions 1 and 2 probably result from the tips of shovels impacting from the right. The nature of the lesions is consistent with the heavy, blunt, smooth edge of a metal shovel. They are too large to have been inflicted by stone blades, and a flaked stone axe would have left a more irregular lesion containing splintering and striations. Lesion 3 is probably from a similar tool, not impacting directly but glancing across the surface of the bone. Lesions 7, 8, 12, 15 and 17 – and by extrapolation all the others in this group – are the results of more direct impacts. We see no signs in lesion 17 of the healing claimed by Hallam et al. (1973: 116). Stuart (1976) argues that lesion 8 on the right tibia, excavated by the archaeologists, cannot have been inflicted during the excavation. The lesion is, however, similar to the other ones of modern derivation (Fig. 13), and almost certainly results from the same cause. We are not clear how this happened, but note that the lateral side of this bone was uppermost when excavated (Hallam et al. 1973: fig. 2). It would therefore have been exposed to any potential impacts from above. Thus, whoever lifted it out of the ground, we parsimoniously interpret it as excavation damage.

We conclude that the original hypothesis involving two hunting episodes cannot be sustained. We concur with Noe-Nygaard (1975) that the 'rain of projectiles' and 'hand-to-hand fighting' interpretation is illusory. We are left with an elk which has been shot in one (perhaps both) hind feet with projectiles tipped with uniserial barbed points, or with one projectile tipped with the two points leister style. Hallam et al. (1973: 125-126) suggest that the hunters may have deliberately aimed at the legs, perhaps with the intention of capturing the animal alive so that it could be driven to their settlement. Hitting the elk in both hind feet would, however, seem to require superhuman (if not supernatural) accuracy on behalf of the hunters; and if the intention was that the animal be led or driven, shooting it in the feet would not seem to be the best policy. The hits were probably the result of a single or double fluke, which injured but did not cripple the animal. It was thus able to escape and live for a further, if brief, period. The Poulton water pond was not a kill site. Now, we can go a little further in our interpretation by turning to the barbed points themselves.

The harpoons and manner of the elk's death

At Poulton, there is no clear archaeological context for the elk, although on the basis of its age and wider parallels one would expect this to be culturally Federmessergruppen. In this context, however, it stands out. Most British lithic material attributable to the Federmessergruppen derives from the south and east and, as Conneller (2007: 218) has observed, dates to the later Allerød. Poulton, by contrast, demonstrates an earlier Allerød presence in the northwest of Britain. As the few radiocarbon measurements suggestive of an early Allerød human presence in Britain derive from organic armatures such as the examples we discuss below (Pettitt & White 2012: 480), we speculate whether early Federmessergruppen hunters in Britain tipped their weapons predominantly with bone points, and that lithic federmesser became characteristic only of the later Allerød presence. If the decreasing visibility of flint as forest cover grew lead to the use of poorer quality stone as Conneller (2007) has suggested, it may have also have led to increased use of bone for armatures in the earlier Allerød, particularly if they were effective in watery environments. Alternatively, the difference could be revealing a shift in weapon systems from bone point tipped javelins to flint point tipped arrows. In either case, a shift of weaponry and associated hunting tactics might be implied.

The two bone points from Poulton are uniserial barbed examples (Figs. 14 & 15) and although clearly of Allerød age most similar to continental 'Mesolithic' forms of the Preboreal and younger (e.g. from Star Carr) but which, as AMS radiocarbon dating has shown, originated in the Allerød and persisted through the Younger Dryas (e.g. Dinslaken and Bützee, Germany and Europort, Netherlands: Cziesla & Pettitt 2003). As Hallam et al. (1973: 120) noted, the two points are similar in shape, size and details of manufacture, if both incomplete. Each was produced by cutting v-shaped grooves or notches oblique to the edge of thin bone splinters, to create short, angular barbs above them. Point 1 is now 12.7 cm in length, and Point 2 is 8.2 cm in length. Both points show evidence of proximal snapping, subsequent reworking and, finally, some sediment wear. Presumably this wear originated in snaps that occurred close to the hafting during use, perhaps even against the Poulton elk.

Our observations suggest that the two points were made at the same time and shared similar life histories (Fig. 16). Their transverse thickness is similar – a constant 4-5 mm below each barb; each has a similar, gentle curvature in profile, the size and shape of the barbs is similar, and rejuvenation modifications are shared between the two. The blank bone splinters used to make them were clearly very similar. In addition to their proximal snaps both show wear at the tip, and on Point 2 this is modified by a resharpening concavity just below the tip wear. Clearly, the reduced length of Point 2 is a result of both base and tip loss and rejuvenation. The loss of barbs 3 and 4 on Point 1 has been addressed by similar use of concave recutting. Thus, as excavated, Point 1 retains four complete barbs (Fig. 16 B1, 2 5, 6) and remnants of three others, and Point 2 retains four (B2, 3, 4, 5).

Organic points of Allerød age are rare in Britain, as with neighbouring regions of the continent (e.g.

Fig. 14. Poulton. Barbed bone Point number 1. The point is now 12.7cm in length. Courtesy Preston Harris Museum.
Abb. 14. Poulton. Widerhakenspitze aus Knochen Nummer 1. Das Objekt misst heute 12,7 cm in der Länge. Foto Preston Harris Museum.

Fig. 15. Poulton. Barbed bone Point number 2. The point is now 8.2cm length. Courtesy Preston Harris Museum.
Abb. 15. Poulton. Widerhakenspitze aus Knochen Nummer 2. Das Objekt misst heute 8,2 cm in der Länge. Foto Preston Harris Museum.

Baales 2004). Similar bone points with closely-spaced barbs of the type noted above are known from Allerød contexts at Devil's Wood Pit, Sproughton (Ipswich, Suffolk) and dredged from the Leman and Ower Banks of the North Sea (respectively 11'485 ± 60 BP [~13.2 -13.5 calBP: OxA-14943] and 11'740 ± 150 BP [~13.8-13.4 calBP: OxA-1950], Wymer et al. 1975. Jacobi et al. 2009), and a typologically similar although undated antler form was recovered 213 km east of Poulton from Lateglacial lake deposits in a birch-dominated environment at Gransmoor, East Yorkshire (Sheldrick et al. 1997). It is notable that bone and antler points of the period have been recovered from watery environments, which lead Cziesla and Pettitt (2003) to interpret these as leister prongs, and Jacobi et al. (2009) to a specific association with the hunting of elk at the time of year when they feed on aquatic plants. The similar morphology of the two Poulton examples, and particularly their curvature (Fig. 17) is consistent with a paired hafting in this manner, i.e. as curved diverging or (as in the photo) converging leister prongs. If this is correct, the one weapon that can be associated with the elk is a barbed leister-tipped projectile.

Given the association of Barbed Point 2 with the elk's metatarsal and the probability that the point and lesion 4 are associated, we can be sure that it has been recovered in the association it had with the elk at the time of its death. Point 1 was recovered in close proximity to the elk's ribs (Hallam et al. 1973: 102). While we can be less certain that there has been no post-depositional movement of this point, let us assume given the intact nature of the skeleton and for the sake of argument that it, too, was recovered close to where it was last associated with the elk, i.e. in its side.

The orientation of Point 1 to the metatarsal – assuming it has not changed postdepositionally – suggests that the point entered the elk's lower limb from below, i.e. hoof upwards. The lower leg could have been presented to the hunter in this way for two reasons: either the elk was fleeing and kicking as it did so in reaction to mortal danger, or it was swimming or diving for aquatic food in shallow water. The latter would render it particularly vulnerable (Petersen 2009). If we assume that both points were hafted together and were recovered in their last association with the elk, a hypothetical explanation becomes clear (Fig. 18).
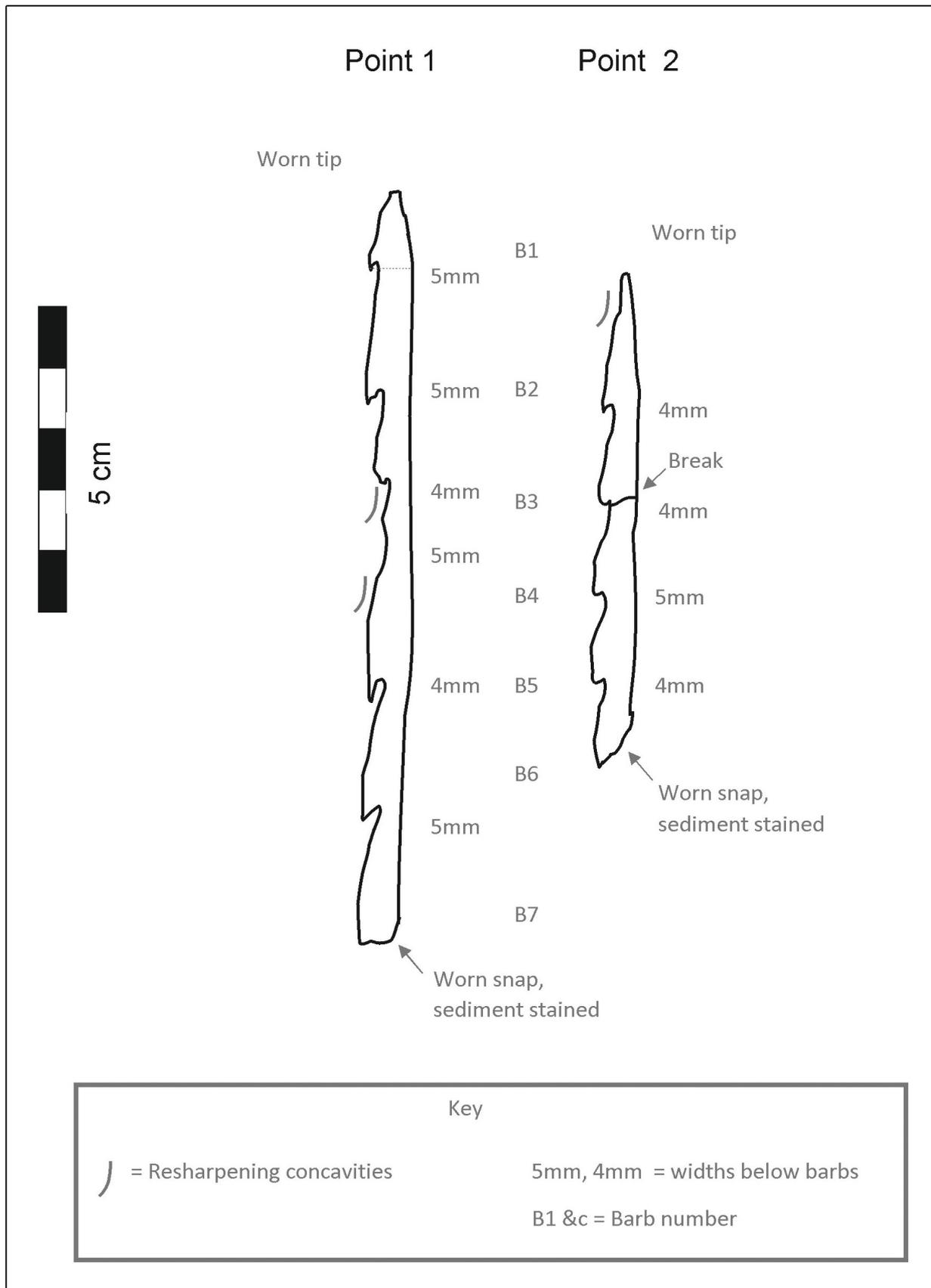
Fig. 16. Outline drawings of the two Poulton barbed bone points showing barbs and modifications (PP).
Abb. 16. Umzeichnung der beiden Widerhakenspitzen mit Widerhaken und Bearbeitungsspuren (PP).

projectile or in hand, to an animal possibly disadvantaged in water presenting its rear legs to the hunter/s. If leisters were inappropriate for hunting such large animals (which might explain the lack of success) it may reflect an opportunistic attempt to attack a vulnerable elk, with a weapon not designed specifically for the purpose. Whatever the case, the hunt failed.

We realise that we must assume that the points were indeed hafted together, and that the position of their recovery has not changed taphonomically. We do believe, however, that the information that is available at least renders such an interpretation parsimonious. Furthermore, our interpretation draws together the views of Cziesla and Pettitt (2003) and Jacobi et al. (2009) that the points were hafted together as leisters, and were used to hunt elk in watery environments.

If we are correct, therefore, the Poulton elk takes its place as a 'normal' example of an escaped prey animal, similar to the Vig and Prejlerup aurochsen, and perhaps the Taaderup elk, described above. Perhaps it came eventually to take refuge on the western side of the small pool. This was the gently shelving side of the pool (Fig. 2), which probably had a broader belt of vegetation. This spot provided the three things the elk most needed: concealment, food, and water. But it was ultimately to no avail: the elk died there.

Conclusion: a cold case, a failed kill

The Poulton elk is a very rare example of an Allerød elk, hunted, unsuccessfully, ~13-13.2 ka calBP. We offer the following conclusions by way of revising our understanding of the elk's life and death.

- A parsimonious interpretation of the strontium in the elk's tooth enamel suggests that it was, like modern elk, territorial in its habits, with no evidence of wider ranging during its growth.
- Carbon and nitrogen isotope ratios from its ribs are consistent with browsing in an open birch environment, consistent with its palaeoenvironmental context in which birch and pondweed dominate. Enamel strontium concentration profile may also record the change to a spring/summer diet of lush (aquatic) vegetation observable in modern elk. However, this remains a hypothesis awaiting testing in modern elk teeth.
- Dental development and antler growth suggest that the elk died between the ages of 3.5 and 4.5 years.
- It was killed during winter, most likely January or February, when its antlers were ready for shedding.
- The original hypothesis of two hunting episodes cannot be sustained.
- All of the lesions on its skeleton are consistent with damage caused during recovery: spades do not respect relatively hard bone. We can dispense with hypothetical flint-tipped arrows, axes and maces.
- Only one violent episode is evident; the elk was shot in one – perhaps both – of its hind feet, by barbed
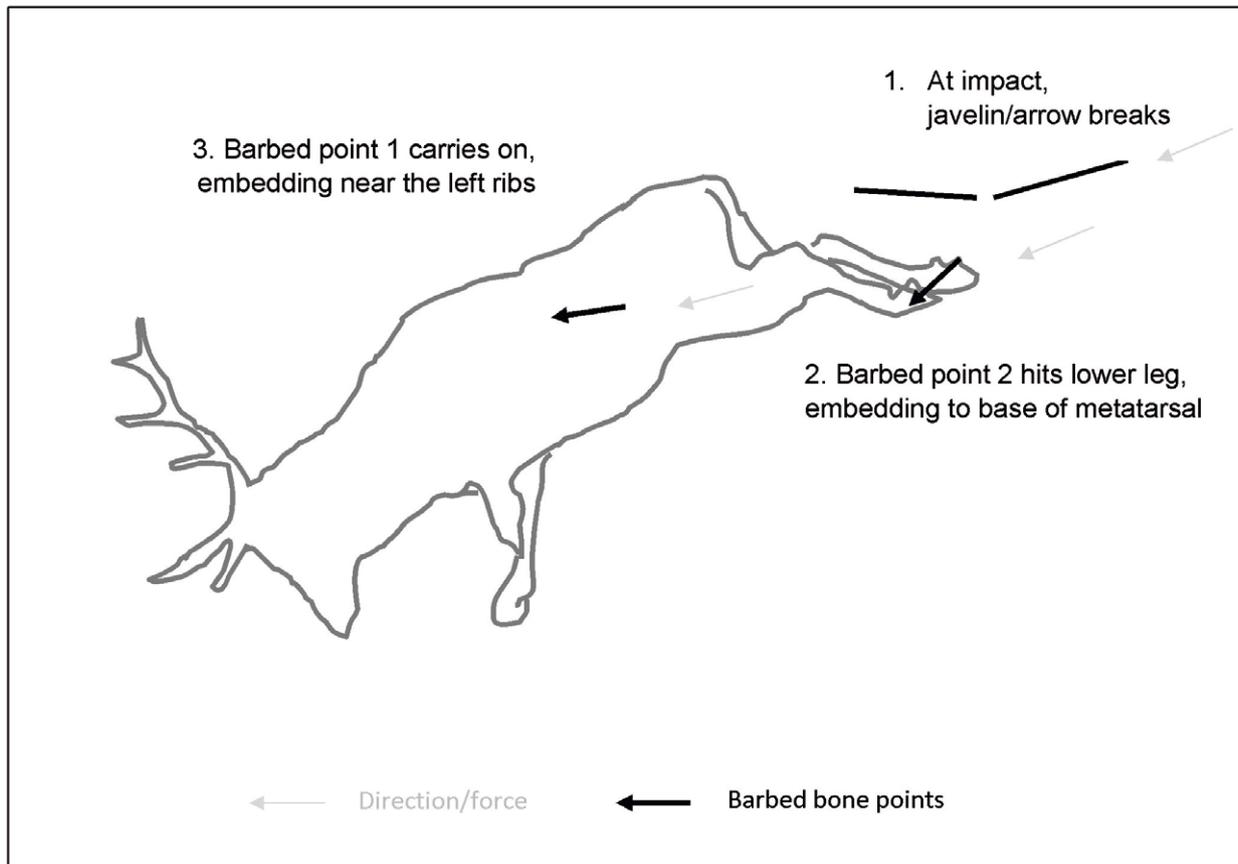

Fig. 17. The two Poulton barbed bone points shown orientated like converging leister prongs, and showing their opposed curvature. Photo PP and courtesy Preston Harris Museum.

Abb. 17. *Die beiden Widerhakenspitzen aus Poulton entsprechend konvergierender Fischspeer-Zacken orientiert weisen deutlich eine gegenläufige Krümmung auf. Foto PP und Preston Harris Museum.*

The elk was approached from the rear, on foot or by canoe, and a leister-tipped projectile was launched or thrust as the elk swam/kicked, either movement of which presented its rear legs to the thrower. The projectile stuck, Point 1 striking the elk's lower left leg and snapping off, embedding itself in the muscle and sinew around the elk's metatarsal, there to stay until it died. The momentum of the projectile continued, however, until Point 2 also snapped off the haft and embedded itself in the elk's side, i.e. in proximity to its ribs, again there to stay until its death. If lesion 9 (the two antemortem grooves on the right metatarsal) really was also caused by a leister-tipped projectile that fell out before the animal died, this might favour the close-range option of shooting or stabbing a swimming animal from a pursuing canoe.

Thus, our interpretation favours the use of one or two leister-tipped weapons, delivered either by

Fig. 18. Hypothetical sequence leading to the association of two barbed bone points with the Poulton elk, resulting from one or two impacts with leister-mounted points onto a swimming/kicking elk (PP).

Abb. 18. *Hypothetische Geschehnisse, die zu der gemeinsamen Ablage der beiden Widerhakenspitzen neben dem Poulton Elch geführt haben könnten. Das Bild resultiert aus der Projektion von ein oder zwei Impakten der montierten Fischspeere auf einen schwimmenden/austretenden Elch (PP).*

bone points best interpreted as leisters. The angle of entry of one of these is consistent either with the elk swimming for food at the time – a highly vulnerable situation – or kicking out at its hunters. More widely, we hope that our conclusions will act as a call for further research into the behaviour and hunting of this elusive Late Glacial animal. For Poulton, at least we might now close this 13'000 years old cold case.

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