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1 Scales of analysis: evidence of fish and fish processing at Star Carr

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17 18 **Abstract**

19 This contribution directly relates to the paper published by Wheeler in 1978 entitled ‘Why
20 were there no fish remains at Star Carr?’. Star Carr is arguably the richest, most studied and
21 re-interpreted Mesolithic site in Europe but the lack of fish remains has continued to vex
22 scholars. Judging from other materials, the preservation conditions at the site in the late
23 1940s/early 1950s should have been good enough to permit the survival of fish remains, and
24 particularly dentaries of the northern pike (*Esox lucius* L., 1758) as found on other European
25 sites of this age. The lack of evidence has therefore been attributed to a paucity of fish in the
26 lake. However, new research has provided multiple lines of evidence, which not only
27 demonstrate the presence of fish, but also provide evidence for the species present, data on
28 how and where fish were being processed on site, and interpretations for the fishing methods
29 that might have been used. This study demonstrates that an integrated approach using a range
30 of methods at landscape, site and microscopic scales of analysis can elucidate such questions.
31 In addition, it demonstrates that in future studies, even in cases where physical remains are
32 lacking, forensic techniques hold significant potential.

33
34 **Keywords:** Mesolithic; Star Carr; Flixton Island, Fish remains; Seasonality; Use wear

35 **1.0. Introduction**

36

37 *Figure 1: location map of Star Carr.*

38

39 Grahame Clark excavated Star Carr from 1949-1951 (Clark 1954) (Figure 1). His discoveries
40 have led to what has become known as one of Europe's most famous Mesolithic sites. This
41 was due to the outstanding preservation of organic remains, including the discovery of a
42 brushwood platform associated with an extensive faunal assemblage and extremely rare
43 artefacts such as 'headdresses' made from the crania of red deer (*Cervus elaphus* L., 1758).
44 Clark noted that:

45

46 'No remains of fish survived. Negative evidence is notoriously dangerous in prehistory, and
47 never more so than when a substance so perishable as fish-bone is in question. Yet to judge
48 from what was found on similar sites in different parts of northern Europe, traces might at
49 least have been expected for the lower jaws of pike, had these been caught. It should be
50 remembered though that the evidence for pike-fisheries among the later Maglemosian comes
51 from sites occupied during the summer, in the early months of which the fishing was carried
52 on with leisters in temperate Europe down to modern times. The absence of pike remains
53 from Star Carr may therefore be a true reflection of the circumstance that the site was
54 *abandoned during the summer months*' (Clark 1954, 16, our emphasis).

55

56 In the 1970s and 1980s a number of articles reinterpreted the evidence from Star Carr, in
57 particular reconsidering the seasonality of the site and importantly, suggesting that the site
58 had been occupied during the spring and summer (Carter 1998, Caulfield 1978; Jacobi 1978;
59 Legge and Rowley-Conwy 1988; Mellars and Dark 1998). This overturned Clark's
60 hypothesis, as set out above, and with new interpretations of summer occupation, it became
61 even harder to account for a lack of pike at the site.

62

63 In 1978, Wheeler, wrote a seminal paper entitled 'Why were there no fish remains at Star
64 Carr?'. Importantly, he drew attention to the fact that pike can be fished all year round, which
65 negated the seasonality argument. Therefore, he suggested that there were probably no fish
66 present in the lake throughout the course of site occupation. His hypothesis was that fish,
67 attempting to colonise up the riverine systems, would not have permeated the Lake Flixton

68 basin because the water was too fast flowing at Kirkham Gorge, located roughly 40
69 kilometres downstream.

70

71 However, Wheeler (1978) did not mention the presence of waterfowl, which can transport
72 fish spawn via their feet. The Star Carr faunal assemblage contained at least seven species:
73 white stork (*Ciconia ciconia* L., 1758), common crane (*Grus grus* L., 1758), red-breasted
74 merganser (*Mergus serrator* L., 1758), red-throated diver (*Gavia stellata* P., 1763), great
75 crested grebe (*Podiceps cristatus* L., 1758), little grebe (*Podiceps ruficollis* P., 1764) and a
76 duck of similar size to the pintail (*Anas acuta* L., 1758) (Clark 1954). Thus fish could have
77 colonised the lake via this method of passive dispersal.

78

79 The only potential (indirect) evidence for fishing is in the form of the barbed points. Clark
80 found 190 barbed points and 1 harpoon at Star Carr (Figure 2). These were made out of red
81 deer antler and manufactured so that they could be hafted onto wooden shafts for spearing or
82 throwing. In some cases they may have been hafted in pairs or with the addition of a central
83 bone point to provide a leister as has been observed at other sites in Europe: one such pairing
84 of barbed points was observed by Clark *in situ* (Clark 1954, plate 12).

85

86 *Figure 2: A range of the different types of barbed points/harpoons found at Star Carr including the harpoon in*
87 *the middle (scale: 5cm).*

88

89 Further evidence for the use of barbed points and harpoons related to fishing practices derives
90 from a number of other Early Mesolithic ('Maglemosian') sites in north-west Europe:
91 Holmegård, Lundby, Mullerup, Ulkestrup Lyng, Sværdborg, Vinde-Helsing and Ögaarde (in
92 Denmark) and Duvensee, Friesack 4, Friesack 27a, Hohen Viecheln and Wustermark (in
93 northern Germany) (Aaris-Sørensen 1976; Broholm 1924; Clark 1948; Gramsch and Beran
94 2010; Groß 2014; Jessen *et al.* 2015; Noe-Nygaard 1995; Robson 2015; Rosenlund 1980;
95 Schuldt 1961). In addition, fish remains were also encountered at the majority of these sites
96 and are solely pike, or pike dominant. However, wels catfish (*Silurus glanis* L., 1758),
97 European perch (*Perca fluviatilis* L., 1758), tench (*Tinca tinca* L., 1758), carp (Cyprinidae
98 sp.), common bream (*Abramis brama* L., 1758), common rudd (*Scardinius erythrophthalmus*
99 L., 1758) and European eel (*Anguilla anguilla* L., 1758) have also been identified (Aaris-
100 Sørensen 1976; Broholm 1924; Gramsch and Beran 2010; Groß 2014; Jessen *et al.* 2015;
101 Noe-Nygaard 1995; Robson 2015; Rosenlund 1980; Wundschedt 1961).

102

103 In addition, there is a close correlation between pike remains and barbed points, similar to
104 those found at Star Carr. For instance, at Sværdborg, Denmark, 80 upper and 64 lower pike
105 jaw bones were found along with 274 leister prongs and 11 hooks (Clark 1952, 47). There are
106 also sites where barbed points have been found in association with pike bones within the lake
107 bed. Clark (1948, appendix 1) lists Calbe (Germany), Esperöds Mosse (Scania), and Kunda
108 (Estonia). In two cases at the latter site barbed points were found impaling pike skeletons:
109 one in the back of a large pike and the other in the skull (Clark 1952, 47).

110

111 In comparison, there is very little evidence in Britain for freshwater fishing, particularly in
112 the Early Mesolithic. The only comparable example to the European evidence appears to
113 derive from nearby Holderness: in 1903 an antler harpoon was found at Atwick, East
114 Yorkshire and in 1932 further investigations were carried at the nearby site at Skipsea by
115 Godwin and Godwin (1933, 39) who found ‘fragments of *Pinus* bark, fins of pike (*Esox*
116 *lucius*) and flint artifacts’.

117

118 In the later part of the British Mesolithic evidence for fishing freshwater species exists but
119 these specimens are not found alongside barbed points: for example a single precaudal
120 vertebrae of a pike was found at Bouldnor Cliff on the Isle of Wight (Momber *et al.* 2011, 52)
121 and from the Severn Estuary Mesolithic sites a total of 513 identifiable fragments of fish
122 were found including Salmonidae (salmon family), eel and a possible cyprinid (Cyprinidae
123 sp.) as well as coastal species (Bell 2007, 166-168).

124

125 The reason for the lack of fish remains at Star Carr has therefore remained a mystery that has
126 intrigued scholars and members of the public alike. A possible explanation for the absence of
127 fish remains at Star Carr could be that Clark did not sieve the sediments, meaning that small
128 specimens may have been missed. Sieving was not a common practice at the time; peat is
129 extremely difficult to sieve because it is highly organic and does not easily pass through a
130 sieve and therefore it is perhaps unsurprising that this was not attempted.

131

132 Renewed research since 2004 (Conneller *et al.* 2012; Milner *et al.* 2013) has provided further
133 opportunities to test for the presence of fish remains at the site. Initially, it was considered
134 highly unlikely that any fish remains would be found, even with sieving, due to the extremely
135 acidic sediments that have formed over the last couple of decades (Boreham *et al.* 2011; High

136 *et al.* 2015). Some bone and antler has become ‘jellybone’: the mineral has dissolved in the
137 acidic peat and the collagen has turned to gelatin (Milner *et al.* 2011a). Furthermore,
138 quantities of bone and antler are extremely low when compared to Clark’s faunal collection,
139 suggesting that much of this material has completely disappeared (Milner *et al.* 2011a).

140

141 During the last four years, three different lines of evidence have at last provided definitive
142 evidence that not only a range of fish species were present in the lake, but that they were
143 caught and processed by humans. Significantly, these lines of evidence came from
144 completely different scales of analyses:

- 145 1. landscape scale: coring the lake sediments for environmental and climate records
- 146 2. site scale: excavations at Star Carr and at Flixton Island Site 2
- 147 3. microscopic scale: microwear traces on flint tools from Star Carr

148

149 **1.1. Background to the sites**

150 Star Carr and Flixton Island Site 2 are two of a number of Early Mesolithic sites that have
151 been recorded in the area around the palaeo-Lake Flixton, in the eastern Vale of Pickering,
152 North Yorkshire, UK (Figure 3). The palaeo-lake formed at the start of the Windermere
153 Interstadial (c. 14,700-12,800 cal BP; 12,700-10,800 cal BC), a warm phase at the end of the
154 last Ice Age before the final cold period of the Younger Dryas (12,700-11,600 cal BP;
155 10,700-9600 cal BC), and it persisted as a water body until the end of the Mesolithic (c. 6000
156 cal BP; 4000 cal BC).

157

158 John Moore, a local amateur archaeologist first carried out investigations in the area in the
159 late 1940s and identified 10 sites around the lake. Moore excavated a trench at Star Carr in
160 1948, and from 1949-1951 Grahame Clark from the University of Cambridge conducted
161 three further seasons of fieldwork (Clark 1954). Moore also conducted fieldwork at Site 2 on
162 Flixton Island which was published as a three-page summary at the end of the Star Carr
163 monograph (Clark 1954).

164

165 Further work in the area has been carried out by the Vale of Pickering Research Trust since
166 the 1980s, with the aim of mapping the extent of the lake and identifying further sites (for a
167 full account see Milner *et al.* (2011b)). Since 2004, NM, CC and BT have been co-directing
168 excavations at Star Carr and in 2012 the POSTGLACIAL project commenced: this is a five
169 year, European Research Council funded project with the aim ‘To implement an

170 interdisciplinary, high-resolution approach to understanding hunter-gatherer lifeways within
171 the context of climate and environment change during the early part of the post-glacial period
172 (c. 10,000-8000 BC)'. In order to address this aim, further excavations have been carried out
173 at Flixton Island Site 2 (2012-14) and Star Carr (2013-2015), in conjunction with a
174 programme of coring lake sediments in order to reconstruct local climate and environmental
175 change.

176

177 *Figure 3: The locations of Star Carr and Flixton Island Site 2 as well as all other known Mesolithic sites within*
178 *the Lake Flixton basin (lake area a reconstruction of the water at its maximum during the Holocene). Key: 1,*
179 *Star Carr; 2, Ling Lane; 3, Seamer Carr Site F; 4, Seamer Carr Sites L and N; 5, Seamer Carr Site K; 6,*
180 *Seamer Carr Site D; 7, Seamer Carr Site B (Rabbit Hill); 8, Seamer Carr Site C; 9, Manham Hill; 10–12,*
181 *Cayton Carr; 13, Lingholme Site B; 14, Killerby Carr; 15, Lingholme Site A; 16, Barry's Island; 17, Flixton*
182 *School Field; 18, Flixton School House Farm; 19, Woodhouse Farm; 20, VP Site E; 21, VP Site D; 22, Flixton*
183 *Site 9; 23, Flixton Island Site 1; 24, Flixton Island Site 2; 25, No Name Hill.*

184

185 **2.0. Methodology**

186 **2.1. Sediment coring**

187 Between 2010-2013, alongside the lake-edge excavations, a sediment core-based
188 palaeoenvironmental study was undertaken as part of the POSTGLACIAL project. The
189 preliminary results of this research were reported by Palmer *et al.* (2015). During coring, a
190 single fish scale was identified toward the base of sediment core C (Palmer *et al.* 2015).

191

192 **2.2. Excavations at Flixton Island Site 2**

193 In 2012, excavations were carried out at Flixton Island Site 2, approximately 500 metres east
194 of Star Carr. A programme of sieving the archaeological sediments was carried out and a
195 50% sample was sieved using a 4 mm mesh in order to retrieve small pieces of bone or flint
196 debitage, which otherwise would have been missed through trowelling. As the focus was on
197 the lakeshore deposits, where fewer archaeological remains are generally found, a very small
198 proportion of finds were retrieved in the sieve. However, a fish vertebra was discovered in
199 the sieve from context 1003 (Mesolithic reed peat).

200

201 **2.3. Excavations at Star Carr and the flotation of the dryland deposits**

202 During the excavations in 2008 at Star Carr, the remains of a structure were discovered on the
203 dryland, which has become known as the 'Earliest house in Britain' (Conneller *et al.* 2012).
204 The structure was composed of a hollow in the ground, infilled with organic rich sediment,

205 and surrounded by postholes. It should be noted, that although significant quantities of
206 mammal bone have been found on the dry land deposits, and in the structure itself, the
207 preservation of the bone is generally extremely poor and most remains are unidentifiable
208 either in terms of genus/species or in many cases element.

209

210 Sediment was sampled from the structure and processed in the laboratory using the bucket
211 flotation method. Volumes ranged from 1.5 to 2.5 litres. A 300 μ sieve was used to collect the
212 flot and a 1 mm sieve was used to catch the residue. Samples were dried in a drying cabinet
213 for approximately 12 hours at 40°C. The flot was examined primarily for plant remains and
214 the residue for other biological remains. The content of each sieve was examined a small
215 fraction at a time under a stereomicroscope. Plant remains and any other biological remains
216 retrieved were extracted using tweezers and stored in a sealed glass tube, clearly labelled with
217 the site code and sample number in preparation for identification. A total of 11 fish remains
218 were recovered from grid square I3, context 149, by ET, and analysed by HR using the
219 modern reference collection housed at the University of York.

220

221 More recently, in 2015, excavations were carried out in the vicinity of Clark's trenches
222 including a small area of unexcavated baulk and here two fish remains were recovered by
223 hand during the careful excavation of context 312 (Mesolithic reed peat).

224

225 **2.4. Microwear analysis**

226 Microwear analysis is the study of traces that are visible on a tool and which develop through
227 the course of the tool's use. Traces can vary depending on the contact material that is worked
228 and the direction in which the tool is used. (Vaughan 1985). This is determined by comparing
229 archaeological traces with those on experimentally used tools. It is this comparison that
230 allows an analyst to make an informed inference about the function of artefacts (van Gijn and
231 Little in press).

232

233 Identifying fish within prehistoric assemblages is recognised as difficult due to their
234 vulnerability of the traces and a frequent lack of distinction from other animal processing
235 activities (van Gijn 1986, 23). However, experimental work replicating different aspects of
236 fish processing, such as filleting, gutting and scaling (see García Díaz and Clemente Conte
237 2011; van Gijn 1986) has enabled similar traces to be identified on archaeological lithic
238 assemblages (Clemente *et al.* 2010; Högberg 2009). Recent research has even identified fish

239 microwear traces on Neanderthal stone tools (Hardy and Moncel 2011), showing that fish
 240 processing tools have great antiquity.

241

242 **3.0. Results**

243 **3.1. Sediment coring**

244 The scale recovered from the sediment core had a characteristic ctenoid form and was
 245 identified by DS as a scale from a perch. The scale was identified at c. 17.1 m.a.s.l around
 246 705 cm below the current ground surface. The deposits in which it lay are carbonate-rich lake
 247 sediments (Palmer *et al.*'s lithofacies 2a), associated with the Windermere interstadial
 248 (equivalent to the European Bølling/Allerød chronozone and dating between c. 14,700-
 249 12,800 cal BP, or 12,700-10,800 cal BC). The scale sat within the earliest sediments of this
 250 interval and reflects the presence of fish within the lake soon after the commencement of
 251 climatic warming. Fish scales of Lateglacial age are relatively uncommon finds within
 252 sediment cores in the UK, being first reported for Esthwaite Water in the English Lake
 253 District by Pennington and Frost (1961), and this chance find was not repeated in any other
 254 samples.

255

256 **3.2. Flixton Island Site 2 and Star Carr ichthyoarchaeological results**

257 A total of 14 fish remains have been recovered from Flixton Island Site 2 and Star Carr
 258 (Table 1). Two of the remains were vertebral fragments that could not be determined to
 259 species. The following provides a brief summary of these data.

260

Taxon/skeletal element	<i>Esox lucius</i>	<i>Esox lucius</i> / Salmonidae	Cyprinidae	<i>Perca fluviatilis</i>	Unidentifiable	Totals
<i>Lake Flixton</i>						
Ctenoid scale				1		1
<i>Flixton Island Site 2</i>						
Caudal vertebra	1					1
<i>Star Carr</i>						
Caudal vertebra			2			2
Posterior abdominal vertebra	1					1
Pharyngeal tooth			2			2
Premaxilla	1					1
Rib			1			1
Tooth		3				3
Vertebral fragment				1	2	3
Totals	3	3	5	2	2	15

261 *Table 1: Represented skeletal elements of the various taxa found during the excavations and in the post*
262 *excavation processing of bulk samples from Flixton Island Site 2 and Star Carr and also the ctenoid scale from*
263 *the sediment core.*

264

265 Although neural and haemal spines were absent, the bone recovered from Flixton Island Site
266 2 was a caudal vertebra which was identified by HR and AKGJ as pike (Figure 4). The total
267 length (hereafter TL) of the pike was estimated as a function of bone size according to the
268 methods as set out by Morales and Rosenlund (1979) utilizing the regression equations as
269 stated by Zabilska (2013). The size of the vertebra, 12.1 mm across the greatest medio-lateral
270 breadth of the centrum, corresponded to that of an individual approximately 815 mm in TL.
271 Since adult pike normally range from 400 to 1000 mm in TL (Davies *et al.* 2004), this falls
272 well within that range.

273

274 The vertebra was sent to Oxford Radiocarbon laboratory for direct AMS radiocarbon dating
275 but unfortunately failed to produce a date due to a lack of collagen. However, a sample of
276 willow (*Salix* sp.) from the same level was successfully dated to 9170-8570 cal BC (95.4%
277 probability: OxA-X-2495-12, 9480 ± 90 BP). This date is contemporary with the dates
278 yielded for Star Carr.

279

280 *Figure 4: SEM image of the pike caudal vertebra from Flixton Island Site 2.*

281

282 All of the fish remains recovered from the bucket flotation method were less than 1 cm in
283 size, and all but one was calcined. It is likely that the one that was not visibly calcined had
284 been subjected to some burning in order for it to have survived in this dryland context.

285

286 Although largely incomplete, a premaxilla that could not be sided was identified as that of
287 pike. This specimen was calcined and was dark grey, almost black, in colour. Comparison
288 with modern specimens suggested that it derived from an individual that was less than 200
289 mm in TL.

290

291 Three isolated teeth were identified as likely to derive from Salmonidae: however, it must be
292 noted that salmon and pike have very similar teeth and there is the possibility that these also
293 belonged to pike. If they are Salmonidae there is a possibility that these remains could have
294 belonged to either the anadromous brown trout (*Salmo trutta* L., 1758) or Atlantic salmon

295 (*Salmo salar* L., 1758). All specimens were calcined, ranging from light grey almost white to
296 dark grey in colour.

297

298 A fragile, isolated pharyngeal tooth was identified as deriving from Cyprinidae (carp and
299 minnow family). It was not possible to identify the specimen to species level. The specimen
300 was calcined and was dark grey in colour. Although neural and haemal spines were absent,
301 two caudal vertebrae were identified as Cyprinidae. The specimens were calcined and were
302 light grey, almost white and white in colour respectively. It was not possible to estimate the
303 TLs, although they derived from an individual that was less than 200 mm in TL by
304 comparison with modern specimens. In addition, one rib was identified as Cyprinidae. The
305 specimen was incomplete, as only the proximal end was present.

306

307 In addition, one vertebra was identified as that of perch. The specimen was incomplete, as
308 only half of the vertebral centrum was present. It was calcined, and was light to dark grey,
309 almost black in colour. It was not possible to estimate the TL, although it derived from an
310 individual that was less than 100 mm in TL based on comparison with modern taxa.

311

312 In 2015, excavations at Star Carr yielded a further two fish remains. Although fragile, the
313 first specimen, an isolated tooth with a portion of the pharyngeal bone was identified by HR
314 as deriving from Cyprinidae. It was not possible to identify the specimen to the lower species
315 level or estimate the TL. The second bone, a posterior abdominal vertebra (Figure 5) was
316 identified by HR as pike. The TL of this specimen was estimated according to the criteria
317 outlined above (Morales and Rosenlund 1979; Zabilska 2013). The size of the vertebra, 11.4
318 mm across the greatest medio-lateral breadth of the centrum, corresponded to that of an
319 individual approximately 873 mm in TL.

320

321 **3.3. Evidence that fish had been processed at Star Carr from microwear analysis**

322 The current programme of microwear analysis of flint tools from Star Carr is the first since
323 Dumont's studies (Dumont 1983, 1988). Microwear analysis of the flint in and around the
324 structure has only just begun. Two flints with fish processing polish have already been
325 identified a short distance from the structure (Figure 6). Neither of the tools (92184 and
326 91949) are retouched. One (92184) is classified typologically as a fragment; the other
327 (91949) is a proximal blade fragment. The fish processing polish are presented in Figure 7.

328

329 The two tools from Star Carr were taken to the Laboratory for Artefact Studies at Leiden
330 University to be blind tested by three experienced microwear analysts. None of the analysts
331 knew the original identification was fish processing. After independently analysing tool
332 91949, two analysts identified the wear traces as resulting from fish processing; the other said
333 'possibly fish processing'. The test was repeated for tool 92184, with two analysts identifying
334 fish processing and the third saying the polish was 'indeterminate'. When presented with the
335 conclusions from the other two analysts, this third analyst accepted that fish processing was a
336 strong possibility.

337

338 *Figure 5: Photograph of the pike vertebra in situ.*

339

340 Fish processing traces consist of randomly distributed lines of matt, dull polish often
341 described as having a corrugated appearance (Figure 7a) sometimes located away from the
342 edge (van Gijn 1986). Edge damage in the form of small flake scalar scars, which form a
343 repeated but irregular appear along the edge of the flint, are visible on some tools (van Gijn
344 1986; Högberg 2009). Lately, analysts have observed another feature to fish polish: areas
345 where fish scales adhering to the surface of the tool have prevented polish forming, resulting
346 in rounded, scalar areas of unpolished surface (García Díaz 2014, 98; see also Figure 7c).

347

348 Although not located within the structure, the fish processing tools were located a short
349 distance from it and are from the same context as the calcined fish remains from within the
350 structure. Due to taphonomic processes such as bioturbation and the palimpsests of activity
351 on the dryland, we cannot be sure that the tools and fish remains are contemporary. Future
352 microwear analysis of the flint assemblage from within the structure will determine whether a
353 contextual relationship exists between the remains and tools. As this analysis is ongoing it
354 also remains to be seen if future microscopic studies of the flint assemblages from other areas
355 of the site will reveal similar evidence for fish processing tools.

356

357 *Figure 6: Structure at Star Carr showing the distribution of finds. Key: triangle, location of fish remains within
358 the structure; stars, lithics exhibiting fish processing traces.*

359

360 *Figure 7: Flint 92184 (above) and 91949 (below), both of which display fish processing polish. All micrographs
361 20x.*

362

363 **4.0. Discussion**

364 **4.1. The earliest evidence of fish in Lake Flixton**

365 A particularly significant discovery of this research is that the evidence of perch in the lake
366 originates in the Windermere interstadial, roughly between 2000-4000 years before
367 settlement commenced at Star Carr. Native to Britain, perch are presently distributed across
368 the northern Palearctic, with the exception of the Iberian Peninsula, central Italy and the
369 Adriatic basin (Freyhof and Kottelat 2008). They occur across a diverse range of habitats,
370 including estuarine lagoons, lakes and medium-sized streams, spawning in NW Europe in
371 early spring when water temperatures reach a minimum of c. 10°C (Gillet and Dubois 2007;
372 Hokanson 1977) and the photoperiod conditions increase. As opportunistic feeders, they prey
373 on a wide range of aquatic invertebrates, with larger individuals becoming piscivorous once
374 they reach 120 mm in length (Freyhof and Kottelat 2008).

375

376 The spread of *Perca fluviatilis* across Europe after the last Ice Age has been documented
377 using molecular techniques (Nesbø *et al.* 1999). This suggests that perch found in modern
378 day western Europe dispersed along the major river systems centred around the Vistula, Elbe,
379 Rhine Rhône, Saône and Thames, with British perch originating from a southern glacial
380 refugium, probably located in France although the exact position remains unclear (Nesbø *et*
381 *al.* 1999). A similar southern French refugium has been suggested for other freshwater taxa
382 today found in Britain, such as barbel (*Barbus* sp.) (Persat and Berrebi 1990), chub
383 (*Leuciscus cephalus* L., 1758) (Durand *et al.* 1999) and brown trout (García-Marín *et al.*
384 1999), with the molecular data implying rapid northward expansion through northern
385 European riverine systems since the last Glacial Maximum in the UK. Here, it is suggested
386 that the presence of perch in Lake Flixton during the early Windermere interstadial could
387 indicate colonisation through the Derwent river system.

388

389 **4.2. The fish trophic system in Lake Flixton**

390 This research also demonstrates the presence of pike, known from a number of Early
391 Mesolithic sites in Denmark. Pike can be found throughout Asia, eastern North America and
392 the majority of Europe. In Britain, it is the largest predatory freshwater fish, and consumes
393 invertebrates, lesser fish, aquatic birds, amphibians and small mammals. Although it occurs
394 in lakes to larger ornamental ponds and from canals and slow flowing rivers to streams, it can
395 also reside in bogs as well as brackish lagoons and shallow, protected bays (Davies *et al.*
396 2004). It has a high tolerance to changes in pH and is capable of surviving in polluted waters,
397 including those with low oxygen content (Noe-Nygaard 1995). Whilst it is a solitary

398 carnivore, it is not territorial, often congregating in shoals to rest. Aided by its camouflaged
399 appearance, it hides in submerged vegetation, where it lurks near its prey. Mating takes place
400 between March and April when pike congregate and seek shallow water; it is during this time
401 when they can almost be caught by hand (Noe-Nygaard 1995). Both the presence of perch
402 and pike in Lake Flixton indicates a mature water body with an established trophic system.

403

404 Five of the fish remains have been identified to Cyprinidae. Although these specimens could
405 not be identified to the species level, other species routinely identified in contemporaneous
406 European faunal assemblages include the following: bream, white bream (*Abramis bjoerkna*
407 L., 1758), Crucian carp (*Carassius carassius* L., 1758), common carp (*Cyprinus carpio* L.,
408 1758), roach (*Rutilus rutilus* L., 1758), rudd and tench. Cyprinidae are, in general, lower
409 down in the trophic level hierarchy, compared to perch and pike, and mainly feed on benthic
410 invertebrates, including worms, molluscs and insect larvae (Maitland and Linsell 2009).

411

412 Although we cannot be 100% certain at the present that we have trout or salmon, it is
413 important to discuss them in case further discoveries prove their presence. Both are
414 anadromous species (migrate from the sea into freshwater to spawn) (Wheeler and Jones
415 2009). During their spawning runs, they can often become concentrated, albeit sometimes for
416 a short period, making them abundant and prime targets for fishing. Atlantic salmon enter
417 freshwater from the sea and migrate upstream at different times throughout the year. Whilst
418 this is largely dependent upon the flow of the river and the water temperature, they arrive at
419 the spawning grounds from November through February (Mills 1971). Here they are
420 extremely vulnerable to predation since they are in shallow waters and occupied by
421 spawning.

422

423 **4.3. Fishing and consumption**

424 Apart from the barbed points, there is no other evidence of fishing gear, such as nets, hooks,
425 or traps, found at any of the sites along the former lake edge. However, some suggestions can
426 be made as to the possible techniques that might have been used. Since pike are known to
427 congregate within the littoral zone of a lake during their spawning period in the spring, they
428 could have been more easily exploited at this time (Noe-Nygaard 1995). The pike may also
429 have been attracted to some of the food waste, such as bones, which were deposited at the
430 lake margins and from these areas it may have been possible to spear the pike using the
431 barbed points found at the site. However, it should be noted that the barbed points found in

432 the lakeshore deposits are not hafted and are therefore unlikely to have been lost during
433 fishing activities. In addition, it is possible that bows and arrows were used or blows via
434 clubs, and then collected (Aaris-Sørensen 1976).

435

436 Clark (1952, 48) recounts how Lapps spear pike from boats by targeting them when they sun
437 themselves in the upper part of the water body. The use of boats is well established at this
438 time, since people used the islands on the lake and presumably accessed them by boat. Clark
439 (1954) also found what he thought was a wooden paddle at Star Carr: this is very thin but
440 broken at both ends so difficult to estimate its full length. It has sometimes been dismissed as
441 a paddle due to its thinness, however, paddles of this shape are known to be favoured in some
442 place for navigating through reeds. Boats and paddles are also well documented for the
443 Mesolithic across Europe.

444

445 As well as spearing fish in the day, Clark describes how the Lapps also enticed fish to the
446 surface of the water at night by burning dry wood at the prow of the boat. An argument for
447 night fishing has been suggested for pine tapers found on Irish Midland waterways linked to
448 night-time fishing/eeling activities (Little 2009). At Star Carr, numerous burnt birch bark
449 rolls have been found and analysed (Figure 8). Experiments have shown that plain rolls of
450 bark burn for only a matter of minutes because the lack of oxygen in the middle of the roll
451 suffocates the fire. However, if strips of bark are positioned within the rolls the torches burn
452 for longer though tend not to survive as a burnt roll (Figure 9). Research is ongoing to
453 determine whether the birch bark rolls from Star Carr could have been used for torches.

454

455 *Figure 8: Birch bark roll with evidence of burning from Lake Flixton.*

456

457 Clark (1952, 48) further mentions that the Lapps also catch pike using dragnets between two
458 boats. Although nets have not been found at Star Carr, there are a large number of birch bark
459 rolls some of which have not been burnt, and from ethnographical analogues, it can be
460 demonstrated that they can be used as net floats (Figure 10).

461

462 *Figure 9: experimental torch made from a birch bark roll.*

463

464 *Figure 10: Picture of birch bark rolls used as net floats (from The National Museum of Finland).*

465

466 The site has yielded a tantalising glimpse of fish processing, and presumably consumption,
467 from the use-wear traces on two flint tools. What is interesting is that this has taken place
468 near to the structure where the calcined fish remains have been found. Future analysis will
469 help to determine whether there is further patterning to these processes; however, the nature
470 of the remains means that we will not be able to say how extensive fish consumption was.

471

472 Excluding the scale recovered from the sediment core, a total of 14 fish remains have been
473 recovered from two archaeological sites located within the palaeo-Lake Flixton basin: Flixton
474 Island Site 2 and Star Carr. In comparison with contemporaneous Maglemose sites in
475 southern Scandinavia the assemblage is small. However, we believe that there are several
476 reasons as to why so few have been recovered, and in particular from Star Carr: (1) Clark did
477 not sieve the sediments; (2) the increase in the acidity of the sediments since the 1950s is
478 likely to have destroyed any fish remains due to their delicate nature; (3) fish bones may have
479 been deposited on the dry land and it is highly likely that they would not have survived unless
480 burnt, as found in the structure; (4) we have previously demonstrated that ca. 5% of the site
481 has been excavated, and so the possibility exists that fish remains (and possibly associated
482 technology) may be present elsewhere on the site, possibly around the lake edge or
483 discarded in the deeper deposits further into the lake as has been noted elsewhere in southern
484 Scandinavia, such as Ringkloster (Andersen 1998).

485

486 **5.0. Conclusion**

487 This paper has yielded a number of important conclusions:

- 488 1. The evidence demonstrates that different species of fish were available in the lake
489 during the Early Mesolithic and that these were exploited by the inhabitants of Star
490 Carr. This data significantly adds to our understanding of Early Mesolithic economy
491 in Britain.
- 492 2. The research demonstrates the importance of conducting flotation on sediments from
493 dry land deposits and particularly from contexts such as structures. Although bone
494 from this part of the site is generally very poorly preserved, the fish bone has been
495 subjected to heating (in all likelihood it was thrown on a fire) which has meant that it
496 has survived normal destructive taphonomic processes.
- 497 3. The application of use-wear analysis is of great importance for Mesolithic sites where
498 faunal evidence is lacking. It holds the potential to uncover archaeological

499 information that is invisible to the naked eye, and answer economic questions that
500 would otherwise remain unanswered.

501 4. By 3D plotting all artefacts using a Total Station and mapping using GIS important
502 spatial relationships come to light that otherwise might be missed: the current
503 evidence suggests people were processing the fish outside the structure, and then
504 possibly cooking or consuming it within the structure before throwing the bones on a
505 fire.

506

507 In sum, fish and fish-processing activities would have remained a mystery for Star Carr if it
508 were not for the multi-scalar approach applied to the study of artefacts and the
509 palaeoenvironment. Thus we believe the importance of combining micro- and macro-
510 methods is critical when investigating hunter-gatherer settlement sites.

511

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522

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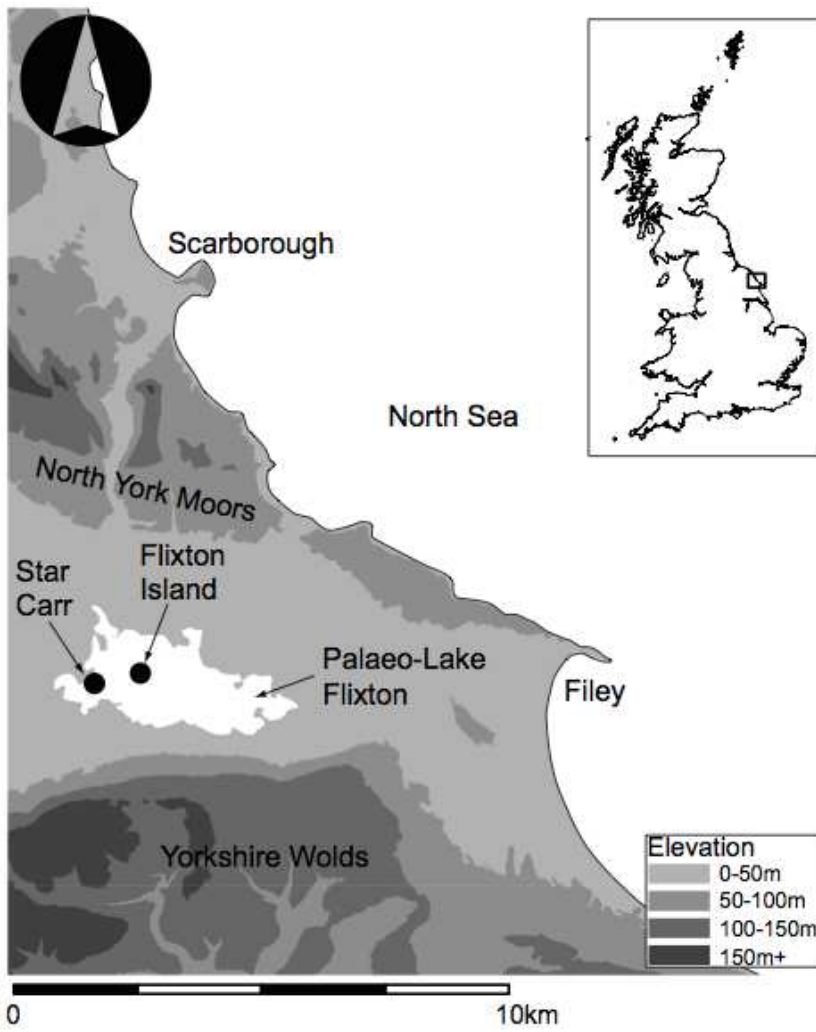
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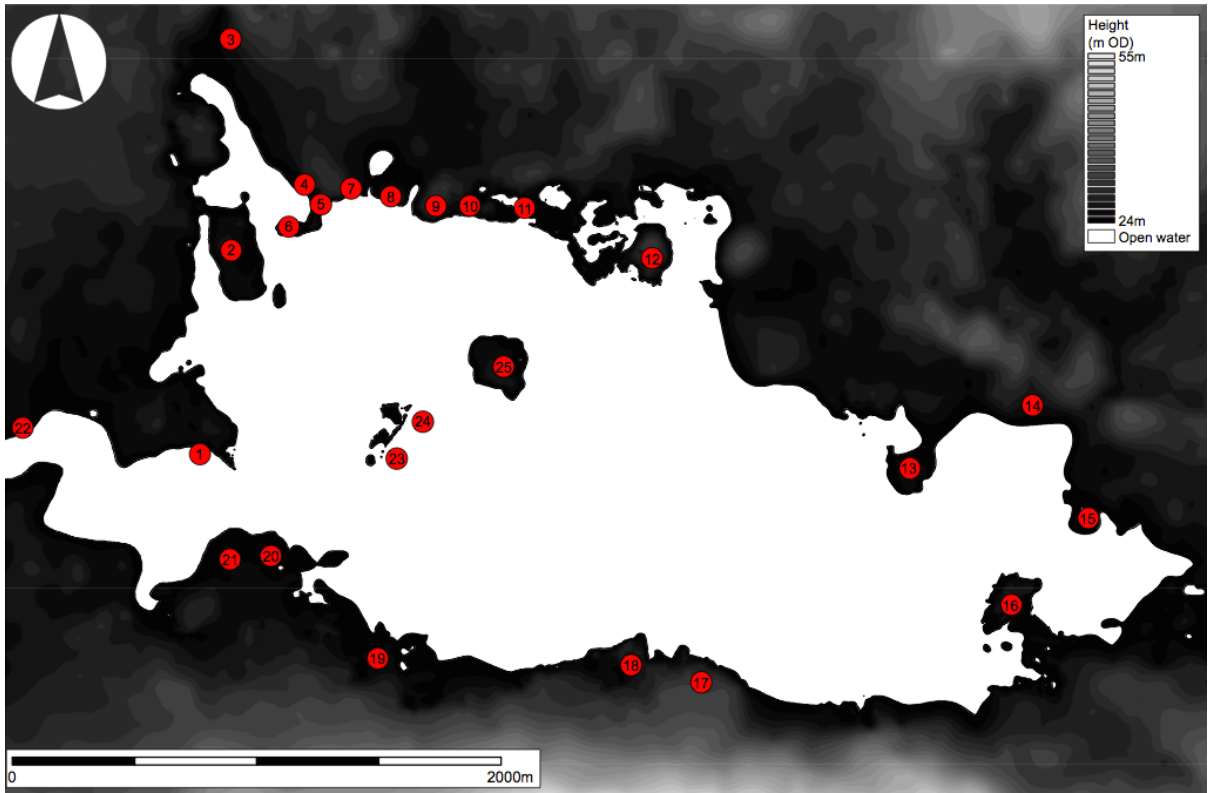
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Figure 3



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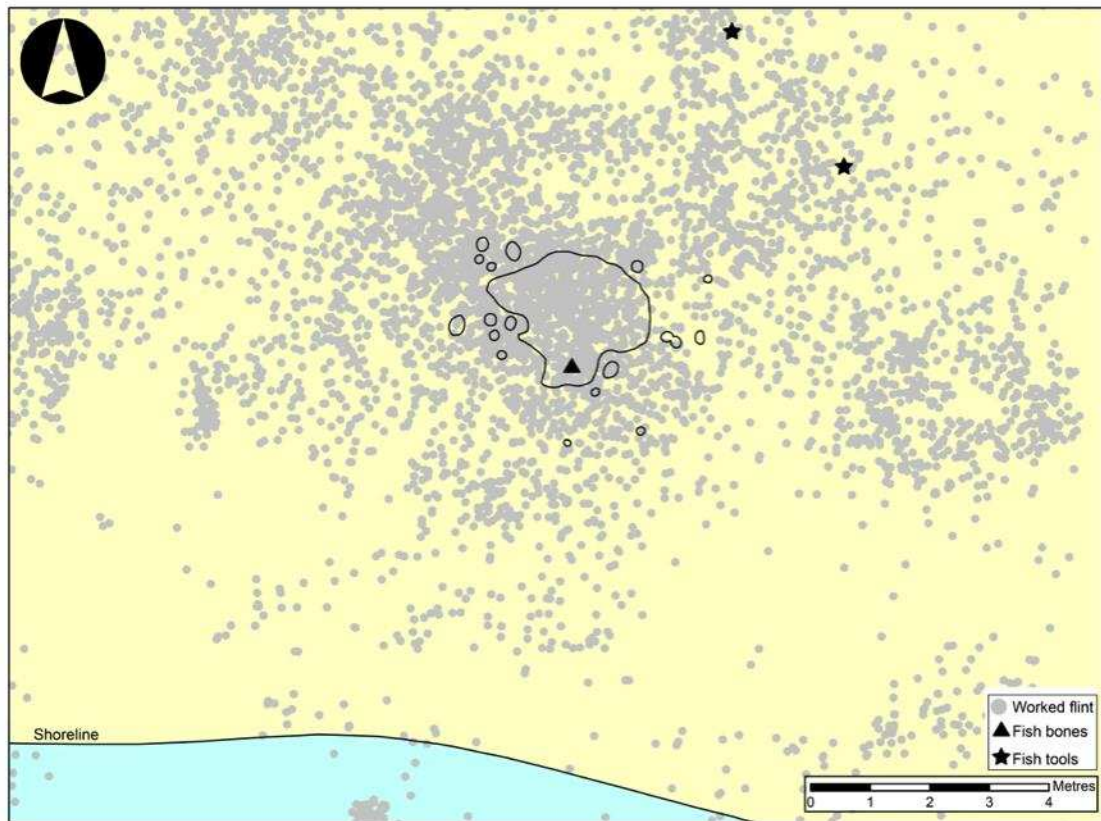
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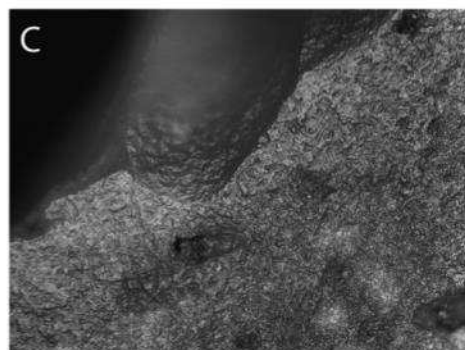
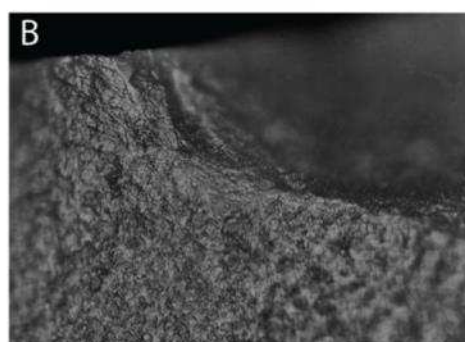
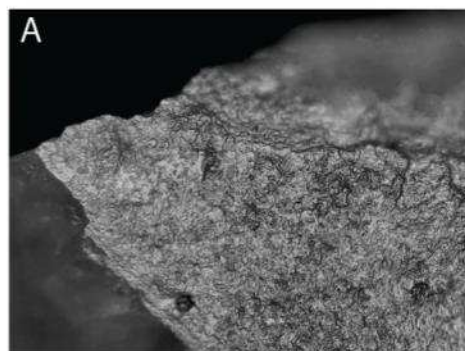
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