

The ups & Downs of Iron Age animal management on the Oxfordshire Ridgeway, south-central England: a multi-isotope approach

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1 Abstract

2

3 The hillforts of the Oxfordshire Ridgeway in south-central England have been interpreted as central
4 places in the Early/Middle Iron Age, ca. 600–100 BC, serving, among other functions, to integrate
5 the management of animals, particularly sheep, between the upland Chalk downs and the adjacent
6 low-lying Vale of the White Horse. Since these landforms differ geologically and pedologically,
7 they lead to distinct isotopic ratios in the biosphere and so present the potential to investigate
8 animal management practices in some detail. Here, we report the results of a multi-isotope study on
9 domestic fauna (cattle, sheep and pig) within a very constrained study area, with the aim of testing
10 the hypothesis that the Ridgeway's hillforts were placed to control and coordinate the movement of
11 sheep between the Chalk and the Vale. However, the results suggest a different scenario. Bone
12 collagen $\delta^{15}\text{N}$ results indicate that cattle and sheep were both kept locally. Strontium isotopes,
13 conversely, indicate that, while sheep and pigs were raised locally, cattle appear to have been
14 mainly kept in the Vale during at least the first year of their lives. The apparent discrepancy
15 between the two isotopes can be reconciled by the different periods of life represented by enamel
16 and bone collagen measurements, with the movement of cattle onto the Ridgeway in their second or
17 third year of life. Sequential measurements of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in dentine, and of $\delta^{13}\text{C}_c$ and $\delta^{18}\text{O}_c$ in
18 enamel, provide further detail on the management of cattle, and offer some support for the above
19 scenario. Early/Middle Iron Age stock-keeping in south-central England was complex, being
20 integrated in some respects but distinct in others. The study demonstrates the level of detail it is
21 possible to achieve with a multi-isotope approach to animal management practices in prehistory.
22 The focus on a micro-region contrasts with, or rather complements, studies addressing larger-scale
23 movement of animals in prehistory.

24

25 **Keywords:** stable isotopes; carbon, nitrogen; oxygen; strontium; sequential sampling; animal
26 mobility

27

28

29 **Introduction**

30

31 As in any mixed farming system, the management of animals doubtless played an important part in
32 the Iron Age societies of southern Britain. Economically, they furnished meat, milk and wool, and
33 served as draught animals for transport and tillage. Intersecting with their economic uses, they were
34 also important socially, politically and ritually (Green 2002; Parker Pearson 1996). It is relatively
35 straightforward to determine the proportional representation of the major economic species –
36 sheep/goat, cattle and pig – and their respective kill-off patterns, e.g., whether animals were killed
37 upon reaching their maximum weight, or were retained longer for their secondary products. While
38 this can provide insights into how and why animals were managed, it does not allow the detailed
39 investigation of how individual animals were actually kept, how they were moved around the
40 landscape, and how various nearby communities integrated their animal management practices.
41 Isotopic approaches can offer new insights into just these aspects.

42

43 Hillforts are one of the most prominent sites types in the British Iron Age, both in terms of their
44 physical presence on the landscape (Lock and Ralston 2017), and in the amount of research
45 attention they have received. One long-standing and pervasive interpretation has been that they
46 served as central places, as foci for a range of political, economic and ritual activities (Cunliffe
47 1984; 2001; Harding 2012; though this view has not gone uncontested, not least because the
48 category of ‘hillfort’ itself is problematic – see Hill 1996). The size and density of occupation at
49 Danebury, for example, would seem to necessitate provisioning from the surrounding communities
50 (Cunliffe 1984). Recent studies have attempted to investigate these connections more specifically
51 for domestic fauna (Stevens et al. 2010; 2013) and cereals (Lightfoot and Stevens 2012). Once
52 elucidated, the nature of the economic relationships between hillforts and contemporary farmsteads
53 would have clear implications for discussions of political power, subordination and control. At
54 present, however, the matter is far from settled.

55

56 As with hillforts more generally, those of the Oxfordshire Ridgeway in south-central England have
57 been interpreted in various ways. Segsbury, for example, has been seen as a central place, serving,
58 among other functions, to integrate the management of animals, particularly sheep, between the
59 upland Chalk downs and the adjacent low-lying Vale of the White Horse (Lock et al. 2005).
60 Alfred’s Castle, in contrast, seems to be a more self-sufficient community with a mixed farming
61 economy, though again with a special focus on sheep, while, in the neighbouring Vale of the
62 White Horse, Watchfield shows an emphasis on cattle. This area therefore forms an ideal micro-
63 region to test the hypothesis that Segsbury served as a central place to which sheep were brought,

64 and, more generally, to investigate variability in animal management practices (Figure 1). Firstly,
65 there has been an intensive programme of investigation on both the Ridgeway ‘hillforts’ and a
66 number of non-hillfort sites in the Vale of the White Horse, complemented by rescue excavations in
67 advance of development (Birbeck 2001; Gosden and Lock 2014; Heawood 2004; Kamash et al.
68 2010; Lock et al. 2005). All have yielded abundant remains of domestic fauna in a good state of
69 preservation. Secondly, the study area straddles a geological boundary (Norton et al. 2004),
70 facilitating the use of strontium isotope ratios in the identification of animals raised on the Chalk
71 uplands (the Berkshire Downs) vs. those raised in the lowlands (the Vale of the White Horse). In
72 addition, the Chalk grasslands appear to be depleted in ^{15}N (Hamilton 2016; Stevens et al. 2010;
73 2013), meaning that another isotope system is available to help distinguish animals kept on the
74 Chalk and in the Vale.

75

76 Here, we use a multi-isotope approach – combining stable carbon and nitrogen isotope analyses on
77 bone and dentine collagen together with carbon, oxygen and strontium isotope analyses on tooth
78 enamel – to test the hypothesis that some Early/Middle Iron Age (ca. 600–100 BC) hillforts served
79 as central places, to which were brought animals, especially sheep, from both upland and lowland
80 pastures. We compare isotopic results on cattle, sheep and pigs from two Ridgeway hillforts with
81 two unenclosed sites in the adjacent Vale. While a number of studies have used stable isotopes to
82 investigate animal management, this has usually been in the context of long-distance mobility
83 (Minniti et al. 2014; Towers et al. 2010; 2011; Viner et al. 2010). By focussing on a micro-region
84 (ca. 25 by 20km), we are able to address the kinds of animal management practices that would have
85 occurred on a daily and seasonal basis, forming an integral part of the mixed farming economy in
86 the Iron Age of south-central England (cf. Stevens et al. 2013).

87

88

89 Figure 1. Map of the study area showing study sites and plant sample locations.

90

91 *Isotopic analyses*

92

93 Stable carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotopes are now routinely used in archaeological studies
94 of past human and animal diets (Lee-Thorp 2008). Measurements on bulk bone collagen inform on
95 an average of foods consumed over months to years, depending on the species and the age of the
96 animal. Bone growth is rapid in very young animals, so that measurements will primarily reflect
97 averaged diet over the order of several months, while with older animals, a longer-term average of
98 some years will be represented, particularly in cortical bone (cf. Pearce et al. 2007). Sequential

99 sampling of tooth dentine provides much higher resolution than bone collagen, relating to the period
100 of root growth of the tooth in question (Mainland et al. 2016; Makarewicz 2014). Since primary
101 dentine does not remodel, the analysis of molars in adult animals will reflect their early diet. In a C₃
102 terrestrial ecosystem such as that of Britain, variation in ¹³C will be limited, but can nevertheless be
103 informative. Plants – and hence the herbivores consuming them – can vary in their δ¹³C values
104 according to species, the part of the plant ingested, season and location (Takahashi and Miyajima
105 2008; Tieszen 1991). The latter in particular may be relevant even within very small regions, such
106 as that being investigated here, since light levels have been shown to have a significant effect, with
107 lower values seen in more shaded areas (Berry et al. 1997; Bonafini et al. 2013; van der Merwe and
108 Medina 1991). Stable carbon isotopes can be measured both in collagen, where it is biased towards
109 dietary protein, and in the mineral carbonate fraction of bone or enamel, where it reflects whole diet
110 (Ambrose and Norr 1993).

111

112 Stable nitrogen isotopes in archaeology are used primarily to infer trophic level (Hedges and
113 Reynard 2007). Since the main species of interest in this paper are herbivores (cattle and sheep), it
114 is necessary to consider other factors potentially impacting on ¹⁵N levels in plants within a small
115 micro-region. This would also rule out, for example, aridity effects that could be relevant in a much
116 broader comparative study (Amundson et al. 2003). This leaves two main factors. The first relates
117 to different levels of bacterial activity between the thin soils of the Downs, derived predominantly
118 from the immediately underlying chalk bedrock, and those of the Vale, which are much heavier
119 colluvial and alluvial soils with higher clay content. The second potentially relevant factor relates to
120 the anthropogenic modification of soils, both through the intentional manuring of arable fields (with
121 stock grazing on the stubble or being fed crop waste), and indirectly through higher stocking rates
122 on the best pastures. Both of these practices can lead to quite substantial levels of ¹⁵N-enrichment in
123 plants, and hence in the animals consuming those plants (Bogaard et al. 2007; 2013; Fraser et al.
124 2011; Handley and Raven 1992; Robinson 2001).

125

126 Stable oxygen isotopes (δ¹⁸O) record sources of ingested water, with the relative contributions of
127 drinking water and food varying with the physiology of the animal (Bowen et al. 2005; Sponheimer
128 and Lee-Thorp 1999). While the distances involved in the study area are not great, δ¹⁸O values for
129 drinking water sources may nonetheless differ between the Ridgeway and Vale, particularly given
130 the scarcity of surface water on the Downs (Levick 2015, 51-53). The combined sequential analysis
131 of δ¹⁸O and δ¹³C in enamel can track seasonal variation in the sources of water and food (Balasse et
132 al. 2002; 2009; 2012; Towers et al. 2011).

133

134 Strontium isotope analysis is being increasingly used to investigate the mobility of both humans and
135 animals in prehistory (Bentley et al. 2003; Chenery et al. 2010; Minniti et al. 2014; Stevens et al.
136 2013; Towers et al. 2010; 2011; Viner et al. 2010). Briefly (for more detailed overviews see Bentley
137 2006; Montgomery 2010), ^{87}Sr is a radiogenic decay product of ^{87}Rb , and so will become more
138 abundant the older the rock, assuming the same starting concentration of rubidium. Measurements
139 are made of the ratio of ^{87}Sr and ^{86}Sr , with geologically recent values ranging around 0.707-0.709
140 for most calcareous formations, while older rock typically has values >0.710 . Recent volcanic rock
141 will exhibit even lower $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, but does not feature in the study area. The Chalk is a very
142 homogeneous calcareous formation dating to the Cretaceous, and has highly constrained $^{87}\text{Sr}/^{86}\text{Sr}$
143 ratios of ca. 0.708, reflecting those of the ocean of that time (McArthur et al. 1993). The Vale is
144 considerably more varied geologically, with a greater contribution of more radiogenic Greensands
145 and Gault Clays (Norton et al. 2004), such that the two geologies are isotopically distinct (Evans et
146 al. 2010, fig. 1b). The preferred skeletal tissue for $^{87}\text{Sr}/^{86}\text{Sr}$ analysis is dental enamel, to minimise
147 issues of contamination from the burial environment (Hoppe et al. 2003; Sealy et al. 1991).
148 Moreover, because of the incremental deposition of enamel during growth, there is the possibility of
149 tracking animal movements between lowlands and uplands in considerable detail (Balasse et al.
150 2002; Bentley and Knipper 2005).

151

152 *The sites*

153

154 Segsbury is a large hillfort of 11 ha, adjoining the Ridgeway near the edge of the chalk Downs and
155 overlooking the Vale. Excavation places the site within the Early (7th – 4th c. BC) and Middle Iron
156 Age (4th – 2nd c. BC) and suggests that it was not permanently or densely occupied but was, perhaps,
157 a communal meeting place for the surrounding population (Lock et al. 2005). The primarily EIA
158 faunal remains derive largely from a series of internal pits, dated mainly by pottery associations.
159 Sheep dominate the faunal assemblage, including lambs but no neonates, while there is evidence for
160 on-site cattle breeding (Mulville and Powell 2005) (Table S1; Figure 2).

161

162 Alfred's Castle is a small 'hillfort' of 1.2 ha, located some 5km south of the north edge of the
163 Downs, and not in a locally elevated position. A series of radiocarbon dates place the site in the
164 MIA (4th – 3rd c. BC), though the pottery assemblage suggests the possibility of an earlier Iron Age
165 presence. Excavation has shown that it was fairly densely occupied, with the usual range of
166 domestic activities represented, especially those associated with sheep, together with evidence for
167 ritual deposition (Gosden and Lock 2013). The presence of neonatal animals of all three main
168 domestic species suggests they were reared on or near the site (Lange 2013). Evidence for

169 metalworking together with the substantial enclosing earthwork suggests that this was a high status
170 settlement.

171

172 Watchfield is one of a number of unenclosed Iron Age settlements in the Vale (Birbeck 2001;
173 Heawood 2004). Part of an excavated field system featured a complex funnel-type entrance that
174 must relate to the management of large numbers of animals (Birbeck 2001, fig. 3; Lambrick and
175 Robinson 2009, 386), presumably cattle as these dominated the faunal assemblage to an unusual
176 degree (Figure 2). The Early and Middle Iron Age faunal remains were recovered from a series of
177 pits and ditches, dated primarily through pottery associations.

178

179 Marcham is an unusual site and probably not a ‘normal’ settlement but rather consisted of a series
180 of pit groups and circular enclosures defined by banks and ditches, possibly demarcating a ritual
181 space. The animal bone analysed here derived from a series of MIA pits, again dated mainly by
182 pottery. The site became the focus of more overtly ritual activity in the Romano-British period, with
183 the construction of a temple complex including an amphitheatre (Kamash et al. 2010).

184

185

186 Figure 2. Bar chart of the three main domestic species at the Ridgeway (Segsbury and Alfred’s
187 Castle) and the Vale (Marcham and Watchfield) sites (sources: Birbeck 2001; Lange 2013; Mulville
188 and Powell 2005; P. Levick pers. comm.).

189

190

191 **Materials and Methods**

192

193 *Materials*

194

195 Samples of dental enamel of sheep, cattle and pig were taken for strontium isotope analysis from
196 the Ridgeway ‘hillforts’ of Alfred’s Castle and Segsbury Camp, and from the unenclosed Vale sites
197 of Marcham and Watchfield (Figure 1). It is possible that some goats were included in the analysis,
198 but since very few of their remains were positively identified in any of the sites we assume that
199 most if not all were sheep. The comparison between the three species addresses the question of
200 whether or not their patterns of movement are similar. One might expect, for example, that pigs
201 would tend to be more local to the immediate area, as they are more difficult to drive (Grigson
202 1982; though see Madgwick et al. 2012). The contexts sampled date to the Early and Middle Iron
203 Age (600–300 BC), though some Late Iron Age material may also be included. We selected 61

204 archaeological tooth enamel samples from 55 distinct individuals for $^{87}\text{Sr}/^{86}\text{Sr}$ analysis, comprising
205 21 sheep, 26 cattle and 14 pig teeth from Segsbury Camp and Alfred's Castle on the Ridgeway, and
206 Marcham and Watchfield in the Vale (Birbeck 2001; Gosden and Lock 2013; Heawood 2004; Lock
207 et al. 2005). Adhering sediments were sampled for $^{87}\text{Sr}/^{86}\text{Sr}$ analysis from five teeth, two from the
208 Ridgeway and three from the Vale.

209
210 Twenty-nine plant samples were taken from 11 Ridgeway and Vale locations, targeting the various
211 geologies represented (Figure S1). Two or three plant samples were collected from each location,
212 with one being grass and the others either hazel, hawthorn and/or oak. These represent different
213 rooting depths, and hence potentially tap into different water sources, which can in turn influence
214 strontium isotope ratios (Reynolds et al. 2012). Locations were recorded by GPS.

215
216 Fifty-one mandibular or maxillary bone samples from the same individuals as selected for $^{87}\text{Sr}/^{86}\text{Sr}$
217 analysis were analysed for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ to compare Chalk and Vale values. Four cattle molars
218 from Alfred's Castle and Marcham were analysed sequentially for $\delta^{18}\text{O}_c$ and $\delta^{13}\text{C}_c$; the dentine of
219 three of the same teeth were analysed sequentially for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$.

220

221 *Bone collagen carbon and nitrogen isotope analysis*

222

223 Bone collagen samples were prepared using the modified Longin (1971) method in place in the
224 Research Laboratory for Archaeology and the History of Art, University of Oxford. Samples were
225 analysed on a SerCon Callisto CF-IRMS system, together with an alanine standard to correct for
226 machine drift, and two internal standards (cow and seal bone collagen) used to calibrate the values
227 (see Coplen et al. 2006). Reported values are the averages of duplicate measurements of standards,
228 with errors of ca. $\pm 0.2\%$ for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. In a small number of cases (three) where the
229 difference between the two runs exceeded 0.5% in either isotope, the measurements were repeated
230 in duplicate. In one case a clear outlier emerged and was removed, with the remaining three results
231 averaged. In the other two cases the final reported result is the average of all four measurements.

232

233 *Enamel carbonate oxygen and carbon isotope analysis*

234

235 Intra-tooth enamel samples were taken using a diamond-tipped dental burr, horizontally along the
236 crown in order to produce a series of samples parallel to the direction of tooth growth. Samples
237 were prepared following the methods outlined in Sponheimer and Lee-Thorp (1999).

238 Approximately 5 mg of powdered enamel was placed into a 2 ml micro-centrifuge tube, to which

239 1.8 ml of sodium hypochlorite (NaOCl) solution (1.5% v/v) was added and left for 30 minutes to
240 remove any organic matter. The samples were then rinsed three times with distilled water and
241 centrifuged to ensure that all NaOCl solution was removed. Then 1.8 ml of 0.1 M of acetic acid
242 (CH_3COOH) was added and centrifuged to remove exogenous carbonate. The samples were rinsed
243 again with distilled water and then freeze-dried.

244
245 Samples of pre-treated enamel powder weighing ca. 0.5 mg were loaded into a microCAPS
246 carbonate analysis preparation unit, directly connected to a Sercon Geo 20-22 dual-inlet gas IRMS.
247 The enamel carbonate of each sample was reacted with 100% phosphoric acid at 90°C. CO_2
248 released by the reaction was analysed by mass spectrometry along with CO_2 from a reference
249 supply. The resulting $\delta^{13}\text{C}_c$ and $\delta^{18}\text{O}_c$ ratios were calibrated against internal laboratory (mammoth
250 and wildebeest enamel) and international standards (CO-1, a Carrara marble prepared by the
251 International Atomic Energy Agency) and are reported relative to VPDB. Analytical precision
252 based on repeat measurement of standards is ca. $\pm 0.1\%$ for both isotopes.

253

254 *Strontium isotope analysis*

255

256 Plant samples for strontium isotope analysis were dried naturally and crushed in a coffee grinder.
257 To remove all organic matter, the samples were then ashed in a muffle furnace by step-heating from
258 200 to 650-700°C. A subset of 10 samples were analysed at both the University of Cape Town and
259 at the Université Libre de Bruxelles (Suppl Appendix 1).

260

261 Enamel surfaces were shotblasted and abraded with a clean diamond-tipped burr, prior to sampling
262 with another burr. Unless otherwise noted, all samples were taken vertically down the tooth, and so
263 reflect an averaged signal over the period the specific tooth formed. Four horizontal samples were
264 taken at ca. 10mm intervals from one cattle tooth to explore intra-tooth variability. Samples
265 underwent no further pre-treatment, following a comparison by Chenery et al. (2012) suggesting
266 minimal difference when using an acetic acid wash as recommended by Hoppe et al. (2003). The
267 main drawback to the acetic acid wash is the loss of approximately half the sample that this entails.

268

269 All enamel strontium isotope measurements were undertaken at the MC-ICP-MS facility in the
270 Department of Geological Sciences, University of Cape Town. After dissolution of enamel in HNO_3 ,
271 routine facility procedures for strontium separation chemistry (Pin et al., 1994) and analysis on a
272 NuPlasma HR MC-ICP-MS were followed (Copeland et al., 2008; Radloff et al., 2010). Analyses
273 are referenced to a $^{87}\text{Sr}/^{86}\text{Sr}$ value of 0.710255 for the NIST international standard SRM987. An in-

274 house carbonate standard, NM95 (0.708907 ± 23 , $n = 56$), measured alongside the samples on two
275 separate occasions returned values of 0.708907 ± 28 ($n = 5$) and 0.708909 ± 26 ($n = 7$), respectively.

276

277 *Strontium isoscape*

278

279 An updated version of the map of biosphere $^{87}\text{Sr}/^{86}\text{Sr}$ variation across Britain (Evans et al. 2010, fig.
280 1b) was generated using British Geological Survey 1:625,000 bedrock geology digital mapping
281 (DiGMapGB-625). The Evans et al. (2010) dataset was supplemented with data for plants growing
282 on key rock types relevant to the study area from Gloucester (Chenery et al. 2010) and with new
283 results from the Ridgeway (see below). Mean values and standard deviations were calculated for
284 samples corresponding to each polygon in the DiGMapGB-625 dataset. Where possible, only
285 values from plant samples were used to calculate the mean values and standard deviations for each
286 polygon. Where no plant data were available, mean values and standard deviations were calculated,
287 in order of preference, as follows: 1) other samples – using values from bone, dentine, soil and
288 water samples; 2) rock types – using values from other polygons of the same rock type, and; 3)
289 isotope packages – using values for other polygons of the same isotope package.

290

291 *Statistical analysis*

292

293 The data were assessed for departures from normality using Shapiro-Wilk tests, with parametric
294 (Student's t-tests, ANOVA) or non-parametric (Mann-Whitney, Kruskal-Wallis) statistical tests
295 applied as appropriate. All tests are two-tailed, with $\alpha = 0.05$.

296

297

298 **Results**

299

300 *Bone collagen stable carbon and nitrogen isotope results*

301

302 Bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ measurements (Tables 1, S2; Figure 3a) all met the criteria for well-
303 preserved collagen in terms of collagen yield, C:N ratios, and %C and %N (DeNiro 1985; van
304 Klinken 1999). C:N ratios were between 3.1 and 3.5 (averaging 3.3 ± 0.06), within the more
305 conservative range proposed by van Klinken (1999). Fauna from Alfred's Castle previously
306 analysed by one of the present authors (Hamilton 2013) have been included in the summary
307 statistics and discussion. Stable carbon isotope values exhibit remarkably little variation by site or
308 species, averaging $-21.6 \pm 0.4\%$ overall (Kruskal-Wallis ANOVA, $p = 0.487$, $n = 51$). Stable

309 nitrogen isotopes however, demonstrate clear differences between species ($p = 0.000$); as might be
 310 expected in an Iron Age context, it is the pigs that have higher $\delta^{15}\text{N}$ values (Hamilton et al. 2009).
 311 But this global picture glosses over distinct differences between the Ridgeway and Vale. Pigs from
 312 the Vale sites of Marcham and Watchfield do not differ from cattle and sheep in their $\delta^{15}\text{N}$ values
 313 ($p = 0.210$), while those from the Ridgeway sites do ($p = 0.000$). It is the latter, then, that are
 314 driving the significant species difference seen in the combined sample. No difference is seen in the
 315 values of pigs from the Ridgeway and Vale (Mann-Whitney U-test, $p = 0.923$).

316
 317 Cattle and ovicaprids from the Ridgeway sites are not statistically distinguishable in $\delta^{15}\text{N}$ ($p =$
 318 0.186), nor do they differ from one another in the Vale sites ($p = 0.534$). However, the combined
 319 Ridgeway herbivores are clearly depleted in ^{15}N compared to those of the Vale ($p = 0.000$) (Figure
 320 3b). This is part of a wider pattern that has been noted for the Upper Thames (Hamilton 2016;
 321 Stevens et al. 2010; 2013). It can be related to natural ^{15}N differences in the soils (Robinson 2001),
 322 but also perhaps to more intensive agricultural practices in the Vale, involving higher stocking rates,
 323 and/or foddering of animals with chaff grown on manured fields (Bogaard et al. 2007; 2013; Fraser
 324 et al. 2011). This difference in bone collagen results, which represents an averaged diet over some
 325 years (depending on the age of the animal), implies the existence of separate cattle herds and sheep
 326 flocks on the Ridgeway and in the Vale. This does not mean that no animals were moving between
 327 the two areas, but it does indicate that any such movements were limited, with most animals
 328 spending much of their time grazing in one place or the other.

329
 330
 331 Table 1. Summary faunal bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from the Ridgeway and Vale.
 332 Alfred's Castle includes data previously published by Hamilton (2013). Individual measurements
 333 are provided in Table S2.

334
 335 Figure 3a, b. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope results on faunal bone collagen from the Ridgeway (Segsbury
 336 and Alfred's Castle) and the Vale (Marcham and Watchfield).

337
 338 *Sequential dentine stable carbon and nitrogen isotope results*

339
 340 There is relatively limited variation in the sequential samples taken from three cattle second molars,
 341 two from Alfred's Castle and one from Marcham. The range of values in each tooth is less than 1‰
 342 for $\delta^{13}\text{C}$ (only 0.2‰ in the case of M09), and 0.8 to 1.1‰ for $\delta^{15}\text{N}$ (Tables 2, S3, Figure 4a-c). The
 343 only hint of covariation between the two isotopes is seen in the molar (AC08) from Alfred's Castle.

344 In two cases (AC06, M09) the bone collagen $\delta^{15}\text{N}$ values are more than three standard deviations
 345 lower than the dentine average for the same individual, while in the third case (AC08) it is one SD
 346 lower. It may not be a coincidence that this animal is the youngest of the three at 18-30 months,
 347 while the others are adult (4+ years) and 30-36 months, respectively.

348

349

350 Table 2. Summary of sequential dentine $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from Alfred's Castle and Marcham.

351 Individual measurements are provided in Table S3.

352

353 The high $\delta^{15}\text{N}$ values for second molars cannot be due to nursing. Instead, it may be that young
 354 animals of less than two years of age were preferentially kept on the richer pastures of the Vale. The
 355 bone collagen isotope results discussed above, together with other studies on Iron Age fauna from
 356 sites on the Chalk, convincingly demonstrate that soils there are significantly ^{15}N -depleted
 357 compared to the Vale. Why this pattern is seen at both Alfred's Castle and Marcham is unclear, but
 358 here we run up against the limitations of the small sample size.

359

360 Figure 4. Sequential dentine collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from: a) AC06, b) AC08, and c) M09.

361

362

363 *Sequential enamel carbonate stable oxygen and carbon isotope results*

364

365 The expected sinusoidal pattern in $\delta^{18}\text{O}_c$ values can be seen in three of the four cattle molars
 366 (Tables 3, S4, Figure 5b-d). This captures seasonal variation in drinking water, with the troughs
 367 indicative of the colder winter months, and the peaks of the summer months. The curve for the
 368 remaining molar, from Alfred's Castle (AC06), exhibits a surprisingly dampened signal, with less
 369 than half the range seen in the other teeth; specifically, it lacks the expected ^{18}O -enriched warm
 370 season values (Figure 5a). This may relate to the use of drinking water from the spring-lines at the
 371 foot of the Downs some 4km to the north of the site, which served this purpose in historic times.
 372 Indeed, many villages along the foot of the Downs are known as 'spring-line settlements' because
 373 they formed around these dependable, year-round sources of water. Because of residence time, the
 374 Chalk aquifer is thought to include a substantial contribution of Pleistocene precipitation, and so is
 375 slightly depleted in ^{18}O (Darling et al. 1997; Edmunds et al. 1987). As early as the 1930s, Sir Cyril
 376 Fox surmised that people in the Bronze Age 'tended to live at the spring-line below the Downs,
 377 driving [their] herds and flocks on to the plateaux and hill-tops for pasture; while in the [Iron] Age

378 that followed he moved his actual dwelling sites on to the uplands, using them both for arable and
 379 for pasture and driving his flocks down to the spring-line for watering' (Fox 1932, 69).

380

381 While by no means a perfect relationship, the $\delta^{18}\text{O}_c$ and $\delta^{13}\text{C}_c$ results generally covary positively
 382 (Figure 5), so that the colder months of the year are associated with lower $\delta^{13}\text{C}$ values. This is a
 383 common trend seen in other studies in mid- to high-latitude environments (Balasse et al. 2009;
 384 2012). There is a notable departure from this relationship in the lower crown of a molar from
 385 Alfred's Castle (AC08) (Figure 4b), which sees increasing $\delta^{13}\text{C}_c$ values at the same time as sharply
 386 decreasing $\delta^{18}\text{O}_c$ values, possibly reflecting winter foddering with summer hay.

387

388

389 Table 3. Summary of sequential enamel $\delta^{18}\text{O}_c$ and $\delta^{13}\text{C}_c$ results. Individual measurements are
 390 provided in Table S4.

391

392 Figure 5. Sequential enamel carbonate $\delta^{18}\text{O}_c$ and $\delta^{13}\text{C}_c$ results from Alfred's Castle and Marcham

393

394

395 *$^{87}\text{Sr}/^{86}\text{Sr}$ results*

396

397 Modern plants

398 Measurements on modern plants (grass and trees) confirm the expected difference in biologically
 399 available strontium in the Chalk and the Vale (Figure 6; Table S5). The Chalk is relatively
 400 homogeneous, with eight plant samples from three locations (Segsbury, White Horse bottom and
 401 Alfred's Castle) averaging 0.7080 ± 0.0004 ($n = 8$), consistent with the ratio expected for
 402 Cretaceous marine deposits (McArthur et al. 1993). This includes one sample (an oak from the
 403 vicinity of Alfred's Castle) with an unexpectedly high value of 0.7088, the removal of which lowers
 404 the Chalk mean to 0.7079 ± 0.0002 . The Vale shows greater heterogeneity, reflecting its more
 405 complex and varied geology, but its overall average of 0.7089 ± 0.0008 ($n = 21$) is significantly
 406 higher than that of the Chalk (Mann-Whitney U, $p = 0.002$). There are three outliers (>1.5 times the
 407 interquartile range) with higher $^{87}\text{Sr}/^{86}\text{Sr}$ values from two locations (Longcot and the road to
 408 Woolstone); one of these samples was re-analysed in a second run of samples, producing a very
 409 similar result (averaging 0.7101). Longcot is located on the West Walton, Ampthill and
 410 Kimmeridge Clay Formations, and Woolstone is on the Gault and Upper Greensand Formations
 411 (Figure S1).

412

413

414 Figure 6. Plant $^{87}\text{Sr}/^{86}\text{Sr}$ isoscape for the study area (a) with associated prediction error map (b).

415

416

417 A small number of sediment samples found adhering to specific teeth were also analysed (Table S5).

418 Calcium carbonate adhering to two *Bos* teeth (SC97, samples 2 and 5) from Segsbury Camp yielded419 $^{87}\text{Sr}/^{86}\text{Sr}$ values of 0.707854 and 0.708027, in keeping with the plant values for the Chalk. In both

420 cases the corresponding tooth enamel samples were enriched above this, 0.708468 and 0.708871,

421 respectively. Adhering sediment from three teeth at Watchfield gave a mean value of 0.709167 ± 15 ,

422 consistent with Vale plants (though no plant values were available specifically from Watchfield).

423

424

425 Table 4. Average $^{87}\text{Sr}/^{86}\text{Sr}$ values for tooth enamel and plants from Ridgeway and Vale sites.

426

427

428 Pigs

429 In traditional subsistence farming, pigs tend not to be moved over more than very short distances,

430 generally staying close to the settlement (Grigson 1982). They are therefore often seen as good

431 proxies for the local $^{87}\text{Sr}/^{86}\text{Sr}$ signal (Bentley and Knipper 2005). This is supported here, with pigs432 from the Ridgeway and Vale differing significantly (Mann-Whitney U-test, $p = 0.004$), and closely

433 matching their find locations (Tables 4, S6; Figure 7). There are no significant differences between

434 the pig enamel and plant strontium isotope results for either the Ridgeway (Mann-Whitney U, $p =$ 435 0.298) or Vale sites ($p = 0.353$). And, although the Vale as a whole is quite variable in $^{87}\text{Sr}/^{86}\text{Sr}$, it436 can be noted that the Marcham pigs (0.7087 ± 0.0005 ; $n = 3$) closely match the values of modern437 plant samples collected from the site itself (0.7085 ± 0.0004 ; $n = 4$). This does not in itself

438 necessarily mean that they were raised locally, since this isotopic range is shared with other

439 locations in the Vale.

440

441

442 Figure 7. Boxplots of $^{87}\text{Sr}/^{86}\text{Sr}$ results for Ridgeway and Vale plants and fauna (created using443 BoxPlotR, <http://shiny.chemgrid.org/boxplotr/>)

444

445 Sheep

446 What was less expected, and contrary to the hypothesis set out in the beginning of this paper, is that

447 sheep show a very similar pattern to that seen for pigs (Figure 7). That is, the $^{87}\text{Sr}/^{86}\text{Sr}$ values for

448 sheep from the Ridgeway sites are clearly distinct from those from the Vale (Mann-Whitney U-test,
449 $p = 0.001$), and do not differ significantly from the modern plant values of the Chalk ($p = 0.142$).
450 The ten Vale sheep analysed, on the other hand, are on average more radiogenic than that zone's
451 available average plant values ($p = 0.013$), but, given the geological variability of the Vale, this may
452 just be a matter of its inadequate characterisation (Figure 7). While dividing the results by
453 individual site leads to sample sizes too small to test statistically, it can be noted that the sheep
454 values from the two Ridgeway sites of Segsbury and Alfred's Castle are very similar, averaging
455 0.7084 ± 0.0005 and 0.7083 ± 0.0004 , respectively. Since the sites date primarily to the EIA and
456 MIA, respectively, this also suggests that the observed pattern persists over some centuries.

457
458 An outlying value of 0.7089 on a sheep from Alfred's Castle suggests that this animal, unlike the
459 others, did spend time grazing in the Vale when this tooth was forming. An even more extreme
460 outlier was found at Marcham, with a value of 0.7122, higher than any of the modern plant values
461 in this study. Thus, this animal must have spent time in a more radiogenic location, the closest of
462 which, using the available broad-scale Sr isoscape map for Britain, would be either to the north or
463 to the west (Evans et al. 2010). However, isotope maps at this scale can mask considerable local
464 variation (cf. Chenery et al. 2010), and it is possible that there is a closer source of enriched ^{87}Sr ,
465 hinted at by the three highest plants values (one of which was analysed twice, with close agreement
466 – see above) from the Vale in the present study, averaging 0.7106 ± 0.0005 . Nevertheless, there is
467 certainly no reason to discount such long-distance movement/exchange of animals in the Iron Age
468 (or in preceding periods for that matter: cf. Viner et al. 2010; Towers et al. 2010).

469
470 To explore variability within a single individual, vertical samples of the first, second and third
471 permanent molars were taken from the same sheep mandible from Segsbury Camp (SC97-17). The
472 results for the M1 and M3 are both considerably higher (ca. 0.7092) than is possible for the Chalk,
473 and so this animal must have spent the time during which those teeth were forming on pasture in the
474 Vale (or another area with similar Sr isotope ratios). None of the other sheep teeth from the
475 Ridgeway sites gave values this enriched in ^{87}Sr , with the next highest being 0.7089. The M2 from
476 the same individual, by contrast, yielded a lower value of 0.7082 that is consistent with plants on
477 the Chalk. Therefore, this animal at least fits the model of movements between the Ridgeway and
478 Vale, though it appears that it may be unusual in so doing.

479
480 Cattle

481 Cattle present a very different pattern. The $^{87}\text{Sr}/^{86}\text{Sr}$ measurements from the Ridgeway and Vale
482 sites do not differ, and indeed largely overlap, except for a single Vale outlier with a higher value

483 (Figure 7). Moreover, the Ridgeway cattle differ markedly from values of the Chalk plants (Mann-
484 Whitney U, $p = 0.003$), instead clearly grouping with those of the Vale ($p = 0.929$). It can also be
485 noted that cattle from the two Ridgeway sites provide very similar values, so that this pattern is not
486 being driven by the much larger Segsbury hillfort, which might be expected to be a more prominent
487 hub in the local network of animal exchange and consumption, and so to have functioned
488 differently than Alfred's Castle. Nor can any change over time be observed, i.e., the pattern persists
489 from the EIA through the MIA.

490

491 To explore intra-tooth variation, four horizontal samples were taken on a *Bos* first molar from
492 Alfred's Castle (AC-8), at approximately 1 cm intervals. The results show significant variation,
493 with the second sample being more enriched in ^{87}Sr relative to the other three (Figure 8), indicating
494 movement to different pastures during the months represented. The average of the four values is
495 0.70991 ± 0.00015 , which, as would be expected, closely matches that of 0.70981 obtained on a
496 vertically oriented sample from the same tooth.

497

498 Figure 8. $^{87}\text{Sr}/^{86}\text{Sr}$ results on four sequential samples from a first molar from Alfred's Castle, taken
499 at ca. 10mm spacing starting near the occlusal surface (AC8-1); AC08 represents a separate
500 measurement of a vertical sample from the same tooth (i.e., an averaged signal over the entire
501 crown formation time).

502

503

504 Discussion

505

506 Contrary to the expectations set out in the beginning of this paper, both the bone collagen $\delta^{15}\text{N}$ and
507 the $^{87}\text{Sr}/^{86}\text{Sr}$ results indicate the existence of distinct sheep flocks on the Ridgeway and Vale, with
508 relatively little evidence for overlap, and hence movement, between these locations. The analysis of
509 three molars in one animal, however, does suggest mobility for some individuals. It may be that
510 additional sequential strontium and stable isotope measurements will provide further evidence for
511 mobility. But if this were common, we would expect a more variable and intermediate Sr isotope
512 signal, rather than the observed clear separation in their average values. While not differing in $\delta^{15}\text{N}$,
513 the $^{87}\text{Sr}/^{86}\text{Sr}$ results for pigs also demonstrate the presence of distinct groups of animals on the
514 Ridgeway and Vale. By and large, it seems that both sheep and pigs were raised and slaughtered
515 locally.

516

517 The situation with cattle is considerably more complex. As with the sheep, the cattle bone collagen
 518 $\delta^{15}\text{N}$ results show a clear separation between the Ridgeway and the Vale, suggesting surprising little
 519 movement between the two areas. In contrast to those for the sheep and pigs, however, the
 520 strontium isotope results for the Ridgeway cattle group with the Vale plants. This indicates that
 521 most cattle spent the time during which their teeth were forming in the Vale (or in another region
 522 with similar $^{87}\text{Sr}/^{86}\text{Sr}$ values, but parsimony favours the Vale as their most probable origin). The
 523 apparent discrepancy in the scenarios presented by the two isotopes may relate to the different
 524 formation times represented by measurements on tooth carbonate and bone collagen. The former
 525 represents the restricted period during which the tooth formed, while the latter reflects a longer
 526 period, the duration of which depends on the animal's age at death. The teeth represented in the
 527 study, from deciduous premolars to permanent second molars, span *in utero* crown development to
 528 approximately the end of the first year of life in the case of M2s. The ages-at-death of the nine
 529 Ridgeway cattle analysed for strontium are more or less equally divided between juvenile (ranging
 530 1–8 months to ca. 2 years) and fully adult (4+ years) animals (Table S2). Early skeletal growth is
 531 very rapid, so that new bone formation will quickly swamp earlier isotopic signals (Hedges et al.
 532 2007).

533
 534 The interpretation suggested above receives tentative support from two sources. First, there is a hint
 535 of a positive correlation between $^{87}\text{Sr}/^{86}\text{Sr}$ and $\delta^{15}\text{N}$ values on the Ridgeway cattle ($r^2 = 0.373$, $p =$
 536 0.143 , $n = 8$), though this only becomes statistically significant with the removal of one outlier (the
 537 lowest $\delta^{15}\text{N}$ value in the dataset, of 1.7‰; $r^2 = 0.787$, $p = 0.009$, $n = 7$). This is the trend that would
 538 be expected if animals were moved from the Vale to the Ridgeway at various times in their early
 539 lives, such that those moved while their tooth crowns were still forming would present lower
 540 $^{87}\text{Sr}/^{86}\text{Sr}$ values than those moved after their crowns were fully mineralised. The two cattle with the
 541 lowest $^{87}\text{Sr}/^{86}\text{Sr}$ values of ca. 0.7080 are consistent with the Chalk, and they also provide two of the
 542 lowest $\delta^{15}\text{N}$ values. It is possible that a small number of cattle were bred on the Ridgeway, as
 543 suggested by the presence of newborn calves in the faunal assemblages at both Segsbury and
 544 Alfred's Castle. While neonatal lambs were not found at Segsbury, they were recovered from
 545 Alfred's Castle (Lange 2013; Mulville and Powell 2005), which is consistent with the $^{87}\text{Sr}/^{86}\text{Sr}$ and
 546 $\delta^{15}\text{N}$ results for the existence of distinct flocks on the Downs.

547
 548 Second, and following on from the above, there are the differences between the sequential dentine
 549 and bone collagen $\delta^{15}\text{N}$ results for the same individuals. While only based on two individuals from
 550 Alfred's Castle and one from Marcham, the dentine average is in all cases higher (by 0.4 to 1.1‰)
 551 than the bone collagen values of the same individuals, suggesting that during the period the second

552 molar roots were forming, from approximately age 6 to 24 months, these animals were all kept
553 predominantly on pastures in the Vale, relatively enriched in ^{15}N compared to those of the
554 Ridgeway.

555

556 Cattle dominate the Iron Age faunal assemblages of the Vale (Birbeck 2001; Hey 1995), suggesting
557 that they were of the greatest economic importance among the domestic stock. This is part of a
558 pattern long recognised for the Iron Age of south-central England, in which cattle tend to dominate
559 faunal assemblages in the lower-lying Upper Thames Valley, while sheep dominate the Downs
560 (Grant 1984; Hambleton 1999); indeed, this division persists today. This difference in landscape use
561 can be related both to the paucity of reliable sources of drinking water on the Downs, and to the
562 preference of sheep for the better-drained Chalk grasslands, as they are more susceptible to liver
563 fluke and foot-rot than cattle (Grant 1984). Sheep are able to obtain sufficient water from the grass
564 they consume, but cattle are obligate drinkers, requiring daily watering. While the water table was
565 higher in the Iron Age (Dark 2006; Robinson and Lambrick 1984), it is unlikely that there would be
566 sufficient flowing water to supply the needs of substantial numbers of cattle (though see Levick
567 2015, 51-53). Bringing the cattle to the springs emerging from the lower slopes of the Downs would
568 mitigate the scarcity of water on the Chalk to some extent, and might account for the dampened
569 $\delta^{18}\text{O}$ signal seen in one of the cattle from Alfred's Castle (though not in the other animal analysed
570 from the site). The floodplains of the river valleys, on the other hand, were very well suited to the
571 pasturage of cattle (Grant 1984; Hesse 2011; Lambrick and Robinson 2005).

572

573 Furthermore, lactating cows require additional water (Dado and Allen 1994; Woodford et al. 1984),
574 and so it would make sense to keep them in the Vale at least until their calves were fully weaned.
575 Thus, cows at least may have been preferentially kept on the richer and better-watered pastures of
576 the Vale during the calving and nursing season, before some were moved to the Ridgeway, so that
577 their bone collagen values reflect the signature of the Chalk grasslands. Favourable pastures used
578 repeatedly for cows in calf, for example, could lead to ^{15}N -enrichment of the soil through self-
579 manuring, particularly as there are clear legacy effects (Commisso and Nelsen 2008; Bogaard et al.
580 2007). As mentioned above, the enclosure at Watchfield seems designed to manage large numbers
581 of animals, and the site's faunal assemblage is dominated to an unusual extent by cattle (Lambrick
582 and Robinson 2005, 265). The advantages of raising cattle in the Vale appears to have been
583 recognised in the Romano-British period; Gill Mill, only 12km northwest of Marcham, has been
584 suggested to have functioned as a specialised cattle-rearing site to supply markets at regional
585 centres such as Cirencester (Booth 2016).

586

587 An obvious point of comparison for the results presented here is provided by the broadly
588 contemporary sites of the Danebury Environs, located ca. 50km south of the Oxfordshire Ridgeway.
589 The Danebury project set out to address some of the same questions posed here regarding animal
590 management between an Iron Age hillfort and its surrounding farmsteads. Initially, the variability in
591 $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results on faunal remains from the Danebury hillfort suggested a scenario in which
592 animals were brought to the site from a series of isotopically distinct parts of the surrounding
593 landscape (Stevens et al. 2010), much as was originally proposed for the Ridgeway hillforts (cf.
594 Madgwick and Mulville (2015) for a comparable example relating to an EIA feasting site in South
595 Wales). However, a subsequent isotopic study of faunal remains from a number of
596 contemporaneous unenclosed settlements found that, rather than the expected inter-site variability,
597 they exhibited a high degree of intra-site variability (Stevens et al. 2013). Interpretation thus shifted
598 to propose that each community had access to a range of different pastures, though whether these
599 were to be found nearby or more distantly could not be determined with $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ data alone.
600 The results of the present project suggest a third scenario, one in which animals were largely kept
601 'locally' (recognising that movement within either the Chalk or the Vale will not be discernable
602 isotopically), regardless of whether the site was a 'hillfort' or unenclosed settlement. At the same
603 time, there are some indications that young cattle born and raised in the Vale were moved to the
604 Ridgeway and kept on pastures there for a year or more before slaughter. While this could imply a
605 subordinate role for the unenclosed Vale settlements (paying tribute?), it could also be that these
606 communities were compensated in some manner that it is not apparent archaeologically. It must
607 also be reiterated that Marcham does not appear to have been a 'normal' domestic settlement, with
608 possible evidence for a range of ritual activities. As such, it might have been expected to perform a
609 similar integrative role to that proposed for the hillforts. In neither case, however, is there evidence
610 for the significant presence of animals from the adjacent landform. There remain, then, many
611 questions regarding the nature of the relationship between the Ridgeway and Vale in the Iron Age.
612
613

614 **Conclusions**

615
616 This study has provided new insights into animal management practices and mobility in the
617 Early/Middle Iron Age of the Oxfordshire Ridgeway. A baseline of 29 modern plant $^{87}\text{Sr}/^{86}\text{Sr}$
618 measurements confirm and provide more detail on the expected difference between plants growing
619 on the Cretaceous Chalk soils of the Ridgeway and the more varied geology of the Vale. As
620 expected, pig enamel $^{87}\text{Sr}/^{86}\text{Sr}$ values closely followed the local plant values, consistent with these
621 animals being raised locally. Unexpected was that sheep generally followed this same pattern, and

622 clearly spent most of their time grazing either on the Ridgeway or in the Vale. Cattle showed a very
623 different pattern to that seen in the other two species, with $^{87}\text{Sr}/^{86}\text{Sr}$ values consistent with grazing
624 in the Vale, regardless of whether the animal was from a site in the Vale, or from a Ridgeway
625 hillfort. In addition to these general patterns, more detailed analysis of a subset of samples
626 highlights the mobility of individual animals.

627

628 Stable carbon and nitrogen isotope measurements on the bone collagen of the same animals analysed
629 for $^{87}\text{Sr}/^{86}\text{Sr}$ provide additional information. While not differing in $\delta^{13}\text{C}$, both sheep and cattle from
630 the Ridgeway are on average lower in $\delta^{15}\text{N}$ than those from the Vale. This is somewhat surprising
631 in the case of the cattle, since their enamel $^{87}\text{Sr}/^{86}\text{Sr}$ values strongly suggest origins in the Vale. A
632 possible explanation for this is that calving and nursing took place in the Vale, after which some
633 animals were moved to the Ridgeway, allowing the bone collagen to turn over to reflect Chalk
634 pastures. The sequential dentine results, albeit on a very limited number of individuals, offers some
635 tentative support for this scenario. While many isotopic studies of animals in prehistoric Britain are
636 emphasising larger-scale mobility, the present study suggests instead persistence patterns in the use
637 of the landscape at a very local level.

638

639 As well as Iron Age sites, the Ridgeway and Vale contain a number of Romano-British sites, often
640 at the same locations. A strontium isotope study of Iron Age and Romano-British cattle teeth at the
641 rural settlement of Owslebury, Hampshire, found a change in the scale of procurement, with greater
642 evidence for the movement of cattle beginning the Late Iron Age and continuing into the Roman
643 period (Minniti et al. 2013). Neither of these periods is well represented (if at all) in the present
644 study, and it would be interesting to see whether a similar pattern holds for the Oxfordshire
645 Ridgeway. The initial results presented here are certainly promising, and have already provided new
646 insights – and raised new questions – regarding animal management in the Early/Middle Iron Age
647 of south-central England. More broadly, they have highlighted the considerable potential in a
648 targeted study of animal management practices using a multi-isotope approach within a small, well-
649 defined region, where suitable variation in natural isotope systems exists.

650

651

652

653

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655

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659

660

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973 **Table and Figure captions**

974

975 Table 1. Summary faunal bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from the Ridgeway and Vale. Alfred's Castle
976 includes data previously published by Hamilton (2013). Individual measurements are provided in Table S2.

977

978 Table 2. Summary of sequential dentine $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from Alfred's Castle and Marcham. Individual
979 measurements are provided in Table S3.

980

981 Table 3. Summary of sequential enamel $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ results from Alfred's Castle and Marcham. Individual
982 measurements are provided in Table S4.

983

984 Table 4. Average $^{87}\text{Sr}/^{86}\text{Sr}$ values for tooth enamel and plants from Ridgeway and Vale sites.

985

986
987 Figure 1. Map of the study area showing study sites and plant sample locations.

988

989 Figure 2. Bar chart of the three main domestic species at the Ridgeway (Segsbury and Alfred's Castle) and
990 the Vale (Marcham and Watchfield) sites (sources: Birbeck 2001; Lange 2013; Mulville and Powell 2005; P.
991 Levick pers. comm.).

992

993 Figure 3a. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope results on faunal bone collagen from the Ridgeway and the Vale.

994

995 Figure 3b. Summary plot (mean \pm 1 SD) of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope results on faunal bone collagen from the
996 Ridgeway and the Vale.

997

998 Figure 4. Sequential dentine collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope results from Alfred's Castle and Marcham.

999

1000 Figure 5. Sequential enamel carbonate $\delta^{18}\text{O}_c$ and $\delta^{13}\text{C}_c$ isotope results from Alfred's Castle and Marcham.

1001

1002 Figure 6. Plant $^{87}\text{Sr}/^{86}\text{Sr}$ isoscape for the study area (a) with associated prediction error map (b).

1003

1004 Figure 7. Boxplots of $^{87}\text{Sr}/^{86}\text{Sr}$ results for Ridgeway and Vales plants and fauna.

1005

1006 Figure 8. $^{87}\text{Sr}/^{86}\text{Sr}$ results on four sequential samples from a first molar from Alfred's Castle, taken at ca.
1007 10mm spacing starting near the occlusal surface (AC8-1); AC08 represents a separate measurement of a
1008 vertical sample from the same tooth (i.e., an averaged signal over the entire crown formation time).

1009

1010 **Supplementary Information**

1011

1012 Appendix 1. Plant sample preparation for replicate $^{87}\text{Sr}/^{86}\text{Sr}$ analysis.

1013

1014 Table S1. Summary of main mammalian fauna from Early and Middle Iron Age contexts.

1015

1016 Table S2. Faunal bone collagen $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from the Ridgeway and Vale.

1017

1018 Table S3. Sequential dentine $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results.

1019

1020 Table S4. Sequential enamel $\delta^{18}\text{O}_{c\text{VPDB}}$ and $\delta^{13}\text{C}_{c\text{VPDB}}$ results, with conversions to $\delta^{18}\text{O}_{c\text{VSMOW}}$ and $\delta^{13}\text{C}_{p\text{VSMOW}}$.

1021

1022 Table S5. Plant sample locations and $^{87}\text{Sr}/^{86}\text{Sr}$ results.

1023

1024 Table S6. $^{87}\text{Sr}/^{86}\text{Sr}$ results on sediment samples.

1025

1026 Table S7. $^{87}\text{Sr}/^{86}\text{Sr}$ results for tooth enamel from Ridgeway and Vale fauna.

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1028

1029 Figure S1. Bedrock geology of the study area (DiGMapGB-625) showing study sites and plant sample
1030 locations.