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22 Abstract

23 Africa's southern Cape is a key region for the evolution of our species, with early symbolic
24 systems, marine faunal exploitation, and episodic production of microlithic stone tools taken
25 as evidence for the appearance of distinctively complex human behavior. However, the
26 temporally discontinuous nature of this evidence precludes ready assumptions of intrinsic
27 adaptive benefit, and has encouraged diverse explanations for the occurrence of these
28 behaviors, in terms of regional demographic, social and ecological conditions. Here, we present
29 a new high-resolution multi-proxy record of environmental change that indicates that faunal
30 exploitation patterns and lithic technologies track climatic variation across the last 22,300 years
31 in the southern Cape. Conditions during the Last Glacial Maximum and deglaciation were
32 humid, and zooarchaeological data indicate high foraging returns. By contrast, the Holocene is
33 characterized by much drier conditions and a degraded resource base. Critically, we
34 demonstrate that systems for technological delivery – or provisioning – were responsive to
35 changing humidity and environmental productivity. However, in contrast to prevailing models,
36 bladelet-rich microlithic technologies were deployed under conditions of high foraging returns
37 and abandoned in response to increased aridity and less productive subsistence environments.
38 This suggests that posited links between microlithic technologies and subsistence risk are not
39 universal, and the behavioral sophistication of human populations is reflected in their adaptive
40 flexibility rather than in the use of specific technological systems.

41 **Keywords:** paleoclimate; paleoecology; rock hyrax middens; microlithic; macrofauna;
42 Boomplaas Cave

43

44 **Introduction**

45 South Africa's southern coastal margin is a key region for the evolution and development of
46 our species (Ambrose, 2002; Ambrose and Lorenz, 1990; Brown et al., 2012; Henshilwood et
47 al., 2004a; Henshilwood et al., 2002; Marean, 2010; Powell et al., 2009). The southern Cape
48 archaeological record has reframed the debate about the evolution of human behavior,
49 providing early examples of engravings, ornaments, heat treatment of tool-stone and the
50 focussed consumption of marine resources (Delagnes et al., 2016; Henshilwood et al., 2004b;
51 Henshilwood et al., 2002; Henshilwood et al., 2014; Marean, 2014). The region also exhibits
52 regular technological turnover through the last 100,000 years, with the intermittent production
53 of bladelets, bifacial points and backed artefacts and the use of fine-grained rock, interspersed
54 with periods lacking regular retouched flake forms and dominated by locally available rocks
55 such as quartzite and quartz (Deacon, 1984; Wilkins et al., 2017). The links between these
56 variable technological and subsistence records and their environmental context – necessary to
57 arguments about the evolution of human adaptation – remain surprisingly unclear (Deacon,
58 1982; Roberts et al., 2016). This reflects the region's particular climatic dynamism (Chase and
59 Meadows, 2007) coupled with disagreement concerning the interpretation of its
60 paleoenvironmental archives (e.g. Chase and Meadows, 2007; Deacon and Lancaster, 1988;
61 Faith, 2013b; Marean et al., 2014).

62 In this paper, we focus on the Later Stone Age record in the southern Cape, for which
63 - in contrast with the Middle Stone Age - high resolution environmental and archaeological
64 data are now available. We explore the strength of coupling between environments, subsistence
65 behavior and lithic technology over the last 22,300 years to understand whether, and how
66 closely, human behavior tracked environmental change. Spanning the transition from the Last
67 Glacial Maximum (LGM; 26.5-19 ka; Clark et al., 2009) to the Holocene (11.7 ka to present
68 Lowe et al., 2008), and episodes of the use of bladelet-rich technological systems, our data also
69 have a bearing on broader debates about the role of what are often termed 'microlithic'
70 technologies in issues of human adaptation and expansion.

71 **Later Stone Age environments and archaeology in the southern Cape**

72 Influenced by both temperate and tropical climate systems (Figure 1), long-term climate change
73 in the southern Cape is characterized by significant and often abrupt fluctuations (Bard and
74 Rickaby, 2009; Chase et al., 2013; Chase and Meadows, 2007; Heaton et al., 1986; Quick et

75 al., 2015; Quick et al., 2016; Talma and Vogel, 1992). Existing evidence indicates that during
76 the Holocene the relative influences of the two dominant synoptic scale moisture-bearing
77 systems – 1) the southern westerly storm track, which expands/shifts northward in the winter,
78 and 2) the tropical easterly flow, which transports moisture from the Indian Ocean during the
79 summer – have varied significantly (Chase et al., 2013; Chase et al., 2015b). However, there is
80 little detailed paleoenvironmental evidence pre-dating the Holocene (Carr et al., 2016b; Chase
81 and Meadows, 2007), and as a result there are contradictory opinions concerning conditions
82 since the LGM (Chase and Meadows, 2007; Deacon and Lancaster, 1988; Faith, 2013b;
83 Kohfeld et al., 2013; Partridge et al., 1999; Partridge et al., 2004; Sime et al., 2013; Stone,
84 2014), to the extent that some studies conclude that the region was exceptionally “harsh” and
85 arid during the LGM (Deacon and Lancaster, 1988; Scholtz, 1986), while others infer greater
86 humidity and highly productive terrestrial environments (e.g. Faith, 2013b; Parkington et al.,
87 2000). This uncertainty has fundamentally hindered our understanding of past climate
88 dynamics in the region, and, by extension, the impact of past climate change on hunter-gatherer
89 adaptive and subsistence strategies during both the Later and Middle Stone Age.

90 In the southern Cape, the Later Stone Age archaeological sequence is typically divided
91 into several industries or technocomplexes: early Later Stone Age (ELSA ~<40-24 cal kBP),
92 Robberg (~24-12 cal kBP), Oakhurst (~12-8 cal kBP) and Wilton (~8-2 cal kBP), followed by
93 the arrival of Khoikhoi herders in the last 2000 years (Deacon et al., 1984; Deacon, 1978;
94 Lombard et al., 2012; Mitchell, 1988). The ELSA is associated with the production of small
95 flakes, often through bipolar reduction of cores, though it otherwise lacks unifying
96 characteristics and has been described as a period of technological heterogeneity (Mitchell,
97 1988; Wadley, 1993). The Robberg presents more coherent characteristics, including the
98 production of large numbers of bladelets (small, elongate flakes usually less than 24 mm long)
99 produced both from dedicated bladelet cores and from those worked by bipolar reduction
100 (Mitchell, 1988). The Robberg also sees more concentrated, if episodic, use of fine-grained
101 rocks such as a silcrete and chert than the preceding or subsequent phases (Deacon, 1978;
102 Deacon, 1982). The Oakhurst (or Albany) is typified by fewer bladelets, larger flakes, a range
103 of scraper forms and declining use of fine-grained rock, while the Wilton features both scrapers
104 and backed artefacts and highly variable patterns of raw material use (Deacon, 1972; Deacon,
105 1978; Lombard et al., 2012). While these units are coarse and mask considerable variation,

106 they provide a useful heuristic for discussing broad patterns in technological change across the
107 later LSA.

108 Consistent with the imprecise meaning of the term (Pargeter, 2016), the ELSA, Robberg
109 and Wilton have all been described as ‘microlithic’ (Bousman, 2005; Deacon, 1984; Mitchell,
110 1988; Wadley, 1993), but based on different characteristics – small flakes in the case of the
111 ELSA, bladelets in the case of the Robberg and backed artefacts in the Wilton (Lombard et al.,
112 2012). The advent of dedicated bladelet production in particular – as characterizes the Robberg
113 – is argued to have presented humans with a significant adaptive advantage during our
114 evolution and dispersal (Ambrose, 2002; Bar-Yosef and Kuhn, 1999; Clarkson et al., 2009;
115 Foley and Lahr, 2003). Some researchers have linked an emphasis on bladelet production with
116 responses to heightened subsistence risk associated with low or declining subsistence resource
117 productivity (Elston and Brantingham, 2002; Petraglia et al., 2009) (for discussion of the risk
118 concept used here see Bamforth and Bleed, 1997). Others have suggested that bladelet
119 production provided benefits under conditions of high residential mobility (Goebel, 2002;
120 Neeley, 2002). Both explanations – increased subsistence risk and increased mobility – have
121 been posited for bladelet-rich systems in southern Africa during globally cooler conditions
122 (Ambrose, 2002; Grosjean et al., 2003; McCall, 2007; McCall and Thomas, 2012; Mellars,
123 2006; Mitchell, 2000). The Robberg specifically has been associated with increased residential
124 mobility in response to inferred diminishing resource density (Ambrose, 2002; Mitchell, 2000),
125 and has been explained as a risk-dampening response to resource stress (Mackay, 2009). Other
126 researchers, however, have suggested that any tracking between LSA technological systems
127 and paleoenvironmental variation was relatively weak, and occurred only at the broadest scale
128 of environmental change (e.g. Deacon, 1982). The reality of coupling between technology,
129 subsistence conditions and environmental change in this period is thus contested, and with it
130 the viability of high-order explanations for the behavioral significance of artefacts such as
131 bladelets.

132 **Sites and regional setting**

133 To explore the relationship between environmental change and human activities and
134 technology, we focus on sites from the Swartberg mountains of South Africa’s southern Cape,
135 one of the major ranges in the east-west axis of the Cape Fold Mountains (Figure 1). From
136 Seweweekspoort, a deep transversal valley in the central Swartberg mountains, a series of rock
137 hyrax (*Procapra capensis*) middens – stratified accumulations of dried urine and fecal pellets

138 (see Chase et al., 2012) – were identified, and six middens from two sites, Seweweekspoort-1
139 (SWP-1; 33.3668°S, 21.4144°E) and Seweweekspoort-3 (SWP-3; 33.4092°S, 21.4031°), were
140 analysed for this study. SWP-1 is located on a west-facing cliff on the northern slope of the
141 pass (Figure 1). The SWP-1 middens were taken from several locations within the same larger
142 shelter, formed by a ~100 m overhanging cliff. SWP-3 is located on a low eastern cliff in the
143 central section of the valley near the valley bottom, and experiences a more humid
144 microclimate relative to the exposed position of SWP-1.

145

146 <insert Figure 1>

147

148 The SWP-1 site is located in the North Swartberg Sandstone Fynbos, but less than a
149 kilometre to the north is the Matjiesfontein Shale Renosterveld (Mucina and Rutherford, 2006).
150 The former, depending on altitude and aspect, is predominantly asteraceous, proteoid and
151 restioid fynbos, while the latter is dominated by asteraceous elements, particularly
152 *Elytropappus rhinocerotis*, *Eriocephalus* sp. and *Euryops* sp., and by an increasing number of
153 succulents, primarily from the Crassulaceae family (Mucina and Rutherford, 2006). At SWP-
154 1, these vegetation types inter-digitate to some extent, with the broad west-facing drainage just
155 north of the site supporting more hydrophilic taxa, such as *Protea*. The north-facing rock
156 shelves directly adjacent to the site maintain only shallow soils and a dominance of succulents.
157 Grasses in the region are a mixture of C₃ (e.g., *Erharta*) and C₄ (e.g., *Aristida*, *Stipagrostis*)
158 varieties (<http://sibis.sanbi.org/faces/DataSources.jsp>; Rutherford et al., 2012; Rutherford et
159 al., 2003; SANBI, 2003). SWP-3 is located in the South Swartberg Sandstone Fynbos, which
160 at the site is primarily proteoid in character. In addition, there are numerous arboreal/Cape
161 thicket elements (e.g., *Podocarpus*, Celastraceae, *Dodonaea*, *Searsia*, *Euclea*, Oleaceae)
162 associated with drainages and the nearby riparian zones of the valley bottom.

163 The Seweweekspoort sites are located 70 km west of the well-stratified late Pleistocene
164 / Holocene archaeological site of Boomplaas Cave. This site is also situated on the flanks of
165 the Swartberg and occupies a very similar climatic regime, making it ideal for exploring
166 linkages between climate, environment, subsistence and technology at high temporal
167 resolution. Located on the southern flanks of the Swartberg range overlooking the Cango
168 Valley, Boomplaas Cave was excavated by Hilary Deacon in the 1970s (Deacon, 1979). The

169 excavated sediments were divided into a series of members, some of which were subdivided
170 into units. The site is positioned within a transitional shrubland whose component species vary
171 as a function of temperature and moisture gradients moving upslope from the floor of the valley
172 (Vlok and Schutte-Vlok, 2010). The lowlands to the south are characterized by renosterveld
173 habitats, which give way to fynbos vegetation along the slopes of the Swartberg. Along
174 watercourses and ravines in the Cango Valley are more densely wooded habitats that include
175 sweet thorn trees (*Vachellia (Acacia) karroo*) and ironwood (*Olea* spp.) among others (Moffett
176 and Deacon, 1977). As is also the case at Seweweekspoort, Boomplaas today receives
177 contributions of both winter and summer rainfall (Figure 1). Thus, the limited grasses that do
178 occur in the area today include a mixture of both C₃ and C₄ species.

179 **Materials and methods**

180 Rock hyrax middens accumulate over thousands of years and preserve continuous records of
181 past climate change (Chase et al., 2012). The six middens from Seweweekspoort sites SWP-1
182 and SWP-3 were selected for analysis because they are composed almost entirely of hyraceum
183 (no visible fecal pellets). Our experience suggests that such middens have superior stratigraphic
184 integrity compared to more pellet-rich middens. Representative portions of the middens were
185 processed as described in Chase et al. (2013; 2012). Radiocarbon age determinations ($n=36$)
186 were processed at the ¹⁴CHRONO Centre, Queen's University Belfast using accelerator mass
187 spectrometry (AMS) (Supplementary Online Material [SOM] Figure S1; Table S1). The
188 radiocarbon ages were corrected for isotope fractionation using the AMS measured $\delta^{13}\text{C}$ and
189 calibrated using the SHCal13 calibration data (Hogg et al., 2013). The Bacon 3.0.3 software
190 package (Blaauw and Christen, 2011) was used to generate all age-depth models (SOM Figure
191 S1). Results indicate that these sequences continuously span the last 22,300 years.

192 The fossil pollen content of 82 adjacent, contiguous pollen samples were prepared with
193 standard physical (600 μm sieving and decanting) and chemical (HCl, KOH, HF and acetolysis)
194 methods (Moore et al., 1991). *Lycopodium* tablets were added to the weighed sample to
195 estimate pollen concentrations (Stockmarr, 1971). A minimum pollen sum of 400 grains was
196 counted at a magnification of $\times 400$ under a light microscope, and identified with the help of
197 the literature (Scott, 1982; van Zinderen Bakker, 1953, 1956; van Zinderen Bakker and
198 Coetzee, 1959), and photographic and slide reference collections at the Universities of the Free
199 State, Cape Town, and Montpellier.

200 The bulk stable nitrogen (^{15}N) and carbon (^{13}C) isotope contents of 767 overlapping
201 hyraceum samples were measured at the Department of Archaeology, University of Cape Town
202 following Chase et al. (2010; 2009; 2011; 2012), with contiguous/overlapping samples
203 obtained from two series of offset 1 mm holes. For the stable isotope analyses, the standard
204 deviation derived from replicate analyses of homogeneous material was better than 0.2‰ for
205 both nitrogen and carbon. Nitrogen isotope results are expressed relative to atmospheric
206 nitrogen (SOM Figure S2). Carbon isotope results are expressed relative to Vienna PDB (SOM
207 Figure S3).

208 Stable isotope results from the different Seweweekspoort rock hyrax middens were
209 combined into a single aggregate record using Local Regression (LOESS) curve fitting of the
210 combined datasets (SOM Figures S2 and S3). As individual middens under the same climate
211 regime may exhibit differences in their isotopic records due to microclimatic influences on
212 individual foraging ranges (i.e., baseline $\delta^{15}\text{N}$ variability), we have adjusted the $\delta^{15}\text{N}$ to account
213 for these differences prior to LOESS curve fitting. Using the SWP-1-1 and SWP-1-4b records
214 as a datum, an estimated offset of 1.5‰ was added to the $\delta^{15}\text{N}$ data from the SWP-3-1 to
215 compensate for the more humid microclimate in which the midden was found, and 0.5‰ and
216 1‰ were added to SWP-1-5 and SWP-1-2a respectively to account for their more exposed
217 positions.

218 The carbon isotopic composition of the hyraceum is representative of vegetation around
219 a midden site (Carr et al., 2016a) and provides information on 1) the relative contribution of
220 C_3 , C_4 and CAM plants (Smith, 1972) to the animals' diet, and 2) variations in plant water-use
221 efficiency (WUE) as a function of climate (Ehleringer and Cooper, 1988; Farquhar et al., 1989;
222 Farquhar and Richards, 1984; Pate, 2001). Throughout the broader region, the distribution of
223 C_3 and C_4 grasses tracks the proportion of winter versus summer rainfall (Vogel, 1978). As
224 mentioned, at Seweweekspoort today, grasses are a mosaic of C_3 and C_4 varieties (Rutherford
225 et al., 2012; Rutherford et al., 2003; SANBI, 2003), and where aspect and soil depth limit soil
226 water content, CAM plants become increasingly abundant. As C_3 plants are depleted in ^{13}C
227 compared with most CAM and all C_4 plants, higher $\delta^{13}\text{C}$ values indicate more abundant warm
228 season (C_4) grasses and/or succulent plants (CAM), and generally warmer/more arid
229 conditions.

230 Hyraceum $\delta^{15}\text{N}$ is an indicator of changes in ecosystem water-availability (Carr et al.,
231 2016a; Chase et al., 2013; Chase et al., 2015b; Chase et al., 2009; Chase et al., 2011). A positive

232 relationship exists between aridity and $\delta^{15}\text{N}$ in soils, plants and herbivores, with drier
233 conditions correlating with enriched $\delta^{15}\text{N}$ (Carr et al., 2016a), most likely as a result of
234 denitrification processes in arid/semi-arid soils (Handley et al., 1999; Handley et al., 1994;
235 Hartman, 2011; Heaton, 1987; Murphy and Bowman, 2006, 2009; Wang et al., 2010). In the
236 hyraceum samples, the narrowly defined feeding range of the hyraxes (<60 m; Sale, 1965), and
237 the accumulation rates of the middens (~20-60 years/sample) enforce a spatio-temporal
238 averaging that reduces the $\delta^{15}\text{N}$ variability observed in modern ecosystem studies (Carr et al.,
239 2016a), and provides a more reliable index of past water variability (Carr et al., 2016a; Chase
240 et al., 2012).

241 *Boomplaas faunal and archaeological archives*

242 The Boomplaas sequence spans much of the last >65,000 years (Deacon, 1982), though we
243 focus here on the fauna and flaked stone artifacts from the upper stratigraphic units
244 corresponding in age with the Seweweekspoort record (SOM Table S2). We use these data to
245 explore the relationship between the paleoenvironmental changes documented at
246 Seweweekspoort and mammal community composition, foraging efficiency, and technological
247 organization. Ages for Boomplaas follow Deacon (1982), calibrated using SHCal13 (Hogg et
248 al., 2013). These published data do present limitations, as they do not adequately bracket each
249 stratigraphic unit. In an effort to maximize their utility, and estimate likely intervals of time
250 that each unit may represent, we derived depths from the published stratigraphic diagrams and
251 calculated a general age-depth model for the sequence. While apparently quasi-continuous,
252 with a relatively constant depositional rate, the nature of the sequence, in terms of lithology,
253 suggests more sporadic deposition. In plotting each unit, we have included both minimum and
254 maximum weighted mean ages as well as potential minimum and maximum ages of the units
255 considering potential sources of error related to radiocarbon calibration and assumptions of
256 accumulation rates (SOM Figure S4). This highlights the clear need to initiate a systematic
257 revision of the chronologies of many archaeological sites in the region (e.g. Loftus et al., 2016;
258 Sealy et al., 2016) to enable more robust inter-site and inter-regional comparisons.

259 Taxonomic abundances (number of identified specimens: NISP) of ungulates from
260 Boomplaas Cave were derived from Faith (2013a), with Klein's (1983) specimen counts used
261 for the uppermost member DGL. Comparable data (minimum number of individuals: MNI) for
262 the Boomplaas microfauna were derived from Avery (1982). To facilitate comparison with the
263 SWP record, we conducted a detrended correspondence analysis (DCA) for both data sets,

264 using the first axis (rescaled from 0 to 100) to broadly summarize faunal composition (Figure
265 3). The linear trends in both taxonomic groups closely parallel a decline in ungulate grazers
266 (Figure 3), suggesting that the DCA axis 1 scores are related to the replacement of grasslands
267 by more shrubby habitats (see also Faith, 2013a). Broadly parallel changes are also observed
268 in the south coast faunal sequences from Nelson Bay Cave (Klein, 1983) and Byneskranskop
269 1 (Schweitzer and Wilson, 1983) (Figure 1), implying regional shifts in habitat structure.

270 Humans are the primary accumulator of the Boomplaas Cave macrofauna from stratum
271 CL4 and above (Faith, 2013a; see also Faith, 2011). This allows us to explore how the
272 environmental changes documented at SWP translate to changes in foraging efficiency. Based
273 on models grounded in optimal foraging theory, we examine two zooarchaeological indicators
274 of foraging efficiency. These include the relative abundance of small-bodied and presumably
275 low-ranked prey (leporids and tortoises) and the average food utility index (FUI; Metcalfe and
276 Jones, 1988) – a proxy for energetic returns (e.g., meat, fat, marrow) of various ungulate body
277 parts – of large mammal (size classes 3 and 4: 84 to 900 kg) skeletal elements (data from Faith,
278 2011b). Given the evidence for attrition at Boomplaas Cave (Faith and Thompson, in press),
279 we follow Cleghorn and Marean’s (2004) taphonomic model of bone survivorship and restrict
280 analysis to the long-bones (femur, tibia, humerus, radius, and metapodials) and skull elements
281 (crania and mandibles). Building on previous studies conducted elsewhere (e.g., Grayson,
282 1991, 2005; Broughton, 1994, 1999; Cannon, 2003; Faith, 2007; Munro 2004;), we predict
283 that declining foraging efficiency will be characterized by (1) increasing frequencies of low-
284 ranked prey, reflecting declining availability of high-ranked prey (e.g., large game) on the
285 landscape, and (2) increasing mean FUI values, reflecting intensified field processing due to
286 an increase in carcass transport distances and/or search times. We recognize that because
287 tortoises are slow-moving and easily captured, they might be considered a high-ranked prey
288 type that should be collected whenever encountered (e.g. Stiner et al., 2000). However, the
289 significant positive correlation between their abundances and those of leporids (Spearman’s ρ :
290 $r_s = 0.814$, $p \leq 0.001$), which are unequivocally a low-ranked prey type, suggests that we can
291 treat tortoises as low-ranked prey in this context.

292

293 <insert Table 1>

294

295 All lithic data are taken from Deacon (1982), standardized to site mean (standardized
296 value = (layer value – site mean) / site standard deviation). We focus on the abundance of
297 bladelets (Figure 3d), and three indicators of technological delivery: ratio of cores to retouched
298 flakes (Figure 3g), total proportions of retouched flakes (Figure 3e), and artefact density
299 measured as total number of artefacts per bucket of excavated sediment following Deacon
300 (1982) (Figure 3h). These last three values function, respectively, as proxies for the transport
301 of retouched flakes vs tool-making potential (mode of technological ‘provisioning’ (Kuhn,
302 1995)), frequency of flake curation, and intensity of site-use (Barton and Riel-Salvatore, 2014;
303 Kuhn and Clark, 2015; Parry and Kelly, 1987; Riel-Salvatore and Barton, 2004). Provisioning,
304 which we define as the systems by which stone artefact technologies are delivered in
305 anticipation of future needs, has been argued to mediate the response of mobility to
306 environmental change (Mackay et al., 2014; Wilkins et al., 2017). Under conditions of
307 diminished residential mobility, we expect increases in core transport and artefact density, and
308 lower rates of curation. The inverse is expected when mobility increases and the scheduling of
309 movements becomes harder to predict. If bladelets are a response to diminishing subsistence
310 returns, then their abundance should track humidity and resource productivity inversely.
311 Similarly, if bladelets are positively associated with increasing residential mobility and
312 declining durations of site occupancy then we expect an inverse relationship with artefact
313 density. We also consider the relative abundance of spatially-rare, fine-grained rocks such as
314 silcrete and crypto-crystalline silicates (CCS, subsuming chert and chalcedony) (Figure 3f); it
315 has recently been shown that the abundance of rocks such as silcrete is responsive to increases
316 in overall artefact abundance (Will and Mackay, 2016), and may thus reflect diminished
317 residential mobility and improved scheduling of movements.

318 **Results**

319 *Climate change since the Last Glacial Maximum at Seweweekspoort*

320 The Seweweekspoort record shows substantial changes in both $\delta^{13}\text{C}$ (range 5.1‰) and $\delta^{15}\text{N}$
321 (range 9.5‰) over the last 22,300 years, implying significant changes in vegetation and climate
322 (Figure 2). These changes are coherent with the pollen data from the same material. Across this
323 period, a strong first-order trend is apparent, with cool, humid glacial conditions (indicated by
324 increased cryophilic Fynbos Biome vegetation pollen and lower $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$) transitioning
325 into warmer, but substantially drier conditions during the Holocene (declining fynbos pollen
326 and higher $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$; Figure 2). This aridification coincides with the deglacial decline in

327 Antarctic sea-ice extent (using sea-salt sodium as a proxy) between 19-11 ka (Fischer et al.,
328 2007; Levine et al., 2014; Wolff et al., 2010) (Figure 2), which is considered to be a strong
329 determinant on the position of the westerly storm track (Bard and Rickaby, 2009; Stuut et al.,
330 2004). The elevated grass pollen percentages during the last glacial period, coupled with low
331 $\delta^{13}\text{C}$ suggest the increased prevalence of cool growing season C_3 grasses (Vogel, 1978),
332 consistent with the model that much of the precipitation during this period fell during the winter
333 months as a result of increased westerly influence. While recent work has indicated that
334 variability in summer rainfall may have had some significant impact in the winter rainfall zone
335 (Chase et al., 2015a; Chase et al., 2015b), long-term (i.e., glacial-interglacial timescales)
336 precipitation trends in the summer rainfall zone (Chevalier and Chase, 2015) exhibit a clear
337 antiphase relationship with humidity at Seweweekspoort (Figure 2), indicating that tropical
338 systems played a limited role in the region at these timescales.

339

340 <insert Figure 2>

341

342 Within this broad first-order trend of deglacial aridification at Seweweekspoort,
343 significant second-order abrupt episodes of wetter conditions (centred at 14.5, 11 and 4 cal
344 kBP, and the last millennium) indicate major reorganisations of regional climate dynamics. In
345 southern Africa, where rainfall regimes are defined by their strong seasonality, the varying
346 contribution of the non-dominant moisture-bearing system can have a substantial impact on
347 regional environments, shortening or attenuating the impact of often pronounced drought
348 seasons (Chase et al., 2015a). In this context, humid episodes within the last glacial-interglacial
349 transition (LGIT; 18.5-11.7 ka) – previously identified as being a period of exceptionally high
350 effective precipitation in the region (Scholtz, 1986) – can be linked to the warming of both high
351 southern latitudes (Stocker, 1998; Stocker and Johnsen, 2003) and the oceans surrounding
352 southwestern Africa (Barker et al., 2009; Farmer et al., 2005; Kim and Schneider, 2003),
353 including a response to the slow-down of Atlantic Meridional Overturning Circulation
354 (AMOC) during Heinrich stadial 1 (HS1; ~18-14.6 ka) (McManus et al., 2004) (Figure 2).

355 While the influence of the westerly storm track may have diminished as the Subtropical
356 Front shifted poleward (Barker et al., 2009), increased evaporation from warmer oceans and
357 the invigoration of the southern African monsoon system would have augmented the summer

358 rain component in what was then primarily a winter rainfall regime, reducing rainfall
359 seasonality and drought stress. At Seweweekspoort, peaks in humidity at 14.5 and 11 cal kBP
360 typify this, with reductions in fynbos vegetation under slightly warmer conditions, and with
361 increased grass cover as a function of more regular rains promoting shallow rooting vegetation.
362 With the onset of the Holocene, as warming continued, the combination of tropical and
363 temperate systems that resulted in these phases of LGIT humidity broke down. Changes in
364 global boundary conditions resulted in 1) a more permanent southerly position of the westerly
365 storm track, and less winter rain, and 2) strong regional warming that intensified potential
366 evapotranspiration, enhancing drought stress (Chevalier and Chase, 2016). Combined, these
367 factors are interpreted to have driven the marked aridification exhibited in the Seweweekspoort
368 records (Figure 2).

369 *Changing resources and technology*

370 The climatic changes robustly identified at Seweweekspoort are strongly reflected in our newly
371 synthesised faunal and archaeological records (Figure 3). Large mammals and microfauna from
372 Boomplaas Cave indicate open and grassy environments during the LGM, giving way to
373 shrublands across the Pleistocene-Holocene transition; a phase marked by large mammal
374 extinctions and shifts in faunal community composition throughout the region (Faith and
375 Behrensmeier, 2013). These changes are evident in the DCA axis 1 scores (Figure 3). The
376 abundance of ungulate grazers and axis 1 scores at the site closely tracks $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ (Figure 3),
377 and changes observed in the pollen record at Seweweekspoort (Figure 2). Likewise, the carbon
378 isotope composition of tooth enamel from Boomplaas grazers parallels the $\delta^{13}\text{C}$ shifts at
379 Seweweekspoort, with predominantly C_3 grasses consumed during the LGM giving way to
380 increased C_4 grasses during the LGIT (Sealy et al., 2016).

381

382 <insert Figure 3>

383

384 These findings contrast with earlier interpretations from floral (Deacon et al., 1984;
385 Scholtz, 1986) and faunal assemblages (Avery, 1982; Klein, 1972; Klein, 1980, 1983) from
386 southern Cape archaeological sequences, wherein open grassland environments – inferred
387 primarily from a predominance of grazers in large mammal fossil records – were interpreted as
388 signs of increased aridity. Our results support inferences that evidence for grassier vegetation

389 indicates the influence of more/more regular precipitation on the richer soils of the valleys and
390 plains of the southern Cape (Chase, 2010; Faith, 2013b), which currently support relatively
391 xeric karroid vegetation (Cowling, 1983). In contemporary African ecosystems, elevated
392 precipitation is typically associated with increased biomass of large herbivores (Coe et al.,
393 1976; East, 1984), a phenomenon likely to have been enhanced by increased plant nutrient
394 content under reduced atmospheric CO₂ concentrations (Faith, 2011a). The implication for
395 human populations is that cooler, more humid late Pleistocene conditions presented a more
396 productive resource base, including the proliferation of large grazing ungulates.

397 Zooarchaeological evidence from the human-accumulated vertebrate assemblages at
398 Boomplaas Cave (CL4 and above) indicates that aridification through the LGIT is associated
399 with a decline in foraging efficiency. Across the LGIT (CL4 to BRL5), tortoises and leporids
400 increase in abundance relative to ungulates (tortoises: $\chi^2_{\text{trend}} = 90.332, p < 0.001$; leporids: χ^2_{trend}
401 $= 64.854, p < 0.001$). Because ungulates are larger and provide greater energetic returns than
402 tortoises or hares – in which case they should be pursued whenever encountered – these trends
403 imply a decline in their abundances on the landscape. This is also reflected in changes in carcass
404 transport strategies. The average food utility index of large mammal high-survival skeletal
405 elements increases steadily across the LGIT (Spearman's rho = 0.964, $p < 0.001$), indicating a
406 greater emphasis on skeletal parts providing the highest energetic returns. Within an optimal
407 foraging framework, this trend is consistent with an increase in carcass transport distances
408 and/or search times stemming from diminished availability of large game (Cannon, 2003;
409 Faith, 2007). These parallel trends imply that the cooler and more humid conditions of the late
410 Pleistocene provided a more productive vertebrate resource base with higher average energetic
411 returns than did the more arid conditions of the early Holocene.

412 The decline in foraging efficiency through the deglaciation reverses through the
413 Holocene. Barring an increase observed in the two upper units (Table 1), leporids decline in
414 abundance relative to ungulates after the peak in BRL5 (~11-12 cal kBP) ($\chi^2_{\text{trend}} = 15.854, p <$
415 0.001). This trend, which is consistent with an increase in ungulate abundances on the
416 landscape, complements a decline in the mean FUI of large mammal skeletal parts (Spearman's
417 rho = 0.821, $p = 0.034$).

418 From the LGM through the Holocene, there are marked temporal trends in lithic
419 indicators of technological systems at Boomplaas Cave (Figure 3). Though not without some
420 variation, there is a general decline through time in the abundance of bladelets ($\chi^2_{\text{trend}} =$

421 1323.693, $p < 0.001$), cores relative to retouched flakes ($\chi^2_{\text{trend}} = 921.328$, $p < 0.001$), and fine-
422 grained raw materials ($\chi^2_{\text{trend}} = 775.322$, $p < 0.001$), coupled with an increase in the frequency
423 of retouched pieces ($\chi^2_{\text{trend}} = 1510.282$, $p < 0.001$). A relationship between technological
424 systems and the environment is suggested by strong correlations between these indicators and
425 the DCA axis 1 scores derived for both ungulates and microfauna (Figure 3b, c; Table 2).
426 Indeed, all the measures of technological change we employ for the Boomplaas assemblage are
427 significantly correlated with changes in ungulate community composition, and most with the
428 composition of micromammal communities (Table 2). Both sets of axis 1 scores track changing
429 frequencies of grassland indicators at the site, as well as the $\delta^{15}\text{N}$ and especially $\delta^{13}\text{C}$ values
430 from Seweweekspoort (Figure 3). It follows that technological change is tracking
431 environmental change, including the patterns of climate-driven environmental change
432 documented in the Seweweekspoort records.

433

434 <insert Table 2>

435

436 During the LGM and early LGIT bladelets are abundant and artefact indicators are
437 consistent with low residential mobility (Figure 3). With the exception of the earliest LGM
438 members (GWA/HCA), for which taphonomic data suggest limited human occupation (Faith,
439 2013a), artefact densities are well above the overall mean at Boomplaas, flake curation is
440 uncommon, and all core to retouched flake values pre-13 ka (CL member units) are higher than
441 all those that follow. Associated high frequencies of rock such as silcrete and CCS before 12
442 cal kBP (CL + BRL 7) imply regular and predictable access to fine-grained rock through this
443 period (Figure 3). These factors combined imply an emphasis on the transport of tool-making
444 potential to sites.

445 Coincident with the onset of the first-order aridification trend after ~14 ka (BRL
446 member units), artefact densities decrease, as do proportions of fine-grained rock and bladelets.
447 The period is broadly characterised by more common acquisition and reduction of readily
448 available local rocks (quartz and quartzite), with diminishing intensity of site use and little
449 transport of cores or curation of flakes. Investment in technological costs in the later LGIT
450 appears minimal and may reflect greater allocation of energy to search and handling of
451 subsistence packages in response to diminishing ungulate abundance (cf., Hames, 1992;

452 Mackay and Marwick, 2011). From the beginning of the Holocene (BRL3 through to DGL
453 member), and tracking diminishing humidity, artefact densities are low and locally abundant
454 rock continues to dominate, but flake curation becomes markedly more common –
455 technological systems show a much greater emphasis on transportation and maintenance of
456 implements in this period than in the Pleistocene.

457 Conclusions

458 The findings presented here overturn prevailing models of environmental and behavioral
459 change in Africa's southern Cape. A continuous and high-resolution environmental base-line
460 is provided for the first time, indicating a trend from relative humidity during the LGM to
461 increased aridity during the Holocene, with marked shifts in moisture across the LGIT. Rather
462 than being characterised by 'harsh,' conditions (Deacon and Lancaster, 1988; Scholtz, 1986),
463 the mesic environments of the late Pleistocene were highly productive, with more extensive
464 grasslands existing in areas now dominated by drought resistant succulent shrublands.
465 Zooarchaeological data indicate proliferation of a diverse ungulate grassland community
466 during this time, suggesting greater resource availability for humans living in the area, and
467 reduced search and handling times for large game. While lithic technologies track these
468 changes, we found no evidence to support an association between the production of bladelets
469 during the LGM/early LGIT (Robberg) and diminished subsistence conditions. Indeed,
470 bladelets seem to have flourished in a period of relative resource abundance. The period of
471 lowest subsistence productivity inferred from the Seweweekspoort data probably occurred
472 during the Holocene, associated with aridification and the concomitant loss of large ungulates
473 and faunal diversity recorded at Boomplaas. This change led to increases in carcass processing
474 at kill sites, as evidenced by more selective transport of high utility body parts, increased
475 reliance on low-ranked prey, and a technological response in which flakes from locally
476 acquired rocks were curated, core transportation was relatively rare, and bladelets were
477 uncommon. In documenting the strong coupling of environmental, subsistence and
478 technological behavior in Later Stone Age foragers, our data reflect the simple observation that
479 all lithic technologies can be adaptive solutions, not only those often assumed to provide
480 particular adaptive benefits. The findings afforded by high resolution analysis of late
481 Pleistocene and Holocene climate imply more generally that the lack of certain kinds of
482 technologies – such as bladelets, backed artefacts and bifacial points - in the earlier stages of
483 human evolution need not carry inherent meaning. The ability of foragers to track rapid climatic

484 and environmental changes with adaptive cultural responses is a better arbiter of cognitive
485 complexity than the deployment of any specific technological system.

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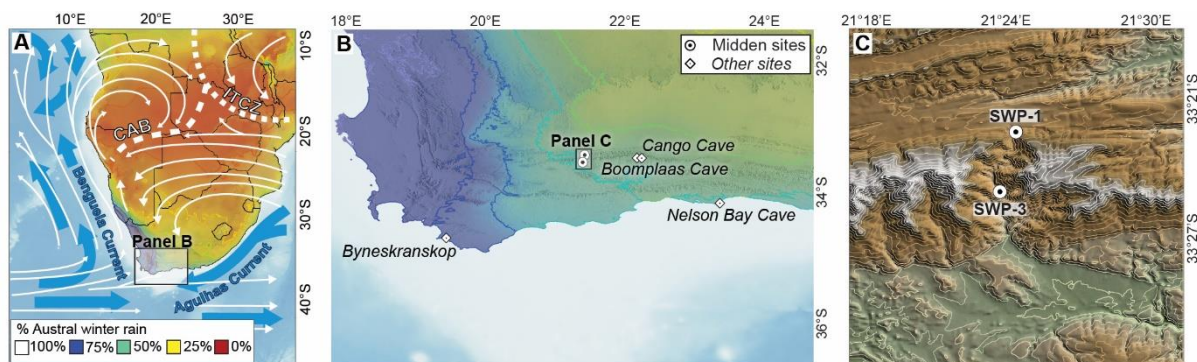
836 Table Captions

837 **Table 1:** Zooarchaeological indicators of foraging efficiency at Boomplaas Cave. These include the
838 relative abundance of tortoises (%), leporids (%), and mean food utility index (FUI) of high-survival
839 body parts belonging to size 3-4 mammals.

840 **Table 2:** The correlation (Spearman's ρ) between lithic technological indicators and faunal community
841 composition (DCA Axis 1 scores) for ungulates and microfauna at Boomplaas Cave. Significant values
842 in bold.

843

844 Figure Captions



845
846 **Figure 1:** (A) Map of southern Africa showing seasonality of rainfall and climatic gradients dictated
847 by the zones of summer/tropical (orange) and winter/temperate (blue) rainfall dominance. Winter
848 rainfall is primarily a result of frontal systems embedded in the westerly storm track. Major atmospheric
849 (white arrows) and oceanic (blue arrows) circulation systems and the austral summer positions of the
850 Inter-Tropical Convergence Zone (ITCZ) and the Congo Air Boundary (CAB) are indicated. The
851 location of the study site in the transitional southern Cape region is shown. (B) Map of southwest
852 African coastal region with the Seweweekspoort sites and other key palaeoenvironmental and
853 archaeological sites indicated (shading as for panel 'A'). (C) Topographical map of Seweweekspoort,
854 with the SWP-1 and SWP-3 sites indicated.
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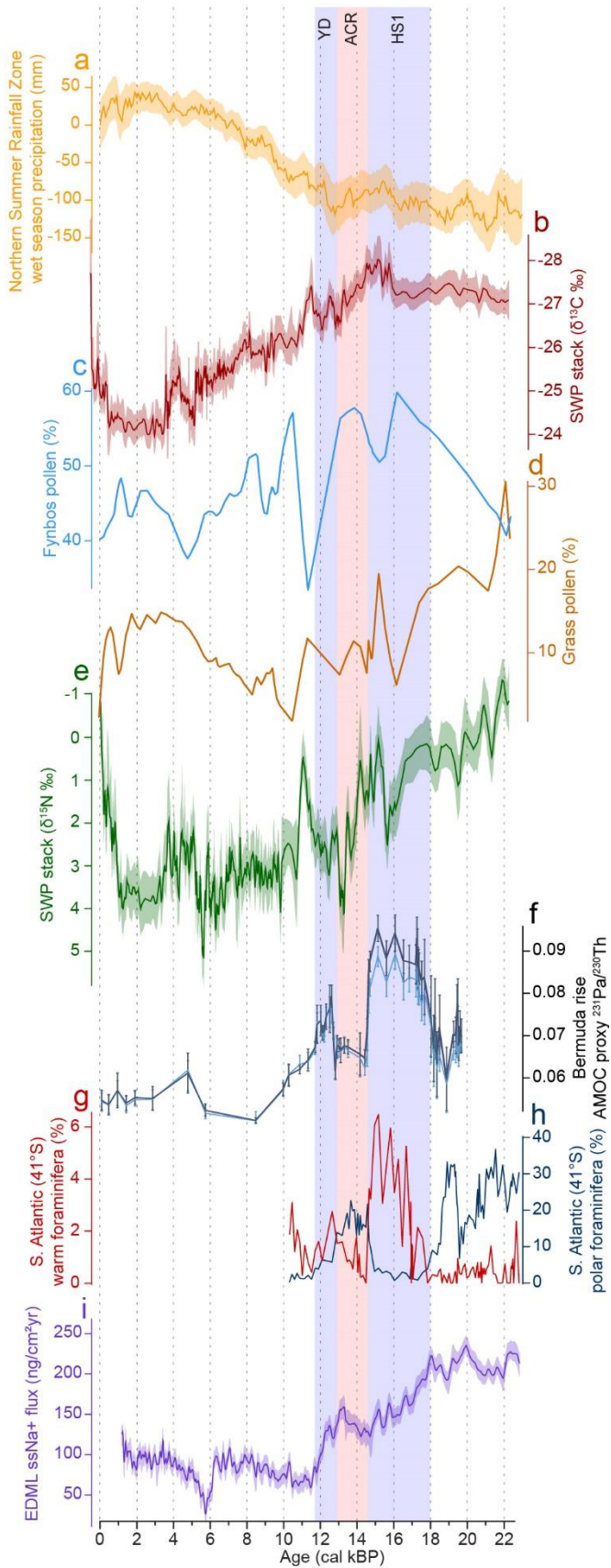


Figure 2: Comparison of $\delta^{15}\text{N}$ (e), $\delta^{13}\text{C}$ values (b), fynbos (c) and grass (d) pollen percentages from the Seweweekspoort hyrax middens with relevant palaeoenvironmental records including the northern summer rainfall zone wet season precipitation reconstruction (a; Chevalier and Chase, 2015), the Bermuda Rise record of Atlantic Meridional Overturning Circulation (AMOC) strength and the northward oceanic transport of heat (f; McManus et al., 2004), foraminifera records indicating conditions in the ocean to the south of the Africa (g, h; Barker et al., 2009) and sea salt sodium concentrations from the EPICA DML ice core in Antarctica (i; Fischer et al., 2007).

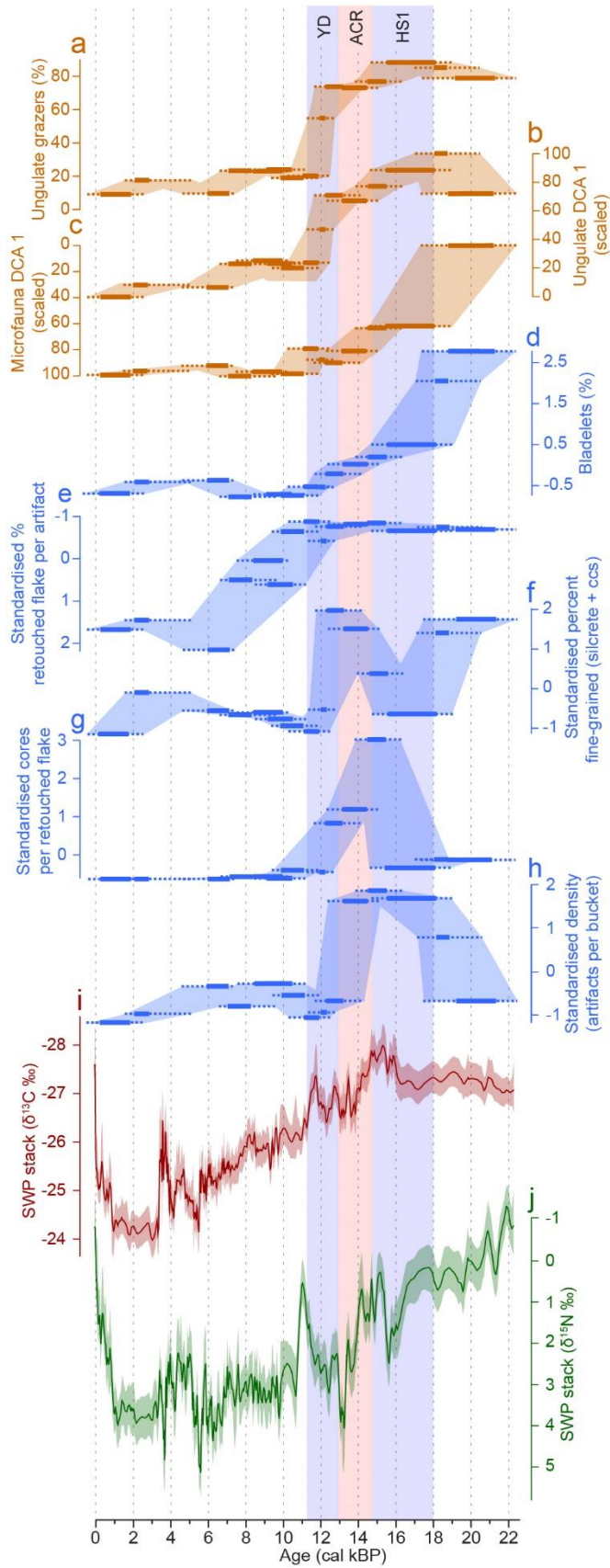


Figure 3: Comparison of $\delta^{15}\text{N}$ (j) and $\delta^{13}\text{C}$ (i) values from the Seweweekspoort hyrax middens with zooarchaeological records (a-c) of macrofauna (Faith, 2013a; Klein, 1983) and microfauna (Avery, 1982), and (d-h) lithic data (Deacon, 1979; Deacon et al., 1984) from Boomplaas Cave. Error bars on the data from Boomplaas reflect potential age ranges (2σ) of each stratigraphic unit.

883 Supplementary Information

884 *Material and methods*

885 The Seweweekspoort middens were selected for analysis because they are composed almost
886 entirely of hyraceum (no visible pellets). Our experience suggests that such middens have
887 superior stratigraphic integrity compared to more pellet-rich middens. Representative portions
888 of the middens were processed according to the methods described by Chase et al. (Chase et
889 al., 2013; Chase et al., 2012). Radiocarbon age determinations were processed at the
890 ¹⁴CHRONO Centre, Queen's University Belfast using accelerator mass spectrometry (AMS)
891 (Figure S1; Table S1). The radiocarbon ages were corrected for isotope fractionation using the
892 AMS measured $\delta^{13}\text{C}$ and calibrated using the SHCal13 calibration data (Hogg et al., 2013).
893 The Bacon 3.0.3 software package (Blaauw and Christen, 2011) was used to generate all age-
894 depth models (Figure S1). Stable isotope analysis of bulk midden samples were performed at
895 the Department of Archaeology, University of Cape Town according to the methods described
896 in Chase et al. (2010; 2009; 2011; 2012), with a contiguous/overlapping samples obtained from
897 two series of offset 1 mm holes. For the stable isotope analyses, the standard deviation derived
898 from replicate analyses of homogeneous material was better than 0.2 ‰ for both carbon and
899 nitrogen. Carbon isotope results are expressed relative to Vienna PDB. Nitrogen isotope results
900 are expressed relative to atmospheric nitrogen.

901

Table S1: Radiocarbon ages were calibrated using the SHCal13 calibration data (Hogg et al., 2013), except for the surface sample from SWP-1-4b, which was not calibrated, and UBA-19558, which was calibrated with CALIBomb using SHCal13 and the SHZ1_2 dataset of Hua et al. (Hua et al., 2013).

Sample	¹⁴ C age BP	F ¹⁴ C	1 sigma error	95.4 % (2σ) cal age ranges		relative area under distribution	median probability (cal BP)
				lower cal range BP	upper cal range BP		
SWP-1-1							
UBA-16698	3067		32	3078	3094	0.02947	3222
				3108	3129	0.031819	
				3138	3349	0.938712	
UBA-18638	4509		40	4892	4900	0.006407	5131
				4915	4927	0.009555	
				4959	5299	0.984038	
UBA-18639	5322		35	5940	5977	0.111729	6068
				5981	6183	0.888271	
UBA-18640	6226		33	6954	7178	0.982768	7082
				7219	7236	0.017232	
UBA-18641	8535		39	9447	9540	1	9502
SWP-1-2a							
UBA-22927	10243		39	11721	11733	0.009155	11886
				11748	12040	0.990845	
UBA-18645	13621		60	16145	16620	1	16359
UBA-18646	17143		83	20377	20894	1	20627
UBA-18647	18746		95	22372	22837	1	22564
SWP-1-4b top							
surface	modern		1				
UBA-19558		1.0181	0.0043	-7	-6	1	
UBA-19559	975		27	775	782	0.020244	853
				787	919	0.979756	
UBA-22921	1543		25	1314	1426	1	1378
UBA-22922	2238		25	2117	2123	0.008228	2231
				2148	2319	0.991772	
SWP-1-4b bottom							
UBA-19560	11138		47	12811	13076	1	12961
UBA-22924	12190		41	13836	14166	1	14030
UBA-19561	12626		55	14547	15185	1	14923

UBA-22925	12618	46	14586	15164	1	14917
UBA-19562	13425	67	15855	16313	1	16102

SWP-1-5

UBA-19565	410	21	328	378	0.344762	456
			391	401	0.018871	
			439	497	0.636367	
UBA-22742	1657	35	1415	1582	1	1504
UBA-22743	3428	28	3512	3528	0.013505	3629
			3558	3719	0.986495	
UBA-22744	4973	29	5596	5728	1	5651
UBA-22745	6216	29	6959	7168	1	7077
UBA-22746	7559	32	8206	8263	0.154807	8348
			8290	8403	0.845193	
UBA-22747	8292	35	9035	9047	0.011584	9224
			9088	9329	0.882282	
			9342	9403	0.106134	
UBA-22748	8609	35	9480	9564	0.955713	9535
			9567	9597	0.044287	
UBA-19566	9341	42	10296	10360	0.074017	10496
			10366	10597	0.897515	
			10624	10650	0.028468	

SWP-3-1

UBA-19320	3405	32	3482	3535	0.122002	3604
			3547	3694	0.877998	
UBA-19321	3509	40	3612	3848	1	3741
UBA-19322	4661	65	5051	5191	0.201609	5354
			5213	5481	0.745676	
			5532	5578	0.052715	
UBA-19323	5454	46	6014	6081	0.097688	6221
			6104	6158	0.115457	
			6171	6301	0.786855	
UBA-21381	6212	30	6956	7167	1	7074
UBA-21382	7840	32	8455	8502	0.081029	8574
			8506	8642	0.918971	
UBA-19324	9354	52	10296	10359	0.069114	10512
			10367	10668	0.930886	
UBA-19325	10717	52	12553	12718	1	12651
UBA-19326	12874	84	15060	15648	1	15310

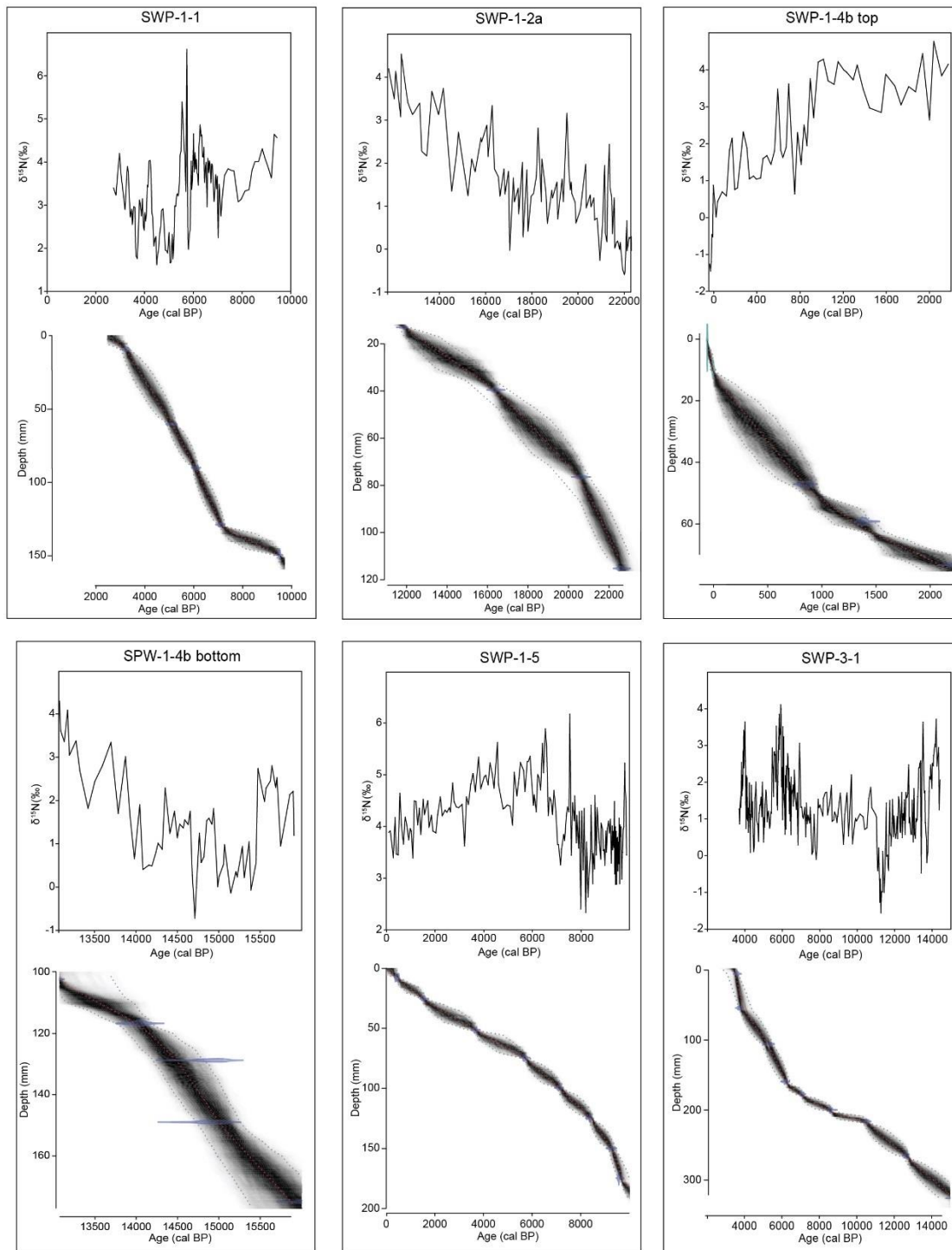


Figure S1: Stable nitrogen isotope results from the Seweweekspoort rock hyrax midden considered in this study with associated age models. Age-depth models were generated using the Bacon 3.0.3 software package (Blaauw and Christen, 2011).

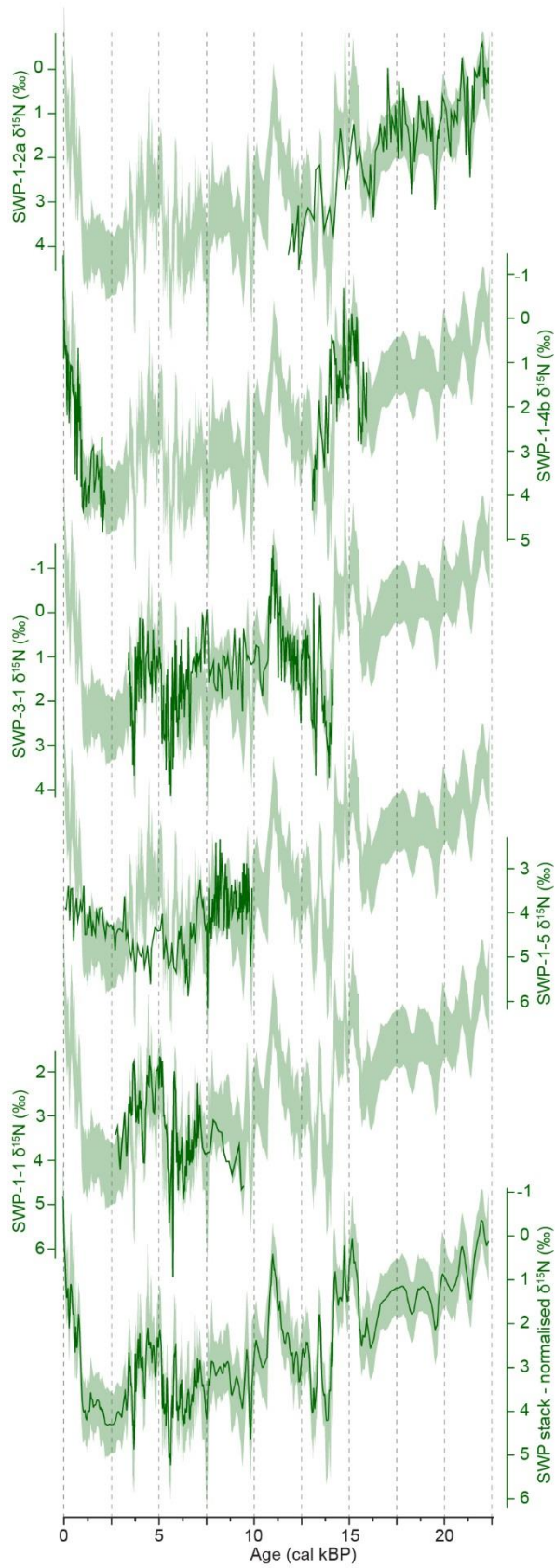


Figure S2: Stable nitrogen isotope results from the Seweweekspoort rock hyrax midden shown individually in relation to the aggregate record obtained using Local Regression (LOESS) curve fitting of the combined datasets. For comparability, 1.5‰ was added to the $\delta^{15}\text{N}$ data from the SWP-3-1 to compensate for the more humid microclimate, relative to the SWP-1 site, in which the midden was found.

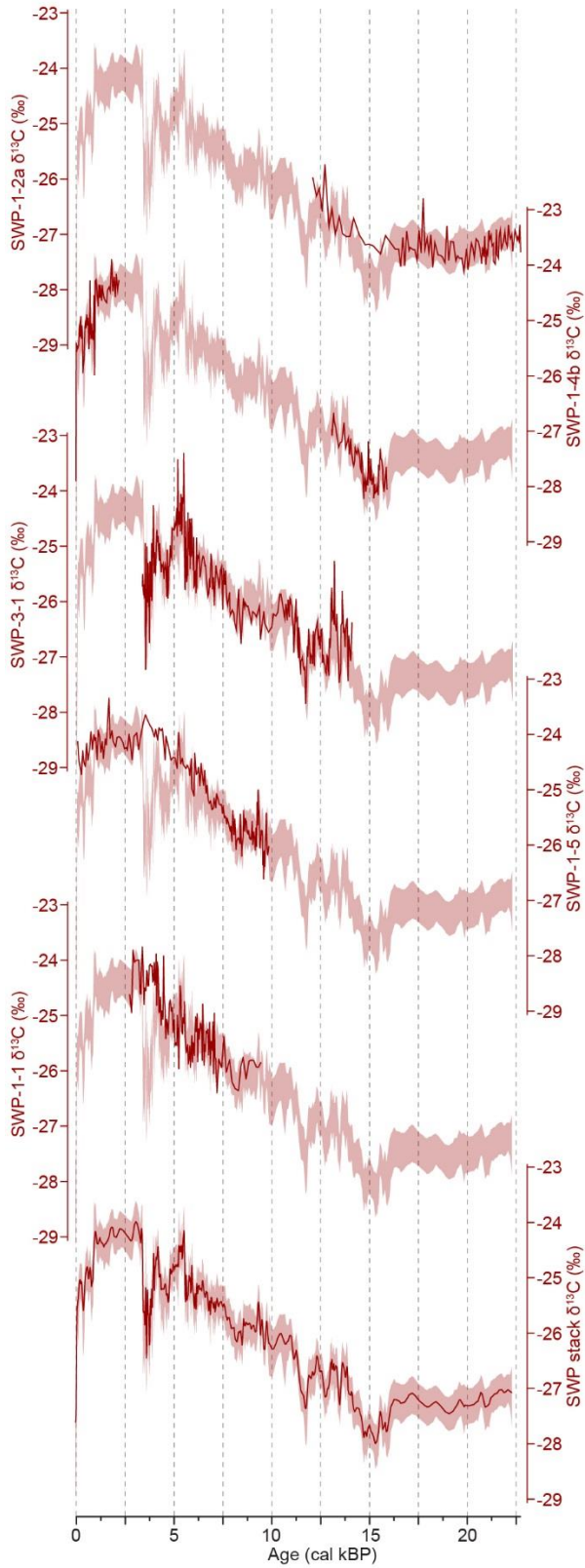


Figure S3: Stable carbon isotope results from the Seweweekspoort rock hyrax midden shown individually in relation to the aggregate record obtained using Local Regression (LOESS) curve fitting of the combined datasets.

909

910

911

912 *Faunal and archaeological archives*

913 Taxonomic abundances of ungulates from Boomplaas Cave were derived from Faith (Faith,
 914 2013), with Klein’s (Klein, 1983) data used for the uppermost member DGL. Comparable data
 915 for the Boomplaas microfauna were derived from Avery (Avery, 1982). We conducted a
 916 detrended correspondence analysis (DCA) for both data sets, using the first axis (rescaled from
 917 0 to 100) to broadly summarize faunal composition (Figure 3). The linear trends in both
 918 taxonomic groups closely parallel a decline in ungulate grazers (Figure 3), suggesting that the
 919 DCA Axis 1 scores are related to the replacement of grasslands by more shrubby habitats (see
 920 also Faith, 2013). Parallel changes are also observed at Nelson Bay Cave (Klein, 1983) and
 921 Byneskranskop 1 (Schweitzer and Wilson, 1983), implying regional shifts in habitat structure.

922 Zooarchaeological indicators of foraging efficiency at Boomplaas Cave (Table S2),
 923 including the relative abundance of small-bodied prey (leporids and tortoises) and the average
 924 utility of high-survival body parts (following the taphonomic model of bone survivorship
 925 outlined in Cleghorn and Marean (Cleghorn and Marean, 2004)), were derived from Faith
 926 (Faith, 2011). Despite small body size, because tortoises are slow-moving and easy to capture,
 927 they might be considered a high-ranked prey type that should be collected whenever
 928 encountered (e.g. Stiner et al., 2000). While this makes tortoises a somewhat ambiguous
 929 indicator, the parallel increase in leporids – unequivocally a low-ranked prey type – across the
 930 LGIT more definitively suggests a decline in foraging efficiency that parallels changing body
 931 part representation for large-bodied prey.

Table S2: Zooarchaeological indicators of foraging efficiency at Boomplaas Cave. These include the relative abundance of tortoises (%), leporids (%), and mean food utility index of high-survival body parts belonging to size 3-4 mammals (FUI).

Stratum	% Tortoises	% Leporids	FUI
BLD3	74.6	30.9	1405
FBL/BLA	79.1	28.7	1737
BRL/BRL1	61.8	10.4	1465
BRL2	71.7	13.5	1910
BRL3	78.1	24.2	1610
BRL4	74.1	24.2	2245
BRL5	80.3	36.2	2432
BRL6	68.2	15.2	2246
BRL7	70.9	22.3	2188
CL1	68.9	8.5	2028
CL2	71.9	3.6	2037

CL3	47.1	4.4	1840
CL4	54.5	0.0	1458

932

933 Ages for Boomplaas follow Deacon (1982), calibrated using SHCal13 (Hogg et al.,
934 2013). All lithic data are taken from Deacon (1982), standardised to site mean (standardised
935 value = (layer value – site mean) / site standard deviation). We use core to tool ratios to track
936 changes in the way in which technology was delivered; alternative measures such as core to
937 flake ratios may increase or decrease with changing intensity of core reduction independent of
938 delivery systems. All the measures of technological change we employ for the Boomplaas
939 assemblage are significantly correlated with changes in ungulate community composition, and
940 most with the composition of micromammal communities (Table S3).

941 As with the faunal data, the technological trends noted for Boomplaas are replicated at
942 Byneskranskop (Schweitzer and Wilson, 1983) (Table S4) and Nelson Bay Cave (Deacon,
943 1982) (Table S5) (methods as per Boomplaas), with the exception of changes in artefact
944 density. Given the coastal location of these two sites, changes in artefact density – effectively
945 number of artefacts per unit sediment – are likely to have been influenced by changes in
946 sedimentation associated with sea level fluctuations (Chase and Thomas, 2007). Microlithic
947 technologies in the forms of bladelets do reappear at Byneskranskop and Nelson Bay Cave
948 during the more arid conditions of the mid-Holocene, along with backed artefacts, reinforcing
949 arguments for the diversity of contexts in microlithic systems were deployed (Hiscock et al.,
950 2011).

951

Table S3: The correlation between lithic technological indicators and faunal community composition (DCA Axis 1 scores) for ungulates and microfauna at Boomplaas Cave. Significant values in bold.

	Ungulates		Microfauna	
	r_s	p	r_s	p
%Bladelets	-0.696	0.004	0.878	<0.001
Core/tool	-0.842	<0.001	0.680	0.015
Tool/aft	0.732	0.002	-0.674	0.012
CCS+Silcrete	-0.604	0.017	0.484	0.094
Density	-0.618	0.014	0.355	0.234

Table S4: Technological measures of the assemblage from Byneskranskop. Ages following (Loftus et al., 2016).

Layer	Age (cal yr BP)	Core/tool	Tool/aft	CCS+Silcrete	Density	Bladelets
1	1715-1870	-0.568	-0.232	-0.954	-0.834	-1.084
2	3450-3818	-0.616	1.608	-0.142	-1.253	-0.868
3		-0.589	1.579	0.325	-0.581	0.740
4	3720-3970	-0.605	1.380	0.387	-0.682	-0.696
5	6015-6290	-0.665	1.591	1.947	0.031	0.845
6	6315-6495	-0.617	1.223	1.542	0.090	1.119
7	5905-6180	-0.564	0.650	0.828	0.218	1.665
8	6285-6410	-0.578	0.314	1.339	1.017	0.540
9	6740-6945	-0.593	0.162	0.845	0.634	0.752
10		-0.511	-0.350	0.537	0.194	-0.475
11	6505-6740	-0.522	-0.708	-0.010	2.304	1.288
12	8342-8725	-0.457	-0.509	0.413	1.936	-0.548
13		-0.196	-0.711	-0.557	-0.448	-0.514
14	10796-11245	0.053	-0.988	-1.174	-0.939	-1.372
15	11245-11695	1.926	-1.004	-1.439	-1.315	-1.359
16		0.963	-1.002	-1.359	-1.013	-1.046
17	13855-14320	0.168	-0.992	-0.689	-0.728	0.290
18		0.886	-0.986	-1.254	0.534	-0.827
19	16060-16535 16550-17105	3.086	-1.025	-0.583	0.835	1.549

Table S5: Technological measures of the assemblage from Nelson Bay Cave. Ages following (Loftus et al., 2016).

Layer	Age (cal yr BP)	Core/tool	Tool/aft	CCS+Silcrete	Density	Bladelets
Ivan	5330-5655 5590-5730	-1.037	3.073	1.597	1.370	-0.369
BSC		-0.891	0.163	-0.034	1.920	-0.499
Rice A	9030-9400	-0.849	0.006	-1.443	-0.611	-0.650
Rice B	9305-9520 9460-9545	-0.610	-0.039	-1.404	-0.707	-0.636
Jake	10275-10590	0.082	-0.301	-1.536	-0.541	-0.650
BSBJ	11405-11975	0.260	-0.476	-1.572	-0.576	-0.634
CS	11825-12400	2.730	-0.590	-1.295	-0.742	-0.612
BSL	12020-12515 13775-14135	-0.501	-0.334	1.464	-0.532	0.000
GSL		0.133	-0.525	1.266	-0.794	0.440
YSL	17645-18050	0.412	-0.499	3.105	1.213	2.775
YGL	21960-22485 22615-23355	0.271	-0.477	-0.150	1.370	0.834

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