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1 **Behind white-tailed deer teeth: A micro- and mesowear analysis**
2 **from three Panamanian pre-Columbian archaeological sites**

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35 **Abstract**

36 The white tailed-deer (*Odocoileus virginianus* Zimmermann 1780) is one of
37 the largest mammals in Holocene America. It was a primary resource for
38 pre-Columbian communities in the wooded savannas of Panama for several
39 millennia. The oldest remains yet found refer to the Late Preceramic period
40 (6000-4500 cal yr BP), when people were already farming (i.e. at Cerro
41 Mangote). Deer bones, antlers, and inferentially, sinews and skins, were
42 used for tools, ornaments, musical instruments, and furniture. A prominent
43 role in regional (i.e., Greater Coclé) symbolism is evidenced by the frequent
44 representation of these cervids on ceramic, gold, and bone art objects at
45 hierarchized villages and burial grounds during the period 2300-500 cal yr
46 BP. We infer the duration and seasonality of human-deer interactions across
47 a region characterized climatically by ~4 month intense dry seasons, and
48 ~8 month unpredictable wet seasons. We combine microwear and
49 mesowear analyses of deer teeth at three pre-Columbian sites with different
50 time spans –Cerro Mangote (AG-1) (5900-3020 cal yr BP), Sitio Sierra (AG-
51 3) (2300-500 cal yr BP), and Cerro Juan Díaz (LS-3) (2300-400 cal yr BP)–.
52 The two dental wear methods indicate that the white-tailed deer was a
53 browser at these sites. The microwear results, based on the degree of
54 variability in the numbers of microwear traits such as scratches and pits,
55 show that white-tailed deer hunting was restricted to wet seasons at Cerro
56 Mangote and Cerro Juan Díaz while, at Sitio Sierra, different kinds of
57 occupational events involving white-tailed deer occurred throughout the
58 year.

59

60 **Key words**

61 *Odocoileus virginianus*; microwear; mesowear; Sitio Sierra; Cerro Mangote;
62 Cerro Juan Díaz; Panama

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75 **1. Introduction**

76 **1.1 The white-tailed deer**

77 The white-tailed deer (*Odocoileus virginianus* Zimmermann 1780) is one of
78 the largest extant mammals in tropical America whose body mass averages
79 50 kg for males, and 30 kg for females (Emmons, 1999). This species is
80 notably protean in its choice of habitat, being able to adapt to vegetated
81 deserts, savannas, prairies, mountains, and both temperate deciduous, and
82 tropical dry and evergreen forests (Smith, 1991). Generally, the white-
83 tailed deer avoids densely wooded biomes. Behaviorally, it is plastic, and
84 trophically, it is opportunistic especially in regard to its consumption of
85 human food crops. It chooses relatively nutritious and highly digestible
86 plants and plant parts, such as young leaves (Eisenberg, 1989; Smith,
87 1991; Teer, 1994; Arceo et al., 2005; Gallina et al., 2010). However, it also
88 feeds on grasses, sedges, nuts, fungi, fruits, and fallen flowers (Eisenberg,
89 1989; Smith, 1991; Gallina et al., 2010; Ramírez Lozano, 2012).

90 Habitat use by this deer species is predicated upon the quality, quantity,
91 and heterogeneity of available forage (Sánchez-Rojas et al., 1997; Gallina
92 et al., 2010; Ramírez Lozano, 2012). Diet varies among seasons due to
93 discontinuities in the availability of food, cover, and water (Sánchez-Rojas
94 et al., 1997). In high rainfall periods, a large quantity of food resources
95 becomes available to the deer although, paradoxically, dietary diversity may
96 be diminished at the beginning of the rains when the deer become more
97 selective, choosing young leaves of trees, shrubs, and vines (Sánchez-Rojas
98 et al., 1997; Bello et al., 2001; 2004; Arceo et al., 2005). Dry seasons are
99 critical periods during which the deer orientate their foraging towards the
100 most nutritious fruits, and leaves trees, shrubs and herbs that are then
101 available (Sánchez-Rojas et al., 1997; Bello et al., 2001; 2004; Arceo et al.,
102 2005).

103 **1.2 Pre-Columbian targeting of white-tailed deer on the Pacific** 104 **watershed of Panama**

105 Zooarchaeological data show that the white-tailed deer was a targeted
106 mammal species across the ancient anthropogenic savannas of central
107 Pacific Panama for at least 8000 cal years (Cooke et al., 2007; 2008). It
108 merits the term “apex species,” not only for its primary role in human
109 dietary well-being and in social feasting events (Martínez-Polanco and
110 Cooke, 2019), but also for affording a ready supply of raw material for
111 making tools and personal ornaments. In addition, after about 2300 cal yr
112 BP, adult male white-tailed deer became prominent actors in the symbolic
113 realm of the Greater Coclé culture area being often depicted in diverse ways
114 on painted and modelled ceramic art and on goldwork (Cooke, 2004b;
115 2011; Cooke and Jiménez-Acosta, 2010).

116 This paper concentrates on three pre-Columbian sites located within 15 km
117 of the active Pacific coast of Parita Bay – Cerro Mangote (AG-1), Sitio Sierra

118 (AG-3), and Cerro Juan Díaz (LS-3) (Figure 1), which is the most north-
119 westerly extension of the much more extensive Panama Bay. Politically,
120 Parita Bay belongs today to the provinces of Herrera and Coclé, and,
121 geographically, it represents the north-eastern corner of the Azuero
122 Peninsula. Known in popular parlance as the dry crescent (*Arco Seco*), its
123 eponym (Parita) refers to the paramount chieftain who held sway over
124 several chiefdoms that abutted onto Panama Bay during the immediately
125 pre-Conquest years (1515 and 1522) (Haller, 2004; Isaza Aizpurua, 2007;
126 2013; Cooke et al., 2008). The term dry crescent refers to the fact that
127 strong north-south trade winds accentuate desiccation during the usually 4
128 to 5 month dry season in this region (Cooke et al., 2008). All over the
129 isthmus, wet season precipitation is heavily influenced by orography, and,
130 in the vicinity of Parita Bay, convectional up-lift, and electric storms are less
131 pronounced than elsewhere. During the wet season (May-December), the
132 landscape is green and lush, and seasonal swamps form in low-lying areas.
133 Fresh water is provided by rivers, which rise in the central mountain range
134 (Cordillera Central), or down the north-south hilly spine of the Azuero
135 Peninsula. During the sunny dry season (strongest in January-April) the
136 water table falls dramatically and evapo-transpiration is very rapid. Some
137 streams (but not the largest rivers) dry out, and vegetation cut for clearing
138 fields burns quickly (Cooke et al., 2008). By April, the landscape has
139 become brown and parched (Cooke et al., 2008). Vegetation history has
140 documented an early Holocene onset of fire-induced forest removal in the
141 central Pacific lowlands and foothills, except for gallery forests included
142 some tall trees (e.g. *barrigón* (*Bombax barrigon*) and *higuerón* (*Ficus*
143 spp.)), which remain lush and tall along stretches of major rivers, such as
144 the Santa María, Parita and La Villa, in whose watersheds the referred three
145 sites are located (Piperno, 2011b) (See Figure 2 a. and f.). Surviving
146 wooded patches contain many fire-tolerant taxa that have xeromorphic
147 characteristics (i.e. microphyllous leaves, thorns, leaves, and thick bark) as
148 well as drought-adapted tree species, such as *chumico* (*Curatella*
149 *americana*), and *nance* (*Byrsonima crassifolia*), which often occur in large
150 stands (Linares, 1977: Figure 3). This was the kind of anthropogenic
151 environment that nurtured human-white-tailed deer symbiosis during most
152 of the Pre-Columbian Era.

153 Our objective in this article is to use microwear and mesowear analysis of
154 teeth in order to infer the duration and seasonality (wet versus dry season)
155 of human interactions with white-tailed deer at three Panamanian
156 archaeological sites with different chronologies and unequal population size
157 and density – Cerro Mangote (AG-1), Sitio Sierra (AG-3), and Cerro Juan
158 Díaz (LS-3).

159 **2. Regional setting**

160 Cerro Mangote (AG-1), Sitio Sierra (AG-3), and Cerro Juan Díaz (LS-3) are
161 now located respectively eight, 13 and four km inland from the active
162 coastline of Parita Bay in central Pacific Panama, (provinces of Coclé and
163 Herrera) (Figure 1). The Pre-Columbian landscape in the vicinity of the

164 three sites would not have been identical, but would have comprised
165 variable combinations of wooded savanna (with extensive open and/or
166 grassy areas), dry forest remnants especially on hills, tidal flats,
167 mangroves, freshwater seasonal swamps, and mature gallery forest along
168 larger rivers (Cooke et al., 2008). Since about 6000 cal years ago, the
169 deltas of the Santa María and Parita rivers have been prograding seawards.
170 Delta formation is particularly rapid at the outlet of the Santa María because
171 of its particularly large sediment load due to its length of 145 km from its
172 source in the central cordillera, to Parita Bay (Clary et al., 1984; Weiland,
173 1984; Cooke and Ranere, 1999; Isaza Aizpurua, 2007; 2013).

174 **Cerro Mangote (AG-1):** is today located in Aguadulce District, Coclé
175 Province, Panama at the edge of Parita Bay, and just landward of a zone of
176 high tidal flats (Clary et al., 1984; Cooke and Ranere, 1999). It is situated
177 on the flattish summit (~48 m a.s.l.) of a small hill located on the north
178 bank of the Santa María River (Figure 1). The active marine shore would
179 have been only 2 km away at the time people stopped living there on a
180 regular basis (Cooke, 1984; Cooke and Ranere, 1999). Excavations were
181 conducted by McGimsey in 1955 and by Ranere in 1979 (McGimsey, 1956;
182 1958; Ranere, 1979; McGimsey et al., 1986; Cooke and Ranere, 1992c). It
183 is a small site (ca. 2250 m²) that was used exclusively as a dwelling for a
184 maximum of 2880 years (5900-3020 cal yr BP) (Table 1). The shell-bearing
185 kitchen middens spread across the hill's summit are assigned exclusively
186 to the Late Preceramic in the regional cultural sequence (McGimsey, 1956;
187 1958; Ranere, 1979; McGimsey et al., 1986; Cooke and Ranere, 1992c).
188 Burial activities, however, continued long after the abandonment of the
189 dwelling site, by which time pottery was in use (4425-2010 cal yr BP)
190 (Smith-Guzmán, personal information, August 2019). Isotope proportions
191 (C and N) calculated from human bone collagen infer a predominantly
192 terrestrial diet that included significant amounts of C₃ plants, but with input
193 from C₄ plants, whose source is likely to have been maize (Norr, 1995;
194 Cooke et al., 1996). Cerro Mangote had a small catchment area, over
195 which the mammals most frequently hunted were white-tailed deer and
196 raccoon (*Procyon lotor*) (whose isthmian subspecies is known to prefer
197 mangroves), green and black iguanas (*Iguana iguana* and *Ctenosaura*
198 *similis*), and several bird species from marine edge, mangrove, dry forest,
199 and riverine biomes (Cooke et al., 2013a). Aquatic foods comprised
200 inshore molluscs and crabs, and almost exclusively marine fish with a clear
201 bias towards the capture of oligohaline marine catfish (Ariidae), snook
202 (*Centropomus* spp.), and toadfish (*Batrachoides* spp.), as well as smaller
203 sleepers (*Dormitator latifrons*) from inshore pools. Non-fish vertebrates
204 provided as much dietary meat as fish (Cooke and Ranere, 1989; 1992a;
205 Cooke, 1992; Mayo and Cooke, 2005).

206 Ranere's (1979) interpretation of the stratigraphy at Cerro Mangote is that
207 there are only two major culture-bearing zones, which he named the "Red
208 Zone" and the "Brown Zone". During the red zone occupation, which is
209 estimated to have lasted from ca 5900 cal yr B.P. to ca 5500 cal yr B.P., the
210 intensity of human settlement was not sufficient to modify the natural (red

211 clay) character of the soil development with organic matter. The more
212 intense brown zone occupation apparently added much larger amounts of
213 organic matter, and built up from ca 5500 B.P. to ca 4500 cal yr B.P. or
214 whenever the first Monagrillo complex pottery entered the record (Willey
215 and McGimsey, 1954; Ranere, 1979; Cooke and Ranere, 1992c). Table 1
216 presents radiocarbon data for the site and a description of each occupation
217 zone.

218 **Sitio Sierra (AG-3):** is located 4 km south-east of La Loma village
219 (Aguadulce District, Coclé Province, Panama), on the north bank of the
220 River Santa María, and 12.5 km straight line distance from its current
221 marine outlet (Figure 1). This site was excavated by Richard Cooke from
222 1971 to 1975 (Cooke, 1979; 1984; Isaza Aizpurua, 1993; 2007). This
223 village was established by the end of the second millennium BP, and people
224 were still living there at the time of the conquest (1515-1519 CE). It
225 appears to have been occupied continually based on the unbroken ceramic
226 sequences (Cooke, 2011). There is no evidence that it was a high-ranked
227 village in a chiefdom known to be under the aegis of Escoria at Spanish
228 contact (Cooke et al., 2003; Cooke, 2011). The subsistence pattern of this
229 population at about 1500 cal yr BP comprised fishing (30% freshwater and
230 70% marine fish) and hunting mostly deer, iguanas, and freshwater turtles
231 (Cooke and Ranere, 1989; Cooke et al., 1996; Cooke and Ranere, 1999;
232 Cooke et al., 2007; 2008; 2013a). Carbonized macrobotanical remains were
233 found in some quantity in houses and rubbish dumps at AG-3. Nearly 99%
234 belong to maize, and many fragments of legged maize-grinding tables
235 (*metates*) and grinding stones (*manos*) were deposited on structure floors,
236 and in trash heaps. Squash (*Cucurbita* sp.) pollen and phytoliths were
237 identified in domestic contexts. Carbonized palm nuts (*Attalea butyracea*)
238 were probably collected in nearby fields where these palms are usually left
239 standing today during de-vegetation for pastures and fields (Dickau, 2005;
240 2010) (see Figure 2 c.).

241 In the 1975 excavations, two major areas were opened, and worked by
242 *décapage*: Cut A and Cut B. Table 1 presents a list of the features employed
243 for this study together with their inferred functions. In most cases, animal
244 remains were found on in pit fills, and in refuse lenses found adjacent to
245 houses or thrown over their living floors (Cooke, 1979:35).

246 **Cerro Juan Díaz (LS-3):** is located on the coastal plain bordering Parita
247 Bay and on both banks of the tidal valley of the Parita River. The site is
248 dominated by a 42 m-high hill located in Los Santos Province (Figure 1).
249 Today, Cerro Juan Díaz is 4.3 Km inland from the active marine shore
250 although, when the settlement was thriving, it would have been 0.25 - 1
251 Km closer to the coast (Cooke et al., 1998). Fieldwork was carried out by
252 an international team under Cooke's supervision from 1992 to 2001. Eleven
253 field "operations" were performed here, each one with different dimensions
254 ranging from 2 x 1 m test pits to an 800 m² *décapage* excavation (Cooke
255 et al., 1998; 2000). Cerro Juan Díaz is a residential-cum-mortuary site
256 (2300-400 cal yr BP), where dwelling floors, kitchen middens, and trash

257 pits, alternate with graves, many of which have multiple burials with
258 individuals treated for death in different ways (Díaz, 1999; Cooke et al.,
259 2000). Residential areas, shell and bone artifact workshops (Mayo, 2004;
260 Mayo and Cooke, 2005), and several ritual zones including burials and
261 associated features, such as stone-walled ovens, were located. Also, there
262 is evidence for low-level modification of the hill's topography by the ancient
263 inhabitants of the site who, for example, leveled the southern section of the
264 hill where some of the burials were placed, and which probably functioned
265 as a social or ritual space used for gatherings (Cooke et al., 1998; 2000).
266 Some grave units at Cerro Juan Díaz contained individuals buried with
267 special artifacts, such as hammered gold plaques, carefully crafted marine
268 shell necklaces and other personal ornaments made of marine shells,
269 including thorny oyster (*Spondylus* spp.), and preforated teeth of carnivores
270 including jaguar (*Panthera onca*), puma (*Puma concolor*), and ocelot
271 (*Leopardus pardalis*) (Sánchez, 1995; Cooke et al., 1998; Díaz, 1999). The
272 subsistence economy of this population was mixed: marine shellfish
273 gathering; fishing in inshore waters and tidal rivers; agriculture heavily
274 biased towards maize; hunting emphasizing iguanas, birds, white-tailed
275 deer, and smaller terrestrial mammals (Jiménez-Acosta and Cooke, 2001;
276 Cooke et al., 2007; 2013a; Isaza Aizpurua, 2007; Cooke and Jiménez-
277 Acosta, 2008).

278 In sum, Cerro Juan Díaz presents a complex stratigraphy produced by
279 multiple activities carried out in the same settlement over at least 1900
280 years (i.e., burials and associated activities, dwellings, kitchen refuse,
281 workshops, and social and residential areas). In table 1, we present the
282 radiocarbon dates and a brief description of the operations.

283 **3. Materials and Methods**

284 **3.1 Materials**

285 We selected all available white-tailed deer dental material from the three
286 sites. For mesowear analysis, we sampled 124 teeth (Cerro Juan Díaz
287 n=70; Sitio Sierra n=20; Cerro Mangote n=34). In order to perform
288 microwear analysis, 102 teeth were employed (Cerro Juan Díaz, n=57; Sitio
289 Sierra, n=18; Cerro Mangote, n=27). In both cases, we selected only
290 adults, taking into account the degree of wear of the teeth, not including
291 the most worn ones, and also the teeth without wear. In the case of Cerro
292 Juan Díaz, we selected teeth from operations 1, 3, 4, 5 and 31. We sampled
293 all contexts at Sitio Sierra (A3, A2-1 / A2-2, A1-1 / A1-2, B4, B3, and B2).
294 At Cerro Mangote, we focused our sample on the brown zone, which
295 represents the more intense occupation in the site.

296 **3.2 Methods**

297 **3.2.2 Microwear and mesowear**

298 Analyses of microwear and mesowear allow different kinds of dietary
299 inferences. Broadly speaking, microwear distinguishes among browsers,
300 grazers, and mixed feeders (Solounias and Semperebon, 2002). Since plant
301 species, and their component parts, vary with regard to hardness and

302 abrasiveness, distinct patterns are etched into the tooth enamel in the form
303 of microscopic pits and scratches (Solounias and Semprebon, 2002).
304 Patterns are produced quickly, and are continuously overwritten.
305 Consequently, they indicate the type of diet during the last days or weeks
306 before an individual's death (Grine, 1986). In addition, paleoenvironmental
307 conditions, food preferences, and dietary ecology can be inferred weeks, or
308 even days, before an animal dies (Solounias and Semprebon, 2002; Davis
309 and Pineda Munoz, 2016; DeSantis, 2016; Xafis et al., 2017).

310 Microwear patterns are also sensitive to seasonal, local and individual
311 variations in diet (Semprebon et al., 2016). This variability depends to a
312 degree upon how long it took a death assemblage to accumulate (Rivals et
313 al., 2009) and, by inference, how long, or at which season of the year,
314 people lived in a given locality (Rivals and Semprebon, 2011; Sánchez-
315 Hernández et al., 2014; Rivals and Takatsuki, 2015). In addition, microwear
316 is capable of identifying whether archaeological assemblages are the result
317 of a short death event, or of multiple ones over longer periods of time
318 (Rivals et al., 2015). Taking into account that, firstly, scratches in the
319 enamel are sensitive to seasonal variation, and, secondly, that each season
320 may be associated with specific foods, it stands to reason that that each
321 season produces a specific microwear signal. The more seasonal are the
322 mortality events, the more diverse will be the range of food and the
323 microwear signal (Rivals et al., 2011; Rodríguez-Hidalgo et al., 2016). By
324 using the standard deviation and the coefficient of variation, analysis of
325 scratch variability permits distinguishing short or long mortality events
326 (Rivals et al., 2015).

327 On the other hand, mesowear reflects the physical characteristics of the
328 plants that the animals consume, which are visible on the occlusal relief and
329 overall shape of the molar cusps (Fortelius and Solounias, 2000). For
330 example, browser diets show little abrasion and molars are characterized by
331 sharp buccal cusp apices. Conversely, grazers have abrasive diets and they
332 ingest grit. Thus, their molars have more rounded and blunt apices. To sum
333 up, mesowear results from attrition and abrasion over a long period of time,
334 and reflects the annual diet of an animal (Fortelius and Solounias, 2000;
335 Rivals et al., 2013; 2017; Amano et al., 2016).

336 *Tooth mesowear:* Mesowear analysis involves the observation of cusp
337 morphology, and proceeds by describing the sharpness and the relief of
338 molar tooth cusps (Fortelius and Solounias 2000). These attributes are
339 scaled from 0 (more sharp) to 6 (more blunt); mesowear is scored on each
340 specimen and then averaged for each sample (Mihlbachler et al., 2011;
341 Rivals et al., 2013; 2017).

342 *Tooth microwear:* We follow the method proposed by Solounias and
343 Semprebon (2002) and Semprebon et al. (2004). Microwear analysis
344 comprises several steps: 1) selecting teeth, 2) making a mould of the
345 occlusal surface using a material appropriate for dental impressions, such as
346 polyvinylsiloxane, 3) making a cast using transparent epoxy. In order to
347 observe the epoxy casts under incident light, we used a Zeiss Stemi 2000C

348 stereomicroscope at 35× magnification. The microwear features (pits and
349 scratches) were quantified on the enamel bands, and on the mesiobuccal
350 cusp of the second molar within a standard (0.4 x 0.4 mm) area by using
351 an ocular reticle. Counting the scratches allows distinguishing three dietary
352 categories: browsers (numbers of scratches in the range of 0-17), grazers
353 (numbers of scratches in the range of 17.5-29.5), and mixed feeders which
354 present some overlapping values (Solounias and Semperebon, 2002). In
355 order to compare the variability of the scratches and the pits, we performed
356 a two-way variance analysis (ANOVA) without replication when the data
357 meet the assumptions to carry out the test, while, in the opposite case, we
358 performed a Kruskal-Wallis test and a Mann-Whitney pairwise test in order
359 to identify differences between groups. In this article, the R code proposed
360 by Rivals (2019) was used to create the bivariate plots.

361 *Scratch variability:* We also quantified the variability of the number of
362 scratches, in order to estimate the relative duration of the occupation of the
363 sites by following Rivals et al. (2015). This tool allows to distinguish among
364 three types of human occupations (A. Seasonal or shorter events; B.
365 Longer- than- a- season events; C. Two separated events) according to
366 their position on the heat map of the scratches' coefficient of variation (X-
367 axis) and the scratches' standard variation (Y-axis).

368 **4. Results**

369 *Tooth mesowear:* In Table 2 we present the results of the mesowear
370 analysis. Mesowear analysis shows very low values indicating that white-
371 tailed deer diet at the archaeological sites was low in abrasiveness -- a
372 situation that is similar to that of present-day typical browsers or browse-
373 dominated mixed feeders. It is likely that Cerro Mangote deer were heavier
374 browsers than those hunted at the other sites, although the difference is not
375 statistically significant (Figure 3). However, the Kruskal-Wallis test shows
376 that there are no significant differences between the three sites ($H=0.06$;
377 $p=0.96$).

378 *Tooth microwear:* The number of scratches and pits is low in the three cases
379 (Table 2), locating their values in the lower part of the 95% confidence
380 ellipse in comparison to the modern browsers (Figure 4). Microwear analysis
381 indicates that deer were typical browsers at the time of death. There is no
382 significant difference in the number of scratches among the three sites
383 ($F=1.82$; $gl=2$; $p=0.16$). However, there are significant differences in pits
384 among the three sites (Table 1). The number of pits is highest at Sitio
385 Sierra ($H=6.06$; $p=0.04$). Table 3 summarizes graphically the differences in
386 pit variation among the samples from Sitio Sierra, Cerro Mangote and Cerro
387 Juan Díaz, and shows that there no differences in the case of Cerro Mangote
388 and Cerro Juan Díaz.

389 *Scratch variability:* Scratch variability at Cerro Mangote is low (see Figure
390 5) falling in Area a on the heat map, and thus corresponding to seasonal or
391 shorter events. In the case of Cerro Juan Díaz, it is not possible clearly to
392 distinguish scratch variability because it falls on the boundary between

393 areas a and b. On the other hand, scratch variation at Sitio Sierra is
394 notably higher than at the other sites, falling in area b of the heat map, and
395 thus indicating several events at different time of the year or events
396 distributed over one or several years (Figure 5).

397 **5. Discussion**

398 This study presents mesowear and microwear analyses of white tailed deer
399 teeth from three Panamanian pre-Columbian sites located in the so-called
400 dry crescent of the central Pacific lowlands of the isthmus. The low scratch
401 and pit variation in the samples from Cerro Mangote and Cerro Juan Díaz
402 suggests that white-tailed deer were more likely to have been hunted at
403 these sites during the rainy season (May-December) when the deer were
404 more selective about their diet, and focused on the young leaves of
405 particular shrub and vine taxa (Sánchez-Rojas et al., 1997; Bello et al.,
406 2001; 2004; Arceo et al., 2005). On the other hand, at Sitio Sierra, deer
407 were likely hunted mostly during the dry season since pits and pit variation
408 have a higher frequency in these samples than in those from Cerro Mangote
409 and Cerro Juan Diaz. A wide diversity of available plant species and plant
410 parts (e.g. fruits, seeds, leaves and woody forage) from several taxa of
411 shrubs and trees, are conducive to a more variable white-tailed deer diet
412 during the dry months (Sánchez-Rojas et al., 1997; Bello et al., 2001;
413 2004; Arceo et al., 2005).

414 Martínez-Polanco and Cooke (2019) presented a detailed zooarchaeological
415 and taphonomical study of the white-tailed deer at Sitio Sierra. They
416 describe a communal feasting event at which deer meat was consumed in
417 large quantity. Socially, holding communal feasts of this nature would have
418 been more practical and appealing between late December and late April,
419 than during the rainy and stormy months. Dry season is the time of year
420 when the communities of the Pacific-side Ngäbe (formerly Western Guaymí)
421 held their stick-throwing competitions – the *krun* (Ngäbere) or *balsería*
422 (Spanish) –, which were attended by many people from dispersed hamlets
423 scattered over the landscape, and which offered great prestige to the
424 individual or kin group that had been able to accrue sufficient food and
425 fermented maize beverages – known as *do kwaga* in Ngäbere and *chicha*
426 *fuerte* in Panamanian Spanish) – for feeding a throng of guests (Young,
427 1976).

428 The Maya, whose realms were situated further north on the Central
429 American isthmus, linked the white-tailed deer to agriculture, the sun, rain,
430 and the cyclical nature of time – features that they believed were the
431 supernatural correlates of fecundity and prosperity (Pohl, 1981; Brown,
432 2001). According to Pohl (1981) the Maya still hold feasts in mid-December
433 in the hope of a good harvest the following year, and no harvest ceremony
434 can be held until the agricultural cycle has been formally concluded. The
435 Maya situation described by Pohl lends support to the hypothesis that the
436 feasting event identified at Sitio Sierra was timed for the early dry season
437 when cobs are harvested rapidly in order to diminish weevil (Curculionidae:

438 *Sitophilus zeamais*) and avian attacks (e.g., in Panama's case, parrots and
439 parakeets [*Amazona*, *Aratinga*, and *Pionus* spp.] (Cooke et al., 2013a)).

440 Cerro Mangote is a considerably older dwelling-site than Cerro Juan Diaz
441 and Sitio Sierra (likely maximum span, 7800-5500 cal yr BP), and, covering
442 2250m² (McGimsey, 1956), its lifestyle and subsistence were
443 understandably quite different from that of the Sitio Sierra nucleated
444 village. The earliest Late Preceramic inhabitants of this hill-top settlement
445 consumed maize according to microbotanical data (Piperno, 2011b) -- an
446 issue discussed in greater detail below --, and two coeval rock-shelters did
447 so also. At one of these -- the Aguadulce Shelter (AG-13) --, located ca 18
448 km inland from the Parita Bay shoreline in a narrow coastal plain (Ranere
449 and Hansell, 1978; Piperno et al., 2000). At this site, Late Preceramic
450 cultigens included, in addition to maize, squash (*Cucurbita moschata*), *lerén*
451 (*Calathea allouia*), bottle gourd (*Lagenaria siceraria*), arrowroot (*Maranta*
452 *arundinacea*), manioc (*Manihot esculenta*), and, possibly, an American yam
453 (*Dioscorea* sp.) (Piperno, 2011a). These domesticates would have needed
454 rain to germinate and sprout.

455 The multi-cultigen Late Preceramic agriculture in the lands bordering Parita
456 Bay was enhanced by palms, such as the American oil palm (*Elaeis*
457 *oleifera*), whose easily-collected and bunched orange-red fruits provide an
458 oil, which would have afforded an important source of calories (see Figure 2
459 e.). Carbonized remains of the American oil palm have only been identified
460 at the Aguadulce Shelter among the Parita Bay sites, and they dominated
461 the macrobotanical assemblage here during all periods, including the Late
462 Preceramic (Dickau, 2010) -- meriting the consideration that the intensive
463 exploitation and processing of this palm's fruits was a major wet season
464 activity at the Aguadulce Shelter (Cooke and Ranere, 1992b). Ecologically,
465 this makes sense since the American oil palm forms large stands in poorly
466 drained soils, which leave the palms under water during the rainiest
467 periods. Such habitats surround the Aguadulce Shelter today. Carbonized
468 parts of the fruits of *coyol* or wine palm (*Acrocomia aculeata*), whose fruits
469 have an edible mesocarp, a hard oily kernel, edible hearts, and a sap used
470 today for making palm wine (See Figure 2 d.). Carbonized seeds of the
471 fruits of the fire-resistant *nance* tree (*Byrsonima crassifolia*), which today is
472 made into drinks and flavoured desserts, and would have provided an
473 important source of vitamins in the past, were found under the shelter, too.
474 Lastly, phytolith and pollen evidence shows that maize was used at the
475 Cueva de los Ladrones rockshelter (LP-1) from the very bottom of its Late
476 Preceramic occupation (7800–7630 cal yr BP) (Piperno et al., 1985;
477 Piperno, 2011b). At this early stage of maize's evolution, of course, it would
478 not have been as productive as varieties used at the later villages (Cooke,
479 1984: 283-286; Dickau, 2010: Table 2). At such an early stage of
480 development, of course, maize would have been far less productive than
481 varieties used at Panamanian villages until about 2300 cal yr BP (Galinat,
482 1980; Cooke, 1984:283-286). The discovery at El Gigante rockshelter, in
483 Honduras, of robustly domesticated productive staple grain landraces with
484 10-14 rows, which were directly AMS-dated between 4,340 and 4,020 cal yr

485 BP (Kennett et al., 2017), suggests that the timing of the appearance in the
486 regional diet of productive staple maize landraces has not yet been
487 identified on the isthmus of Panama.

488 Archaeologists who work in Panama have discussed whether Cerro Mangote
489 was occupied preferentially during the dry season, and whether its
490 temporary residents participated in a seasonal round, moving from site to
491 site and changing subsistence activities as the optimality of resources varied
492 seasonally (Piperno and Pearsall, 1998: 293; Cooke, 2005: 142). The
493 question is whether the denizens of coastal sites such as late Preceramic
494 Cerro Mangote (7800-5500 cal yr BP) and the Early Ceramic Monagrillo site
495 (4500-3200 cal yr BP) would have preferentially fished during the dry
496 months when this activity was purportedly more practical. But, there are
497 multiple issues with this supposition. Artisanal fishing practiced today
498 around Parita Bay does not offer a perfect analogy with pre-Spanish fishing
499 practices since it relies mostly on dug-out and gunwaled canoes with
500 outboard motors. Before the recent globalization of fishing practices in
501 Panama, however, modern fisherfolk often preferred to stay in port during
502 the dry season because of the strength of on-shore winds and the real
503 dangers of capsizing. Falling into shallow waters in Parita Bay would have
504 been dangerous in ancient times because of the threat caused by large
505 inshore sharks, such as hammerheads (*Sphyrna* spp.), tiger-shark
506 (*Galeocerdo cuvier*) and bull-shark (*Carcharhinus leucas*) (Cooke et al.,
507 2016). Estuary-loving American crocodiles (*Crocodylus acutus*) would have
508 represented another genuine threat to life in those pre-firearm days. It is
509 understandable why these afore-named marine animals were so prominent
510 in the painted and modelled ceramic art of the Greater Coclé semiotic
511 tradition, which materialized in the last five centuries BCE (Cooke, 2011),
512 because, on a cognitive level, these animals would have required
513 supernatural appeasement mediated by shamans (Cooke, 2004a; Cooke
514 and Jiménez-Acosta, 2010).

515 At the time of the shell-bearing middens, in which our deer samples were
516 laid down at Cerro Mangote, between 8000 and 5500 cal yr BP, fishing was
517 bimodal, comprising a focus on fish taxa whose body masses averaged 0.7
518 kg weight, and were likely taken in mangrove channels and tidal rivers close
519 by the site, and a second strategy concentrating on smaller fish, such as fat
520 sleepers (Eleotridae: *Dormitator latifrons*), which became entrapped in
521 desiccating *albina* pools when the rains stopped, when they could be easily
522 have been caught by hand or with scoops (Cooke and Ranere, 1999).
523 Fishing strategies around Parita Bay had changed, however, by 4500 cal yr
524 BP (Cooke, 1992): thereafter, human consumption focused on small fish
525 under about 200 g live weight, which move into estuarine waters in large
526 shoals, and are most economically trapped with inter-tidal barrier tidal traps
527 that do not require complex technology (Cooke and Tapia, 1994; Zohar and
528 Cooke, 1997; 2019). Until the last decade, when globalization caused great
529 changes in traditional fishing in Panama, a sizable proportion of catches
530 around Parita Bay was salted and wind-and-sun dried, and then exported or
531 carried to inland communities. In pre-Columbian times, salt would have

532 been most economically obtained by scraping the salt-laden dried out
533 surface of the *albinas* during dry periods, and then boiled down in clay
534 vessels. Arguments have been made that the coast to interior movement of
535 fish was prevalent in pre-Conquest times (Carvajal-Contreras et al., 2008)
536 and it is substantiated by finds of the bones of small thread-herrings
537 (Clupeidae: *Opisthonema libertate*), long-fin herrings (Pristigasteridae:
538 *Ilisha fuerthii*) and croakers (Sciaenidae: *Ophioscion typicus*) in the Early
539 Ceramic middens at the Cueva de los Ladrones rock-shelter, located 20 km
540 inland (Cooke, 2001; Carvajal-Contreras et al., 2008).

541 Dry seasons at Cerro Mangote, then, would have *facilitated* both drying and
542 salting fish, and collecting sleepers in *albina* pools, but that does not mean
543 that fishing was ignored during the wet months. A dry season occupation of
544 Cerro Mangote may also have coincided temporally with trapping
545 over-wintering shore birds, e.g., whimbrel (*Numenius phaeopus*), willet
546 (*Catoptrophorus semipalmatus*), and small calidrid sandpipers, as well as
547 iguana-hunting by night in the mangroves (Cooke, personal observation in
548 mangroves near Cerro Mangote). All these taxa were reported in the
549 middens at Cerro Mangote (Cooke et.al 2007; Cooke et al., 2013b). But,
550 there again, arguing for rigid seasonality in this case is counter-intuitive:
551 exploiting birds and iguanas could have been practiced by people who
552 stayed year-round at the site. In sum, dry and wet seasons favoured
553 different subsistence activities at Cerro Mangote, and wet season occupation
554 is substantiated by the mass collection of the mangrove crab (Gecarcinidae:
555 *Cardisoma crassum*) (Ranere, 1979; McGimsey et al., 1986). This crab
556 species is very abundant at the beginning of the wet season (late April-
557 June), when vast numbers congregate at the landward edges of mangroves,
558 where they can be trapped using collective methods (Bright, 1966).

559 Even though the maize planted at Cerro Mangote (Norr, 1995; Dickau,
560 2010; Piperno, 2011a) would not have yet attained the foliage density and
561 kernel-size of later varieties, the large number of grinding implements in
562 the kitchen midden (some with maize phytoliths incrustated on them) is
563 consistent with constant maize use, and the existence of nearby fields
564 (McGimsey, 1956; Ranere, 1979; Piperno, 2011a). It is well known that
565 crops planted in fields or garden plots increase the deer population because
566 deer prefer second-growth vegetation, and would thus have benefitted from
567 the disturbance of primary forest cover for opening garden plots and fields
568 (Smith, 1991; Teer, 1994; Geist, 2000; Gallina et al., 2010; Cherry et al.,
569 2018). It is interesting to pointed out that even the palm fruit availability in
570 the area our results do not evidence that deer consumed it.

571 Lastly, as an addendum, the fact that isotope data for intensive maize
572 consumption at Cerro Mangote (Norr, 1995; Cooke et al., 1996: 114 figure
573 5), which is very similar to Sitio Sierra's, would appear to be at odds with
574 the early maize that, we argue, would have been sown in Cerro Mangote's
575 fields or garden plots, on-going evaluation of the burials at this site by
576 Smith-Guzmán (personal communication, August 2019) is confirming that
577 their calibrated [INTCAL 13] ¹⁴C age spans the time period between 2475

578 BCE and 230 CE. Therefore, Norr's published isotope estimates for high
579 maize consumption at Cerro Mangote should correspond temporally, not to
580 the shell-bearing middens there, but to a time-span during when large-
581 kernelled and multi-rowed productive races were likely being consumed.

582 At Cerro Juan Díaz, seasonality for deer hunting could not be evidenced
583 from the microwear analysis. Two alternatives stand out: firstly, Cerro Juan
584 Díaz represents a village occupied all year round, and secondly, inferring
585 only wet season hunting is a sampling issue because we used samples from
586 different excavation units or "operations," which could belong to dissimilar
587 occupational events. This may explain their location on the boundary
588 between area A and B on the heat map (Figure 5). But the discovery at
589 Cerro Juan Diaz of several funerary precincts spanning at least 1800
590 calendar years, some of which show evidence for discrete burial groups with
591 connotations of kinship relationships and ancestor-worship (Cooke and
592 Sánchez Herrera, 1997; Cooke et al., 1998; 2000; Díaz, 1999), argues
593 strongly for long-term sedentary occupation.

594 **6. Conclusion**

595 Microwear and mesowear analyses address the issue of the times of year
596 when deer hunting was practiced at three sites bordering Parita Bay in the
597 strongly seasonal dry crescent of Pacific Panama: Cerro Mangote (AG-1),
598 Cerro Juan Díaz (LS-3), and Sitio Sierra (AG-3). At two sites located in two
599 different watersheds with markedly different calibrated radiocarbon ages,
600 and very different population sizes -- Cerro Mangote and Cerro Juan Díaz --,
601 the tooth wear data infer that the ubiquitous white-tailed deer were likely
602 hunted mostly during the wet season (May to November). On the contrary,
603 results from Sitio Sierra show that white-tailed deer were hunted
604 preferentially during the early dry season (December to April) when
605 productive varieties of maize would have been nearing collection or already
606 harvested, and rapidly consumed during seasonal festivities evinced by our
607 taphonomic studies.

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618 **References**

619 Amano, N., Rivals, F., Moigne, A.M., Ingicco, T., Sémah, F., Simanjuntak,
620 T., 2016. Paleoenvironment in East Java during the last 25,000 years
621 as inferred from bovid and cervid dental wear analyses. *Journal of*

- 622 Archaeological Science: Reports 10, 155–165.
623 doi:10.1016/j.jasrep.2016.09.012
- 624 Arceo, G., Mandujano, S., Gallina, S., Perez-Jiménez, L.A., 2005. Diet
625 diversity of white-tailed deer (*Odocoileus virginianus*) in a tropical dry
626 forest in Mexico. *Mammalia* 69, 159–168.
627 doi:10.1515/mamm.2005.014
- 628 Bello, J., Gallina, S., Equihua, M., 2001. Characterization and Habitat
629 Preferences by White-Tailed Deer in Mexico. *Journal of Range
630 Management* 54, 537. doi:10.2307/4003582
- 631 Bello, J., Gallina, S., Equihua, M., 2004. Movements of the white-tailed deer
632 and their relationship with precipitation in Northeastern Mexico.
633 *Interciencia* 29, 357-361+403.
- 634 Bright, D.B., 1966. The land crabs of Costa Rica. *Revista de Biología
635 Tropical* 14, 183–203.
- 636 Brown, L.A., 2001. Feasting on the periphery: The production of ritual
637 feasting and village festival at the Cerén site, El Salvador. In: Dietler,
638 M., Hayden, B. (Eds.), *Feasts. Archaeological and Ethnographic
639 Perspectives on Food, Politics and Power*. Smithsonian Institute Press,
640 Washington, D.C., pp. 368–390.
- 641 Carvajal-Contreras, D.R., Cooke, R.G., Jiménez-Acosta, M., 2008.
642 Taphonomy at two contiguous coastal rockshelters in Panama:
643 Preliminary observations focusing on fishing and curing fish. *Quaternary
644 International* 180, 90–106. doi:10.1016/j.quaint.2007.08.027
- 645 Cherry, M.J., Chandler, R.B., Garrison, E.P., Crawford, D.A., Kelly, B.D.,
646 Shindle, D.B., Godsea, K.G., Miller, K. V., Conner, L.M., 2018. Wildfire
647 affects space use and movement of white-tailed deer in a tropical pyric
648 landscape. *Forest Ecology and Management* 409, 161–169.
649 doi:10.1016/j.foreco.2017.11.007
- 650 Clary, J., Hansell, P., Ranere, A.J., Buggey, T., 1984. The Holocene geology
651 of the western Parita Bay coastline of central Panama. In: Lange, F.
652 (Ed.), *Recent Developments in Isthmian Archaeology*. BAR editions,
653 Oxford, pp. 55–83.
- 654 Cooke, R.G., 1979. Los impactos de las comunidades agrícolas
655 precolombinas sobre los ambientes del trópico estacional: datos del
656 Panamá prehistórico. In: *Actas Del IV Simposio Internacional de
657 Ecología Tropical*. Tomo III. pp. 2–57.
- 658 Cooke, R.G., 1984. Archaeological research in central and eastern Panama:
659 a review of some problems. In: *The Archaeology of Lower Central
660 America*. pp. 263–302.
- 661 Cooke, R.G., 1992. Prehistoric nearshore and littoral fishing in the eastern
662 Tropical Pacific: An ichthyological evaluation. *Journal of World
663 Prehistory* 6, 1–49. doi:10.1007/BF00997584
- 664 Cooke, R.G., 2001. La pesca en estuarios panamaños: una visión histórica y
665 cultural desde la Bahía de Parita. *Panama: Puente Biológico* 45–53.

- 666 Cooke, R.G., 2004a. Observations on the religious content of the animal
667 imagery of the "Gran Coclé" semiotic tradition of pre-Columbian
668 Panama. In: O´Day, S., Neer, W. Van, Eryvynck, A. (Eds.), Behaviour
669 behind Bones : The Zooarchaeology of Ritual, Religion, Status and
670 Identity. Oxbow Books, pp. 114–127.
- 671 Cooke, R.G., 2004b. Rich, poor, shaman, child: animals, rank, and status in
672 the 'Gran Coclé' culture area of pre-Columbian Panama. In: Jones
673 O´Day, S., Neer, W. Van, Eryvynck, A. (Eds.), Behaviour behind Bones :
674 The Zooarchaeology of Ritual, Religion, Status and Identity. pp. 271–
675 284.
- 676 Cooke, R.G., 2005. Prehistory of native Americans on the Central American
677 land bridge: Colonization, dispersal, and divergence. *Journal of*
678 *Archaeological Research*. doi:10.1007/s10804-005-2486-4
- 679 Cooke, R.G., 2011. The Gilcrease collection and the Gran Coclé. In: *To*
680 *Capture the Sun : Gold of Ancient Panama*. Gilcrease Museum, Tulsa,
681 pp. 129–173.
- 682 Cooke, R.G., Jiménez-Acosta, M., 2008. Marine Catfish (Ariidae) of the
683 Tropical Eastern Pacific: An Update Emphasising Taxonomy,
684 Zoogeography, and Interpretation of Pre-Columbian Fishing Practices.
685 *Archéologie du poisson : 30 ans d'archéo-ichtyologie au CNRS* 161–179.
- 686 Cooke, R.G., Jiménez-Acosta, M., 2010. Animal-derived artefacts at two
687 pre-columbian sites in the ancient savannas of Central Panama. An
688 update on their relevance to studies of social hierarchy and cultural
689 attitude towards animal. In: *Anthropological Approaches to*
690 *Zooarchaeology: Complexity, Colonialism, and Animal Transformations*.
691 pp. 79–86.
- 692 Cooke, R.G., Ranere, A.J., 1989. Hunting in pre-columbian Panama: A
693 diachronic perspective. In: Clutton-Brock, J. (Ed.), *The Walking Larder:*
694 *Patterns of Domestication, Pastoralism, and Predation*. Unwin Hyman,
695 London, pp. 295–315.
- 696 Cooke, R.G., Ranere, A.J., 1992a. Precolumbian influences on the
697 zoogeography of Panama: An update based on archaeofaunal and
698 documentary data. In: Darwin, S.P., Welden, A.L. (Eds.), *Biogeography*
699 *of Mesoamerica*. Tulane University, pp. 21–58. doi:10.1111/j.0033-
700 0124.1985.00482.x
- 701 Cooke, R.G., Ranere, A.J., 1992b. Prehistoric human adaptations to the
702 seasonally dry forests of Panama. *World Archaeology* 24, 114–133.
- 703 Cooke, R.G., Ranere, A.J., 1992c. The Origin of Wealth and Hierarchy in the
704 Central Region of Panama (12,000-2,000 BP). In: *Wealth and Hierarchy*
705 *in the Intermediate Area*. pp. 243–316.
- 706 Cooke, R.G., Ranere, A.J., 1999. Precolumbian Fishing on the Pacific Coast
707 of Panama. *Pacific Latin America in Prehistory: The evolution of Archaic*
708 *and Formative Cultures* 103–121.
- 709 Cooke, R.G., Sánchez Herrera, L.A., 1997. Coetaneidad de metalurgia,
710 artesanías de concha y cerámica pintada en cerro Juan Díaz, Gran

- 711 Coclé, Panamá. Boletín Museo del Oro 42, 57–85.
- 712 Cooke, R.G., Tapia, G., 1994. Fishing and Paleoeconomy. pp. 287–298.
- 713 Cooke, R.G., Norr, L., Piperno, D.R., 1996. Native Americans and the
714 Panamanian landscape. In: Reitz, E.J., Newsom, L.A., Scudder, S.J.
715 (Eds.), *Case Studies in Environmental Archaeology*. Plenum Press, pp.
716 103–126.
- 717 Cooke, R.G., Sánchez Herrera, L.A., Isaza, I., Pérez, A., 1998. Rasgos
718 mortuorios y artefactos inusitados de Cerro Juan Díaz. Una aldea
719 precolombina del Gran Coclé. *Revista La Antigua* 53, 127–196.
- 720 Cooke, R.G., Sánchez Herrera, L.A., Udagawa, K., 2000. Contextualized
721 goldwork from “Gran Coclé”, Panama. In: McEwan, C. (Ed.),
722 *Precolumbian Gold. Technology, Style and Iconography*. British Museum
723 Press, London, pp. 153–176.
- 724 Cooke, R.G., Isaza Aizpurua, I., Griggs, J., Desjardins, B., Sánchez Herrera,
725 L.A., 2003. Who Crafted, Exchanged, and Displayed Gold in Pre-
726 Columbian Panama? In: Quilter, J., Hoopes, J. (Eds.), *Gold and Power*
727 *in Ancient Costa Rica, Panama and Colombia*. *Dumbarton Oaks*
728 *Research Library and Collection*, Washington, D.C., pp. 91–158.
- 729 Cooke, R.G., Jiménez-Acosta, M., Ranere, A.J., 2007. Influencias humanas
730 sobre la vegetación y fauna de vertebrados de Panamá: Actualización
731 de datos arqueozoológicos y su relación con el paisaje antrópico. In:
732 *Ecología y Evolución En Los Trópicos*. Nova art, Panamá, pp. 562–593.
- 733 Cooke, R.G., Jiménez-Acosta, M., Ranere, A.J., 2008. Archaeozoology, art,
734 documents, and the life assemblage. In: Reitz, E.J., Newsom, L.A.,
735 Scudder, S.J., Scarry, C.M. (Eds.), *Case Studies in Environmental*
736 *Archaeology*. New York, pp. 95–121.
- 737 Cooke, R.G., Steadman, D.W., Jiménez-Acosta, M., Aizpurua, I.I., 2013a.
738 Pre-Columbian exploitation of birds around Panama Bay. *The*
739 *Archaeology of Mesoamerican Animals* 479–530.
- 740 Cooke, R.G., Ranere, A., Pearson, G., Dickau, R., 2013b. Radiocarbon
741 chronology of early human settlement on the Isthmus of Panama
742 (13,000–7000BP) with comments on cultural affinities, environments,
743 subsistence, and technological change. *Quaternary International* 301,
744 3–22. doi:10.1016/j.quaint.2013.02.032
- 745 Cooke, R.G., Wake, T.A., Martínez-Polanco, M.F., Jiménez-Acosta, M.,
746 Bustamante, F., Holst, I., Lara-Kraudy, A., Martín, J.G., Redwood, S.,
747 2016. Exploitation of dolphins (Cetacea: Delphinidae) at a 6000 yr old
748 Preceramic site in the Pearl Island archipelago, Panama. *Journal of*
749 *Archaeological Science: Reports* 6. doi:10.1016/j.jasrep.2015.12.001
- 750 Davis, M., Pineda Muñoz, S., 2016. The temporal scale of diet and dietary
751 proxies. *Ecology and Evolution* 6, 1883–1897. doi:10.1002/ece3.2054
- 752 DeSantis, L.R.G., 2016. Dental microwear textures: Reconstructing diets of
753 fossil mammals. *Surface Topography: Metrology and Properties* 4,
754 23002. doi:10.1088/2051-672X/4/2/023002

- 755 Díaz, C., 1999. Estudio bioantropológico de rasgos mortuorios de la
756 Operación 4 del sitio arqueológico Cerro Juan Díaz, Panamá Central.
757 Universidad de los Andes.
- 758 Dickau, R., 2005. Resource use, crop dispersals, and the transition to
759 agriculture in prehistoric Panama: Evidence from starch grains and
760 macroremains. Temple University.
- 761 Dickau, R., 2010. Microbotanical and Macrobotanical Evidence of Plant Use
762 and the Transition to Agriculture in Panama. doi:10.1007/978-1-4419-
763 0935-0
- 764 Eisenberg, J., 1989. Mammals of the Neotropics. University of the Chicago
765 Press, Chicago.
- 766 Emmons, L., 1999. Mamíferos de los bosques húmedos de América tropical.
767 Editorial FAN, Santa Cruz.
- 768 Fortelius, M., Solounias, N., 2000. Functional Characterization of Ungulate
769 Molars Using the Abrasion-Attrition Wear Gradient: A New Method for
770 Reconstructing Paleodiets. American Museum Novitates 3301, 1–36.
771 doi:10.1206/0003-0082(2000)301<0001:FCOUMU>2.0.CO;2
- 772 Galinat, W.C., 1980. The Archaeological Maize Remains from Volcan
773 Panama--A Comparative Perspective. In: Linares, O.F., Ranere, A.J.
774 (Eds.), In Adaptive Radiations in Prehistoric Panama. Peabody Museum
775 of Harvard University, Cambridge, pp. 175–180.
- 776 Gallina, S., Mandujano, S., Bello, J., López Arévalo, H., Weber, M., 2010.
777 White-tailed deer *Odocoileus virginianus* (Zimmermann 1780). In:
778 Barbanti Duarte, J.M., González, S. (Eds.), Neotropical Cervidology.
779 Biology and Medicine of Latin American Deer. Jaboticabal, pp. 110–118.
- 780 Geist, V., 2000. Descent, adaptation, adjustment: lessons from the
781 Cervidae and other beasts. In: Vrba, E.S., Schaller, G.B. (Eds.),
782 Antilopes, Deer, and Relatives. Fossil Record, Behavioral Ecology,
783 Systematics, and Conservation. Yale University Press, New Haven and
784 London, pp. 180–188.
- 785 Grine, F.E., 1986. Dental evidence for dietary differences in
786 *Australopithecus* and *Paranthropus*: a quantitative analysis of
787 permanent molar microwear. *Journal of Human Evolution* 15, 783–822.
788 doi:10.1016/S0047-2484(86)80010-0
- 789 Haller, M.J., 2004. The emergence and development of chiefly societies in
790 the Rio Parita valley, Panama. University of Pittsburgh.
- 791 Isaza Aizpurua, I., 1993. Desarrollo estilístico de la cerámica pintada del
792 Panamá central con énfasis en el periodo 500 AC-500 DC. Universidad
793 Autónoma de Guadalajara.
- 794 Isaza Aizpurua, I., 2007. The ancestors of Parita: Pre-Columbian settlement
795 patterns in the lower La Villa River Valley, Azuero Peninsula, Panama.
- 796 Isaza Aizpurua, I., 2013. Los dominios sureños del cacicazgo de Parita en el
797 Gran Coclé , Panamá. *Canto Rodado* 8, 115–132.

- 798 Jiménez-Acosta, M., Cooke, R.G., 2001. Pesca Precolombina en un Estuario
799 Neotropical : el Caso de Cerro Juan Díaz (Bahía de Parita, Costa del
800 Pacífico de Panama). *Noticias de Antropología y Arqueología*.
- 801 Kennett, D.J., Thakar, H.B., Vanderwarker, A.M., Webster, D.L., Culleton,
802 B.J., Harper, T.K., Kistler, L., Scheffler, T.E., Hirth, K., 2017. High-
803 precision chronology for Central American maize diversification from El
804 Gigante rockshelter , Honduras 114, 9026–9031.
805 doi:10.1073/pnas.1705052114
- 806 Linares, O.F., 1977. Ecology and the arts in ancient Panama: On the
807 development of social rank and symbolism in the central provinces.
808 *Studies in Pre-Columbian Art and Archaeology* 7–86.
- 809 Martínez-Polanco, M.F., Cooke, R.G., 2019. Zooarchaeological and
810 taphonomical study of the white-tailed deer (*Cervidae: Odocoileus*
811 *virginianus* Zimmerman 1780) at Sitio Sierra, a Pre-Columbian village
812 in Pacific Coclé province, Panama, with an evaluation of its role in
813 feasts. *Archaeological and Anthropological Sciences*.
- 814 Mayo, J., 2004. La industria prehispánica de conchas marinas en “gran
815 coclé”, panamá. Universidad Complutense de Madrid.
- 816 Mayo, J., Cooke, R., 2005. La industria prehispánica de conchas marinas en
817 Gran Coclé , Panamá . Análisis tecnológico de los artefactos de concha
818 del basurero-taller del Sitio Cerro Juan Díaz , Los Santos , Panamá.
819 *Archaeofauna* 14, 285–298.
- 820 McGimsey, C.R., 1956. Cerro Mangote: A preceramic site in Panama.
821 *American Antiquity* 22, 151–161.
- 822 McGimsey, C.R., 1958. Further data and a date from Cerro Mangote,
823 Panama. *American Antiquity* 23, 434–435.
- 824 McGimsey, C.R., Collins, M.B., McKern, T.W., 1986. Cerro Mangote and its
825 population. *Journal of the Steward Anthropological Society* 16, 125–
826 157.
- 827 Mihlbachler, M.C., Rivals, F., Solounias, N., Semprebon, G.M., 2011. Dietary
828 change and evolution of horses in North America. *Science* 331, 1178–
829 1181. doi:10.1126/science.1196166
- 830 Norr, L., 1995. Interpreting dietary maize from stable isotopes in the
831 American tropics: the state of the art. In: Stahl, P. (Ed.), *Archaeology*
832 *in the Lowland American Tropics: Current Analytical Methods and*
833 *Applications*. Cambridge University Press, Cambridge, pp. 198–223.
- 834 Piperno, D.R., 2011a. Prehistoric human occupation and impacts on
835 Neotropical forest landscapes during the Late Pleistocene and
836 Early/Middle Holocene. In: Bush, M.B., Flenley, J.R., Gosling, W.D.
837 (Eds.), *Tropical Rain Forest Responses to Climatic Change*. Praxis,
838 Chichester, pp. 185–206.
- 839 Piperno, D.R., 2011b. The Origins of Plant Cultivation and Domestication in
840 the New World Tropics. *Current Anthropology* 52, S453–S470.
841 doi:10.1086/659998

- 842 Piperno, D.R., Pearsall, D.M., 1998. From Small-Scale Horticulture to the
843 Formative Period : The Development of Agriculture. The Origins of
844 Agriculture in the Lowland Neotropics 243–320. doi:10.1016/B978-
845 012557180-7/50006-0
- 846 Piperno, D.R., Clary, K., Cooke, R.G., Ranere, A.J., Weiland, D., 1985.
847 Preceramic maize in Central Panama: Pytolith and pollen evidence.
848 *American Anthropologist* 87, 871–878.
- 849 Piperno, D.R., Raneret, A.J., Hoist, I., Hanseit, P., 2000. Starch grains
850 reveal early root crop horticulture in the Panamanian tropical forest.
851 *Nature* 407, 894–897.
- 852 Pohl, M., 1981. Ritual Continuity and Transformation in Mesoamerica :
853 Reconstructing the Ancient Maya Cuch Ritual. *American Antiquity* 46,
854 513–529. doi:10.2307/280598
- 855 Ramírez Lozano, R., 2012. Alimentación del venado cola blanca. *Biología y*
856 *ecología nutricional*, Palibrio. ed. Bloomington.
- 857 Ranere, A.J., 1979. The re-excavation and reinterpretation of Cerro
858 Mangore: A preceramic shellmidden in Central Panama. Panamá.
- 859 Ranere, A.J., Hansell, P., 1978. Early Subsistence Patterns along the Pacific
860 Coast of Central Panama. In: Stark, B.J., Voorhies, B. (Eds.),
861 Prehistoric Coastal Adaptations: The Economy and Ecology of Maritime
862 Middle America. Academic Press, New York, pp. 43–59.
- 863 Rivals, F., 2019. MicrowearBivaR: a code to create tooth microwear
864 bivariate plots in R (Version 1).
865 doi:http://doi.org/10.5281/zenodo.2587575
- 866 Rivals, F., Semprebon, G.M., 2011. Dietary plasticity in ungulates: Insight
867 from tooth microwear analysis. *Quaternary International* 245, 279–284.
868 doi:10.1016/j.quaint.2010.08.001
- 869 Rivals, F., Takatsuki, S., 2015. Within-island local variations in tooth wear
870 of sika deer (*Cervus nippon centralis*) in northern Japan. *Mammalian*
871 *Biology* 80, 333–339. doi:10.1016/j.mambio.2015.02.001
- 872 Rivals, F., Schulz, E., Kaiser, T.M., 2009. A new application of dental wear
873 analyses: estimation of duration of hominid occupations in
874 archaeological localities. *Journal of Human Evolution* 56, 329–339.
875 doi:10.1016/j.jhevol.2008.11.005
- 876 Rivals, F., Solounias, N., Schaller, G.B., 2011. Diet of Mongolian gazelles
877 and Tibetan antelopes from steppe habitats using premaxillary shape,
878 tooth mesowear and microwear analyses. *Mammalian Biology* 76, 358–
879 364. doi:10.1016/j.mambio.2011.01.005
- 880 Rivals, F., Rindel, D., Belardi, J.B., 2013. Dietary ecology of extant guanaco
881 (*Lama guanicoe*) from Southern Patagonia: seasonal leaf browsing and
882 its archaeological implications. *Journal of Archaeological Science* 40,
883 2971–2980. doi:10.1016/j.jas.2013.03.005
- 884 Rivals, F., Prignano, L., Semprebon, G.M., Lozano, S., 2015. A tool for
885 determining duration of mortality events in archaeological assemblages

- 886 using extant ungulate microwear. doi:10.1038/srep17330
- 887 Rivals, F., Uzunidis, A., Sanz, M., Daura, J., 2017. Faunal dietary response
888 to the Heinrich Event 4 in southwestern Europe. *Palaeogeography,*
889 *Palaeoclimatology, Palaeoecology* 473, 123–130.
890 doi:10.1016/j.palaeo.2017.02.033
- 891 Rodríguez-Hidalgo, A., Rivals, F., Saladié, P., Carbonell, E., 2016. Season of
892 bison mortality in TD10.2 bone bed at Gran Dolina site (Atapuerca):
893 Integrating tooth eruption, wear, and microwear methods. *Journal of*
894 *Archaeological Science: Reports* 6, 780–789.
895 doi:10.1016/j.jasrep.2015.11.033
- 896 Sánchez-Hernández, C., Rivals, F., Blasco, R., Rosell, J., 2014. Short, but
897 repeated Neanderthal visits to Teixoneres Cave (MIS 3, Barcelona,
898 Spain): A combined analysis of tooth microwear patterns and
899 seasonality. *Journal of Archaeological Science* 49, 317–325.
900 doi:10.1016/j.jas.2014.06.002
- 901 Sánchez-Rojas, G., Gallina, S., Mandujano, S., 1997. Área de actividad y
902 uso del hábitat de dos venados cola blanca (*Odocoileus virginianus*) en
903 un bosque tropical caducifolio de la costa de Jalisco, México.
- 904 Sánchez, L.A., 1995. Analisis Estilístico de Dos Componentes Ceramicos de
905 Cerro Juan Diaz: Su Relacion con el Surgimiento de las Sociedades
906 Cacicales en Panama. Universidad de Costa Rica.
- 907 Semprebon, G.M., Godfrey, L.R., Solounias, N., Sutherland, M.R., Jungers,
908 W.L., 2004. Can low-magnification stereomicroscopy reveal diet?
909 *Journal of Human Evolution* 47, 115–144.
910 doi:10.1016/j.jhevol.2004.06.004
- 911 Semprebon, G.M., Rivals, F., Solounias, N., Hulbert, R.C., 2016.
912 Paleodietary reconstruction of fossil horses from the Eocene through
913 Pleistocene of North America. *Palaeogeography, Palaeoclimatology,*
914 *Palaeoecology* 442, 110–127. doi:10.1016/j.palaeo.2015.11.004
- 915 Smith, W., 1991. *Odocoileus virginianus*. *Mammalian species* 1–13.
916 doi:10.1016/B978-0-12-388437-4.00011-9
- 917 Solounias, N., Semprebon, G.M., 2002. Advances in the Reconstruction of
918 Ungulate Ecomorphology with Application to Early Fossil Equids.
919 *American Museum Novitates* 3366, 1–49. doi:10.1206/0003-
920 0082(2002)366<0001:AITROU>2.0.CO;2
- 921 Teer, J., 1994. El venado cola blanca: historia natural y principios de
922 manejo. In: Vaughan, C., Rodríguez, M. (Eds.), *Ecología y Manejo Del*
923 *Venado Cola Blanca En México y Costa Rica*. EUNA, Heredia, pp. 32–48.
- 924 Weiland, D., 1984. Prehistoric settlement patterns in the Santa María
925 drainage of Panama: a preliminary analysis. In: Lange, F.W. (Ed.),
926 *Recent Developments in Isthmian Archaeology*. Oxford (International
927 Series 212), Oxford, pp. 31–53.
- 928 Willey, G., McGimsey, C.R., 1954. The Monagrillo Culture of Panama.
929 *Papers of the Peabody Museum of Archaeology and Ethnology* 49, 1–
930 233.

931 Xafis, A., Nagel, D., Bastl, K., 2017. Which tooth to sample? A
932 methodological study of the utility of premolar/non-carnassial teeth in
933 the microwear analysis of mammals. *Palaeogeography,*
934 *Palaeoclimatology, Palaeoecology* 487, 229–240.
935 doi:10.1016/j.palaeo.2017.09.003

936 Young, P.D., 1976. The expression of harmony and discord ia a Guaymi
937 ritual: the symbolic meaning of some aspects of the balseria. In:
938 Helms, M., Loveland, F. (Eds.), *Frotiner Adaptations in Lower Central*
939 *America. Insitute for the Study of Human Issues, Philadelphia, pp. 37–*
940 *53.*

941 Zohar, I., Cooke, R., 2019. *Journal of Archaeological Science : Reports* The
942 *role of dried fish : A taphonomical model of fish butchering and long-*
943 *term preservation. Journal of Archaeological Science: Reports* 26,
944 101864. doi:10.1016/j.jasrep.2019.05.029

945 Zohar, I., Cooke, R.G., 1997. The impact of salting and drying on fish
946 bones: Preliminary observations on four marine species from Parita
947 Bay, Panama *Archaeofauna* 6, 59–66.

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Table captions

Table 1.

Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3) context descriptions and dates. The dates were calibrated by using INTCAL13.

Table 2.

Summary of mesowear and microwear data for the archaeological white-tailed deer (*Odocoileus virginianus*) from Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3). Abbreviations: n: sample size; MWS: Mesowear score; NS: Number of scratches; NP: Number of pits; M: mean; SD: Standard deviation; CV: coefficient of variation.

Table 3.

Mann-Whitney pairwise pit comparison between Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3).

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Table 1.

Site code	Context	Context description	Method	Material	Lab. Number	Measured date ¹	Cal BP (2 σ) ²
AG-1	Above red clay	Preceramic dump site	Radiometric	charcoal	Y-458d	6810 \pm 110	5974-5531 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	charcoal	β -1219	6670 \pm 215	6014-5215 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Protothaca	TEM-206/Beta-1703	6330 \pm 170	5617-4859 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Crassostrea	TEM-174	5990 \pm 180	5317-4488 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Crassostrea	TEM-176	5440 \pm 130	4532-3982 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Crassostrea	TEM-175	5140 \pm 120	4241-3666 BCE
AG-1	Red zone	Preceramic dump site	Radiometric	Crassostrea	TEM-207/Beta-1702	4630 \pm 150	3661-2926 BCE
AG-1	Brown zone	Preceramic dump site	Radiometric	Crassostrea	TEM-208/Beta-1704	3980 \pm 160	2901-2039 BCE
AG-1	Brown zone	Preceramic dump site	Radiometric	charcoal	β -1218	3555 \pm 100	2196-1641 BCE
AG-3	A2-1 / A2-2	Kitchen refuse	Radiometric	charcoal	I-8556	1475 \pm 110	335 – 770 CE
AG-3	B1	Floor of a circular structure	Radiometric	charcoal	I-9702	2015 \pm 80	350 BCE – 209 CE
AG-3	B1	Floor of a circular structure	Radiometric	charcoal	I-9703	1975 \pm 80	177 BCE – 224 CE
AG-3	A1-1 / A1-2	Oval domestic structure	Radiometric	charcoal	CEI-9701	1835 \pm 90	21 BCE – 395 CE
AG-3	A1-1 / A1-2	Oval domestic structure	Radiometric	charcoal	I-8613	1715 \pm 90	90 – 540 BCE
LS-3	OP.1	Kitchen refuse	AMS	Maize	TO-4594	1470 \pm 90	390-764 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1-18679	1730 \pm 80	87-107 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1-18222	1370 \pm 80	474-485 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1-18287	1310 \pm 80	583-894 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1-18288	1450 \pm 80	415-694 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1-18675	1330 \pm 110	435-450 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1-18672	1380 \pm 80	433-489 CE
LS-3	OP.3	Kitchen refuse	Radiometric	charcoal	1-18671	1570 \pm 80	265-273 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Charcoal	β -121163	1260 \pm 90	635-976 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Carbonized tallo	β -121162	1180 \pm 60	690-983 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Carbonized food	β -121157	1110 \pm 50	777-1019 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Carbonized food	β -121156	1010 \pm 60	894-1162 CE
LS-3	OP. 4	Kitchen refuse	Radiometric	Charcoal	β -121164	950 \pm 60	990-1214 CE
LS-3	OP.31	Kitchen refuse	Radiometric	charcoal	1-18681	750 \pm 80	1049-1399 CE
LS-3	OP.31	Kitchen refuse	Radiometric	charcoal	1-18682	650 \pm 110	1058-1458 CE

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¹ conventional C-14 age BP \pm 1-sigma range.² calibrated 2-sigma range BCE/CE.

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1009 **Table 2.**

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SITE	Mesowear			Microwear		
		n	MWS	n	NS	NP
LS-3	M	70	1.17	57	11.59	7.5
	SD		1.31		2.52	4.52
	CV		1.12		0.21	0.6
AG3	M	20	0.95	18	10.75	9.61
	SD		0.82		3.12	4.11
	CV		0.86		0.29	0.42
AG-1	M	34	1.02	27	10.92	7.25
	SD		1.02		1.89	3.86
	CV		1.02		0.17	0.53

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1033 **Table 3.**

	Sito Sierra (AG-3)	Cerro Juan Díaz (LS-3)
Cerro Juan Díaz (LS-3)	<i>0.02</i>	-
Cerro Mangote (AG-1)	<i>0.01</i>	0.94

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1059 **Figure captions**

1060 **Figure 1.**

1061 Geographical location of Cerro Mangote (AG-1), Sitio Sierra (AG-3) and
1062 Cerro Juan Díaz (LS-3) and pictures of the areas during the wet and dry
1063 seasons. Images Cooke's personal archive.

1064 **Figure 2.**

1065 Some examples of typical plant species of the dry crescent of the central
1066 Pacific lowlands of the isthmus of Panama.

1067 a. Barrigon (*Bombax barrigon*), a tall deciduous tree of the remnant gallery
1068 forest along the Santa María river near Sitio Sierra (AG-3). Image:
1069 Martínez-Polanco, M.F. April, 2015, Coclé province.

1070 b. Ciruelo (*Spondias purpurea*), a cultivated deciduous tree, which produces
1071 an edible fruit (hog-plum in English). Stakes of this species are planted to
1072 make living fences between pastures, usually reinforced with barbed wire
1073 fences. The juicy fruits are eaten by birds, cows, horses and humans.
1074 Image: Martínez-Polanco, M.F. April 2014, Coclé province.

1075 c. Corozo gunzo (*Attalea butyracea*). This palm species was planted around
1076 pre-Columbian settlements, and is still protected in pastures, which have
1077 been cleared for homogenizing forage. The fronds are much appreciated for
1078 roof- and wall-thatching. Image: Cooke, R. 1975, Coclé province.

1079 d. Wine palms (*Acrocomia aculeata*). Image: Dickau, R. 2005. Ancón,
1080 Panama City.

1081 e. American oil palm (*Elaeis oleifera*). Image: Dickau, R. 2005. Casita de
1082 Piedra, Chiriquí,

1083 f. Gallery woods along Santa Maria River in the late dry season. The tall
1084 palms are coconuts (*Cocos nucifera*) which were observed by the Spanish
1085 around Parita Bay in the early sixteenth century CE and appear to have
1086 been in the process of colonizing the Pacific coast of Panama. Image:
1087 Martínez-Polanco, M.F. April 2015, Coclé province.

1088 **Figure 3.**

1089 Mesowear results for the archaeological white-tailed deer (*Odocoileus*
1090 *virginianus*) from Cerro Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan
1091 Díaz (LS-3). Data on modern ungulates from Fortelius and Solounias (2000)
1092 and Rivals et al. (2013, 2017).

1093 **Figure 4.**

1094 Bivariate plot of the average numbers of pits and scratches in the
1095 archaeological white-tailed deer (*Odocoileus virginianus*) from Cerro

1096 Mangote (AG-1), Sitio Sierra (AG-3) and Cerro Juan Díaz (LS-3). Error bars
1097 correspond to standard error of the mean (± 1 SEM). Ellipses correspond to
1098 the Gaussian confidence ellipses ($p = 0.95$) on the centroid for the extant
1099 leaf browsers and grazers from Solounias and Semperebon (2002).

1100 **Figure 5.**

1101 Heat map (boundary lines of the three regions with the error probability)
1102 and the fossil samples from Cerro Mangote (AG-1), Sitio Sierra (AG-3) and
1103 Cerro Juan Díaz (LS-3). a. Seasonal or shorter events; b. Longer than a
1104 season events; c. Separated events (data from Rivals et al. 2015).

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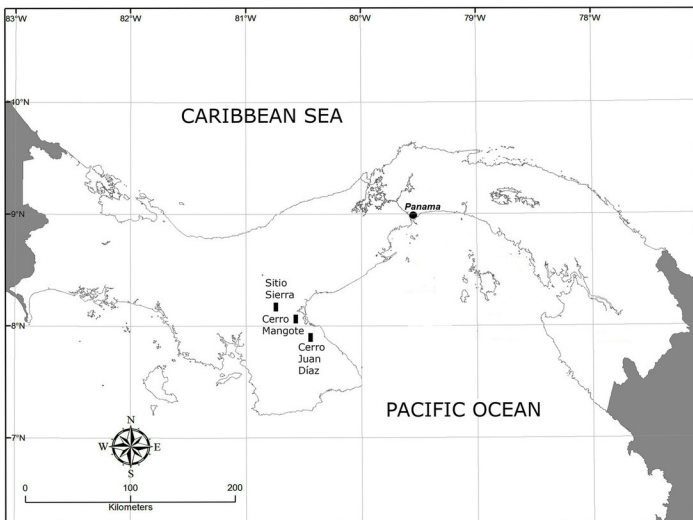
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DRY SEASON

WET SEASON



Sitio Sierra
AG-3



Cerro Mangote
AG-1



Cerro Juan Díaz
LS-3





