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Fresh water fishing among Lapita People:

The Sleepers (Teleostei: Eleotridae) of Teouma, Vanuatu

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21

Abstract

23

24 The study of the ichthyofaunal corpus yielded by the archaeological site of Teouma, Efate Island,
25 Vanuatu, has revealed the unexpected presence of a significant number of bones of Eleotridae (Sleepers) on
26 the site, as early as 2920-2870 cal. B.P. Out of the 8,560 identified fish remains associated with the Lapita
27 layers, which document the period of initial settlement of the archipelago, 1,368 have been determined as
28 belonging to eleotrids, including species of the genera *Giuris*, *Ophiocara* and *Eleotris*. They represent 16% of
29 the corpus and occupy second place among the dominant families in an assemblage composed otherwise of a
30 wide-range of marine coastal and reef-associated taxa. Even though the Lapita economy is characterised by an
31 intensive and broad-spectrum exploitation of all terrestrial and marine resources available and readily
32 procurable, the eleotrids of Teouma are the first clear evidence thus far of the exploitation of freshwater
33 environments by Lapita communities anywhere in their range. A river and a swamp are present in the vicinity
34 of the site, and hooks and lines and/or multi-pronged spears could have been used. Passive gear such as weirs,
35 fish-traps or nets might have been applied as well, enabling the capture of sleepers in larger quantities. The
36 results presented here offer an original insight of an unknown facet of Lapita subsistence strategies and aim to
37 highlight the antiquity of freshwater fishing at a regional scale.

38

Keywords

40

41 Ichthyoarchaeology; river fishing; Melanesia; Pacific Islands; subsistence strategies

42

43 INTRODUCTION

44

45 The colonisation of Vanuatu, New Caledonia and Fiji in Southern Melanesia by Lapita populations
46 about 3000 years ago (Sheppard et al., 2015) was accompanied by the spread of a Neolithic-type culture,
47 whose earliest manifestations have been identified in the Bismarck Archipelago (Specht, 2007; Sheppard,
48 2010) up to a couple of hundred years earlier. The archaeological sites associated with this *Lapita Cultural*
49 *Complex* (Green, 2003) are scattered across a vast region extending from New Guinea to Samoa (Fig.1).
50 Besides the well-known dentate-stamped and incised pottery vessels, the Lapita cultural tradition is marked
51 by a distinctive suite of shell and lithic artefacts, the introduction of Asian and Southeast Asian domesticates,
52 commensals and crops, long distance exchange networks (Spriggs, 2013), and an apparent homogeneity of
53 cultural expression.

54 Lapita settlements identified to date are overwhelmingly coastal: most of the sites are located on
55 palaeoshorelines, now forming beach ridges or low terraces above the intertidal zone, and often close to
56 freshwater sources (Frimigacci, 1980; Clark & Anderson, 2001; Bedford & Sand, 2007; Sand, 2010), such as
57 streams, rivers or intertidal springs (Clark & Anderson, 2009). Shallow bays and sheltered locations seem to
58 have been privileged as well as areas suitable for the exploitation of both marine and terrestrial resources
59 (Bedford & Spriggs, 2014).

60

61 Fig.1: Map of the Pacific with known extents of the Lapita Cultural Complex (modified from Hawkins,
62 2015: 9, fig. 2-1).

63

64 Concerning Lapita subsistence economies, researchers were previously torn between theories of a
65 strictly coastal exploitation of resources (or *Strandlooper Concept*, see Groube, 1971) and a model in which
66 horticulture and husbandry were implemented from first arrival (the idea of *Transported Landscapes*, see
67 Green, 2003; Kirch, 1997). Current interpretations strive instead for a hypothesis of opportunistic behaviour
68 and a greater diversity of practices, depending on social, environmental and/or chronological factors
69 (Kinaston et al., 2015a). Biogeochemical analyses reveal varied diet-types, composed of marine fish and
70 shellfish as well as plants and terrestrial fauna (Nunn et al., 2007; Field et al., 2009; Jones & Quinn, 2009;
71 Valentin et al., 2010b, 2014; Kinaston & Buckley, 2013; Kinaston et al., 2014b, 2015b).

72 In Vanuatu, archaeological evidence shows that the first Lapita groups who arrived c. 3000 cal. B.P.
73 (Galipaud et al., 2014; Petchey et al., 2014) relied on an intensive and broad-spectrum foraging of available
74 resources. Concentrated remains of native birds, reptiles, fruit bats and also shellfish and fish are common in
75 the layers associated with the phase of initial settlement of the archipelago (Bedford, 2006a: 258; Hawkins,
76 2015). Extinctions and extirpations of indigenous species, such as megafauna and avifauna, occurred from
77 the first decades of the human occupation (Mead et al., 2002; White et al., 2010; Worthy et al., 2015). The
78 early introduction of both exogenous plants and animals has also been documented (Horrocks et al., 2009;
79 Horrocks & Bedford, 2005, 2010; Storey et al., 2010, 2013; Horrocks et al., 2014).

80 However, and despite a clear generalist exploitation of marine and terrestrial resources, there has to
81 date been no consistent data indicating the importance of freshwater environments in Lapita subsistence
82 strategies. The researchers working at the Teouma site on Efate Island had previously mentioned the
83 possibility of a freshwater component in the diet, based on the results obtained from isotopic or lipid
84 analyses (Valentin et al., 2010b: 1826; Kinaston et al., 2014a: 14; Petchey et al., 2015: 103; Leclerc et al.,
85 2018: 715-718) and on the nature of the environmental features close to the site, in particular the Teouma
86 River. The unprecedented numbers of well-preserved ichthyofaunal remains at the site have made it possible
87 successfully to study this previously unknown aspect of the Lapita economy. In this regard, the present
88 analysis of the Teouma fishbones provides new insights and original results, as it is the first and thus earliest
89 zooarchaeological evidence of the exploitation and consumption of freshwater resources by Lapita settlers in
90 Melanesia and indeed therefore by human groups in most of the tropical islands of the Pacific.

91

92 **CONTEXT**

93

94 The archaeological site of Teouma is located on the southern coast of Efate Island, Central Vanuatu
95 (Fig.2), at the southern end of the Teouma Graben. This site was occupied continuously from the Lapita
96 period, dated 3000-2870 cal. B.P. and during the subsequent Arapus and Early Erueti periods, dated 2880-
97 2560 cal. B.P. (Petchey et al., 2014, 2015: 102), and then abandoned until the Historic period (Bedford et al.,
98 2009). Situated on a low promontory on the left bank of the Teouma River, it is today 800 m from the sea but
99 was initially coastal; eustasy and a continuous tectonic uplift (Lecolle et al., 1990; Cabioch et al., 2008) led
100 to shoreline progradation, and alluvial deposits and volcanic ashfall brought about the partial infilling of the
101 Teouma Bay over time (Bedford et al., 2010: 141).

102

103 Fig.2: Map of Efate Island with the location of the Teouma site (data NASA, SRTM v.2, 2005).

104

105 The extensive excavation of the site, carried out during six field seasons between 2004 and 2010,
106 revealed the presence of an important Lapita cemetery and an associated habitation zone, partly covered by a
107 large Post-Lapita midden (Spriggs & Bedford, 2013). A total of 67 single and multiple Lapita burials
108 containing 93 individuals, 78 adults and 15 subadults, were identified and documented (Valentin et al.,
109 2010a; Buckley et al., 2014; Bentley et al., 2018), as well as hundreds of distinctive dentate-stamped vessels,
110 some of which were uncovered nearly intact in association with burials (Bedford, 2006b; Bedford et al.,
111 2007; Valentin et al., 2015). The site also yielded numerous shell and lithic artefacts (Reepmeyer et al.,
112 2011; Constantine et al., 2015; Torrence et al., 2018), shellfish in large quantity and almost 50,000 remains
113 (NISP) of mammals, birds and reptiles, constituting by far the largest Lapita faunal assemblage excavated to
114 date (Hawkins, 2015: 63). Among them, 57 non-fish vertebrate taxa at least have been identified and studied,
115 including fruit bats, sea turtles, crocodiles, small reptiles, birds and introduced commensals such as pigs,
116 chickens and rats (Storey et al., 2010, 2013; Hawkins, 2015). Extinct megafaunal specimens of tortoise
117 (White et al., 2010), megapode (Worthy et al., 2015) and land crocodile (Hawkins, 2015) were attested in the

118 earliest layers of the site, reflecting both a rich biodiversity and the heavy exploitation of the local resources
119 by Lapita peoples on their arrival.

120 When the Lapita colonists reached Teouma Bay, sheltered from the trade winds blowing from the
121 south-east, they settled on the upper beach and on a large uplifted karstic reef terrace covered with an ancient
122 unweathered tephra. The cemetery was established at the edge of the terrace, parallel and adjacent to the
123 former shore. The occupation area was protected by limestone cliffs to its eastern and south-eastern sides and
124 bordered to the west by the sea (Bedford et al., 2009: 219). The site chosen was approximately at equal
125 distance from the mouth of the Teouma River and the shallow Emaotfer Swamp (Fig. 3; Wirmann et al.,
126 2011; Combettes et al., 2015). This ideal location on the coast and in the vicinity of various aquatic and
127 pristine environments provided the Lapita community of Teouma with a wide range of natural resources.

128 Nowadays, reef flats run along the sides of Teouma Bay and are bounded by coral drop-offs that
129 quickly reach great depths. Only the end of the embayment hosts shallow waters as well as sandy and muddy
130 bottoms, typical of estuarine environments and mainly composed of sediments flowing out from the alluvial
131 plain via the Teouma River. The shallower zones framing the reef flats, less affected by sedimentation,
132 consist of sandy and rocky bottoms punctuated by coral patches. Further west in Eratap and Erakor, islets
133 and large areas of reef flats, mangrove and seagrass meadows dot the littoral zone, sheltering conspicuous
134 biodiversity.

135

136 Fig.3: Map of the Teouma Bay and its surroundings, with a focus on the current bathymetric and
137 geomorphologic features (modified from Admiralty Publications and Maps, 1987).

138

139 Although species richness decreases progressively when moving away from the Coral Triangle,
140 Vanuatu's ichthyofauna is still remarkable, with estimates of more than 1500 reef-associated taxa (Randall,
141 2005; Cowman, 2014). In addition, biodiversity inventories mention almost 70 freshwater fish species in the
142 archipelago (Keith et al., 2010). Indo-Pacific insular freshwater systems are mainly dominated by
143 amphidromous species (Keith et al., 2015), especially sicydiine gobies (Gobiidae) and sleepers (Eleotridae).
144 Amphidromous species spawn in freshwater; after hatching, larvae drift downstream to the sea where they
145 undergo a planktonic phase. After a few months, larvae metamorphose and individuals return to rivers to
146 grow (McDowall, 1992; Keith et al., 2015). Out of the 15 genera and 28 species of extant eleotrids recorded
147 in the Western Central Pacific (Larson & Murdy, 2001), 6 genera and 7 species are attested nowadays on
148 Efate Island: *Belobranchus belobranchus* (Valenciennes, 1837); *Butis amboinensis* (Bleeker, 1853); *Eleotris*
149 *fusca* (Bloch & Schneider, 1801); *Eleotris melanosoma* Bleeker, 1853; *Giuris margaritaceus* (Valenciennes,
150 1837); *Hypseleotris cyprinoides* (Valenciennes, 1837) and *Ophiocara porocephala* (Valenciennes, 1837).

151 According to Keith et al. (2010), the freshwater genus *Giuris* is composed of omnivorous and
152 carnivorous individuals. Adults live in the lower course of rivers, along the riverbanks in vegetated and
153 sheltered environments. The carnivorous taxon *Ophiocara porocephala* is more ubiquitous than *Giuris* spp.:
154 it is common along the riverbanks in the lower course of rivers but sometimes frequents brackish waters,
155 such as mangroves and estuarine environments. The adults of *Eleotris*, depending on the species, are mainly
156 found in brackish waters and lower courses of rivers or only in lower courses, especially in sheltered areas
157 with a slow current, but they venture sometimes further upstream. Although most sleepers are small-sized,

158 usually up to 20 cm, some species may reach larger dimensions (> 30 cm) and may be sought after for
159 consumption.

160

161 MATERIAL AND METHODS

162

163 Out of a total of almost 40,000 fish remains recovered at the Teouma site, 25,914 have been
164 associated stratigraphically with the Lapita period, dated from 2920-2870 cal. B.P. to 2870-2750 cal. B.P.
165 (Petchey et al., 2015: 103). They mainly stem from the cemetery zone (353 m²) and Lapita midden zone (120
166 m²) in Areas 2 and 3 (Fig.4). The sediments of the Lapita layers associated with the use of the cemetery and
167 the adjacent midden zone were systematically wet-sieved through 1-2 mm mesh. Only the Lapita deposits
168 that postdate and cover the cemetery zone, and in which remains were described as scarcer, were dry-sieved
169 through 5 mm mesh (Hawkins, 2015: 57). The choice of using different recovery methods at Teouma was
170 determined by: 1) Time constraints, 2) Research objectives and priorities 3) The important density and
171 number of early Lapita cultural remains compared with those of the superior layers (Hawkins, 2015: 58).

172

173 Fig.4: Plan of the site with all areas excavated between 2004 and 2010 (modified from Spriggs & Bedford,
174 2013: 160, fig.2).

175

176 The ichthyofauna were separated from the other faunal remains and sent for analysis in France. The
177 fishbones were then counted, weighed and recorded. Whenever practicable, they were identified
178 anatomically and taxonomically to the family, genus and species-levels, using the Indo-Pacific reference
179 collection housed at the UMR 7209 of the Muséum national d'Histoire naturelle (MNHN). The cranial and
180 postcranial elements were all included in the analysis (Bouffandeau et al., 2018). The body mass represented
181 by each individual bone was also visually estimated by comparison with the reference specimens of the
182 collection. This simple method provides only approximate values but offers an overview of the average
183 weights of all the fish identified in the assemblage. The number of identified specimens (NISP), which
184 includes all of the elements that have been identified at least to the family-level, was calculated; it is a secure
185 quantifying unit but must be considered as a maximum number. The minimum number of individuals (MNI)
186 was determined by combining the laterality or anatomical position of the elements and the estimated body
187 mass of the individuals (Poplin, 1976), and calculated by using the levels/spits as aggregation unit.

188

189 All the species of Eleotridae listed today in Vanuatu have been considered during the analysis,
190 assuming that some of the taxa present on Efate Island during the Lapita period may have since been subject
191 to local extirpation. New specimens of modern eleotrids from Melanesia were collected and prepared with a
192 view to enrich the comparative osteological collection of the MNHN and enable a more accurate
193 identification of the Teouma remains. The elements that were too fragmented, altered or lacking discrete
194 criteria, and thus not diagnostic of a genus, were recorded as "gen. sp." in the database. The individuals of
195 the assemblage that were assigned to a precise species were identical to the reference specimen of the
196 comparative collection.

196

198

199 Amongst the 25,914 fish remains composing the Lapita sample, 8,560 (NISP) were identified
200 taxonomically, corresponding to an identification rate of 33% and a MNI of 3,712. The total weight of
201 identified specimens (WISP) reached 2.88 kg. The Lapita assemblage was composed of 34 families of local
202 coastal and reef-associated taxa, such as Carangidae (Scads and Jacks), Scaridae (Parrotfishes), Acanthuridae
203 (Surgeonfishes) and Serranidae (Groupers), but also freshwater and mangrove fish represented by the family
204 Eleotridae (Sleepers).

205 With a NISP of 1,368, a MNI of 419 and a WISP of 113 g, the Eleotridae unexpectedly occupied
206 second place among the dominant families, corresponding to 16% of the assemblage. A total of 15 cranial
207 and postcranial elements were determined, accompanied by numerous vertebrae (Tab.1). The proportions of
208 cranial (NISP = 663) and postcranial (NISP = 705) elements were similar and rather well-balanced, which
209 indicates that the fish were likely brought back whole to the occupation area and not beheaded during the
210 fishing expeditions or in some other location. The presence of several thin elements such as cleithra, opercles
211 and parasphenoids was noticeable and reflected the excellent state of preservation of the cranial remains at
212 Teouma. The latter could also explain the high proportion of cranial elements compared with vertebrae in the
213 assemblage. No burning traces or cut marks were observed on the bones.

214

215 Tab.1: Distribution of the number of identified specimens of Eleotridae (NISP) per skeletal element and
216 genus (in descending order).

217

218 Despite slight fragmentation, the fish remains were easily recognisable during the analysis (Fig.5),
219 and most of the eleotrid bones appeared to be diagnostic of the family and even of the genus. The regular
220 improvement of the reference collection and addition of new specimens of eleotrids would undoubtedly
221 allow greater precision in the bone assignation to species.

222 Out of the 1,368 fishbones associated with the family Eleotridae, 946 have been identified as
223 belonging to 3 genera, *Giuris*, *Ophiocara* and *Eleotris*. The individuals of the genus *Giuris* (NISP = 842) are
224 prominent in the Lapita sample. Among them, 735 elements could not be determined to species-level (*Giuris*
225 spp.), but it has been possible to identify with certainty 12 remains as *Giuris margaritaceus* and 95 as
226 another species of *Giuris* (referred to as *Giuris* sp.1), especially by means of their vertebrae, cleithra and
227 anguloarticulars. It should be noted here that although only one species of *Giuris* (*G. margaritaceus*) is
228 known on Efate, another undescribed species (*Giuris* sp.) is present in Northern Vanuatu (Keith et al., 2010).
229 The genus *Ophiocara* is mainly represented in the corpus by vertebrae and dentaries: 93 individuals (NISP)
230 have been identified in the sample. *Ophiocara porocephala* is the only species of the genus listed in the
231 region, and the associated remains appeared to be more altered superficially and deformed in a greater
232 number than those of the other eleotrids of the assemblage. No cleithrum was found or identified, perhaps
233 because it is thinner and more fragile in this species. Facing the lack of local specimens of *Eleotris* spp. in
234 the reference collection, the identification of the 11 individuals of the sample was based on *Eleotris picta*
235 Kner, 1963 from the Eastern Pacific, and has been consequently limited to the genus-level. Three species of

236 the genus *Eleotris* are known in Vanuatu, namely *Eleotris acanthopoma* Bleeker 1853, *E. fusca* and *E.*
237 *melanosoma* (Keith et al., 2010).

238

239 Fig.5: Examples of representative skeletal elements of Eleotridae identified within the Lapita sample of
240 Teouma, scale 1 cm. A: First precaudal and precaudal vertebrae; B: Left and right cleithra; C: Right dentary;
241 D: Right opercles; E: Left and right ceratohyals; F: Right quadrate; G: Right maxilla; H: Vomers; I: Left and
242 right hyomandibulas; J: Right anguloarticulars.

243

244 The estimated weights of the eleotrids identified within the Lapita sample ranged between 20 and
245 500 g and 13 and 35 cm total length (TL), and all taxa are represented by both small and large individuals.
246 However, almost 30% of the specimens are rather large, weighing between 200 g and 500 g and a high
247 number of their bones show deformity as often observed in large fish. In the comparative collection, the
248 biggest specimen of *Giuris margaritaceus* (MNHN-ICOS-01178) is 25.2 cm TL and weighs 211 g, and
249 *Ophiocara porocephala* (MNHN-ICOS-01348) reaches 24.6 cm TL for 174 g. The maximum standard
250 lengths (SL) mentioned by Keith et al. (2010) for the three genera range between 20 and 27 cm, i.e. 26 to 35
251 cm TL.

252

253 Fig.6: Plan of the Areas 2 and 3 of Teouma, showing the spatial distribution and density of the bones of
254 Eleotridae (NISP per m²). The crosses mark the location of the Lapita burials (after Valentin et al., 2015: 86,
255 fig.4).

256

257 The spatial distribution of the eleotrid elements within the excavated areas is relatively extensive but
258 two clusters are visible (Fig.6). The main one is located in the north-eastern part of the midden zone whereas
259 the other one stretches in the west half of the cemetery zone. Most of the bones stem from squares situated at
260 the periphery of the cemetery, however a few of them were uncovered in close proximity to the Lapita
261 skeletons. There is no imbalance in the spatial distribution of skeletal elements per type, per taxon or per
262 estimated weights: the eleotrid remains occur in a rather homogenous way all across the area. Out of the 421
263 remains of eleotrids uncovered in the cemetery area, 314 are associated with the Layer 3 and the burials,
264 corresponding to the earliest phase of occupation of the site, as early as 2920-2870 cal. B.P. (Petchey et al.,
265 2015). The remains of the midden zone are the most numerous (NISP = 940). Among them, 210 stem from
266 the early Lapita Layer 3, and 730 from the Layers 2/3 and 2, associated with subsequent Lapita deposits.

267

268 Besides the Lapita sample, a total of 305 eleotrid bones were collected within the Layer 2 of the
269 cemetery zone, identified as a Post-Lapita midden covering the Lapita layers and associated with the
270 following Arapus and Early Erueti periods. In addition, a large number of eleotrid remains (NISP = 639)
271 were found 80 m south of the main occupation zone in the Area 7C (see Fig.4), whose complex stratigraphy
272 unfortunately hindered the clear differentiation between Lapita and Post-Lapita deposits. These two samples
273 were left aside in the present study but reveal that Eleotridae remains obviously occur throughout the
274 chronological sequence associated with the Lapita and Post-Lapita periods at the site of Teouma.

274

276

277 The sleepers identified within the Lapita sample of Teouma represent 16% of the assemblage. They
278 therefore might have constituted a significant part of the Lapita fish catch and consumption, from 2920-2870
279 cal. B.P (see Petchey et al., 2015). Eleotridae remains are still present in the later Arapus and Early Erueti
280 layers: the exploitation of the close freshwater environments by the inhabitants of the site is consequently not
281 solely limited to the phase of initial settlement. It is, however, the oldest evidence so far of freshwater fishing
282 in Melanesia and the results reinforce the theory of broad-spectrum exploitation of all available resources by
283 Lapita colonists.

284 Eleotridae are amongst the most common freshwater fish present in Vanuatu, along with individuals
285 of the families Anguillidae (Eels), Gobiidae (Gobies), Kuhliidae (Flagtails), and Mugilidae (Mulletts), which
286 were not identified in the sample: the mullets present in the assemblage are marine and brackish water taxa
287 only. Unlike some of the euryhaline members of the genus *Eleotris*, which can generally be found in areas of
288 interface between fresh and marine waters, the adult species of *Ophiocara* and especially *Giuris* (Fig.7) live
289 in freshwater and are restricted to the lower course of rivers or swamps and ponds. The predominance of the
290 latter in the sample confirms that the Lapita exploitation of aquatic environments was not only littoral and
291 circumscribed to marine and brackish waters, but also targeted freshwater biotopes and inland waters.

292 Information on modern and traditional fishing in freshwater environments at a regional and local
293 scale is rare. Today in Vanuatu, the practice of freshwater fishing seems to be limited to the lower courses
294 and deltas of large rivers (Cillaurren et al., 2001), and especially targets adults and post-larvae of Eleotridae
295 and Gobiidae. With the exception of reef flats and reefs, it is brackish environments such as river mouths and
296 mangroves where most of the fishing activities of village populations are concentrated: only small-sized
297 individuals are captured, usually by means of fish-traps deployed in these environments (David, 1999).

298 As for the archaeological material, the only pieces of fishing gear uncovered at Teouma are probable
299 pumice floats for nets. However, some fishhooks and possible line or net sinkers made of stone or shell are
300 attested elsewhere in Vanuatu in Lapita contexts (Bedford & Spriggs, 2002; Szabó, 2010). Interestingly,
301 eleotrids were identified as the dominant family in an assemblage recovered in Polynesia, at the Tangatatau
302 Rockshelter on Mangaia, Cook Islands, a site dated between 1000 and 1700 cal. A.D. (Butler, 2001),
303 showing that the place of freshwater fish within the subsistence economies of Pacific populations over time
304 is far from being anecdotic.

305

306 Fig.7: Specimen of sleeper, *Giuris* sp., collected in New Caledonia (Photograph by N. Charpin)

307

308 Sleepers are rather inactive benthic fish, hence their common name (Larson & Murdy, 2001) and
309 they are of small to moderate dimensions. Most of the eleotrids are carnivorous and Lapita settlers could
310 have utilised specific hooks and lines to catch them. To fish them in large quantities it would have been
311 undoubtedly easier and more effective to use traps and/or weirs with bottlenecks across the river bed. The
312 capture of eleotrids is mentioned ethnographically in Viti Levu, Fiji, where the Naiwasomo people drive the
313 fish towards nets with a screen of leaves in shallow waters (Waqaniu & Rogers, 1991). However, passive

314 gear such as fish traps, adapted to marine biotopes as well, would require less effort and a reduced human
315 presence, preventing the sleepers from hiding or burying themselves in sand or mud. Multi-pronged spears
316 could also have been used to catch these bottom-dwelling fish, as is the case today. Polyvalent fishing
317 devices (see Kirch, 1997; Green, 2003), operable in marine as well as in freshwater, could have facilitated
318 the broad-spectrum exploitation of all available aquatic resources (Clark & Szabó, 2009). These may have
319 been part of an inherited cultural kit or a set of survival and/or colonisation strategies enabling Lapita people
320 to demonstrate a remarkable adaptability facing new environments.

321 The absence of cut marks on the bones of the corpus could be explained by the fact that Eleotridae
322 are small-sized fish that did not necessitate any butchery operations and were consumed whole. There is no
323 evidence that the fish were grilled or cooked in direct contact with fire since the bones were not burnt,
324 particularly the extremities or the lateral sides of external elements. They may thus have been boiled in pots
325 (Leclerc et al., 2018).

326

327 Fig.8: Current view of the Teouma Bay from the northwest showing the mouth of the Teouma River. The
328 location of the archaeological site is indicated with an arrow.

329

330 Sleepers would have likely been an easy prey for the Lapita community of Teouma, especially
331 considering the proximity of the river (Fig.8) and swamp, and the fact that the local fauna had never been
332 previously exposed to predators or anthropic pressure. The pristine state of these island ecosystems at the
333 time of first human arrival could also explain the presence of large-sized individuals and the remarkable
334 amount of eleotrids within the ichthyofaunal assemblage. The analysis of the marine ichthyofauna of the
335 Teouma site has yet to be completed; the final results should clarify the importance of freshwater taxa
336 versus marine taxa, as well as the place of fish within the general faunal spectrum, during the Lapita, Arapus
337 and Early Erueti periods at Teouma. Furthermore, it will be interesting to re-examine the isotopic and
338 biomolecular data available on Lapita diet or artefacts by including this new element in interpretations. This
339 could, for instance, provide an opportunity to determine whether the occurrence of eleotrid bones next to the
340 human skeletons constitutes remnants of the content of vessels or are ritual deposits, and thus whether
341 sleepers have been subject to special treatment or status in Lapita times.

342 Three millennia ago the Lapita settlers of Efate Island not only exploited efficiently a wide range of
343 marine and terrestrial resources but also took advantage of nearby freshwater environments. This first
344 evidence of the occurrence of freshwater taxa within a Lapita assemblage is perhaps only due to the
345 fortuitous presence of an important river and a swamp next to the occupation site. However, the general
346 absence of identification of freshwater fish in other ichthyoarchaeological and regional studies, which remain
347 rare, could also have been caused by several factors: 1) Poor or differential preservation of the osteological
348 remains on some sites, 2) Heterogeneous excavation and sieving strategies, 3) A lack of modern comparative
349 collections, especially for freshwater species, 4) Possible cultural choices or local circumstances, as it seems
350 unlikely that freshwater fishing was a necessity, or 5) Ecological differences influencing fish abundance in
351 rivers, swamps and streams. The detailed analysis of more ichthyofaunal Lapita collections could provide
352 new data to define whether freshwater fishing at Teouma is unique or whether it was practised regionally on
353 other sites.

355 **CONCLUSION**

356

357 The identification of sleepers from the Lapita site of Teouma, Efate Island, in Vanuatu, further
 358 enriches the previous archaeological and biogeochemical evidence of the generalist subsistence strategies
 359 implemented by these first settlers in Melanesia. The number of eleotrid remains identified in the assemblage
 360 is substantial and these freshwater fish may have constituted an abundant resource, easily accessible and
 361 exploitable in Lapita times. The absence of large-sized eleotrids in the rivers and streams of Vanuatu today
 362 could be due to the impact of environmental changes and/or anthropic pressure on the hydrographical
 363 network. Sleepers likely were an important component of the Lapita diet, thereby demonstrating that the
 364 broad-spectrum exploitation of local resources by Lapita communities was not limited to marine
 365 environments but rather encompassed all nearby aquatic ecosystems. Furthermore, the initial and heavy
 366 exploitation of a wide range of aquatic and terrestrial resources by Lapita settlers strongly suggest that they
 367 were not only sea fishermen but, rather, skilled and generalist foragers prepared for many possible scenarios.
 368 The occurrence of freshwater taxa in the archaeological record of Teouma from the beginning of the
 369 chronological sequence implies that the Lapita people probably already had the technical skills and the
 370 appropriate fishing devices, as well as an essential ecological knowledge on diverse biotopes at the time of
 371 their arrival on Efate Island.

372

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374

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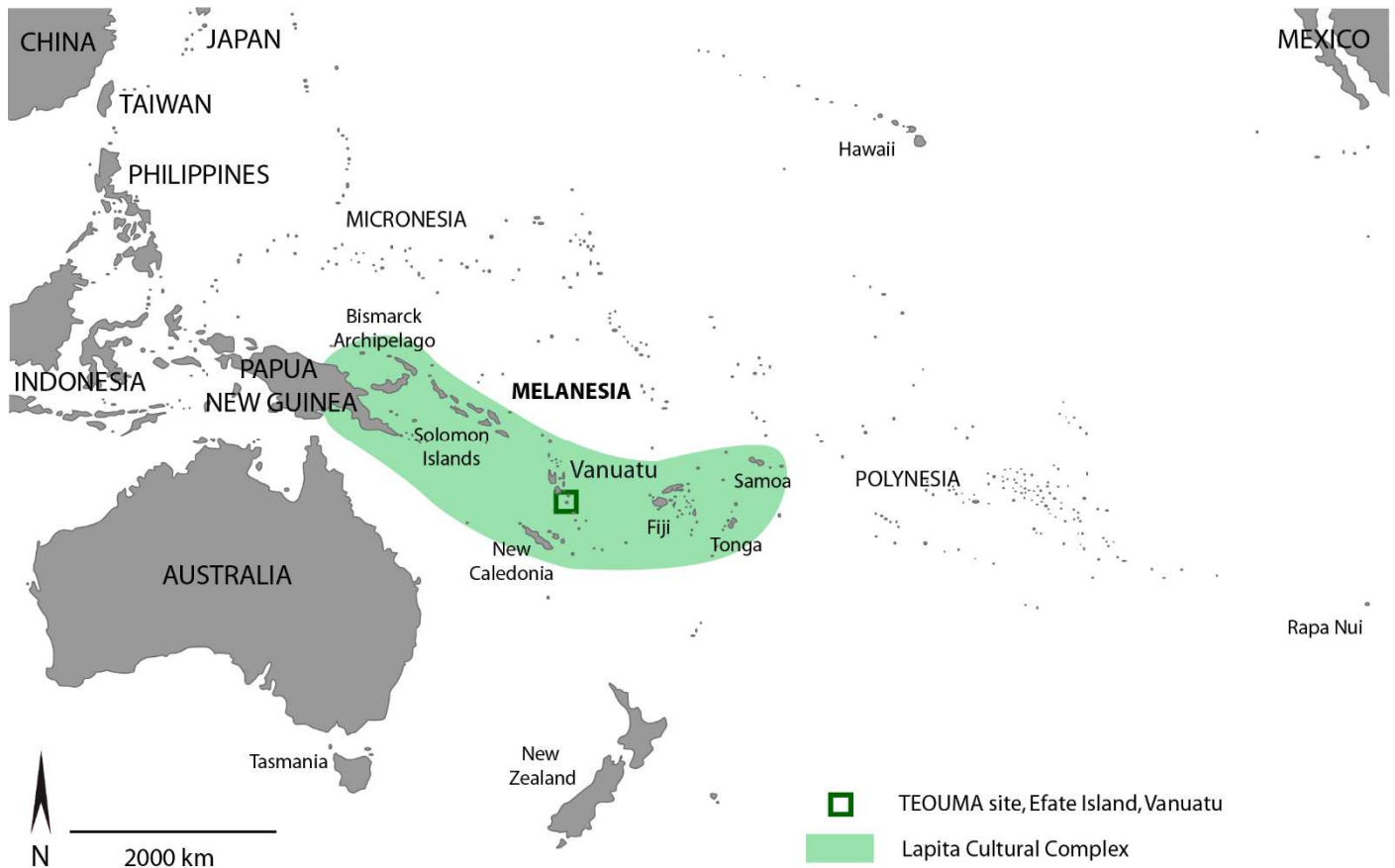
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INTRODUCTION

Fig.1: Map of the Pacific with known extents of the Lapita Cultural Complex (modified from Hawkins, 2015: 9, fig. 2-1).

(Width: 2 columns, please)



CONTEXT

Fig.2: Map of Efate Island with the location of the Teouma site (data NASA, SRTM v.2, 2005).

(Width: only 1 column, please)

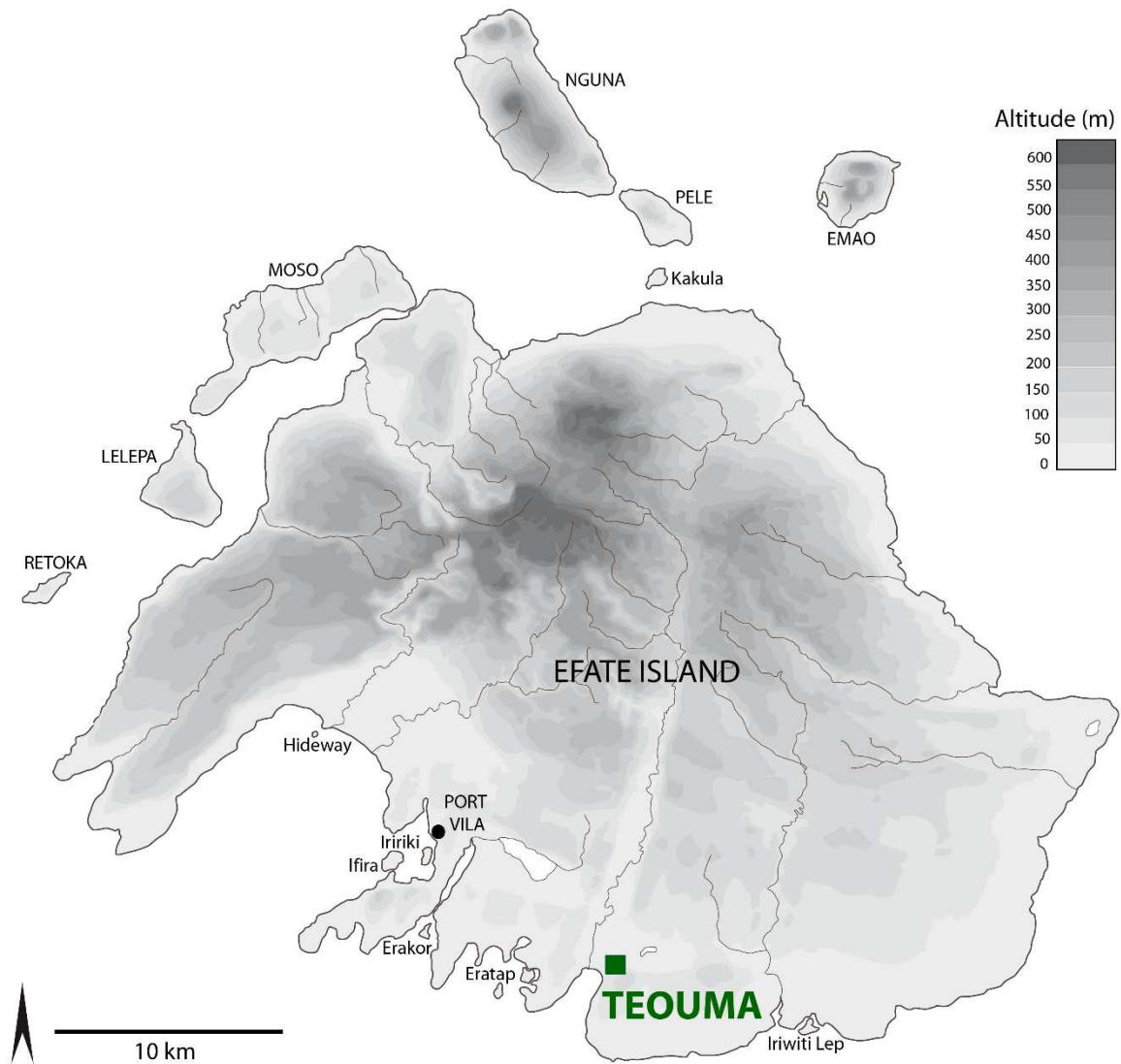
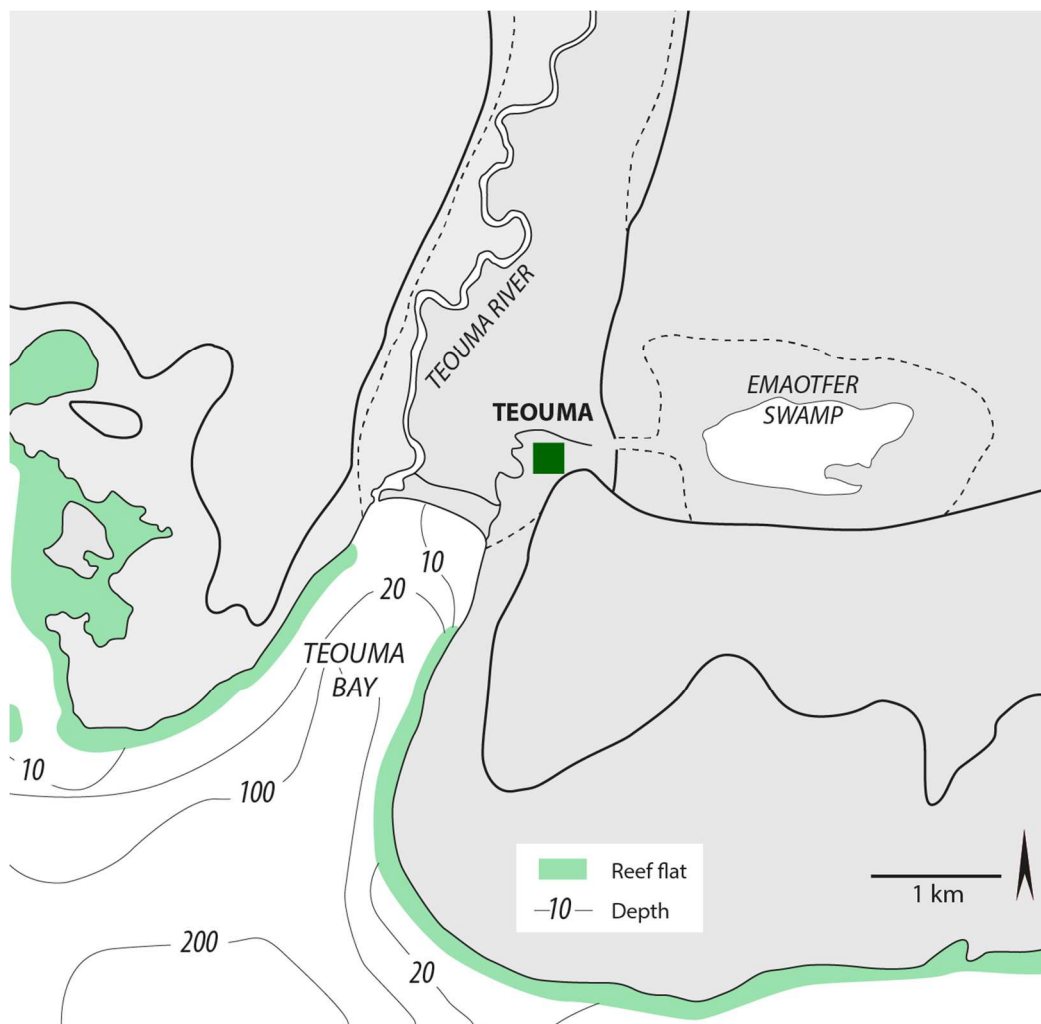


Fig.3: Map of the Teouma Bay and its surroundings, with a focus on the current bathymetric and geomorphologic features (modified from Admiralty Publications and Maps, 1987).

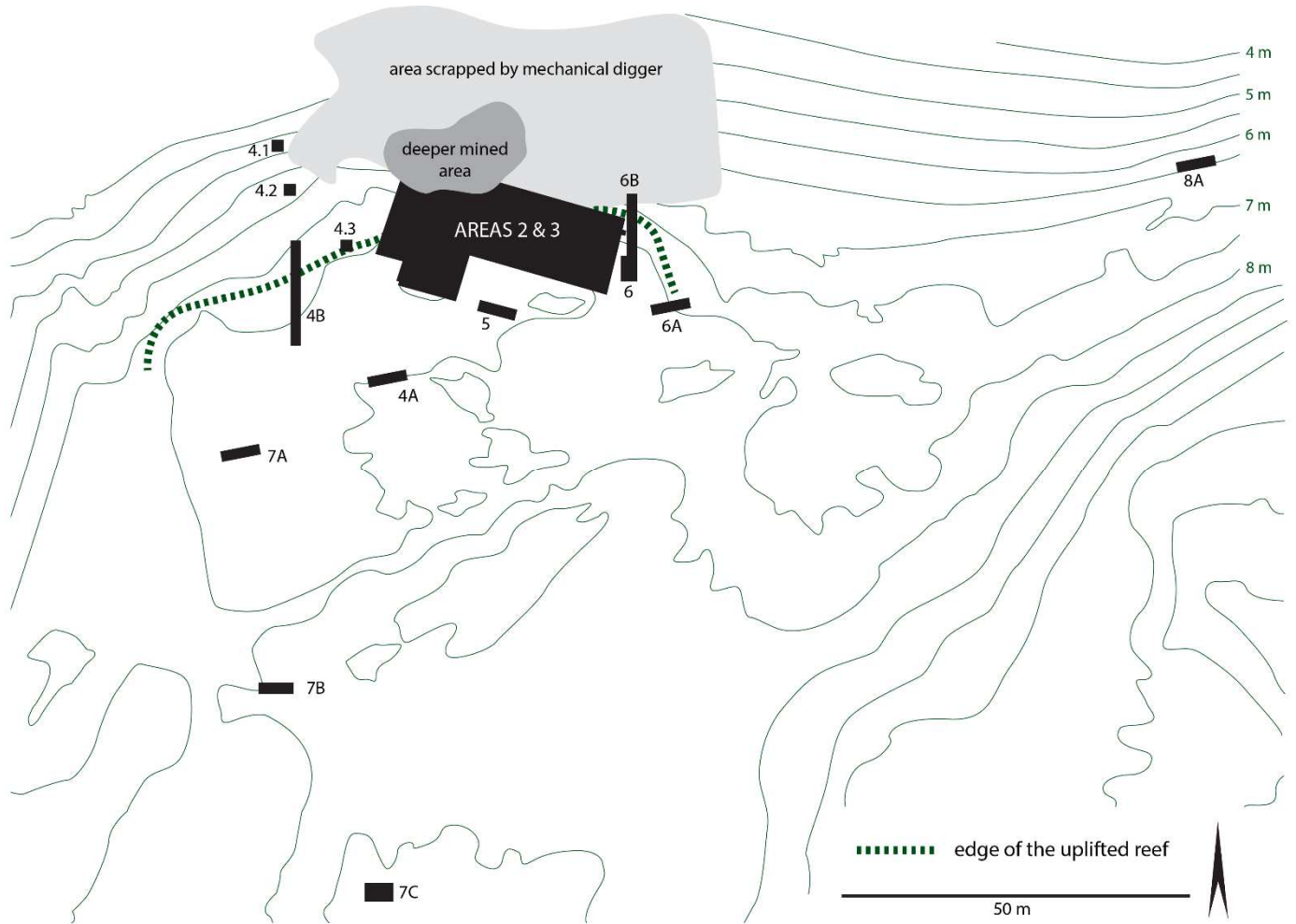
(Width: only 1 column, please)



MATERIAL AND METHODS

Fig.4: Plan of the site with all areas excavated between 2004 and 2010 (modified from Spriggs & Bedford, 2013: 160, fig.2).

(Width: 2 columns, please)



RESULTS

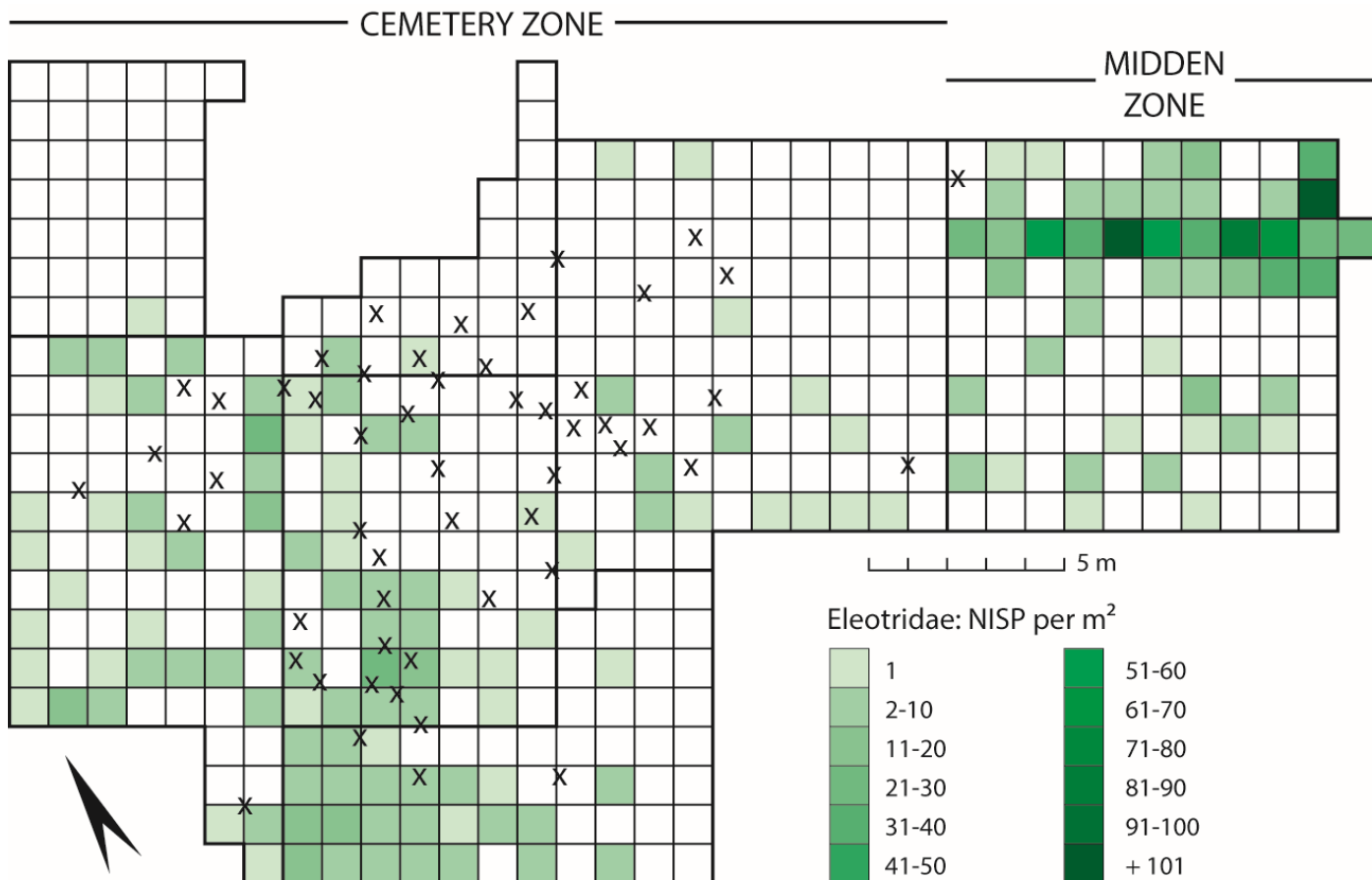
Fig.5: Examples of representative skeletal elements of Eleotridae identified within the Lapita sample of Teouma, scale 1 cm. A: First precaudal and precaudal vertebrae; B: Left and right cleithra; C: Right dentary; D: Right opercles; E: Left and right ceratohyals; F: Right quadrate; G: Right maxilla; H: Vomers; I: Left and right hyomandibulas; J: Right anguloarticulars.

(Width: 2 columns, please)



Fig.6: Plan of the Areas 2 and 3 of Teouma, showing the spatial distribution and density of the bones of Eleotridae (NISP per m²). The crosses mark the location of the Lapita burials (after Valentin et al., 2015: 86, fig.4).

(Width: 2 columns, please)



DISCUSSION

Fig.7: Specimen of sleeper, *Giuris* sp., collected in New Caledonia (Photograph by N. Charpin).

(Width: 2 columns, please)



Fig.8: Current view of the Teouma Bay from the northwest showing the mouth of the Teouma River. The location of the archaeological site is indicated with an arrow.

(Width: 2 columns, please)



RESULTS

Tab.1: Distribution of the number of identified specimens of Eleotridae (NISP) per skeletal element and genus (in descending order).

(Width: 2 columns, please)

	<i>Giuris</i> spp.	gen. sp.	<i>Ophiocara porocephala</i>	<i>Eleotris</i> spp.	Total elements
Vertebra	354	272	64	10	700
Cleithrum	140	54			194
Anguloarticular	74	5	1		80
Dentary	29	19	13		61
Opercle	55	4	2		61
Quadrate	50	9	1		60
Hyomandibula	44	6	5		55
Ceratohyal	35	16	1		52
Maxilla	31	1	2		34
Basioccipital	4	18	3		25
Premaxilla	12	6			18
Vomer	14		1	1	16
Parasphenoid		6			6
Urostyle		5			5
Pharyngeal		1			1
Total Eleotridae	842	422	93	11	1,368