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## Exploitation of dolphins (Cetacea: Delphinidae) at a 6000 yr old Preceramic site in the Pearl Island archipelago, Panama<sup>☆</sup>

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## ABSTRACT

Dolphins are widespread in warm oceanic and coastal waters. They habitually frequent islands. In California, Chile, and other localities, prehistoric peoples targeted dolphins. Some communities specialised in their capture. Elsewhere, prehistoric human use of cetaceans is attributed to opportunistic exploitation of active or stranded animals. In Meso- and Central America, the scarcity of cetaceans in archaeological sites is inferred to reflect the difficulties of their capture at sea with available technology. An unrecorded regional pattern is evident on Pedro González Island in the Pearl Islands (Panama). Remains of bottlenose and common dolphins were found in a Preceramic midden (“Playa Don Bernardo” [PDB]) located in a reef- and mangrove-fringed bay. Eight <sup>14</sup>C-dates bracket the deposit between 6200 and 5600 calibrated years BP. The Preceramic strata, which are between 0.8 m and nearly 4 m deep, are capped by a pottery-bearing soil deposited after a 3000-yr. hiatus in occupation. Delphinid bones and teeth represent 8% of 3660 mammal specimens identified to Family in three small test cuts. These cuts represent only 0.7% of the estimated midden area. A minimum of fourteen dolphin individuals is inferred: 11 belong to common dolphin (*Delphinus*), two to bottlenose dolphin (*Tursiops*), and one, possibly, to harbour dolphin (cf *Stenella*). Several bones show evidence for cuts, scrapes and thermal alteration. Some modifications are anthropogenic. Dry season upwelling induces shoaling fish to enter bays in the Pearl Islands attracting their nektonic, avian and dolphin predators. Ecologically, Don Bernardo Bay suits the short-beaked common dolphin (*Delphinus delphis*) and the common bottlenose nose dolphin (*Tursiops tuncatus*) – the most likely species to be present on the basis of osteology and zoogeography. The opportunistic use of naturally beached dolphins is one hypothesis for their procurement at PDB. Another is intentional human interference: corralling and driving dolphins with watercraft when they entered Don Bernardo Bay to feed or under threat from shark attacks. Ethnographic evidence around the world is supportive. PDB’s total subsistence strategy was multi-faceted, comprising exploiting dolphins and marine turtles, farming, marine shore collecting, marine coastal fishing, and hunting in island forests and secondary vegetation. The population included experienced seafarers. Among the exploited mammals, dolphins provided easily the largest quantities of edible tissues, fats and oils.

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### 1. Human exploitation of oceanic dolphins: prehistoric and present

#### 1.1. Introduction

Dolphins (Cetacea: Odontoceti: Delphinidae) are widespread in warm oceanic, island and platform waters around the world in spite of mortality caused by pollution and entrapment in fishing gear. Dolphins are still exploited in some areas by artisanal fisheries (usually illegally) for their meat, teeth, and oil (Takekawa, 1996a,b, 2000; Robards and Reeves, 2011; Oremus et al., 2013; [http://www.bluevoice.org/news\\_perudolphinhunts.php](http://www.bluevoice.org/news_perudolphinhunts.php)). Dolphins were also used for food by prehistoric peoples. The opportunistic or sporadic exploitation of harpooned,

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entrapped and stranded animals is the generally inferred pattern of pre-historic cultural use (e.g., Henshilwood, 1994, p. 97; Smith, 1989, p. 100; Volkmer de Castilho, 2007). In select localities, however, the conjunction of coastal geography, ocean conditions, maritime technology, and human social organisation was particularly favourable for targeting oceanic dolphins for food using small boats, nets, and drive techniques, e.g., Japan (Hiraguchi, 1992, 1993; Itoh et al., 2011), oceanic Pacific islands (including Easter Island) (Steadman et al., 1994), California's Channel Islands (Glassow, 2005; Porcasi and Fujita, 2000; Raab, 2009), Baja California (Mexico) (Porcasi and Fujita, 2000), and Chile (Olguín et al., 2015).

The exploitation of dolphins by the Jōmon people in Japan reached a prodigious level around the present Noto Peninsula and Toyama Bay during the later Early and Middle Jōmon periods about 5000 radiocarbon-dated years BP (~6000 cal BP) (Imamura, 1996). Two sites belonging to these two periods, Higashikushiro (Hokkaido) and Tsugumenohauana (Nagasaki), show evidence for hunting tuna and dolphins from boats in the open sea using harpoons. On the other hand, at two sites located at the head of ample marine bays, Mawaki (Ishikawa) and Shomyoji (Kanagawa), two other strategies were employed: (1) small-scale hunting with spears of pods that strayed into the inlets and (2) driving dolphins into the bays with nets and spearing them inshore. At the Mawaki site, 246 dolphin individuals were identified in one depositional unit mixed in with stone tools inferred to be projectile points, knives and scrapers. Sixty percent of the remains referred to the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) (Itoh et al., 2011). Common dolphins (*Delphinus*) and bottlenose dolphins (*Tursiops*) were also caught (Hiraguchi, 1992). Rituals involving the arrangement of whole dolphin skulls attest to the cognitive significance of dolphins, which represented the apex of Mawaki hunting effort and cultural identity (Hiraguchi, 1992, Fig. 7).

On the California Channel Islands and in Baja California, archaeofaunas with unusually large concentrations of dolphin remains have been found at particular sites. For example, Punta Arena on Santa Cruz Island (6300–5300 BP) contains more abundant dolphin remains than any other sites on this island thereby inferring specialisation in dolphin-hunting. Four species were exploited here including the short-beaked common dolphin (*Delphinus delphis*). In the southern Channel Islands, one site on San Clemente Island and another on Santa Catalina Island also infer specialisation in dolphin-hunting at the same time period when local sea temperatures based on isotopic studies of mussels were 2.5 °C below modern values thus favouring dolphin abundance (Glassow, 2005; Porcasi and Fujita, 2000).

Specialised dolphin exploitation is in evidence much later in time at the southernmost tip of the Baja California peninsula in Mexico. At one site (Las Tinas-3) – an extensive shell midden deposited about 750 cal BP – dolphin remains are the most abundant among large vertebrates even though pinnipeds and terrestrial mammals were available nearby (Porcasi and Fujita, 2000).

Further south, in Chile, pinnipeds and dolphins are judged to have provided the highest caloric proportion of the diet of the coastal site of Copaca-1 (7866–5040 cal BP) (Olguín et al., 2015). At other approximately coeval sites on the Chilean coast, large pelagic off-shore fish species were taken as early as 7000 cal BP including shortfin mako shark (*Isurus oxyrinchus*), swordfish (*Xiphias gladius*) and marlin (*Kajikia audax*). The inhabitants of this region clearly possessed a deep tradition of exploiting the resources of oceanic waters handling sturdy and stable watercraft with great expertise.

Easter Island lies more than 3000 km west of the Chilean coast in the southern Pacific Ocean, at the south-eastern extremity of the Polynesian Triangle. Delphinid bones were the most abundant vertebrate remains in middens at Ahu Naunau, a site occupied during the “expansion phase” ~1000 cal BP. The diagnostic tympanic periotic bones were all referred to the common dolphin (*D. delphis*) (Steadman et al., 1994; see Appendix A).

While the above sites attest to a specialised maritime technology in particular Pacific regions, Porcasi and Fujita (2000) hypothesised that

prehistoric people were probably capable of hunting oceanic dolphins efficiently using simpler strategies and methods. Drawing analogies with present-day artisanal dolphin-hunting in the Solomon Islands, they argue that they may have achieved this by taking advantage of delphinid socio-biologic communication and aggregation behaviour, i.e., by resorting to disruptive sounds to encircle and drive dolphins until they became exhausted and disoriented in shallow waters or mangroves where they could be easily captured (Takekawa, 1996 a,b; Takekawa, 2000).

### 1.2. Cetacean use in pre-Columbian Meso- and Central America

Götz et al. (2014) argued that pre-Columbian peoples in Meso- and Central America did not consider whales and dolphins to be attainable prey because they were too dangerous or difficult to hunt with available technology. In their opinion, carcasses of stranded cetaceans were the most likely source of occasional remains that ended up in stratified middens or whose bones and teeth were used for ritual and sartorial artefacts.

In Mexico, Costa Rica and Panama there is support for this hypothesis. Cetacean bones are rarely reported in Precolumbian domestic contexts. At the early ceramic Monagrillo (He-5) site in Parita Bay, Pacific Panama, cetacean remains including killer whale (*Orcinus orca*) were found scattered through a shell-bearing midden that built up between 5500 and 3200 cal BP in a prograding Holocene marine coastal environment (Willey and McGimsey, 1954, pp. 151–2; Clary et al., 1984; Iizuka et al., 2014). Since cetaceans have beached in this bay since the Middle Holocene, it is likely that the remains at Monagrillo were incorporated naturally or as cultural curiosities into the midden matrix.

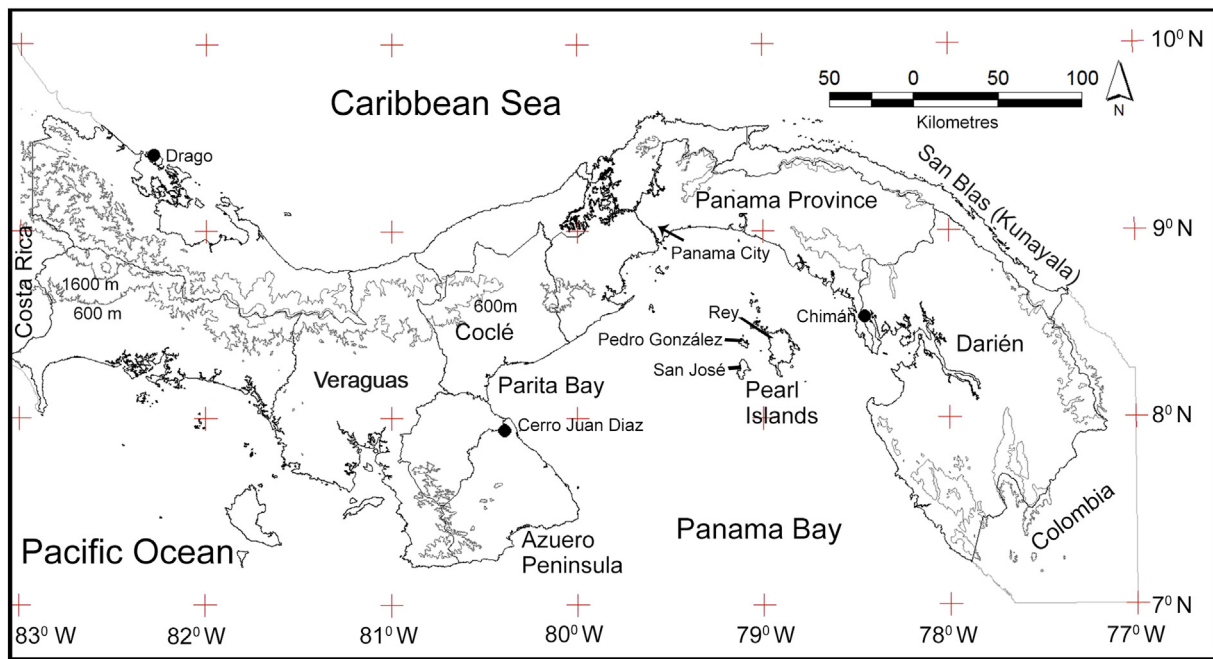
A large whale vertebra found under a human skeleton in the grave of a high-ranked person at El Caño (Coclé, Panama) probably derived from an individual that stranded on the coast of Parita Bay, which is now ~17 km away. Its deposition in the grave occurred ~1100–1000 cal BP (J. Mayo-Torné, personal communication, 2015). On the opposite (Caribbean) side of Panama, a balaenopterid whale bone found at Isla Drago in Bocas del Toro (1250–550 cal BP) is likely also to have derived from a stranded animal (Wake et al., 2013; TAW, personal observation).

Sperm whale (*Physeter macrocephalus*) strandings have been reported in Panama in recent times. Panama Bay was a centre for whaling activity in the late 19th century CE (Cooke and Jiménez-Acosta, 2010, and included references). Several carved sperm whale teeth were found in mortuary contexts at Sitio Conde (Coclé, Panama), which is close to the El Caño site. Carved sperm-whale ivory is associated here with individuals of highest rank (Briggs, 1989; Lothrop, 1937: fig. 3.3b & pp. 179, 230 & 269). An exquisite carved sperm whale tooth was found at the Rodríguez site in Costa Rica (Snarskis, 1992). Its location only 5 km away from the summit of the imposing Irazú volcano (3430 masl [metres above sea level]) elicits the speculative interpretation that a cognitive relationship encouraged the transport of this artefact to such a distant place, i.e., sperm whale blows were spiritually related to volcanic eruptions.

Another prehistoric ritual use of cetacean remains is evidenced by a fin whale rib (*Balaenoptera* sp.) found at Monte Albán (Oaxaca, Mexico). This ceremonial centre lies 140 km inland from the Pacific coast of this state. Four groups of deep incisions were placed along one edge of the rib. Corona-Martínez et al. (2014) inferred that it was removed from the carcass of a stranded and decomposing whale, and transported inland where it was displayed in a building erected between 2050 and 1850 cal BP.

### 1.3. Procurement of dolphins for food in the Pearl Island archipelago in Panama (Pacific)

An unrecorded pattern of prehistoric cetacean exploitation in Central America is evident at an archaeological site in the Pearl Island archipelago in Panama Bay on the Pacific side of the country (Fig. 1).



**Fig. 1.** Map of Panama showing the location of the Pearl Island archipelago, other geographic highlights, and mainland Precolumbian sites mentioned in the text. Figure by Roxana Segundo based on a map by John Griggs.

Frequent dolphin remains were found in a shell-bearing midden, which accreted between 6200 and 5600 cal BP alongside Don Bernardo Beach at the southern end of a small coastal embayment (Don Bernardo Bay) (Fig. 2). This site is PG-L-19/20, alternatively named Playa Don Bernardo (henceforth: PDB) (Lat.: 8° 23' 56" N–Long.: 79° 5' 1" W). Delphinid bones and teeth found in this midden represent nearly 8% of 3663 mammal specimens that were identified to Family, in three test cuts (Table 1).

The representative delphinid genera are, by rank order of abundance: 1) common dolphin (*Delphinus*), 2) bottlenose dolphin (*Tursiops*), and 3) possible harbour dolphin (cf *Stenella*). Several specimens show evidence for cuts, scrapes and various degrees of thermal alteration, which, in some cases, infer anthropogenic modification of dolphin carcasses.

The opportunistic use of naturally stranded dolphins is one working hypothesis for their procurement at PDB. Another is the use of watercraft and disruptive human behaviour for corralling and driving dolphins that ventured into Don Bernardo Bay in order to feed or under threat of attacks by large sharks (e.g., Corkeron et al., 1987; Heithaus and Dill, 2002). These hypotheses, which will be evaluated below, are not mutually exclusive.

The people who settled on Pedro González ~6000 cal BP were not hunter-gatherers. Preceramic communities throughout Pacific Panama and the northern Colombian lowlands, as well as in large areas of the northern Andes and adjacent Pacific coastal lowlands, developed mixed subsistence economies with varied emphases after ~8000 cal BP (Aceituno and Loaiza, 2015; Piperno, 2011a,b; Santos-Vecino et al., 2014; Stothert et al., 2003). The scheduling of natural resource acquisition at some early California Channel Island and coastal Chilean sites, where specialised dolphin hunting is evident and where agriculture was not practiced, would have been very different from scheduling at coeval coastal tropical sites with mixed economies, including PDB (see Section 5.1).

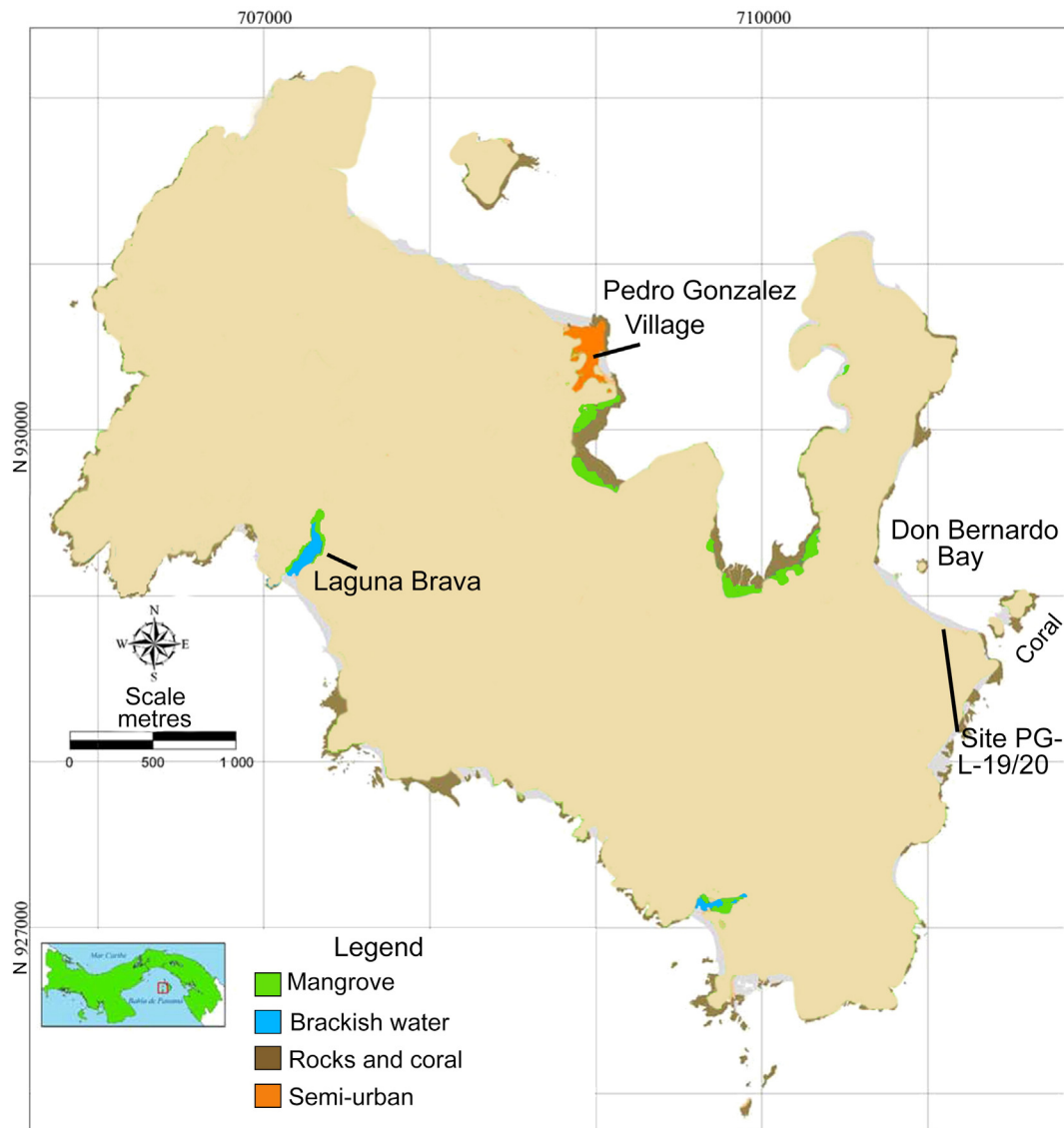
## 2. Geographic, ecological and historical setting

The ~200 islands that comprise the Pearl Island archipelago range in size from small rocky stacks to Isla del Rey (234 km<sup>2</sup>), which is the second largest island in Central America after Coiba (490 km<sup>2</sup>). They

are 'platform islands' connected to the isthmian mainland only after average sea level rose above –90 m during marine transgressive stages of the last glacial period (inferred by SR from data summarised in Peltier, 2002, and Rohde, 2005). Pedro González (14.9 km<sup>2</sup>) is the third largest island in the archipelago. Its varied topography rises to 110 masl (metres above sea level). Potential natural vegetation is Tropical Dry Forest. About one per cent of the island is mangrove, dispersed and poorly developed on rocky substrates and in sandy areas. Most of the small freshwater streams are seasonal. One runs to one side of PDB (see Fig. 4). Two bar-formed brackish lakes – one (Laguna Brava) much larger than the other – are present on the southern side of the island (Fig. 2). Reefs and coral patches are scattered around the island. The best preserved reefs are found today on four peripheral islets including two (conjoined at low tide) in the south-eastern corner of Don Bernardo Bay (Fig. 2).

The present-day Pearl Island climate is characterised by a short, but intense dry season (January through April), which is followed by a wet season (May–December) with periodic heavy rains. Annual and multiannual climate variability in this archipelago and across much of the tropical eastern Pacific is driven by the interface between the Inter-Tropical Convergence Zone (ITCZ) and the El Niño-Southern Oscillation (ENSO). In years of high north–south trade wind velocity, upwelling occurs in Panama Bay, and is strongest between 81° E and 79° E. Sea surface temperature can drop as low as 15 °C. Pedro González Island is located within the zone of strongest upwelling (Reilly and Fiedler, 1984; D'Croz and O'Dea, 2007; Toth et al., 2012). During strong El Niño events, the trade wind lessens in intensity, and upwelling weakens. ENSO and upwelling drive fluctuations in the abundance of small pelagic shoaling fish, e.g., anchovies (Engraulidae), long-fin herrings (Pristigasteridae), thread-herrings (Clupeidae, especially *Opisthonema* spp.), and their fish, avian and mammalian predators including dolphins (Forsbergh, 1969; Reilly and Fielder, 1984; Danil and Chivers, 1998; D'Croz and O'Dea, 2007). For more than 2000 years (~4000–1800 cal BP), the coupling of the Inter-tropical Convergence Zone and ENSO led to stronger and more frequent warm water El Niño events, which in turn triggered the collapse of coral reefs in the tropical eastern Pacific including the Pearl Islands (Toth et al., 2012). Currently, however, there is no archaeological evidence that people





**Fig. 2.** Map of Pedro González Island showing the location of site PG-L-19/20 (Playa Don Bernardo) in Don Bernardo Bay. Image by Segundo Roxana, based on a photograph provided by Marco Díaz, INGENAR S.A., Panama City.

were living on the Pearl Islands from 4000 to 2300 cal BP, hypothetically for this very reason.

Preceramic people settled at PDB after Pedro González Island had become completely surrounded by the rising post-glacial ocean ~9000 cal BP (date inferred by SR from data summarised in Fleming et al., 1998; Peltier, 2002, and Rohde, 2005). We hypothesise that they arrived by sea in dependable watercraft after traversing a broad stretch of

open sea. PDB now lies 52 km south-west of Chimán on the coast of Panama province, and 70 km south-east of the pre-Columbian site of Playa Venado at the Pacific entrance of the Panama Canal, with which the Pearl Island settlements had particularly strong cultural connections between 1500 and 1100 cal BP (Fig. 1; Martín et al., in press). The distances across Panama Bay would have been slightly shorter about 6200 cal BP by which date post-glacial sea level is inferred to have risen to an elevation of 1–2 m below the present-day level although this estimate does not factor in evidence for a sea-level high stand that occurred in many parts of the Pacific ~6000/4000 cal BP (Perry and Smithers, 2010; Toth et al., 2012). PDB is the only preceramic site yet found on Pedro González Island or elsewhere in the Pearl Island archipelago. Excepting an un-dated and unpublished preceramic deposit in a small rock-shelter in eastern Panama province (Cueva Bustamante) (Snarskis, 1984, p. 201, *vide* R.G. Cooke), it is the only post-Paleoindian and pre-pottery archaeological site that has been recorded anywhere in Panama east of the modern Canal (Martín et al., in press). Strong off-shore winds in the dry season and frequent squalls with lightning in the wet season would have increased the risk of canoe crossings to and from the archipelago. Dolphins would have been encountered frequently since they are accustomed to accompanying watercraft. On one

**Table 1**  
Playa Don Bernardo, Pedro González Island: Distribution of mammalian specimens by Family.

Family	Common name	Specimens	% specimens
Cebidae	Monkeys	1	<0.01
Cervidae	Deer	2502	68.3
Cuniculidae	Pacas	2	0.1
Dasyproctidae	Agoutis	306	8.4
Delphinidae	Dolphins	288	7.9
Didelphidae	opossum	536	14.6
Echimyidae	Spiny rats	28	0.8
Total		3663	100



**Table 2**

Radiocarbon dates from Playa Don Bernardo (PG-L19/20), Pedro González, and Pearl Island archipelago, Panama.

Site	Test cut	Arbitrary level	Natural layer	Macrostratum	Material	Lab. number	Measured date	$^{13}\delta$	Calibration	Conventional date	Uncalibrated date BCE	Cal BP (2 $\sigma$ )	Intercept (cal BP)
PDB	L-19	5	2	I	<i>Argopecten circularis</i>	$\beta$ -256752	4860 $\pm$ 50	−0.6	Ma	5260 $\pm$ 50	3310	5720–5560	5600
PDB	L-19	8	2	I	carbonised palm kernel	$\beta$ -256751	4900 $\pm$ 40	−26	Terr	4880 $\pm$ 40	2930	5660–5580	5600
PDB	L-19	12	2	I	<i>Argopecten circularis</i>	$\beta$ -243898	4980 $\pm$ 40	0	Ma	5390 $\pm$ 40	3440	5870–5650	5740
PDB	Corte 1	13	4	II	carbonised material	$\beta$ -261219	5240 $\pm$ 50	−29	Terr	5170 $\pm$ 50	3220	6000–5890 & 5810–5760	5920
PDB	Corte 1	19	6	III	carbonised material	$\beta$ -261218	5140 $\pm$ 40	−26	Terr	5120 $\pm$ 40	3170	5840–5750 & 5840–5750	5900
PDB	Corte 1	26	6	III	carbonised material	$\beta$ -261217	5150 $\pm$ 40	−27	Terr	5120 $\pm$ 40	3170	5840–5850 & 5840–5750	5900
PDB	B' 17	39	7	III	carbonised <i>Delphinus</i> bone	$\beta$ -304632	5350 $\pm$ 40	−14	Ma	5540 $\pm$ 40	3590	5990–5870	5910
PDB	B' 17	41	7	III	carbonised material	$\beta$ -278902	5330 $\pm$ 40	−28	Terr	5280 $\pm$ 40	3330	6190–5930	6000

Note: All dates were run by Beta Analytic Inc. using INTCAL 09. Ma: marine calibration, Terr: terrestrial calibration.

such journey a sooty shearwater (*Puffinus griseus*) was captured, and its remains deposited in the PDB midden. These oceanic birds do not come to land in Panama Bay during their June–November annual migrations from the southern hemisphere where they nest (Cooke et al., 2013b) thus inferring that this individual was taken at sea.

Anthropogenic sediments at PDB built up over ~800 years (6200–5600) cal BP based on the maximum 2 $\sigma$  range of eight  $^{14}\text{C}$  dates run on marine shell, charcoal and burnt bone (Table 2). The latest dates are samples  $\beta$ -256751 and  $\beta$ -256752. Thereafter, the locale experienced a hiatus in occupation for at least 3000 years: no pottery older than ~2300 cal has been recorded on Pedro González Island, elsewhere in the Pearl Island archipelago or on the mainland opposite (Panama and Darién provinces) (Martín et al., in press). The oldest pottery complex in Panama (Monagrillo) is  $^{14}\text{C}$ -dated between 5470 and 3250 cal BP. It has only been reported further west in central Panama (Veraguas, Coclé and Herrera provinces), across an area that covers 5600 km<sup>2</sup> and includes the Parita Bay coast (Pacific), Pacific coastal lowlands and Pacific and Atlantic foothills. A local development of Monagrillo ceramics is inferred (Willey and McGimsey, 1954; Cooke, 1995; Iizuka et al., 2014).

From 2300 cal BP onwards, human settlement continued on the largest islands of the archipelago until Spanish contact in 1515 CE. Cultural interchange and trade among the islands of the archipelago, and between these and the central Pacific isthmian mainland from Veraguas province to eastern Panama province, is particularly well substantiated during the period 1450–1000 cal BP (Cooke, 1998; Sánchez-Herrera and Cooke, 2000; Cooke, 2012; Núñez-Cortes, in press; Martín et al., in press). A change in ceramic traditions after ~1000 cal BP in Eastern Panama including the Pearl Islands, in addition to the first record in lower Central America of ridged fields in seasonally flooded areas, announced stronger connections with communities in northern Colombia than with central Panama (Martín, 2002a,b; Martín et al., 2015; Martín et al., in press). The people who lived on the archipelago at Spanish contact used the 'language of Cueva' (*lengua de Cueva*). The term 'Cueva' is not a patronym. A Cueva people did not exist. The Cueva language was arguably a mode of communication across a multi-ethnic and socio-economically complex landscape in eastern Panama province, much of the Darién, and the *comarca* of Kuna Yala (Helms, 1979; Romoli, 1987; Constenla-Umaña, 1991, 2012). The chief of the largest and most populous island in the Pearl Island archipelago (Terarequi, Islas de las Flores or Isla del Rey) was renowned for the ferocity of his raids with a flotilla of war canoes against villages along the Darién coast (Mártir de Anglería, 1965, p. 296; summarised in Linné, 1929: pp. 63–70). Terarequi's warriors did not fight with bows and arrows, but rather with palm wood spears whose points had been fire-hardened — a cultural usage to which we refer in Section 4.2.1.2. Understory palms,

which produce appropriate lengths of very hard and flexible wood, are a prominent component of dry forest remnants on the archipelago (Erlanson, 1946). In the year 1515 CE, Spanish captain Gaspar de Morales crossed over to chief Terarequi's island and enslaved the survivors of the initial violent confrontation with the troops under his command. Many native males were transported to the gold mines of Darién, and the females to Spanish towns (Castillero Calvo, 1995, 2008). No autochthonous people remained on the archipelago by 1553 CE according to Spanish chronicler Cieza de León (1984, p. 76). Sub-Saharan African slaves were brought in to work on the pearl fisheries after 1562 CE (Camargo-Ríos, 1983; Ward, 1993, p. 35). Most of the people who live permanently on the Pearl Islands today, including at the villages on Pedro González and Casaya islands, are descendants of Sub-Saharan Africans.

### 3. The midden at Playa Don Bernardo

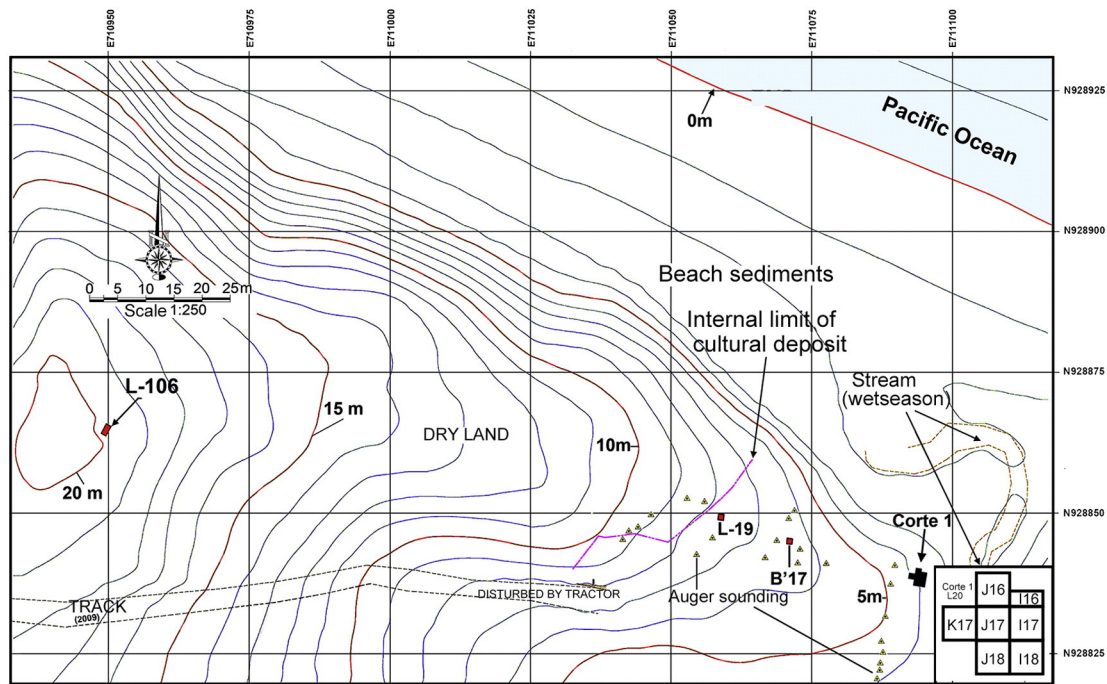
The excavations at PDB were one component of a project financed by Panama's National Secretariat for Science and Technology (SENACYT) and the Panamanian development company, Grupo Eleta, S.A. (2007–2010). Its goal was a rapid assessment of the pre-Spanish cultural and archaeo-biological resources of the archipelago before large-scale tourist ventures got under way. Swedish archaeologist Sigvald Linné conducted the only prior academic research on these islands in 1927 (Linné, 1929, pp. 63–134). He recovered cultural remains and marine molluscs, but, as far as we know, did not collect vertebrate bone.

#### 3.1. Excavation procedures

The Preceramic shell-bearing midden at PDB was located by JGM in January, 2008, while he was surveying on foot along a low ridge that parallels the beach in Don Bernardo Bay in the north-eastern sector of Pedro González Island (Figs. 3–5).

The ridge was located within a coconut grove interspersed with remnants of dry secondary forest. Several low mounds containing marine molluscs, stone tools, lithic debris, and pottery sherds, were visible on the surface, as they were in other sectors of this island. Hoping to find a flatter area in which to search for habitation zones without shell, JGM opened a 1 × 1 m cut (L-19 in Fig. 3). At a depth of ~30 cm, he came across packed marine shells. These lay underneath a dark soil horizon with sporadic faunal and cultural remains including pottery (Fig. 6).

Cultural sediments were removed in arbitrary horizontal levels of ~10 cm in the first two exploratory 1 × 1 m test cuts (L-19 and L-20). In cut L-19, these bottomed out abruptly at ~1.2 m, and lay on top of a soil that lacked evidence for human activity (this soil was breached for



**Fig. 3.** Contour map of Playa Don Bernardo, Pedro González Island, showing the location of the three test pits (L-19, B-17' and Cut 1). L-106 is not Preceramic (~1300–1200 cal BP). *Insert:* plan of the quadrats in Cut 1. Image: Roxana Segundo based on an original map provided by Grupo Eleta, SA.

0.5 m). It appears that a group of large rose cabbage murex shells (*Hexaplex [Muricanthus] brassica*) – seen protruding from the north-west corner of L-19 – were deposited as a single action, perhaps a basketful (Fig. 6). This shell-dominated deposit belongs to the Preceramic stratigraphic unit subsequently denominated 'Macrostratum I'.

In 2009, test cut L-20 was enlarged into a 1 × 2 m unit, and taken down, also by arbitrary levels of ~10 cm, until it reached ~2.6 m below ground surface (Fig. 7). Then it was expanded into a 6.5 m<sup>2</sup> excavation divided into six 1 × 1 m quadrats and one of 1 × 0.5 m. It was

re-named 'Corte 1' (in this paper: 'Cut 1') (Fig. 3, inset). Thereupon the archaeologists (FB and AL-K) attempted to adjust removal of the Preceramic deposits to stratigraphy, which they inferred visually as they excavated. They proposed seven 'natural strata' (I–VII). Natural stratum I was the dark soil with pottery mentioned above. Natural strata II–VII did not contain pottery. The same strategy was applied to a third test cut (B'17, 1 × 1 m) whose anthropogenic deposits attained a depth of 4.1 m from modern ground surface. In Cut 1, a sudden rise in the water-table following torrential rains in early April, 2010, led to



**Fig. 4.** Playa Don Bernardo, Pedro González Island, 2009. The blue tarpaulin covering Cut L-20 is visible on the right. Photo: R.G. Cooke. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)





**Fig. 5.** Playa Don Bernardo, Pedro González Island, 2009, from Don Bernardo Bay. Note the blue tarpaulin of Cut L-20. Photo: R.G. Cooke. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

dangerous undercutting, and suspension of the excavation. Auger soundings showed that the cultural deposit in Cut 1 was just over 4 m in depth.

Summing up, natural stratum I is the dark surface soil, visible in the three test cuts. It varies between 0.3 and 0.7 m in thickness, and contains potsherds, occasional flaked lithics, and a few marine shells and vertebrate bones. Its stratigraphic discontinuity with the Preceramic shell bearing midden below natural (strata II–VII), is very clear in all the cuts, facilitating the tracing of the ceramic/preceramic interface.



**Fig. 6.** West profile of Cut L-19, Playa Don Bernardo, Pedro González Island (2008). The edaphic horizon on top of the packed shell layer represents occupation after ~2300 cal BP. Photo: J.G. Martín.

In some places, natural stratum I has the appearance of slope wash or alternatively an intentional fill laid down in order to level the surface of the midden when the area was re-occupied by pottery-using people after ~2300 cal BP.

### 3.1.1. Re-fitting vertebrate bones and re-definition of cultural strata

When the vertebrate remains from B'17 and Corte 1 were studied in the laboratory, several anciently broken specimens found in more than one natural stratum (strata 3 + 4 + 5; and strata 6 + 7) allowed single or multiple re-fitting, showing that meaningful temporal and cultural horizontal divisions were deeper and fewer than those indicated by the original natural strata. Therefore a vertical zonation of three Preceramic stratum groups or 'Macrostrata' was inferred: Macrostratum I contains packed marine shells mixed with moderate amounts of vertebrate bone; Macrostratum II is a more laminated and heterogeneous unit containing irregular patches of marine shell fragments; Macrostratum III is edaphically quite homogeneous. It is characterised by sporadic marine shell and dense vertebrate bone in an excellent state of preservation. This stratigraphic unit becomes sandier and more humid with depth. Macrostrata II and III were not observed in Cut L-19.

The Macrostrata in each test cut were considered independent units of analysis for the quantification of the vertebrate remains including dolphins (Table 3). Fig. 7 summarises visually the distinction between natural strata and stratum groups (Macrostrata) in the early stages of Cut 1 (to 2.6 m).

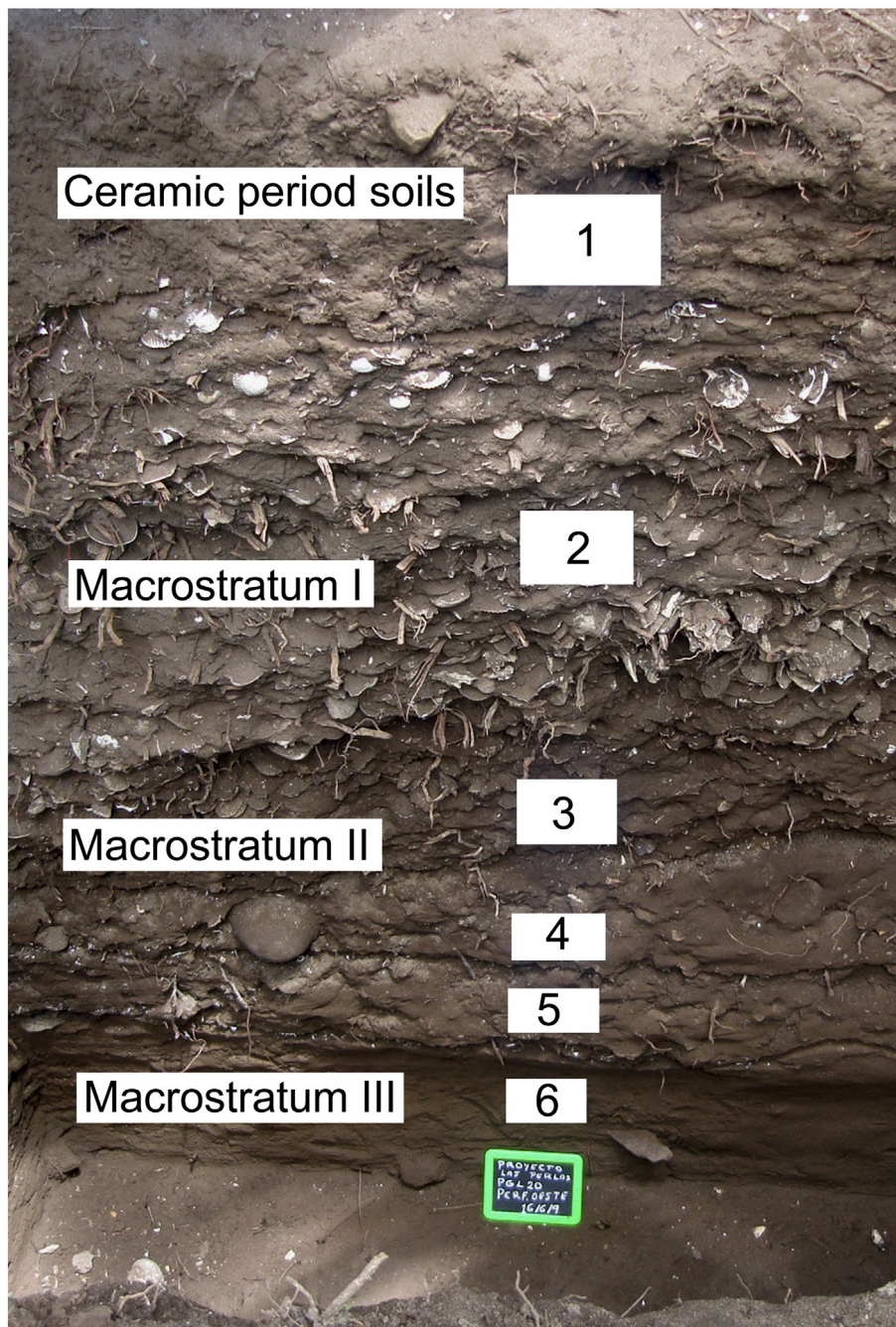
The suite of eight  $^{14}\text{C}$  dates (Table 2), in addition to the absence of pottery, infer that the deposits that formed Macrostrata I–III are Late Preceramic in the Panama cultural sequence (Sánchez-Herrera, 2000: Cuadro 1; Isaza-Aizuprúa, 2007: 49–52). No floors, hearths with stones or postholes were found in the three test cuts although scattered burning activity was observed throughout the midden especially in Macrostratum III indicating that fires were lit for preparing food including dolphins. Some scattered human bone, belonging to at least three individuals, was found stratified within Macrostratum III (Cut 1, quadrats J and K; see Fig. 3, inset) at a depth of 2.6–2.9 m from the present-day surface. Remains of one adult female were identified along with one [1] child and one [1] young adult (Nicole Smith, personal communication, 2014).

## 4. Vertebrate remains

### 4.1. Zooarchaeological procedures

During test-excavations at PDB, wood-framed sieves with commercial 1/8 in. (3.2 mm) wire meshes (placed horizontally on trestles) were





**Fig. 7.** West wall of Cut L-20, Playa Don Bernardo, Pedro González Island at  $-2.60$  m (2010) (later enlarged into Cut 1). Roman numerals identify the original 'natural strata'. A grinding stone with maize starch grains and phytoliths protrudes from natural stratum 4 (Macrostratum II). Image: A. Lara-Kraudy and Roxana Segundo.

**Table 3**

Playa Don Bernardo, Pedro González Island: Distribution of numbers of cetacean specimens (NISP) and minimum numbers of individuals (MNI) by macrostrata.

Taxonomy	Macrostratum												Total			
	I				II				III							
	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%	NISP	NISP%	MNI	MNI%
Cetacea	1	1.4	0	0	3	3.6	0	0	22	13.9	0	0	26	8.3	0	0
Delphinidae	19	26	1	14.3	35	42.2	1	25	71	44.9	0	33.3	125	39.8	3	21.4
<i>Delphinus delphis</i>	34	46.6	4	57.1	42	50.6	2	50	65	41.1	3	66.7	141	44.9	8	57.1
<i>Tursiops truncatus</i>	18	24.7	1	14.3	3	3.6	1	25	0	0	0	0	21	6.7	2	14.3
cf <i>Stenella</i>	1	1.4	1	14.3	0	0	0	0	0	0	0	0	1	0.3	1	7.1
Total	73	100	7	100	83	100	4	100	158	100	3	100	314	100	14	100

used to recover cultural and biological remains. One 0.5 m<sup>2</sup> column was taken in B'17 and another in Cut 1 as controls for the quantification of faunal remains through time using graded geological sieves with water. The data were discarded as unusable, however, because of errors in labelling procedures in the field. More column samples will be taken from the walls of the much larger rescue excavation (7 × 4 m) currently in progress (October, 2015). Thus precise estimates of the relative dietary importance of all vertebrates and invertebrates will be obtained.

#### 4.2. Identification

All vertebrate remains recovered during the test-excavations were separated from cultural materials and invertebrates in the field, and then dried in the shade, and bagged. They were transported to the Archaeology Laboratory of the Smithsonian Tropical Institute (STRI) in Panama City where MJ-A organised the entire sample by Phylum and Class. Once bones had been numbered individually, all diagnostic cetacean remains were sent to TAW at the Zooarchaeology Laboratory of the Cotsen Institute of Archaeology, University of California, Los Angeles. TAW proceeded to identify the remains using reference cetacean skeletons housed in three California institutions: California Academy of Sciences; Los Angeles County Museum of Natural History, and UCLA Dickey Natural History Collection (Appendix A). He then returned the sample to STRI where RGC and MFM-P related the identified material to contextual information from the test cuts. Subsequently, MFM-P undertook a taphonomic analysis of cetaceans (Section 4.2.1) and cervids (Martínez-Polanco et al., n press),

Three hundred and ten specimens were classified as Cetacea (Table 4). TAW assigned 288 of these to Delphinidae. Three delphinid genera are present: common dolphin (*Delphinus*) (NISP: 122), bottlenose dolphin (cf *Tursiops* and *Tursiops*) (NISP: 21), and possible harbour dolphin (cf *Stenella*) (NISP: 1).

*Delphinus* comprises two currently recognised species across its extensive range in tropical and warm temperate waters: short-beaked common dolphin (*D. delphis*) and long-beaked common dolphin (*D. capensis*). These species are sympatric in some areas of the world, but not in the Pacific and Caribbean waters of Central America (Perrin, 2009: Fig. 4). It is likely on zoogeographic grounds, therefore, that all *Delphinus* remains at PDB refer to the short-beaked dolphin. In some

cases, this inference was substantiated by species-specific osteological details (Appendix A).

Genus *Tursiops* contains three species. The Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) is restricted to the Indian and western Pacific oceans (Hammond et al., 2012). The Burren dolphin (*Tursiops australis* sp. nov.) is found only in southern Australia (Charlton-Robb et al., 2011). The lack of geographic overlap between these two newly described species and the common bottlenose dolphin legitimises referring all the *Tursiops* material at PDB to the common bottlenose dolphin (*T. truncatus*). Inshore populations of this ecologically plastic species frequent estuaries, bays, lagoons and other shallow coastal regions, and can be found far up rivers (Grigg and Markowitz, 1997; Hammond et al., 2012). In the Caribbean, bottlenose dolphins frequent mangrove edges and sea-grass beds where they congregate to feed on the large biomasses of juvenile fish that can be found in these habitats. Mullet (Mugilidae) were shown to be favourite prey on a Belizean atoll. Bottlenose dolphins also consume benthic molluscs and crustaceans. In Belize, they have been observed rolling lobster traps trying to get at the food inside (Grigg and Markowitz, 1997). Cooperative behaviour between bottlenose dolphins and human fishers has been documented (Daura-Jorge, 2012).

A damaged tooth in the PDB sample was tentatively assigned to *Stenella* on the basis of its very small size and the nature of its curvature (Appendix A). The average body mass of some species in this speciose genus is lower than that of the short-beaked common dolphin, e.g., 25–80 kg in the Central American spinner (*Stenella longirostris*) (Perrin et al., 2005). In comparison, the common dolphin's body mass averages 70–135 kg, and that of the bottlenose dolphin, 200–650 kg (Reid, 2009, pp. 295–297).

The majority of the complete anatomical elements at PDB are teeth, of which 104 were found (34% NISP). Ninety-six teeth were referred to *Delphinus*, six to *T. truncatus*, and one to cf. *Stenella*. The numerical prominence of *Delphinus* teeth in the PDB samples reflects the high numbers of undifferentiated mandibular teeth (46–65) in *D. delphis*. *T. truncatus* has 18–26 teeth (<http://www.hartnell.edu/sites/default/files/u276/referencetomammals.pdf>).

Differential wear is observed on delphinid teeth at PDB. This is most evident on common dolphin teeth found in Macrostratum III of Cut 1 (Fig. 8, a–f & h) whose wear patterns infer different individuals: some

**Table 4**  
Playa Don Bernardo, Pedro González Island: Distribution of cetacean body parts.

ANATOMY	Cetacea	Odontoceti	cf Delphinidae	Delphinidae	<i>Delphinus</i>	<i>Delphinus</i> cf. <i>delphis</i>	<i>Delphinus delphis</i>	cf <i>Tursiops</i>	<i>Tursiops truncatus</i>	cf <i>Stenella</i>	Total
Basioccipital					2						2
Parietal					1						1
Cranium				4							4
Neurocranium					1						1
Periotic							5				5
Epiotic							4				4
Mandible	4		1	20	2	5	3				35
Tooth			1		96				6	1	104
Vertebra	4	1		45	9	1		7	7		74
Xiphoid							1				1
Rib	5		1	27	1						34
Humerus					1						1
Radius				1							1
Radius or ulna				1							1
Ulna				1	2		1				4
Pelvis					1		1				2
Metacarpal				3	1						4
Carpal				1							1
Podial	1										1
Metapodial					1						1
Navicular					1						1
Phalanx				13							13
Limb bone				2	3				1		6
Unclear	9										9
Total	23	1	3	118	122	6	15	7	14	1	310





**Fig. 8.** Playa Don Bernardo, Pedro González Island. Teeth of *Delphinus* (a–f & h) and *Tursiops* (g). a: Macrostratum (MS) III, burnt, STRI 11–100, b: Cut 1, MS III, STRI 11–195, c: Cut 1, MS III, STRI 11–239, d: Cut 1, MS III, STRI 11–537, e: Cut 1, MS III, STRI 11–99, f: Cut 1, MS III, Cat. 11–421STR1 11–42, g: Cut L–19, MS–I, STRI 8–92, h: Cut 1, MS III, STRI 11–561. Image: Raiza and Roxana Segundo.

teeth show incipient wear at the tip (Fig. 8, a, h), some have rounded and lightly worn apices (Fig. 8, b), and others, chipping that exposed the dentin. Yet others had been chipped and ground down through use (Fig. 8, c, d, e, f). One *Delphinus* tooth is burnt (Fig. 8, a). Six *T. truncatus* teeth from a single individual show very heavy grinding in addition to prior chipping (Fig. 8, g, g1). Bottlenose dolphins have been observed feeding on molluscs and crustaceans in shallow lagoonal waters (Grigg and Markowitz, 1997).

None of the *Delphinus* teeth at PDB was intentionally perforated for use as personal ornaments. This suggests that the Pearl Island Preceramic dolphin fishers had not developed a demand for cetacean teeth for non-utilitarian purposes, e.g., as traditional currency, bride price and personal adornment (cf Takekawa, 2000 for the Solomon Islands). Drilled shark teeth were found, however (see Section 6.3).

The large number of vertebrae (74) and vertebral ribs (34) in the cetacean sample from PDB likewise reflects the natural proportionality

of these bones in the delphinid skeleton. The short-beaked common dolphin has 13 vertebrae, of which seven are cervical (the atlas and axis are fused) (Long et al., 2007). Most *Delphinus* and *Tursiops* vertebrae can be distinguished to genus (Appendix A). Nine vertebrae at PDB were referred to *Delphinus*, seven to cf. *Tursiops* and seven to *Tursiops*. The degree of epiphyseal union was used to distinguish vertebrae from adult and immature animals (Fig. 9).

The tympanic periotic is considered to be particularly reliable for species differentiation in dolphins (Steadman et al., 1994; Glassow, 2005). Five complete examples recovered at PDB were referred to *D. delphis* (Fig. 10). They represent four individuals. Fifteen (15) other complete elements were referred to the short-beaked common dolphin (*D. delphis*): posterior mandible (3), epiotic (4), pelvis (1), ulna (1) and xiphoid (1) (see also Glassow, 2005). This distribution lends weight to the hypothesis that all the *Delphinus* remains relate to *D. delphis* in line with current zoogeographic studies.



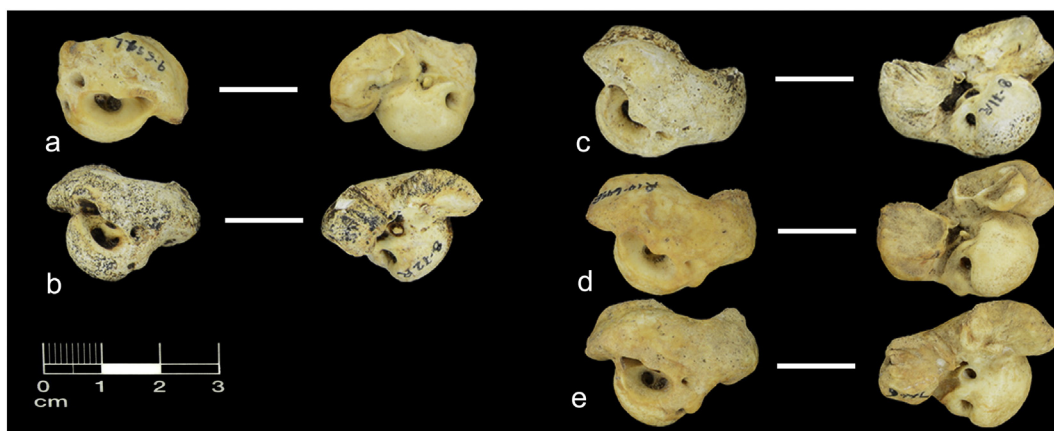


**Fig. 9.** Playa Don Bernardo, Isla Pedro González. Delphinid vertebrae. A: *Delphinus cf. delphis*, caudal vertebra, adult, STRI 10-580, Cut 1, Macrostratum (MS) I. b: Delphinidae, upper caudal vertebra, immature, STRI 10-857, Cut 1, MS II, c: *Delphinus*, lower trunk vertebra, immature, STRI 8-85, d: *Delphinus*, thoracic vertebra, immature, STRI 100-529, Cut 1, MS III.

### 4.3. Taphonomy

**4.3.1. Methods.** All skeletal specimens were examined using a binocular magnifier (OPTHEC HZ, up to 120 $\times$ ). Surface alterations were identified macro- and microscopically. Bone breakage was inferred on the basis of colour changes along the edges of cuts, and also fracture angle (see Fig. 11, d & e). These features distinguish old breakage (occurring at or near

the time of deposition) from new breakage (occurring during or after the excavation). The following aspects of marks and cuts were specifically searched for in the examination: a) number of cut marks and striations, b) location on the modified anatomical element, c) orientation with regard to the longitudinal axis of the bone, and d) distribution across the bone surface (Pérez Ripoll, 2004; Lloveras et al., 2009). Following stiner et al. (1995), six degrees of thermal alteration were



**Fig. 10.** Playa Don Bernardo, Pedro González Island. *Delphinus delphis* tympanic periotics. R - right side, L - left side. a: STRI 9-654, Cut 1, MS II, b: STRI 8-72, Cut L-19, MS I, c: STRI 8-71, Cut L-19, MS I, d: STRI 10-645, Cut 1, MS III, e: STRI 9-974, Cut 1, MS II. Photos and image: Raiza and Roxana Segundo. (MS: Macrostratum).

estimated (range from 0 [unburned] to 5 [calcined], and 6 [when two colours were observed together]).

Alterations attributed to human trophic behaviour, other mammalian carnivores, and rodents were classified following: Andrews and Evans, 1983; Brain, 1981; Cochard, 2004; Hockett, 1995; and Lloveras et al., 2008, 2009. These included: crenulated edges, notches, pitting, punctures and scores. Special attention was paid to marks commensurate with the activity of carrion-eating avian raptors (cf Andrews, 1990). Post-depositional modifications divorced from prehistoric animal and human action were also looked for, e.g., manganese (an indicator of humidity) (López González et al., 2005), and root damage (Grayson, 1988).

**4.3.2. Anthropogenic modifications.** Modifications to delphinid bones that were attributed to human activity are summarised in Table 5. Two incisions on the ascending ramus of a *D. delphis* mandible (Fig. 11, c, c1) appear to have been made by a sharp agate flake tool of the kind illustrated in Fig. 14, k, l (see Appendix B). So do shallower multiple cuts on another mandible (Fig. 10, a, a1). Similar cuts on dolphin *rami mandibulae* were observed in samples from Mawaki in Jomōn Japan (Hiraguchi, 1992, p. 42). On the other hand, incisions with a rounded cross-section, observed on a neural spine at PDB (Odontoceti; possibly *Tursiops*), are more likely to have been made by a softer pointed tool of hardened wood or bone (Fig. 11 b; cf. Martín et al., in press, Fig. 5, d).

The underside of a *Delphinus* basioccipital (Fig. 11, f) was perforated by a blunt-pointed instrument, which may have been the point of a spear or lance made of wood of *Bactris* palms collectively called “chonta” in Panama and Colombia. *Bactris* palms were reported as “plentiful” along streams and dry gullies on San José Island in the 1940s (Erlanson, 1946, p. 7), and are a prominent component of the Pedro González Island flora in the same habitat. A palm kernel used for a  $^{14}\text{C}$  date (Table 1) is from a *Bactris* palm. This multiple-utility hard and flexible wood is widely used by forest peoples in the region for making projectiles (e.g., Reichel-Dolmatoff, 1960). Since the dolphin in question was lying on its back when struck, the blow must have been made while the animal was on land or, perhaps, while it lay entangled in fishing gear or stuck in a barrier trap (see Section 5.3).

Twenty-two cetacean specimens in the PDB sample showed evidence for thermal alteration: 16 are vertebra fragments; five, rib fragments (cf Fig. 11, g.); and one [1], a tooth (Fig. 8, a). In the basal layers of Macrostratum III in Cut B'17, a carbonised cetacean bone belongs to Stiner et al.'s Stage 3 burning. It was probably a *Delphinus* humerus or ulna. It was used for a  $^{14}\text{C}$  date (Table 2,  $\beta$ -304632). Drawing analogies with Jomon Mawaki, this blackened bone may be evidence for oil extraction at the site (Hiraguchi, 1992).

**4.3.3. Other modifications.** It is inferred that other modifications to cetacean specimens at PDB are due to non-anthropogenic causes, both biotic and abiotic. A mammalian canine tooth may have been responsible for the puncture wound visible on a delphinid ulna (Fig. 12, a, a1). No wild mammalian carnivores were reported in the archaeofaunas of any Precolumbian sites on the Pearl Island archipelago although an omnivorous opossum (*Didelphis marsupialis*) is the second most frequent mammal species at PDB after dwarf deer (*Mazama* sp.). Adult opossums of this species sport formidable canines. Domestic dogs are an alternative source for the puncture wound. Canid remains were not reported at PDB; but they were present in two ceramic-period refuse piles on Isla del Rey (RGC, personal observation). A dog humerus (*Canis*), referred to a domestic collie-like breed, was reported at Preceramic Cerro Mangote, Coclé, Panama, whose midden is partially coeval with PDB (Cooke and Ranere, 1989, p. 309).

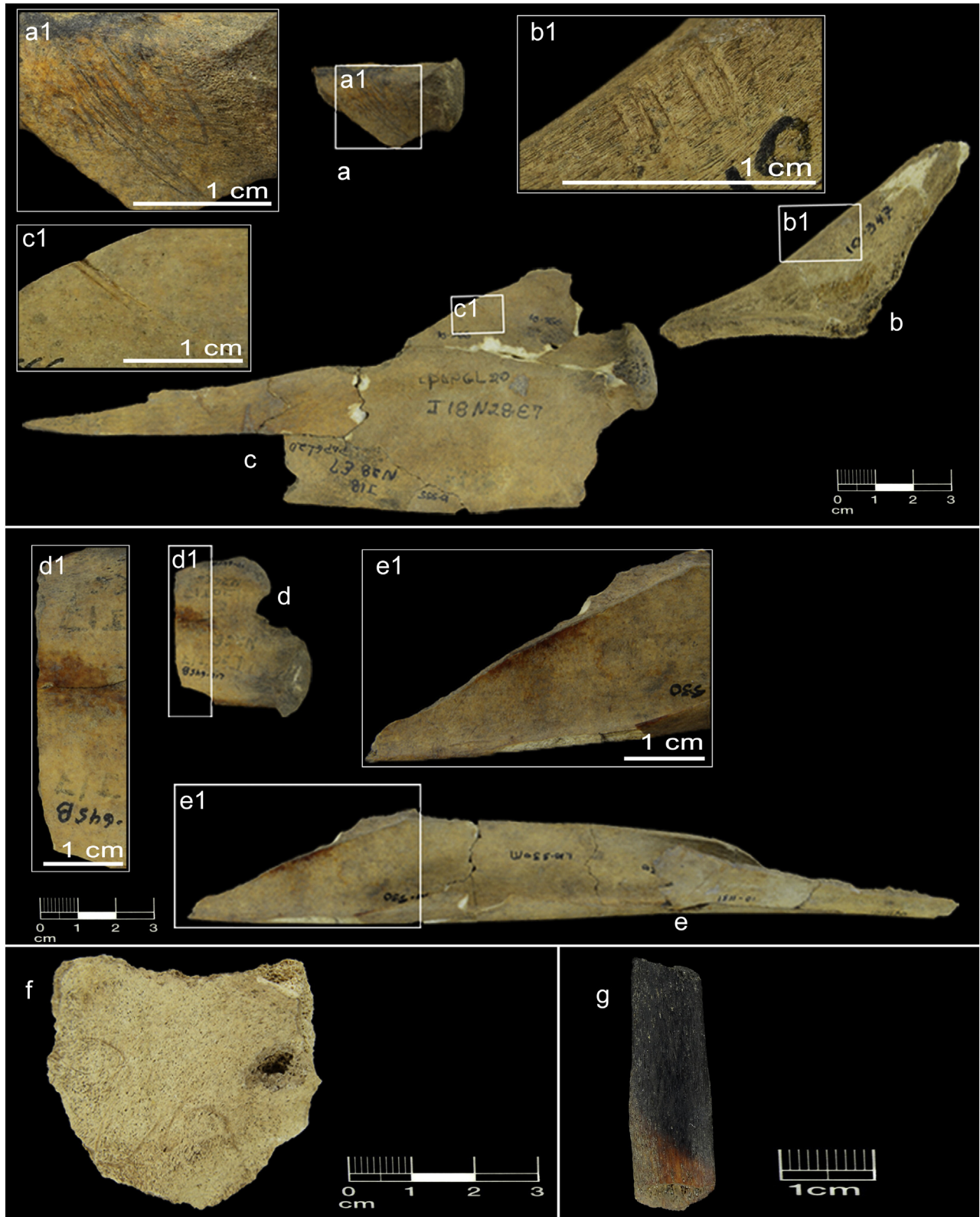
We infer that the much smaller multiple incisions on a delphinid epiotic (Fig. 12, b, b1, b2) were caused by a small rodent's gnawing. Two rodent genera were recorded in the PDB midden: spiny rat (*Proechimys* cf. *semispinosus*) and furry spiny rat (*Diplomys* cf. *labilis*). On the other hand, the irregular marks observed on a delphinid rib (Fig. 12, d, d1, d2, d3) recall the random pecking of an avian raptor, such as a cathartid vulture or a carrion-eating falcon (*Milvago chimichima*). These taxa are common members of the archipelago's avifauna (Wetmore, 1968). They form large and noisy congregations around animal carcasses.

## 5. Other subsistence activities at Playa Don Bernardo

### 5.1. Agriculture

There is ample evidence for widespread forest clearance in Panama and Colombia before 6000 cal, and also for the subsequent multi-stage and multi-directional dispersal of farmers into virgin mainland forests and Caribbean islands, accompanied by a full complement of early forms of plant cultigens that later became New World staples, i.e., maize (*Zea mays*), manioc or cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), native yams (*Dioscorea* spp.), other tuber- or rhizome-producing domesticates, squash (*Cucurbita* spp.), and bottle gourd (*Lagenaria siceraria*) (Piperno, 2006; Dickau, 2010; Piperno, 2011a,b; Aceituno and Loaiza, 2015; Pagan-Jiménez et al., 2015).

Several small grinding stones and flat bases were recovered in the Preceramic strata at PDB. Five were analysed for starch grain and phytolith presence by IH; four of these were found in Macrostratum I in Cut L-19, and one in Macrostratum II in Cut 1. On discovery, the stones



**Fig. 11.** Playa Don Bernardo, Isla Pedro González, anthropogenic modification of cetacean bones. a, a1: *Delphinus*, left articular condyle, immature, STRI-10-305, Cut 1, Macrostratum (MSW) III, b, b1: Odontoceti, vertebra (neural spine), STRI 10-347, Cut 1, MS III, c, c1: *Delphinus*, left mandible, adult, STRI-10-566, Cut 1, MS III, d, d1: *Delphinus delphis*, left mandible, STRI-10-645, Cut 1, MS III, e, e1: *Delphinus delphis*, right mandible, STRI 10-530, Cut 1, MS III. f: *Delphinus*, basioccipital with puncture wound, STRI 8-94, Cut L-19, MS 1, g: Delphinidae, distal rib with zonal burning, STRI-10-527, Cut 1, MS III. Image: Raiza and Roxana Segundo.

were wrapped in aluminium foil and sealed immediately in plastic bags. The five artefacts analysed all contained maize starch – two samples (3 & 4) in large quantities (Table 6).

A few starch grains are similar to the ones found in three genera that produce edible starch (*Canna*, *Heliconia*, and *Maranta*). One starch grain is from a native yam (*Dioscorea* sp.). One maize phytolith, probably



**Table 5**  
Playa Don Bernardo, Pedro González Island: Distribution of cetacean bones showing evidence for human modification.

Macrostr.	Cat. #	Taxonomy	Element	Cut type	#	Delineation	Orientation	Depth
II	10–1751	Cetacea	Indeterminate	Incision	4	Straight	Transverse	Deep
	8–76	<i>Delphinus delphis</i>	Cranium	Scrape	1	Straight	Oblique	Slight
	10–119	<i>Delphinus delphis</i>	Rib	Incision	1	Straight	Transverse	Deep
III	10–532	Cetacea	Rib	Incision	2	Straight	Transverse	Deep
	10 1967	Cetacea	Rib	Incision	3	Straight	Oblique	Slight
	10–311	Delphinidae	Rib	Incision	2	Straight	Transverse	Deep
	10–347	Delphinidae	Vertebra	Scrape	1	Straight	Transverse	Slight
	10 1961	Delphinidae	Rib	Incision	1	Straight	Transverse	Slight
	10–565	<i>Delphinus delphis</i>	Mandible	Incision	3	Straight	Transverse	Deep
	10–1470	<i>Delphinus delphis</i>	Mandible	Incision	3	Straight	Transverse	Deep
	10–307	<i>Delphinus</i>	Rib	Incision	2	Straight	Transverse	Deep
	10–567	<i>Delphinus</i>	Rib	Incision	2	Straight	Transverse	Deep
	10–305	<i>Delphinus delphis</i>	Mandible	Incision	9	Straight	Transverse	Deep

from a cob, is present on the grinding-stone visible at 2.6 m depth in Macrostratum II of Cut 1 (Fig. 7). Since the abundance of marine shell in Macrostratum I would have been inimical to phytolith preservation, phytolith numbers and types are probably underestimated in this analysis.

The above data infer that the Preceramic inhabitants of Playa Don Bernardo cultivated plots on Pedro González Island in the wet season (April through December). The intense dry season would have allowed effective clearing of standing vegetation before planting, effective drying of mature maize ears on the stalk, and consolidation of starch in tubers.

### 5.2. Hunting terrestrial non-volant animals including marine turtles

Deer bones, numerically predominant in the non-fish sample, were heavily modified by human intervention: 2310 deer (*Mazama* sp.) specimens correspond to an estimated 16 individuals, i.e., a ratio of 144 specimens per individual (summed MNI by excavation cut and Macrostratum) (Martínez-Polanco et al., in press). Nearly all deer long bone diaphyses were intentionally fractured in prehistory. The corresponding ratio for delphinids, using the same methodology, is 288/14: 20.6 specimens per individual. Deer long bones were subjected to a greater degree of anthropogenic modification apparently because of the value of sharp longitudinal sections and splinters for manufacturing tools.

The Preceramic deer on PDB belongs to a dwarfed population (estimated body mass <10 kg) (Martínez-Polanco et al., under review). Buckley et al. (under review) inferred from collagen fingerprinting that this ancient population, as well as that of a small deer found today only on neighbouring San José Island (Fig. 1), both belong to genus *Mazama*, and could represent the same lineage. (Described in the 1940s as a new species [*Mazama permira*] [Kellogg, 1946], the San José Island cervid was transferred by Handley [1966] to subspecies *permira* of the South American grey brocket [*Mazama gouazoubira*]. Subsequently, Rossi et al. [2008, 2010] intuitively referred it to the Amazonian brown brocket [*Mazama nemorivaga*], the remainder of whose distribution lies in northwest South America).

Apart from the *Mazama* deer species, the following non-fish vertebrate taxa were taken by the Preceramic inhabitants of Pedro González Island (here ranked by NISP): 1) opossum (*Didelphis marsupialis*)\*, 2) green iguana (*Iguana iguana*), 3) Central American agouti (*Dasyprocta punctata*), 4) boa (*Boa constrictor*), 5) colubrid snakes, 6) hawkbill turtle (*Eretmochelys imbricata*), 7) cormorant (*Phalacrocorax* cf. *olivaceus*), 8) spiny rat (*Proechimys semispinosus*)\*, 9 = mud turtles (*Kinosternon* spp.)\*, (9 =) furry spiny rat (*Diplomys labilis*)\*, 11 =) green turtle (*Chelonia*), 11 =) paca or tepescuintle (*Cuniculus paca*)\*, 13) yellow-crowned night-heron (*Nyctanassa violacea*), 14 =) capuchin monkey (*Cebus* sp.)\*, 14 =) sooty shearwater (*Puffinus griseus*) (Steadman in

Cooke et al., 2013b), 14 =) black iguana (*Ctenosaura* sp.), 14 =) dove (*Leptotila* spp.) and 14 =) great egret (*Ardea alba*) (\* – no longer present on Pedro González Island; \*\* – no longer present anywhere in the archipelago). No dwarf deer remains have yet been recorded at any of the pottery-using sites on the archipelago.

A high rank for agouti remains (*Dasyprocta punctata*) is an indication that Preceramic people on Pedro González Island sought game in forest-garden habitats. Agouti population health is dependent upon the abundance of the tree fruits and seeds, which these rodents habitually scatter-hoard (Smythe, 1978; see also Linares, 1976). Green iguanas do not require extensive forest tracts. They adapt well to coastal mangroves, riparian woods and gardens interspersed with trees. Most of the iguana individuals in the PDB samples were assigned approximate body masses of 1.3–2.5 kg judging from skeletons in the STRI reference collection. Iguanas and agoutis remained an important food source until the last five years on Pedro González Island when hunting restrictions were imposed. Before that, both species were intensively hunted with dogs–iguana for their eggs as well as their meat.

The proportions of delphinid and cervid specimens by macrostratum bear witness to differential human impacts on these taxa during the Preceramic occupation of PDB: 63.1% of the cervid specimens were found in Macrostratum III, 34.7% in Macrostratum II and only 2.1% in Macrostratum I. Corresponding delphinid proportions are: Macrostratum III: 51.6%, Macrostratum II: 19.7% and Macrostratum I: 29.6%. It is inferred, therefore, that, the brocket deer succumbed rapidly to human predation on Pedro González, while delphinids continued to be a primary food resource until the site's abandonment ~5600 cal BP. No Delphinid remains were reported in much smaller achaeofaunal samples at ceramic-using post-2300 BP sites on the archipelago.

Sixteen delphinid individuals were assigned to three age-classes (adult, immature and young) based on epiphyseal union and overall size:

Cut L-19, Macrostratum I: *Tursiops truncatus* – one [1] adult; *Delphinus delphis* – two [2] adults, one [1] immature, and [1] young.

Cut B'17, Macrostratum I: Delphinidae – one [1] immature.

Cut B'17, Macrostratum II: Delphinidae – one [1] adult, one [1] immature.

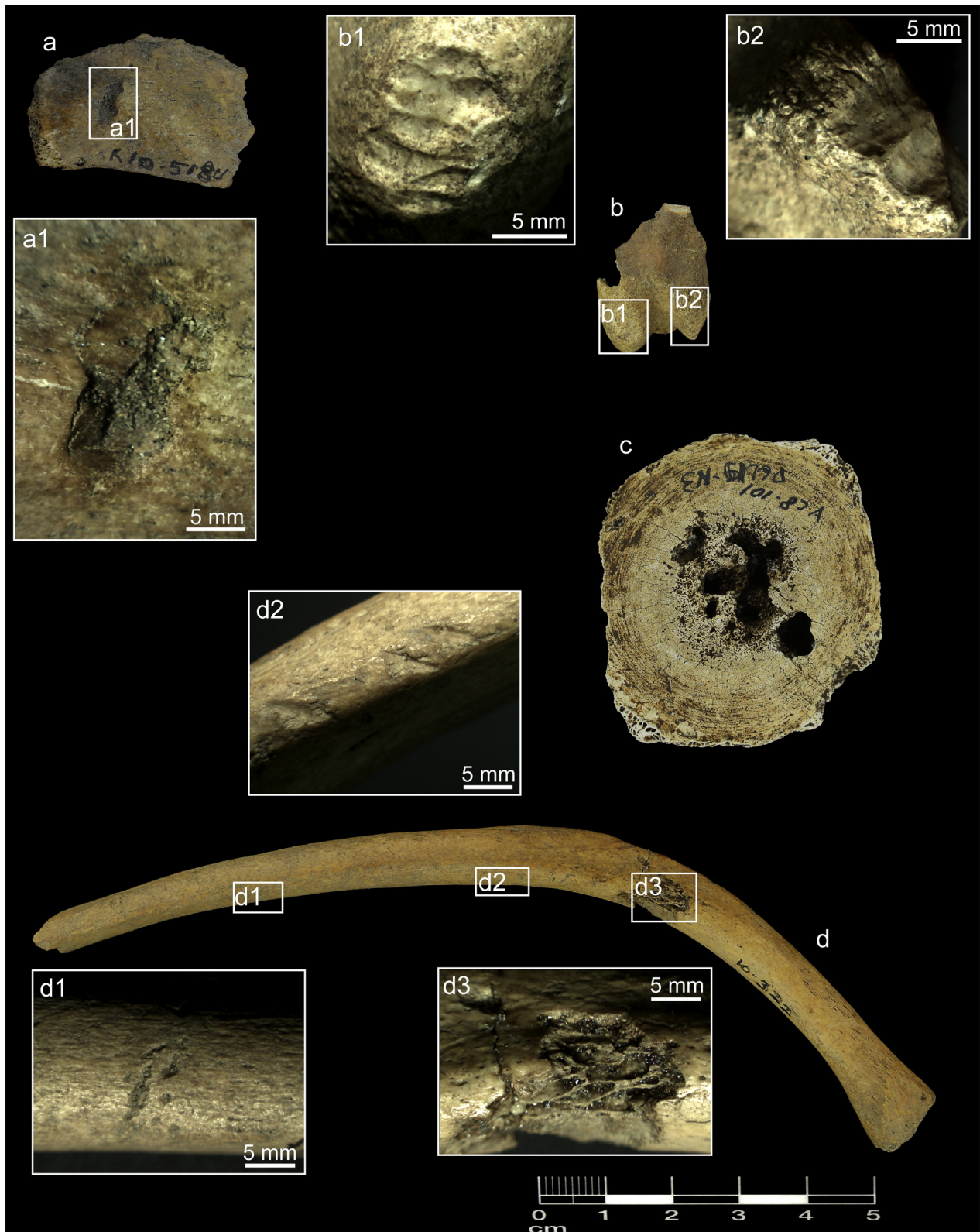
Cut B'17, Macrostratum III: Delphinidae – one [1] adult, one [1] immature.

Cut 1, Macrostratum II: *Delphinus* – one [1] adult, one [1] immature, one [1] young.

Cut 1, Macrostratum III: *Delphinus delphis* – two [2] adults, [1] immature.

To sum up, eight [8] dolphin individuals showed criteria for adults, six [6] for immatures and two [2] for young individuals.

Field observations on Australian bottlenose dolphins show multiple-level alliance formation including the pairing of dolphin mothers and offspring in inshore waters (Connor and Norris, 1982). Common



**Fig. 12.** Playa Don Bernardo, Isla Pedro González. Non-human modification of cetacean bones. A,a1: Delphinidae, right ulna showing possible puncture wound inflicted by a mammal canine, STRI 10-158, Cut L-19, Macrostratum (MS) I, b, b1, b2: *Dophinus delphis*, right epiotic, showing multiple parallel incisions suggesting rodent-gnawing, STRI 10-795, Cut 1, MS III, c: *Tursiops* vertebra, adult, STRI 8-101, Cut L-19, MS I, showing post-depositional insect damage, d, d1, d2, d3: Delphinidae rib, 10-322, Cut 1, MS III, showing multiple lesions possibly caused by an avian raptor. Image: Raiza and Roxana Segundo.

dolphins also form groups based on age and sex (Perrin, 2009). It was not possible to assign sex to the dolphin remains in the PDB sample. But finds of adults and immature individuals together in five

stratigraphic contexts, as well as the presence of two young animals who would have been with their mothers, allude to the human use of pairings of dolphin mothers and their offspring.



**Table 6**

Playa Don Bernardo, Pedro González Island: Distribution of starch grains by taxon and type on five grinding stones.

Tool ID	Taxon Cut & level (I)	<i>Zea mays</i>			<i>Canna</i> -type			<i>Heliconia</i> -type			<i>Dioscorea</i> -type			<i>Maranta</i> -type			Unidentified			
		N	L*	W*	N	L	W	N	L	W	N	L	W	N	L	W	N	L	W	
PAPG 1930	L-19, I. 20	4	23	20																
PAPG 1794	L-19, I. 19	13	19	17	2	68	36	1	22	22								1	16	18
PAPG 1769	L-19, I. 19	36	19	17	1	44	22											1	16	18
PAPG 1449	L-19, I. 17	29	19	17	2	39	25				1	20	14							
PGL-20-1	Cut 1, I. 14	8	17	16										1	70	22				

Note: L\* = average length. W\* = average width.

### 5.3. Fishing and marine littoral collection

The vertebrate class most frequently taken at Preceramic PDB was, predictably, fish. Fish represented 96% of a sample of 24,250 vertebrate specimens recovered over 1/8-inch. (3.2 mm) mesh, which was studied by MJ-A and A-LK in 2008–10. The total contribution of fish to the settlement's diet has not yet been determined formally because it will require factoring in the abundant remains of very small fish which will be recovered over fine meshes in future column samples. The fish taxa identified to date point to a broad range of island marine habitats, to variable fish size, and to several capture methods inferred from fish behaviour and from analogies with modern fishing. One level (105–115 cm) in Cut L-19 was sieved through geological screens down to 0.13 mm (Cooke and Jiménez-Acosta, 2009: Fig. 5). The five most frequent genera in this sample are: grunts (*Haemulon* spp), sergeant-majors (*Abudefduf* spp.), jacks (*Caranx* spp.), groupers (Serranidae genera & spp.), and parrot-fish (*Scarus* spp.). The species identified in each speciose genus are frequent to abundant in the archipelago today in their preferred habitats, i.e., sandy beaches, sand-mud flats, reefs (including patchy corals), bays, and clearer and deeper water currents at the entrance to Don Bernardo Bay and, perhaps, further offshore. Fish of several sizes were taken, ranging from parrot fish, hawkfish (*Cirrhitis rivulatus*), Mexican hogfish (*Bodianus diplotaenia*), and scorpion fish (*Scorpaena mystes*) with estimated body masses of 2–4 kg, to grunts and groupers averaging ~500 g, and sergeant-majors (*Abudefduf* sp.) with individual body masses <150 g.

Eighty percent of carangid specimens in the fine-screened sub-sample from Cut L-19 represent the green jack (*Caranx caballus*), an abundant predatory epipelagic species, which exploits the high biomasses of smaller shoaling fish in the nutrient-rich upwelling waters of Panama Bay (Forsbergh, 1969). The second most frequent species in this ecological category is the black skipjack (*Euthynnus lineatus*), which, like the green jack, forms large shoals and can readily be taken line-fishing with lures. Small carangids, including the green jack, used to be caught in large numbers in tidal traps set over sand-mud substrates near Panama City (Cooke and Tapia-Rodríguez, 1994).

Tidal traps with semicircular bases made of loose-set stones can be seen on virtually every island in the Pearl Island archipelago including Pedro González (Fig. 13). Present-day islanders have no recollection of their construction, and assume they are all pre-Spanish. Their relationship to sea level and coastal features, such as mangroves, varies across the archipelago: they were probably constructed at different times in prehistory. Pearl Island residents now make rudimentary pole and net super-structures in order to raise the height of the traps. An elegant structure made of thick canes (perhaps Poaceae: *Gynerium sagittatum*) was photographed by a Swedish ethnographer on an island in the archipelago in 1927; but this image does not show whether this particular trap was sustained by a stone base (Nordenskjöld, 1928). *G. sagittatum* is reported to have been used for walling palm-thatched houses on San José Island (Erlanson, 1946, p. 2).

The importance of fast-swimming pelagic fish taxa at PDB was reaffirmed by an analysis by AL-K and MJ-A of measurable complete fish bones showing taxonomically diagnostic information at the species

level, from the Preceramic strata in cut B'17. In a sample of 167 specimens, the green jack (*C. caballus*) comprises 85%, and the rainbow runner (*Elagatis bipinnulata*), 1.7%. Formerly, the latter species had only been reported in Precolumbian Panama at a site on Jicarita Island in Pacific western Panama (just south of Coiba Island), which is located near a deep marine trough. Rainbow runner adults are found in oceanic and coastal waters, generally near the surface over reefs or sometimes far from the coast, often around floating logs or other debris (<http://www.fishbase.org/summary/412>). Local people recently (October, 2015) told RGC that they have caught rainbow runners inside Don Bernardo Bay.



**Fig. 13.** Semicircular stone bases of presumed Pre-Columbian age, Pedro González Island. It is inferred that they functioned as traps for fish and marine turtles, surmounted originally by perishable superstructures. Photograph: Guillermo St. Malo.



It is clear from Figs. 6 and 7 that marine molluscs comprised a large proportion of the cultural sediments in the first Preceramic macrostratum (I). They decline in Macrostratum II, and are scarce in Macrostratum III. JGM identified the molluscs from Macrostratum I in Cut PG-19 (0.8 m<sup>3</sup>). Human selectivity is notable: only 11 bivalve genera and five gastropod genera were identified. Four genera represent 87% of the specimens recovered in this cut: a murex or rock snail (*Hexaplex*), a large and small venus clam (*Megapitaria* and *Chione*) and a nektonic scallop (*Argopecten*).

Column samples taken in 2010 were discarded because of labelling problems. One of the goals of the rescue archaeology programme (August–November, 2015) is to provide data from new columns for a formal site-wide test of the hypothesis that a rise in marine shell consumption was synchronous with a decline in terrestrial vertebrate consumption (see Section 5.2).

## 6. Preceramic dolphin exploitation in the Pearl Island archipelago, panama bay: stranded, entrapped or driven animals?

Table 4 indicates that elements belonging to the delphinid cranium, axial skeleton, pelvic girdle, limbs and limb appendages are represented at PDB. Even phalanges of flippers, considered to have low utility value (Hiraguchi, 1992), were deposited. It is inferred, therefore, that whole animals were taken to the settlement at PDB to be manipulated from the very beginning of the occupation, to the very end.

We offer comments on the possible avenues for the acquisition of these animals in the Pearl Islands.

### 6.1. Dolphin stranding and herding behaviour

Cetaceans strand singly, or in small and large groups. Mass-beachings of dolphins have been reported in recent years. But these events were influenced by noise pollution from boats and ships, which affects dolphins' acoustic communication inducing irregular behaviour and disorientation (Jepson et al., 2013). Some dolphins beach singly when they are sick and incapable of reproduction (Danil and Chivers, 1998). Groups of dolphins have been observed floundering onto coastal land-forms while herding shoals of small fishes under the direction of leader (Gazda et al., 2005). Shallow Don Bernardo Bay is an ideal environment for this particular behaviour, which may have given PDB residents the opportunity to acquire dolphins stranded on the long sandy beach adjacent to the settlement. They would have had to move quickly: carcasses would have been quickly torn apart and devoured by large aggregations of cathartid vultures and caracaras.

### 6.2. Entrapment of dolphins

In the eastern tropical Pacific, short-beaked common dolphins show preferences for seasonal changes in sea surface temperature, upwelling-modified waters, and extensive shelf areas (Reilly and Fielder, 1984). These features characterise the Pearl Island archipelago especially in normal (i.e., non El Niño) dry seasons. Archaeo-ichthyological data from PDB vouch for the high rank of epipelagic shoaling fish, such as green jack (*Caranx caballus*) and skipjack tuna (*Euthynnus lineatus*), which, along with their nektonic prey, are preferred food sources for in-shore dolphins (Section 5.3). Double-pointed and symmetrical artefacts made of deer bone diaphyses, tied as lures, would function as gill-hooks for catching these and other fish that readily snap at anything in the water column (Martín et al., in press: Fig. 5c).

Certain anatomical features of delphinids, such as long tooth rows, thin mouth-parts and weak fin mechanics, compromise their ability to break free from fishing gear (Wells and Scott, 1999). Aside from the hypothetical gill-hooks, however, no artefacts appropriate for use in fishing gear have been recovered at PDB, including fashioned net weights and shell fish hooks.

Since un-carbonised plant macrofossils do not survive in this environment, it is to be expected that cordage and nets have not preserved,

although raw materials for nets and fishing lines were probably available in the island's dry tropical woods, which harbour many classes of fibrous epiphytic and terrestrial plants (Erlanson, 1946) (see Appendix B).

Bottlenose dolphins are known to forage around fish-farm cages and to take fish from gillnets and crab traps exposing themselves to entrapment and incidental mortality (Wells and Scott, 1999). These dolphins were possibly capable of muscling their way into fish traps set around the southern shore of Don Bernardo Bay in order to eat the entrapped contents (Fig. 13). It is not known, however, whether these traps extend back in time to the Late Preceramic.

### 6.3. In-shore movement as a response to shark attacks

In tropical and sub-tropical marine coastal waters, the major predators on dolphins are large and aggressive sharks, e.g., tiger-sharks (*Galeocerdo cuvier*) and various *Carcharhinus* species (Corkeron et al., 1987; Mann and Barnett, 1999; Heithaus and Dill, 2002).

Two perforated shark teeth were recovered in Macrostratum III in Cut I. One is a left lower lateral tooth from a tiger-shark whose total length was estimated to be 3.5 m by reference to specimens with biometric data in the Florida National History Museum, Gainesville by Catalina Pimiento (personal communication, 2012) (Fig. 14, a). Another example, which refers to a bull shark (*Carcharhinus leucas*), also belongs to an individual about 3.5 m in total length (Fig. 14, b) (see also Martín et al., in press, Fig. 5, a, b). The selection of the largest sharks for making these sartorial artefacts at PDB infers a shark-human symbiosis that included a cognitive component. PDB residents desiring to take advantage of floundering or stranded dolphins after shark attacks would have been aware of the dangers of working in shallow marine waters, and how to circumvent them.

### 6.4. Driving dolphins

Coastal and island-centred dolphin populations are considered to be particularly vulnerable to hunting (Curry and Smith, 1997). The organised driving of dolphins using boats and sometimes nets is proposed as one of the methods that incremented harvesting efficiency at those archaeological sites around the Pacific rim that are inferred to have specialised in these marine mammals (Section 1.1). The

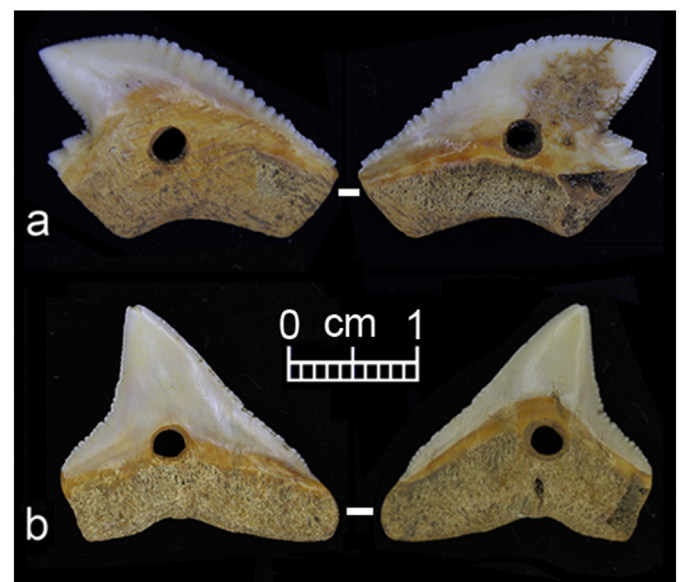


Fig. 14. Perforated shark teeth from Playa Don Bernardo, Isla Pedro González. a: tiger shark (*Galeocerdo cuvier*), L: ~3.5 m. b: bull shark (*Carcharhinus leucas*), L: ~3.5 m. Data from Catalina Pimiento. Photographs: Elizabeth Morales.

ethnographic analogue most frequently applied as supporting evidence for prehistoric dolphin drives derives from communities in the present-day Solomon Islands. Following Takekawa (1996:67–72), Porcasi and Fujita (2000) summarise the Solomon Island strategy thus: “an armada of dugouts locates and surrounds an incoming dolphin herd. The hunters then knock together, underwater, 15-cm cobbles. The dolphins become disoriented and flee the sound, often following a societal leader, into narrow passages where they can be captured in the shallow waters and among mangrove roots. There, everyone from the village, including women and children, jumps into the water to hand-catch the dolphins. Each villager holds a dolphin softly by its mouth and swims with it toward a canoe. The dolphins are hauled into canoes, killed on shore, and taken back to the village.”

There is a strikingly close topographic resemblance between Don Bernardo Bay on Pedro González Island and Mawaki Bay, Japan, where a 6000 cal BP Jomōn settlement specialised in hunting dolphins (Fig. 15; cf. Itoh, 2011: Fig. 2). At both Mawaki and PDB the earliest dolphin remains were found four metres below modern ground surface in small depressions near the mouths of small brooks. The fact that Mawaki (~13,200 m<sup>2</sup>) is about ten times as large as PDB (~1300 m<sup>2</sup>), and must have had a correspondingly larger population, would explain the far greater number and density of dolphin bones at the Japanese site. A large population enhances the efficiency of drive tactics, which require large groups of people working from watercraft. A lower population at PDB may also explain why, to date, no Late Preceramic dwellings have been found there in contrast to Mawaki where a few pit houses were located (Hiraguchi, 1992). But while Mawaki people during the later Early and Middle Jomōn periods had knowledge of nets, the same cannot be inferred at PDB. Dolphin abundance at Mawaki is strongly seasonal. Although professional observational data are lacking, dolphins are likely to have been more abundant in-shore in the Pearl Islands in the dry season for reasons given in Sections 2 and 5.3.

To sum up, there is no conclusive evidence for drive techniques using boats and nets at PDB. However, the very close ecological and topographic similarities between Mawaki and Don Bernardo bays, in addition to the shared exploitation of common and bottlenose dolphins, raise the possibility of finding such evidence on the Pearl Islands in the future. The island location of PDB, 50–70 km from the isthmian mainland coast, infers knowledge of the handling of seaworthy boats in seasonally dangerous waters. In this sense, PDB aligns itself with other sites of the same antiquity or slightly older around the Pacific Rim from Japan to central Chile.

## 7. Summary and conclusion

Test excavations at Playa Don Bernardo (PDB) on Pedro González Island in the Pearl Island archipelago, Panama Bay, revealed evidence for a multi-faceted Late Preceramic subsistence economy comprising fishing and mollusc-collection in inshore marine waters; hunting marine turtles, iguanid lizards, snakes, birds, dolphins, and small (<10 kg) terrestrial mammals; palm fruit gathering; and farming (including maize and root crops). This subsistence panorama would probably have been enhanced by the collection of iguana, marine turtle and marine bird eggs judging from the contemporary situation.

PDB is the first and only Preceramic site yet identified on Central American islands. It consists of a midden that built up in a natural depression near the present-day island coastline, and attained four metres in depth. A very clear stratigraphic discontinuity is apparent below about 2.5 m from the modern ground surface in a stratum group named Macrostratum III. This is almost devoid of molluscs while Macrostratum II above it contains moderate and variable amounts of marine shell. The most recent macrostratum (I), which contains very dense mollusc remains, extends over an area of about 1300 m<sup>2</sup>. Eight <sup>14</sup>C dates infer a maximum time span of 6200 to 5600 cal BP for the Preceramic midden after which this locality was not used again until after ~2300 cal BP. By this time pottery had arrived on the Pearl Island archipelago.

PDB is located at the south-eastern edge of edge of a small embayment, which faces north-east and, in the dry season, is open to the influence of the prevailing trade winds that lower sea surface temperatures considerably, attracting shoaling fish and their avian and cetacean predators (Fig. 15). It is clear that delphinid exploitation there 6200–5600 cal BP was dietarily and culturally much more significant than the occasional opportunistic capture inferred by former data on Precolumbian dolphin use from Meso- and Central America (Götz et al., 2014). Fourteen delphinid individuals from a sample of 288 specimens represent a very conservative biomass of 1200 kg. Sixteen individuals from 2502 cervid specimens, which were assigned to a dwarf (<10 kg) species of *Mazama* brocket deer, represent a maximum biomass of 160 kg.

People settled at PDB after Pedro González Island had become completely surrounded by the rising post-glacial ocean, probably by 9000 cal BP (see Section 2). It is hypothesised on the basis of current data that Preceramic voyagers arrived in watercraft sturdy enough to have traversed more than 50 km of open water in Panama Bay, which is windy and choppy during the months of strong trade wind activity.



Fig. 15. Playa Don Bernardo, Isla Pedro González, looking to the north-east. Photo: Adriano Herrera.



In the rainy season, fierce and squally electric storms can also make boat travel hazardous. A laden dug-out canoe with low HP outboard takes 4–5 h to get there from the city depending on weather conditions. By 6200 cal BP sea level is estimated to have risen to 1–2 m below the present-day level although this estimate does not factor in evidence for a sea-level high stand that occurred in many parts of the Pacific ~6000/4000 cal yr. B.P. (Perry and Smithers, 2010; Toth et al., 2012). During voyages to and from the Pearl Islands, dolphins would have been sighted frequently. On one such journey a sooty shearwater (*Puffinus griseus*) was captured. These oceanic birds do not come to land in Panama Bay during their June–November annual migrations from the southern hemisphere where they nest (Cooke et al., 2013b). Thus it is inferred that PDB was occupied during the wet season. The intense dry season favours cultigens that benefit from long sunny periods for maturation and storage. Therefore occupation from January to March also seems likely.

PDB is the only Preceramic site yet found on Pedro González Island or elsewhere in the Pearl Island archipelago. In fact, it is one of only two post-Paleoindian and pre-pottery archaeological sites yet recorded in Panama east of the modern Canal. The archaeofaunal evidence supports the hypothesis that the initial group of human settlers found Pedro González Island in a pristine or quasi-pristine state and vegetated with tropical dry forest. They impacted the island fauna differentially. A dwarf deer (<10 kg body mass) that was hunted regularly has vanished from this island although a possible direct descendant survives today on San José island, 8 km away (Martín et al., in press; Buckley et al., under review; Martínez-Polanco et al., in press). Another attractant for human settlement was the northeast-facing location and the ecological and topographic suitability of Don Bernardo Bay for fishing, and exploiting dolphins, which favour cool upwelling waters. We hypothesise, in fact, that early and mid-Holocene coastal populations in Panama and elsewhere in Pacific Central America retained a tradition of maritime seafaring that was inherited from much earlier populations. Delphinids were not found at Cerro Mangote, a Late Preceramic site in Coclé, which is partially coeval with PDB. But this site was located in an extensive mangrove-estuary system with extensive mud-flats – an environment inimical to *Delphinus* and *Tursiops* (Clary et al., 1984; Cooke and Ranere, 1999).

At about the same time as the Preceramic occupation of PDB, and somewhat earlier, intensive dolphin exploitation around the Pacific Rim took advantage of local geographic and ecological conditions including, in the northern Pacific, the temporary lowering of sea temperatures – a situation that augments biomasses of food fish favoured by delphinids. A few sites in Japan, the California Channel Islands and central Chile clearly specialised in hunting dolphins. This tradition may have had its roots in Late Pleistocene coastal adaptations including knowledge of skilled canoe manufacture and boat-handling in dangerous and frigid waters.

In Meso- and Central America, technological limitations and unfamiliarity with the sea are cited as reasons for Precolumbian peoples' not taking dolphins regularly for food (Götz et al., 2014). None of the Native Americans of Panama hunt dolphins today, nor did their Precolumbian ancestors. On the Pearl Island archipelago, anthropogenic cuts and marks on bones, evidence for thermal alteration, and general body part distribution, together infer that dolphins were taken whole to a 6000 yr. old settlement on the island's coast to be butchered and cooked. The current data set, based on three small test cuts set several metres apart, does not allow the accurate estimation of the spatial distribution of these remains across a midden that ultimately covered more than a hectare. This is about 10% of the area occupied by the Mawaki dolphin-hunting site in Jomōn Japan where a much larger inferred human population utilised a correspondingly larger number of dolphins (Hiraguchi, 1993). Given the orientation, configuration and ecology of Don Bernardo Bay, it is likely that short-beaked and bottlenose dolphins entered to feed on fish and invertebrates, especially in periods of cool water. The observation of this behaviour by Preceramic voyagers and the realisation of its potential for the acquisition of large

quantities of animal meat, fat and oil, is conceivably a principal reason why they decided to settle on Don Bernardo beach. Conversations with contemporary islanders who joined the workforce at PDB show that this dolphin behaviour occurs today although no formal studies have been undertaken. Another attraction of PDB for Preceramic people was the proximity of large amounts of agate for making sharp stone tools. Lastly, the dry forests sustained a variety of vertebrate fauna, some of whose species were rapidly hunted out.

One method of dolphin capture that would be feasible in Don Bernardo Bay is the use of rows of canoes placed sea-ward of dolphin pods when they came in-shore to feed, in order to drive them toward the beach in conjunction with simple methods for acoustic interference, just as in the Solomon Islands today (Takekawa, 2000). This operation, however, would be much more effective with nets than without them. Since no hard evidence for nets has been found at PDB, we must reject this hypothesis. Taking advantage of dolphins that beached while chasing shoals of small fish to shore or while attempting to escape shark attacks, are more plausible scenarios. The latter situation would have been dangerous for humans. This may explain the use of perforated shark teeth as personal ornaments – the first evidence for this behaviour in the Americas. Finds of perforated teeth from 3.5 m-long tiger sharks (*Galeocerdo cuvier*) and bull sharks (*Carcharhinus leucas*) infer a cognitive relationship between dangerous marine animals and the advertisement of human prowess. We hypothesise, in fact, that early and mid-Holocene coastal populations in Panama and elsewhere in Pacific Central America retained a tradition of maritime seafaring that was inherited from much earlier populations whose dwelling sites now lie submerged under the transgressed continental platform (Cooke et al., 2013a).

We do not know why the Preceramic settlers left PDB. Their departure antedates by 1500 years a coral die-off between 4000 and 1800 cal BP, which was triggered by the coupling of the Inter-tropical Convergence Zone and ENSO, and led to stronger and more frequent warm water El Niño events in the tropical eastern Pacific including the Pearl Islands (Toth et al., 2012). Mid-Holocene sea level rise has been observed in the central Pacific and is inferred locally by series of Holocene fossil strand-lines visible from the air to the east of Panama City (Dickinson, 2009; Perry and Smithers, 2010; SR, personal observation). Improved survey coverage in search of other Preceramic shell middens on the island, including inland of the present-day coastline, is a priority for future research in the Pearl Island archipelago where the island environments are especially favourable to common and bottlenose dolphins, and their shark and human predators.

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#### Appendix A. Identification of delphinid bone specimens from Playa Don Bernardo, Pedro Gonzalez Island, Pearl Island Archipelago, Panama

Thomas A. Wake

1. Distinguishing delphinid teeth: The single tooth identified as *Stenella* is distinguished from the genera *Delphinus* and *Tursiops* by its gracile

form and pronounced S-shaped curve. *Delphinus* teeth tend to be more robust and thicker at the gum than those of *Stenella* and have a less-pronounced S-shape (e.g. Jefferson and Van Waerebeek 2002; Jordan 2012). *Tursiops* teeth are peg-like, much larger and robust than either *Stenella* or *Delphinus* (e.g. Rommel, 1990:38).

2. Distinguishing delphinid periotic bones: Five periotic bones are identified as representing *Delphinus delphis*. These specimens are distinguished here from *D. capensis* primarily by known range, with *capensis* absent from the Gulf of Panama and the Lower Central American Bight (Perrin, 2009). *Delphinus* periotics can be distinguished from those of *Stenella* and *Tursiops* by the geometry of the arrangement of the openings of the various ducts and meati on the dorsal surface of the element (see Kasuya, 1973; Mead and Fordyce, 2009:184; Oelschlager, 1986), using specifically the finer aspects of the arrangement of the aperture of the aquaeductus cochleae (AC), aperture of the ductus endolymphaticus (DEL) and the openings in the fundus of the internal auditory meatus (FIAM), the foramen singulare (FS) and internal aperture of the aquaeductus fallopii (AF). The cochlear portion of the periotic is more bulbous and rounder in *Tursiops* than either *Delphinus* or *Stenella*. The AC is relatively larger, lies in a pronounced projection and faces the dorsal surface in *Tursiops*. The DEL in *Tursiops* is more pronounced than either *Delphinus* or *Stenella*. In *Delphinus* the FIAM is more open and the DEL is more distant from the FIAM than in *Stenella*. The FS and AF are larger, more open and more obvious in *Stenella* than in *Delphinus*.
3. Distinguishing delphinid crania and mandibles: Several osteological treatises on delphinid cranial osteology were consulted in concert with museum specimens to identify the delphinid head bones present in the PG assemblage (Jordan 2012; Lal Mohan 1985; Mead and Fordyce, 2009; Rommel, 1990). Four (4) large cranial fragments are identified as *Delphinus* passed on direct comparison with museum specimens and parameters discussed by Jordan (2102) and Rommel (1990). Ten (10) mandibles or parts thereof are identified as *Delphinus* based on the morphology of the mandibular condyle and the conformation of the proximal (post-alveolar) ramus including the coronoid process, the angular process, the post-alveolar crest, the acoustic window and the mandibular foramen (e.g. Mead and Fordyce, 2009).

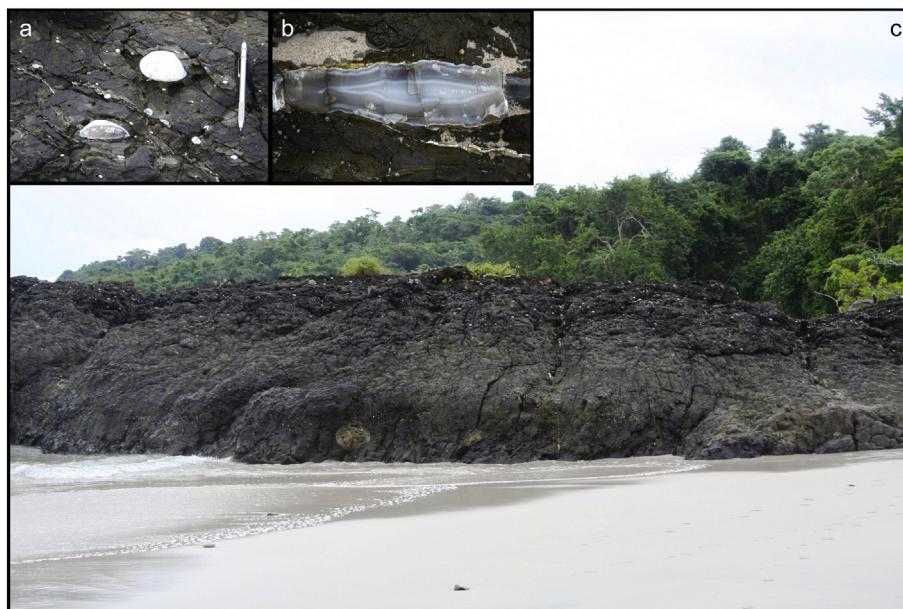


Fig. 16. Basalt outcrop just south of Playa Don Bernardo (PDB), Isla Pedro González. A: 'kidney' split in order to view the agate centre, b: 'kidneys' ensconced in the basalt. (The grey pen used as a scale is about 15 cm long). Photos: Stewart Redwood.



4. Distinguishing delphinid vertebrae: The first and second cervical vertebrae fuse in adulthood in the Delphinidae and can be readily distinguished by their finer morphological features. The thoracic, lumbar and caudal vertebrae can be distinguished between *Tursiops*, *Delphinus*, *Stenella* and *Lagenorhynchus* on the basis of the ratio of centrum length versus height (Buchholtz and Schur, 2004). *Tursiops* vertebrae are larger, more robust and longer than those of *Delphinus* or *Stenella* (Costa and Simões-Lopes, 2012; Rommel, 1990). *Delphinus* centrae are larger and longer than *Stenella* and *Lagenorhynchus* (Buchholtz and Schur, 2004) and have more diamond-shaped transverse processes (TVP) where they insert on the centrum than the oval TVP's found in *Stenella*. Wake found *Stenella* and *Lagenorhynchus* vertebrae difficult to distinguish due to their relatively short centra lengths and indistinct basal TVP morphology.

Specimens examined include: *Delphinus capensis*, LACM 84040, LACM 86002, LACM 91915, LACM 92067, LACM 95727; *Delphinus delphis*, CAS 23141, CAS 13336, CAS 21037, CAS 16242, CAS 21374, CAS 13337, CAS 24156, CAS 22947, LACM 30809, LACM 72368, UCLA 1438; *Globicephala macrorhynchus*, LACM 54150, LACM 54151; *Grampus griseus*, LACM 47145; *Lagenorhynchus obliquidens*, CAS 26749, CAS 23139, CAS 28128, CAS 27310, LACM 43470, LACM 54076, LACM 54077; *Lissodelphis borealis* LACM 54081, LACM 54082, LACM 54083, LACM 54084, LACM 54085, LACM 54086; *Peponocephala electra*, LACM 54090, LACM 54092; *Sotalia fluviatilis*, LACM 19594; *Souza teuszi*, LACM 72168; *Stenella attenuata*, CAS 23247, CAS 16434, CAS 16453, CAS 16454, LACM 54867, LACM 54863; *Stenella coeruleoalba*, CAS 24368, CAS 16720, CAS 22178, CAS 21749, LACM 54962, LACM 54965; *Stenella goffmani*, CAS 12763, CAS 15662; *Stenella longirostris*, CAS 16455, CAS 16456, CAS 16457, CAS 15668, LACM 27428, LACM 27424; *Tursiops truncatus*, CAS 15996, CAS 16183, CAS 23911, CAS 16283, CAS 26901, CAS 23152, LACM 58016, LACM 84120, LACM 88905. CAS = California Academy of Sciences, San Francisco, CA; LACM = Los Angeles County Museum of Natural History, Los Angeles, CA; UCLA = UCLA Dickey Natural History Collection, Los Angeles, CA.

#### Appendix B. Technological resources at Preceramic Playa Don Bernardo

Two technological resources, which are indispensable for the prehistoric human settlement of platform islands and the efficient exploitation of island marine fauna, are seaworthy watercraft, and stone tools used for manufacturing these and other, wooden artefacts such as paddles and projectiles.

With regard to canoe manufacture, carefully polished adzes and axes made of igneous rocks such as basalt were not observed in the PDB Preceramic lithic inventory. These tools are appropriate, if inefficient, for felling canoe-size trees, and for shaping and hollowing out their trunks although they are not indispensable for these tasks. It was not until ~2300 cal BP that polished basalt axes, adzes and chisels with standardised forms and shapes began to be made and distributed regularly across the Isthmian Sub-Area (Ranere and Cooke, 1996). Ranere (1980a) assigned a suite of distinctive wood-working tools, i.e., splitting wedges, scraper planes and choppers – mostly made of blackish igneous rocks – to the Preceramic Talamanca Phase, considering them to be the industry of hunters and gatherers who lived between 8000 and 5200 cal BP in the premontane seasonal forests of Chiriquí province, Panama, ~800 m above sea level. It is now known that these were the tools of farmers (Dickau et al., 2007).

Outcrops of workable basalt have not been observed on Pedro González Island. What was available close to PDB is banded agate, found in nodules in basalt lava outcrops located on a nearby beach (Fig. 16). These 'kidneys', as they are known to geologists, form in air pockets in the molten lava. In 2009, FB studied 2674 stone artefacts found in Cut L-20, whose volume was about 4.6 m<sup>3</sup> at the time of analysis. Fifty-eight percent of the total lithic assemblage at consists of agate,

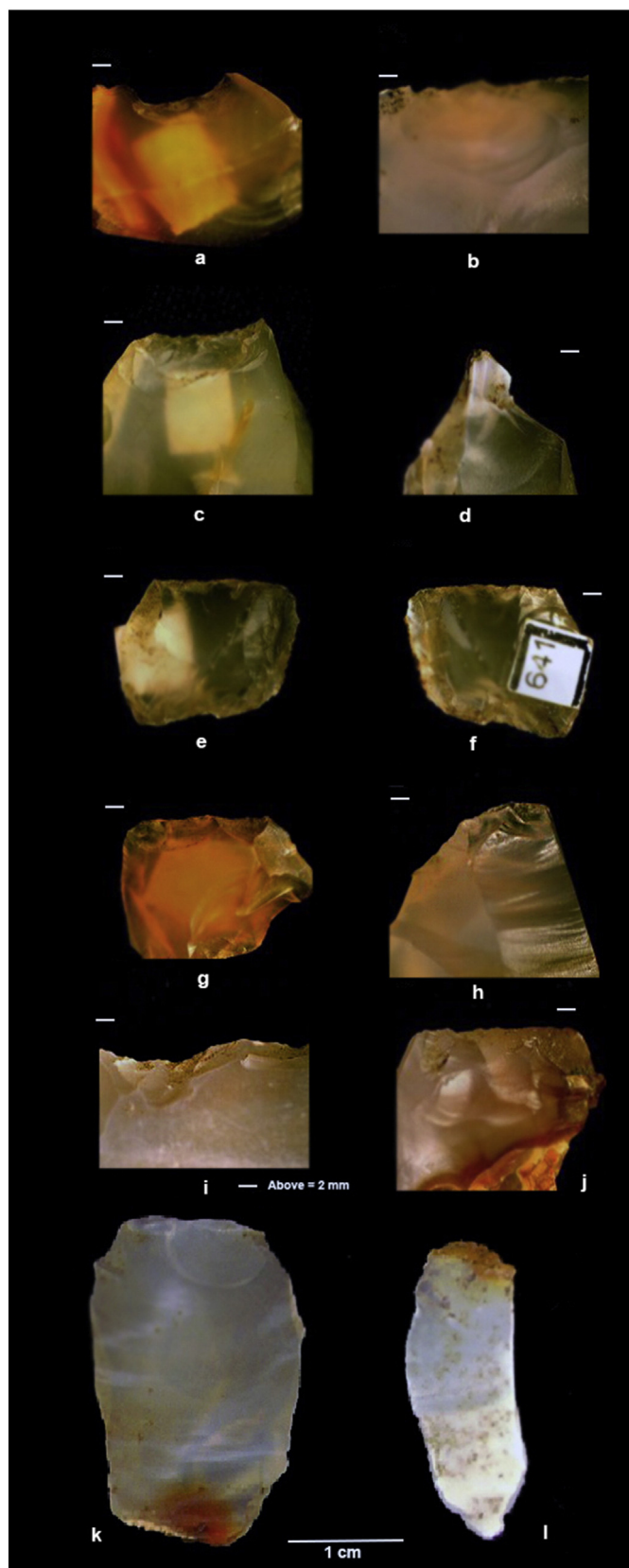


Fig. 17. Playa Bon Bernardo, Isla Pedro González. Flake tools made out of agate nodules from the basalt flow near the site (see Fig. 16). a–j: magnified to highlight different forms of edge wear (scale bar: 2 mm). k, l: flakes heated before being struck from the core placed on an anvil. Photos: a–j: FB, k–l: RGC.

and 2% of coloured chalcidies (red, yellow and green jasper). Jasper pebbles can be found scattered across the island, but outcrops have not been located.

The agate kidneys are unlikely to have been prised from the very hard lava. Rather they were probably collected already eroded out on the beach and taken the short distance to the settlement. None is bigger than a smallish human fist. This fact, in addition to the intrinsic hardness of agate, meant that the most efficient method of producing usable sharp flakes in a series was achieved by placing a small core on a hard base or 'anvil', and then striking off flakes with a hammer stone or billet rotating the nodule systematically. Damage to the extremities of some argillite pebbles infers this function. The returning force from the anvil allowed the detachment of parallel-sided and straight flakes (Fig. 17, k, l). These flakes could then be hafted individually for use as knives and scrapers or as multiple inserts in composite tools. Heating the agate enhances flaking regularity – a fact demonstrated formerly by Ranere with regard to Panamanian Paleoindian (13,200–12,000 cal BP) and Early Pre-ceramic (12,000–8000 cal BP) chalcidony tools (Ranere and Cooke, 1996, p. 59).

A group of agate stone tools from PDB bears a close resemblance to Ranere's 'tabular wedges' or chisels – a hall-mark of the Pre-ceramic Boquete Phase of Chiriquí in western Panama (4300–2300 BP). In Chiriquí, these were made mostly of coloured chalcidies (Ranere, 1980b: fig. 8/5, a–y). Ranere (1975) demonstrated with replicative experiments that these carefully fashioned tools, set in rows, could be used effectively to split wood (Fig. 17, e, f, g and j). The wear on several flakes at PDB (Fig. 17 a, c) is concave and alludes to the preparation of fibres by stripping succulent leaves placed on a hard base, such as those of the wild pineapple (*Aechmea magdalenae*), or the fronds of the understory cyclanthacid "Panama hat palm" (*Cardulovica palmata*.) Flakes used for boring or graving (Fig. 17, d), saw-cutting (Fig. 17, h) and scraping (Fig. 17, i) are also evident. The deep cuts made on some delphinid bones were probably made with agate blades (Figs. 11, c, cf 17, c, c1).

Image: Raiza and Roxana Segundo. (MS: Macrostratum).

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