HUMAN ADAPTATION TO COASTAL EVOLUTION: LATE QUATERNARY EVIDENCE FROM SOUTHEAST ASIA (SUNDASIA) - A REPORT ON THE THIRD YEAR OF THE PROJECT

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1. Introduction

The SUNDASIA project is centred in the Tràng An limestone massif, a World Heritage Site (WHS) of Ninh Binh province, northern Vietnam. Initially, a 3.5-year programme, scheduled to conclude at the end of December 2019, the project has been extended to the end of December 2020. Principal funding has come from the UK Arts and Humanities Research Council (AHRC) allocation of the British Government's 'Global Challenges Research Fund' (GCRF) and the Xuan Truong Construction Enterprise, which is also responsible for establishing and managing property infrastructure within Tràng An. The programme of research being undertaken is examining how changing coastal conditions between the Late Pleistocene and Mid-Holocene, impacted on early human behaviour and settlement patterns. Furthermore, it also draws on prehistoric evidence in

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order to inform modern-day responses to sea-level change and the associated socio-economic challenges that will result. This third annual project report briefly summarises work during the period from the end of 2018 to early 2020. It draws on recent published and presented research outputs as well as project grey literature, in the form of field reports, that are submitted and lodged with the Tràng An Management Board. The report is divided into three sections; each section relates to one of the central exploratory themes of the project.

2. Coastal environments and human behaviour

The Pleistocene and Holocene human occupation of Tràng An has taken place in the context of significant coastal change. Two archaeological sites have come to feature prominently in SUNDASIA's study of this shift in conditions: Thung Binh 1 (section 2.1) and Hang Moi (section 2.2). A reconstruction of palaeoshorelines for the northwest area of the South China Sea (Yao *et al*. 2009) suggests that 19-20,000 years ago the coastline lay beyond Hainan Island, *c*.500 km away from Tràng An. By the end of Heinrich Event 1 (17,500-14,700 cal. BP) that situation had not changed significantly, yet a perforated Neritidae (*Neripteron violaceum*) shell recovered from archaeological deposits in Thung Binh 1 is attributed to this period (Rabett 2018), implying the existence of either direct or exchange contact with the coast. Between 15,000 and 10,000 years ago the modelling by Yao *et al*. (2009) indicated a phase of much more rapid coastal inundation. While there is no substantive evidence that marine resources were being brought back to sites in Tràng An during this time, further examples of perforated Neritidae and a fragment of *Cypraea* sp. hint that coastal contact persisted through-out (e.g. Rabett *et al*. 2011). Sea-levels continued to rise through the Early Holocene culminating in a high-stand 6000-4000 cal. BP. During this time lagoon conditions and mangrove forest existed within the TràngAn massif and were exploited by foragers. This section of the report summarises the final phases of excavation at Thung Binh 1 and Hang Moi.

2.1. Hang Thung Binh 1 (Site ID code: 2B-001)

Hang Thung Binh 1 (TB1) is a small east-facing cave comprised of a main chamber and a small secondary chamber that is open on two sides - total area: 12 x 5 x 2.5m. The cave is located at 20.26162N 105.86474E *c*. 31m asl. and was first surveyed by the Vietnamese Institute of Archaeology, Hanoi (VIA) in 2008, with subsequent excavation (a 2 x 2 m trench) by the Institute in 2012, as part of research carried out ahead of Tràng An's World Heritage nomination. Nine radiocarbon dates obtained during that investigation indicated a period of occupation between 14-16,000 calendar years before present (cal. BP) (Ito *et al*. n.d. 2012; Su n.d). A team from the SUNDASIA project excavated two further trenches (one in each chamber) over the course of five field seasons, between Mar. 2017 and Dec. 2018, identifying several phases of site use, including and extending the Late Pleistocene occupation previously identified, as well as significant human skeletal remains. Detailed field season reports lodged with the Tràng An Management Board (Rabett *et al*.

2017a, 2017b, 2017c, 2018, Stimpson *et al*. 2018) include information about this and all other aspects of project work; published annual summaries (2016-17 & 2017-18, respectively) arepresented in UNESCO 7B-VietNam-Tràng An_20171206_public-1 Sub-Annex 1.1., and Rabett *et al*. (2019).

In Nov 2018, the objective at Thung Binh 1 was to establish and date the base of the Pleistocene midden in Trench 2 (main chamber) from where human skeletal remains (HSR) had been recovered in Dec. 2017 and Apr. 2018 (*see* Rabett *et al*. 2019). Following the removal of backfill from the trench, sediment was removed following previously established contexts and spits and 100% dry sieved (2 mm mesh). A long-bone fragment - accession number TBH-F907-SF-38b - was exposedat the base of context (F907.5), directly beneath the site's principal human skeletal assemblage (TBH-F907.4-SF-36) (*see* 2.1.1). An exploratory slot (0.5 x 1m) was dug to reveal the bone and investigate the surrounding deposits. The specimen lay principally within context (F908.1) and was identified by the project biological anthropologist (AW) as a human proximal left humeral shaft fragment. It was recovered in association with a large mammal (likely sambar deer, *Rusa unicolor*) phalanx catalogued as (SF39) and the right mandible from a small cervid (SF40) - both lifted from context (F908.2). A robust human right femoral shaft fragment identified section, context (F907), was deemed to be likely part of this assemblage and accessed as: TBH-F908.1-SF-38b.

Further investigation of the underlying midden deposits required the removal and cleaning-back of residual baulks that had been created during the course of exposing the site's principal Pleistocene inhumation: TBH-F907.4-SF-36 (Rabett *et al*. 2019; Stimpson *et al*. 2018). As the excavation area covered portions of three grid squares (151/243, 151/244 & 151/245) with a significant area in the eastward extension (designated T2-EE) it was given a new designation 'midden sounding - MS' and divided equally into eastern and western slots: MS-E (which included the exploratory slot discussed above) and MS-W. All excavated sediment continued to be dry sieved; bulk and small archive soil samples were taken following standard project procedure. Sedimentary compaction in the upper *c*.3 cm of (F908) from excavator foot traffic was underlain by an ash-rich deposit (F909) that interdigitated with a clay matrix in the northern half of MS-W and directly underlay the areas from which portions of TBH-F907.4-SF-36 had been recovered. Contacts with overlying (F908) and underlying (F911) were diffuse (essentially this probably represented a continuous midden deposit). A large human tibial shaft fragment (TBH-F910-SF-42) was recovered from the underlying context (F912), as was a juvenile third metatarsal (TBH-F912.2-#122) and two fragments of a medial right fibula (TBH-F912-SF-45A+B).

Context number (F910) was assigned to a more defined and compact area of ash in the north part of MS-W, and from which a complete distal mammal humerus (SF46) was recovered. Near to the centre of the context (in plan) a rectilinear feature, potentially a pit, was later removed separately as (F913). Context (F910) continued down onto a compact

clay-rich layer (F915) notably devoid of shell, but not sterile. A radiocarbon date on charcoal from this context returned a date of 17,992-18,442 cal. BP (UBA-40554) at 2-sigma, which we take provisionally as the likely period when midden accumulation began. This age overlaps with the Pleistocene dates we obtained from Trench 1 - 17,500-17,940 cal. BP (UBA-34739) and 17,422-17,889 cal. BP (UBA-34737), suggesting that during this phase of occupation both parts of the cave were utilised. Given the record of recovery from Trench 1 (Rabett *et al*. 2019), use of the smaller secondary chamber/rock-shelter may have been short-lived and curtailed by infilling. The accumulation of younger deposits, comparable to those found within the Trench 2 stratigraphy could, however, have been truncated by erosion (likely, slope wash), perhaps during the period of strengthened Asian summer monsoon during the early Holocene between *c*.7300 and 6500 cal. BP (e.g. Cook & Jones 2012; Wu *et al*. 2012). The undulating upper surface of the middenin Trench 2 appears consistent with the effects of surface water movement. On-site observations of slope wash during excavation also confirmed that this is likely to have been a factor in site formation.

The remainder of the MS trench (F912) was underlain by (F914), a continuation of the midden. An important find in (F914.2) was a carnivore premolar (SF49) from a large cat (*Panthera* sp.) dated by associated charcoal to 16,051-16,467 cal. BP (UBA-40555). Further removal in the SW of the midden sounding began to expose further contact with the ashy (F910). It was clearly the case that the deeper stratigraphy of Trench 2 was consistent with overlying strata by sloping quite appreciably north-south and west-east. Removal of (F914.2) revealed the same compact clay-rich layer, devoid of shell (F915). Small areas of deposit, consistent in nature with (F910) were also revealed in the southwest of the trench.

Our hypothesis that ash-rich layers were in direct association with and directly underlying the more significant assemblages of Pleistocene HSR recovered at the site found further support with the late discovery of an apparently articulated human foot (TBH-F914.2-SF-52) directly underneath a slim, flat rock and overlying (F910) in the SW corner of the trench. The exposed material was removed, analysed and consolidated (the ends of exposed bone in the trench section were consolidated on-site) before being reinterred in a robust sealed plastic box (also containing a note explaining the significance of the bones) next to the associated material still in-situ. A cairn was built around the immediate area before the Midden Sounding and the rest of Trench 2 was backfilled and the excavation closed.

2.1.1. Inhumation TBH-F907.4-SF-36

SUNDASIA field reports have described the recovery of fragmentary human remains of several individuals coming from Holocene and potentially Pleistocene levels of Trench 2 in ThungBinh 1 (Rabett*et al*. 2017b, 2017c, 2018; Stimpson *et al*. 2018). The

most complete remains belonged to an inhumation (TBH-F907.4-SF-36). Three ^{14}C dates have been obtained on charcoal found in direct association with the remains: 10,493-10,680 cal. BP (UBA-40556), 11,949-12,249 cal. BP (UBA-36372) and 12,702-13,089 cal. BP (UBA-38671). The spread of dates might suggest that a shallow burial pit was dug into older underlying deposits; however, they are in stratigraphic order with no reversals to imply significant depositional mixing around the body and only an inconclusive divot was identified in the layers visible in the south-facing section behind the cranium; no clear burial cut, change in the sediment character or content was identified during excavation. The skeleton dipped along its long-axis (north-south) *c*. -15°.The top of the cranium was exposed at an elevation of 31.27 m (note that the deposits at the cave mouth slope down to the site survey elevation datum) while the elevation recorded beneath the feet was 31.03 m. The youngest charcoal sample (UBA-40556) came from 31.23 m, but at the position of its recovery this overlay the bones being exposed by *c*. 20 mm. As such, it is possible that it may not be dating the interment. A direct date was attempted on bone from the cranium (UBA-38261), but this failed due to insufficient collagen. UBA-40556 represents the most conservative estimate of antiquity for TBH-F907.4-SF-36, though a Terminal Pleistocene ageis possible.

The cranium and mandible of this individual were lifted in two blocks of sediment in December 2017 and placed in cold storage ahead of analysis in January 2018; surviving post-cranial remains were excavated with the assistance of a specialist from the Vietnamese Institute of Archaeology in Apr. 2018 (*see* Rabett *et al*. 2017c, 2019; Wilshaw 2018). Upon close analysis it was determined that although the bones were fragmentary their condition was generally good and only limited use of museum-grade consolidant (Butvar B76) was required to stabilise them. The post-cranial remains were not found in a similar state of breakage, indicating this was a highly localised event. Evidence of animal activity (chewing) to the feet was noted; however, there was nothing to suggest that the bones had been dispersed. Age traits suggest that this individual (a male) died when he was *c*.35 years old. There was minimal evidence of pathology. The skull was highly fragmented, but most pieces could be accounted for. On-site evidence suggests that damage to the skull was probably the result of impact from a heavy object (a rock) after burial causing it to become flattened. Following consolidation and reconstruction of the skull in the field, photogrammetric scanning enabled us to produce a 3D print (to medical grade standard), providing the architecture for a full facial reconstruction, now nearing completion (*see* section 4.4).

2.1.2. Lithic analysis

Lithic analysis of the TB1 assemblage (n=615) suggests a lithic toolkit primarily focused on the manufacture of expedient unretouched limestone flake tools. However, 34 artefacts are made from non-local igneous raw material (tables 1 & 2), suggesting extensive foraging ranges or long-distance exchange networks.

Table 1. **Lithic raw materials (TB1)** ***Table 2.*** **Limestone and Basalt by data-class (TB1)**

Material	Count
Limestone	466
Basalt	34
Quartz	25
Sandstone	2
Other	88
Total	615

Data-class	Limestone count	Basalt count
Complete Flake	104	14
Flake Fragment	129	4
Core	2	3
Angular Chunk	14	0
Shatter	187	10
Splinter	24	0
Other	4	3
Total	464	34

Technological analysis of the assemblage reveals slight differences in the ways that different raw materials were fashioned into tools. Nearly 50% of the basalt artefacts were complete flakes, whereas only 22.3% of the limestone artefacts were complete flakes. Small sample size remains an issue. Observed differences may also reflect differences in preservation between limestone and igneous rock (e.g. Dahlin *et al*. 2011); however this variance may be picking up different approaches to reducing local versus non-local raw materials. Interestingly, 17 of the 34 basalt lithics were recovered from layer F907.4 (the inhumation layer). Whether this speaks to a distinct period of activity, a particular burial tradition or post-depositional site processes is unclear, but future investigation of the cave geoarchaeology might help shed light on this observation.

2.2. Hang Moi (Site ID-2B-001)

This single-chamber cave is located in the north-central area of the Tràng An massif (20.254111N, 105.894889E) *c*. 15m asl. and has a floor area of 23 x 11m though much of it is obscured by rocks. The site was first investigated by the Tràng An Archaeological Project in 2011. Two trenches excavated in different parts of the cave quickly revealed an early Neolithic occupation (5,400-5,600 cal. BP), comprising a complex hearth sequence and a spatially separate but chronologically contemporaneous midden. The midden deposits contain large quantities of molluscan, crustacean and vertebrate faunal remains, with a significant marine element, and were found in association withnumerous sherds of Đa Bút coarse ware (Rabett 2013). In 2012 the Vietnamese Institute of Archaeology extended investigation of the site with a third deeper trench and further radiometric dating. This revealed a comparable Neolithic sequence in the site's uppermost stratigraphy but demonstrated that this was underlain by earlier phases of occupation dating back to *c.* 15,000 cal. BP (Masanari &Toan 2012; Su n.d.). The SUNDASIA project returned to the site in 2016 and gathered additional information about the changing nature of cave use in the centre of the massif before and during the Mid-Holocene sea-level high stand. A ^{14}C date from beneath the Đa Bút era midden (Trench 2) confirmed that pre-ceramic occupation of the site extended back to 14,226-15,017 cal. BP (UBA-36373). In Trench 1, the Neolithic hearth sequence was underlain by early Holocene midden depositsdating to 9500-10,500 cal. BP. These contained high frequencies of land

snails (*Cyclophorus* spp.) and a vertebrate fauna characteristic of the massif interior. The inhumation uncovered within these layers in late 2017 (Rabett *et al*. 2019) appears to have been cut from Mid-Holocene levels.

2.2.1. Inhumation (HMCH-6612-SF-101)

Recovery of the Hang Moi skeleton required partial removal of the one metre wide baulk that lay between Trench 1 and the VIA trench immediately to the SE. All excavated sediments were dry-sieved (2mm) and routine environmental and archival samples taken. As excavation of the baulk proceeded (*see* Stimpson *et al*. 2018), the second of two similar contexts, characterised by burnt white shell (6603) and (6608), was identified as the probable surface from which the burial pit had been cut.

The burial fill (6609) was then excavated in two spits down to contact with the skeleton, 2.01m below the uncalibrated arbitrary 500m site datum. The remains were given the accession number HMCH-6612-SF-101. A cluster of five bivalves were found at the interface between (6608) and (6609) in close association with points on the NE edge of the burial cut (Stimpson *et al*. 2018, figure 12) in a configuration that may reflect deliberate placement of the shells. Another notable find from within context (6609.1) was a perforated shell disc bead. This piece resembles specimens recovered in the upper part of the Thung Binh 1 sequence in Trench 2 (Rabett *et al*. 2017b) and have been tentatively attributed to the Phung Nguyen cultural complex (*c*. 4000-3500 cal. BP): a transitional phase between the local final Neolithic and emerging Metal Age societies that includes expressions of social identity through funerary practice (Matsumura *et al*. 2011). Anew statistical study of 69 perforated shell discs from mortuary contexts in Thung Binh 1 (Magill 2020) has demonstrated strong evidence for standardisation. Based on metric criteria, use of the Heishi manufacturing technique is indicated - where-by bead pre-forms are tightly threaded together and ground in unison rather than individually. This findingappears consistent with knownemphasis onstandardisation of cultural motifs and funerary expressions of social identity during the Phung Nguyen period (Matsumura *et al*. 2011; Nguyen Ba Khoach 1980). While cultural affiliation to the Phung Nguyen has yet to be formally confirmed at either site, such a record in Tràng An now looks likely. The disturbed nature of burial fill though was confirmed through the presence of infrequent degraded Đa Bút sherds, potential lithics and a high frequency of *Cyclophorus* shells – the latter likely reflecting early Holocene subsistence activities. Two charcoal samples found in direct association with the bones werealmost certainly intrusive. These produced dates of 10,575-10,795 cal. BP (UBA-40553) and 10,381-10,594 cal. BP (UBA-40552), but they do at least support the early Holocene antiquity of deposits that the burial was cut into. A single charcoal sample from the overlying context (6608) produced a date range of 5041-5315 cal. BP (UBA-40551), giving a more reliable estimate for the age of interment. If correct, this suggests that burial was probably of late Đa Bút affiliation, but may have occurred some hundreds of years after the principal Đa Bút occupationat the site.

The bones of HMCH-6612-SF-101 were highly degraded. The skeleton lay largely in anatomical position, in a protracted orientation (aligned SW-NE). The project's physical anthropologist (AW) spent four days painstakingly consolidating the bones in-situ. Photogrammetric scanning and measurements for lower limb biometrics were undertaken before the bones were lifted. Assessment of epiphyseal fusion and dental formation indicated that the individual was 13-14 years of age at death (probably male). Pathologies were identified indicative of metabolic disruption early in life and possible infection.

After the bones had been lifted, the remainder of (6609) was removed from the burial cut down to contact with the underlying early Holocene context (6108). Finds from the sediment immediately beneath the body included a stone bowl rim fragment, designated (SF103) and broken edges from ground-stone axes. Both artefact types were clearly intrusive from higher in the sequence. Context (6108) marked the beginning of a sequence of shell midden contexts and hearths (6110-6115) of pre-ceramic character.

2.2.2. Lithic analysis

Preliminary analysis of the lithic assemblage from Hang Moi (n=103) that was collected during late 2017 indicates consistent use of expedient limestone flakes during the Pleistocene and Holocene sections of the excavated sequence, with a small component of basalt and quartz artefacts (table 3). There is limited evidence of platform preparation or retouch, which is consistent with other assemblages from Tràng An (Phan 2014, Utting 2017).

Table 3. **Lithic raw materials (HMC)**

Material	Count
Limestone	92
Basalt	4
Quartz	2
Other	5
Total	103

Technological comparison to material from Thung Binh 1 reveals no significant differences in reduction strategy through time or by location. Raw material selection in the older part of the Hang Moi sequence (i.e. the basalt and quartz artefacts come from contexts likely to date either to the Terminal Pleistocene or earliest Holocene) bears certain similarity to the Thung Binh 1 record. This may support a shift in site use at Hang Moi between its earlier and later occupation phases, or may reflect changes in raw material collection strategies over time.

2.3. Digital Terrain mapping

The total SUAV (Small Unmanned Aerial Vehicle) survey coverage of the TràngAn core zone was expanded during the Nov-Dec. 2018 season to include a further 600 m extension to the east. This additional flight work was undertaken in order to increase the extent of overlap between the Structure from Motion (SFM)-mapped corridor and LiDAR surveyed portion of the property. Flight parameters matched those of previous seasons: with a 600 m flight ceiling and 80-90% image overlap as standard. Eleven ground control points (GCPs) were collected in the newly surveyed area. Previously-collected GCPs were also re-surveyed and double-checked for integrity and consistency. Results show an acceptable margin of inter-season error given the extreme nature of the property's topography and scale of the survey as between 0.1 and 0.2m. Over the course of 4 seasons, the total project SUAV coverage included 39 sectors of 35 ha per/sector with a native GSD (ground sampling distance) of 0.19m for the DSM and 0.097m for the orthophoto. The DSM (digital surface model) resolution was subsequently reduced to 0.5m GSD to match the existing Lidar DSM. The aerial surveyed corridor accounted for 24.5% of the core zone. Taken in conjunction with the LiDAR data the project acquired, highly accurate DSM of the Tràng An massif is now available for 53.75% (3315/6156 ha) of the core zone at a resolution of 0.5m/pix. This constitutes a dramatic improvement on existing DEMs (digital elevation models) that achieved a maximum GSD of 10 m with low spatial accuracy and that grossly under-represented the steep topography of the landscape. These data along with all principal site and object datasets will be accessible through the Tràng An GIS database where they will be vailable for further spatial analysis, World Heritage Site management and the development of online mapping solutions. 2.3.1. *3D photogrammetry & reconstruction.*

Following procedures instigated earlier in the project (Rabett *et al*. 2019: 32) SFM surveys were carried out at Hang Moi and Thung Binh 1 at the close of excavations in December 2018. The resulting scans updated and concluded the catalogue of photogrammetic models that illustrate key intervals of work at each site and supplement standard site-records - most notably in relation to the recovery of prehistoric HSR in both caves.

The scanning of the TBH1 mandible and TBH1 cranium (including maxilla), and the reconstructed and consolidated mandible from HMCH1 was undertaken in a field photo-lab where light conditions could be controlled. Two static LED sheet lights and two wirelessly controlled speed lights were used to keep the effect of shadow casting on the specimens to a minimum. The TBH1 mandible and cranium were also photographed to publication standard; and all recovered HSR remains were photographed for archival purposes.

2.4. Reconstructing past environmental conditions

In parallel to mapping modern terrain and modelling geomorphological transitions between landlocked and inundated landscape phases in Tràng An botanical, vertebrate and invertebrate analyses have been employed to elucidate changes to the state and diversity of ecological communities through time.

The botanical programme has integrated evidence obtained through the analysis of pollen from cave sediments, pollen traps, open-ground sediment coring, modern vegetation surveys and herbarium comparative collections. Field work during the third year of the project concentrated on the recovery of pollen traps, and extending vegetation surveys and the collection of herbarium specimens, while laboratory work has concentrated on analysis of sediment cores collected in 2017 and early 2018; in particular leading to the publication of a detailed Holocene record of limestone and mangrove forest based on data from Vung Tham and Hang Moi (O'Donnell *et al*. 2020).

2.4.1. Pollen traps and vegetation surveys

In late 2018, pollen traps that had been set out during the Sept. 2017 and the Nov-Dec 2017 field seasons were collected. Of the 24 traps originally set 13 were recovered; from the 11 not recovered, eight were lost because they had been removed during the intervening months (n=8/11). These were as follows: all three traps from Thung Binh (i.e. R2205, R2206 and R2207); both of the traps set in Hang Ang Noi (R2200 and R2201); one that had been set in the open landscape near Mai da Vang (R2211); one from near Den Thai Vi (R2212); one from Thung Chua (R2215); one from the northern half of Vung Chay (R2218); and two traps from Vung Tham (R2220 and R2221). The remaining three traps could not be re-located due to vegetation growth. The 13 recovered traps were conserved in the field-lab, boxed and shipped to Queen's University Belfast (QUB) for detailed examination and taxonomic identification.

In order for qualitative pollen-vegetation relationships to be established vegetation surveys were conducted in the vicinity of seven recovered pollen traps (specifically, near Hang Hanh, Ong Hay [where two surveys were combined], Mai Da Vang, Vung Chay, Hang Boi, Hang Moi, and Hang Trong). Sharp topography and density of understorey growth presented significant challenges to laying out a systematic sampling strategy (e.g. one that was plot- or transect-based). This prevented collection of quantitative cover-abundance data at the survey sites/pollen trap sites. Taxonomic lists of plants identified during site surveys are presented in Rabett *et al*. (2018: 22-24).

2.4.2. Herbarium collection

In addition to observational vegetation surveys, during Nov-Dec. 2018, a further 22 plant specimens were added to the previous 54 taxa collected in Apr. 2018 (Figure 1; see Rabett *et al*. 2019). Full taxonomic lists for herbarium work are presented in Rabett *et al*. (2018: 14-15) for Apr. 2018 and in Stimpson *et al*. (2018: 25) for Nov-Dec. 2018. The

collection of fertile plants continued to concentrate on valley bottom habitats. Heat-assisted drying (using a suspended clothes drying enclosure) replaced air-drying used previously, with corrugated aluminium ventilators and blotting papersplaced between each pressed specimen. This improvised system proved highly effective and greatly enhanced the quality of conserved specimens. In accordance with the dissemination procedure adopted in April, a total of five duplicate sets were made. Three were distributed (by NTMH) to the Vietnam Academy of Science and Technology, the Forest Inventory and Planning Institute, and the Hanoi College of Pharmacy. The remaining two sets were sent back to the UK, with one submitted to the Herbarium at the Royal Botanic Gardens, Kew and the final set retained at QUB.

Figure 1. **NTMH, NTH and VTL collecting a species of Rubiaceae (collection number NTMH 0036) in Thung Boi on 26 Nov. 2018**

(Source: S. O'Donnell)

2.4.3. Zooarchaeological remains

Archaeological excavation of five cave and rock shelter sites within Tràng An has yielded zooarchaeological records that date from the late Pleistocene to the historical period. The main vertebrate remains from the SUNDASIA caves sites derive from shell middens and the recovered bones and teeth are highly fragmented. Common identified mammal remains include a range of bovids (*Capricornis*, *Bos*), cervids (*Muntiacus*, *Hyelaphus*, *Rusa*), carnivores (*Panthera*, *Arctonyx*) and primates (*Macaca*, Colobinae).

The zooarchaeological record currently suggests that hunting behaviours varied more as a function of space, rather than time in Tràng An. The evidence suggests a consistent, long-term pattern in the exploitation of several mammalian taxa while inter-site variability is suggestive of local-scale variation in the targeting of prey animals, most parsimoniously explained as a function of differing local environmental conditions and habitats. Taphonomic analyses suggest that varied preservation of animal bones was principally dictated by site formation processes rather than denoting differences in carcass processing. Despite the likely abundance and diversity of mammalian prey, however, exploitation of individual carcasses of a range of taxa appears to have been intense and indicative of expedient utilisation of prey animals, particularly throughout the late Pleistocene.

In addition to shedding light on the hunting behaviour of the prehistoric occupants of Tràng An, the zooarchaeological remains are also yielding insights into poorly known and threatened mammals. Only described in 1994, the large-antlered or giant muntjac, *Muntiacus vuquangensis* (syn. *M. gigas*), is a critically endangered species known only from the Annamite region in Southeast Asia. In a recent article (Stimpson *et al*., 2019) we report sub-fossil evidence of giant muntjac from TràngAn dated between 11,100 and 11,400 cal. BP. In that article we describe a mandible that had been recovered from Hang Boi during previous excavations, consider the palaeoenvironmental context of the specimen in the World Heritage Site and the implications for habitat requirements for remaining giant muntjacs. The find from Hang Boi extends the known spatial and temporal range of the species in Vietnam and is further evidence that giant muntjacs were more widely distributed in Holocene East Asia than current records would indicate. This new find is also important because it supports the notion that the remaining extant populations of giant muntjac are in a refugial state, as a result of anthropogenic pressures, rather than confined to a centre of endemism (see Turvey *et al*., 2016); a condition that highlights the increasingly urgent need for the conservation of remaining giant muntjacs in Vietnam and regionally.

2.4.4. Archaeomalacology

Given the dominance of shell-bearing midden sites of Late- to Post-Pleistocene antiquity in the massif, close examination of changes in midden character and composition offers insight into consumption trends, site formation processes, taphonomic preservation, and palaeo-environments. These variables are essential to understanding the effects of inundation on people and place. In order to widen the molluscan analysis already undertaken at the mid-elevation (78m asl.) site of Hang Boi (10,500-13,700 cal. BP) (Rabett *et al*. 2011) and at the high elevation (142m asl.) site of Hang Trong (12-18,500

cal. BP) (Rabett *et al*. 2017), sample columns were obtained (by EH) from Thung Binh 1 and Hang Moi - low elevation caves in quite different settings to one-another and higher elevation sites.

In Thung Binh 1 a 15 x 15cm sample column was extracted from 115cm of stratigraphy in the south-facing section of Trench 2, starting immediately beneath the modern surface and extending back to *c*. 10,500 cal. BP. The contexts sampled were: (E900), (E901), (F918), (E903), (E907) and (F907). While this exposed section provided the most accessible stratigraphic sequence in the trench, the column was halted at *c*. 80 cminto the Late Pleistocene/Early Holocene midden just above the TBH-F907.4-SF-36 inhumation. This was primarily a conservation measure to preserve stratigraphic integrity around the area of the body. In Hang Moi, a slightly larger sample column (15 x 20cm) was extracted in order to accommodate parallel sampling for pollen (at the back of each excavated sample to minimise contamination) - with the aim of tying palynological evidence within the cave to that obtained from a sediment core in the Vung Tham doline outside it (O'Donnell *et al*. 2020). The column extended 185 cm through all exposed layers/contexts in the east-facing section of the VIA trench.

Samples of archaeological *Cyclophorus* spp. from both sequences will also be selected for ^{14}C dating and for $\delta^{18}O$ and $\delta^{13}C$ stable isotope analysis to investigate local and regional variation in aridity that can be linked to changes in palaeomonsoon conditions. The results of these analyses will be published elsewhere. Assessment carried out in the field, however, suggested that the terrestrial Mollusca mostly comprise various species of intact Cyclophoridae (>90% of both midden assemblages). Many contexts in both column samples also appear to contain varying quantities of freshwater and estuarine species of Mollusca, predominantly: *Sermylariqueti*, *Unio* sp., cf. *Meretrix* sp., *Ostrea* sp. and *Crassotrea* sp. Taphonomically, the majority of midden assemblages contained intact or near-intact specimens. Taken in conjunction with the presence of burnt shell layers of *Ostrea* sp. and *Crassostrea* sp. and the presence of occasional shell artefacts, this confirms that human action was the principal agent of midden formation. Evidence published in O'Donnell *et al*. (2020) dates the midden assemblage in Hang Moi Trench 1 and 2 to the Da Dong Marine Transgression, a time when much of the doline outside appears to have been dominated by mangrove forest. Midden layers deeper in the stratigraphy are almost entirely composed of *Cyclophorus* spp., which together with a smaller array of edible forest-dwelling molluscs are indicative of a heavily forested environment within the doline perhaps akin to the present day interior of Tràng An.

3. The Impact of coastal evolution on tropical settlement systems

SUNDASIA's programme of high resolution terrain mapping, marine notch, provenancing and survey data is enabling landscape-scale simulations to be modelled within an ArcGIS virtual environment. Accurate modelling of the position and effects of past changes to local coastline, tied into the inventory of known caves and site-specific

archaeological and palaeoenvironmental datasets, provides a first glimpse of patterning to occupation in a tropical karst setting and how it evolved as that setting was transformed by coastal flooding.

3.1. Erosional notch survey

Erosional tidal (or marine) notches provide a readily accessible record of ancient coastlines and are a prominent feature of limestone tower landscapes in Southeast Asia (e.g. Moses *et al*. 2015) and are well represented in Tràng An. Such notches comprise continuous bands on exposed cliffs during periods of stable sea level around the tidal apex. The morphology of tidal notches relates directly to tidal range, direction of flow and intensity of wave action. These are parameters that are either not recorded or are not easily discernible from other sea level proxies (such as via sediment cores).

In Tràng An erosional notch surveys (*see* figure 2) were undertaken as part of the SUNDASIA project (during Sept. 2017, Apr. 2018 & Nov-Dec. 2018) (Rabett *et al*. 2019: 31) to revisit, supplement and extend previous work conducted by the Vietnamese Institute of Geosciences and Mineral Resources (VIGMR) in 2012. Elevations were obtained with a Leica TS06 total station that was oriented to geo-referenced points that were obtained by a Leica GS15 GNSS tied into the Vietnamese NRTK network. A total of 48 elevations were measured at 22 notch sites across the massif, incorporating new sites and some previously identified by VIGMR. Following protocol from previous surveys of notches in Tràng An (Boyd & Lam 2004; Nguyen *et al*. 2012), all elevations were calibrated to Hon Dau national datum and incorporated into wider regional sea-level records (Kahlert *et al*. *2021*) and the Tràng An GIS database.

Figure 2. **Notch survey at Thanh Warf, Thai Vy using a Leica TS06 total station**

(Source: E. Hill)

3.2. Chronology - modern carbon off-set analysis

Land snail apices and aperture fragments are easily identifiable and preserve well in limestone karst environments. This makes them a potentially valuable dating resource. However, these same environmental conditions introduce dead or old carbon into the shell formation. Ingestion of ^{14}C-depleted calcium carbonate during feeding means that snail shells will yield radiocarbon dates of exaggerated age. As part of the SUNDASIA project a comprehensive programme of analysis (Bachtsevanidou Strantzali 2020) was initiated to evaluate the scale of the modern carbon or shell reservoir offset (SRO) and the dating potential of shells from land snails of the genus *Cyclophorus*. These snails arefound frequently in the modern landscape of Tràng An and their shells are ubiquitous within its archaeological record. Live modern *Cyclophorus* specimens, most of them fully grown (determined by the thickness of the aperture) were collected from 22 areas within the Tràng An massif and its immediate environs to determine the magnitude of the SRO between sample sites, enabling local geographic variation to be factored into the analysis, and as an average off-set across the sample series. Rabett *et al*. (2019: 40-41) presented an outline of the field sampling strategy and methods applied, together with a preliminary average age offset for *Cyclophorus* spp., of 417 ± 57 ^{14}C yrs, based on the equations in Hill *et al*. (2017) and a sample size of 62 specimens. Now completed, the work incorporates data from a total of 97 live *Cyclophorus* spp. specimens collected over three field seasons (2017-18).The addition of further data has led to a revision of the preliminary pre-calibration mean off-set. Incorporating all sample sites, this isnow placed at 317 ±338 ^{14}C yrs. As the high error margin indicates, geographic variation becomes an important consideration for landscape-scale studies in karst settings. In this case, standard deviation varied from as high as ±505 ^{14}C yrsat one location to as low as ±13 ^{14}C yrs at another, with apparent correspondence to levels of local human disturbanceof habitat and its impacts on organism diet. The results indicate that shells of *Cyclophorus* spp. can be used to obtain reliable ^{14}C dates in archaeological contexts after application of anaveraged SRO; however, an averaged off-set error margin may be higher than that obtained on materials such as charcoal or bone.

3.3. Genetic analysis of Cyclophorus species diversity

In addition to the SRO work the project malacologists (IBS & EH) submitted six field specimens for molecular for genetic analysis to the Museum für Naturkunde–Leibniz Institute for Evolution and Biodiversity Science. The aim of this work (by PVvO & KCMvO) was to obtain a clearer picture of the *Cyclophorus* diversity within the massif, as shell morphology alone can be insufficient for species identification in this genus (Oheimb

et al. 2019). Good quality DNA sequence data was obtained from all six specimens. Thus far a fragment of the mitochondrial 16S rRNA gene been sequenced; however the general findings, including taxonomic assessment are unlikely to change with the sequencing of additional markers.While a full analysis of the data will appear elsewhere, a preliminary molecular phylogenetic examination incorporating the dataset of Oheimb *et al*. (2019) indicated the presence of two different species among the six specimens with neither confined solely to the Tràng An massif. One of the six specimens clustered with members of mutual group 39 *sensu*. Oheimb *et al*. (2019) and probably belongs to an unidentified *Cyclophorus* species that has also been found in the near-by Cuc Phuong National Park. The other five individuals were identified as *Cyclophorus jourdyi*. This species has not been identified in the Cuc Phuong vicinity, but is known from an area near to the coast, north of the Red River. The Tràng An massif is so far the most inland location from which genetically identified individuals of *C. jourdyi* have been recorded (see Oheimb *et al*. 2019). It remains as yet unknown, however, whether its presence in Tràng An relates to periods when the area was more directly influenced by maritime conditions.

3.4. Local ceramics clay temper provenancingandpXRF analysis

Field analysis of Đa Bút corded ware sherds from Hang Moi (Nyiri 2011) showed consistently that a clay temper was in use through-out the Mid-Holocene occupation of the site. Characteristically this temper contained frequent manganese granules 1-3 mm in diameter (infrequently as large as 7 mm). The use of similar clay temper has been observed in thin-section on from other sites within this cultural technocomplex, which is linked to limestone formations flanked by river deltas, and is considered to provide the best evidence for human adaptation in Vietnam to the Mid-Holocene high-stand (Nguyen 2005). In 2011, preliminary hand-auguring in nearby dolines revealed that manganese granules occur commonly in local clays, though samples were not at that time taken from depositional levels that would have been accessible during the Mid-Holocene so a comparison between the frequency of granule occurrence in the sherds and that naturally occurring could not be made with confidence. Nonetheless, the provisional implication was that the clay being used to make the Đa Bút vessels recovered archaeologically in Tràng An was quite possibly being locally sourced. In the context of considering group mobility strategies during the Mid-Holocene high-stand, this hypothesis required further testing.

The sampling protocol applied during the Nov-Dec 2018 field season was guided by and supplemented existing data on the mineral and elemental composition of Đa Bút sherds from Tràng An sites, including Hang Moi (Green 2018), and by our evolving

understanding about site use. All sherds >30 mm from selected contexts were categorised following criteria for basic fabric analysis - involving quantification by weight and a brief description of colour, size and occurrence of inclusions (Orton & Hughes 2014). Each sherd was then subjected to non-destructive X-Ray Fluorescence analysis using a portable unit (Bruker Tracer-III SD Series pXRF Analyzer). Total number of sherds in the study sample was n=174. Data on sherd composition needed to be complemented by field data from coring samples. To this end, a total of n=33 sediment samples were obtained from four sites within the Tràng An massif (Stimpson *et al*. 2018; table 4-8). Coring sites were selected on the basis of sediment data obtained from VIGMR. In the case of Vung Tham these data were also referenced against a separate ^{14}C dated sediment column taken by SUNDASIA. Detailed comparison was then made between the chemical spectra of the field samples and those obtained from the sub-set of sherds sampled.

In preparation for pXRF analysis core samples were dried overnight in a heated-air field-drying cupboard until moisture levels were negligible. Individual samples were homogenised using a heavy wooden mortar and pestle and weighed. The 'green' Al, Ti, Cu filters coupled with energies 40keV and 8ua are the most suitable for analysing obsidian and ceramics (Drake 2018). These filters specifically target trace elements, including low- to mid-Z elements and high-Z elements that are not altered by post-depositional or firing processes (Hunt *et al*. 2014). Our hypothesis wasthat these trace elements could be used to construct geochemical 'finger-prints' for the samples to determine the provenance of the ceramic vessels. Both the sherds and the prepared clay samples were measured using the same parameters.

Each sample was measured twice for 120 seconds. The resulting spectra from the pXRF device were first quantified (parts per million) using Bruker Artax calibration software. When the calculated values were checked against geological samples of known geochemical composition, however, it was found that the quantified values proved to be inaccurate. The spectra were then quantified instead using constructed calibrations, but the results proved again to be inaccurate when compared against the benchmark geological samples.

Results from the basic fabric analysis of ceramic samples from Trench 2 in Hang Moi, however, did provide additional insights into pottery production and differences in design within and between contexts. Colour descriptions from the sherds selected for pXRF analysis suggest that the ceramic was manufactured at relatively low firing temperatures in an environment with fluctuating oxygen availability; a few sherds showed decoration divergent from the majority of the assemblage, such as some potentially comb-

impressed ceramics: sample HG133 from context (6503) and samples HG166 and HG208, from (6509); one sherd exhibited no decoration (HG138); while finger impressions were noted on sherds (HG162, HG165 & HG168) from (6509). The majority though were very similar with regards to design and form. Whilst most sherds were in a highly fragmented state, some larger pieces could be refitted, for example HG245 and HG239 from context (6509); both of which were found to contain ash, and the latter also contained faunal remains that have been preliminarily identified as likely belonging to *Pomadasys argenteus* (silver grunt or silver javelin), attesting to their incorporation in the food-processing activities.

Table 4. **Coring locations and samples collected in the temper provenancing study**

Site	Lat. (N)	Long. (E)	Nos. samples
Dong Tong (Bich Dong)	20.2391	105.90205	12
Vung Chay	20.246417	105.90675	9
Thung Binh	20.261867	105.866367	4
Vung Tham	20.25355	105.895633	8
		TOTAL	**33**

Table 5. **Sediment characteristics from the Dong Trong core**

Sample No.	Sample depth (cm)	Sample weight (g)	Description
ER001	15-32	25	7.5YR 3/3 dark brown, silty organic clay, shell inclusion, modern roots
ER002	32-38	17	10YR 3/2 very dark greyish brown, clayey silt, charcoal flecks
ER003	38-64	25	10YR 3/2 very dark greyish brown, fine clayey silt, charcoal flecks, shell inclusions
ER004	64-77	24	10YR 3/1 very dark grey
ER005	78-80	19	Gley 1 2.5/10Y greenish black, clayey silt
ER006	88-95	18	2.5Y 2.5/1 black, clayey silt, charcoal, oxidised iron
ER007	104-112	20	2.5Y 4/2 olive brown, iron mottled clay (low silt content) evidence of redox, and degraded limestone
ER008	128-141	21	2.5Y 4/1 dark grey, clay, oxidised element has decreased with depth compared with ER007
ER009	160-170	21	2.5Y 3/2 Very dark greyish brown, clay, charcoal flecks, slight redox evidence but mostly reduced
ER010	190-199	28	2.5Y 4/3 olive brown, clay
ER011	199-207	22	2.5Y 5/4 light olive brown, clay
ER012	213-218	22	5YR 5/4 reddish brown, clay

Table 6. **Sediment characteristics from the Vung Chay core**

Sample No.	Sample depth (cm)	Sample weight (g)	Description
ER013	25-28	18	5YR 2.5/1 black, clayey silt, shell inclusion estuarine gastropods
ER014	28-35	20	Gley 1 2.5/10Y greenish black, clayey silt, charcoal flecks
ER015	40-50	18	2.5Y 3/1 very dark grey clayey silt
ER016	70-80	19	7.5YR 3/2 dark brown, clayey silt
ER017	100-110	20	7.5YR 3/2 dark brown, clayey silt
ER018	150-160	21	7.5YR 3/2 dark brown, clayey silt
ER019	200-210	20	7.5YR 3/2 dark brown, clayey silt
ER020	250-260	22	7.5YR 3/2 dark brown, clayey silt
ER021	340-350	23	7.5YR 3/2 dark brown, clayey silt

Table 7. **Sediment characteristics from the Thung Binh environs core. Sample ER025 was a bulk sample taken from an exposed agricultural ditch adjacent to the core site, this sample was selected due to the observation of frequent mangrove inclusions in the sediment**

Sample No.	Sample depth (cm)	Sample weight (g)	Description
ER022	45-60	30	10YR 6/1 grey, silty clay
ER023	60-75	26	Gley 1 6/10Y greenish grey, silty clay angular coarse sand sized degraded limestone
ER024	75-90	26	2.5Y 6/2 light brownish grey, silty clay, angular gravel degraded limestone, brown oxidised patches, manganese inclusions infrequent but present
ER025	100-120	43	Gley 1 4/N dark grey, clay with gravel sized inclusions and frequent manganese inclusions

Table 8. **Sediment characteristics from the Vung Tham core**

Sample No.	Sample depth (cm)	Sample weight (g)	Description
ER026	25-28	24	5Y 4/3 olive, clayey silt
ER027	28-34.5	19	10YR 3/1 very dark grey silty clay, decaying organic inclusions
ER028	50-60	26	7.5YR 3/2 dark brown, silty clay
ER029	90-100	25	Gley 1 4/10Y dark greenish grey, silty clay with fine sand sized degraded limestone, evidence of redox and organic fragments
ER030	150-160	29	Gley 1 3/5GY very dark greenish grey, silty clay becoming lower in silt towards bottom of unit, degrading vegetation fragments, 162-165 cm included degraded limestone lens
ER031	200-210	34	Gley 1 3/5GY very dark greenish grey, clay with some organic content, slight colour change *c*. 210 cm to Gley 1 5/5GY greenish grey, infrequent manganese and limestone inclusions
ER032	230-240	35	As above - not analysed
ER033	253-264	36	5Y 4/3 olive, clay with coarse sand sized degraded limestone

3.5. Local lithic raw material provenancing

Analysis of stone tool production from sites in Tràng An indicates a repeated occurrence and potential preference for the reduction of smooth beach or river pebbles/cobbles (Phan 2014; Utting 2017). One of the objectives of SUNDASIA has been to identify possible sources of this material in the landscape as a proxy for exploring patterning in forager mobility. To this point efforts have focused within the Tràng An massif. In 2018 this included a pedestrian survey in the vicinity of Dong Thien Ha (in the vicinity of N20.218698, E105.886828) following advice from the Vietnamese Institute of Geosciences and Mineral Resources that this area of the massif may contain surface palaeo-beach deposits. While our survey has been selective rather than exhaustive, it has been informed and the results have been consistent: the only raw materials it has been possible to source locally are shale, quartz and limestone. Based on their representation in site production sequences, their local availability was clearly exploited. It is increasingly likely, however, that the full range of raw material sources utilised included a non-local component, even if there is limited immediate evidence to suggest that this different sourcing had a significant on production techniques and end products (Utting 2017). Further raw material sourcing work by the project's lithic analyst (BU) is expanding survey coverage and applied analytical technique in an effort to address this aspect of the sourcing question and shed further light on changing patterns of forager mobility.

4. Responding to the impacts of future sea-level change

In the face of modern anthropogenic-induced climate change and predicted impact of this to regional sea-level and the socio-economic well-being of coastal communities, limestone karst habitats offer significant conservation value. They have the potential to form part of sustainable governance that seeks to minimise maladaptive impacts and maximise activities that promote and protect local communities and biodiversity. Protected tropical karst areas like Tràng An represent some of Southeast Asia's most critical biodiversity hotspots. They have been an emerging focus of ecotourism, but frequently are imperilled by intensive and progressive degradation from extractive industries (Clements *et al*. 2006). The 'terrestrial island' nature of karst landforms and the variety of habitats that arises from their topographic complexity promote high levels of species endemism and diversity compared to surrounding landscapes (Gao *et al*. 2015). Emerging evidence suggests that tropical karst has the capacity to maintain broad ecological stability across otherwise disruptive cycles of climate and environmental change (e.g. Huang *et al*. 2018; O'Donnell *et al*. 2020; Rabett *et al*. 2017d). SUNDASIA's commitment to utilising deep-time research to provide a new perspective on these contemporary challenges is demonstrated through scientific output and initiatives to disseminate information through training, exhibition and collaborative programmes.

4.1. Regional modelling of sea-level change

Digital terrain mapping combined with the collection of marine notch data create an independent line of assessment for baseline Early to Mid-Holocene relative sea-level change in this part of the region that has been based predominantly on cross-comparisons between sedimentological records and limited surveys of geomorphological markers (Kahlert *et al. 2021*). With recent research (Mann *et al*. 2019) highlighting inconsistences and contradictions between several sub-regional relative sea-level records in Southeast Asia (including the Red River Delta area) and the relevance of these to identifying driving mechanisms behind future sea-level change, the data from Tràng An has a significant contribution to make. By creating a detailed elevation record of tidal notches in conjunction with two sedimentary cores from the same location and calibrated to the notches and additional ^{14}C dates from 2 notches within Tam Coc (Boyd & Lam 2004), it is possible to create a sequence that transcends the limits of previous data and reaches into the tidal zone, establishing refined upper and lower limits of relative sea levels during the Mid-Holocene high-stand and possible periods of relative still-stands post 7000 cal. BP. By drawing comparisons to Ha Long Bay, which can be seen as an analogue to Tràng An during the Mid-Holocene, the survey also reveals how hydrological factors influenced relative sea levels in topographically constrained loci, such as narrow valleys and enclosed dolines may have caused variability in notch morphology and elevation.

4.2. Tràng An GIS database

The beta version of SUNDASIA project's online ArcGIS database (currently hosted on QUB servers) was published in early 2020. Work to refine the system is on-going. Not only will this enable mapping of time-increment-based sea-level change and its effects on the massif; it will also be a vital tool in managing local sustainable development and conservation practice within the World Heritage site. All principal lines of collected data from the project (including archaeological and palaeoenvironmental work, landscape survey, mapping and monitoring data, chronometric data, artefact imaging and inventory) will be accessible through this interface. Full access is being prepared for principal stakeholders and will also be available to other parties by arrangement. A web-app version of the database is also in development. The web app is intended to supply the general public with an interactive map that summarises the various work packages of SUNDASIA, along with principal information about specific sites and supplementary information. Presenting the project outcomes in context with the World Heritage property and its associated visitor destinations, the app will be capable of providing a better understanding of the environmental and archaeological evolution of this landscape complex.

4.3. Biodiversity and conservation

Working within the remit of the project, SUNDASIA's commitment to incorporating contemporary conservation into its research programme has continued. Four updates are provided here.

4.3.1. Delacour's langur trial reintroduction

During the Nov-Dec. 2018 season, quantitative vegetation estimates that had been obtained previously in Sept. 2017 for the planned island trial release site for the *Trachypithecus delacouri* (Delacour's langur) (see Rabett *et al*. 2019: 44-45), were refined and updated. Meetings with all stakeholders, including the Endangered Primate Rescue Centre, Cuc Phuong National Park, and Leipzig Zoo were also undertaken during this period and subsequently. In addition, new GCRF-GIAA funding obtained by the SUNDASIA project in late 2018. Working in collaboration with the Vietnamese IUCN Primate Specialist Group, Green Viet NGO, Ninh Binh Dept. of Forestry Protection, Van Long Nature Reserve, Tràng An Management Board, and Ninh Binh Dept. of Tourism, this enabled the training of 64 park staff in Feb. 2019 in conservation practice ahead of the reintroduction. These funds also paid for filming of an associated TV documentary and a multi-panel exhibition, both to be displayed at the Tràng An Visitor Centre.

4.3.2. Faunal community monitoring

Local small vertebrate communities are often sensitive to site disturbance. Regular sampling by the SUNDASIA team (09/16-12/18) of skeletal remains deposited in owl pellets and bat 'deadfall' in one cave near an arterial route through Tràng An provided the very first baseline biodiversity data of this sort in the property. As previously, this was processed locally using the bucket flotation technique and recovered small vertebrate remains were shipped under agreement to the UK for analysis using the comparative collections at the Oxford University Museum of Natural History. The taxonomic inventory of the rodent, bat and shrew remains is now near completion and will form the basis of a specialist article.

To support the archaeomalacological analysis of shell material from Thung Binh 1 and Hang Moi, a survey of modern mollusc abundance and diversity was undertaken from nine sites within Tràng An and superficially in neighbouring Tam Diep (*see* Stimpson *et al*. 2018, table 17 & figure 15). Preliminary identification to genus in the field relied on Raheem *et al*. (2017);Vermeulen *et al*. (1998) and Vermeulen *et al*. (2003). More detailed species level identifications will be carried out at QUB. Mindful of the fact that dry season conditions meant that many molluscs were starting to aestivate or reaching the end of their seasonal lifecycles, an abundance and diversity survey was conducted. Only two sites showed significant diversity and abundance – one was located in recently disturbed habitat, the other in the essentially undisturbed centre of the property. At sites studied outside the core zone substrate soils have been built-up recently and this is considered to be credible

reason why significant quantities of species have not yet fully colonised these more altered landscapes. The two Tam Diep sites also exhibited low snail diversity comparable to the managed landscapes of the edge of the Tràng An massif. Two immediate conclusions can be drawn from this preliminary study: [1)] the most significant assemblage diversity is confined to the remote interior of the park; [2)] land snail diversity and abundance can provide a useful proxy in monitoring the environmental state, including the incidence of invasive species (e.g. *Achatinafulica*) in different land-parcels within Tràng An.

4.3.3. Landscape restoration

Analysis of the VungTham sediment core in conjunction with palaeoenvironmental proxies from the neighbouring archaeological site of Hang Moi (O'Donnell *et al.* 2020), has produced an excellent case study showing how enclosed regional coastal karst habitats responded to the Mid-Holocene marine transgression. Furthermore, evidence from the study points to the survival of mangrove forest taxa within the massif thousands of years after the Mid-Holocene coastline had retreated. These data suggest that Vung Tham and other similar enclosed sites have the potential to form stable centres for mangrove restoration in the context of future coastal stabilization efforts.

4.4. Knowledge transfer and dissemination

Key deliverables from the SUNDASIA project will feature prominently in a 5-year (2020-25) cultural heritage programme being prepared by the Tràng An Management Board in line with WHC recommendations (https://whc.unesco.org/en/decisions/7291). This is anticipated to begin with the redevelopment of a film set within the property into an archaeological-themed exhibition public space focused on Tràng An's prehistoric stories, including phases of marine inundation, that are central to the property's inscribed "outstanding universal value". It is anticipated that this will also involve further collaborative training initiatives for local park staff to those seen as part of Tràng An's langur reintroduction initiative. A centre-piece exhibit to be presented to the Management Board will be a life-size forensic facial reconstruction from the human remains recovered in Thung Binh 1in bronze resin by the RN-DS Partnership UK and the generous support of the Academic Centre of Reconstructive Science at Guy's Hospital, London and Dr Trevor Coward.

5. Conclusions and Compliance

SUNDASIA's survey and excavation programmes have considerably extended the evidence for early human occupation within the Tràng An massif. This has been achieved in the context of a large-scale detailed palaeoenvironmental reconstruction, revealing landscape evolution from the Late Pleistocene to Mid-Holocene,the transformative changes in sea-level that have affected it and insights into the impacts of this on terrestrial ecology.

The first part of this report summarises findings from archaeological investigation at Thung Binh 1 to the base of a midden accumulation that extended from the climatic down-turn at the onset of Heinrich Event 1 until around the time of the Pleistocene-Holocene transition. During later field seasons at this siteparticular attention was paid to the recovery and reconstruction of a near-complete inhumation that is likely to date from the Terminal Pleistocene or Pleistocene-Holocene Transition. The presence of these and other more fragmented human skeletal remains from this period was not confined to residential activities, but included (and during later periods was perhaps even confined to) funerary activities.The lithic evidence from Thung Binh 1 provides an excellent example of a toolkit centred round un-retouched expedient limestone technology. Further exploration of this assemblage should yield insights into some of the technological adaptations that enabled humans to live in Tràng An. The consistent presence of non-local igneous raw material in the stone tool assemblage might be interpreted as evidence for long distance mobility or trade networks by the Terminal Pleistocene in Southeast Asia. Vertebrate faunal evidence from the site suggests a hunting camp, with particular (but not exclusive) emphasis on deer (Cervidae).

Our research has demonstrated that Mid-Holocene Da But groups did not confine their activities to open-air sites, as is often assumed, but also utilised caves; a practice that appears to have beenat least partlyin connection with funerary activity. This has been determined by a study of organic and inorganic residues on pottery fragments (Green 2018), through direct association with faunal remains,and through the burial of a young adolescent at Hang Moi provisionally dated to *c*. 5300 cal. BP and of likely late Đa Bút affiliation.Observations made on this skeleton indicate marked malnutrition at an early age and bone lesions suggestive of disease. While these findings cannot be taken in isolation they unquestionably contribute to our understanding of the privations that were impacting people's lives at this time.

Evidence suggests that the Mid-Holocene sea-level high-stand was also associated with a period of marked change in subsistence activity in Tràng An. No immediate connection to reduced nutrition can be presently substantiated, though the difference in condition between the TB1 and HMC inhumations may point in that direction. What is clear is that upland hunting and gathering that dominated earlier periods now become secondary to a reliance on marine resources (O'Donnell *et al.* 2020). The data presentedare consistent with previous results (Rabett *et al*. 2011) in suggesting that this re-orientation of resource use within Tràng An was quite sudden and comparatively late. The observed change in habitat use, notably towards mangrove forest exploitation, appears here only when the massif lay on the coast and was itself partly inundated. Indications from material

culture recovered from Pleistocene deposits, however, suggest that the history of coastal contact almost certainly extends back at least to a period soon after the end of the Last Glacial Maximum (Rabett 2018). Conceivably, this could have followedthe palaeo-Red River or other riversout towards a deltaic system that then passed southwest of Hainan Island (*see* Feng *et al*. 2018). Emerging evidence for the long-distance transportation of lithic raw materials to sites in Tràng An during the Terminal Pleistocene lends further support to a model of early forager mobility that saw people or materials moving quite widely across the landscape.

Nyiri (2011) observed that the clay temper found in Đa Bút ceramics from Hang Moi contained characteristic manganese nodular inclusions very similar to that extracted during preliminary subsurface sediment coring. The implication was that clay had been sourced locally and if correct, would suggest that the Mid-Holocene period may have seen a reduction or at least a change in patterns of forager mobility. In an effort to explore this proposition systematically, clay samples of suitable antiquity were taken from a dedicated test series of sediment cores from dolines inside the massif and analysed using a pXRF, calibrated against samples of known geological provenance. Application of this novel non-destructive approach holds considerable promise, but in this instance did not provide conclusive and reliable data, indicating that methodological issues remain to be identified and addressed. Unfortunately, these are unlikely to be explored in the context of the current project. Analysis using destructive methods to homogenize and prepare selected pottery sherds prior to analysis using a bench-based XRF would be required to determine more conclusively whether the clay used in Đa Bút ceramics was sourced locally or transported into Tràng An from elsewhere. Nonetheless, evidence from the project's GIS modelling makes it likely that the massif was completely cut off from the mainland during the Mid-Holocene high-stand (Kahlert *et al*. *2021*). This being the case, an emphasis on local clay sources remains an interesting prospect, and one that may be supported by the lower observed frequency of non-local lithic raw materials. Determining if this pattern of ceramic raw material use was one influenced, if not dictated, by the situation of the massif will have to wait for a future assessment that includes comparison to the composition of Đa Bút ceramics from sites outside of Tràng An.

The affordances granted by the physical properties of this landscape (such as position, accessibility, elevation or view-shed from sites) were progressively transformed by the increasing proximity to the sea during the middle millennia of the Holocene. Molecular genetic data from land snails provided new research perspectives on a possible

influence of sea-level change on species composition. Radiocarbon dating of *Cyclophorus* spp. shell has been demonstrated to be viable. Observed variation in the SRO of modern molluscs appears to be less affected by any inter-species differences than it does by habitat disturbance from human activity and impacts this may have on organism diet.

Utilising the project's programme of high resolution digital terrain mapping and calibrated elevation data it has been possible to model accurately the impact of coastal inundationto site access and forager mobility. These maps also provide a powerful tool that can be used to assist future studies into the response of biological communities to sea-level change, aiding predictions and management decisions regarding, use, accessibility and conservation. The project's botanical and faunal (vertebrate & invertebrate) programmes are similarly building a detailed picture of palaeoenvironmental conditions within Tràng Anthat are also providing scientifically-grounded guidence for species and habitat rehabilitation. Combining the assessment of past and contemporary conditions provides a context in which it becomes possible to examine not just theimpact that sea-level change had on ancient communities, but the long-term impact that people have had in this landscape - a proposed future focus of research in Tràng An.

SUNDASIA's third annual reportcovers the final phase of planned project field work. As such it is appropriate here to affirm that field activities undertaken by the project have been in compliance with regulations laid out in Section VII.1.1 of the Tràng An Management Plan: *Management objectives, policies and actions: Protection of cultural heritage: Pre-historic archaeological sites, resources and artefacts*. The project has made remote-sensing a core component of its fieldwork through the use of Ground-Penetrating Radar and aerial SUAV surveys. The extent of excavations has been limited to ensure the preservation of archaeological resources in-situ (VII.1.1.5). International collaboration between Vietnamese and UK members has been central to the effective delivery of this research project and attainment of its objectives (VII.1.1.6). There has been considerable opportunity for knowledge exchange and training through the close involvement of staff from the Tràng An Management Board, the Ninh Binh Provincial Museum, Vietnamese doctoral and undergraduate students in all aspects of the project's field data collection, as well as processing, curation and publication (VII.1.1.7 & VII.1.13). In addition to reports being submitted to the Tràng An Management Board at the end of each field season (themselves now constituting a detailed resource and archive of all project activities, totalling nearly 200 pages), comprehensive annual reports such as this have been prepared for publication. All published material is accessible via the www.sundasia.com project website (VII.1.1.8). All archaeological trenches located in sites excavated by the project

since Sept. 2016 - i.e. Hang Ang Noi, Hang Hanh, Thung Binh 1 and Hang Moi - were lined and backfilled at the conclusion of work. Excavation spoil was used in this process. In one instance backfilling also included the reburial of human skeletal remains (VII.1.1.10). The Project has committed resources and attention to the conservation and curation of excavated finds and data. This has included the creation of a digital data repository (the Tràng An Web-based GIS database) and provision of climate-controlled storage cases for the excavated human skeletal remains from Thung Binh 1 and Hang Moi (VII.1.1.11). In addition to regular local and national television (and newspaper) interviews by project members, in collaboration with the Tràng An Management Board and the Xuan Truong Enterprise, SUNDASIA is also contributing content for public display within Tràng An; the centre-piece of which will be a forensic facial reconstruction of the Thung Binh 1 individual (VII.1.1.12). Finally, all fieldwork has been undertaken at the written invitation of the Tràng An Management Board and relevant permission-granting bodies (notably, the Vietnam Academy of Social Sciences, Institute of Archaeology, and the Vietnamese Immigration Authority), with a full schedule of planned activities provided ahead of departure into the field (VII.1.14).

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