Human Adaptation to Coastal Evolution: 
Late Quaternary evidence from Southeast Asia (SUNDASIA) – 
A report on the first year of the project

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ABSTRACT
The 3.5-year SUNDASIA project is funded through the UK Global Challenges Research Fund (Arts and Humanities Research Council) and the Xuan Truong Enterprise. The project explores how prehistoric foraging communities adapted to cycles of inundation along the northern coastline of Southeast Asia, and how understanding of that process of adaptation can help inform modern responses to climate-induced rising sea levels and habitat change. This report presents a brief summary of work undertaken through the course of the first year of research. During this period, the project has made a solid contribution to the record of sites and cultural evidence pertaining to the early Neolithic Da But technocomplex of the (Mid-Holocene) Dong Da transgression period; and has presented new evidence relating to the Late Pleistocene occupation of Tràng An. Survey and laboratory analysis have begun to expand our understanding of local changes in sedimentological, vegetation and faunal records through both periods; new locales have been added to the record of known landscape features and caves within the Tràng An massif; and collaborative work with local staff and stakeholders is widening participation and building a collaborative initiative between the project’s archaeological and local conservation programmes.
1. INTRODUCTION
Southeast Asian countries are currently experiencing sea level rise at a rate approximately three times the global average (Nicholls & Cazenave 2010). In Việt Nam more than 24 per cent of the population live in coastal districts, with more than 17 million people in the Song Hong River Delta alone (Thanh et al. 2004). Việt Nam has been identified as one of the top five countries likely to be most affected by sea level rise (DFID Operational Plan 2011-15) in the coming decades and the country’s 2nd National Communication to the UN Framework Convention on Climate Change has conveyed the likely impact this will cause to economic production, livelihood, environment, infrastructure and public health (UNFCCC 2010: 12).

The SUNDASIA project, which is funded through the UK Arts and Humanities Research Council portion of the British Government’s Global Challenges Research Fund, and by the Xuan Truong Enterprise in Việt Nam, is seeking to establish a greater understanding about the impact that changing sea levels and environmental conditions had on early socioeconomic systems in Việt Nam. It is undertaking this study both, to increase our knowledge of how communities and environments responded to global climate change in the remote past, and to assess how such knowledge can contribute towards modern mitigation and adaptive measures. As such, the ambitions of the project are aligned with six of the UN’s 17 Sustainable Development Goals – i.e. 1.5, 2.4, 6.6, 11b, 13.1, 15.4, 15.5 and 15c (UN A/70/L.1 2015). There are three central questions that the project is seeking to answer and nine associated objectives; these are, as follows:

Question 1: How do coastal environments shape human behaviour?

1. Create detailed datasets that track cultural and economic changes through time and from sites across the massif in relation to cycles of marine inundation. This will be achieved through archaeological excavation and analysis of cultural and faunal remains (including new and archival material).

2. Compile a series of digitised terrain maps using GIS to show the full extent of coastal flooding across three cycles of marine inundation and recession around the Tràng An massif. These will be constructed initially from existing data.

3. Obtain new sedimentary, chronological, palaeoclimate, biodiversity and vegetation records relating to cycles of inundation. These will complement existing data by bringing fine-grained detail to our terrain maps and context into which early human activities can be projected.

Question 2: How does coastal evolution impact upon tropical settlement systems?

4. Develop a robust protocol for the radiocarbon dating of terrestrial and riverine molluscs in tropical contexts. This will build on recent success at Queen’s University Belfast (QUB) in creating a protocol for AMS dating Mediterranean shells (Hill 2015), and refine the chronology of cultural and environmental transitions in Tràng An.

5. Establish high-resolution (near-annual) tracking of precipitation, especially monsoon cycles, linked to environmental change. The isotopic samples for this work will be obtained from
ubiquitous shell midden material. These data will further assist in identifying patterning in human subsistence and periodicity of site occupation.

6. **Build a pioneering reconstruction of tropical forager site networks, how these responded to cycles of coastal change and the transformative impact on cultural and economic strategies. This will be achieved by synthesising the results of archaeological, palaeoenvironmental, climatic and chronological analyses and digital modelling. Particular attention will be paid to tracking transitional and transformative periods of human behaviour in relation to the extent and timing of environmental change (sea level rise).**

**Question 3: How do past cycles of cultural adaptation to sea level change inform on future responses to sea level change in Southeast Asia and globally?**

7. **Present a new long-term perspective on human responses to coastal flooding: essential contextual data for Southeast Asian and particularly Vietnamese stakeholders in their consideration of responses to modern rising sea levels.**

8. **Streamline methods (e.g. quantifying sea level change) and outcomes to fit with and address issues of current global climate-change models. For example the project will produce key data on adaptive processes that can be translated into general principles of adaptation and risk mitigation, and will help to build understanding about non-linear changes in coastal environments and human responses to them.**

9. **Highlight the importance of the longue durée (i.e. long-term records) as revealed archaeologically, particularly with respect to economic and climate change research models (e.g. Integrated Assessment Models), through knowledge-transfer efforts with international organisations and policy advisory bodies.**

At the end of the first year of work, significant progress has been made towards addressing the first of the three central questions and its associated objectives, and preliminary progress is being made in response to questions two and three (e.g. with reference to Objective 9: combined efforts of the project zooarchaeological work and local conservation). This report summarises SUNDASIA’s preliminary results across these fields.

2. **HOW DO COASTAL ENVIRONMENTS SHAPE HUMAN BEHAVIOUR?**

The SUNDASIA project set out to accumulate detailed datasets from a range of different archaeological and palaeoenvironmental proxies to track cultural and economic change through time and from sites across the Tràng An massif in response to cycles of marine inundation. It has already been established that this landscape contains multiple prehistoric archaeological sites spanning at least the last 30,000 years, as well as evidence for the last three major marine transgression episodes: the Quang Xuong (c. 2600–1500 cal. years before present [BP]), the Dong Da (Flandrian) (c. 7000–4000 cal. BP) and the little known Vinh Phuc transgression (c. 59,000–30,000 BP) (Trung et al. 2012; UNESCO Nomination Document-1438 2014).

2.1 Tracking the prehistoric cultural and economic change through time

Fourteen of the 30 caves recorded in the World Heritage nomination document for Tràng An, and known to contain cultural evidence, had been archaeologically investigated by the
time the property was inscribed in 2014. Three of these had been excavated by the Cambridge-led Tràng An Archaeological Project, which ran from 2007-14 (Rabett 2012, 2013; Rabett et al. 2009a, 2009b, 2011, 2017); the remainder were excavated by Vietnamese colleagues from the Institute of Archaeology, Hanoi during the latter part of the same period (e.g. Đỗ & Dang n.d.; Mai Huong et al. n.d.; Su 2012a; Su n.d.; Su & Tuan n.d.). The existing body of investigated sites includes examples relevant to all three of the inundation cycles being considered by SUNDASIA. Many of these sites are shell middens (dominated by terrestrial, riverine and marine molluscan taxa in varying proportions). Although such middens are common in Tràng An (and elsewhere in the region), past analysis of them has rarely examined underlying inter-site variability and the potential significance of this to reconstructing human movement and behaviour (Piper & Rabett 2014). The aim of the archaeological component of this project is to expand the record of known sites from each phase of inundation in order to more fully understand site selection criteria in relation of resources and palaeo-shorelines; how early human communities exploited and settled this landscape; and how cultural practices changed in space and through time in response to short-term coastal evolution. During the first year of work, three seasons of geophysical and archaeological work have been undertaken at four sites associated primarily with the Dong Da transgression (Green et al. n.d.; Loyer n.d.; Rabett et al. n.d.[a,b]; Stimpson et al. n.d.).

2.1.1 Hang Ang Noi
This cave site with an internal surface area of c. 240 m² is located in the NE of the Tràng An massif (20.275000N, 105.916667E) c. 45 m asl and featured in the property’s World Heritage nomination (UNESCO Nomination Document-1438 2014, Annex 4: 103). Cultural remains recovered during excavations in 2012 by the Institute of Archaeology, and ahead of the World Heritage nomination, pointed towards ephemeral occupation during the last 2000 years, as evidenced by ceramic sherds from a range of periods from the Dong Son to Medieval period (Toan n.d.). This places use of the site within the time window of the most recent Quang Xuong transgression.

Excavations by the SUNDASIA project at Hang Ang Noi were carried out between 25th August and 5th September 2016. These were preceded by a ground-penetrating radar (GPR) investigation of the site (Green et al. n.d.). Drawing on the results of the GPR work, we initiated further excavation in ‘Trench 1’, which had been opened in 2012. Over the period of work on site three additional trenches were opened: ‘Trench 3’ within an area of apparent midden accumulation adjacent to the southern wall of the cave; ‘Trench 4’ to the southeast of Trench 1 and excavated into silty layers that contained large quantities of small vertebrate remains (bird, bat, rodent and amphibian); and ‘Trench 5’ at the back of the cave. Each of these was initially 1 x 2 m in size, Trench 3 was extended to 3 x 2 m as we sought to understand the complex and disturbed deposits we were finding here from multiple cultural periods.

None of the new trenches at Hang Ang Noi (nor extended excavation within Trench 1) yielded appreciable cultural remains. Of those examined, Trench 3 proved to be the most productive. Hints of ash and charcoal concentrations found in this part of the cave, quickly led to much greater concentrations in sub-surface contexts (notably in square 615/201) and areas of ash across that square. Some of this might be the result of material dropping from an overhanging ledge, used in recent and possibly historical times for burning incense, but the presence of 13th century polished ware, together with several fragments of Da But corded ware (which included several surface finds) suggest that the cave has been visited over a much longer period of time, seemingly back to the Neolithic. The depositional character of
the cave stratigraphy here probably involved some degree of water action – possibly periodic flood events. The direct effect these may have had on any cultural remains that did accumulate cannot be determined at this stage, though the scarcity and positioning of such evidence that does survive, including Da But fragments at points around the perimeter of the cave floor, hints that this might have been considerable. Silty and guano-rich surface deposits towards the back of the cave (intersected by Trench 5) produced a rich faunal assemblage of small vertebrate taxa: roof-fall from bird and bat roosting sites above. This material is being collected and examined periodically (including as part of a Queen’s University Belfast student dissertation), to provide a contemporary comparative for the archaeological evidence being recovered and to help inform the modern status of biodiversity within the park.

2.1.2 Hang Moi
This cave site is located in the north-central part of the massif c. 23 m asl. at 20.254111N, 105.894889E and with an exposed surface area of c. 200 m². The site was initially excavated two trenches as part of the Tràng An Archaeological Project (TAAP) in 2011 (Rabett 2013). The first of these (1 x 2 m) was located at the back of the cave and revealed a complex sequence of hearth deposits and likely evidence of hearth accoutrements: stake-holes suggestive of a tripod structure. Numerous Da But ceramic sherds (particularly in context 6007) and a small trapezoidal jade adze (context 6009) with all surfaces polished, typical of middle phases of the Da But (Viet 2005), were excavated here. The second trench (1 x 3 m) was located immediately adjacent to the northern wall of the cave. This trench had fewer discernible stratigraphic contexts and appeared to bear the character of a food midden from which large quantities of fish, crab and mollusc (predominantly of marine affinity) were recovered, together with equally numerous, but often larger fragments of Da But pottery (3-5 cm) (Nyiri n.d.). Charcoal samples obtained from the base of the trenches date to 5464-5591 cal. BP and 5436-5611 cal. BP, respectively (Calib. Rev. 7.0.0. – 2-sigma).

Vietnamese colleagues returned to the site in 2012 and undertook further work: opening a third trench (1 x 2 m), which was dug to an average depth of c. 1.4 m, with cultural deposits of Neolithic (Da But) affinity with faunal evidence of a coastal economy in the upper layers (1-4), mirroring those of the TAAP excavation. These were found to overlie an upland interior phase of site-use, comprising a terrestrial and freshwater shell midden of probable early Holocene antiquity (layers 7-12) (Masanari & Toan n.d.).

A SUNDASIA project team, together with members of the Institute of Archaeology returned to the site again in December 2016 with the aim of obtaining additional cultural evidence for the Da But that would shed further light on socio-cultural adaptations from the period of the Dong Da (Flandrian) transgression. Trench 2 of the TAAP excavation was expanded by two further 1 x 1 m grid squares and dug to a depth of 0.8 m in close stratigraphic correspondence to the 2011 excavation sequence. Vertebrate remains were less abundant than shell and crab remains, which were recovered in quantities, as were Da But ceramics, including a large base sherd (Small Find No.3), lifted from the interface between spits 4 and 5 of context (6303) in grid square 323/414; however, no stone tools were recovered.

2.1.3 Hang Hanh
This previously unstudied site comprises a small rock-shelter (of surface area c. 30 m²) situated on the south side of an isolated karst tower on the eastern margin of the Tràng An massif (20.243917N 105.924167E) c. 19 m asl. The site was first visited and identified as of
potential interest in December 2015. The site contained comparatively shallow deposits, but guided by a GPR survey, conducted in late August 2016 (Green et al. n.d.), the SUNDASIA team and colleagues from the Institute of Archaeology opened a 1 x 2 m trench (figure 1) adjacent to the back wall of the rock-shelter 7-9th September 2016 (Rabett et al. n.d[a]). Excavation here immediately started to yield a productive set of depositional contexts: Da But ceramic sherds, marine and riverine shell, crab and diagnostic large vertebrate faunal remains began emerge. Work was resumed in December 2016 (Stimpson et al. n.d.) over a period of seven days, and the midden deposits that we had opened continued to produce substantial archaeological remains and a second trench (1 x 2 m) was opened to expand areal coverage and ease of access. As work progressed, however, it became clear that the site had experienced considerable disturbance historically and that this would diminish the clarity of archaeological associations. For example, Da But sherds were emerging mixed with ceramics from later periods.

Figure 1: Excavations in progress at Hang Hanh, Tràng An (Sept. 2016); pictured (L-R): C. Stimpson, R. Holmes, P.T. Son and N.T. Dong. (Photo. R. Rabett).

Small vertebrate remains recovered from the site include insectivoruos bat, frog, bird and rodents – these are likely to be intrusive, rather than archaeological. The remains of larger vertebrate taxa were highly fragmented, but diagnostic specimens include reptile (Python sp.; Varanus sp.), large caprine (cf. Capricornis) deer (Cervidae), pig (Sus sp.), macaque (Macaca sp.) and civet (Viverridae).

The most notable osteological discovery at the site came from square A of Trench 1 (context B500): a human mandible fragment (figure 2). This was followed in quick
succession by a series \((n = 9)\) of additional but highly fragmented human remains (isolated teeth and post-cranial elements) from across both trenches. Preliminary laboratory analysis (Loyer n.d.) has been carried out and the possibility offered that several of these pieces could be from the same individual (taphonomy and age-related features show consistency). No grave cut or other burial-like context was identified, though interment within midden deposits during this period is not without precedent – e.g. burials excavated at Con Co Ngua (Vinh 1991). Our current reading of site formation processes at Hang Hanh would suggest that the human remains (and other archaeological material) are likely to have been redeposited from their primary context through human and animal activity, erosion or water action, or indeed a combination of these. Indications are that archaeological material has been accumulating at the site since at least the Mid-Holocene. Much of the observed disturbance identified (e.g. trampling and midden re-working) probably occurred in antiquity; however, erosional processes affecting the locale are likely to be ongoing, even if not necessarily at a rate consistent to that in the past.

Figure 2: Recovery of human mandible fragment (centre-right of frame) from square A, Trench 1 (context B500) at Hang Hanh, Tràng An. (Photo: R. Holmes).

Efforts to directly-date the mandible proved unsuccessful when the 14Chrono laboratory at Queen’s University Belfast determined that nitrogen levels within the bone (0.13‰) were below the required minimum threshold of 0.5‰ (J. MacDonald pers. comm. 2017). An alternative approach is being sought that will utilize one of the isolated teeth that have been recovered, as the datable dentine is likely to be better preserved. As this procedure is destructive, the aim is to extract the maximum amount of data from the chosen
specimen including, in addition to nitrogen, analysis of carbon and hydrogen isotopic values as a way to investigate palaeodiet; and ideally analysis for ancient DNA, which remains a comparative rarity in eastern Asia generally (e.g. Siska et al. 2017).

Other notable artefact finds at Hang Hanh included a pierced shark tooth (from Trench 1, square A) and a small stone adze, recovered in a disturbed context in a void fill in Trench 2, square D. The lithic technological assemblage at Hang Hanh comprised of several notched flakes, possible cores, a quern, and a Neolithic groundstone adze. However, turbulent site formation processes make it difficult to place any specimen within a discrete temporal context. Furthermore, goats frequent the rockshelter, so many of the observed fragmentation patterns might be attributed to goat trampling, which may generate false positives in the archaeological record (Pargeter & Bradfield 2012). With this being said, the Neolithic groundstone adze has the greatest potential for further analysis. By applying sourcing techniques to the piece, we may contribute to a greater understanding of raw material sourcing and exchange in the Vietnamese Neolithic. Use-wear studies and residue analysis may also prove fruitful in placing the specimen within technological context.

2.1.4 Hang Thung Binh 1
This small two-chambered cave (20.26162N 105.86474E) c. 20.4 m asl. was surveyed by the Vietnamese Institute of Archaeology in 2008. The cave mouth faces east over fields towards the north-west margin of the massif. It is the most accessible of five small caves located within an isolated limestone outcrop (see below), four of which were investigated by members of the Institute of Archaeology (Su & Tuan 2012). A 2 x 2 m trench was excavated towards the back of this cave and considered (on the basis of cultural remains) to span the Holocene (UNESCO Nomination Document-1438 2014: 41).

A GPR survey of the floor of the main chamber of this cave, carried out for the SUNDASIA Project in September 2016 (Green et al. n.d.), produced further positive results; however, without immediate access to artificial lighting, and recalling the surprising productivity of Hang Hanh, it was decided instead to explore seemingly undisturbed deposits in the smaller and well-lit adjoining chamber (Rabett et al. n.d.[b]). A single trench was excavated. Initially, a 2 x 1 m test pit was opened. This was subsequently expanded to a 2 x 2 m over the digging season (20th March – 3rd April 2017) to a maximum depth of c. 0.7 m. An ephemeral ash deposit, containing significant quantities of charcoal, was passed and a dense shell midden, comparable to that seen in the Institute’s trench in the main chamber was uncovered. The new midden contained frequent terrestrial molluscs (predominantly Cyclophorus sp.) and moderately frequent river gastropods. Comparatively little charcoal was recovered, though burnt bone was quite frequent as were vertebrate remains generally – from large mammals, fish and turtles.

Vertebrate remains included well-preserved porcupine mandibles (Hystricidae) from square 150/251 (context C804) spit 2. A softshell turtle costal fragment came to light during on-site dry sieving of an adjacent square in the same context and spit. Aside from three sherds of Da But corded ware associated with the interface between the midden and overlying deposits, artefact evidence was sparse – including small numbers of flakes with apparent platforms, and one piece of modified shell: a perforated Neritidae (Neritoperon [Neritina] violacea) from the base of (C804) spit 2 in square 151/250. A small cowrie-like shell fragment (possibly worked/pigmented) was also found again during sieving (C804) spit 1. The proportion of sediment within the matrix of the midden began to increase noticeably within the fourth 0.1 m spit of (C804) and had become compact and clay-dominated. The frequency of bone and shells dropped precipitously and indications were that the base of the
midden had been reached. Radiocarbon dating of the midden has shown it to be of considerably greater antiquity than was expected: two almost indistinguishable dates place its accumulation 17,500-17,940 (UBA-34739) context (C804) spit 2 and 17,422-17,889 (UBA-34737) context (C804) spit 3 (Calib. Rev. 7.0.0. – 2-sigma). The slight reversal in these dates and the presence of a third historical date of 653-717 cal. Ka (UBA-34738) from (C804) spit 2 suggests that some mixing or disturbance of these deposits has probably occurred. The consistency between the two early dates, though, does provide a case for attributing the midden to the period immediately after the Last Glacial Maximum; a settlement phase that has also been identified at Hang Trong in the massif interior (Rabett et al. 2017). The Thung Binh 1 data will thus provide further environmental and climatic detail to the setting of human activity during that time.

2.1.5 Research programme – Archaeology

Inter-site comparison of the vertebrate and invertebrate faunal remains – including modified material and human remains (from Hang Hanh) – is currently underway at the Oxford University Museum of Natural History, University of Cambridge, and Queen’s University Belfast. Discussions with the Endangered Primate Rescue Centre (Cuc Phong National Park) have also laid the ground-work for mutual supportive measures, including facilitating primate osteological identification. An attribute-analysis based study of the artefactual material (lithics) is taking place at the University of Cambridge, while preliminary typological study of the ceramic inventory has been undertaken by staff from the Institute of Archaeology, and residue analysis (using XRD) is being conducted at Queen’s University Belfast. Further site excavations are planned for 2017 and 2018.

2.2 Data collection for a digital elevation model (DEM) of Tràng An

Geographic Information Science (GIS) is a powerful tool in geological and archaeological data-processing; one that has been used in Việt Nam for more than a decade (e.g. Hung et al. 2002) and which permits analyse of large quantities of data drawn from different sources and to map, model and query relationships between different datasets within their spatial context. Working with sea level, chronometric, topographic (Digital Surface Models – DSM) and geological datasets, SUNDASIA is using GIS to create detailed maps of each marine transgression and the position of ancient shorelines around the massif. Relationships between Tràng An’s past and present vegetative landscapes and the record of existing and new archaeological sites and other environmental characteristics (e.g. slope, slope aspect, geology, proximity to resources, elevation, vegetation type, orientation of cave entrance, distance to other sites) are then accessible to study within the context of local landscape and coastal evolution. Collation of data using a GIS platform also facilitates translation of observed prehistoric variables (e.g. any lag-time in adaptation, resource investment or risk management), which can be usefully integrated into modern economic and climate change scenarios.

Building on field data collected by the Vietnamese Institute of Geosciences and Mineral Resources (VIGMR), existing literature sources (e.g. Laumanns 2014), and in collaboration with surveyors from the local office of the Xuan Truong Enterprise, the first of the current project’s planned surveys was carried out in March and April 2017. During the field assessment, erosional notches were recorded at two locations using a compass and laser distance metre offset measurement from the GPS unit (table 1, figures 3 & 4). The greater part of this survey, however, catalogued cave locations. A sample of 29 caves had been selected out of an existing catalogue of more than 100 known locales. Those selected
were also known or suspected to be inactive and had been minimally described in the literature. Known caves were included in this work to ensure replicable and uniform data collection. Twelve of the caves that were located and catalogued \((n = 26)\) are previously unrecorded (figure 5, table 2).

<table>
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<th>Name</th>
<th>Long.</th>
<th>Lat.</th>
<th>Elevation (asl.)</th>
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<tbody>
<tr>
<td>Mai Da Ham Rong notch</td>
<td>105.87317</td>
<td>20.29725</td>
<td>2.42 m</td>
</tr>
<tr>
<td>Hang Muoi notch</td>
<td>105.90856</td>
<td>20.275239</td>
<td>9.02 m</td>
</tr>
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</table>

Table 1: Location and elevation of newly recorded erosional notch sites.

Figure 3: Erosional notch at Mai Da Ham Rong 2 (scale: 1 m). (Photo: T. Kahlert)
Figure 4: Erosional notch at Hang Muoi (scale: 1 m). (Photo: T. Kahlert)
Figure 5: Sites visited in the western part of the Tràng An massif during the March 2017 season. (Illustration: T. Kahlert)

<table>
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<th>Point_ID</th>
<th>Long.</th>
<th>Lat.</th>
<th>Status</th>
<th>Archaeological potential</th>
<th>Finds</th>
<th>Date</th>
</tr>
</thead>
<tbody>
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<td>HANG LUON BD</td>
<td></td>
<td></td>
<td>located but not recorded</td>
<td>Cave visible as small entrance near top of steep limestone hillock, inaccessible at the time of visit. Not expected to be of archaeological potential due to location and size of entrance</td>
<td></td>
<td>03/25/2017</td>
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<tr>
<td>HANG TIEN</td>
<td>105.90606</td>
<td>20.29015</td>
<td>located but not recorded</td>
<td>Very small chamber, not a true cave</td>
<td></td>
<td>03/31/2017</td>
</tr>
<tr>
<td>HANG THUNG</td>
<td></td>
<td></td>
<td>location added</td>
<td>Excavated, archaeological</td>
<td></td>
<td>03/20/2017</td>
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<td>20.26162</td>
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<td>105.87749</td>
<td>20.29097</td>
<td>location verified</td>
<td>None, concrete floor, used for offerings</td>
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<tr>
<td>HANG TRAU</td>
<td>105.87858</td>
<td>20.28361</td>
<td>location verified</td>
<td>Ex-water cave, possibly prone to frequent flooding. Very low potential</td>
<td></td>
<td>03/24/2017</td>
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<td>HANG TRAU</td>
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<td>2 bags, pottery, shells</td>
<td>03/25/2017</td>
</tr>
<tr>
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<td>20.27526</td>
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<td></td>
<td>03/25/2017</td>
</tr>
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<td>20.27514</td>
<td>location verified</td>
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<td>03/31/2017</td>
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<tr>
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<td>20.27514</td>
<td>location verified</td>
<td>None, modified for farm use. Through cave, probably ex water cave</td>
<td></td>
<td>03/31/2017</td>
</tr>
<tr>
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<td>HANG BA CHUA</td>
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<td>HANG THUNG BINH 5</td>
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<tr>
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<td>20.28355</td>
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<td>20.25017</td>
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<td>1 bag,</td>
<td>03/28/2017</td>
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<tr>
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<td>Long.</td>
<td>Lat.</td>
<td>Status</td>
<td>Archaeological potential</td>
<td>Finds</td>
<td>Date</td>
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<td>(historic) pottery</td>
<td>Some sediments present, surface finds (historic pottery)</td>
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<td>20.24753</td>
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<td>2 bags, pottery, bones</td>
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<tr>
<td>HANG DOI</td>
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<td>20.25151</td>
<td>New site</td>
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<td>1 bag, pottery</td>
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<td>No cave</td>
<td>present at location</td>
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<td>03/23/2017</td>
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<td>03/24/2017</td>
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<tr>
<td>DONG SUA</td>
<td></td>
<td></td>
<td>No cave</td>
<td>present at location</td>
<td></td>
<td>03/24/2017</td>
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<tr>
<td>HANG DUC</td>
<td></td>
<td></td>
<td>No cave</td>
<td>present at location</td>
<td></td>
<td>03/23/2017</td>
</tr>
<tr>
<td>HANG DOI BE</td>
<td></td>
<td></td>
<td>No direct GPS location taken, however, cave is 10 m north of Hang Doi</td>
<td>No significant level of sediments present</td>
<td></td>
<td>03/30/2017</td>
</tr>
<tr>
<td>HANG VONG</td>
<td></td>
<td></td>
<td>Water cave</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 2: List of caves visited during the topographic survey (March-April 2017).

The west and southwest of the park are the least explored areas of the Tràng An, evident in a distinct paucity of caves as well as sea notch sites. These areas consist of steep karst towers and dense limestone forest and it presents itself as the most promising part of the park for new discoveries. Trackways leading into the general area, however, are sparse making access difficult. During the March-April 2017 season only the outer fringe of the western protected zone was explored, where some degree of road access is available and where possible tracks were discerned from the study of aerial imagery. With the help of local guides, a number of previously unrecorded caves were discovered in this area.

2.2.1 Hang Thung Binh 5
A local farmer drew our attention to this cave (Quy 2017, pers. comm.). Access was difficult due to thick vegetation. The cave features two entrances set c. 10 m apart and at similar altitude of 33 m. The southern entrance is larger and gives access to two principle parts of the cave. The first part is a narrow passage that leads to the smaller, second entrance. It is c. 1 m wide and 1.5 m to 1.8 m high. The passage runs parallel to the hill and is c. 15 m long.
The floor slopes towards the centre of the passage and is covered with a thin layer of small stone mixed with little silt. Some isolated areas, where sediments seem to consist of more silt deposits may contain archaeological material. The second part of the cave can be entered via either of two small apertures that both pierce the cave wall near its southern entrance. Both apertures open into a spacious chamber, which leads into a complex network of further chambers that are interconnected by multiple winding passages. The cave was not explored in detail because of health and safety concerns. The entire cave is decorated in speleothems.

2.2.2 Hang Ba Chua

The cave is close to the road and its location is marked by a large rock that resembles a pregnant woman Hang Ba Chua consists of a single open chamber c. 12 m above the surrounding ground and can be accessed via a short climb up a steep slope. The interior of the chamber measures 6.5 m deep by 3.3 m wide and 4.1 m high. There are some speleothems on the walls. The cave floor is mostly covered by concrete which is inscribed with: ‘4.4.1991 25. 2. Tần Mui’. A local told us that the cave is an 18th or 19th century burial site but the concrete slab seems to be commemorative rather than sealing a burial.

2.2.3 Mai Da Ham Rong 1 and 2

These two rockshelters are located on the north facing side of an isolated karst tower remnant at the edge of the buffer zone c. 2 km NE of the Bai Dinh Pagoda. Both rockshelters overlook the Song Boi river and are used by local farmers to house animals. The karst tower features several other rockshelters and erosional notches (see figure 3 and table 1). The ground is very compact and, due to its proximity to the river, likely prone to seasonal flooding.

2.2.4 Hang Kien and ‘Un-named Cave’

Hang Kien and Hang Thor are two caves set c. 7 m apart that are located on the Bai Dinh Pagoda proper. They penetrate a low karst tower on the north-western edge of the Tràng An protected zone. They both consist of a single straight passage of c. 15 m length and are of similar width and height. Both passages can be accessed via a climb up a 1.5 m high ledge that leads into the main chamber. Both passages feature very limited sedimentation, with ‘Un-named Cave’ producing some historic pottery sherds on the surface.

2.2.5 Hang Bat Dua (Cave of the broken pots)

This cave can be reached via a short walk down a track between field and through a short stretch of light undergrowth. The cave is at c. 46 m asl, faces north and consists of a short passage leading into a small chamber, measuring c. 5 x 6 m and is decorated with several large speleothems. The floor is covered with a large quantity of sherds of glazed pottery and stone ware. Deposits inside the chamber are made up of loose sediments overlaying compact alluvial material. Bone fragments and gastropod shells were also recovered.

2.2.6 Hang Quen Thung Chua

Situated 100 m to the west of Hang Bat Dua and at an elevation of c. 60 m asl lies Hang Quen Thung. This locale is reached by following a track that crosses a saddle into a neighbouring doline. The cave was found to comprise a sheltered overhang that leads into an upper and lower chamber. The upper chamber was not explored. The lower chamber is slightly below the ground surface and measures 4 x 5 m. The chamber floor consists of loose sediments that
cover compact alluvium. A 0.2 x 0.2 m sondage was dug in the north of the chamber to a depth of 0.3 m but did not produce any archaeological material below the top 5 cm. The sondage was not excavated to the base of the deposit and it is possible that archaeology is present at deeper strata.

2.2.7 Hang Da Trang
This cave was shown to us by a local man who used to hunt in the western hills of Tràng An and used Da Trang Cave as a shelter. The cave penetrates a karst tower remnant that stands amidst rice paddies c. 100 m west of the Tràng An massif. A rock overhang shelters the cave entrance and provides extensive views along the massif in a southerly direction. An overgrown path leads to the rockshelter, which lies at c. 10 m asl. A low entrance leads into a 1.5 m high by 2.5 m wide winding passage that opens into a small chamber. From there, as well as from the short passage, several crawls lead up onto two balconies; both are formed from slipped bedding planes, which are the result of the advanced erosion of the hill. Modern refuse and historic pottery is scattered across the floor. Among these, one piece of crab was found. Sediments are present through the cave but their depth was not tested.

2.2.8 Hang Doi and Hang Doi Be
This was the second most extensive cave system found during the March-April 2017 survey. Situated in an isolated doline the low cave entrance is reached via the same track that leads to Hang Quen Thung. Six chambers were explored. These were connected via short rift passages. A small bat colony (c. 20-30 individuals) was identified within the cave, as were animal tracks – subsequently identified (by CMS) to be those of a porcupine (cf. Hystrix brachyura). Large speleothems decorate almost all parts of the cave. A 10 x 10 cm sondage was excavated to a depth of c. 0.3 m. The upper 10 cm produced glazed pottery sherds and bone fragments. The deposits extend below the depth of the sondage and it is possible that archaeology is present at deeper strata. Hang Doi Be is situated 10 m north of Hang Doi and consists of a single 2 m by 2 m sunk chamber. The cave floor consists of large stones covered by a thin layer of sediment, which appeared to be archaeologically sterile.

2.2.9 Hang Ong Noi
Hang Ong Noi is situated on the steep slope of a low karst outcrop on the western edge of Tràng An. Access to the cave is challenging, with several scrambles up rock ledges and through dense vegetation. The cave consists of a 2.2 m wide by 8 m long and 2 m high entrance chamber. At its rear is a 1.5 m high ledge that leads into a narrow short winding passage. At the end of the passage is a slightly smaller chamber, measuring 3 x 3 m. Several smaller chambers connect to this chamber. Speleothems are present in the passage, inner chamber and its extensions. A small pile of brush-wood and some refuse indicate recent human activity in the entrance chamber and some historic pottery was found on the surface inside the cave. Sediments were compact, clay-rich and mixed with a large quantity of stones. No other archaeology was noted.

2.2.10 Research programme – GIS
During the first survey season essential infrastructure for data-collection was put into place for future work – e.g. the Real Time Kinematic (RTK) network has been established for Tràng An, with access provided by the Việt Nam Institute of Geodesy and Cartography (VIGAC); technical collaboration was also discussed with VIGMR and VIGAC. Existing DEM data at a resolution of 0.5 m (through VIGMR) only exists for selected areas within the
massif and will need to be supplemented. An application to the German Space Centre (DLR) for TerraSAR-X / TanDEM-X data was approved and the resultant data is currently being examined, though the nature of the topography presents a considerable challenge to satellite remote sensing and it is unclear at this stage if these data will add significantly to the project’s GIS analysis. The possibility of creating a photogrammetric 3D model of Tràng An via a fixed-wing drone survey to augment these data has also been explored with VIGAC though was found to be cost-prohibitive. Further exploration of the western area of the property is planned during the remaining two 2017 field seasons, including with the objective to expand our database of wave-induced and bio-erosion features, such as sea notches (Abensperg-Traun et al. 1990), and bio-constructive features, such as palaeo-oyster beds, on the western flanks of the massif. The second year of the project will also see particular focus on integrating data sources into a GIS database.

2.3 Palaeoecology: sedimentology, chronology, palaeoclimate, biodiversity & vegetation
The reconstruction of coastal and landscape evolution provides the environmental context for the history of human activity in Tràng An. The palaeogeographical evolution of the Song Hong delta has been the subject of several studies, employing both onshore and near-shore sediment cores (e.g. Hori et al., 2005; Tanabe et al., 2003, 2006). While these established that shallow seas extended to the Tràng An massif during the 7000–4000 cal. BP (Dong Da) transgression, specific details about how this and earlier transgressions progressed have yet to be determined. A multiproxy archaeological and palaeoenvironmental study of data from Hang Trong – the oldest archaeological sites in Tràng An – indicates that the limestone tropical forest that predominates across the landscape of the massif today was also present as early as the Last Glacial Maximum (26-19 cal. BP) and appears to show considerable resilience to global climatic and environmental changes (Rabett et al. 2017). This not only highlights the potential importance of karstic landscapes as foci of human activity in the remote past for the access they offered to reliable resources, it also has significant bearing for 21st century conservation if such settings are less susceptible to capricious climate-change.

2.3.1 Sedimentology
A 9.11 m sediment core (TAK101) was drilled by the TAAP/Xuan Truong Enterprise in 2012 in the NE corner of the massif (20.285281N, 105.905997N), close to the site of the Hoa Lu ancient capital (Simpson n.d.). Indications are that the site experienced a complex depositional and erosional sequence. Four 14C dates were obtained from the following levels within the core – spanning most of its total depth: a) 2.47-2.46 m, b) 5.25-5.24 m, c) 8.77-8.76 m, d) 10.30-10.29 m. The dates returned included no reversals and were, as follows (using Calib. Rev. 7.0.0 – 2-sigma): a1) 7458-7576 cal. BP (UBA-25527), b1) 7589-7702 cal. BP (UBA-25528), c1) 7654-7801 cal. BP (UBA-25529), d1) 7720-7948 cal. BP (UBA-25530). This implies that the rate of sedimentation over most of the length of the core was rapid, spanning a maximum of 500 years. It also suggests that post-7000 year deposits were either, subject to a very much slower rate of accumulation, or were removed by processes of erosion associated with the Mid-Holocene high-stand. The latter proposition is currently more in-keeping with existing data from the nearby (c. 35 km distant) Nam Dinh (ND)-1 core (Tanabe et al. 2003). It is also note-worthy that the apparent high rate of sedimentation, and hence mobility of sediment in the landscape, appears during a period of enhanced monsoon activity in the Early Holocene (e.g. Wu et al. 2012); a period that is also linked to heightened hydrological activity, concretion and/or flushing of cultural cave deposits at a number of sites regionally (Rabett 2012), implying that impact to human settlement or site use patterns might be
expected over this period (for initial observations on the vegetation record obtained from this core, please see section 2.3.5 below).

2.3.2 Chronology

Radiocarbon (¹⁴C) dating provides the chronological framework for the project’s research questions. A total of 78 ¹⁴C dates currently exist from archaeological and geological deposits in Tràng An. These include organic (charcoal) dates \( n = 48 \) from cave and rockshelter sites within the massif and dates obtained on stranded oyster shell beds from erosional sea-notches on its flanks and interior \( n = 13 \), and a small number \( n = 17 \) taken on terrestrial snails. The chemical signature of the dominant land snail \( \text{Cyclophorus} \) sp. component of occupation middens excavated thus far in Tràng An have hampered the dating of shell by Amino Acid Racemization (Rabett et al. 2011), and a formal calibration curve incorporating carbon reservoir offsets are only now being examined in detail by this project. Working in collaboration with the Oxford Radiocarbon Accelerator Dating Service, 14CHRONO Centre, and Stable Isotope Facility (QUB), and the School of Geography (QMUL), we have begun working towards a more widely applicable tropical shell calibration protocol.

The radiocarbon dating of mollusc samples shells will provide a higher resolution and stratigraphic constraint on contexts within excavated sites. Preliminary results indicate a good correlation between modern snails and the expected percentage of modern carbon values from the cyclophorids tested so far. This means that terrestrial snail shells will be of considerable value when radiocarbon dating contexts where charcoal recovery has been limited or as a complementary line of dating evidence where charcoal is present. Preliminary analysis and measurements undertaken at the 14Chrono Centre, and at the Stable Isotope Facility (QUB) indicate that ‘modern’ cyclophorids recovered in the field date from 0-85 years of age. The radiocarbon dating of individual archaeological \( \text{Cyclophorus} \) sp. shells will also provide a greater time constraint on all palaeoclimate \( \delta^{18}\text{O} / \delta^{13}\text{C} \) data, enabling a deeper understanding of environmental patterns and processes. Thus far \( \text{Cyclophorus} \) sp. shells have been systematically recovered from early post-LGM archaeological contexts at Hang Thung Binh 1; further sampling at this site is envisaged for the coming year.

2.3.3 Palaeoclimate

Growth-increment analysis of land molluscs has been used successfully to reveal changes in isotopic character and thus a proxy for high-resolution (potentially annual) records of rainfall (Leng & Lewis 2012; Ludgate 2013). This approach permits reconstruction of changing precipitation patterns (chiefly in relation to the palaeo-monsoon) around each sea-level transgression, and can identify the potential effects this might have had on settlement and resource availability, and hence on human occupation and activities. As a work-package on the project, this is still in its early stages but data is being generated that will contribute to a forthcoming publication (Ludgate et al., in prep.) with external collaborators.

Modern snail shells were recovered from Tràng An to test for comparison between modern expected \( \delta^{18}\text{O} \) data and those recovered from the snails. Initial data show that modern \( \text{Cyclophorus} \) sp. shells are comparable to modelled \( \delta^{18}\text{O} \) patterns. Previous \( \delta^{18}\text{O} \) \( \text{Cyclophorus} \) sp. shell data used to reconstruct monsoon patterns show good comparison with other proximal data. Records demonstrate the sensitivity of the Southeast Asian monsoon system in relation to wider global climate events such as the Heinrich Event 1 (c. 17.5-14.7 cal. Ka), which takes place in the North Atlantic (Ludgate et al., in prep.).
2.3.4 Biodiversity

A preliminary (invertebrate) biodiversity survey was led by Darren Mann (Head of Life Collections at the Oxford University Museum of Natural History) in late August-early September 2016. Light-traps and baited overnight traps were set in two areas of the core property (Hoa Lu Ancient Forest and Tam Coc), and daily traverses were made within the core and buffer zones of the property to produce an initial assessment of the extant insect fauna. Initial indications are that the diversity of insect life is significantly greater in the core zone than in the buffer zone of the property. This would suggest that the buffer zone of this property is working. It was also apparent, even from a cursory study of the samples collected, that some of the specimens will either extend the range of known insect species in Việt Nam, or may even reveal species within the Tràng An property that are new to science. Further work in this part of the project is anticipated during the remainder of the project.

The maintenance of biodiversity within and across the buffer zones of World Heritage properties is a matter that is drawing increased attention in conservation management (e.g. Laurance et al. 2012; Martin & Piatti 2009) and is one to which the SUNDASIA project is well-positioned to make a positive contribution. The likelihood that the core zone continues to be a habitat for larger vertebrates, such as monkeys, civets and mustelids (badgers) will be the subject of investigation by the project through a campaign of camera trapping across eight locales, beginning in September 2017.

The zooarchaeological record within this landscape (>25,000 years), which investigation by the TAAP, the Vietnamese Institute of Archaeology, and SUNDASIA have uncovered, has demonstrated the existence of a range of fauna, including primates, large felids, wild boar and pangolin that are currently not found (or have not been recorded recently) within the Tràng An massif. The archaeological evidence for these taxa and the apparent stability of the environment within the massif (Rabett et al. 2017) are lines of evidence that may be brought to bear in cases for reintroductions, particularly of locally endemic fauna that have suffered greatly through industrial development and hunting over the last half-century. Following discussions in March 2017, between SUNDASIA, IUCN Việt Nam and other local stakeholders (e.g. Endangered Primate Rescue Centre, Cúc Phương National Park, the Tràng An Management Board, the Ninh Binh Ministry of Tourism, and local industrial partner – the Xuan Truong Enterprise), the overlap between zooarchaeological and conservation research has become a focus of work in line with SUNDASIA’s Objective 9 (see above), with the ultimate ambition of helping to facilitate reintroduction the critically endangered primate, Delacour’s langur (Trachypithecus delacouri), into Tràng An. This would be a significant achievement and one following in the footsteps of that gained for this species in the Van Long Nature Reserve (Dao 2008). It would also have the potential to further enhance the Ninh Binh’s growing heritage-based tourist economy.

2.3.5 Vegetation history

The TAK101 core has been provisionally divided into five environmental phases based on the character and condition of its palynological record (Simpson n.d.). The base of the sequence up to 8 m was found to contain low frequencies of pollen and spores in varied states of preservation. On the basis of the identified record, the local environment comprised open woodland, though taphonomic mixing at this level might be creating a spurious picture.

From 8-6 m pollen preservation continues to be variable – implying some recycling is likely, though spore preservation is generally good. This appears to have been a landscape
of low taxonomic diversity: with grasses and coniferous trees in predominance. The 6-4 m phase grasses and Carophyllaceae point towards some locally dry areas, but recycling is probably still impacting this assemblage. Micro-charcoal concentrations suggests some burning, possibly anthropogenic, was taking place. Pollen and spore preservation is notably better in the 4-2 m phase. Significant charcoal in the core at this point indicates increased levels of burning. The upper 2 m of the core contains well-preserved pollen, suggestive of an herbaceous wetland environment; however owing to uncertainty about depositional processes in this part of the core this is liable to be a mixed assemblage: containing ancient and modern signals. Taken in conjunction with the rapid sedimentation rates observed within TAK101, the environment immediately outside the massif may have experienced more dynamic shifts in composition and structure than that inside it, though recycling and mixing of assemblages is likely to factor in the record obtained from this locale: meaning that it may or may not be more widely representative.

2.3.6 Research programme – Palaeoecology
Working with the VIGMR and the Institute of Archaeology, and building on what has been learnt from the TAK101 core, the project’s new members, working in the field of palaeoenvironmental reconstruction (Drs Shawn O’Donnell and Nguyen Thi Mai Huong), will undertake compositional and facial analyses from cave samples and additional cores taken from the environs of Tràng An. The project will be looking to examine sediment cores records that it obtains (and those previously obtained by collaborators, where appropriate) for micro-tephra signals to enhance both the environmental and chronometric stories; while it will also be using other proxies (e.g. phytoliths) to complement and diversify its palaeoenvironmental programme. Forthcoming work will also explore the Cyclophorus sp. δ¹⁸O shell records obtained through archaeological excavation to build a longer and more geographically extensive pattern of past climatic events. Stable isotope analysis will take place at the Stable Isotope Facility (QUB) using Analytical Precision 2003 IRMS with Acid Digestor for the δ¹³C and δ¹⁸O analysis of carbonates.

3. CAPACITY BUILDING AND OUTREACH ACTIVITIES – YEAR 1
In the context of SUNDASIA’s commitment to local capacity building and outreach, three areas of work have either emerged or have been formalised during the first year of work.

3.1 Staff training
The Tràng An Management Board and SUNDASIA are using this research opportunity to enhance staff capacity through on-site training in archaeological excavation, post-exavation processing and surveying. This represents only one skill-set within cultural heritage management; however the mutual exchange of insights between Board staff and Project members has been positive and constructive, and further development in areas such as remote monitoring and artefact archival and conservation work are planned.

3.2 Biodiversity
Building from the Project’s 2017 Workshop, on-going discussion with the management board of Cuc Phong National Park, the Endangered Primate Rescue Center, and IUCN Việt Nam present an important opportunity to contribute towards Ninh Binh’s conservation efforts and burgeoning heritage economy.
3.3 Media coverage and public engagement
The project has been active in raising awareness about the value of Tràng An’s natural and cultural heritage through television interviews and media coverage through major international platforms (Facebook and Twitter) and international institutions (with blog postings through the University of Cambridge and Smithsonian Institute). SUNDASIA members are also working directly with the Tràng An Management Board towards the development of public displays and interactive, immersive experiences (e.g. 3D digital renderings of cave excavations, and artistic reconstructions of ancient life within the park) for the Tràng An Visitor Centre.

4. CONCLUSION
Research undertaken during the first year of the SUNDASIA project has been focused inevitably on ensuring robust methodological overlap between existing datasets in relation to each work-package, and beginning collection of new primary data. As such, the greatest attention has been placed on building evidence in reply to the first of the three principle project questions, and its associated objectives, though linkages have already started to extend beyond this. The different lines of evidence that have been collected so far cover only part of the project’s chronological span, the expansion of which will be a key focus of field work during the Year 2. The project has already amassed and begun to analyse a significant body of new evidence pertaining to the Dong Da (Mid-Holocene) transgression record. In doing so we have added considerably to the catalogue of known archaeological sites (and in particular cave sites) attributable to the early Neolithic Da But technocomplex. The radiocarbon dates from the midden at Hang Thung Binh 1 align its deposition with a significant period of occupation at a site in the massif interior (Hang Trong), which will expand our understanding of human activity in different parts of the landscape during the centuries ahead of the climatically arid phase associated with Heinrich Event 1. The period in-between and particularly the period of enhanced monsoon activity during the Early Holocene (c. 11,600-7800 cal. BP) and the effect this shift in conditions had on the local landscape and its people will be another focus for the forthcoming year. Through its conservation-linked work, capacity building and outreach, the project is already making progress towards the UN Sustainable Development Goals to which it is linked. The data that has been generated during the first year of the SUNDASIA project will provide valuable points of reference as it expands its work in relation to the second and third of its research questions, and its commitment to assisting in local natural, cultural and economic sustainability over the coming months.

REFERENCES


Mai Nguyen, N.T., Toàn, P.T., Dôi, N.G., Tuán, N.A. 2012. Results of spores-pollen analysis from archaeological sites in Trang An landscape complex (n.d.).


Operational Plan 2011-2016 Department for International Development: Vietnam


**Contributions:**
RR – PI/principal editor
FC – CI/GIS
TTV – CI/geology
CS – Site director/Zooarchaeology report, biodiversity (large vertebrate survey)
TK – DEM cave survey data
IBS – Shell survey data: isotopes (& 14C dating)
BU – Technology (lithics)
TND – Karst geology
AG – GPR survey data
RH – Phytoliths/field data collection
LTTKH – Cave survey data
VTL – Field data collection
NL – Shell survey data: isotopes (& 14C dating)
VDL – Trainee site supervisor/field data collection
JL – Human remains report
DM – Biodiversity (invertebrate survey data)
NTD – Technology (lithics)/field data collection
NTL – Field data collection
PSK – Vice-director TAMB/field operations
PHS – Technology (ceramics)/field data collection
DS – Sedimentology/palynology (TAK101) report
TTKQ – Zooarchaeology/field data collection
MV – Field data collection
NCT – Vice-director, Ninh Binh Ministry of Culture
BVM – Vice-director, Ninh Binh Ministry of Tourism