As Above So Below: Preliminary Investigations for Submerged Landscape Site Discovery in the Greater Central Visayas, Philippines

by

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Thesis

Submitted to Flinders University

for the degree of Masters of Maritime Archaeology

Flinders University of South Australia

December 2017

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ABSTRACT

Submerged landscape studies in the Philippine island arc system are at the preliminary stages of development despite having nearly 200,000 km^2 of land area exposed during the Last Glacial Maximum (LGM) (Robles 2012:40). Glacially induced sea-level fluctuation through the Pleistocene and Early Holocene greatly influenced the exodus of hominin species throughout Southeast Asia and Australia. Drier climatic variability during periods of marine regression affected prehistoric human subsistence adaptations in response to retreating palaeoshorelines and evidence for past human activity likely reside in submerged offshore regions due to sea-level rise. Initial hominin colonization for the Philippine Archipelago extends to the Upper Pleistocene epoch since the discovery of an unknown species of *Homo* on the island of Luzon (Mijares, et al. 2010). Due to Luzon's remote location in context to Southeast Asia, it is likely it would have been the last in the series of islands in the Philippines to be inhabited. Further archaeological investigations are needed to temper chronological issues plaguing the dispersal narrative in the archipelago. With much of the arc system's palaeolandscape lost to inundation, coarse resolution geospatial modelling provides the beginning stages for submerged landscape site discovery. A synthesis of available datasets has been implemented to predict likely areas for drowned regions of archaeological significance. Specific attention has been focused on the Central Visayas in this thesis to provide initial investigation of its surrounding seascapes based on relatively shallow bathymetric contours over large shelf regions.

STUDENT DECLARATION

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Jennifer A. Rickard

2017

ACKNOWLEDGEMENTS

I would like to extend my deepest gratitude to my supervisor, Jonathan Benjamin, for his guidance and support during this process.

To Geoff Bailey for providing his advice and wisdom in submerged landscape studies, and Ingrid Ward for taking the time to share her knowledge in the field of geomorphology.

A special thanks to Alfred Pawlik for allowing me to accompany him to his excavation sites on the island of Mindoro, and providing me with the world's strongest coffee.

To Gay Lacsina, as you became my liaison and familiar face in the Philippines, I am still forever in your debt.

To Emil Robles, for his enthusiasm towards mapping the archaeologically uncharted underwater recesses of a region as complex as the Philippine Archipelago, you have been an inspiration.

A sincere thanks to John Naumann for investing his time and energy to ensure the integrity of my safety remained uncompromised.

To Matt Lloyd, who provided solutions to challenges I could have never foreseen.

An enormous amount of gratitude to Erin Sebo for being a kindred spirit and genuine light in the dark hours of research.

To my fellow students in the archaeology department who I have had the privilege of calling my friends, we'll always have the 'Tav'.

To my mother, nahigugma ko nimo ug salamat kaayo; and my father, who has been my greatest champion in life and believed in me before I ever did myself.

And finally, to my best friend, Brian Blattel, who has kept me laughing through this entire journey. I will never know what I had done to deserve such a partner.

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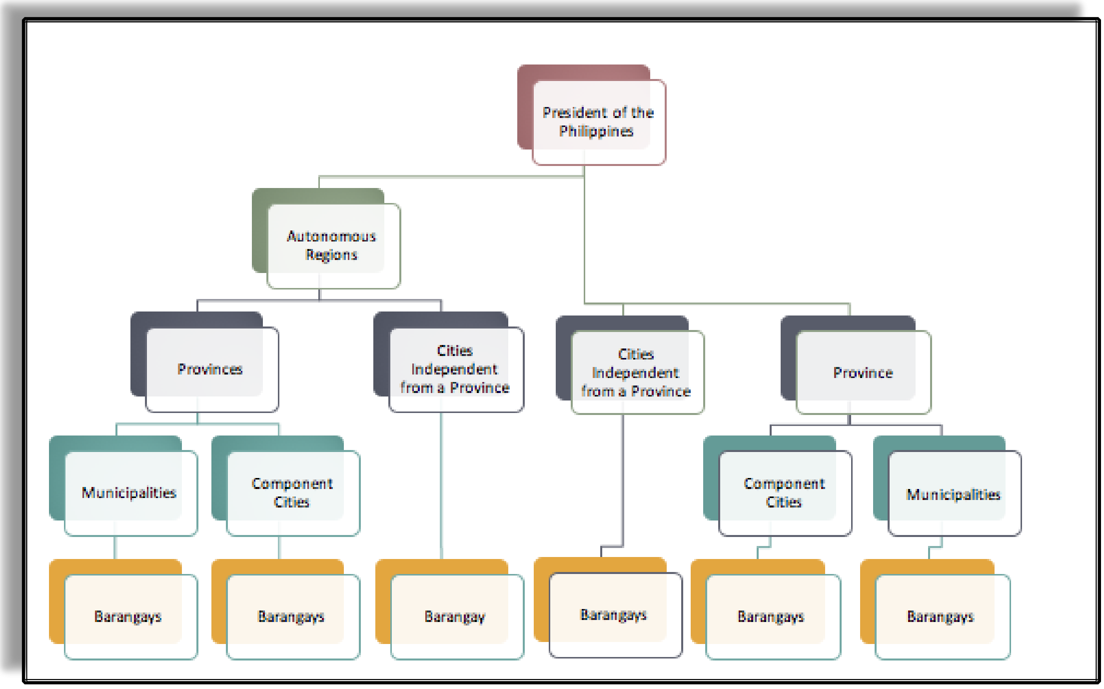
ADMINISTRATIVE STRUCTURE OF THE PHILIPPINES



ABBREVIATIONS

ABOX	Acid Base Oxidation
AMS	Accelerated Mass Spectrometry
ENSO	El Niño Southern Oscillation
ESR	Electron Spin Resonance
IPWP	Indo-Pacific Warm Pool
LGM	Last Glacial Maximum
OSL	Optically-Stimulated Luminescence
RSL	Relative Sea-Level
SST	Sea Surface Temperature
TL	Thermoluminescence
WPWP	Western Pacific Warm Pool

1 INTRODUCTION

Sea-level fluctuation through the Pleistocene and Early Holocene extended and retracted available coastal habitation regions influencing anatomically modern humans' migration patterns and subsistence strategies throughout insular Southeast Asia (Balme, et al. 2009; Erlandson and Fitzpatrick 2006; Hanebuth and Stattegger 2004; Porr, et al. 2012; Voris 2000). Chronological lacunae in the archaeological record of prehistoric humans' coastal adaptions and dispersal movement during the Pleistocene and Early Holocene in Southeast Asia, Wallacea, and Australia has continued to be a topic of debate amongst scholars (Erlandson and Fitzpatrick 2006; Oppenheimer 2009; Porr, et al. 2012). Evidence-based age discrepancies between these regions has provoked questions over the timing of initial occupation due to older archaeological sites found in Australia than that of the Southern Route Hypothesis's precursory trajectory through Southeast Asia and Wallacea (Balme, et al. 2009; Clarkson, et al. 2017; O'Connor 2007).

A growing body of evidence for coastal subsistence patterns through a worldwide appearance of shell middens has challenged the optimal foraging models focused on large land-based mammals once dominating the academic milieu of our scholarly predecessors (Allen, et al. 1988; Biagi 2013; Clune and Harrison 2009; Diana 2015; Erlandson and Fitzpatrick 2006; Fontanals-Coll, et al. 2014; Jerardino 2010; Parkington 2003; Samanti, et al. 2014). A variety of data has emerged indicating early hominin species engaged in aquatic foraging tactics, inferring a more intimate relationship with palaeoshorelines that are now lost to marine inundation (Bailey and Flemming 2008; Erlandson 2001; Erlandson and Fitzpatrick 2006; Fischer, et al. 2007; Masters and Flemming 1983). As submerged landscape studies have entered the enigmatic archaeological debate of prehistoric human dispersal in Europe and the Red Sea (Bailey, et al. 2007; Burgess, et al. 2017; Flemming, et al. 2014; Momber 2000), the Americas (Carbias, et al. 2014; Clark, et al. 2014; Dixon and Monteleone 2014; Faught 2004; González, et al. 2010; Kelley, et al. 2010; Lacroix, et al. 2014; Pearson, et al. 2014), and a growing interest in Australia (Nutley 2014; Ward, et al. 2015), it struggles to gain momentum in insular Southeast Asia.

Deeply vaulted marine channels in insular Southeast Asia infer some form of seafaring technology was necessary for prehistoric colonization even at periods of lowered sea-level. As many palaeolandsurfaces are now inundated due to sea-level rise, it is quite possible evidence for prehistoric human settlement patterns, subsistence strategies, and dispersal are hidden in offshore island regions. Coarse resolution predictive modelling approaches for submerged site discovery in these remote islandscapes provide a provocative opportunity for early-stage development towards the understanding of anatomically modern human insular mobility and behaviour throughout the Pleistocene and Early Holocene in Southeast Asia.

Submerged landscape studies threatens an almost non-existent status in the Philippine Archipelago despite it having nearly 200,000 km^2 of land area exposed during the Last Glacial Maximum (LGM) (Robles 2012:40). With the exclusion of Palawan, the islands of the Philippines were never connected by a pre-existing landbridge conjoining it to the prehistoric Sunda Shelf (Sundaland) or Wallacea during sea-level lowstands (Bird, et al. 2007; Bird, et al. 2005; Hanebuth, et al. 2000; Hanebuth and Stattegger 2004; Robles, et al. 2015). However, evidence of a 67,000-year-old unknown species of *Homo* (Mijares, et al. 2010) made its way into the recesses of the Philippine's largest northernmost island of Luzon, suggesting early islanders had the ability to perform such sea-crossings. With an abundance of steep offshore profiles, karst freshwater aquifers, geographic proximity to nearby mainland Southeast Asia, and momentum of the Mindanao Current feeding into the Indonesian Throughflow, the Philippine Archipelago was likely a strategic locality for prehistoric human occupation and dispersal at periods of lowered sea-level. Due to a growing need to narrow the chronological gaps in the archaeological narrative of human migration and early settlement patterns, it is the aim of this thesis to explore the potential for Pleistocene and Early Holocene submerged landscape site discovery in the Philippine Archipelago.

1.1 Geographic Setting of the Philippine Island Arc System and Palaeo Environmental Climate

The Philippine Archipelago is part of the Pacific Ring of Fire and located between 116° 40’, and 126° 34’ E longitude and 4° 40’ and 21° 10’ N latitude (Figure 1) (Boquet 2017; Carating, et al. 2014). The arc system consists of over 7,000 islands bordered by the Philippine Sea to the east, the South China Sea to the west, and the Celebes Sea to the south. This tectonically active chain of islands is partly volcanic and partly coral reef formation, with vast networks of freshwater river basins carving through karst limestone systems (Boquet 2017; Carating 2014;

DENR-PAWB 2009, 2013). The island's configuration falls into three primary groups: 1) Luzon group to the north, consisting of Luzon, Masbate, and Mindoro; 2) the Central Visayas comprised of Bohol, Cebu, Leyte, Negros, Palawan, Panay, and Samar; and 3) Mindanao in the south (Figure 2) (Boquet 2017; Carating, et al. 2014).

Figure 1 Map showing location of the Philippine island arc system (pink) in context to Southeast Asia. From Mapsof.net (2017a).

Figure 2 The three major geographic regions in the Philippine Islands. The Luzon group in the north is outlined in Green, the Central Visayas in blue, and Mindanao to the south in pink. From Mapsof.net (2017b).

The Philippines is bounded to the east and west by subduction zones that form the Philippines Mobile Belt (Rangin 1991; Yumul, et al. 2008). A left-lateral strike-slip Fault Zone cuts down the entirety of the archipelago system (Figure 3) (Yumul, et al. 2008), making this region a highly active tectonic area subject to earthquakes and volcanism, and likely rotating in clockwise formation since the early Cenozoic (Rangin 1991:211).

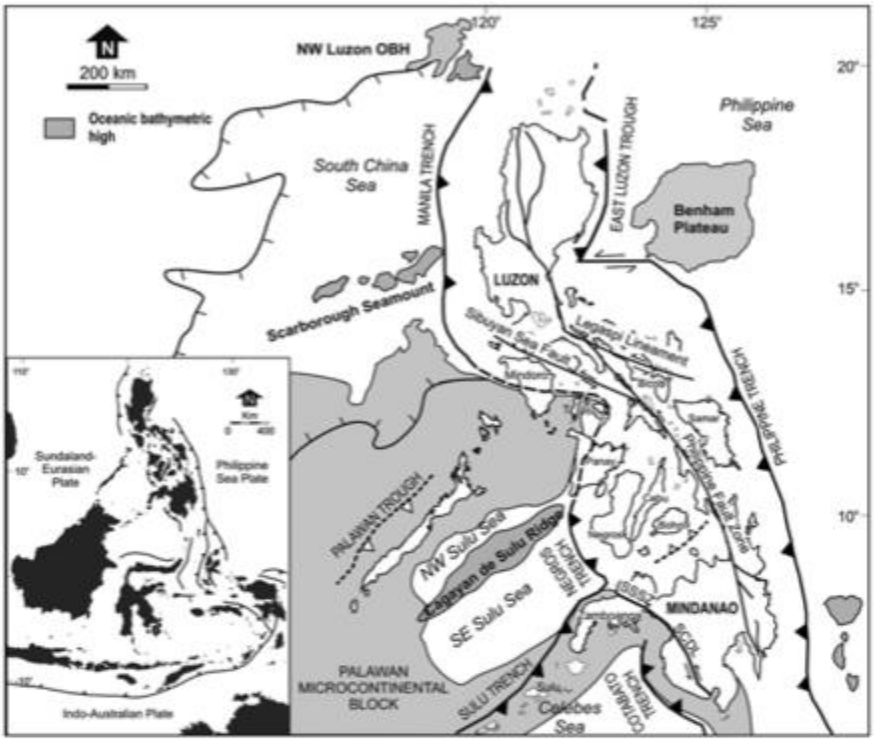


Figure 3 The Philippine island arc system including major plates, trenches, and marginal basins. From 'Tectonic setting of a composite terrane: a review of the Philippine island arc system' (Yumul et al. 2008:8).

Many of the islands are a composition Cretaceous volcanic flows and intrusive folded cretaceous sediment (Carating, et al. 2014), containing a rich myriad of rock shelters, limestone and clay sediments, alluvial fans, karst cave formations, cordillera mountain systems and fossil coral reef platforms (Berdin, et al. 2004; Hanebuth and Stattegger 2004; Lewis, et al. 2008:319; Neri, et al. 2015; Ochoa, et al. 2014; Voris 2000). The Pacific North Equatorial Current flows westward in the equatorial region of the Pacific Ocean, and bifurcates upon reaching the eastern coastline of the Philippine Archipelago into the Kuroshio Current to the north, and the Mindanao Current to the south. This main pathway for meridional heat transfer in the Pacific has a direct influence on Southeast Asian climate and short- and long-term variability of the

Western Pacific Warm Pool (WPWP) (Bolliet, et al. 2011). The Mindanao current transfers water along the southeastern coast of the Philippine islands before contributing to the Indonesian Throughflow (Figure 4).

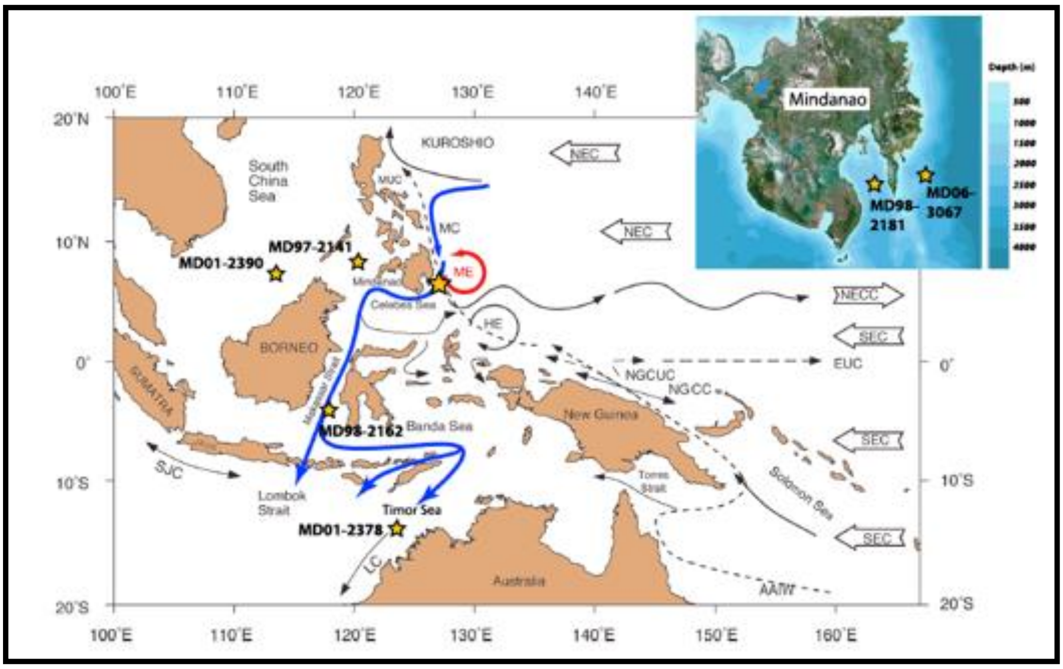


Figure 4 Map showing the North Equatorial Current bifurcating into the eastern coast of the Philippines. From 'Mindanao dome variability over the last 160 ka: episodic glacial cooling of the West Pacific Warm Pool' (Bolliet et al. 2011:2).

This Indonesian Throughflow became a more direct conduit of Pacific surface and thermocline waters after being disconnected from the South China Sea by exposed landmasses during the LGM (Bolliet et al. 2011). Through an analysis of core samples taken from different proxies in the South China Sea, researchers were able to use Sea Surface Temperature (SST) estimates from the LGM to reconstruct models of palaeosurface circulation (Wang, et al. 1995). Demonstrated through these reconstruction models, it was determined LGM winter period SST likely displayed an N-S counter-clockwise pattern trend, whereas, summer periods displayed SST indicating an E-W clockwise current pattern (Figure 5).

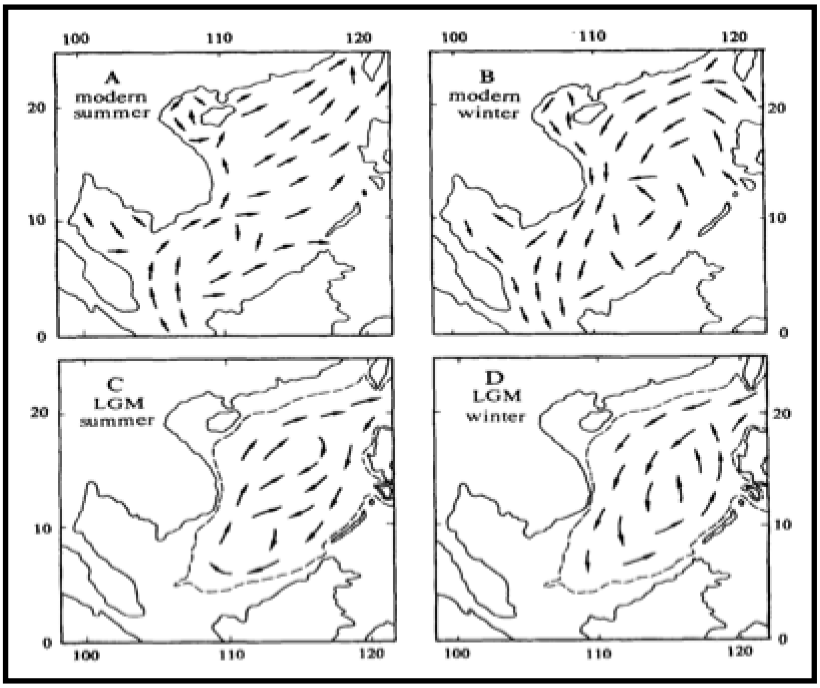


Figure 5 Surface circulation patterns of the South China Sea: (a,b) modern summer/winter; (c,d) LGM summer/winter. From 'Late Quaternary palaeoceanography of the South China Sea: surface circulation and carbonate cycles' (Wang et al. 1995:153).

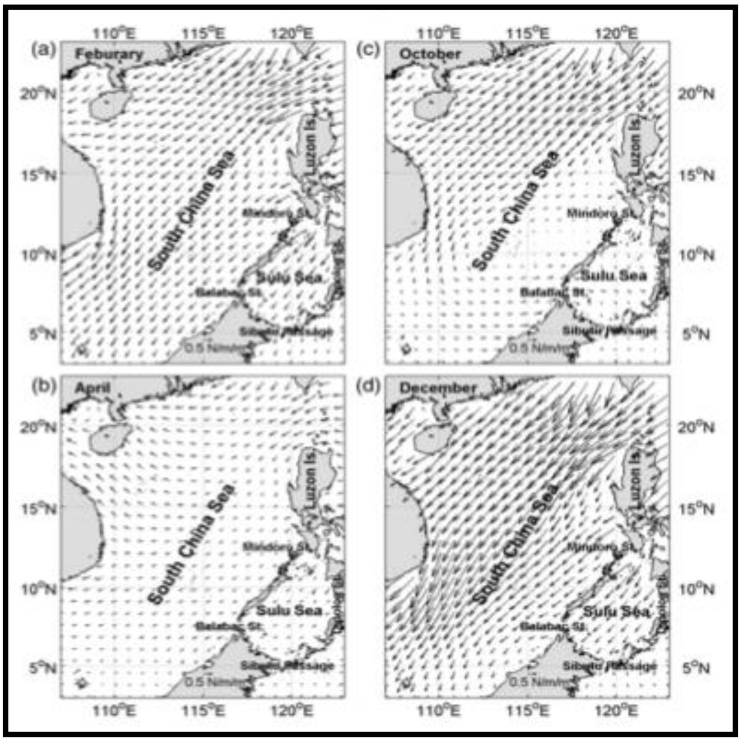


Figure 6 Modern sea circulation of the South China Sea's association with the Sulu Sea. From 'Association of the Sulu Sea surface circulation with the South China Sea' (Cai and He 2010:336).

At present, the Indo-Pacific Warm Pool (IPWP) moves toward the central equatorial Pacific during the summer El Niño events, along with atmospheric convection and rainfall. The weather occurrence is also marked by a slight cooling of SSTs by 1°C due to a shallower thermocline from the relaxing trade winds over the Pacific basin. The relative stability of the Warm Pool is maintained by the exchange of heat and freshwater fluxes at the surface and cold saline deep ocean rising beneath (Gagan, et al. 2004).

Through the analysis of preserved charcoal within lakes and wetland sediments in the surrounding IPWP region, and high resolution records from the Sulu Sea, it was determine that SSTs during the LGM were roughly 3°C cooler than at present (Gagan, et al. 2004; Rosenthal, et al. 2003). In the central region of the IPWP, there were indications of rapid post-glacial rise in SST during the Holocene, projecting near modern SST. Post-glacial shifts in the South China Sea were directly related to the phenomenon in which large armadas of icebergs break from glaciers and travers the North Atlantic (better known as Heinrich events) contributing to a global connection of oceanic thermocline exchange (Gagan, et al. 2004).

Today the Sulu Sea connects with the South China Sea through the Mindoro Straits to the north of Palawan, and Balabac Straits to the south of Palawan (Cai and He 2010:335). While LGM sea-level depressions would have slowed flow through the Balabac Straits, the Sulu Sea's main connecting sill from the South China Sea comes through the Mindoro Straits, maintaining a 420 m channel maximum (Dannenmann, et al. 2003) and would have continued to flow unabated. The Mindoro Strait is much larger and contributes a higher flow from the South China Sea than its southern counterpart; and the Sulu Sea's sea surface circulation is closely related to South China Sea circulation via the Mindoro Straits (Figure 6) (Cai and He 2010). SST are greater in the South China Sea than that of the Sulu sea due to an inflow of cold water coming from the Luzon Strait, giving the Sulu Sea an annual SST variable of 2°C, and is greatly influence by river runoff from surrounding islands as well as the El Niño Southern Oscillation (ENSO) (Bolliet, et al. 2011; Dannenmann, et al. 2003). Under La Niña conditions, strong trade winds fuel a more intense summer wind and an increase in rainfall (Dannenmann, et al. 2003). According to de Gardel-Thoron and Beaufort's (2001) study of phytoplanktonic activity as a quantifier of primary productivity correlated to wind stress relationships, with the stronger northern ocean circulation of the Sulu Sea surface, it was determined ages for heightened productivity associated with the East Asian winter monsoon occurred during MIS 1, 3, 5, and 6. Primary productivity of meridional circulation had a tendency to increase during glacial periods and decrease during inter-glacials (de Garidel-Thoron, et al. 2001:493). It is worth mentioning that for insular regions throughout Southeast Asia exhibiting various geophysical manipulation by tectonic uplift—or offshore steepening by subduction and underthrusting—are still likely to produce localities of archaeological interest for ancient coastal settlements during periods of sea level depression, in the near vicinity of present-day shorelines (Bailey and Flemming 2008:2158). However, these deeply vaulted channels and offshore profiles in the region of the Philippines have a very complex hydrologic influence on the surrounding seas. Research of bat guano deposits in Makangit Cave, Palawan, Philippines, suggest the region was covered by grassland or sparsely wooded savannah during the LGM, indicating a substantially drier climate for the period (Bird, et al. 2007) likely due to less available ocean water feeding into the ENSO (Stott, et al. 2002).

1.2 Research Aims and Questions

To circumscribe avenues for determining the likelihood of site discovery of inundated archaeologic material from the Pleistocene to Early Holocene in the Philippines, a focus on the Central Visayan Region has been determined due to its relatively shallow bathymetry over a considerable area in the Visayan Sea, Panay Gulf, and its conjoining straits. An analysis of the Central Visayan Region's bathymetric content in its surrounding offshore basins could help to answer questions pertaining to which areas were exposed during periods of marine regression and locations of palaeo – bays, harbors, or inland waterways that would have been attractive for prehistoric human maritime activity. Additionally, does modern topography and terrestrial archaeology from adjacent islands reveal predictive indicators towards areas of high resource productivity in submerged palaeo-environments of the Western and Central Visayan Region that were appealing for human occupation during the Pleistocene and Early Holocene?

The research strategy in context to regional familiarization (Benjamin 2010) involved a desktop inventory of the available geological and archaeological datasets (Peeters 2011), and identification of scientific government agencies and museums to establish a broad record engagement from available information (Bynoe, et al. 2016). As part of the initial stage of addressing these questions, it was important to construct a sea-level and landscape reconstruction model (Westley, et al. 2011) that includes bathymetric, geologic, hydrologic, and geomorphologic datasets of the archaeologically scarce regions (i.e., Central Visayas) in the Philippines in context to Pleistocene and Early Holocene. Areas in the offshore Visayas with the highest potential for submerged landscapes site discovery were examined at a coarse resolution scale. Present-day bathymetric contours utilized in the sea-level history reconstruction models in this thesis do not necessarily reflect that of Pleistocene and Early Holocene coastlines regarding geomorphologic consequences from glacial eustatic adjustment over geological time scales, and are only used as predictive models for potential landmasses once attractive for human occupation.

As a premise for further discussion, the term 'coastal adaption' has been adopted from Erlandson and Fitzpatrick's (2006:8) definition: any subsistence lifestyle based along the margins of a large body of water that includes the use of foods from aquatic habitats. Additionally, 'hominin relationship spheres' will be the term attributed to the archaeological, genetic, and dispersal patterns among anatomically modern humans, Denisovan, *Homo. floresiensis*, and *Homo neanderthalensis* interface in context to the growing body of evidence of the 'Southern Route Hypothesis'.

2 LITERATURE REVIEW

2.1 Sea-Level History and Hominin Relationship Spheres in Southeast Asia and Australia

Sea-level fluctuation through the Pleistocene and Early Holocene would have greatly affected the diaspora and subsistence patterns of anatomically modern humans coming out of Africa via the Southern Route into insular Southeast Asia and subsequent Australia (Figure 7) (Erlandson and Fitzpatrick 2006; Hanebuth, et al. 2000; Oppenheimer 2009; Stringer 2000).

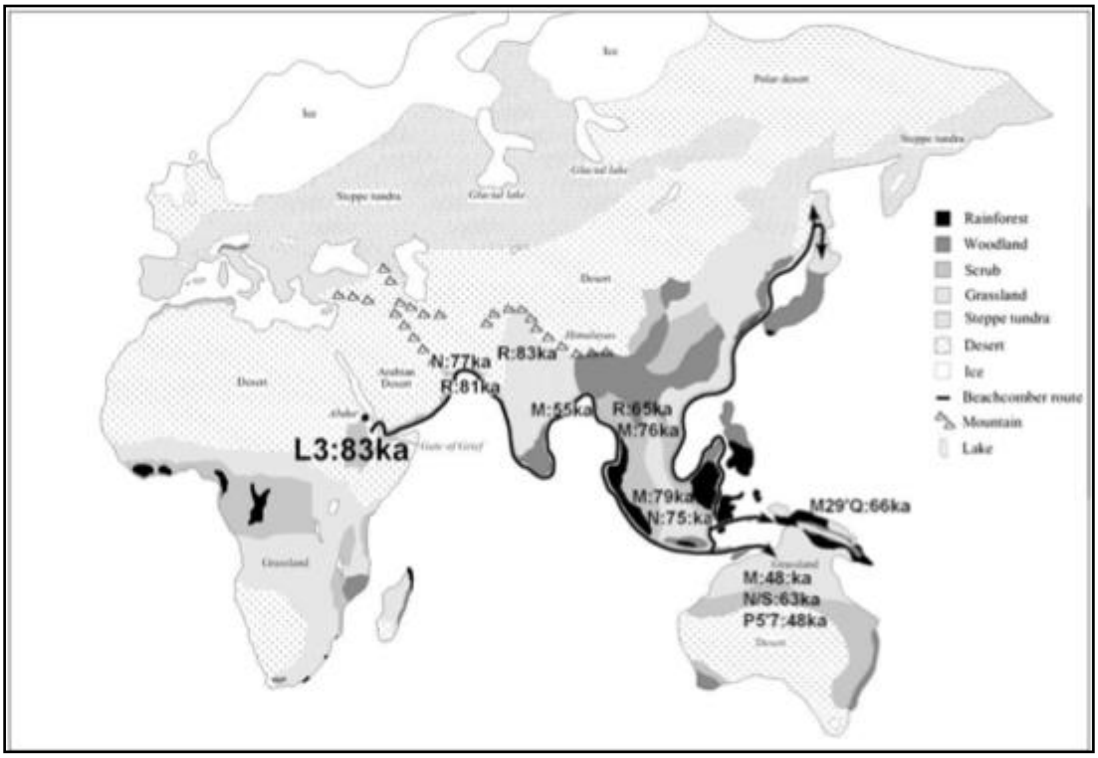


Figure 7 Southern route migration showing exposed Sunda Shelf and 'savannah corridor' extending down the Malaysian Peninsula. From 'The great arc of dispersal of modern humans: Africa to Australia' (Oppenheimer 2009:5).

Glacio-eustatic sea-level fluctuation during the LGM exposed the Sunda shelf (Sundaland), joining mainland Southeast Asia to Sumatra, Java, and Borneo (Bird, et al. 2005; Heaney 1991; Molengraaff 1921; Oppenheimer 2009; Voris 2000). The initial examination of the drowned lowland basin conjoining these now separate regions can be attributed Molengraaff (1921) to which he called 'former Sunda Land'. Heaney (1991) was the first to propose that this once exposed landmass would have had a wide 'savannah corridor' extending down the Malaysian Peninsula, feathered by tropical rainforests to the east and west during the LGM. Sediment analysis of the Java Sea floor suggests that a savannah corridor through the interior of Sundaland did exist (Bird, et al. 2005). Such landscape analyses provide information as to what palaeo-environmental challenges early hominins encountered on their migration throughout Southeast Asia and into Australia (Bird, et al. 2005).

It was further hypothesized that due to the emergence of Sundaland reducing the available surface area of evaporable ocean water in the Indo-Pacific Warm Pool, it generated a colder and drier climate, as much as 2 – 5°C cooler than today (Gagan, et al. 2004; Rosenthal, et al. 2003). Exposed landmasses restricted flow to deep-water channels in insular regions of Southeast Asia (Bird et al. 2005) influencing anatomically modern human migration and subsistence as sea-level fluctuation effected palaeo-weather conditions and availability of freshwater resources. As much of the volume of oceanic waters were locked up in glaciers during the height of the LGM, ENSO rainwater recharged would have decreased. Hominin species subsistence adaptation in response to drier climatic conditions likely provoked a concentration of activity around available freshwater resources. Karstic tropical regions would have been a highly attractive local for anatomically modern humans' subsistence adaptation during periods of sea-level depression (Roberts and Petraglia 2015), not only in the form of freshwater resources found in cenotes or underground aquifers, but alternative water sources found in coconuts and other available flora taxa.

To the east of Sundaland (Figure 8) is the biogeographical region of Wallacea, defined by deep-water channels perpetually separating the two areas (Bird et al. 2005). The corresponding Huxley's Line extends between Bali and Lombok to the south, and through Borneo and Celebes/Sulu archipelago (Bird et al. 2005). These deep-water channels suggest that some level of seafaring technology was needed by early hominin species to reach insular regions throughout Southeast Asia that were never connected by a pre-existing land bridge (Allen, et al. 2008; Birdsell, et al. 1977; Kealy, et al. 2016).

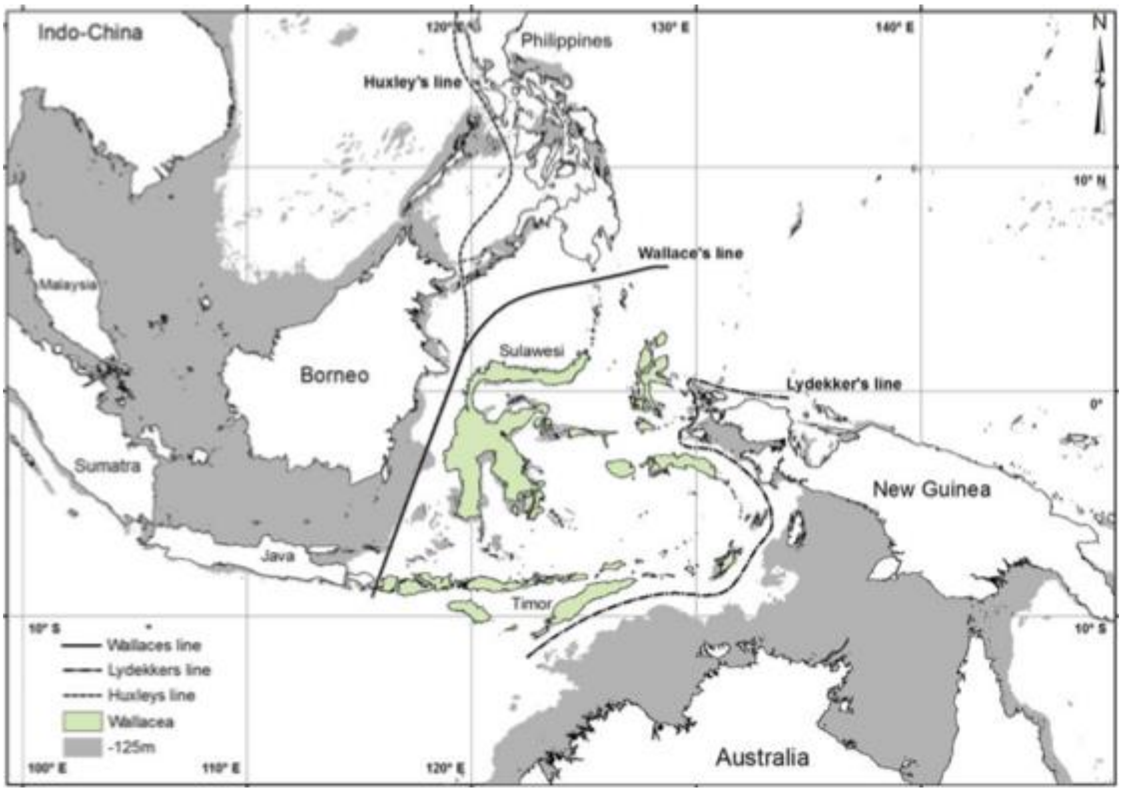


Figure 8 Exposed continental shelf at – 125 m in grey; includes the Huxley, Wallace, and Lydekker lines. From 'Islands under the sea: a review of early modern human dispersal and migration hypotheses through Wallacea' (Kealy et al. 2016:366).

The influence of glacio-isostatic adjustments on oceanic volume resulted in the depression of sea levels as much as – 130 m during the LGM, and 30 – 70 m lower between 85 ka and 30 ka years ago (Figure 9) (Bailey and Flemming 2008; Erlandson and Fitzpatrick 2006; Sathiamurthy and Voris 2006; Voris 2000; Waelbroeck, et al. 2002). Large regions of land exposed during periods of lowered sea-level during the Pleistocene and Early Holocene are now inundated and potentially harbor locations once attractive for human settlement (Bailey and Flemming 2008; Erlandson and Fitzpatrick 2006; Oppenheimer 2009). Submerged landscape studies in insular Southeast Asia could assist in filling the chronological gaps in the southern route migration hypothesis as some form of seafaring technology was needed for prehistoric human dispersal.

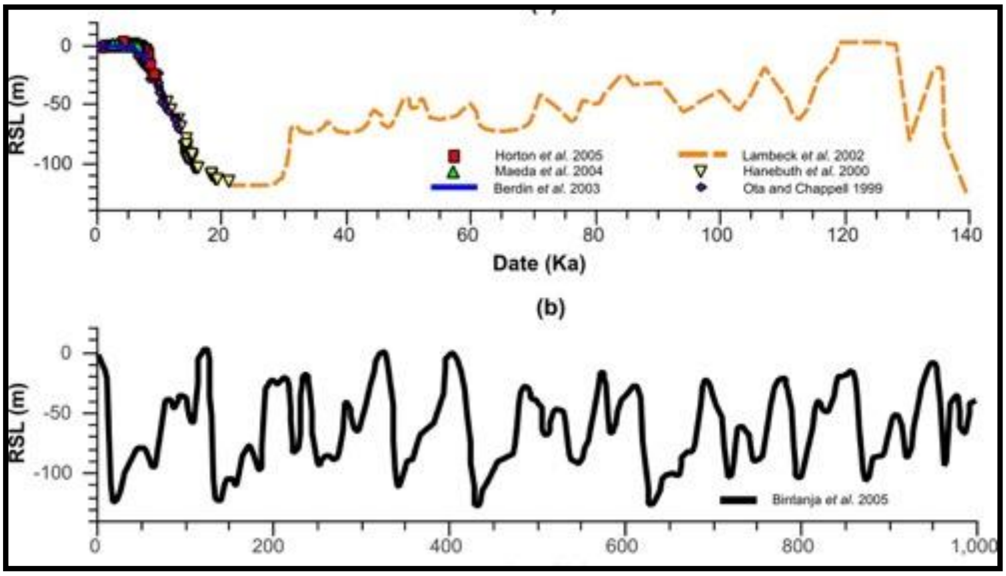


Figure 9 Sea level curve. Top showing 140 Ka, and bottom showing 1000 Ka. From 'Estimates of Quaternary Philippine coastlines, land bridges, submerged river systems and migration routes: A GRASS GIS approach' (Robles 2013:32).

Debates over timing and human cognitive evolution have continued to erupt as part of the dispersal narrative plaguing the current academic zeitgeist (Porr, et al. 2012). Upper Pleistocene hominin colonization is evident in the archaeological record through finds on island Flores, western Melanesia, and greater Australia; suggesting multiple species of hominins were equipped with the ability to perform sea crossings (Allen, et al. 1989; Bednarik 2003; Morwood, et al. 1998). Furthermore, despite spatiotemporal differences in their skeletal morphology and artifactual productions, genetic data suggests Neanderthals, anatomically modern humans, and Denisovans were variants of a single breeding population of *Homo* (Neubauer 2014; Reich, et al. 2011). The presence of an archaic species known as *Homo floresiensis*, on the island of Flores (Brown, et al. 2004), and the yet to be identified species of *Homo* in the Philippines (Mijares, et al. 2010), elevates the possibility of contact and gene flow between these hominins and anatomically modern humans (Clarkson, et al. 2015).

Anatomically modern human migration into the Southeast Asian region is arguably exhibited by the infamous Liu Jiang skeleton, consisting of a cranium and other bone fragments, that were recovered from a small cave at Tongtianyan, in Guangxi South China (Shen, et al. 2002). Uranium dates of 68 – 67,000 years ago were reported from an associated flowstone near the Liu Jiang skeleton, although, direct dates of the remains could not be analyzed due to contamination (Oppenheimer 2009). However, a modern human cranium from Tam Pa Ling, Laos, was recovered from a secured stratigraphic context and dated using both radiocarbon and luminescence from the surrounding sediments (Demeter, et al. 2012). Dating analysis produced an age minimum of 51 – 46 ka, and direct U-dating of the bones indicated a maximum age of ~ 63 ka. Both the Liu Jiang and Tam Pa Ling site could stand to benefit from a soil micromorphological study to determine preservation conditions for organic material known to degrade archaeological deposits in tropical regions (Morley 2017).

Further on the evidenced based migratory path through Southeast Asia to Australia is Niah Cave in Borneo. This site had been connected to mainland China through the once exposed landmass known as Sundaland. Investigations at this site have produced dates for human occupation 46,000 to 34,000 years ago based on charcoal remains from Niah Cave's Pleistocene sediments (Barker, et al. 2007). These dates were derived through Accelerated Mass Spectrometry (AMS) using Acid Base Oxidation (ABOX) method of pre-treatment, and Uranium-series age determinations of bone fragments from a non-fossilized partial cranium.

As the evidence based chronological trajectory continues into Southeast Asia, the fossil finds from Tabon cave, Palawan, Philippines, (Figure 10) have the next oldest date derived from a tibia fragment at 47 + 11/-10 BP (Détroit, et al. 2004:710). Due to the large error range associated with the tibia fragment date, its determination should be considered an indication of age and not absolute (Détroit, et al. 2013). Tabon Cave's human fossil remains were associated with Flake Assemblage III, at 22,000 to 24,000 years ago, derived from radiocarbon dating (Détroit, et al. 2013; Détroit, et al. 2004; Fox 1970).

The Upper Pleistocene human fossil record at Tabon Cave, Palawan, Philippines is frequently quoted as one of the most important sites from insular Southeast Asia (Détroit et al. 2004). The specimens at Tabon Cave are among the limited chronological assemblages available between the Indonesian *Homo erectus* (Ziam et al. 2011), and the earliest *Homo sapiens* from the insular Southeast Asian region (Détroit 2002). According to Pawlik et al.'s (2014a), conventional theory places the diaspora of modern humans into Southeast Asia at 50,000 years ago. Since the discovery of the Callao Cave's right third metatarsal specimen, its hominin classification has been attributed to *Homo*, while its species remains an enigma (Mijares et al. 2010). Its most striking characteristic is the specimen's diminutive size; similar to that of the *Homo floresiensis* remains recovered from Liang Bua in Flores (Brown, et al. 2004; Sutikna, et al. 2016), whose assemblage includes foot bones near the estimated length of the Callao specimen (Mijares et al. 2010:131). If the Callao specimen is determined to belong to anatomically modern humans, initial colonization of the Philippines would occur 20,000 years earlier than the earliest migration to Sahul, placing the nascent stages of human occupation into Southeast Asia prior to 70 ka BP (Pawlik et al. 2014b). However, considering the morphological similarities of the Callao Cave's metatarsal specimen to that of *Homo floresiensis*, as well as dimensions ascribed to Philippine negrito samples (Detroit, et al. 2013), the specimen could suggest an occurrence of interbreeding.

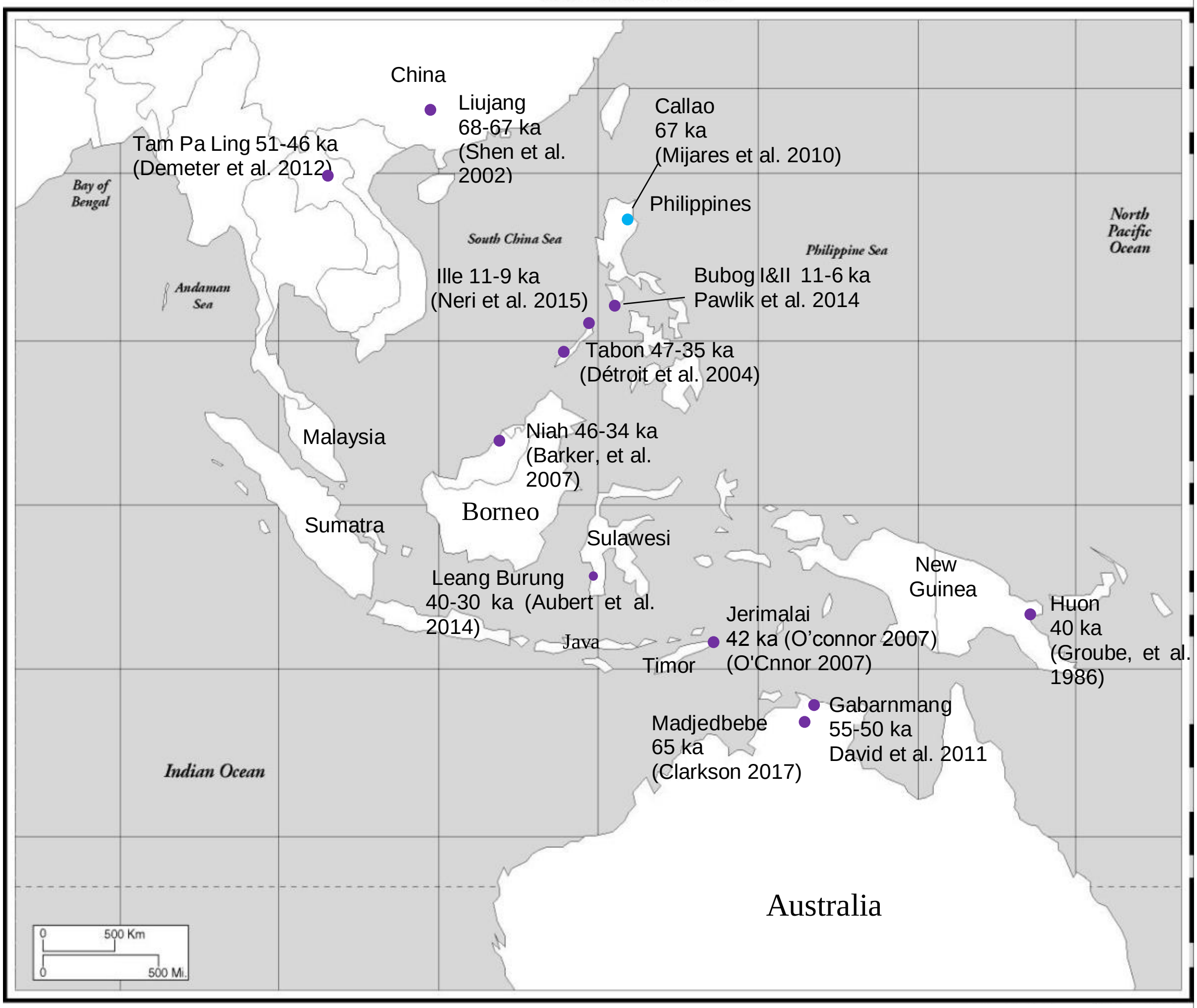


Figure 10 Location of Tabon Cave in relation to the rest of Southeast Asia.

A small-bodied hominin in Flores, Indonesia, was found during an excavation at Liang Bua, along with associated flowstone and a *Stegodon* molar (Brown, et al. 2004; Morwood and Van Oosterzee 2007). AMS dates of type specimen LB1 were approximately 18 ka BP and bracketed by luminescence dates of 35 ka and 14 ka BP. Found below LB1's stratigraphic sequences was another specimen, LB2, with an associated flowstone U-series dated to 37.7 ka BP and the *Stegodon* molar dated to almost 75,000 years ago. *Homo floresiensis* has been fraught with speculative interpretation over whether it is or is not a distinct species of hominin and has continued to be another topic of archaeological debate (Eckhardt, et al. 2014; Gomez-Robles 2016; Henneberg, et al. 2014; Westaway, et al. 2015).

Sulawesi's oldest hominin archaeological material has been recorded at Leang Burung, with radiocarbon dated deposits around 30,0000 BP, and rock art U-series dated to ~ 40,000 years ago (Aubert, et al. 2014). The multiple cave and rockshelters include at least 90 rock art sites, having only two Pleistocene sequences, which include evidence of pigment use and ochre-smeared stone tools. Investigations for earliest human settlement in the Huon Peninsula, Papua New Guinea, produced radiocarbon dates at around 40,000 BP based on a recovered 'waisted axe' (Groube, et al. 1986). Roughly 10,000 years ago, marine regression exposed areas of the Sahul shelf connecting New Guinea to northern Australia (O'Connell and Allen 2004). As the now remote island of New Guinea had once been a part of the continent of Australia, Jerimalai shelter in East Timor maintains the oldest evidence for anatomically modern human settlement site west of Sahul. Investigations at Jerimalai produced evidence of initial human occupation with radiometric dates at 42,000 BP from flaked lithic assemblages (O'Connor 2007). According to Oppenheimer (2009), the best period of opportunity for long crossings over the Sahul shelf would have been 65,000 years ago when sea levels were – 100 m below current. Recently, investigations at Madjebebe Rockshelter in northern Australia has pushed initial human occupation estimates from 50,000 BP (David, et al. 2013; Turney, et al. 2001) back to 65,000 year ago (Clarkson, et al. 2017) further supporting Oppenheimer's hypothesis.

O'Connor (2007) addresses very important issues concerning the chronological sequences from insular Southeast Asia and Australia; primarily, in terms of why Australia's archaeological evidence for initial colonization of anatomically modern humans is older than that of Southeast Asia. Date acquisition from Australia's fossil records had been achieved through the use of Thermoluminescence (TL), Optically-Stimulated Luminescence (OSL), and Electron Spin Resonance (ESR) technologies; however, these methods are rarely employed in the archaeologic dating record for Southeast Asia (O'Connor 2007; Roberts, et al. 2005). The new dates added to the archaeological record further promote issues in the temporal sequences for the region with older archaeological evidence of human settlement patterns in Australia than that of its precursory trajectory (O'Connor 2007).

Despite the evidence of Denisovan genetic flow linking Philippine Mamanwa populations to a common ancestry with Australians (Delfin, et al. 2011; Reich, et al. 2011) and its conflict with mtDNA frequency spheres through various potential migration waves (Gomes, et al. 2015; Hill, et al. 2007), there is a lack of archaeology evidence needed to vindicate these associations. Kealy et al.'s (2017) migration model suggests how the visual proximity of coastlines to adjacent islands through Wallacea influenced anatomic modern humans' migration patterns from Sunda to Sahul, excluding the Philippines. However, Reich et al.'s (2011) evidence of genetic flow linking Philippine Mananwa populations with ancient Australians, may have a correlation with the Mindanao Current feeding into the Indonesian Throughflow, which passes through the Makassar Strait and into the Timor Sea (Figure 11).

With Leang Burung at the crossroads between Southeast Asia and Wallacea and positioned east of the Indonesian Throughflow, East Timor's archaeological evidence (e.g., O'Connor 2007) being at the Sahul threshold from Southeast Asia into Australia, and indirect evidence of seafaring from the initial colonization of Australia (Clarkson, et al. 2017; Clarkson, et al. 2015; Erlandson 2001), the possible palaeo-sea currents linking these regions suggests a potential waterway correlation in hominin dispersal events (Figure 11).

More archaeological evidence is needed to close the gaps in Southeast Asia to Australia chronological dilemma. The frequency of sea level change due to hydro-isostatic adjustments and tectonic up-lift over geological timescales (Bailey and Flemming 2008; Erlandson and Fitzpatrick 2006; Oppenheimer 2009; Robles, et al. 2015; Stringer 2000; Voris 2000; Waelbroeck, et al. 2002), suggests the submerged areas throughout the region may harbor areas of potential archaeological interest capable of elucidating hominin dispersal evolution.

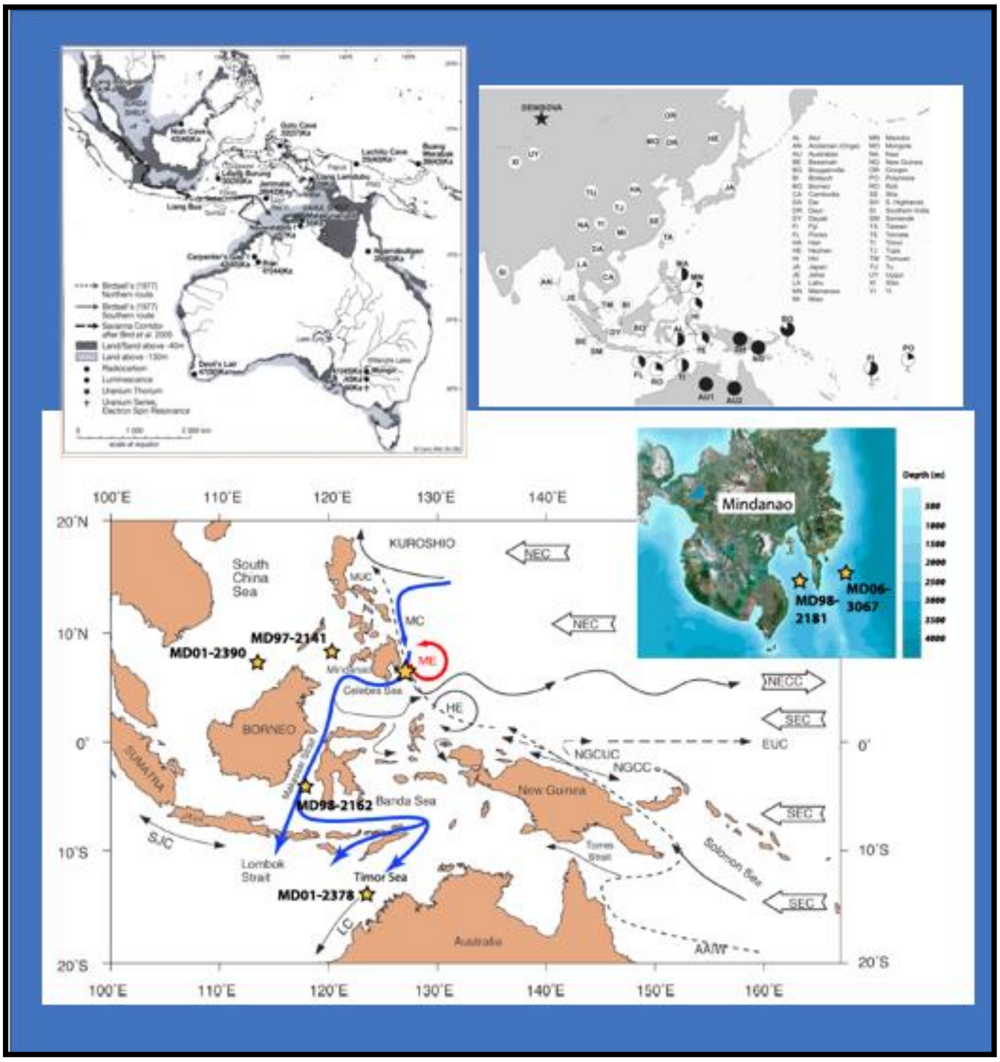


Figure 11 Side-by-side comparison of archaeological sites throughout Southeast Asia, Wallacea, and Australia (top left) to genetic flow chart of populations having Denisova ancestry (top right) and Indonesian Throughflow (bottom). Modified images from Boilliet et al. 2011, Reich et al. 2011, and O'Connor 2007.

2.1 Early Human Migration into the Philippines

Various migratory hypotheses from the Sunda Shelf mainland Asia into the Philippines have been proposed, either through the emerged islands of the Sulu Archipelago into Mindanao, islands between Sulawesi to Mindanao (Dizon and Pawlik 2010:444; A. Pawlik, et al. 2014), or from Borneo to Palawan (Figure 12) (Robles, et al. 2015:86).

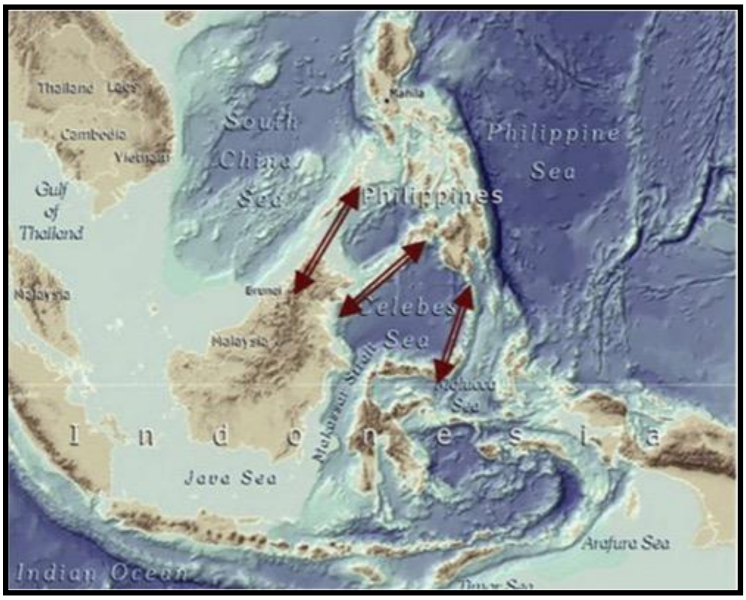


Figure 12 Sunda Shelf migration possible trajectories into the Philippines. From 'The lower palaeolithic record in the Philippines' (Dizon and Pawlik 2010:445).

Through a sea-level history reconstruction model of Palawan, it was determined that the most likely period necessary to expose a 2 km wide landbridge connecting Palawan to Borneo, would have occurred during MIS 12, at – 135 m below present day sea levels (Robles, et al. 2015:92). However, archaeological evidence of the first anatomically modern humans in the Philippines only extends to roughly 50 ka BP (Détroit, et al. 2004; Fox 1970).

The northern Luzon region, the Visayas, and Mindanao—all situated in Wallacea—have never been physically connected to the Sundaic region (A. F. Pawlik, et al. 2014), and are boarder by deeply vaulted tectonically induced channels (Oppenheimer 2009; Robles, et al. 2015; Voris

2000), suggesting some level of maritime technology was needed to facilitate human dispersal into the rest of the Philippines. Despite this, the primary locus of archaeological investigations for initial human migratory entry point into insular Southeast Asia, Philippines, has been the Borneo into Palawan crossing (Détroit, et al. 2004; Dizon and Pawlik 2010; Fox 1970; Heaney, et al. 2011; Mijares 2002, 2005, 2008; Mijares, et al. 2010; Patole-Edoumba, et al. 2012).

More recent archaeological interests have been focused towards Mindoro (Figure 13), the major liminal island between Palawan and Luzon (A. Pawlik, et al. 2014; A. F. Pawlik, et al. 2014; Pawlik, et al. 2015), as a stepping stone into the rest of the Philippine region. Two migratory interpretations have been proposed from Sundaland into Palawan. One migratory hypothesis occurred during the Late Pleistocene by Fox (1970) and Cranbrook (2000), and the other by Heaney (1986), who postulated the endemicity of megafauna and anatomically modern humans—with a Sundaic affinity—would have more likely occurred during the Middle Pleistocene epoch. An amalgam of exposed lowland connections of the Sunda Shelf existed between Sumatra, Java, and Borneo (Robles, et al. 2015:77; Voris 2000:1155).

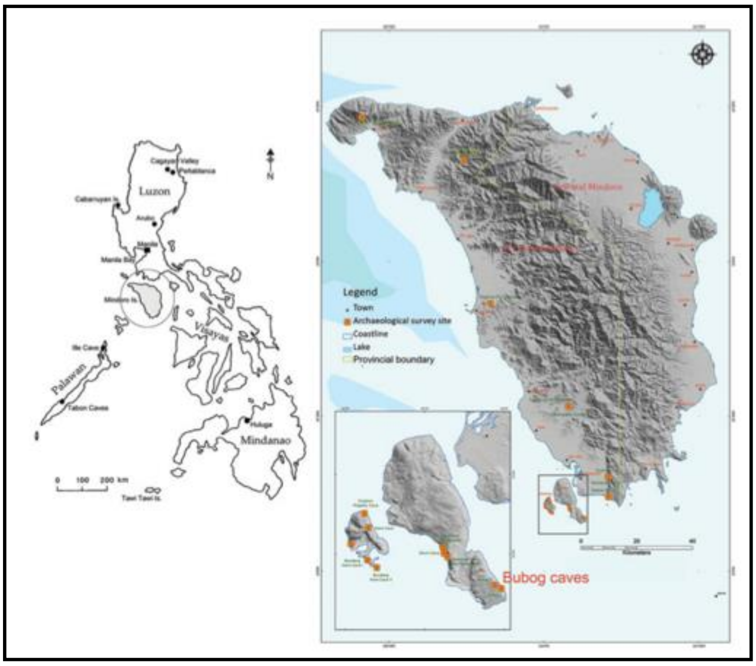


Figure 13 Island of Mindoro as the liminal stepping-stone into Luzon. From 'Shell tool technology in Island Southeast Asia: an early Middle Holocene Tridacna adze from Ilin Island, Mindoro, Philippines' (Pawlik et al. 2015:297).

The floral and faunal fossil remains of Palawan show it is more closely associated with the Sundaic region than it is with the rest of the Philippines (Bird, et al. 2005). Piper et al.'s (2008) zooarchaeological study of the region supports Heaney's (1986) claim with evidence of an extinct tiger *Panthera tigris* (L.) at Ille Cave, Palawan, juxtaposed to biogeographic evidence of the species' presence on Borneo, Java, Bali, and mainland Asia during the Middle Pleistocene. Albeit, during the LGM, the Balabac Straits still flowed unabated by any land bridge between Borneo and Palawan with a breadth of 12 km (Voris 2000:1155). Furthermore, as demonstrated by Robles et al.'s (2015) landscape reconstruction model of sea level change in Palawan, the earliest a dry land bridge necessary for an animal crossing between Palawan and Borneo existed during MIS 12 (Figure 14).

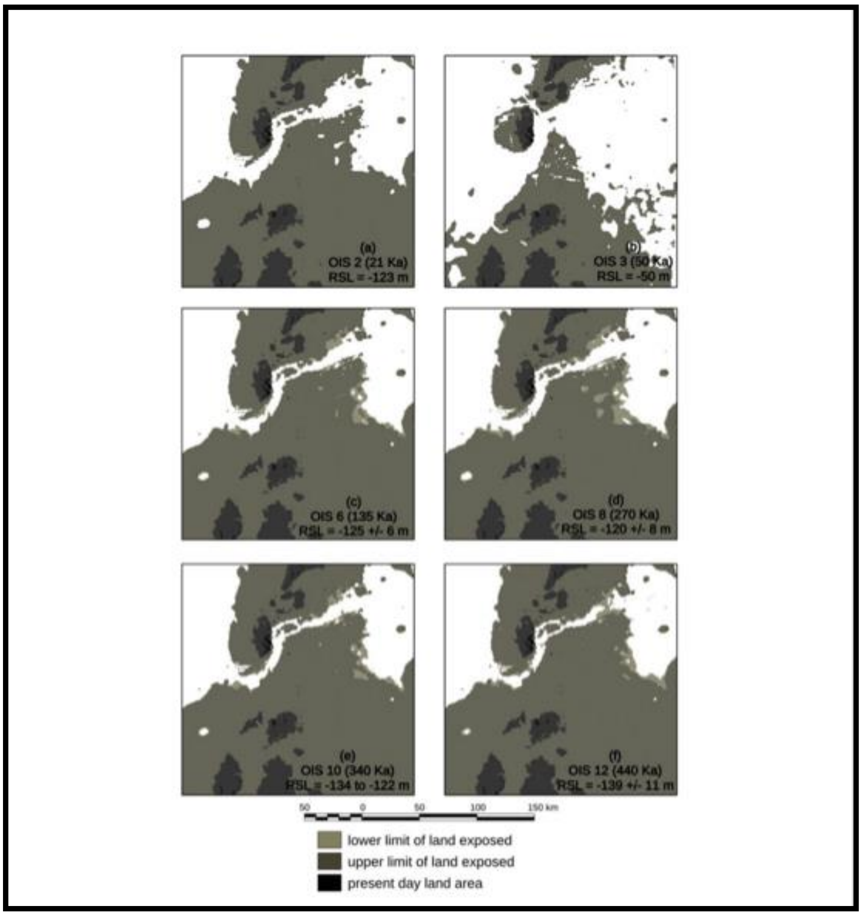


Figure 14 Reconstruction model depicting and existing landbridge in the Balabac strait at OIS 12 (MIS 12). From 'Late Quaternary sea-level changes and the palaeohistory of Palawan Island, Philippines' (Robles et al. 2015:84).

On the other hand, the second migratory hypothesis from Borneo via the Sulu Archipelago suggests shorter island-hopping distances into Mindanao—during periods of sea-level lowstands—and exposed landmasses connecting Mindanao into the Central Visayas (excluding Palawan), and onto the northern Luzon region (Dizon and Pawlik 2010:444; Pawlik et al. 2014a).

Although there is no direct evidence of seafaring technology in the Philippines prior to 1500 years ago (Lacsina 2015:129), and sparse direct or indirect evidence before 3rd to the 5th centuries BCE throughout Southeast Asia (e.g., Manguin 1993; McGrail 2001), some form of seafaring capabilities were inferred through obsidian analysis between Mindoro and Palawan as early as the Late Pleistocene (Neri, et al. 2015). This could have further implications for seafaring into other regions of the Philippine Archipelago, especially when considering the indirect evidence of anatomically modern humans undertaking voyages in excess of 20 – 200 km for the initial colonization of Australia some 65,000 years ago (Clarkson, et al. 2017; Erlandson 2001).

To better understand potential trajectories, it is important to take into consideration palaeo-sea currents of the Sulu Sea. This region would have potentially been an active arena for sea crossings between the insular Greater Philippines. The Sulu Sea is geographically position between Palawan to the east, Luzon to its north, the Central Visayas to the west, Mindanao to the west-southwest, Borneo to the south, and the Sulu Archipelago to the south-southwest (Figure 2) (Dannenmann, et al. 2003). If early hominins had reached insular regions of Southeast Asia and Australia that were never connected by any landbridge (e.g., anatomically modern humans into Australia 50 – 65 ka BP [Clarkson et al. 2017]; *Homo florensiensis* on Flores at 60 – 100 ka BP (Morwood and Oosterzee 2007); and *Homo erectus* into Javan regions 1.8 Ma [Bettis et al. 2004; Swisher et al. 1994]), then investigations towards site discovery for human settlement patterns in context to the Greater Philippines must be considered in tandem with palaeo-sea currents, particularly of the Sulu Sea.

2.2 Pleistocene and Early Holocene Archaeology in the Philippines: a review

Chronological lacunae of the more than 7000 islands that make up the Philippine Archipelago (A. F. Pawlik, et al. 2014:230) provides the arduous challenge of discovering archaeological evidence towards initial peopling of the region. The oldest archaeological evidence of extant genera of catarrhines—east of the Wallacea line—is a right third metatarsal (MT3) of a hominin species recovered in northern Luzon, at Callao Cave. The age of the specimen was determined through direct dating uranium series (U-series) ablation to be at a minimum age range of 66.7 ± 1 ka BP (Mijares, et al. 2010:128). The fossil specimen has been classified *Homo*, although further investigations are necessary to determine its species due to its small size (Mijares et al. 2010). If the specimen, is in fact, ascribed to *Homo sapiens*, this could have major implications for the timing of initial human settlement in the Philippines (Pawlik et al. 2014b). Morphological features associated with MT3 show a close association with Philippine negrito samples in terms of length. However, many of the MT3 specimen's other dimension are relatively diminutive, particularly with the proximal articular facet (Détroit, et al. 2013).

The oldest known *Homo sapiens* fossil remains of the Philippine Archipelago, come from a mandible and frontal bone recovered at Tabon Cave (Fox 1979, 1978), originally dated through stratigraphic sequencing to roughly 30,000 years ago. Almost 40 years later, direct dating of the frontal bone (P-XIII-T-288) was found to be 16,500 ± 2000 BP (Détroit et al. 2004). New U-series direct absolute dates were administered and published in 2004 measuring the uranium decay of the mandibular fragment (PXII-T436 Sg 19), producing an estimated age of 31 ka BP (Détroit et al. 2004:710). A newly found tibia diaphysis (IV-2000-T-197) was recovered and dated using the same U-series technique producing a date of 47 + 11/-10 BP (Détroit et al. 2004:710). This sets Tabon Cave's fossil record to the oldest potential age of ca. 58,000 BP and a substantially large margin of error. Radiocarbon dates on associated charcoal ranged from 9,000 BP to 30,000 BP (Fox 1970). However, even with the associated radiocarbon dates derived from the 1970s, the newly found tibia indicates the fossil could very well be 37,000 BP instead of 58,000 BP, contending with a roughly 20,000-year margin in which the remains may have originated. The Tabon Cave is among over 200 cave sites located on Lipuun Point, Palawan, whose cave complex contains a temporal sequence ranging from the later Palaeolithic to Metal Age burial deposits (Lewis 2007).

At Palawan’s northern end, is a Terminal Pleistocene to Middle Holocene archaeological site known as Ille Cave (Lewis, et al. 2008). Located at New Ibajay, El Nido, this solution cave and rockshelter revealed two prehistoric burials underneath a 7,000-year-old shell midden layer (Szabó, et al. 2004). Deeper deposits were radiocarbon dated from charcoal remains associated with burnt animal bone to 9,000 – 11,000 BP. The Terminal Pleistocene assemblages included unburnt faunal remains (including deer), shells, chert, and obsidian (Lewis, et al. 2008). Ille Cave's stratigraphic sequence revealed by the Middle Holocene deer bones were replaced by pig as the dominantly hunted taxon. At 14,000 to 11,000 BP, a cultural hiatus was apparent in the cave's depositional sequence. According to Robles et al.'s (2015) Palawan sea-level history reconstruction model, sea level would have been 96 m below modern levels at around 14.6 ka BP, and as much as – 64 m relative sea-level (RSL) at 13.1 ka BP. Later occupation of Ille Cave could have been provoked by sea-level transgression, whereas, sites of earlier occupation may remain in the surrounding inundated regions of the island.

Investigations of karstic limestone rockshelter formations produced two likely sites for human occupation known as Bubog I and II, located 7.5 km from the coastline of Mindoro on the isle of Ilin (Pawlik et al. 2014a). Deposits unearthed at these sites produced large amounts of shell middens, faunal remains, and stone artifacts that accumulated during the Terminal Pleistocene into the Holocene (A. F. Pawlik, et al. 2014; Pawlik, et al. 2015; Porr, et al. 2012). A high number of gastropods were produced from the shell middens including: *gastropod Lambis, Trochus, Turbo,* and the bivalve *Tridacna* (A. F. Pawlik, et al. 2014; Porr, et al. 2012). In Layer 8 of Trench 1 – 2 South Wall, at Bubog I, a shell adze (SANU-35132) made from the species *Tridacna* was radiocarbon dated to 7,000 BP. The oldest date derived from the Bubog I site came from a *Canarium hirsutum nut* (WK 32983, Layer 9) radiocarbon dated to 11,000 BP (Pawlik, et al. 2015).

There are only three well documented palaeolithithic sites in the Philippines (Neri 2006). Since the 1950s, lower palaeolithic research in the Philippine Islands were focused on northern Luzon Island in the Cagayan River valley (Fox 1978). In 2008, the Cagayan valley produced lithic materials consisting of unretouched flakes, choppers, and a partially bifacial proto-handaxe (Dizon and Pawlik 2010:444). The Cagayan region is well known for its prehistoric cave and open-air sites where Middle Pleistocene large mammal fossils were recovered in the form of *Rhinoceros*, *Elephas*, and *Stegodon* (Beyer 1947).

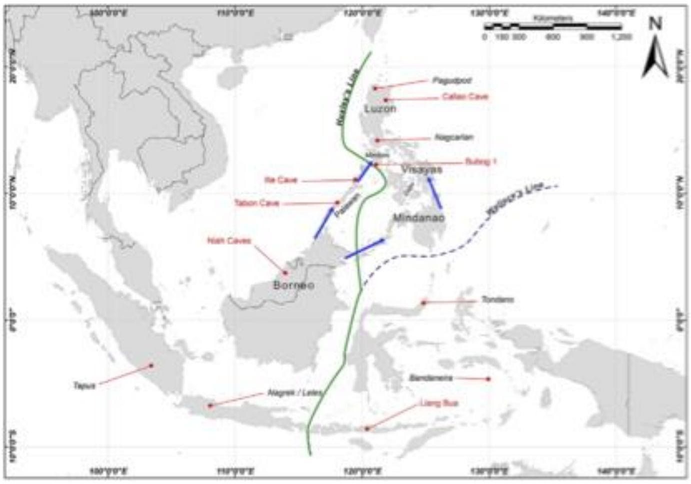


Figure 15 Map of relevant sites and migration pathways in the Philippines. From 'Mobility of early islanders in the Philippines during the Terminal Pleistocene/Early Holocene boundary: pXRF-analysis of obsidian artefacts' (Neri et al. 2015:150).

Dizon and Pawlik (2010) published findings at Arubo 1 (Cabalwanian site), Cagayan, Luzon, consisting of over 100 open sites containing palaeolithic deposits. Investigations in the 1960s lead by Robert Fox, the then head of the Anthropology Division of the National Museum of the Philippines, yielded a unifacial stone handaxe and other lithic artifacts associated with Middle Pleistocene faunal remains (A. Pawlik, et al. 2014). However, estimated dates remain unconfirmed. In 2001, fieldwork at Cabalwanian site recovered 18 stone tools of the lower palaeolithic (Dizon and Pawlik 2010:445) where the region became described as the "Cabalwanan pebble tool complex" (Détroit, et al. 2013).

The Tabon Cave, Palawan, and Callao Cave, Luzon, continue to be the primary records of Upper Pleistocene stratigraphic palaeolithic deposits (50,000 and 30,000 BP) (Détroit, et al. 2004; Dizon 2003; Dizon, et al. 2002; Mijares 2008). Radiocarbon dates for the Tabon site were derived from charcoal deposits associated with archaeological layers containing flake tools to 26,000 BP (Mijares 2005). While cervid teeth from Callao Cave were recovered at ~270 – 295 cm below the cave surface, and U-series dated to 52,000 and 54,000 years ago (Mijares, et al. 2010).

Mindanao and the Visayas have yielded cases of isolated vertebrate faunal fossil remains that date more than 500,000 years ago (Fox and Ikawa-Smith 1978). Albeit, those age estimates were never confirmed and were deemed unreliable. H. Otley Beyer surveyed the Mindanao region and located five sites of potential interest for a palaeolithic record (Beyer 1947). Spoehr

(1968) attempted to survey the southern tip of Zamboanga Peninsula, Mindanao, for evidence of the Borneo to Sulu Archipelago human migration trajectory into the greater Philippines. Unfortunately, the terrain proved difficult to maneuver, and not much was conducted subsequent to his preliminary investigation (Spoehr 1968). Studies at Huluga Open Site in Barangay Indahag, Cagayan de Oro City, Mindanao, has produced obsidian materials whose chemical signatures indicate the same unknown origin with other obsidian rich deposits in the Mindanao region (Bautista 1995; Coutts and Wesson 1980; Neri 2016; Ronquillo and Ogawa 1996; Spoehr 1973). Chemical analysis was determined through X-Ray Fluorescence Specroscopy (XRF) and Proton Induced X-Ray Emission/Proton Induced Gamma-Ray Emission (PIXE/PIGME), while age estimates are unknown.

The archipelago's main islands Luzon, the Visayas, and Mindanao, have never been physically linked; inferring a sea crossing would have been necessary for the dissemination of anatomically modern humans into these regions (Esselstyn, et al. 2004; A. F. Pawlik, et al. 2014:231). Ille Cave and rockshelter, located in a karstic limestone tower in El Nido, Palawan, recovered several obsidian flakes along with associated chert, charcoal, burnt faunal remains of deer and pig, and human cremation burial producing ^{14}C dates ranging between 9,500-11,000 BP (Lewis, et al. 2008). The Bubog I site on Illin Island, Mindoro, also recovered obsidian from layer 9 and 10 of its shell midden, with associated dating to around the Terminal Pleistocene (Porr et al. 2012; Pawlik et al. 2014b,2015). Through the use of portable X-ray fluorescence spectrometry (PXRF), it was determined occupants of Ille Cave, in Palawan, and occupants at Ilin Cave, Mindoro, exploited the same unknown obsidian source; even though the two sites are separated by approximately 210 km (Fig. 7; Neri et al. 2015:155), and have never had a landbridge connection due to a steep offshore profile between the two islands (Neri et al. 2015).

2.3 Submerged Landscape Studies in the Philippines

At present, only one submerged prehistoric cave site investigation has been conducted in the Philippines (Rocha, et al. 2017). The investigation of a submerged rockshelter at Marigondon Cave, Mactan Island, Cebu, Philippines, at 40 m below present sea level, yielded sediment core samples dating to 130 ± 8 ka and 116 ± 7 ka; roughly 120,000 years (Rocha et al. 2017:8). Results of the investigation were minimal, concluding the site may have been attractive for human occupation at periods of lowered sea-level. Understanding the underwater working environment in tandem with understanding the nature of the archaeological praxis is paramount when undertaking submerged landscape investigations (Goggin 1960). Archaeological investigations at – 40 m below sea level are susceptible to physical and financial obstacles not observed on land. Often terrestrial archaeologists are reluctant to conduct investigations underwater, believing preservation would be unlikely, which has been demonstrated not to be the case even in tropical regions (e.g., Faught 2004; Fischer and Flemming 2004; Fischer, et al. 2007; Fischer, et al. 1997; Galili, et al. 1993; González, et al. 2010; Pearson, et al. 2014). Rapid burial by sediment (Stewart 1999) or submerged cave systems (González, et al. 2010) have preserved archaeological records in areas that were once exposed during periods of marine regression.

More recently, interest towards submerged landscape investigations in the Philippines have been developing (e.g., A. F. Pawlik, et al. 2014; Robles 2012; Robles, et al. 2015). A. F. Pawlik, et al. (2014) discussed a channel separating Ille Island from Mindoro, with bathymetric data exhibiting a 20 to 24 m depth range. As early as 11,000 years ago, sea levels were approximately 60 to 45 m below present and would have connected the channel between Ille Island and Mindoro (A. F. Pawlik, et al. 2014; Pawlik, et al. 2015). Through a sea-level history reconstruction model, A. F. Pawlik, et al. (2014) demonstrated several potential palaeolake formations existing on the submerged landmass between these two islands expanses. While a short analysis was discussed on the submerged area between Mindoro and Ille Island in Pawlik et al. (2014b), there was no mentioning of future research for this underwater region. Aside from Robles et al. (2015) and Rocha et al. (2017), all other maritime archaeological investigations in the Philippines are heavily focused on the nautical component (Dizon 2003).

Since the Visayas are geographically set amid Mindanao and Luzon, a study of this region would provide three new domains of archaeological insight. First, it could potentially help to fill the chronological gaps in the Philippine's archaeological record and support the Borneo into Palawan crossing hypothesis (Détroit et al. 2004; Dizon and Pawlik 2010; Mijares et al. 2010; Pawlik 2014a,b; Pawlik et al. 2015; Robles et al. 2015). Second, it could yield indirect evidence of the Borneo/Sulu Archipelago migratory trajectory into the Greater Philippines (Dizon and Pawlik 2010), if older dates are found in its inundated coastal regions. Finally, it could further elucidate early islander insular mobility via the ancient meridional circulation patterns of the Sulu Sea.

3 METHODS

Determining the potential for submerged landscape site discovery in the Philippine Archipelago involved a synthesis between Benjamin's (2010) 'Regional Familiarization' and 'Observation of Potential Survey Locations, Physically and With Sonar' ; along with Westley et al.'s (2011) 'Mapping Archaeological Potential'. Benjamin's (2010) site discovery model expresses the need for familiarization of a region's prehistoric archaeological record as well as its geography, geology, geomorphology, oceanography and hydrology to determine the theoretical framework for underwater site preservation. Although stated as part of the 'Observation of 'Potential Survey Locations, Physically and With Sonar', a physical inspection of an inundated area in the Visayas that meets the prerequisites of the theoretical framework of prehistoric humans' terrestrial settlement patterns (Benjamin 2010), could very well be considered an aspect of regional familiarization. As saline environments produce an inherently different chemical and biological signature—in the form of marine growth and cementation—than that of its terrestrial counterpart, a physical survey of what terrestrial features found at archaeological sites look like in the marine environment could only stand to improve the likelihood of inundated site discovery.

Westley et al.'s (2011) 'Mapping Archaeological Potential' specified features such as proximity to freshwater and subsistence resources, lookout points, availability of a societies' preferential raw materials, and shelter as part of predictive approaches in prehistoric submerged site discovery. However, both publications espoused the importance of sea-level histories that associate specific time intervals to the drowning of palaeoshorelines. Therefore, aspects of Benjamin (2010) and Westley et al.'s (2011) were considered in tandem when determining the highest probability for submerged site preservation amid landscape attributes attractive for prehistoric human occupation in the Philippines. Through the scope of three categories: 1) desktop study; 2) environmental reconnaissance; and 3) developing a sea-level history and reconstruction models, it is suggested that the Visayan Sea Basin, Panay Gulf, and the Guimaras Strait (Figure 16) have the highest likelihood for offshore site discovery.

3.1 Desktop Study

A review of published and unpublished Middle – Late Pleistocene and Early Holocene archaeological investigations in the Philippines provided the requisites necessary for comprehending the body of evidence involving initial human activity and migration throughout the archipelago. A thorough understanding of the geography and topography of the Central Visayan coastal region was implemented through the examination of the Bureau of Mines and Geosciences's (BMG) Geohazard Maps (Figure 17), at a scale of 1: 50,000 based on the National Mapping and Resource Information Authority's (NAMRIA) content. Additionally, bathymetric content from NAMRIA's Topographic Maps (NTMS) 711 series (Figure 18) at a scale of 1: 50,000 in a 15' x 15' interval, with contour intervals of 20 m, and supplementary contours at 10 m interval, were downloaded from NAMRIA.gov.ph (Figure 18). Topographic map sheets were then cross-referenced with the downloaded sheet content from BMG's webpage gdis.mgb.gov.ph.

Figure 16 Regions targeted for evaluation based on relatively shallow bathymetry. These areas include: Bantayan Island, Cebu; Guimaras Strait; the Northern Cebu Basin, Northeast Panay Coast and its adjacent islands; and the Panay Gulf.

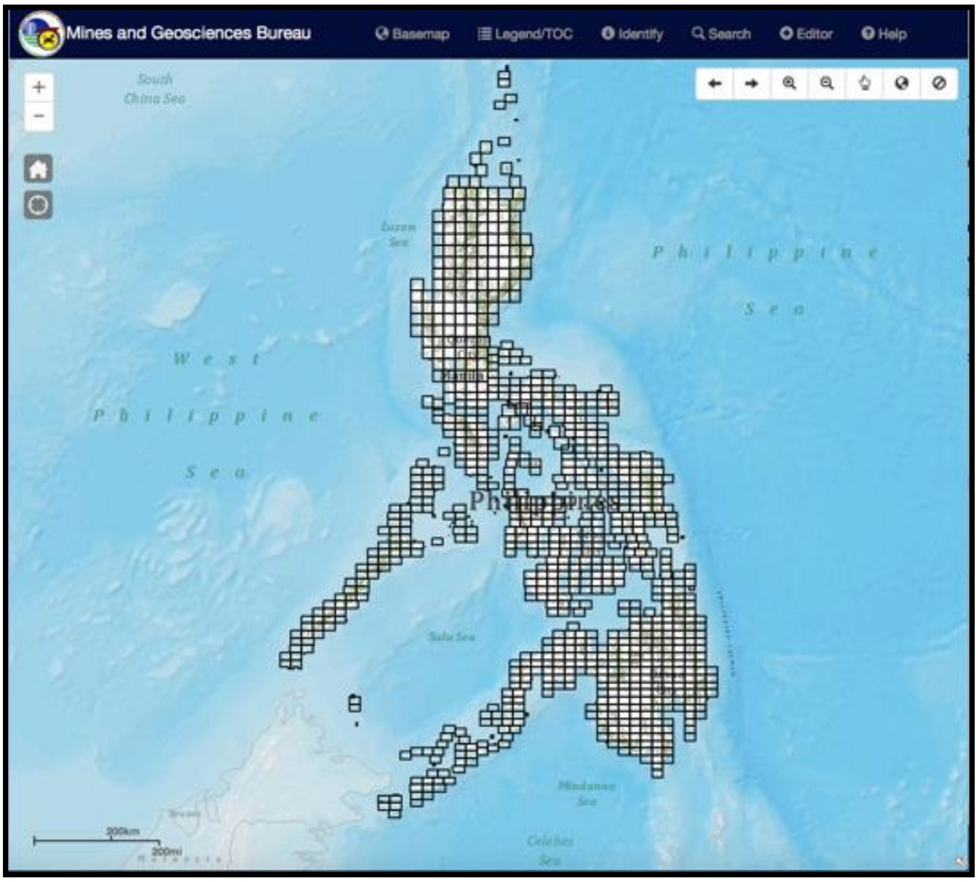


Figure 17 The Philippines 672 sheet 711 series from the Bureau of Mines and Geosciences website gdis.mgb.gov.ph.

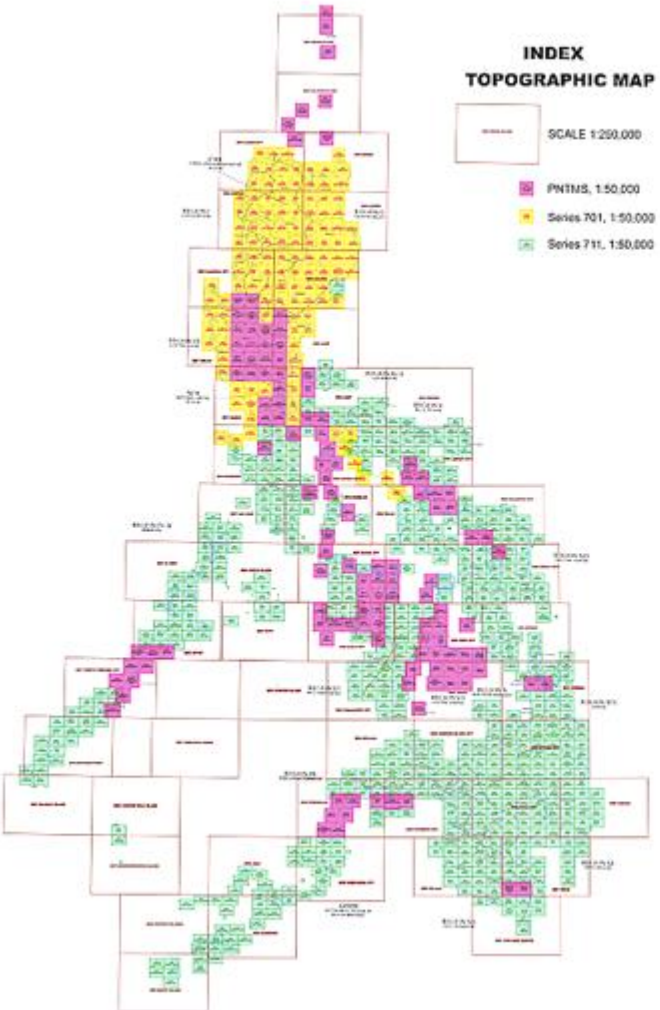


Figure 18 NAMRIA 711 series topographic map index NAMRIA.gov.ph.

Bathymetric content on the BMG website can be observed at a closer 1:50,000 scale through the user interface on the index map (Figure 21). However, the attached map thumbnail for a quadrant only displays a Flood Susceptibility map highlighting river systems and no bathymetric data (Figure 22). A visual examination of both BMG's and NAMRIA's cartographic information had been implemented for the Panay Gulf, Guimaras Island coast, Guimaras Strait, Northeastern Panay coast, Bantayan Island and the Northern Cebu Basin. Of the total 1344 sheets, 40 were examined in detail for the Greater Visayas in the targeted areas highlighted in Figure 16, based on their relatively shallow bathymetric content.

Each sheet from the BMG's website can be identified by its respective Title, Sheet Number, Name of Quadrant, Main Region, and Main Province identifier (Figure 19). Sheets from the NAMRIA Topographic Map Index identify each map by quadrant name and sheet number consistently with BMG's website. For purposes of clarity, area specific identification will be labeled using a sheet's quadrant name followed by sheet number throughout the rest of the thesis (e.g., Pontevedra 3551 II).

The Panay Gulf and offshore Guimaras Island's sheets included: Miagao 3451 I, Iloilo 3552 III, Nueva Valencia 3551 IV, Dumangas 3552 II, Pulupandan 3551 I, Pontevedra 3551 II, Isabela 3550 I, and Ilog 3550 III (Figure 20). A 9th sheet labeled Cabalagnan 3551 III, covering the southwestern quadrant of Guimaras Island was unavailable for examination through BMG website with an error code '400: Unable to complete operation', yet, could still be examined through NAMRIA's topographic maps.

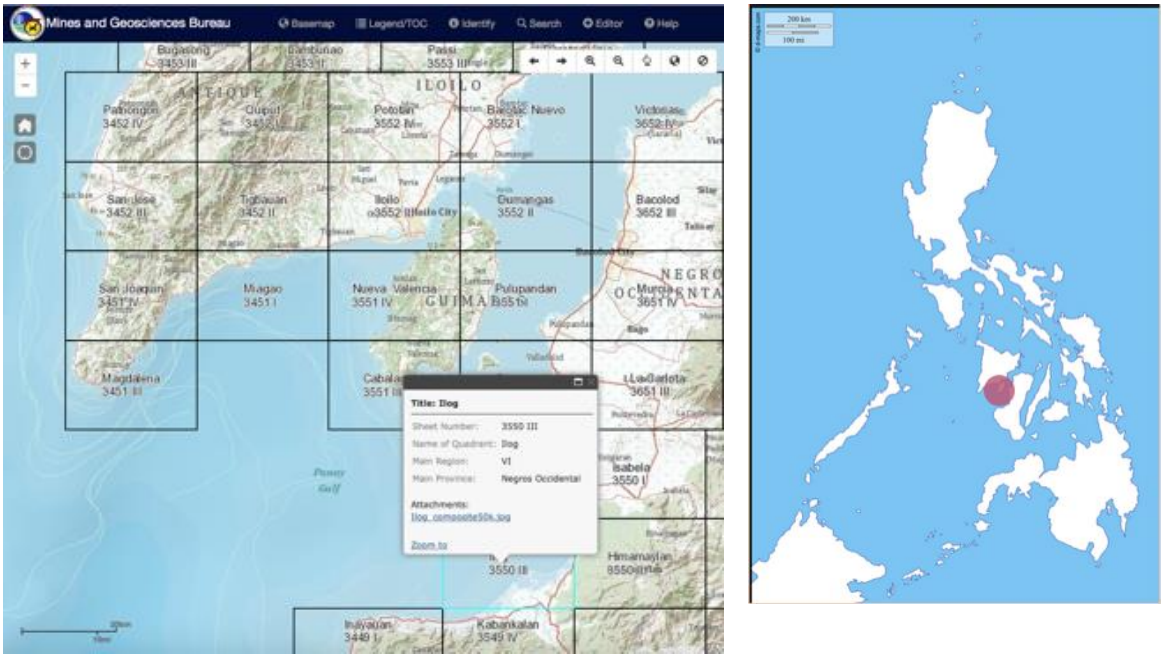


Figure 19 NAMRIA developed 711 series Topographic Maps at a scale of 1:50,000 downloadable content available from the Bureau of Mines and Geosciences website gdis.mgb.gov.ph. Image depicts the information associated with Sheet Number 3550 III in the Panay Gulf at the southwestern coast of Negros.

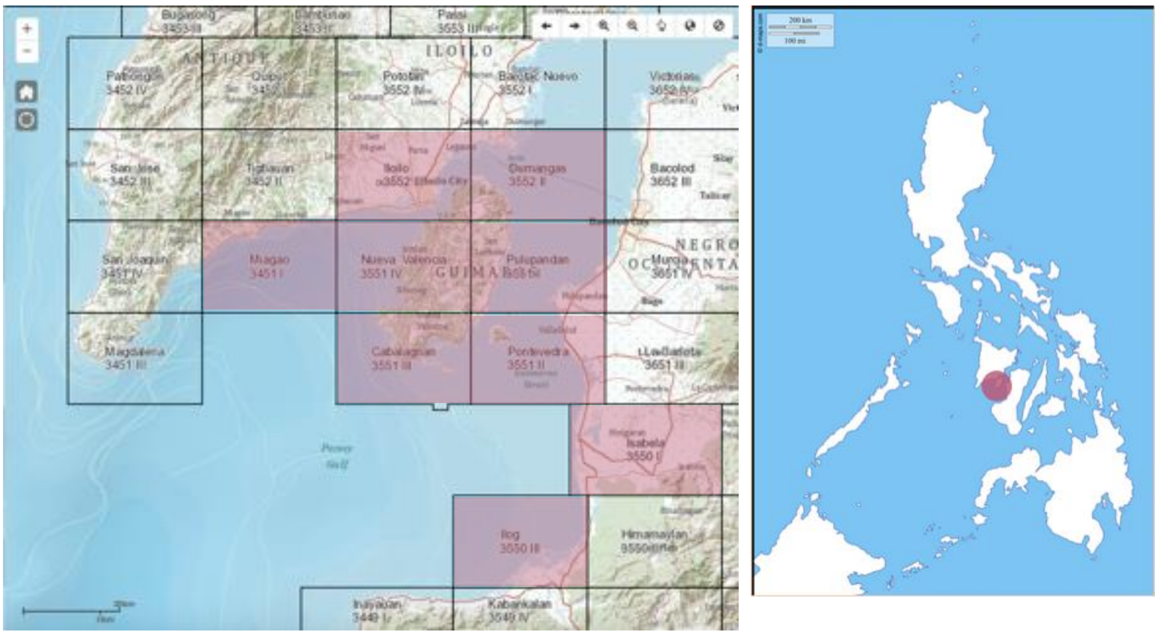


Figure 20 The Panay Gulf and Guimaras Island sheet sequence reading from a left to right and top to bottom configuration to include: Miagao 3451 I, Iloilo 3552 III, Nueva Valencia 3551 IV, Cabalagnan 3551 III, Dumangas 3552 II, Pulupandan 3551 I, Pontevedra 3551 II, Isabela 3550 I, and Ilog 3550 III.

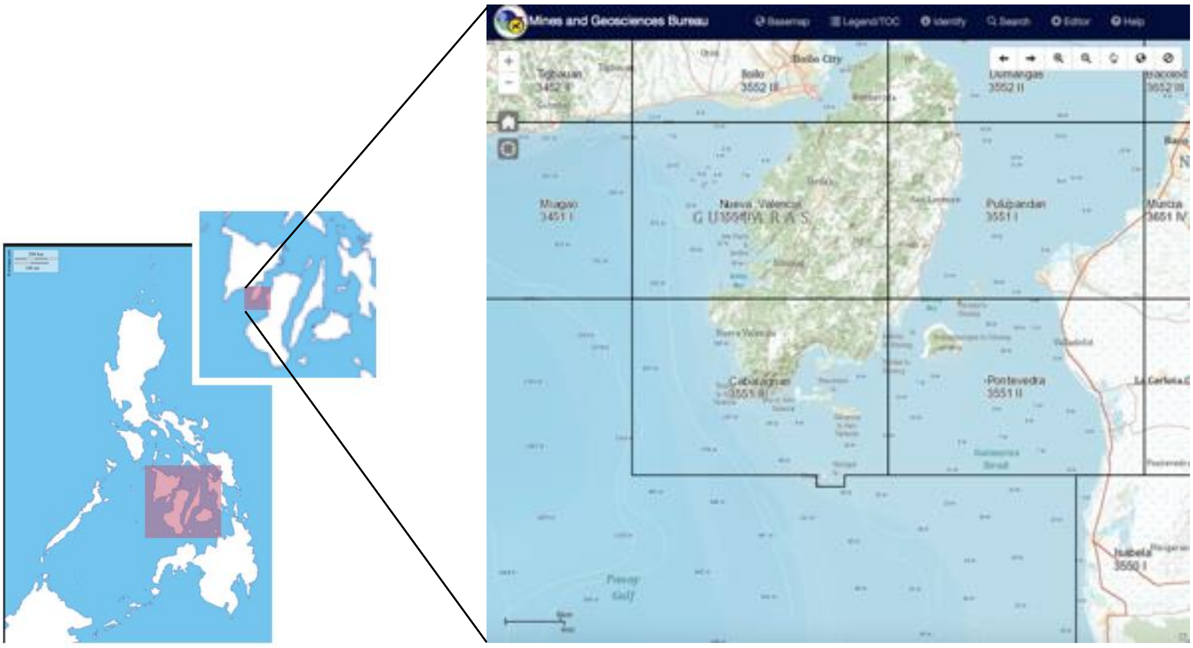


Figure 21 Bathymetric display at a 1:150 000 scale of the 711 series of Nueva Valencia 3551 IV, Cabalagnan 3551 III, Pulupandan 3551 I, Pontevedra 3551 II of Guimaras Island.

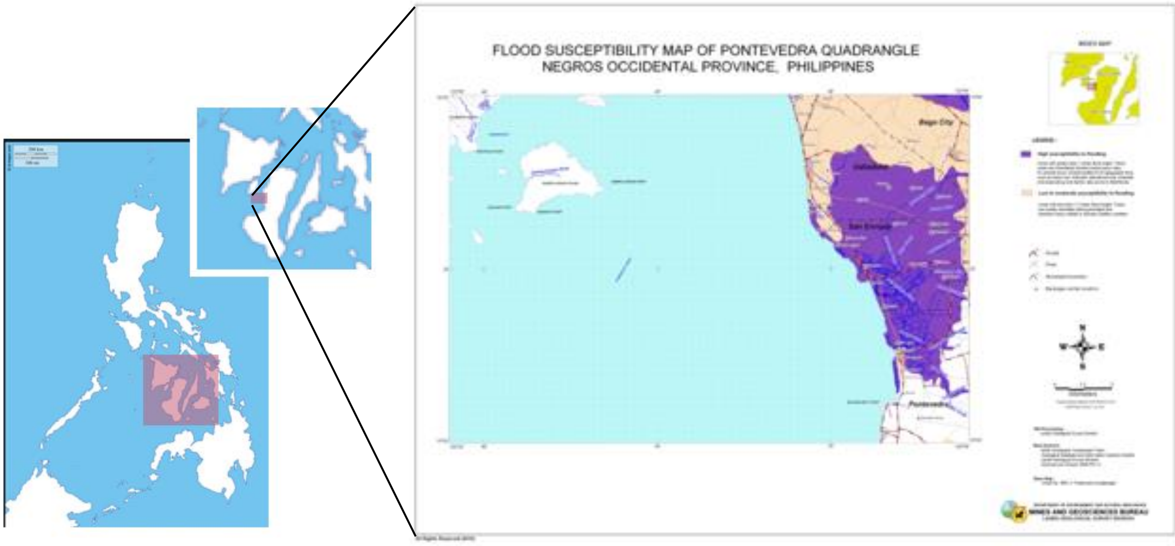


Figure 22 Attachment map on the Bureau of Mines and Geosciences sheet map of Flood Susceptibility of Pontevedra Quadrangle Negros Occidental Province, Philippines Sheet 3551 II.

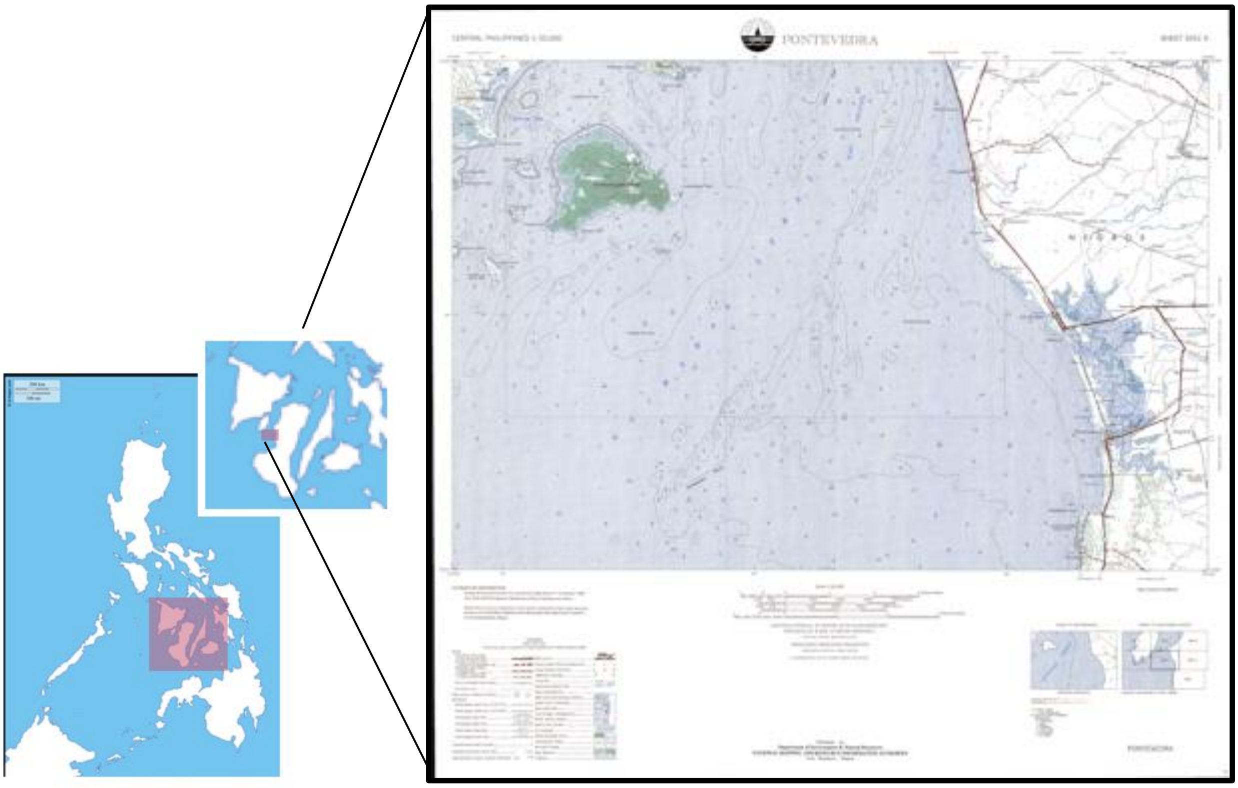


Figure 23 NAMRIA topographic map of Pontevedra Sheet 3551 II in the Panay Gulf.

The Guimaras Strait was chosen for examination not only due to its shallow bathymetric content, but its liminal proximity between the Visayan Sea and Panay Gulf. The strait was inspected through a series of available sheets to include: Barotac Nuevo 3552 I, Bacolod 3652 III, Victorias 3652 IV, Barotac Viejo 3553 II, and Fabrica 3652 I (Figure 24). Taguanhan Island 3653 III listed a 'no attachments found' in the quadrant identification window on the BMG website, while NTMS contained data for this quadrant.

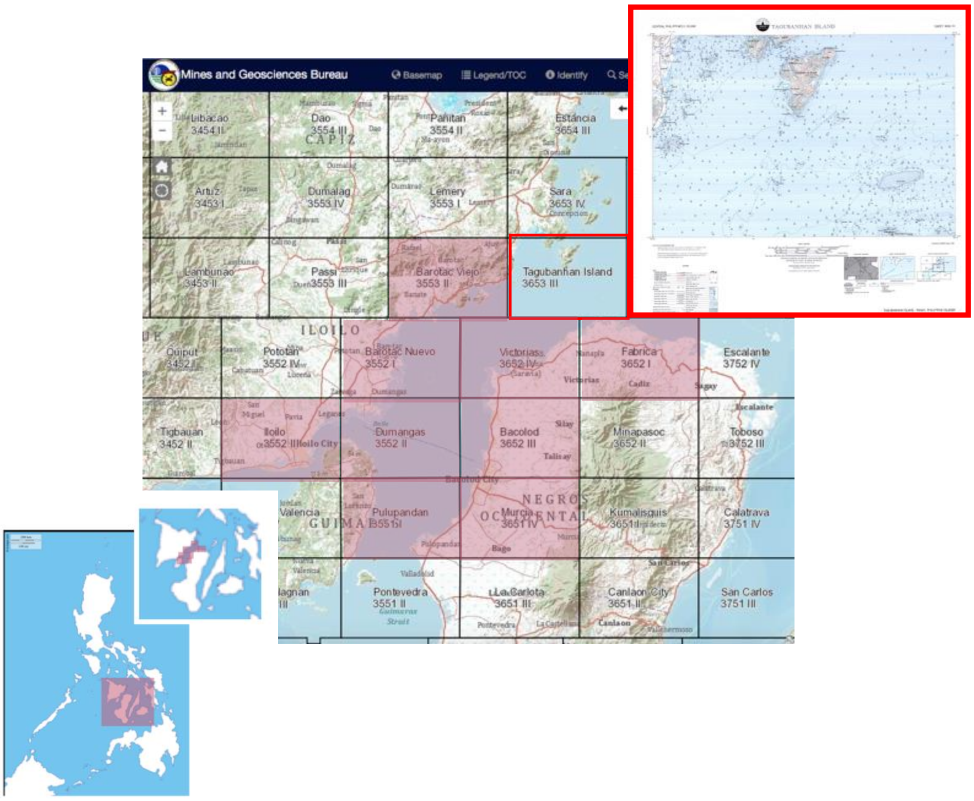


Figure 24 Guimaras Strait quadrant sheets through the Bureau of Mines and Geosciences. Taguanhan Island 3653 III was not listed through the BMG website, but was made available through the NAMRIA website sheet index shown in the top left hand corner of the image.

The northeastern most area of Panay's coast had three sheets: Carles 3654 IV, Estancia 3654 III, and Gigantes Islands 3654 I (Figure 25) of which were inspected due to their semi-remote and central location in the Visayan Sea.

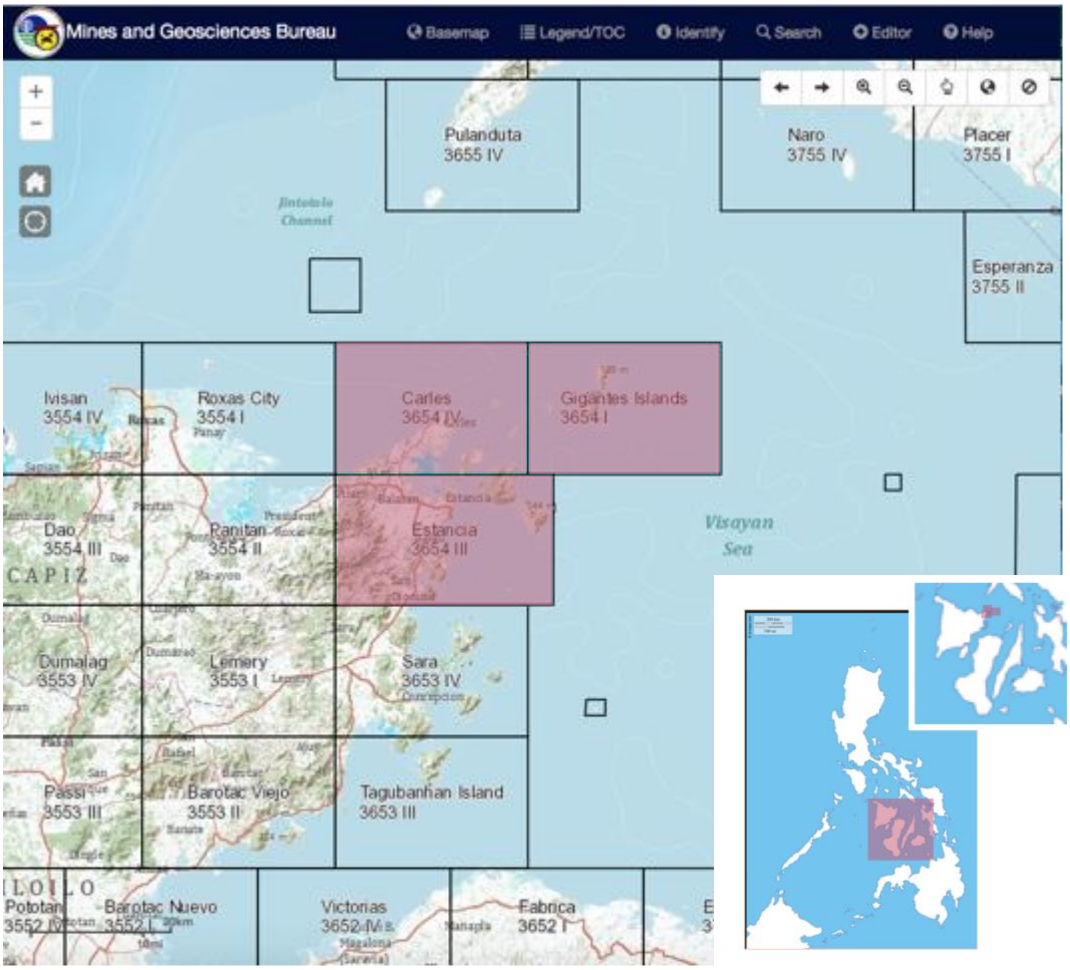


Figure 25 The Northeast Panay Coast Bureau of Mines and Geosciences quadrant maps which include: Carles 3654 IV, Estancia 3654 III, and Gigantes Islands 3654 I.

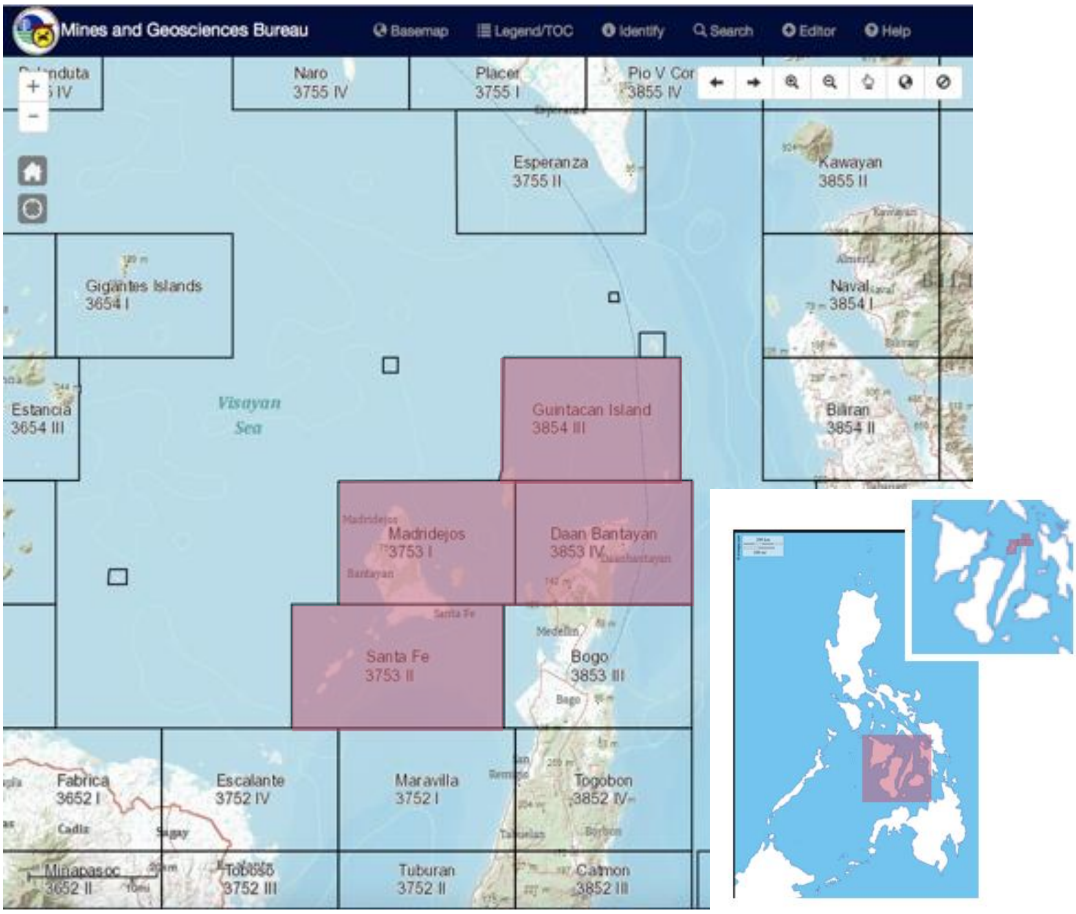


Figure 26 Bureau of Mines and Geosciences quadrant maps for Bantayan Island and the Northern Cebu Basin.

The Northern Cebu Basin and Bantayan Island, Cebu, included sheets: Madridejos 3753 I, Sante Fe 3753 II, Guintacan Island 3854 III (only available through NAMRIA), and Daan Bantayan 3853 IV (Figure 26), and were inspected due to their location at the eastern parameter of the Greater Visayan Sea Shelf.

3.2 Environmental Reconnaissance: Terrestrial and Marine

3.2.1 Terrestrial Environment

Inspection of the natural environment commenced from 05 April 2017 to 26 July 2017. The inland terrestrial environment in rural areas nearby Catmon, Pajo, and Tabiag, Cebu. The terrestrial environment was indicative of mountain ranges and lush tropical rainforest (Figure 27) with average temperatures of 30° C. Coastal regions were densely populated, while mountain communities contained a lesser populous. Interisland visibility was apparent from the shorelines during clear days (Figure 28). Inspection of adjacent island visibility from the coastline of Catmon, Cebu, to the island of Camotes was visually determined, photographed, and marked with a GPS using Garmin Etrex high sensitivity hand-held device (all subsequent GPS points mentioned in the method section of this thesis were also used with the same device).

Figure 27 Left) image of mountain horizon near Pajo, Cebu, Philippines. Right) photo of a rural property owned by Fortunata Commendador Almacen displaying tropical forest conditions near Pajo, Cebu.

Figure 28 Interisland visibility from the Catmon, Cebu, Philippines shoreline. Adjacent island with indicating black arrow is the island of Camotes in the Camotes Sea, 32 km from Catmon, Cebu.

River systems begin in the inland mountain regions, typically fed through a series of freshwater tributaries, tending to flow heavier or lighter depending on available rainwater recharge (Figure 29). A physical inspection of a known freshwater spring once used by local inhabitants for drinking water fed into the Nagnalin River in the northern region of Cebu island. The spring and river section were located on private land owned by Fortunata Commendador Almacen in Tabiag, a small mountainous Barangay in the province of Catmon, Cebu, Philippines. With the permission of the landowner, the river and spring were photographed and GPS points were taken to develop an understanding of common terrestrial water source in context to rural habitation patterns.

Figure 29 Top) Nagnalin River; bottom left and right) freshwater spring that confluences into the Nagnalin River.

3.2.2 Marine Environment

GPS positions and above water pictures were taken at four known dive locations in the surrounding Malapascua Island, Northern Cebu: Chocolate Island, Gato Island, and Monad Shoals. All dives were non-disturbance visual context only and were conducted using standard SCUBA equipment under the Flinders Diving Guidelines.

Dive site maps were obtained through Thresher Shark Divers dive shop located on Malapascua Island, Philippines. A map of Gato Island's surrounding bathymetry was measured using U-shape survey technique and kick-cycles measuring to 1.2 m. Bathymetric readings were taken from Suunto Zoop Yellow dive computer, and directional headings were determined using Suunto SK-8 wrist underwater compass. Any underwater cave formations encountered were not entered, but rather noted for depth and cave entrance direction.

3.2.3 Familiarization of Prehistoric Terrestrial Sites and Cave Formations

Surveys of karstic limestone formations in southern Mindoro and two small nearby islands, Ambulong and Ilin, in 2010 identified 19 cave and rockshelter sites with indicators of past human activity consisting of ceramics, stone artifacts, shell middens and faunal assemblages (Porr, et al. 2012). A visitation to a cave and two rockshelter sites with evidence of prehistoric human activity was initiated between 21 – 23 May 2017, at Ilin Island, Mindoro, at Bubog I & II, and Bilat Cave, Mindoro (Figure 30).

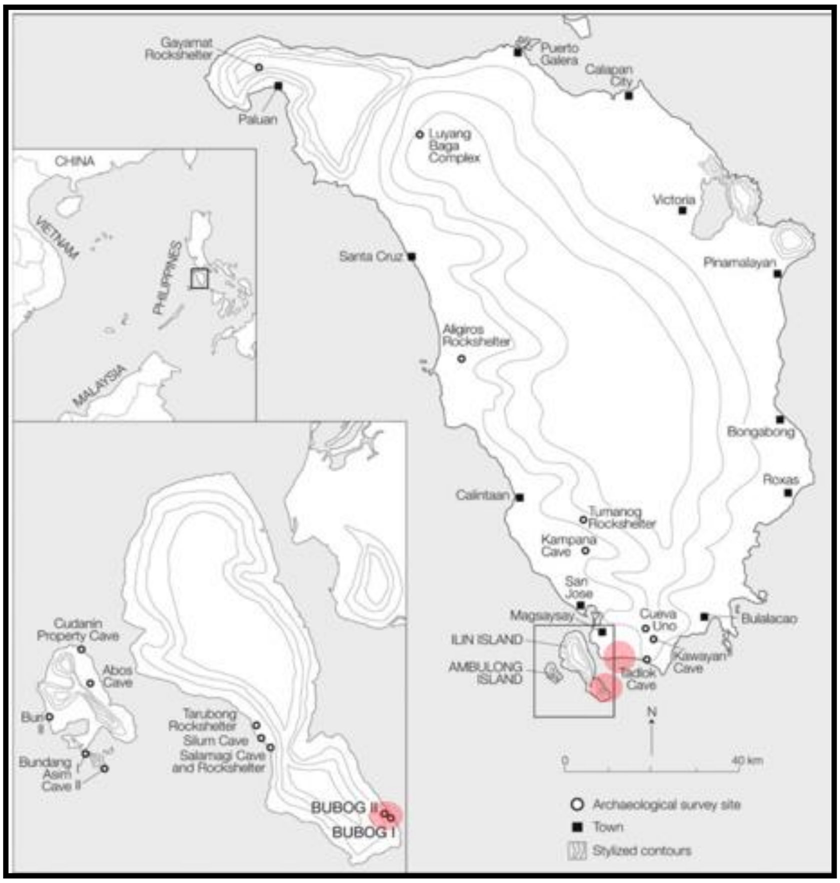


Figure 30 Location of Mindoro, Ilin, and Ambulong Island showing cave a rockshelter sites found during the 2010 survey. The map shows the location of Bubog I & II, Ilin Island, and Bilat Cave, Mindoro, as highlighted in red that were inspected during the regional familiarization process. Modified from 'Adaptation and foraging from the Terminal Pleistocene to the Early Holocene: excavation at Bubog on Ilin, Island, Philippines' (Pawlik et al. 2014:231).

The first site inspected was Bubog I Rockshelter. It is located at 12°10.267'N and 121°7.867'E, with a north-eastward rock face and is roughly 40 – 50 m long with an excess overhang of 4 m wide, at an elevation of 31 meters above sea level (masl) (Figure 31) (A. F. Pawlik, et al. 2014).

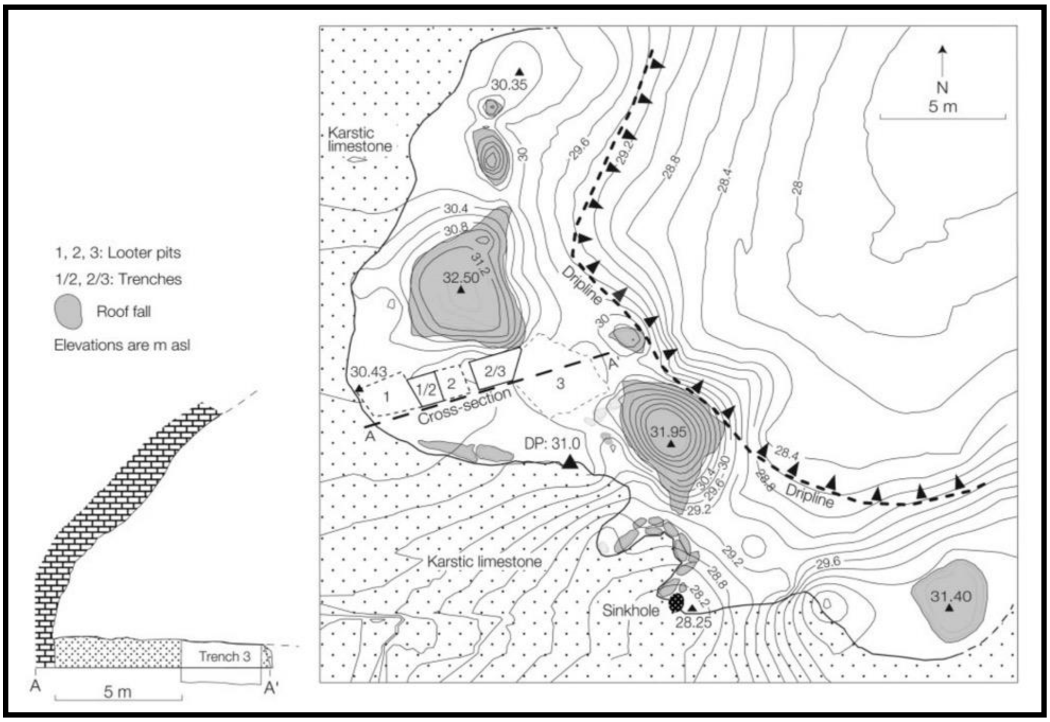


Figure 31 Bubog I site plan with profile of east wall above excavation trenches on the left. From 'Adaptation and foraging from the Terminal Pleistocene to the Early Holocene: excavation at Bubog on Ilin, Island, Philippines' (Pawlik et al. 2014:233).

A small sinkhole in the rock face provided an immediate decrease in temperature at its entrance from air ventilation. Modern local inhabitants of the island comprised of a small migrated group of about 50 individuals, used the stalactites inside the sinkhole's entrance to collect water condensation for drinking, as there was no other source of freshwater available on Ilin Island. The superficial strata of the rockshelter contained an abundance of gastropods of the species *gastropod Lambis, Trochus, Turbo,* and the bivalve *Tridacna,* with evidence of human generated breakage patterns (A. F. Pawlik, et al. 2014). It was here where an Early – Middle Holocene *Tridacna* shell adze (SANU-35132) was recovered at 80 cm in Bubog I's stratigraphic sequence (Pawlik, et al. 2015).

Figure 32 Left) Bubog I Rockshelter trenches; right) Bubog II Rockshelter with large boulder to the right from ceiling debris.

Subsequent visitation from Bubog I was to the nearby Bubog II Rockshelter site (Figure 33). It is located at 12°10.417'N and 121°7.700'E, and about 400 m inland from Bubog I, at an elevation of 45 masl, surrounded by high ceilings and walls to the north, south, and west (A. F. Pawlik, et al. 2014). This site had a shell midden deposit in Layer 6 and a subsequent limestone fragments in Layer 7 indicative of substantial ceiling debris. Layer 9 produced a fragment of *Canarium hirsutum* (WK 32983) δ13C dated to roughly 11,000 BP (A. F. Pawlik, et al. 2014).

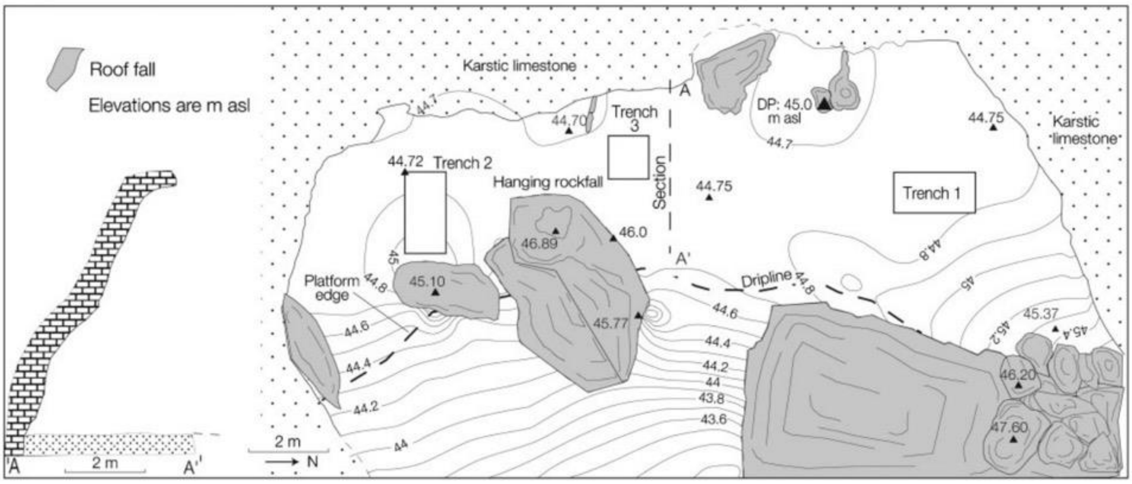


Figure 33 Bubog II site plan from 'Adaptation and foraging from the Terminal Pleistocene to the Early Holocene: excavation at Bubog on Ilin, Island, Philippines' (Pawlik et al. 2014:233).

At both sites, in areas where test pits were excavated, archaeological deposits were found in near vicinity to the rock face. As a likely consequence of seismic activity, both sites had evidence of ceiling collapse in the form of large boulders. Bubog I had apparent human activity from discarded marine shell remnants on the superficial strata, while Bubog II had less obvious activity and little to no visible shell remains.

The last terrestrial site available for inspection was Bilat Cave at the southern coast of main island Mindoro (Figure 34). It is situated at 12°14.428'N and 121°7.642'E, at an elevation of 0 masl, and has a dual chamber karstic system with multiple entrance and exist point. The cave had a long north-easterly opening and was divided by a midsection wall producing a western and southern chamber. At the rear of the cave were smaller karstic windows facing the shoreline through which airflow circulated into the limestone cavity towards the front entrance (Figure 35). The west chamber contained two large lily-pad speleothems whose morphology could have resulted due to flooding of the cave during a sea-level highstand (Figure 35).

The cave's contents included multiple anthropogenic signatures from a contemporary period in the form of graffiti, discarded bottles, and a wooden canoe in the back of the southern chamber.

Figure 34 Bilat Cave, Mindoro, west chamber entrance perspective.

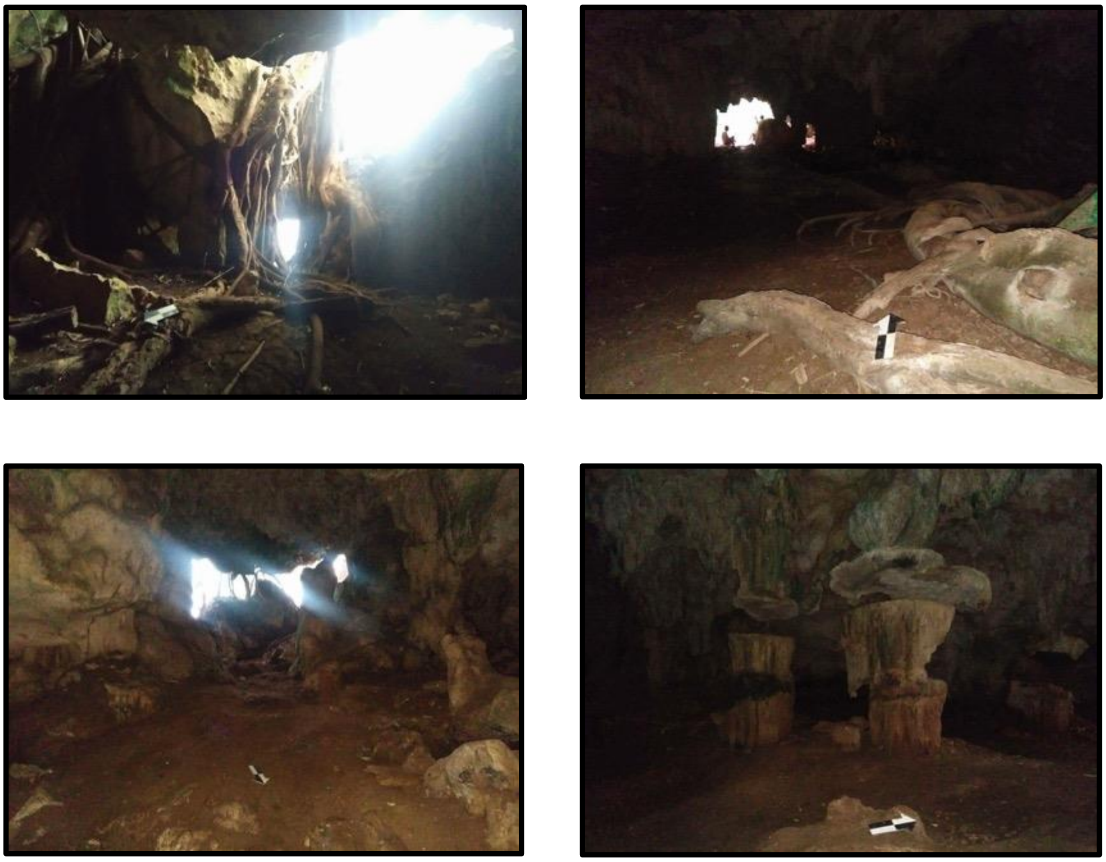


Figure 35 Top left) South chamber rear cave opening. Top Right) south chamber front cave entrance point. Bottom left) western chamber rear opening. Bottom right) speleothems in the west chamber.

While investigations at this site are still underway, characteristics of the cave have continued to attract human attention due to the relatively ample available light during daytime periods, location to nearby coastal resources, significant decrease of inside temperature, and protection from inclement weather.

3.3 Developing a Sea-Level History and Reconstruction Models

Sea-level history and reconstruction models for this thesis were obtained through an examination of various available map sheet datasets. Sea-level history was derived through a juxtaposition of Kealy et al.'s (2017) Wallacean sea-level curve adjusted for 0.5 m/ka uplift, living coral proxy sea-level estimates from Siringan et al.'s (2016) in north-western Luzon, Philippines, and Chappell and Polach's (1991) at the Huon Peninsula, New Guinea. Estimated dates were compared and determined to be associated well enough to rely on Kealy et al.'s (2017) sea-level curve as an adequate sea-level history model.

Sea-level reconstruction models were generated using Navionics 2010 Asia&Africa bathymetric and sonar data, at a 1ft contour of the Philippine Archipelago's surrounding seascapes. By adjusting Navionics's Water Level Advanced Map Options, at a range between – 05 m to – 50 m at 5 m intervals, coarse resolution sea-level models of submerged shoreline topography in the targeted areas were produced.

Quadrant sheets provided through BMG and NAMRIA were cross-referenced to Navionics's nautical charts to determine the reliability of Navionics computer software program. NAMRIA's topographic maps indicated its bathymetric data was measured in fathoms instead of the standard metric system. To ensure consistent bathymetric data using both NAMRIA and Navionics, an application of the formula $1.8288 \times 1_{ftm} = 1_{m}$ to convert NAMRIA's bathymetric data from fathoms to meters was calculated. A side-by-side comparison of NAMRIA's sheet map Pontevedra 3551-II and Navionics's nautical chart at a similar scale of the same quadrant, determined Navionics's cartographic information, listed in meters, were in accordance with NAMRIA's bathymetric datasets (Figure 36 and Figure 37). Furthermore, Navionics's unit of measurement option allows for the choice between meters, feet, and fathoms. Fathoms measurements used in Navionics were identical to NAMRIA's topographic bathymetry and deemed appropriate for use in the coarse resolution reconstruction models of this thesis.

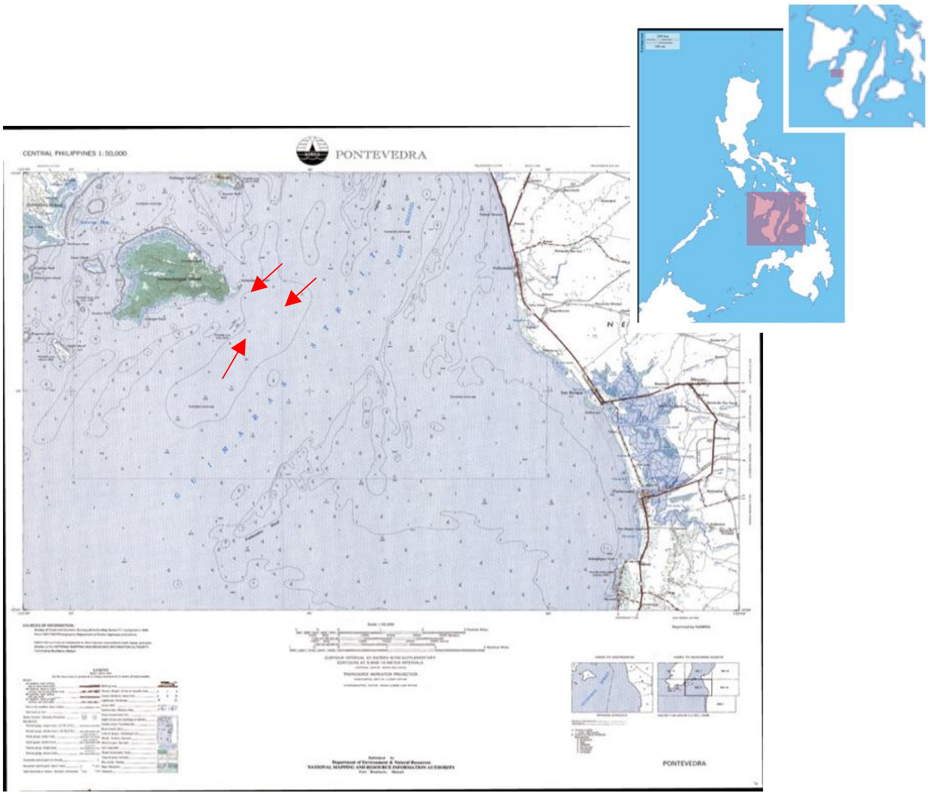


Figure 36 NAMRIA's nautical chart Pontevedra 3551-II. The legend indicates depth curves and soundings are listed in fathoms. At a closer magnitude, off the eastern coast of Inampulungan Island, bathymetric readings display 13, 16, and 16 fathoms.

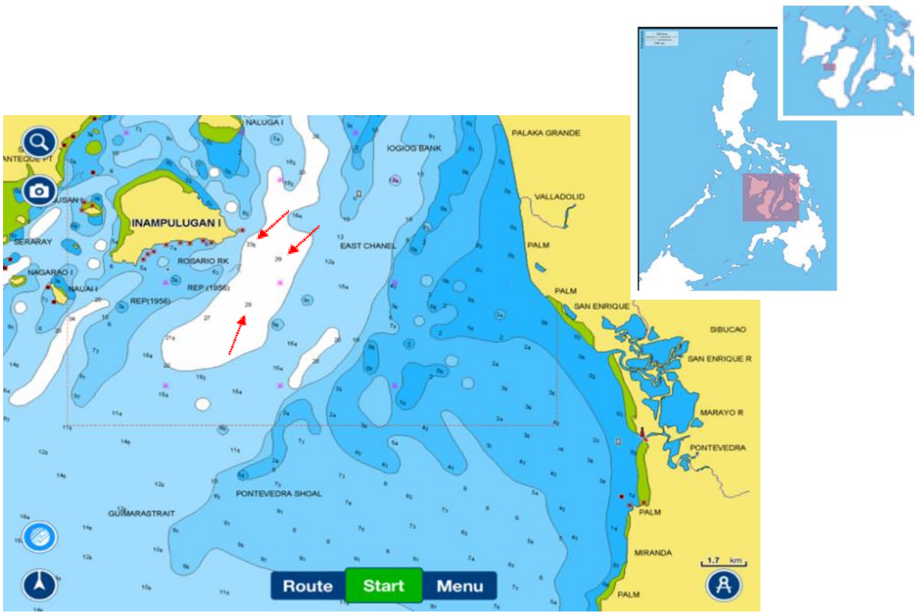


Figure 37 In Navionics 2010 Asia&Africa of the same region as Pontevedra 3551-II, bathymetric values at the same location as the NAMRIA's topographic map in figure 21 are listed as 23.5, 29, and 29 m.

4 RESULTS

4.1 Determining a Sea-Level Curve

Evidence from various sea-level proxies suggests regional variation in the Philippine's palaeosea-level history is related to a complex confluence of hydro-eustatic subsidence, tectonic uplift, and seismic activity (Berdin, et al. 2004; Maeda, et al. 2004; Omura, et al. 2004; Siringan, et al. 2016). Uranium series analyses of above current sea level coral terraces located on the coast of Palawan, Mactan, Panglao, and Bohol islands in the Central Visayas, Philippines, indicate relative tectonic stability since MIS 5e and the Middle Holocene (Berdin, et al. 2004; Omura, et al. 2004). The vertical stability of these regions can be attributed to their remote proximity to major tectonic structures which plague the north-western and eastern Philippine coasts (Omura, et al. 2004). This contrast is due to significant seismic activity in north-west Luzon and the most eastern Philippine islands contending with the thrust component of the Philippine Fault to the north and strike-slip motion in the eastern Samar area (Figure 3) (Maeda, et al. 2004:25). Therefore, sea-level records from one locality may not provide a sufficient palaeosea-level representation for the entire region of the Philippine islands (Siringan, et al. 2016).

According to Siringan et al. (2016), diminutive island settings in the Pacific Ocean exhibit greater hydro-eustatic subsidence and a gradual rising sea level, contrast to their larger continental island or island arc counterparts. This discrepancy is due to different responses in oceanic lithosphere and continental lithosphere meltwater loading, either through hydro-isostasy or 'equatorial ocean siphoning' caused when oceanic waters flow to the subsidence forebulge near deglaciation centers (Siringan et al. 2016:61-65). The Philippine's larger island settings in its island arc system—such as Luzon—exhibits less hydro-eustatic adjustment and a higher relative sea level around 6 – 4 kyr, followed by a gradual regression (Siringan et al. 2016:65).

Table 1 Sea-level comparison among Chappell and Polach 1991 from the Huon Peninsula, Kealy et al.'s 2017 sea-level curve adjusted for tectonic uplift for Wallacea, and Siringan et al. 2016 sea-level data from northwestern Luzon, Philippines.

Comparative Below Sea-Level Values from Luzon and Wallacea			
Below Sea Level	Chappell and Polach 1991	Kealy et al. 2017	Siringan et al. 2016
0 m			
5 m	7980 +/- 70 BP	8 ka BP	7122 +/- 23 BP
10 m	8,130 +/- 80 BP	8.8 ka BP	8490 +/- 29 BP
15 m	8,930 +/- 70 BP	9 ka BP	9082 +/- 59 BP
20 m	9,010 +/- 70 BP	9.8 ka BP	9756 +/- 36 BP
25 m	9,690 +/- 70 BP	10 ka BP	10256 +/- 50 BP
30 m	9,860 +/- 70 BP	10.5 ka BP	
35 m	9,640 +/- 80 BP	10.9 ka BP	
40 m	10,350 +/- 90 BP	11.7 ka BP	
45 m	10,840 +/- 80 BP	12.1 ka BP	
50 m	11,110 +/- 90 BP	12.9 ka BP	

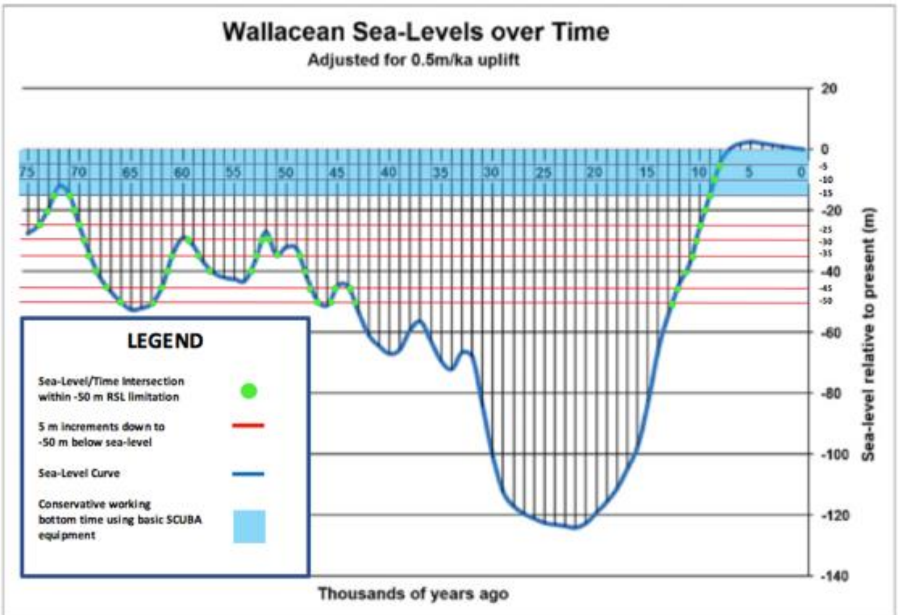


Figure 38 Modified Wallacean Sea-Levels over Time Adjusted for 0.5m/ka Uplift, highlighting time intersections limited to -50 m below sea-level as well as conservative working depth using basic SCUBA equipment. From 'Reconstructing palaeogreography and inter-island visibility in the Wallacean Archipelago during the likely period of Sahul colonization, 65-45000 years ago' (Kealy et al. 2017:5).

Eustatic sea-level change extended the Philippine's palaeolandsurfaces as much as 200,000 km^2 during the LGM (Robles 2012). Albeit, exposed terrestrial land at the peak of the LGM would have existed for a relatively ephemeral period in context to geological time scales, there were much longer periods at or below 30 and 40 m below present sea level (Voris 2000). By evaluating Kealy et al.'s (2017) sea-level curve, limited to a – 50 m depth range, it is apparent there are multiple time periods of lowered sea-level when palaeolandsurfaces would have been available for human habitation (Table 2 and Figure 38).

While depths at 5 – 10 m below RSL are confined to estimated dates of 8 – 8.8 ka BP, at 15 – 20 m in depth, multi-temporal sequences can be observed separated by a 60,000-year gap. By – 35 m meters, seven different dates are associated with lowered sea level range from 10.9 – 69 ka BP. For purposes of clarity, the dates listed on the table below will be used in conjunction with the sea-level reconstruction models.

Table 2 Estimated dates derived from Kealy et al.'s (2017) sea-level curve displaying temporal clusters through related color sequences against their relative sea-level at a - 50 m limitation.

Estimated Dates from Kealy et al. 2017 Sea-Level Curve (ka BP)							
Below Sea Level	First Date	Second Date	Third Date	Forth Date	Fifth Date	Sixth Date	Seventh Date
0 m							
5 m	8						
10 m	8.8						
15 m	9	71	72.8				
20 m	9.8	70.1	73				
25 m	10	70	74				
30 m	10.5	52	60	69.5			
35 m	10.9	48.8	51	53.9	58.2	61	69
40 m	11.7	48	54.7	57	62.8	68	
45 m	12.1	44	45	47.5	62	67	
50 m	12.9	43	46	47	63	67	

4.2 Visayan Sea

Predictive approaches for potential submerged archaeological studies in the Philippines should be considered in tandem with the identification of area-associated low-energy wave activity conducive for site preservation, and locations sheltered from the onslaught of high-energy weather phenomena (Bailey and Flemming 2008; Benjamin 2010; Erlandson 2001; Nutley 2014; Ward, et al. 2015). The Philippine island arc system is situated amid an east-west typhoon corridor, and on average, experiences 21 tropical cyclones annually, with a higher occurrence probability in the northern region (Brill, et al. 2016). Although the Visayan Sea (Figure 39) is not immune to the effects of tropical cyclones, it receives greater protection due to its shallow bathymetry and shelter from the surrounding landmasses of Samar, Leyte, and Cebu (Brill, et al. 2016; Lee and Kim 2015). Its tidal variation is in the range of 0.8 – 1.8 m, and wave action during the summer monsoon are generally moderate (Brill, et al. 2016).

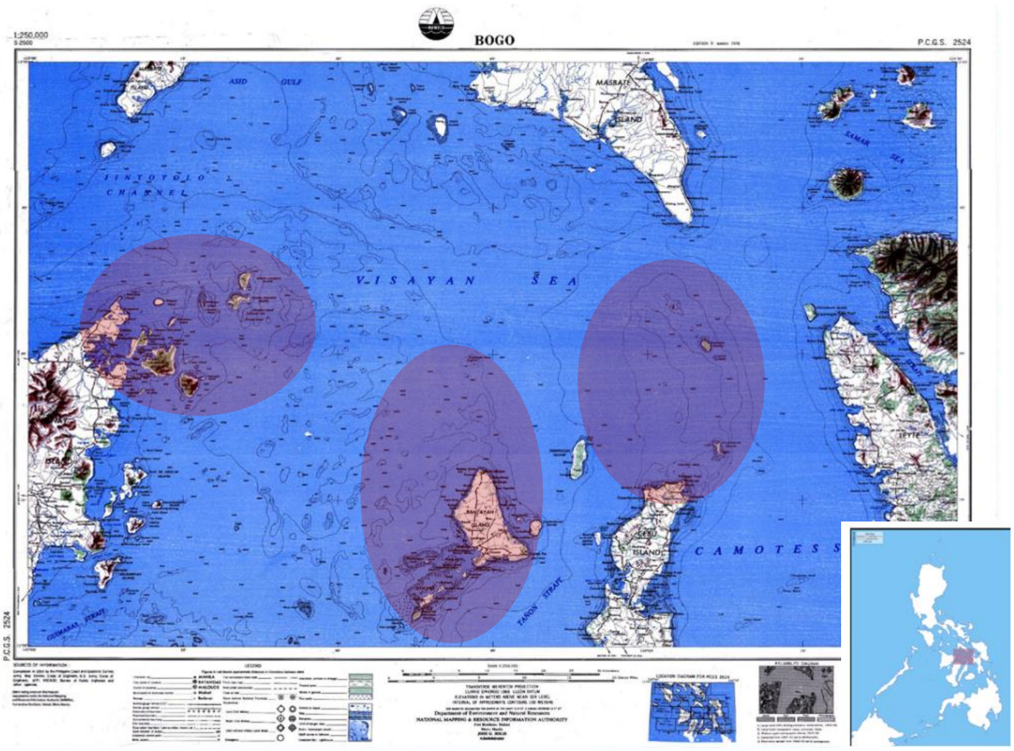


Figure 39 Modified NAMRIA Topographic Map at 1:250 000 scale of the Visayan Sea. Sheet title Bogo 2524. Targeted areas of offshore interest highlighted in red: top left) Northeastern Panay; middle) Bantayan Island; right) Northern Cebu Basin.

The Visayan Sea Shelf in the Central Philippines is the most productive municipal fishing ground in the country (Ferrer 2011), having a relatively shallow basin with most areas <50 m deep, and a maximum depth of 150 m (Brill, et al. 2016; Ferrer 2011; Noblezada and Campos 2012). It is located between 11° and 12° North latitude and 123° and 124° East longitude in the Central Visayas and covers a total of 5184 km^2 (Ferrer 2011; Noblezada and Campos 2012). The Visayan Sea Shelf's shallow bathymetric data indicates the islands of Cebu, Masbate, Negros, and Panay would have connected during periods of lowered sea-level throughout the Late Pleistocene and Early Holocene (Figure 40 and Figure 41). As demonstrated in Robles's (2013) reconstruction model of Philippine coastlines, the Visayan Sea Shelf's terrestrial connectivity would have been uncompromised by inundation at a depth of – 40 m below RSL. When plotted against Kealy et al.'s (2017) sea-level curve, the now submerged region beneath the Visayan Sea would have remained exposed for roughly 35,000 years before the flooding of the basin would begin to disconnect the Greater Central Visayas. According to Robles's (2013) reconstruction model, at – 10 m RSL, areas in the southwestern Guimaras Strait remained unsubmerged as late as 8.8 ka BP (Figure 41).

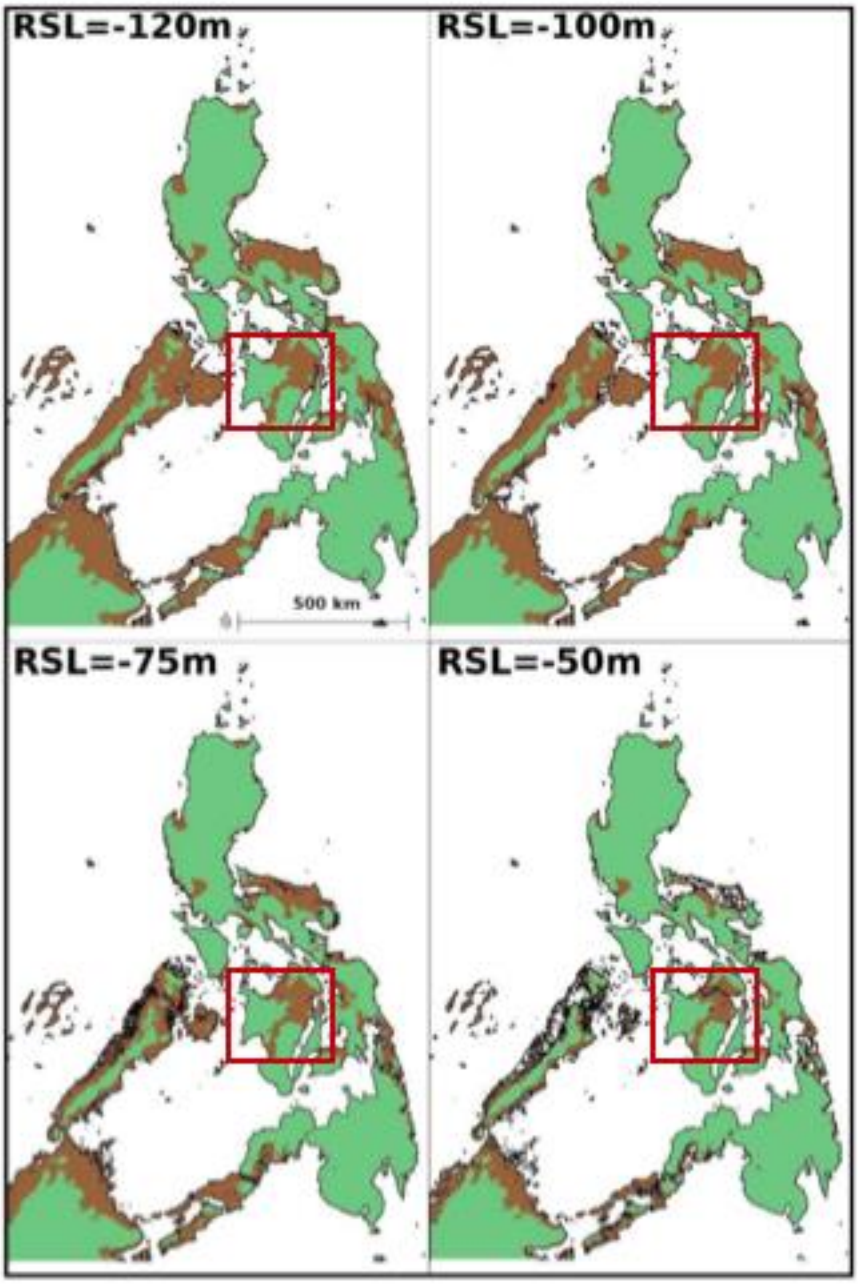


Figure 40 Modified sea-level reconstruction model of the Philippines showing relative sea level depth in meters with the Visayan Sea Shelf highlighted in red. From 'Estimates of Quaternary Philippine coastlines, land bridges, submerged river systems and migration routes: A GRASS GIS approach' (Robles 2013:43).

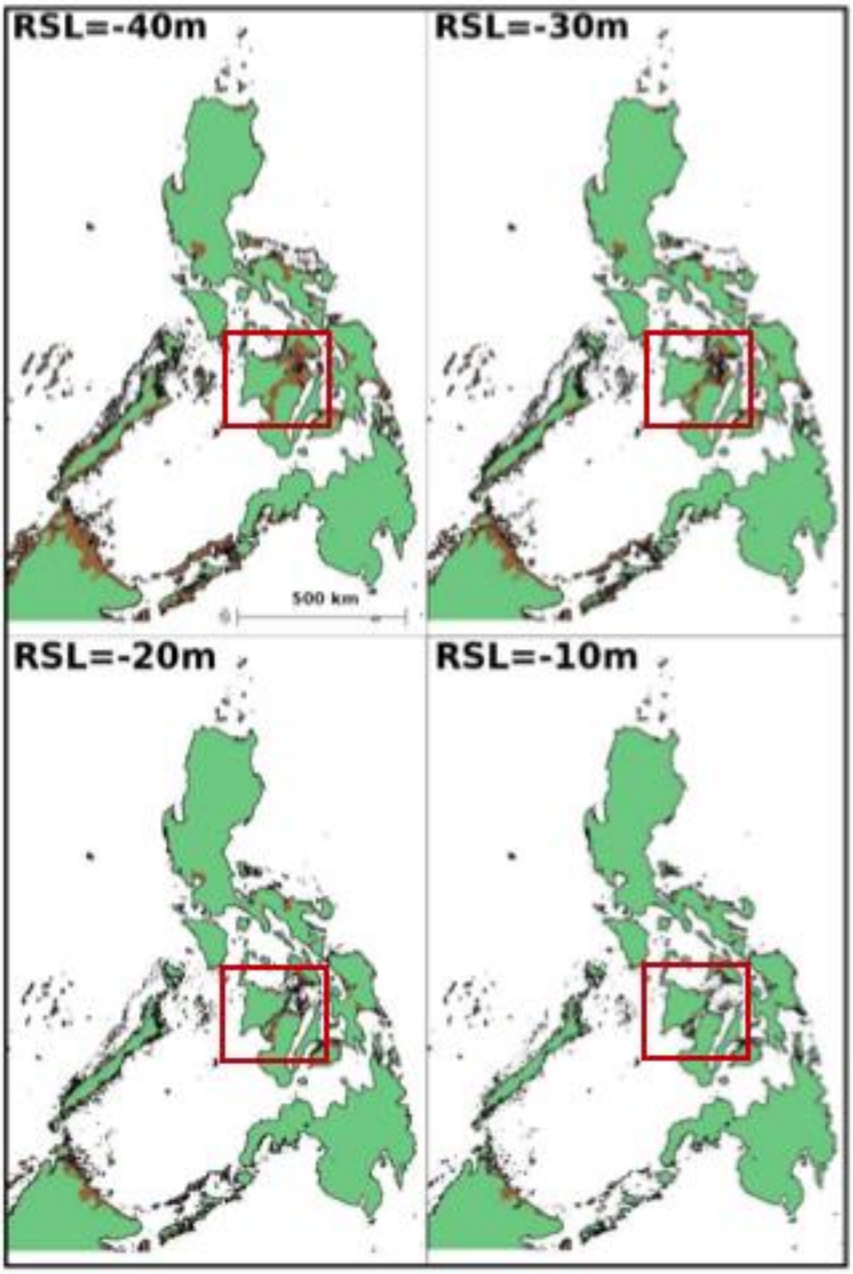


Figure 41 Modified sea-level reconstruction model of the Philippines showing relative sea level depth in meters with the Visayan Sea Shelf highlighted in red. From 'Estimates of Quaternary Philippine coastlines, land bridges, submerged river systems and migration routes: A GRASS GIS approach' (Robles 2013:44).

Today, the exchange of water in the Visayan Sea is regulated through a complex interface between hydrographic processes, bathymetry, and topographic features. The Visayan Sea is connected to the Sulu Sea to its west via the Guimaras Strait inflow (depth average of 18 m), the Pacific Ocean to the east through the San Bernardino Strait inflow (sill depth of 23 m), and the Sibuyan Sea to the northeast through the Jintotolo Channel outflow (Figure 42 and Figure 43) (Hurlburt and Metzger 2009; Mulyila, et al. 2012:950; Noblezada and Campos 2012; Ollé 2012). As high salinity water from the Pacific Ocean flushes through the San Bernardino Strait, it mixes with water of lower salinity from the inner basins, resulting in a salinity gradient decrease in the Visayan Sea (Noblezada and Campos 2012). Additionally, freshwater runoff from tributaries and rivers on the islands bordering the Visayan Sea renders its salinity lower than adjacent basins (Noblezada and Campos 2012).

There are 421 principal inland waterway river systems utilized for modern mobility in the Philippine island arc system (DENR-PAWB 2013). Twenty of the archipelago's rivers basins are larger than 1,000 km^2 and eighteen are larger than 1,400 km^2 (DENR-PAWB 2013). Of the eighteen major river basins in the Philippines three are situated in the Visayas. The Jalaur River Basin and Panay River Basin are situated in the Visayas on the eastern region of Panay, while the Ilog Hilabangan River Basin feeds into the Panay Gulf on the south-western coast of Negros (Figure 44) (A. Lagmay, et al. 2017:20; DENR-PAWB 2013). These basins would be a considerable factor in evaluating the potential for palaeoriver channels and coastal estuaries related to the Visayan Sea Shelf's availability of freshwater resources, which are considered a necessary component for human occupation during the Late Pleistocene and Early Holocene (Erlandson 2001; Pearson, et al. 2014). Robles's (2013) reconstruction model of Quaternary Period potential river systems throughout the Philippines depicts how two distinct river systems from the Greater Negros-Panay converged and drained in the northeastern part of the exposed Visayan Sea Shelf (Figure 45).

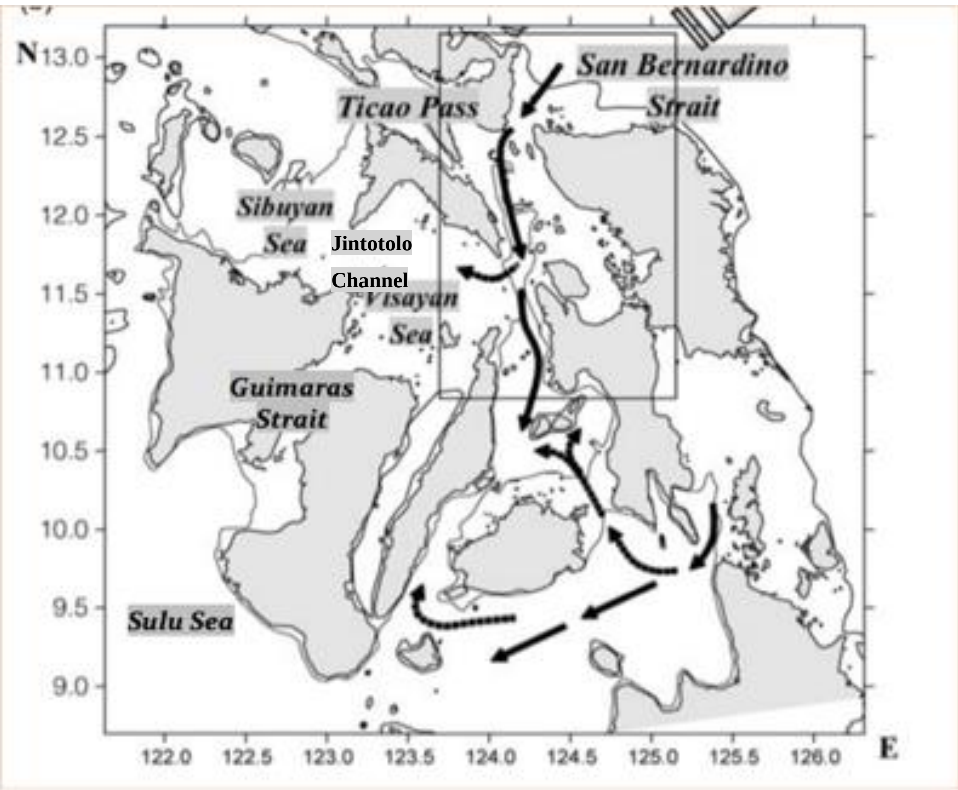


Figure 42 Modified path of water movement into the Central Philippines to include Guimaras Strait and Jintotolo Channel. From 'Chaetognath assemblages along the Pacific Coast and adjacent inland waters of the Philippines: relative importance of oceanographic and biological factors' (Noblezada and Campos 2012:412).

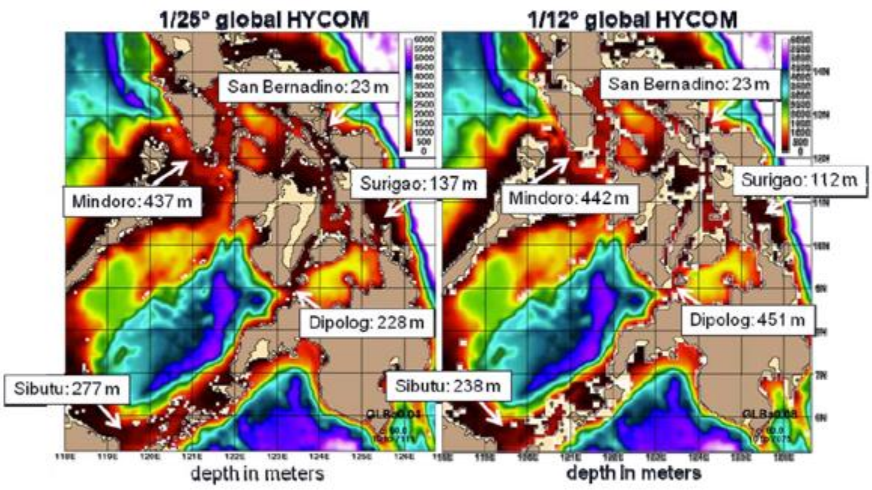


Figure 43 Bottom topography of the surrounding seas in the Philippine Archipelago. The color bar indicates bathymetry in meters in the upper right hand corner and key inflow/outflow sill depths are noted. From 'Flow through the Straits of the Philippine Archipelago Simulated by Global HYCOM and EAS NCOM' (Hurlburt and Metzger 2009:4).

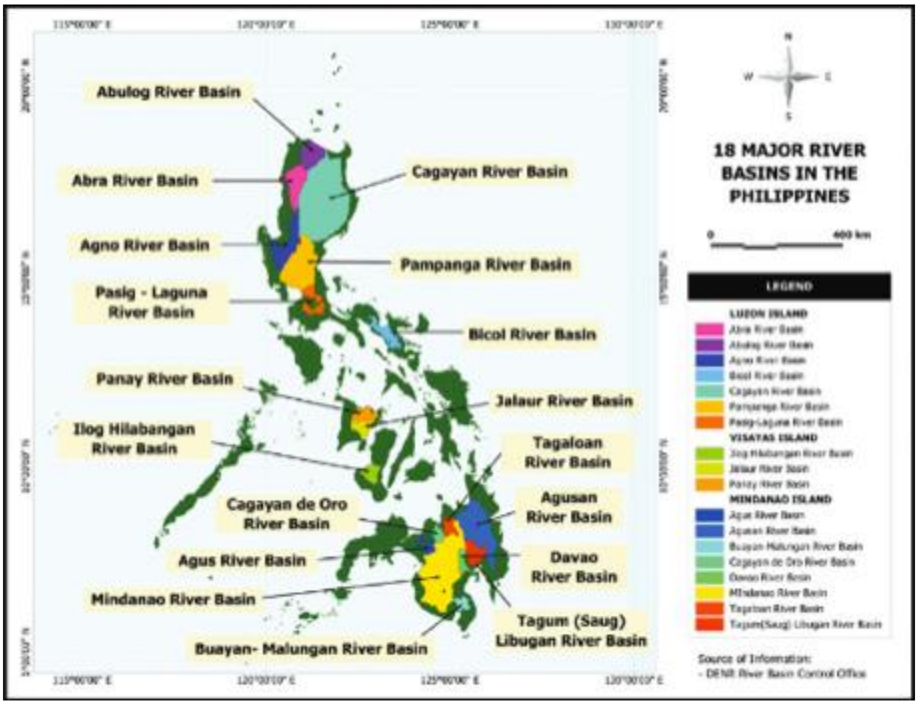


Figure 44 Major river basins in the Philippines. From 'The National Wetlands action plan for the Philippines 2011-2016' (DENR-PWAB 2013:10).

Figure 45 Reconstruction of the Philippine's river systems extending into submerged land areas during the Quaternary using r.watershed. From 'Estimates of Quaternary Philippine coaslines, land bridges, submerged river systems and mirgration routes: A GRASS GIS approach' (Robles 2013:47).

Due to these various attributes of the region, it will be the submerged Visayan Sea Shelf, Panay Gulf, Guimaras Strait, and Northern Cebu Basin (Figure 47) as the focus of predictive coarse resolution geospatial models, based on bathymetric and sonar contours using Navionics Asia&Africa 2010 navigation charts. It should be noted that while bathymetric and sonar contours can provide coarse information for those areas, it is not an exact representation of palaeoshorelines. Moreover, the relatively coarse resolution of these predictive models are in need of refinement in order to synthesize fragments of available datasets across a spectrum of disciplines to recognize emerging patterns and facilitate a transition from the theoretical to the practical (Bynoe, et al. 2016; Peeters 2011).

4.3 Northern Cebu Basin

The island of Cebu is the geographical center of the Philippines and comprised of many short rapid flowing streams, and several small alluvial lowstands in the northern coast (Carating 2014). At 11° North latitude and 123° and 124° E longitude is the Northern Cebu Basin, consisting primarily of limestone (Rillera 1995), and bathymetry of the sea water exhibits a < 50 m depth. Surrounded by a steep channel profile, the Northern Cebu Basin's eastern shelf ranges between 200 – 1000 m in depth, and a shallower channel to the west varies between 100 – 200 m. The Northern Cebu Basin is roughly 30 km from the possible palaeo-estuary of the Greater Visayas convergent river system debouching from northeastern part of the exposed Visayan Sea Shelf (Figure 39). Demonstrated in the reconstruction model at – 35 m RSL (Figure 47), age estimates predict the exposure of the landmass at about 12.9 ka BP (Table 2). The Northern Cebu Basin's eastern coastal shorelines meet into a steep off-shore profile, conducive for pelagic fish exploitation (Bailey and Flemming 2008; Erlandson 2001), and potential estuarine productivity (Correll 1978) to its west.

Contributions to the archaeological record from various parts of the world influenced the focus for this and subsequent areas. First, Pearson, et al. (2014) demonstrated how large river valleys that develop into estuaries from sea-level rise slowly fill with sediments prior to inundation, creating an environment with a higher probability of preservation even in tropical waters. Second, Fischer (1993, 1995) investigations determined how patterns in settlement sites correlated with locations at the mouths of streams, narrow inlets connecting large bodies of water, between a small island and mainland, and at the tip of headlands. Finally, the Philippine's Middle to Late Pleistocene and Early Holocene archaeological sites suggest *Homo sapiens* settlement patterns are primarily found in caves or rockshelters: Bubog I and II (A. F. Pawlik, et al. 2014; Pawlik, et al. 2015), Callao Cave (Mijares, et al. 2010), Ille Cave and Rockshelter (Lewis, et al. 2008), and Tabon Cave (Détroit, et al. 2004; Fox 1970). While there are no investigations of underwater limestone cave systems for purposes of archaeology in the Northern Cebu Basin, it is likely any with characteristics comparable to the Philippine's terrestrial cave archaeological sites, may harbor submerged assemblages of prehistoric human activity.

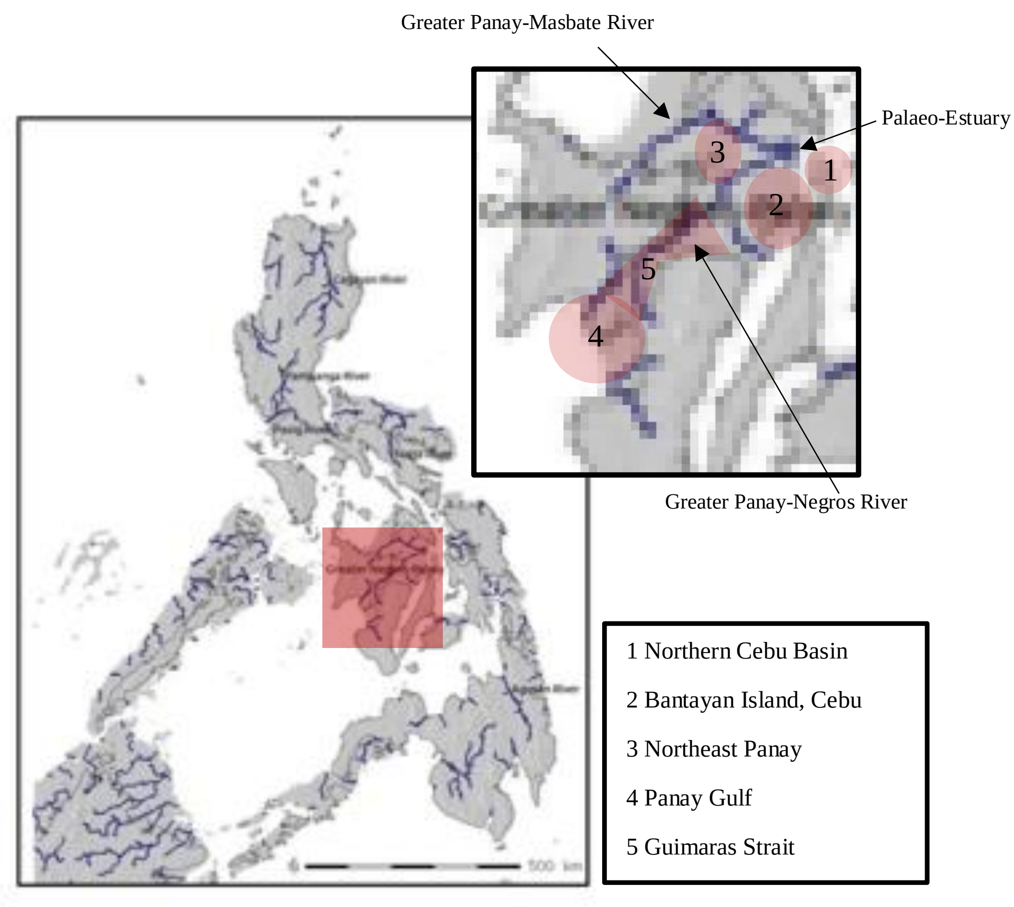


Figure 46 The top right images depicts targeted areas highlighted in red consisting of: 1) Northern Cebu; 2) Bantayan Island, Cebu; 3) Northeast Panay; 4) Panay Gulf; and 5) Guimaras Strait. The Greater Panay-Masbate River system begins in northern Panay and runs east-west through the Visayan Sea Shelf. The Greater Panay-Negros River flows through the Guimaras Strait then converges with the Greater Panay-Masbate River, forming a palaeo-estuary at the east of the Visayan Sea. Modified from 'Estimates of Quaternary Philippine coaslines, land bridges, submerged river systems and mirgration routes: A GRASS GIS approach' (Robles 2013:47).

As demonstrated in the reconstruction model (Figure 47), at – 20 m RSL, the northern tip of Cebu would have had a land bridge connecting it to the nearby Chocolate Island (11°18.368' N and 124°15.146' E) and the island of Malapascua (11°19.584' N and 124°6.938' E), with age estimates at around 9,000 BP (Table 2).

As Gato Island (11°18.368' N and 124°15.234' E) becomes further exposed at the same – 15 m RSL in the reconstruction model, a region to its southeast at 11°23.625' N and 124°2.987' E forms what appears to be a palaeoislandscape. This area would have been exposed during three possible time periods according to Kealy et al.'s (2017) sea-level model: 1) 9.8 ka BP; 2) 71 ka BP; and 3) 72.8 ka BP (Table 2).

At – 30 m RSL, a feature appears to run at a northwest to southeast diagonal configuration across the reconstruction model that could have been a palaeo lagoon environment as late as 11.7 ka BP. As sea-level transgression began to flood the basin, a channel of water began to separate the region before submitting to inundation. At – 35 m RSL, this channel of water would have been available for the exploitation of marine resources or possible fishery traps for a span of roughly 60,000 years (Table 2).

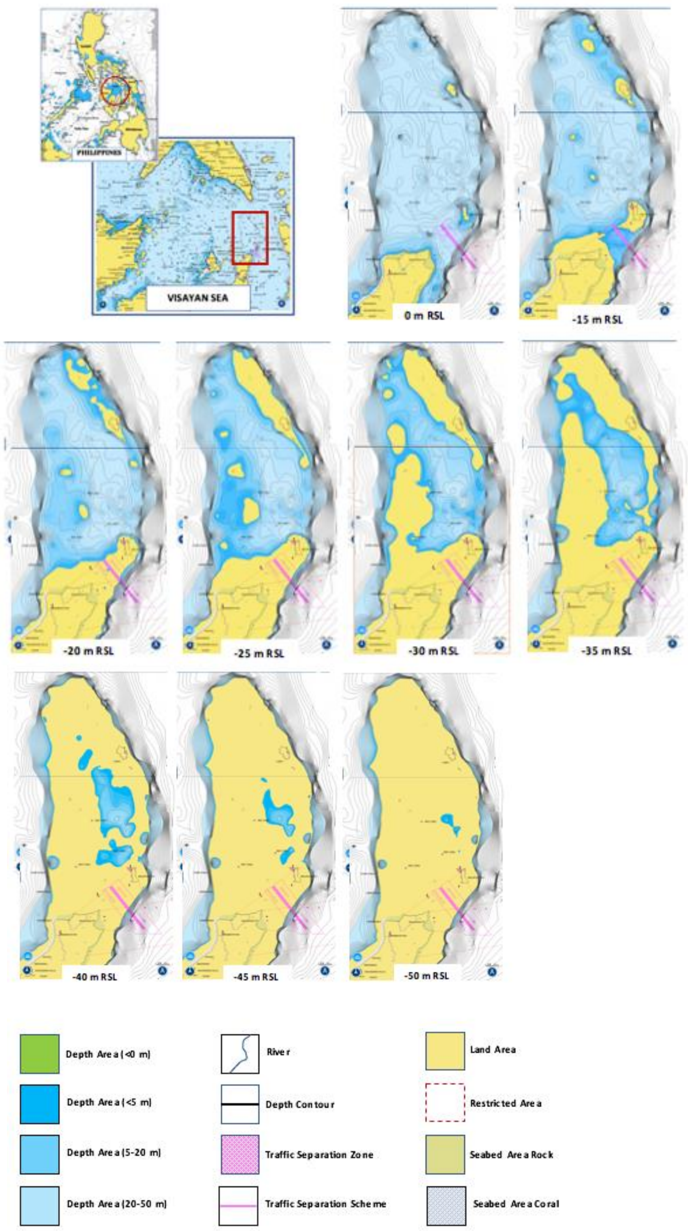


Figure 47 Relative sea-level reconstruction model of the Northern Cebu Basin from 0 m RSL to – 50 m RSL at a 1:50 000 scale using Navionics 2010 Asia&Africa. Legend indicating map features are listed below the figures.

4.3.1 Gato Island

Gato Island resides at the western side of the potential marine channel in the Northern Cebu Basin and would have been 4.0 km from the palaeo-channel at a 90° heading and 2.0 km from a steep off-shore profile at a 270° heading from its position (Figure 48). The now existing island would have been a strategic location for prehistoric humans to take advantage of pelagic fishing from the off-shore profile and net or trap fishing from the palaeo-channel at – 35 m RSL (Figure 48).

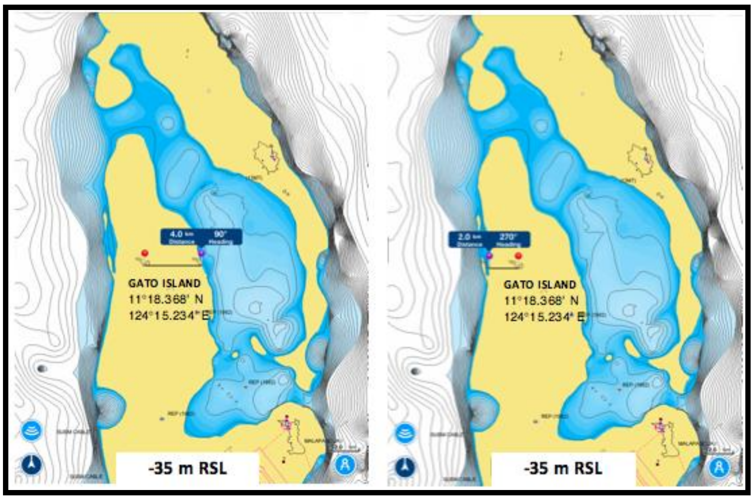


Figure 48 Sea-level reconstruction model using Navionics 2010 Asia&Africa depicting -35 m relative sea-level. The model shows the proximity of Gato Island at a 1:50 000 scale in relation to the submerged palaeo-channel depression at age estimates of around 10,000 years ago.

Gato Island is roughly 98 m above sea-level (Coast and Geodetic 1919) with multiple underwater cave entrances. Its most distinctive feature is a cathedral like cave opening at the southern end of the island (Appendix 1.12.1.1) that traverses through the internal structure before exiting to the east (Appendix 8.1.2.1). Fourteen meters below the water's surface are large boulders in front of the cave entrance. This evidence likely indicates that a part of the cathedral's structure collapsed at some period in time (Figure 49).

Figure 49 Gato Island's southern cave entrance.

The cathedral opening is roughly 70 m wide and extends 30 m from the submerged portion of the cave's entrance. The submerged cave entrance is 10 m in width. The bathymetry of the submerged area of the cathedral ranges in depth between 3 – 5 m below sea-level. The connective cave entrances is a consistent requisite of Late Pleistocene and Early Holocene terrestrial archaeology cave sites in the Philippines, as it would have provided a source of ventilation (Paz 2012) prior to inundation, with entry and exit openings at an east to west configuration. Gato Island's maximum surrounding depth extends to 22 m (see Appendix 8.1.2.1). Pre-submergence age estimates for Gato Island is roughly 10, 000 years ago. Additionally, the island would have connected with mainland Cebu nearly 11,000 years ago at – 35 m RSL (Figure 47).

4.3.2 Northeast River Mouth and Chocolate Island

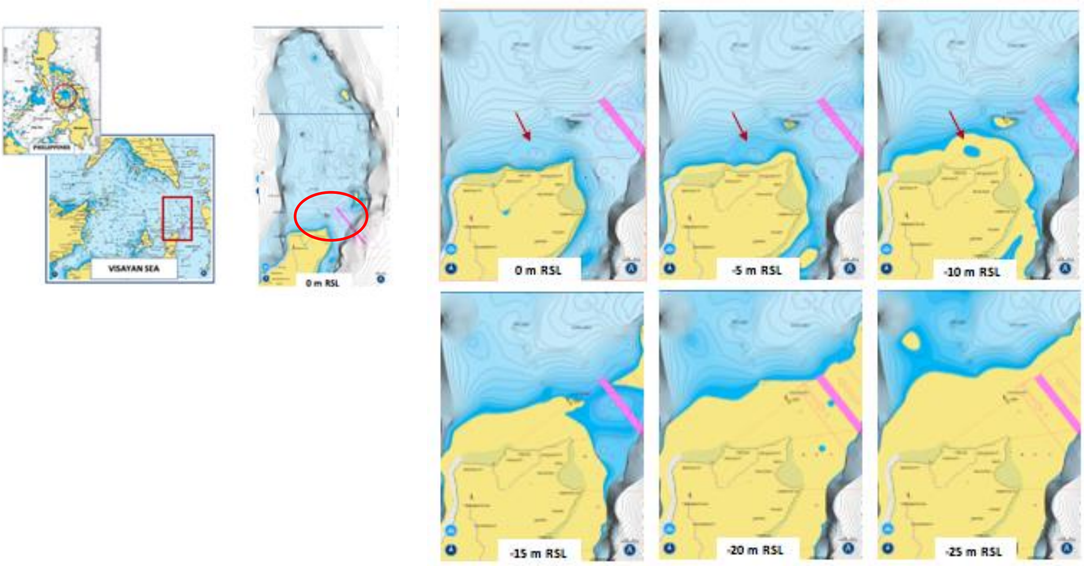


Figure 50 Sea-level reconstruction of Tapilon Creek location in relation to the potential palaeolake formation, at a 1:25 000 scale showing the Northern Cebu Basin, Philippines, using Navionics 2010 Asia&Africa sonar chart.

At the northern extremity of Cebu island is the municipality of Daanbantayan. Two river systems flow from the mainland into the Cebu Basin, Aguno Creek to the west and Tapilon Creek to the east (BMG 2010a) (Figure 50). At – 10 m RSL, demonstrated in the reconstruction model, a shallow water depression appears at the mouth of the Tapilon Creek, roughly 1 km from the current shoreline (Figure 50). Sea-level regression could have exposed this palaeoshoreline as late as 8.8 ka BP and provided an integral freshwater resource necessary for human settlement (Erlandson 2001; Erlandson and Fitzpatrick 2006; Pearson, et al. 2014).

4.3.1.1 Chocolate Island

Chocolate Island (Figure 51), is a small wooded islet roughly 42 m above sea-level and 1.5 km from the northern shore of Cebu (Coast and Geodetic 1919). At – 15 m RSL, the island would have been an extension of Cebu's palaeoshoreline, yet, disconnected to the Malapascua land extension by a narrow marine channel (Figure 50).

Figure 51 Mosaic of Chocolate Island, Northern Cebu Basin, Philippines.

Submerged under water on the western end of the island are three unidentified depressions that extend to 6 – 7 m below sea-level from the surrounding bathymetry of 3 – 5 m below sea-level (Appendix 8.1.1). A steep vertical drop-off from 5 m to 12 m is displayed and a maximum depth is 17 m beneath RSL is indicated.

4.4 Bantayan Island

Bantayan Island is approximately 113 km^2, with its highest elevation at 74 m above RSL, and located west of the northern tip of Cebu province (Angus Jr and Jaque 1996; BMG 2010d, g) (Figure 52). This highly permeable karstic limestone formation consists of several sinkholes, underground aquifers, and solution channels that discharge groundwater directly into the surrounding Visayan Sea and Tañon Strait (Angus Jr and Jaque 1996; Yu, et al. 2017).

The proximity of Bantayan Island to the Greater Panay-Masbate and Panay-Negros convergent river system's palaeo-estuarine environment on the north of its basin, the wetland environment to its west—now submerged in the Visayan Sea—and the Tañon Strait to the south, would have likely been an attractive location for human occupation through various temporal sequences in sea-level fluctuation. The island is considered one of the most important fishery areas in the Philippines, producing bivalves *Paphia textilis*, *Placuna placenta* and the scallop *Chlamys* sp. in commercial quantities (Aliño and Philippines 2002). Its coral reef to the southwest of the island has a substrate of silty-sand and consists of 26 species of coral, but most common are *Acropora*, *Pocilopora*, and *Porites* (Aliño and Philippines 2002; NAMRIA 1995), which are often used as proxies for sea level studies (e.g., Chappell and Polach 1991; Fairbanks 1989; Siringan, et al. 2016).

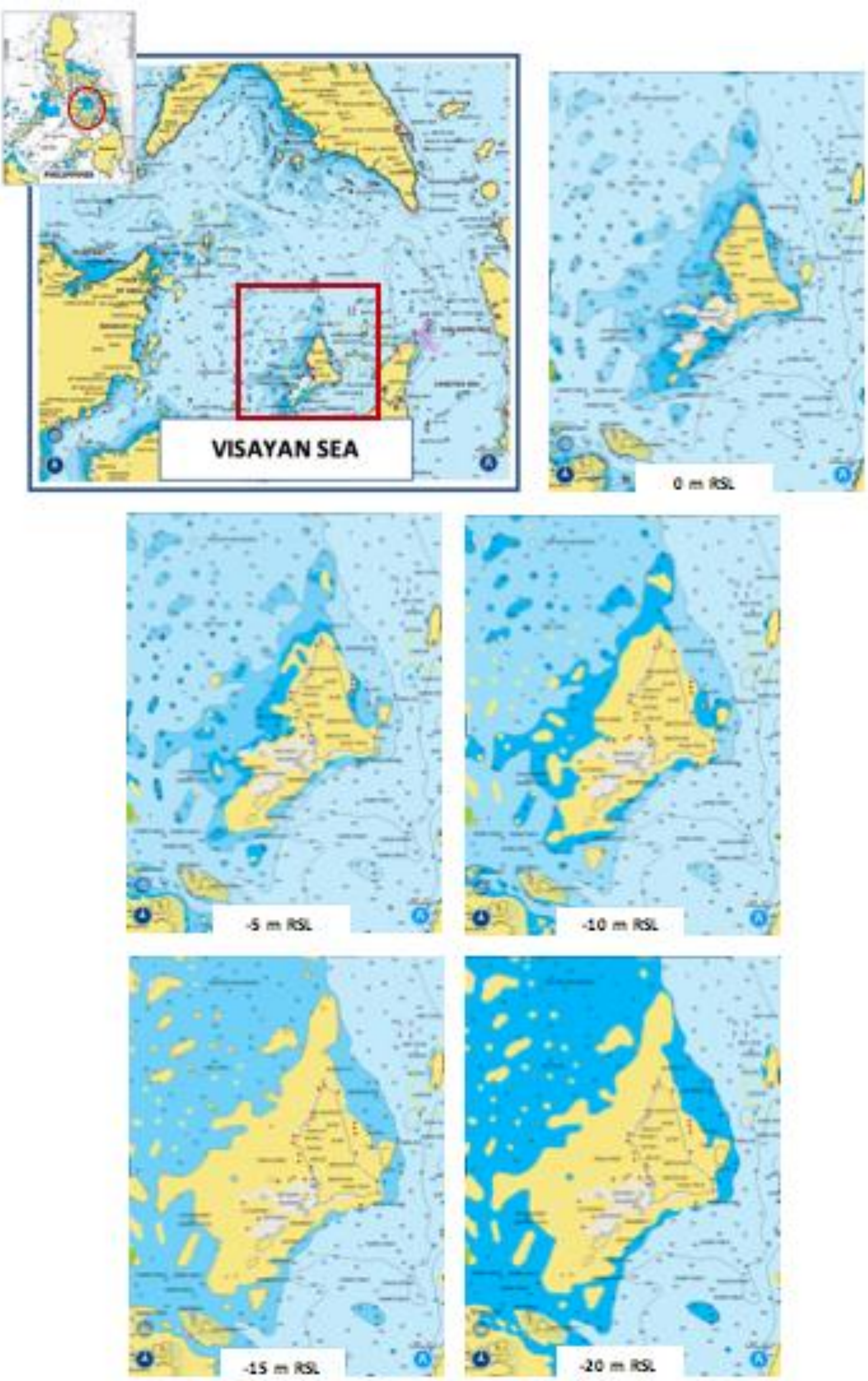


Figure 52 Sea-level reconstruction model using Navionics 2010 Asia&Africa of Bantayan Island, Cebu, from 0 m to 20 m below RSL at a 1:100 000 scale.

At – 20 m RSL in the sea-level reconstruction model, the island's widest breadth between contemporary and palaeoshorelines extends roughly 4 km as late as 9.8 ka BP (Figure 52). At a closer scale, sonar contours in the reconstruction model on the southwestern end of the island depict various features of interest. At – 15 m RSL, with an estimated date of roughly 9 ka BP, a depression in the contour indicates a potential palaeo-lake formation, and yet another at – 20 m RSL (Figure 54).

When compared to an ArcGIS Esri satellite image taken of where Bantayan's southwest freshwater and saltwater interface reaches the adjacent coral reef system, vein like fissures in the submerged topography appear (Figure 53). Further research is needed to examine the geomorphological features of the area and determine whether it is characteristic of a prehistoric freshwater channel, erosional processes due to intertidal displacement of sediment, or ancient volcanic activity.

Figure 53 Satellite image of southwestern coral reef extension on Bantayan Island, Cebu. Portions of this document include intellectual property of Esri and its licensors and are used under license. Copyright © 2017. Esri and its licensors. All rights reserved.

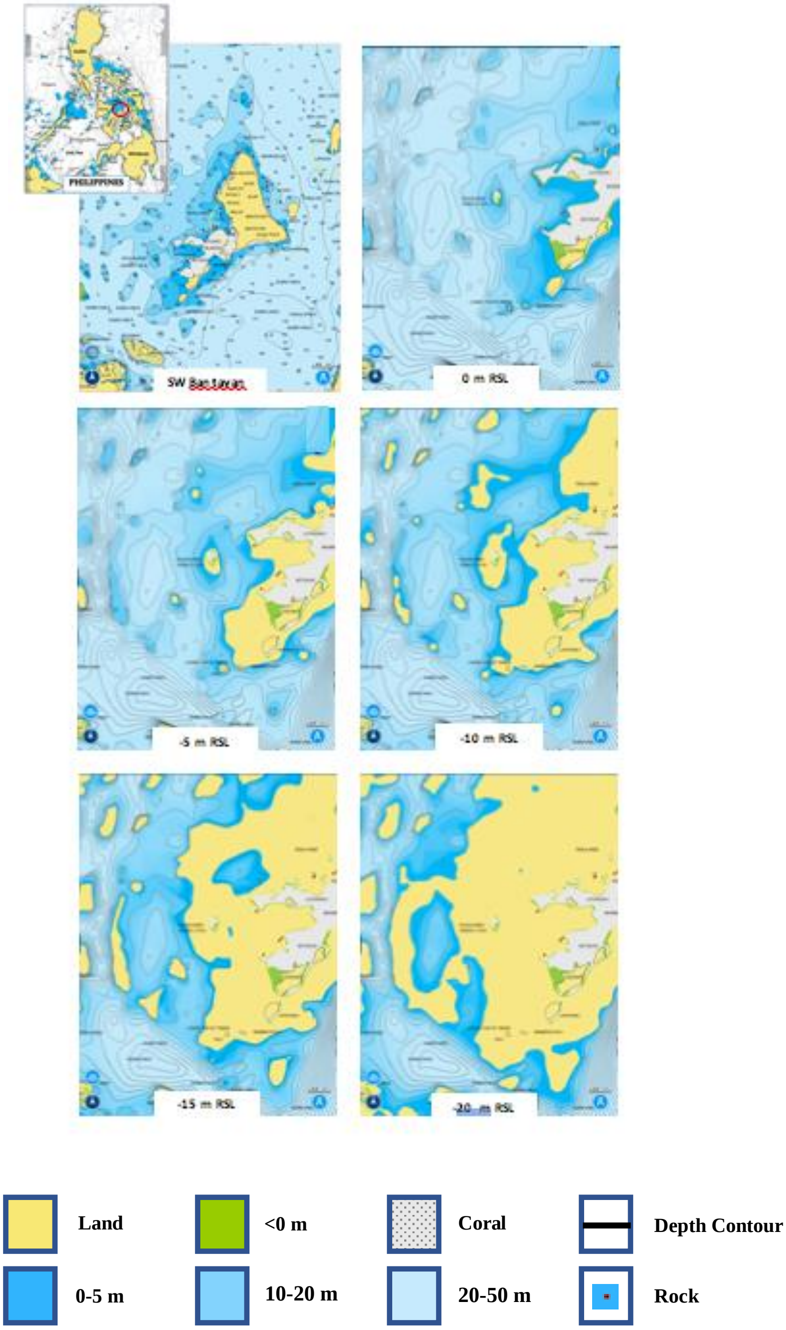


Figure 54 Southwest Bantayan Island, Cebu, at a 1:50 000 scale sea-level reconstruction model using Navionics 2010 Asia&Africa.

4.5 Panay

The island of Panay is located in the west Central Philippines, and is geomorphologically characterized by a north-south mountain range (Antique Range), floodplains in the northern and southern areas, and smaller mountain ranges in the northeastern region (Yumul, et al. 2012). Panay island is divided into four stratigraphic terranes: Buruanga Peninsula (chert-clastic-limestone), Western Panay Antique Range (ultramafic to mafic rock), Central Panay Iloilo Basin (interbeds of sandstone, siltstone and mudstone) and the Eastern Magmatic Arc (igneous rock) (Figure 55) (Yumul et al. 2012). The island of Panay hosts two of three major river basins in all of the Visayas, Panay River and Jalaur River Basin (A. Lagmay, et al. 2017:20; DENR-PAWB 2013:20), and soil profiles range from lateritic to clayey, loamy and sandy-clays derived from weathering of its sedimentary and igneous rock formations (Yumul, et al. 2012).

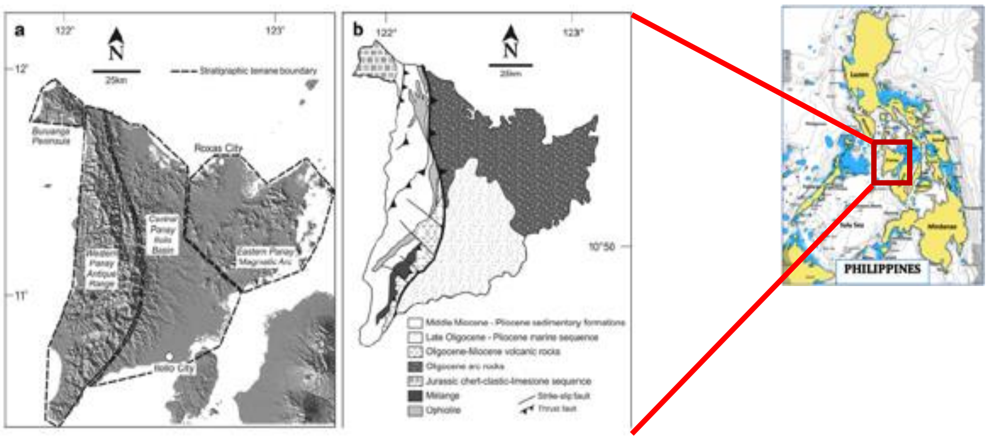


Figure 55 Panay island divided into four major stratigraphic terranes. Western Antique Range made of opholite, volcanic and sedimentary rock. Buruanga Peninsula is comprised of chert-clastic-limestone deposits. Central Panay Iloilo Basin is composed of sandstone, siltstone, and mudstone. Eastern Panay is made up of igneous rock. From 'Tropical cyclone–southwest monsoon interaction and the 2008 floods and landslides in Panay island, Central Philippines: meteorological and geological factors' (Yumul et al. 2012:832). Image modified to include the entire Philippine islands for reference using Navionics 2010.

Coutts and Wesson (1979) hypothesized Panay's surrounding islandscapes would have been connected during the Late Pleistocene – Early Holocene at periods of lowered sea-level. Due to the island's central position, the palaeolandsurface extending from Panay into the Visayan Sea Shelf would have been the epicenter of a cultural amalgamation of early islander activity based on its proximity to landbridges to the east (Samar and Leyte), and the Sulu Sea to the south (Coutts and Wesson 1979). According to Coutts and Wesson (1979) multiple cave complexes on the islands of North and South Gigantes were surveyed, and although most of the caves were subject to bat guano mining, they still produced evidence of past human activity ranging from shell middens, charcoal, fish vertebrae, pottery, and larger animal faunal remains. From eleven surveyed areas, nine produced evidence of prehistoric human activity. According to Coutts and Wesson (1979) collected deposits were taken to the National Museum of the Philippines and inspected over a course of three days. While no analysis of the shell-midden or faunal remains were published from Coutts and Wesson (1979), sites of archaeological significance in the Philippines such as Tabon Cave, Palawan, have produced age ranges as early as 47,000 years to as late as 4,000 years ago (Détroit, et al. 2004; Dizon, et al. 2002; Fox 1970). Therefore, it would be prudent to re-evaluate this area for its submerged archaeological potential.

4.5.1 Northeast Panay

At the northeastern most corner of Panay Island is the Balasan River Delta, comprising a multisystem river network which includes the Balasan River, Garay River, Tupas River, and Lauis River. The converging river network exits from the Panay mainland into the Bancal Bay shoal (BMG 1987). Beyond the bay lies a series of islands and islets whose larger islands include Binuluangan Island, Calagnaan Island, Carles, Isla Gigante Norte (North Gigante), Isla Gigante Sur (South Gigante), and Sicogon Island (Figure 56).

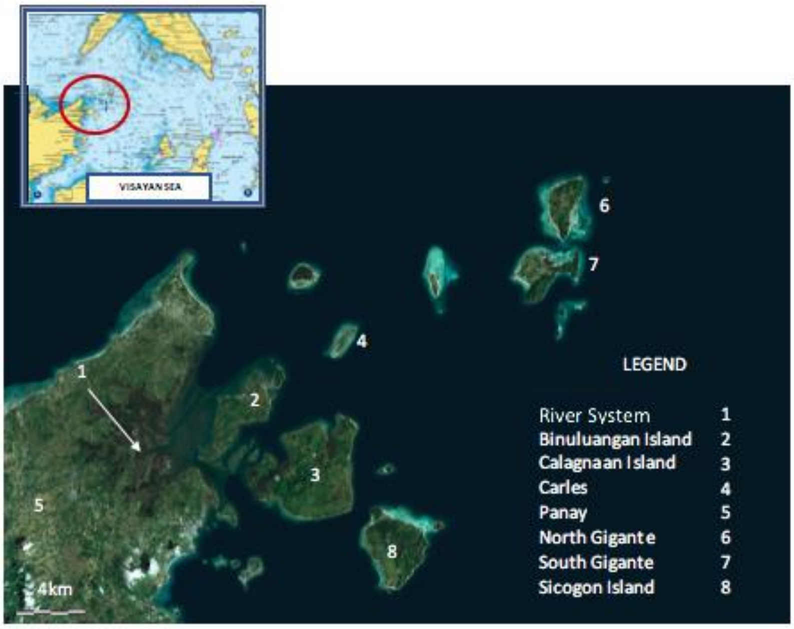


Figure 56 Satellite image of northeastern extension of the Balasan River delta and offshore islands Binuluangan, Calaganaan, Carles, North and South Gigante, and Sicogon. Portions of this document include intellectual property of Esri and its licensors and are used under license. Copyright © 2017. Esri and its licensors. All rights reserved.

The reconstruction model demonstrates how these islandscapes would have been connected at – 25 m RSL (Figure 57), with potential age estimates as late as 9.8 ka BP (Table 2). Throughout periods of marine regression, rivers would have extended beyond contemporary shorelines onto palaeolandsurfaces where sites of archaeological significance have been found in sediments of associated river channels (Tizzard, et al. 2011) and could also apply to this region. The extension of the Balasan River into the Visayan Sea Shelf is not apparent through the reconstruction model and would need further seismic investigation to determine potential submerged channel trajectories.

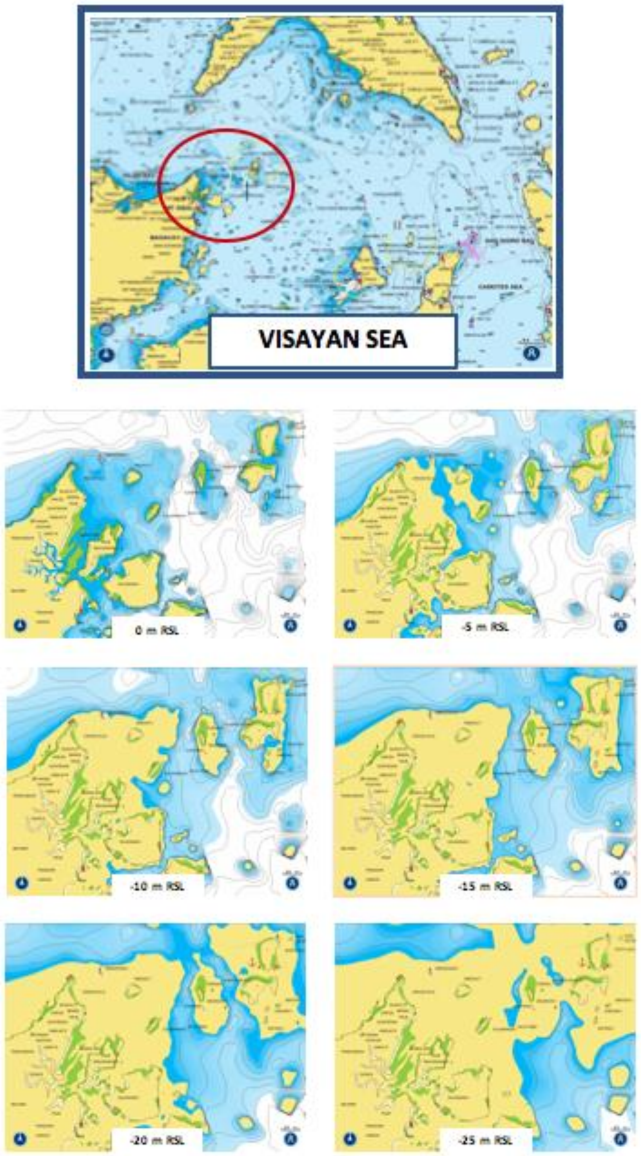


Figure 57 Sea-level reconstruction model of the Northeastern Panay basin using Navionics 2010 Asia&Africa at a 1:50 000 scale.

As indicated through the reconstruction model (Figure 57) at a – 5 m RSL, North and South Gigante would have been conjoined by an internal landmass as late as 8 ka BP. Coutts and Wesson's (1979) survey of North and South Gigante determined evidence of prehistoric human activity, as well as multiple cave systems throughout the two islands, suggesting there may be undisturbed submerged cave sites with material of older archaeological significance in its surrounding waters.

4.6 Panay Gulf

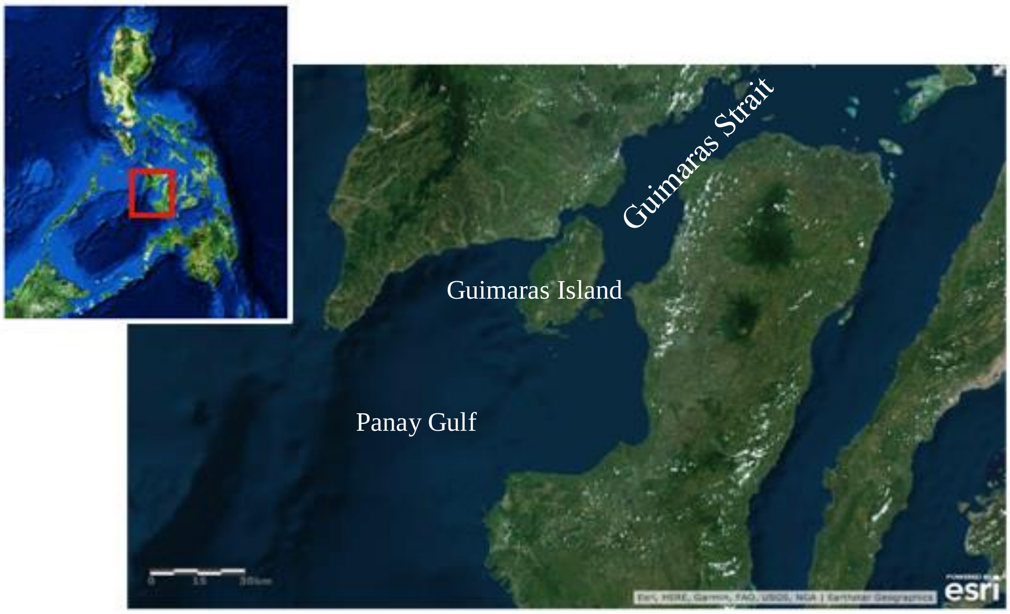


Figure 58 Satellite image of the Panay Gulf, Guimaras Island, and Guimaras Strait. Portions of this document include intellectual property of Esri and its licensors and are used under license.

The Panay Gulf is located between 10° and 9° North latitude and 122° East longitude (Figure 58). The gulf is known for its local and commercial pelagic fishing (Mitsunaga, et al. 2012; Mulyila, et al. 2012:952). Subsistence fishing conducted in this region exploits a variety of pelagic resources (Mulyila, et al. 2012; Whitty 2015) as the connecting Guimaras Strait hosts numerous mangrove ecosystems suitable for juvenile marine species development (Abrogueña, et al. 2012; Pada, et al. 2016).

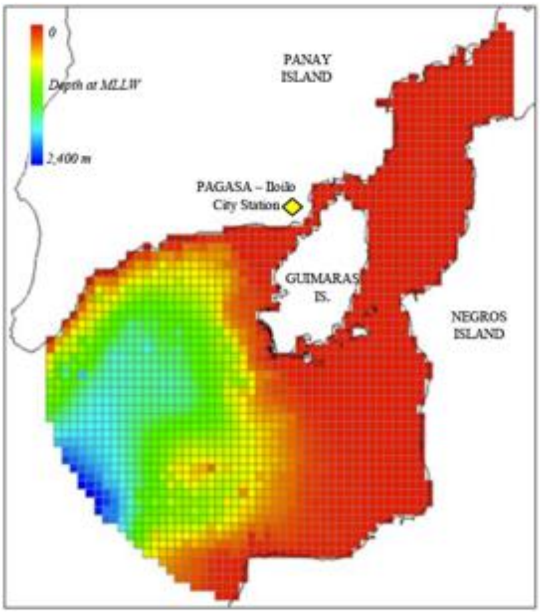


Figure 59 Panay Gulf and Iloilo Guimaras Strait model domain with each cell at a 2km x 2km configured on sigma vertical and orthogonal horizontal coordinate system. From 'Hydrodynamic and Trajectory Modeling of the August 11, 2006 M/T Solar 1 Oil Spill in Guimaras, Central Philippines with Validation Using Envisat ASAR Data' (Santillan and Paringit 2012:3).

Hydrodynamic trajectory models using the Environmental Fluid Dynamic Code to solve three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations, were employed to determine motions for variable density fluid after a 2006 marine oil tanker spill (Santillan and Paringit 2012:2). Their model domain was subdivided into 72x63 square grid with each cell at a 2x2 km resolution (Figure 59). Based on Santillan and Paringit's (2012) model, there is 5,712 km^2 of submerged coastline—highlighted in red—before a steep drop off to a 300 – 2,400 m slope profile. At periods of lowered sea-level, the Panay Gulf would have extended in some places roughly 20 km from its current shoreline, all the while maintaining an existing palaeo gulf region adjacent to the Sulu Sea. If early islanders had access to seafaring technology, this would have been an attractive access point for the Greater Central Visayan Basin to the Sulu Sea, acting as an ancient maritime highway to surrounding Philippine islands of Luzon, Mindanao, Mindoro, and Palawan. Furthermore, the contemporary coastlines are littered with river systems and tributaries as the Ilog Hilabangan River Basin (Figure 44) in Negros, sits directly at the Panay Gulf's southern end (BMG 2010b, c, e, 2011). The reconstruction model (Figure 60) demonstrates at – 45 m RSL, the shelf of the ancient Panay Gulf becomes fully exposed. Estimated age ranges for exposure at this depth are between 69 – 12.9 ka BP (Table 2).

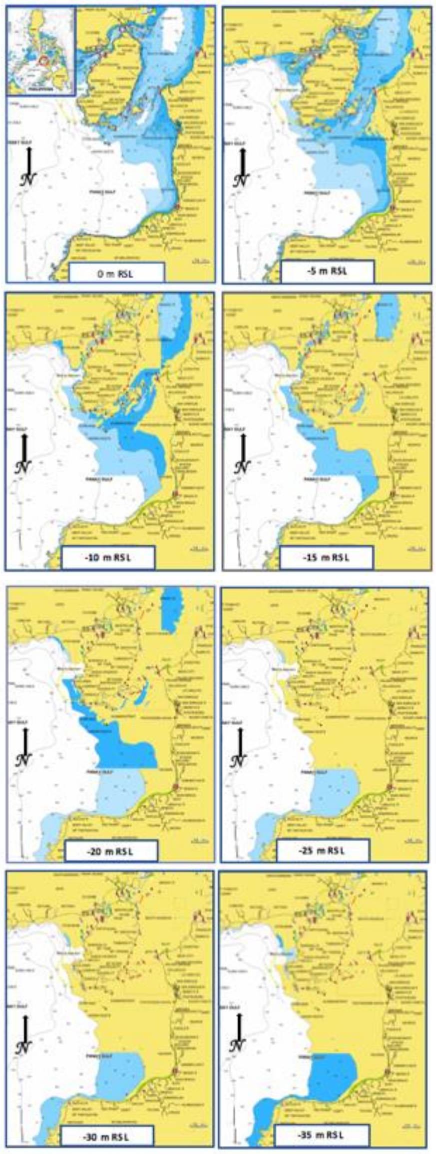


Figure 60 Sea-level reconstruction model of the Panay Gulf from 0 to 35 m below sea level using Navionics 2010 Asia&Africa at a 1:175 000 scale.

4.7 Guimaras Island

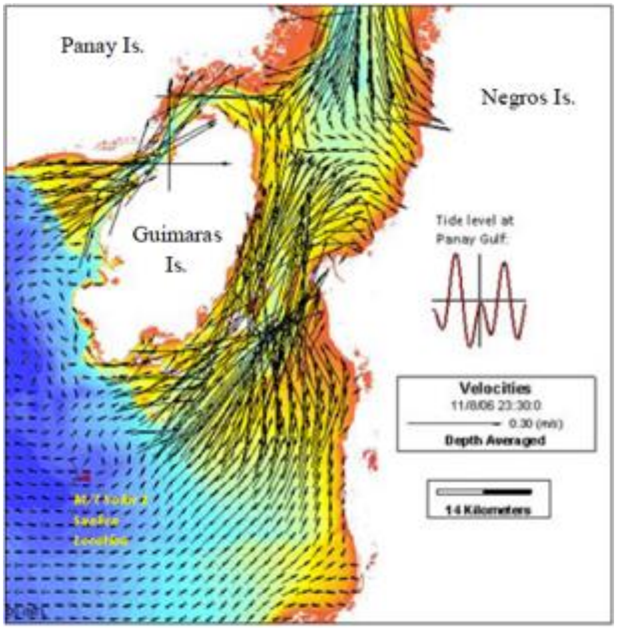


Figure 61 Simulated hydrodynamic model of sea current patterns in the Panay Gulf and Iloilo Guimaras Strait indicating a northeasterly movement from the Panay Gulf towards the Iloilo Guimaras Strait. From 'Hydrodynamic and Trajectory Modeling of the August 11, 2006 M/T Solar 1 Oil Spill in Guimaras, Central Philippines with Validation Using Envisat ASAR Data' (Santillan and Paringit 2012:5).

Located within the Panay Gulf is Guimaras, an island province of the Republic of the Philippines. The region is disconnected from the two larger islands of Panay and Negros by the Iloilo Strait (2.7 km wide and 1.5 km long) to the north, and the Guimaras Strait (11 km wide) to the south (Figure 61) (Abrogueña, et al. 2012; Mulyila, et al. 2012:950; Parreño, et al. 2016:93). Guimaras Island's coastline consists of a complex series of hundreds of small bays, islets, peninsulas, mangrove stands, seagrass beds, and coral reefs (Yender and Stanzel 2011) spread across 605 km^2 (Mulyila, et al. 2012:950). Additionally, these ecosystems support numerous marine resources which local inhabitants exploit through trap, net, and line fishing, as well as filter net and corrals in the shallow subtidal areas (Yender and Stanzel 2011).

The hydrological characteristics of the Panay Gulf indicates a north-westerly current pattern from the gulf towards the Guimaras Strait and opposing incoming water movement from the Guimaras Strait to the gulf (Figure 61) (Santillan and Paringit 2012). This water movement could be the catalyst responsible for a bathymetric contour in Pontevedra 3551 II that shows at – 15 m RSL a benthic depression off the southeast coast of Guimaras Island (Figure 64). According to the reconstruction model, the contour has a maximum depth of 30 m in contrast to its surrounding 15 m marine topography. However, at the southwestern end of Guimaras Island is the Sibunag Creek—albeit, a relatively large creek measuring 2.5 km long and 50 to 100 m wide (Abrogueña, et al. 2012:312)—to the southeast of the depression. On the adjacent side are the Bago-Pulupandan River and San Enrique River located in western Negros-Occidental (Casipe, et al. 2013:69). Both river sources expel freshwater into estuarine environments near the vicinity of the depression situated in the Guimaras Strait (Figure 62).

Due to the nearby proximity of the Bago-Pulupandan River to the northwest (BMG 2010f), the San Enrique River to the east (BMG 2010e), and the Sibunag Creek to the southwest (NAMRIA 1956) it could likely indicate that at periods of lowered sea-level, the bathymetric depression in the reconstruction model juxtaposed to the temporal estimates in the sea-level curve, may have been a freshwater reservoir as late as 9,000 years ago.

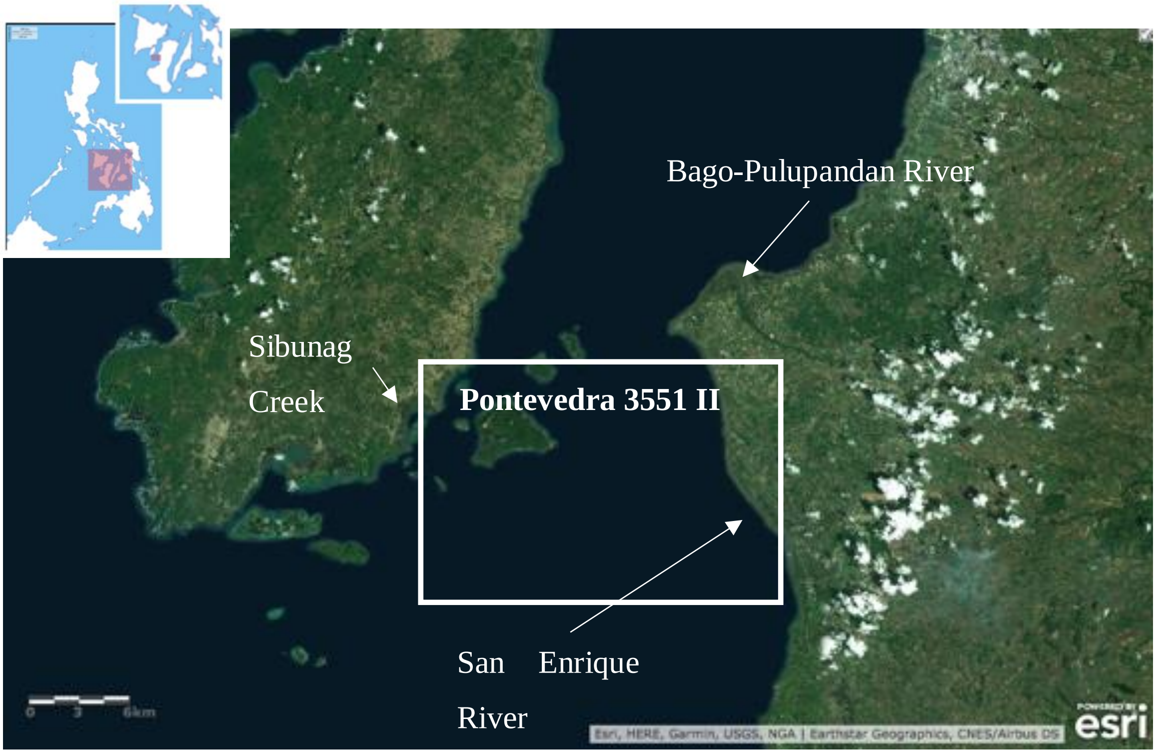


Figure 62 Ersi satellite image of Pontevedra 3551 II in relation to Bago-Pulupandan River, San Enrique River, and Sibunag Creek.

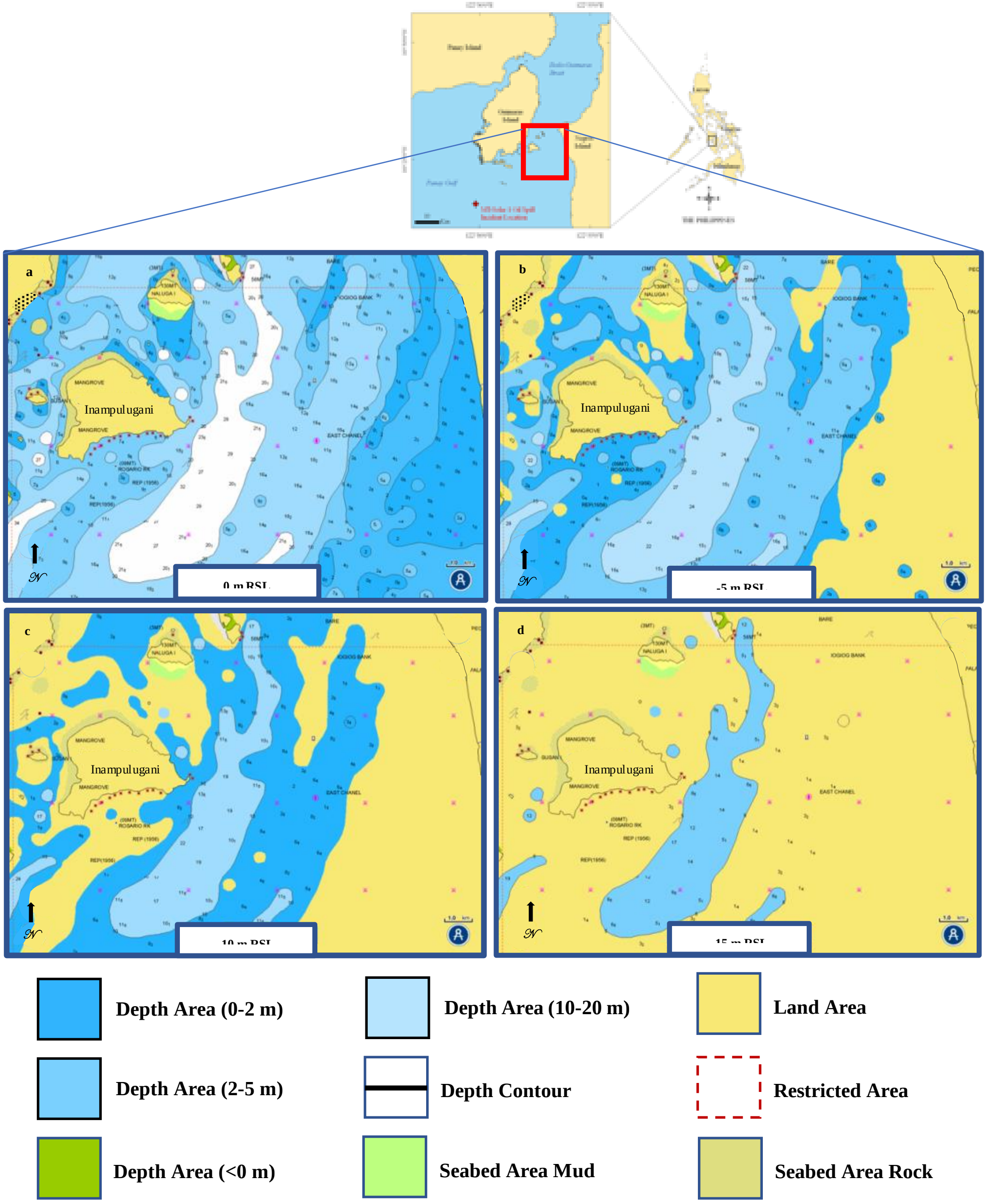


Figure 63 Sea-level reconstruction model of a depression formation in the Pontevedra 3551 II quadrant of the Panay Gulf east of Guimaras Island using Navionics 2010 Asia&Africa at a 1:25 000 scale.

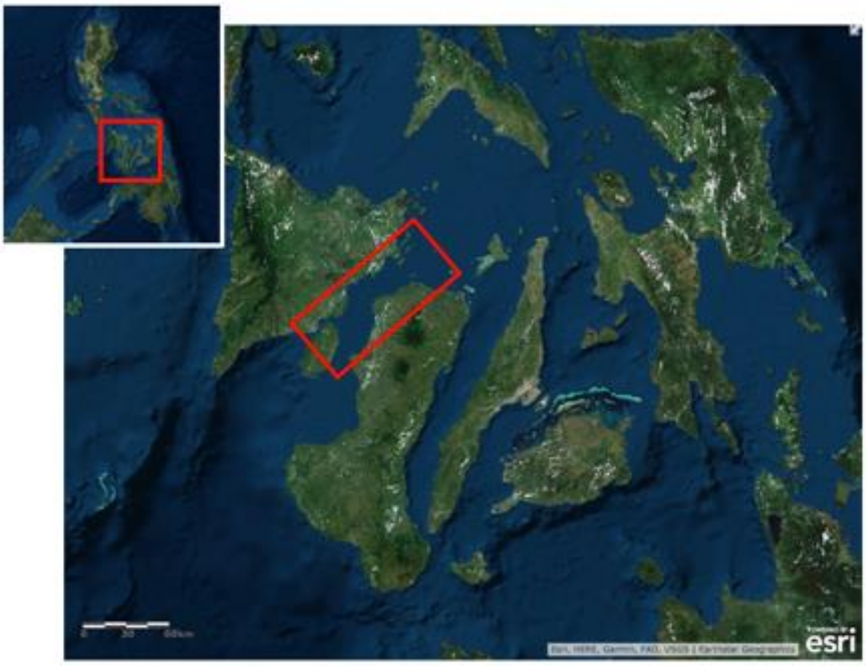


Figure 64 Ersi satellite image of location of the Guimaras Strait.

4.8 Guimaras Strait

The Guimaras Strait (Figure 64) acts as the liminal water passage between the Panay Gulf and Visayan Sea, covers 7,120 km^2 with an average depth 18 m, and is considered another one of the Philippine's major fishing grounds (Mulyila, et al. 2012:950; Padilla and Trinidad 1995). Its sea current flows from a northeast to southwest configuration during the dry season and switches its trajectory to southwest to northeast during the Philippine's yearly rain period (Nakajima, et al. 2017). The Jalaur River in Panay is a major freshwater resource for the strait (Parreno, et al. 2015:102) along with multiple other tributaries. As demonstrated in the reconstruction model (Figure 65) the bathymetric contour within the strait exposes another potential palaeolake formation dating to roughly 9,000 years ago at – 15 m below RSL. Before the encroaching sea fully inundated the region, it is likely the surrounding river basins and tributaries feeding into the Guimaras Strait would have supplied freshwater channels throughout its palaeolandsurface.

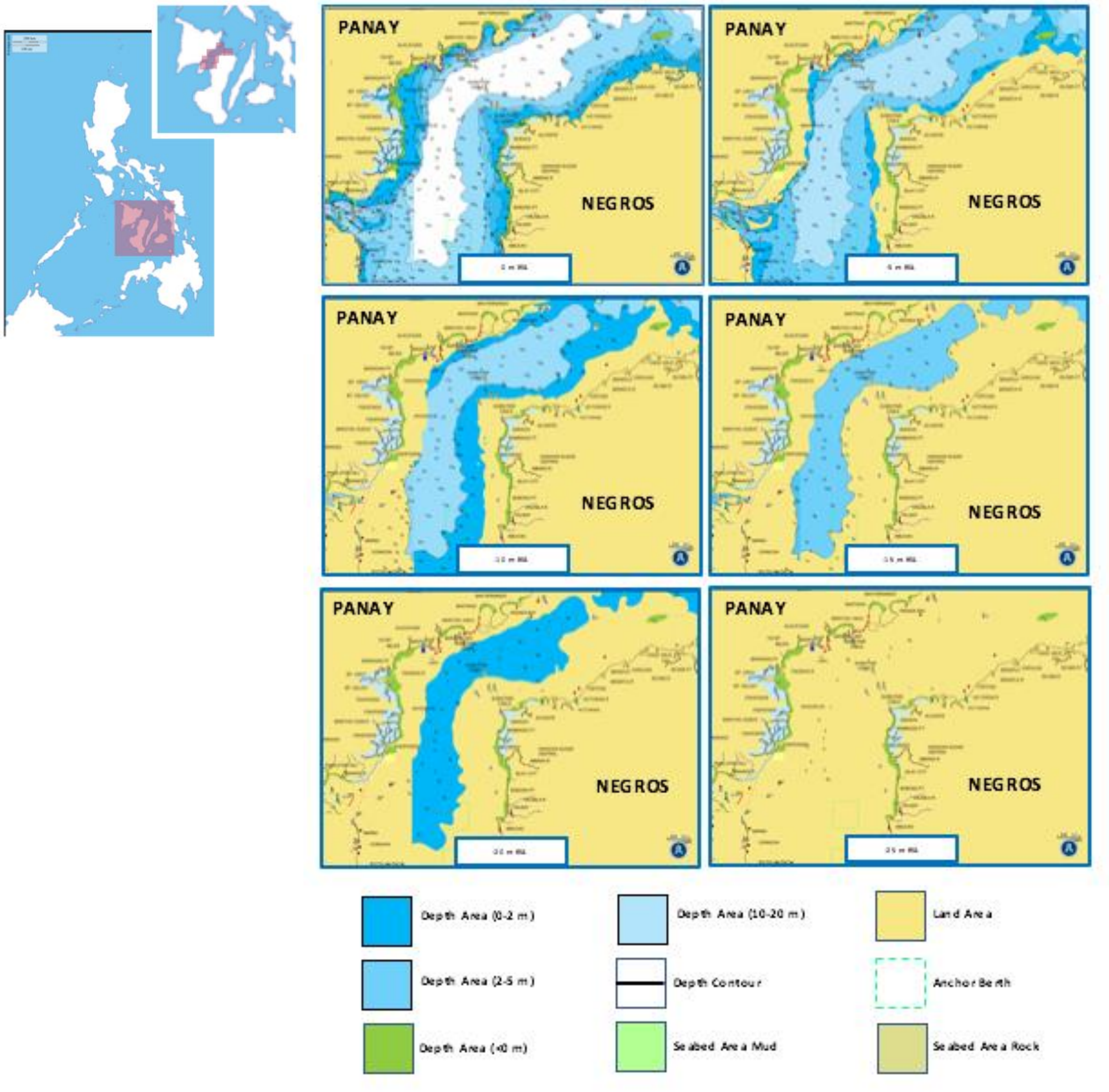


Figure 65 Sea-level reconstruction model of the Guimaras Strait using Navionics 2010 Asia&Africa bathymetric contours to identify a depression feature at a 1:100 000 scale. RSL ranges between 0 m and -25 m.

5 DISCUSSION

Submerged archaeological investigations in the Philippines are in their nascent stages of development. Along with having a highly complex geographic region, research towards locating prehistoric site assemblages in the offshore environments must rely upon a variety of disciplines to synthesize available datasets, and derive coarse resolution modelling to maximize chances for site discovery. Although sea-level regression in the Philippine Archipelago reached – 123 m at its most nadiral amplitude during the LGM (Robles, et al. 2015), this sea-level lowstand existed for a relatively ephemeral period in geological history. While longer temporal sequences existed between 30 – 40 m below present levels (Voris 2000), submerged archaeological investigation at those depths can be fraught with numerous limitations, challenges, and time restrictions (e.g., Rocha, et al. 2017). Dive investigations for purposes of underwater archaeology generally employ one of two types of diving equipment depending on environmental circumstance, i.e. self-contained breathing apparatus (SCUBA) or surface-supplied diving equipment (SSDE) (Benjamin and Mackintosh 2016). The advantage of SSDE is having constant contact with the surface and out-of-air emergencies are less likely than with SCUBA, however, equipment and qualifications can be more expensive (Benjamin and Mackintosh 2016). Successful ongoing underwater investigations in the Red Sea have employed the use of SCUBA for dive investigations down to a 90 m working depth, using mixed gas diving (nitrox and trimix) while adhering to practical safety standards (Geoff Bailey 2011). Sea-level history reconstruction models for the Central Visayan Region of the Philippines in this thesis specifically focused on depths of ≤50 m. More specific interest in areas were limited to less than 25 m to optimize potential working depth using standard or mixed gases SCUBA equipment.

While the Visayan Sea's relatively low-energy wave activity, shallow bathymetry, and shelter from surrounding islands (Brill, et al. 2016; Lee and Kim 2015) does not render the region immune from more severe weather phenomena; it does however, increase the likelihood for archaeological site preservation (Andersen 2011; Fischer 1993, 1995; Flemming 2004; Tizzard, et al. 2011:67; Uldum 2011; Ward, et al. 2015:20). There are cases in which submerged archaeological assemblages have been located in high-energy dominant conditions (e.g., Masters 1983; Westley, et al. 2011). Site survival in underwater tropical environments receiving large tidal ranges and intense episodic weather phenomena have been demonstrated in Central and North America (Clausen, et al. 1979; Faught 2004; Pearson, et al. 2014).

The Gulf of Mexico received substantial interannual and interdecadal variability of tropical cyclone activity over the past 100 years (Goldenburg and Landsea 2001; Khouakhi and Villarini 2017). Yet, Pearson et al.'s (2014) Sabine River, Gulf of Mexico, offshore investigation produced vibracore samples yielding charred wood, floral, and faunal assemblages radiocarbon dating to 8,000 BP. Another submerged prehistoric site off the Gulf coast of northwest Florida, produced a lithic collection indicative of a Palaeoindian to Early Archaic Site (Faught 2004). Radiocarbon estimates from an associated oak tree stump, suggested terrestrial conditions for the site at more than 7,000 years ago.

Tropical regions are considered to have notoriously poor conditions for archaeological site preservation—beyond 2,000 years—as a result of geochemical and geomorphologic processes, and presence of humin acids from jungle vegetation (González, et al. 2010). Yet, submerged cave systems in tropical regions have yielded evidence from older time periods with excellently preserved archaeological assemblages. Researchers at the Naranjal cave system in Yucatan, Mexico, recovered a 90% intact human skeleton at a depth of 22.6 m below sea-level (González, et al. 2010). Associated charcoal clusters found near the skeletal remains were radiometrically dated to roughly 9,000 BP. As many of the Philippine's terrestrial archaeologic sites are found in cave systems, the inference that underwater sites would be found in similar karstic conditions can be induced.

Karst systems are also known to produce sinkholes or cenotes. At the height of the LGM, environmental conditions were substantially drier for equatorial regions as less available ocean water fed into the ENSO (Bird, et al. 2007). The limited rainwater recharge would have made features such as freshwater sinkholes attractive for human settlement (Clausen et al. 1979). An example of prehistoric human occupation comes from Little Salt Springs, Florida. Researchers at this site uncovered an Archaic Period habitation area in and around a 60 m deep freshwater sinkhole (Clausen et al. 1979). Radiocarbon dates from settlement deposits showed a direct response to sea-level variation, idicating multiple periods of occupation between 12,000 and 5,200 years ago. On the island of Palawan, Philippines, the Ille Cave site's depositional sequence suggested a cultural hatis around 14,000 to 11,000 BP in which later occupantion may have been the result of marine transgression.

The Philippine's karst terrain geomorphology and hydrology are largely governed by surface waters interaction between CO_2 from the air and soil, which become acidic as it percolates downward through carbonate rock into the phreatic zone, later discharging typically through springs (De Waele, et al. 2011). Karstification becomes enhanced between a freshwater and saline water interface along coastal areas; and under certain conditions, speleogenesis can develop due to sea-level rise and aggradation (De Waele, et al. 2011; Gulley, et al. 2013). According to De Waele et al. (2011) speleogenesis final stages are characterized by sedimentation, alluviation and collapse processes which can protect cave's floors and walls, becoming a stratigraphic sequences for past geological and palaeoenvironmental conditions.

Hydraulic conductivity from fractures, conduits, and intergranular porosity forms a complex permeable aquifer through karst environments (De Waele, et al. 2011) and can generate multiple areas for freshwater resources. Meteoric water accumulation inside cave environments could have also been collected as a source of freshwater from early island inhabitants.

It is likely multiple cave systems once used for human occupation during the LGM are now inundated due to sea-level rise in the Philippines. Caves and rock shelters constitute the most common terrestrial site type for Upper Pleistocene – Early Holocene period archaeology in the archipelago (e.g., Détroit, et al. 2004; Lewis, et al. 2008; Mijares 2002, 2005; Mijares, et al. 2010; A. F. Pawlik, et al. 2014), usually having deeper chronology for less matrix depth than open sites (Paz 2005). As early as 47,000 BP (Détroit, et al. 2004), karst cave systems played an instrumental role for anatomically modern humans providing shelter, burial sites, and sacred spaces (Paz 2012). The Philippine's Department of Environment and Natural Resources (DENR) – Protected Areas and Wildlife Bureau (2009) has recorded over 1,500 caves and acknowledges a significant number remain *terrae incognitae*.

The Northern Cebu Basin harbors one well known underwater cave at Gato Island, and several unrecorded caves and rockshelters. The sea-level history reconstruction model for the Northern Cebu Basin suggests by 11,000 years ago sea level was at – 35 m below present. At that time, the encroaching seas flooded into a channel separating the north and south regions of the basin, likely created a lagoon or shallow marine environment. Prior to 11,000 years ago, sea levels would have been at or below – 35 m for roughly 38,000 years. Inhabitants of this basin possibly exploited pelagic fish from its steep offshore profiles and engaged in maritime activities. The eastern coast of the Northern Cebu Basin would have been adjacent to the Greater Visayas Convergent River estuarine environment which likely continued to provide a productive ecosystem resources even at the peak of the LGM.

The San Bernardino Strait and Guimaras Strait (Figure 42) are two major inflows feeding into the Visayan Sea. The Jintotolo Channel exists as the Visayan Sea's only outflow passage into the Sibuyan Sea to the northwest. As the San Bernardino Straits sill depth is recorded at – 23 m (Hurlburt and Metzger 2009) and the Guimaras Strait averages – 18 m (Figure 43) (Mulyila, et al. 2012:950), periods of lowered sea-level at 20 – 25 m would have restricted oceanic water flow into the Visayan Sea. The Visayan Sea's bathymetric data indicates – 150 m (Noblezada and Campos 2012) at its northeastern region, where the Greater Visayas Convergent River estuarine environment would have been prior to inundation. According to its bathymetric contour (Figure 39), a depression channel in the Visayan Sea Shelf's marine topography extends westward to the Jintotolo Channel. This feature in the Visayan Sea Shelf could have been a potential inland marine waterway or shallow marine environment as late as the Terminal Pleistocene. Large coastal middens are often associated with embayments, river estuaries and intertidal regions capable of producing mollusk colonies large enough to generate substantial mounds (Bailey and Flemming 2008). Bantayan Island, Cebu, is located at the crossroads of where the San Bernardino Strait and Guimaras Strait inflow intersect in the Visayan Sea. In the coastal regions of Bantayan, various species of bivalves are produced in commercial quantities (Aliño and Philippines 2002) where similar conditions may have existed in the surrounding Visayan Sea region at periods of lowered sea-level. At – 20 m RSL, the island of Bantayan's eastern shorelines would have extended to the southern fringes of the Visayan Sea Shelf's palaeo-estuarine environment as late as 10,000 BP. This palaeolandscape would have remained exposed for almost 60, 000 years at or below 20 m, where prehistoric inhabitants would have benefited from the Greater Panay-Negros Convergent River system bifurcating towards both its northern and southern coasts (Figure 46).

Multiple submerged landscape studies have espoused that freshwater resources in the form of river basins, channels, springs, and tributaries would have extended beyond contemporary shorelines at periods of lowered sea-level during the Late Pleistocene and Early Holocene, and are typically considered an integral component for human settlement patterns and subsistence strategies (Bailey and Flemming 2008:2161; Erlandson 2001:293; Flemming 2010:275; Nutley 2014:258; O'Connell and Alien 2012:8; Pearson, et al. 2014:53; Tizzard, et al. 2011:73; Westley, et al. 2011:147). The Balasan River and the surrounding river network, in Northeastern Panay, would have extended into the Visayan Sea at periods of lowered sea-level and possibly contributed to the Greater Panay-Masbate River. The sea-level reconstruction model (Figure 57) indicates a connecting landmass between Northeastern Panay and the adjacent surrounding islandscapes at – 25 m RSL, placing age estimates around 10, 000 BP. As encroaching seas flooded the river basin to form estuaries, the gradual fill of sediment before submergence could have still protected archaeological deposits beneath the erosive impacts of marine transgression (Pearson, et al. 2014). The region surrounding the ancient Northeastern Panay landmass would have been a highly-productive marine resource for early inhabitants in the form of brackish water tolerant species, and evidence reflecting ancient human settlement patterns may still be locked up in its offshore benthic layers.

Many of the Philippine's terrestrial archaeological deposits are found in the Cagayan River Valley, Luzon (Patole-Edoumba, et al. 2012) where the largest river basin exists for the northern region (Figure 20). Its surrounding area also consists of 6 major river basins: Abulog River Basin, Abra River Basin, Agno River Basin, Pampanga River Basin, and Pasig-Laguna River Basin (A. Lagmay, et al. 2017; DENR-PAWB 2013). The Visayan Region harbors 3 major river basins—Ilog Hilabangan River Basin, Jalaur River Basin, and Panay River Basin—all of which debouch into areas of the Guimaras Strait, Panay Gulf, and Visayan Sea (A. Lagmay, et al. 2017; DENR-PAWB 2013). Due to predicted high resource productivity in lower reaches of river basins in the Guimaras Strait, where stream flow would have been at its heaviest, there would likely be a greater foraging returns for hunter-gather populations (O'Connell and Alien 2012) as late as 10,000 years ago. It is then likely higher concentrations of human activity would have also occurred in the submerged regions of the Guimaras Strait, Panay Gulf, and Visayan Sea during the Terminal Pleistocene. Moreover, drier climatic conditions suggested during the LGM would have provoked prehistoric human populations to congregate around remaining water sources from nearby river basins.

The Guimaras Strait's vast network of river systems may have still provided freshwater resources as late as 9,000 years ago. At – 20 m RSL, the sea-level reconstruction model demonstrates a potential palaeolake formation extending for almost 24 km within the straits valley (Figure 65). As the Guimaras Strait straddles between the gateway to the Sulu Sea and the internal Greater Visayas, prehistoric human activity in the form of social, maritime, or trade interaction, would have occurred near its abundant freshwater resources.

Coastal regions can offer pathways of communication as well as access to inland resources along river channels (Geoff Bailey 2011). Neri, et al. (2015) established evidence of early islander mobility around the Terminal Pleistocene in the Philippines between Ille Cave Site, Palawan, and Bubog I Rockshelter, Ilin Island, Mindoro, through determining inhabitants from these sites exploited the same obsidian resource. As early as 12 ka BP, anatomically modern humans in the Philippines made use of some type of maritime technology to traverse between the islands of Palawan and Mindoro, inferring other localities in the Philippines must have been traversed during that period as well. According to the sea-level curve, age estimates would have placed sea level in the Philippine Archipelago at 45 m below contemporary levels around 12,000 years ago. At – 45 m RSL, the Panay Gulf Shelf would have been fully exposed and could have been an attractive region for human maritime activity and trade due to high resource productivity occurring in the Guimaras Strait.

6 CONCLUSION

Reconstructing submerged palaeolandsurfaces using Navionics 2010 Asia&Africa simulation models of RSL changes in the Central Visayan Region of the Philippine Archipelago at estimated time intervals has been intended to target specific zones for more detailed examination. Each targeted region has been chosen based on relatively shallow bathymetry, availability of freshwater and marine subsistence resources, and minimal anthropogenic influence from modern day populations. The complex rheology of the Philippine island arc system due to hydro-isostasy and volcanism presents the arduous challenge of prescribing accurate profiles of its palaeogeography in relation to submerged landscape site discovery. Since the archaeology of inundate sites remains at the rudimentary stages of development in the Philippines, the need to generate a predictive platform suitable for transitioning the theoretical into practical application, must start at the broad-scale level of interpretation while drawing from an interdisciplinary group of available datasets, and later tested against its hypothesis.

Course resolution models in this thesis suggest the Visayan Sea Shelf would have been potentially a wetland environment at 50 m below present day sea levels. A possible inland waterway would could have existed within the Jintotolo Channel at the northeastern part of the Visayan Sea and extended east to an estuarine environment before debouching into a steep offshore profile just west of the Northern Cebu Basin. The ancient Panay Gulf would have increased its shoreline roughly 20 km in some places east into the Sulu Sea around the Terminal Pleistocene, providing an attractive bay for maritime activity when islander mobility had already been established—at least between Palawan and Mindoro (i.e., Neri, et al. 2015).

Guimaras Island exists at the threshold between the ancient Panay Gulf and the Guimaras Straits and could harbor assemblages of archaeological interest in its underwater regions and inundated karst caves systems. The Guimaras Strait's shallow bathymetry and abundance of rivers flowing into its channel would have made this area a highly productive region of exploitable resources for hunter-gather populations during periods of sea-level transgression. The river systems surrounding the strait could have also been utilized as inland waterways for prehistoric peoples as a means of exploiting hinterland resources (G. Bailey 2011) during periods of the Pleistocene and Early Holocene.

While attempts to synthesize various dataset derived from geological, hydrological, biological, and bathymetric publications are conducive to initial assessments for submerged landscapes studies, further information is needed to better understand the archaeological potential in the submerged Central Visayan Region of the Philippine Archipelago. The complex regional variability of the Philippine island arc system suggests a need for regionally specific sea-level curves. Fortunately, the abundance of coral reef systems throughout the Central Visayan Region could be utilized as biological indicators of sea level fluctuation (e.g., Fairbanks 1989; Lighty, et al. 1982). Additionally, the study of speleothems inside karst cave systems involving tufa and travertine deposits as markers for palaeoclimate and palaeoenvironmental studies (Benjamin 2007; De Waele, et al. 2011; van Hengstum, et al. 2011) may be another method towards advancing the discipline in an area laden with karstic limestone formations. An important consideration for predictive modelling in the Philippines would be obtaining regionally specific sea level coral proxy data from the marine environment. With over 7,000 islands comprising the archipelago, all dependent on regional seismic activity and tectonic uplift, no one area can provide a standardized sea-level curve for the entirety of the island arc system. While above current sea level corral terraces have been determined relatively tectonically stable at MIS 5e and the Middle Holocene for the islands of Palawan, Mactan, Panglao, and Bohol in the Central Visayas (Berdin, et al. 2004; Omura, et al. 2004), northeastern Samar and northwest Luzon experience increased seismic activity from the strike-slip motion of the Philippine Fault line. The only published living water-depth coral proxy for sea level data in the Philippines comes from Siringan, et al. (2016) from the coast of north-western Luzon. Sirigan et al. (2016) had the nearest age estimates to Kealy et al.'s (2017) sea-level curve and accounted for tectonic uplift. However, the Central Visayan Region's tectonic stability could generate inherently different date estimates. Therefore, in water marine coral core samples would need to be analyzed and dated from the Visayan Sea to generate a more reliable sea-level curve.

Further bathymetric analysis making use of high-resolution LiDAR survey would be necessary in attaining a better understanding of submerged palaeotopography (Missiaen, et al. 2017; Westley, et al. 2011) in the targeted areas. Seafloor morphology may have been modified through sediment deposition during sea level highstands, erosional processes, and transgressive parasequences of submerged beach facies (Chiocci, et al. 2017). Since contemporary sediment sequences become superimposed over palaeosol subsurfaces, the use of high-resolution seismic profiles allow for a virtual aperture to delineate between temporal variances in stratigraphy

(Chiocci, et al. 2017). Acoustic analysis of palaeotopography can determine what environmental factors influenced early human settlement patterns (Momber 2011), palaeochannel trajectories (Hepp, et al. 2017), and enhance the potential for submerged landscape site discovery (Missiaen, et al. 2017). Subsequent core samples of subsurface stratigraphy would also be suggested to reconstruct ancient depositional environments while minimally disturbing below surface material (Stein 1986; Westley, et al. 2011).

A final suggestion would be a systematic prospection of underwater cave formations in the Central Visayan Region. A dive survey for submerged caves systems that meet the requisite criteria of prehistoric caves sites throughout the Philippines, needs photographic documentation and to be marked with a global positioning system for future investigation. A coupling with the Filipino Cave Divers, a non-profit organization dedicated to the exploration of underwater caves in the Philippines, would benefit the search for inundated sites of archaeological significance. The concentrated effort between various institutions such as the National Museum of the Philippines; the Archaeological Studies Program at the University of the Philippines, Diliman; the National Institute of Geological Sciences at the University of the Philippines, Diliman; Philippine oil and gas industries; and Australian or other foreign universities, could aid in the enhancement of dating techniques and development of submerged landscape studies for underwater site discovery in the Philippine Archipelago.

7 REFERENCES CITED

A. Lagmay, A. M. F., B. A. Racoma, K. A. Aracan, J. Alconis-Ayco and I. L. Saddi

2017 Disseminating near-real-time hazards information and flood maps in the Philippines through Web-GIS. *Journal of Environmental Sciences* 59(Supplement C):13-23.

Abrogueña, J. B. R., T. U. Bagarinao and L. Chicharo

2012 Fish habitats in a small, human-impacted Sibunag mangrove creek (Guimaras, Philippines): a basis for mangrove resource enhancement. *Ecohydrology & Hydrobiology* 12(4):311-319.

Aliño, P. M. and C. R. I. N. o. t. Philippines

2002 *Atlas of Philippine Coral Reefs*. Goodwill Bookstore.

Allen, J., C. Gosden, R. Jones and P. J. White

1988 Pleistocene dates for the human occupation of New Ireland, northern Melanesia. *Nature* 331(6158):707.

Allen, J., C. Gosden and J. P. White

1989 Pleistocene New Ireland. *Antiquity* 63:548-561.

Allen, J., J. F. O'Connell, G. R. Clark, S. O'Connor and B. F. Leach

2008 *Islands of Inquiry: Colonisation, Seafaring and the Archaeology of Maritime Landscapes*. ANU Press, Canberra.

Andersen, S. H.

2011 Ertebølle canoes and paddles from the submerged habitation site of Tybrind Vig, Denmark. In *Submerged Prehistory*, edited by J. Benjamin, C. Bonsall, C. Pickard and A. Fischer, pp. 1-14. Oxbow Books, Havertown, UNITED STATES.

Angus Jr, P. M. and D. T. Jaque

1996 Bantayan Island water resources study. *Transactions on Ecology and the Environment* 12:111-120.

Aubert, M., A. Brumm, M. Ramli, T. Sutikna, E. W. Saptomo, B. Hakim, M. J. Morwood, G. D. V. D. Bergh, L. Kinsley and A. Dosseto

2014 Pleistocene cave art from Sulawesi, Indonesia. *Nature* 514(7521):223.

Bailey, G.

2011 Continental shelf archaeology : where next? In *Submerged Prehistory*, edited by J. Benjamin, G. Bonsall, K. Pickard and A. Fischer, pp. 311-331. Oxbow Books, Havertown.

Bailey, G.

2011 Continental Shelf Archaeology: where next? In *Submerged Prehistory*, edited by J. Benjamin, C. Bonsall, C. Pickard and A. Fischer. Havertown: Oxbow Books, Havertown.

Bailey, G. N. and N. C. Flemming

2008 Archaeology of the continental shelf: Marine resources, submerged landscapes and underwater archaeology. *Quaternary Science Reviews* 27(23-24):2153-2165.

Bailey, G. N., N. C. Flemming, G. C. King, K. Lambeck, G. Momber, L. J. Moran, A. Al-Sharekh and C. Vita-Finzi

2007 Coastlines, submerged landscapes, and human evolution: the Red Sea Basin and the Farasan Islands. *The Journal of Island and Coastal Archaeology* 2(2):127-160.

Balme, J., I. Davidson, J. McDonald, N. Stern and P. Veth

2009 Symbolic behaviour and the peopling of the southern arc route to Australia. *Quaternary International* 202(1):59-68.

Barker, G., H. Barton, M. Bird, P. Daly, I. Datan, A. Dykes, L. Farr, D. Gilbertson, B. Harrisson, C. Hunt, T. Higham, L. Kealhofer, J. Krigbaum, H. Lewis, S. McLaren, V. Paz, A.

Pike, P. Piper, B. Pyatt, R. Rabett, T. Reynolds, J. Rose, G. Rushworth, M. Stephens, C. Stringer, J. Thompson and C. Turney

2007 The ‘human revolution’ in lowland tropical Southeast Asia: the antiquity and behavior of anatomically modern humans at Niah Cave (Sarawak, Borneo). *Journal of Human Evolution* 52(3):243-261.

Bautista, A.

1995 *Summary Report, Visit, and Assessment of On-Going Archaeological Excavation at Ulilang Bundoc Site, Dayap, Tanagan, Calatagan, Batangas. Field Report*. Manila, Philippines: National Museum.

Bednarik, R. G.

2003 Seafaring in the Pleistocene. *Cambridge Archaeological Journal* 13:41-66.

Benjamin, J.

2007 *The Submerged Prehistory of Europe: A Methodological Approach to Underwater Site Discovery with Special Reference to the Mesolithic and Neolithic of the Eastern Adriatic*.

Benjamin, J.

2010 Submerged Prehistoric Landscapes and Underwater Site Discovery: Reevaluating the ‘Danish Model’ for International Practice. *The Journal of Island and Coastal Archaeology* 5(2):253-270.

Benjamin, J. and R. Mackintosh

2016 Regulating Scientific Diving and Underwater Archaeology: legal and historical considerations. *International Journal of Nautical Archaeology* 45(1):153-169.

Berdin, R. D., F. P. Siringan and Y. Maeda

2004 Holocene sea-level highstand and its implications for the vertical stability of Panglao Island, southwest Bohol, Philippines. *Quaternary International* 115–116:27-37.

Beyer, H. O.

1947 Outline review of Philippine archaeology by islands and provinces. *The Phlippine Journal of Science* 77:3-4.

Biagi, P.

2013 The shell middens of Las Bela coast and the Indus delta (Arabian Sea, Pakistan. *Arabian Archaeology and Epigraphy* 24(1):9-14.

Bird, M. I., E. M. Boobyer, C. Bryant, H. A. Lewis, V. Paz and W. E. Stephens

2007 A long record of environmental change from bat guano deposits in Makangit Cave, Palawan, Philippines. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 98(1):59-69.

Bird, M. I., D. Taylor and C. Hunt

2005 Palaeoenvironments of insular Southeast Asia during the Last Glacial Period: a savanna corridor in Sundaland? *Quaternary Science Reviews* 24(20–21):2228-2242.

Birdsell, J. B., J. Allen, J. Golson and R. Jones

1977 *Sunda and Sahul: Prehistoric Studies in Southeast Asia, Melanesia, and Australia*. NY: Academic Press, New York.

BMG

2010a 1:50,000 Geohazard map of Daanbantayan Quadrangle, Sheet 3853 IV. Bureau of Mines and Geo-Sciences.

2010b 1:50,000 Geohazard map of Ilog Quadrangle, Sheet 3550 III. Bureau of Mines and Geo-Sciences.

2010c 1:50,000 Geohazard map of Isabela Quadrangle, Sheet 3550 I. Bureau of Mines and Geo-Sciences.

2010d 1:50,000 Geohazard map of Madrdejos Quadrangle, Sheet 3753 I. Bureau of Mines and Geo-Sciences.

2010e 1:50,000 Geohazard map of Pontevedra Quadrangle, Sheet 3551 II. Bureau of Mines and Geo-Sciences, Manila.

2010f 1:50,000 Geohazard map of Pulupandan Quadrangle, Sheet 3551 I. Bureau of Mines and Geo-Sciences, Manila.

2010g 1:50,000 Geohazard map of Sante Fe Quadrangle, Sheet 3753 II. Bureau of Mines and Geo-Sciences.

2011h 1:50,000 Geohazard map of Miagao Quadrangle, Sheet 3451 I. Bureau of Mines and Geo-Sciences, Manila.

Bolliet, T., A. Holbourn, W. Kuhnt, C. Laj, C. Kissel, L. Beaufort, M. Kienast, N. Andersen and D. Garbe-Schönberg

2011 Mindanao Dome variability over the last 160 kyr: Episodic glacial cooling of the West Pacific Warm Pool. *Paleoceanography* 26(1):1-18.

Boquet, Y. T.

2017 *The Philippine Archipelago*. Cham : Springer International Publishing : Imprint Springer (Online Service), Switzerland.

Brill, D., S. M. May, M. Engel, M. Reyes, A. Pint, S. Opitz, M. Dierick, L. A. Gonzalo, S. Esser and H. Brückner

2016 Typhoon Haiyan's sedimentary record in coastal environments of the Philippines and its palaeotempestological implications. *Natural Hazards and Earth System Sciences* 16(12):2799-2822.

Brown, P., T. Sutikna, M. J. Morwood, R. P. Soejono, E. Jatmiko and R. A. Due

2004 A new small-bodied homonin from the Late Pleistocene of Flores, Indonesia. *Nature* 431:1055-1061.

Bureau of Mines and Geo-Sciences (BMG)

2011 1:50,000 Geohazard map of Estancia Quadrangle, Sheet 3654 III. vol. 2017. Bureau of Mines and Geo-Sciences, Manila.

Burgess, A., G. Bailey, N. C. Flemming, J. Harff and D. Moura

2017 *Submerged Landscapes of the European Continental Shelf, Volume I : Quaternary Paleoenvironments*. Hoboken: John Wiley &ampSons, Incorporated, Hoboken.

Bynoe, R., J. Dix and F. Sturt

2016 Of mammoths and other monsters: historic approaches to the submerged Palaeolithic. *Antiquity* 90(352):857-875.

Cai, S. and Y. He

2010 Association of the Sulu Sea surface circulation with the South China Sea. *Journal of Marine Systems* 81(4):335-340.

Carating, R. B.

2014 *Soils of the Philippines*. World Soils Book Series. Dordrecht : Springer, Dordrecht.

Carating, R. B., R. G. Galanta and C. D. Bacatio

2014 *Soils of the Philippines*. Dordrecht : Springer.

Carbias, a., I. Cartajena, R. Simonetti, P. López, C. Morales and C. Ortega

2014 Submerged Paleolandscapes: Site GNL Quintero 1 (GNLQ1) and the First Evidences from the Pacific Coast of South America. In *Prehistoric Archaeology on the Continental Shelf: A Global Review*, edited by A. M. Evans, J. C. Flatman and N. C. Flemming, pp. 131-149. Springer New York, New York, NY.

Casipe, K. P., K. E. S. Espinosa, C. J. M. Jarabelo and M. E. L. de la Paz

2013 Foraging behavior association between Irrawaddy dolphins (Orcaella brevirostris) and tidal net fisheries in the coastal waters of Pulupandan, Negros Occidental, Philippines. *The Technical Journal of Philippine Ecosystems and Natural Resources* 25(1 & 2):67-92.

Chappell, J. and H. Polach

1991 Post-glacial sea-level rise from a coral record at Huon Peninsula, Papua New Guinea. *Nature* 349(6305):147.

Chiocci, F. L., D. Casalbore, F. Marra, F. Antonioli and C. Romagnoli

2017 Relative sea level rise, palaeotopography and transgression velocity on the continental shelf. In *Under the sea : archaeology and palaeolandscapes of the Continental Shelf*, edited by G. N. Bailey, J. Harff and D. Sakellariou. Cham, Switzerland : Springer International Publishing.

Clark, J., J. X. Mitrovica and J. Alder

2014 Coastal paleogeography of the California–Oregon–Washington and Bering Sea continental shelves during the latest Pleistocene and Holocene: implications for the archaeological record. *Journal of Archaeological Science* 52(Supplement C):12-23.

Clarkson, C., Z. Jacobs, B. Marwick, R. Fullagar, L. Wallis, M. Smith, R. G. Roberts, E. Hayes, K. Lowe, X. Carah, S. A. Florin, J. McNeil, D. Cox, L. J. Arnold, Q. Hua, J. Huntley, H. E. A. Brand, T. Manne, A. Fairbairn, J. Shulmeister, L. Lyle, M. Salinas, M. Page, K. Connell, G. Park, K. Norman, T. Murphy and C. Pardoe

2017 Human occupation of northern Australia by 65,000 years ago. *Nature* 547(7663):306-310.

Clarkson, C., M. Smith, B. Marwick, R. Fullagar, L. A. Wallis, P. Faulkner, T. Manne, E. Hayes, R. G. Roberts, Z. Jacobs, X. Carah, K. M. Lowe, J. Matthews and S. A. Florin

2015 The archaeology, chronology and stratigraphy of Madjedbebe (Malakunanja II): A site in northern Australia with early occupation. *Journal of Human Evolution* 83:46-64.

Clausen, C. J., A. D. Cohen, C. Emiliani, J. A. Holman and J. J. Stipp

1979 Little Salt Springs Florida: a unique underwater site. *Science* 203(4381):609-614.

Clune, G. and R. Harrison

2009 Coastal shell middens of the Abydos coastal plain, Western Australia. *Archaeology in Oceania* 44(S1):70-80.

Coast, U. S. and S. Geodetic

1919 *United States coast pilot, Philippine Islands*. Washington: Govt. print. off.

Correll, D. L.

1978 Estuarine productivity. *Bioscience* (1):565-648.

Coutts, P. and J. Wesson

1979 Field reconnaissance on eastern Panay Island, Philippines. *Bulletin of the Indo-Pacific Prehistory Association* 1:21-46.

Coutts, P. J. F. and J. P. Wesson

1980 Models of Philippine prehistory: a review of the flaked stone inudstries. *Philippine Quarterly Research in Culture and Society* 8:203-259.

Cranbrook, E.

2000 Northern Borneo environments of the past 40,000 years: Archaeozoological evidence. *Sarawak Museum Journal* 76:61-110.

Dannenmann, S., B. K. Linsley, D. W. Oppo, Y. Rosenthal and L. Beaufort

2003 East Asia monsoon forcing of suborbital variability in the Sulu Sea during Marine Isotope Stage 3: link to Northern Hemisphere climate. *Geochemistry, Geophysics, Geosystems* 4(1):1-13.

David, B., B. Barker, F. Petchey, J. J. Delannoy, J. M. Geneste, C. Rowe, M. Eccleston, L. Lamb and R. Whear

2013 A 28,000 year old excavated painted rock from Nawarla Gambarnmang, northern Australia. *Journal of Archaeological Science* 40(5):2493-2501.

de Garidel-Thoron, T., L. Beaufort, B. K. Linsley and S. Dannenmann

2001 Millennial-scale dynamics of the east Asia winter monsoon during the last 200,000 years. *Paleoceanography* 16(5):491-502.

De Waele, J., F. Gutiérrez, M. Parise and L. Plan

2011 Geomorphology and natural hazards in karst areas: A review, pp. 1-8. vol. 134.

Delfin, F., J. M. Salvador, G. C. Calacal, H. B. Perdigon, K. A. Tabbada, L. P. Villamor, S. C. Halos, E. Gunnarsdóttir, S. Myles, D. A. Hughes, S. Xu, L. Jin, O. Lao, M. Kayser, M. E. Hurles, M. Stoneking and M. C. A. De Ungria

2011 The Y-chromosome landscape of the Philippines: extensive heterogeneity and varying genetic affinities of Negrito and non-Negrito groups. *European Journal of Human Genetics : EJHG* 19(2):224-230.

Demeter, F., L. L. Shackelford, A.-M. Bacon, P. Duringer, K. Westaway, T. Sayavongkhamdy, J. Braga, P. Sichanthongtip, P. Khamdalavong, J.-L. Ponche, H. Wang, C. Lundstrom, E. Patole-Edoumba and A.-M. Karpoff

2012 Anatomically modern human in Southeast Asia (Laos) by 46 ka. *Proceedings of the National Academy of Sciences* 109(36):14375-14380.

DENR-PAWB

2009 *Cave classification handbook*. Department of Environment and Natural Resources, Quezon City, Philippines.

2013 The National Wetlands action plan for the Philippines 2011-2016, edited by D. o. E. a. N. Resources, pp. 1-86. Department of Environment and Natural Resources, Philippines.

Détroit, F., J. Corny, E. Dizon and A. Mijares

2013 "Small Size" in the Philippine Human Fossil Record: Is It Meaningful for a Better Understanding of the Evolutionary History of the Negritos? *Human Biology* 85(1-3):45-65.

Détroit, F., E. Dizon, C. Falguères, S. Hameau, W. Ronquillo and F. Sémah

2004 Upper Pleistocene Homo sapiens from the Tabon cave (Palawan, The Philippines): description and dating of new discoveries. *Comptes Rendus Palevol* 3(8):705-712.

Diana, N.

2015 Geometric microliths as chronological and cultural markers in the Sado shell middens? Reflections from Amoreiras (Alcácer do Sal, Portugal). *Nailos: Estudios Interdisciplinares de Arqueología* 2:89-122.

Dixon, J. E. and K. Monteleone

2014 Gateway to the Americas: Underwater Archeological Survey in Beringia and the North Pacific. In *Prehistoric Archaeology on the Continental Shelf: A Global Review*, edited by A. M. Evans, J. C. Flatman and N. C. Flemming, pp. 95-114. Springer New York, New York, NY.

Dizon, E.

2003 New direct dating of the human fossils from Tabon cave, Palawan, Philippines. *Proceedings of the Society of Philippine Archaeologists* 1:63-67.

Dizon, E. Z., F. Détroit, F. Sémah, C. Falguères, S. Hameau, W. Ronquillo and E. Cabanis

2002 Notes on the morphology and age of the Tabon cave fossil Homo sapiens. *Current Anthropology* 43:660-666.

Dizon, E. Z. and A. F. Pawlik

2010 The lower palaeolithic record in the Philippines. *Quaternary International* 223–224:444-450.

Eckhardt, R. B., M. Henneberg, A. S. Weller and K. J. Hsü

2014 Rare events in earth history include the LB1 human skeleton from Flores, Indonesia, as a developmental singularity, not a unique taxon. *Proceedings of the National Academy of Sciences* 111(33):11961-11966.

Erlandson, J. M.

2001 The archaeology of aquatic adaptations: Paradigms for a new millennium. *Journal of Archaeological Research* 9:287-350.

Erlandson, J. M. and S. M. Fitzpatrick

2006 Oceans, Islands, and Coasts: Current Perspectives on the Role of the Sea in Human Prehistory. *The Journal of Island and Coastal Archaeology* 1(1):5-32.

Esselstyn, J. A., P. Widmann and L. R. Heaney

2004 The mammals of Palawan Island, Philippines. *Proceedings of the Biological Society of Washington* 117:271-302.

Fairbanks, R. G.

1989 A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. *Nature* 342(6250):637-642.

Faught, M. K.

2004 Submerged Paleoindian and Archaic Sites of the Big Bend, Florida. *Journal of Field Archaeology* 29(3-4):273-290.

Ferrer, A. J. G.

2011 Evalution of fisheries management options for Visayan Sea, Philippines: The case of Northern Iloilo, edited by D. o. A.-B. o. F. a. A. Resources, pp. 1-26. University of the Philippines Visayas, Philippnes.

Fischer, A.

1993 *Stenalderbopladser på bunden af Smålandsfarvandet. En teori afprøvet ved dykkerbesigtigelse*.

1995 *Man and Sea in the Mesolithic: Coastal Settlement Above and Below Present Sea Level*.

Fischer, A. and N. C. Flemming

2004 *Submarine Prehistoric Archaeology of the North Sea*. Research Report.

Fischer, A., N. Milner and G. Bailey

2007 Shell Middens and Coastal Resources along the Atlantic Façade. Held in York September 2005.

Fischer, A., A. Pedersen and B. Aaby

1997 *The Danish Storebælt Since the Ice Age-Man, Sea and Forest.*

Flemming, N.

2010 Comment on Jonathan Benjamin's 'Submerged Prehistoric Landscapes and Underwater Site Discovery: Reevaluating the 'Danish Model' for International Practice'. *The Journal of Island and Coastal Archaeology* 5(2):274-276.

Flemming, N. C.

2004 *Submarine Prehistoric Archaeology of the North Sea: Research Priorities and Collaboration with Industry* . York: Council for British Archaeology, New York.

Flemming, N. C., M. N. Çağatay, F. L. Chiocci, N. Galanidou, H. Jöns, G. Lericolais, T. Missiaen, F. Moore, A. Rosentau and D. Sakellariou

2014 *Land beneath the waves: submerged landscapes and sea level change: a joint geoscience-humanities strategy for European Continental Shelf Prehistoric Research* 21. European Marine Board.

Fontanals-Coll, M., M. E. Subirà, N. Marín-Moratalla, J. Ruiz and J. F. Gibaja

2014 From Sado Valley to Europe: Mesolithic dietary practices through different geographic distributions. *Journal of Archaeological Science* 50:539-550.

Fox, R. B.

1970 *The Tabon Caves: Archaeological explorations and excavations on Palawan Island, Philippines*.

Fox, R. B. and F. Ikawa-Smith

1978 *Early Palaeolithic in South and East Asia*.

Gagan, M. K., E. J. Hendy, S. Haberle and W. S. Hantoro

2004 Post-glacial evolution of the Indo-Pacific Wam Pool and El Niño-Southern oscillation. *Quaternary International* 118-119:127-143.

Galili, E., M. Weinstein-Evron, I. Hershkovitz, A. Gopher, M. Kislev, O. Lernau, L. Kolska-Horwitz and H. Lernaut

1993 Atlit-Yam: A prehistoric site on the sea floor off the Israel coast. *Journal of Field Archaeology* 20(2):133-157.

Goggin, j.

1960 Underwater archaeology: its nature and limitations. *American Antiquity* 25(3):348-354.

Gomes, S. M., M. Bodner, L. Souto, B. Zimmermann, G. Huber, C. Strobl, A. W. Röck, A. Achilli, A. Olivieri, A. Torroni, F. Côrte-Real and W. Parson

2015 Human settlement history between Sunda and Sahul: a focus on East Timor (Timor-Leste) and the Pleistocenic mtDNA diversity. *BMC Genomics* 16(1):70.

Gomez-Robles, A.

2016 The dawn of Homo floresiensis. *Nature* 534:188.

González, A. H., C. R. Sandoval, E. A. Núñez, J. A. Olguín, S. A. Ramírez, O. del Río Lara, P. L. Erreguerena, V. Morlet, W. Stinnesbeck, A. T. Mata and M. B. Sanvincente

2010 Evidence of Early Inhabitants in Submerged Caves in Yucatan, Mexico. In *Underwater and Maritime Archaeology in Latin America and the Caribbean*, edited by P. Luna Erreguerena and J. Aviles. Walnut Creek : Left Coast Press, Walnut Creek.

Groube, L., J. Chappell, J. Muke and D. Price

1986 A 40,000 year-old human occupation site at Huon Peninsula, Papua New Guinea. *Nature* 324:453-455.

Gulley, J. D., J. B. Martin, P. J. Moore and J. Murphy

2013 Formation of phreatic caves in an eogenetic karst aquifer by CO 2 enrichment at lower water tables and subsequent flooding by sea level rise. *Earth Surface Processes and Landforms* 38(11):1210-1224.

Hanebuth, T., K. Stattegger and P. M. Grootes

2000 Rapid Flooding of the Sunda Shelf: A Late-Glacial Sea-Level Record. *Science* 288:1033.

Hanebuth, T. J. J. and K. Stattegger

2004 Depostional sequences on a late Pleistocene-Holocene tropical silicclastic shelf (Sunda Shelf, Southeast Asia). *Journal of Asian Earth Sciences* 23:113-126.

Heaney, L.

1986 Biogeographic evidence for middle and late Pleistocene land bridges to the Philippine islands. *Biological Journal of the Linnean Society* 28:127-143.

Heaney, L. R.

1991 A synopsis of climatic and vegetational change in southeast Asia. *Climate Change* 19:53-61.

Heaney, L. R., P. J. Piper and A. S. B. Mijares

2011 The first fossil record of endemic murid rodents from the Philippines: a late Pleistocene cave fauna from northern Luzon. *Proceedings of the Biological Society of Washington* 124(3):234-247.

Henneberg, M., R. B. Eckhardt, S. Chavanaves and K. J. Hsü

2014 Evolved developmental homeostasis disturbed in LB1 from Flores, Indonesia, denotes Down syndrome and not diagnostic traits of the invalid species Homo floresiensis. *Proceedings of the National Academy of Sciences* 111(33):11967-11972.

Hepp, D. A., U. Warnke, D. Hebbeln and T. Mörz

2017 Tributaries of the Elbe Palaeovalley: features of a hidden palaeolandscape in the German bight, North Sea. In *Under the Sea: Archaeology and Palaeolandscapes of the*

Continental Shelf, edited by G. N. Bailey, J. Harff and D. Sakellariou. Springer International Publishing, Cham, Switzerland.

Hill, C., P. Soares, M. Mormina, V. Macaulay, D. Clarke, Petya B. Blumbach, M. Vizuete-Forster, P. Forster, D. Bulbeck, S. Oppenheimer and M. Richards

2007 A Mitochondrial Stratigraphy for Island Southeast Asia. *American Journal of Human Genetics* 80(1):29-43.

Hurlburt, H. E. and E. J. Metzger

2009 Flow through the Straits of the Philippine Archipelago Simulated by Global HYCOM and EAS NCOM, edited by M. S. Naval Research Lab Stennis Space Center.

Jerardino, A.

2010 Large shell middens in Lamberts Bay, South Africa: a case of hunter-gatherer resource intensification. *Journal of Archaeological Science* 37(9):2291.

Kealy, S., J. Louys and S. O'Connor

2016 Islands Under the Sea: A Review of Early Modern Human Dispersal Routes and Migration Hypotheses Through Wallacea. *The Journal of Island and Coastal Archaeology* 11(3):364-384.

Kealy, S., J. Louys and S. O'Connor

2017 Reconstructing palaeogreography and inter-island visibility in the Wallacean Archipelago during the likely period of Sahul colonization, 65-45000 years ago. *Archaeological Prospection* (9999):1-14.

Kelley, J. T., D. F. Belknap and S. Claesson

2010 Drowned coastal deposits with associated archaeological remains from a sea-level "slowstand": Northwestern Gulf of Maine, USA. *Geology* 38(8):695-698.

Lacroix, D., T. Bell, J. Shaw and K. Westley

2014 Submerged Archaeological Landscapes and the Recording of Precontact History: Examples from Atlantic Canada. In *Prehistoric Archaeology on the*

Continental Shelf: A Global Review, edited by A. M. Evans, J. C. Flatman and N. C. Flemming, pp. 13-35. Springer New York, New York, NY.

Lacsina, L.

2015 The Butuan Boats of the Philippines: Southeast Asia edge-joined and lashed-lug watercraft. *AMIA Bulletin* 39:126-132.

Lee, H. S. and K. O. Kim

2015 Storm Surge and Storm Waves Modelling Due to Typhoon Haiyan in November 2013 with Improved Dynamic Meteorological Conditions. *Procedia Engineering* 116:699-706.

Lewis, H.

2007 Preliminary soil micromorphology studies of landscape and occupation history at Tabon Cave, Palawan, Philippines. *Geoarchaeology* 22(7):685-708.

Lewis, H., V. Paz, M. Lara, H. Barton, P. Piper, J. Ochoa, T. Vitales, A. J. Carlos, T. Higham, L. Neri, V. Hernandez, J. Stevenson, E. C. Robles, A. Ragragio, R. Padilla, W. Solheim and W. Ronquillo

2008 Terminal Pleistocene to mid-Holocene occupation and an early cremation burial at Ille Cave, Palawan, Philippines. *Antiquity* 82(316):318-335.

Lighty, R. G., I. G. Macintyre and R. Stuckenrath

1982 Acropora palmata reef framework: a reliable indicator of sea level in the western Atlantc for the past 10,000 years. *Coral Reefs* 1(2):125 - 130.

Maeda, Y., F. Siringan, A. Omura, R. Berdin, Y. Hosono, S. Atsumi, T. Nakmaura and T. Nakamura

2004 Higher-than-present Holocene mean sea level in Ilocos, Palawan and Samar, Philippines. *Quaternary International* (115-116):15-26.

Manguin, P.-Y.

1993 Trading ships of the South China Sea: shipbuilding techniques and their role in the history of the development of Asian trade networks. *Journal of the Economic and Social History of the Orient* 36(3):253-280.

Mapsof.net

2017a Map of Southeast Asia.

2017b Philippine regions map.

Masters, P.

1983 Detection and assessment of prehistoric artifact sites off the coast of southern California. In *Quaternary Coastlines and Maritime Archaeology*, edited by N. C. Flemming and P. Masters, pp. 189-213. Academic Press, London.

Masters, P. M. and N. C. Flemming

1983 *Quaternary Coastlines and Marine Archaeology: Towards the Prehistory of Land Bridges and Continental Shelves*. Academic Press, London.

McGrail, S.

2001 *Boats of the world*. Oxford University Press, Oxford.

Mijares, A. S. B.

2002 *The Minori Cave Expedient Lithic Technology. Contributions to Archaeology Series*.

2005 The archaeology of Peñablanca cave site, northern Luzon, Philippines. *Proceedings of the Society of Philippine Archaeologists* 2(2):65-92.

2008 The Peñablanca flake tools: an unchanging technology? *Hukay Journal of the University of the Philippines Archaeological Studies Program* 12:13-34.

Mijares, A. S. B., F. Détroit, P. Piper, R. Grün, P. Bellwood, M. Aubert, G. Champion, N. Cuevas, A. De Leon and E. Z. Dizon

2010 New evidence for a 67,000-year-old human presence at Callao Cave, Luzon, Philippines. *Journal of Human Evolution* 59(1):123-132.

Missiaen, T., D. Sakellariou and N. C. Flemming

2017 Survey strategies and techniques in underwater geoarchaeological research: an overview with emphasis on prehistoric sites. In *Under the sea : archaeology and palaeolandscapes of the Continental Shelf*, edited by G. N. Bailey, J. Harff and D. Sakellariou. Cham, Switzerland : Springer International Publishing.

Mitsunaga, Y., C. Endo, K. Anraku, C. M. Selorio and R. P. Babaran

2012 Association of early juvenile yellowfin tuna Thunnus albacares with a network of payaos in the Philippines. *Fisheries science* 78(1):15-22.

Molengraaff, G. A. F.

1921 Modern Deep-Sea Research in the East Indian Archipelago. *The Geographical Journal* 57(2):95-118.

Momber, G.

2000 Drowned and deserted: a submerged prehistoric landscape in the Solent, England. *International Journal of Nautical Archaeology* 29(1):86-99.

Momber, G.

2011 Submerged landscape excavations in the Solent, southern Britian: climate change and cultural development. In *Submerged Prehistory*, edited by J. Benjamin, C. Bonsall, C. Pickard and A. Fischer. Oxbow Books, Havertown.

Morley, M. W.

2017 The geoarchaeology of hominin dispersals to and from tropical Southeast Asia: A review and prognosis. *Journal of Archaeological Science* 77(Supplement C):78-93.

Morwood, M. and P. Van Oosterzee

2007 *A New Human: The Startling Discovery and Strange Story of the "Hobbits" of Flores, Indonesia*. Routledge.

Morwood, M. J., P. B. O'Sullivan, F. Aziz and A. Raza

1998 Fission-track ages of stone tools and fossils on the East Indonesian island of Flores. *Nature* 392(2):173-176.

Mulyila, E. J., T. Matsuoka and K. Anraku

2012 Sustainability of fishers' communities in tropical island fisheries from the perspectives of resource use and management: a comparative study of Pohnpei (Micronesia), Mafia (Tanzania), and Guimaras (Philippines). *Fisheries Science* 78(4):947-964.

Nakajima, Y., Y. Matsuki, D. Arriesgado, W. Campos, K. Nadaoka and C. Lian

2017 Population genetics information for the regional conservation of a tropical seagrass, Enhalus acoroides , around the Guimaras Strait, Philippines. *Conservation Genetics* 18(4):789-798.

NAMRIA

1956 1:50,000 Topographic map of Cabalagnan Quadrangle, Sheet 3551 III. Department of Environment and Natural Resources National Mapping and Resource Information Authority, Fort Bonifacio, Makati.

1995 1:50,000 Topogrpahic map of Bantayan Quadrangle, Sheet 3723-III. Department of Environment and Natural Resources National Mapping and Resource Information Authority.

Neri, L.

2006 A possible Palaeolithic site in northern Mindanao. *Hukay Journal of the University of the Philippines Archaeological studies program* 10(2006):25-37.

2016 Obsidan from the Huluga open ste and its implications. *Hukay* 7:55-67.

Neri, L. A. M., A. F. Pawlik, C. Reepmeyer, A. S. B. Mijares and V. J. Paz

2015 Mobility of early islanders in the Philippines during the Terminal Pleistocene/Early Holocene boundary: pXRF-analysis of obsidian artefacts. *Journal of Archaeological Science* 61:149-157.

Neubauer, F.

2014 A brief overview of the last 10 years of major late Pleistocene discoveries in the old world: Homo floresiensis, Neanderthal, and Denisovan. *Journal of Anthropology* 2014(Article ID 581689):7.

Noblezada, M. M. P. and W. L. Campos

2012 Chaetognath assemblages along the Pacific Coast and adjacent inland waters of the Philippines: relative importance of oceanographic and biological factors. *ICES Journal of Marine Science* 69(3):410-420.

Nutley, D.

2014 Inundated Site Studies in Australia. In *Prehistoric Archaeology on the Continental Shelf: A Global Review*, edited by A. M. Evans, J. C. Flatman and N. C. Flemming, pp. 255-273. Springer New York, New York, NY.

O'Connor, S.

2007 New evidence from East Timor contributes to our understanding of earliest modern human colonisation east of the Sunda Shelf. *Antiquity* 81(313):523-535.

O’Connell, J. F. and J. Alien

2012 Forum The Restaurant At The End Of The Universe: Modelling the colonisation of Sahui. *Australian Archaeology* 74(1):5-31.

Ochoa, J., V. Paz, H. Lewis, J. Carlos, E. Robles, N. Amano and R. Ferreras

2014 The archaeology and palaeobiological record of Pasimbahan-Magsanib site, northern Palawan, Philippines. *Philippine Science Letters* 7:22-36.

Ollé, M.

2012 The Straits of the Philippine Islands in Spanish Sources (Sixteenth and Early Seventeenth Centuries). *Journal of Asian History* 46(2):181-192.

Omura, A., Y. Maeda, T. Kawana, F. P. Siringan and R. D. Berdin

2004 U-series dates of Pleistocene corals and their implications to the paleo-sea levels and the vertical displacement in the Central Philippines. *Quaternary International* 115:3-13.

Oppenheimer, S.

2009 The great arc of dispersal of modern humans: Africa to Australia. *Quaternary International* 202(1–2):2-13.

Pada, A., J. Silapan, M. Cabanlit, F. Campomanes and J. Garcia

2016 MANGROVE FOREST COVER EXTRACTION OF THE COASTAL AREAS OF NEGROS OCCIDENTAL, WESTERN VISAYAS, PHILIPPINES USING LID AR DATA. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences* 41.

Padilla, J. E. and A. C. Trinidad

1995 An application of production theory to fishing effort standardization in the small-pelagics fishery in central Philippines. *Fisheries Research* 22(1):137-153.

Parkington, J.

2003 Middens and moderns: shellfishing and the Middle Stone Age of the Western Cape, South Africa. *South African Journal of Science* 99.

Parreno, L. D. B., R. D. Caturao, J. A. T. Gerada, V. M. Bolano and J. G. Eledia

2015 Abundance and distributional ecology of irrawaddy dolphins (Orcaella brevirostris) in Guimaras Island. *Asian journal of biodiversity* 6(2):89-110.

Parreño, L. D. B., R. D. Caturao, J. A. T. Gerada, V. M. Bolano and J. G. Eledia

2016 Abundance and Distributional Ecology of Irrawaddy Dolphins (Orcaella brevirostris) in Guimaras Island. *Asian Journal of Biodiversity* 6(2).

Patole-Edoumba, E., A. F. Pawlik and A. S. B. Mijares

2012 Evolution of prehistoric lithic industries of the Philippines during the Pleistocene. *Comptes Rendus Palevol* 11(2):213-230.

Pawlik, A., P. Piper and A. S. B. Mijares

2014 Modern humans in the Philippines colonization, subsistence and new insights into behavioral complexity. In *Southern Asia, Australia and the search for human origins*, edited by R. W. Dennell and M. Porr, pp. 135-147. Cambridge Universtiy Press, New York.

Pawlik, A. F., P. J. Piper, M. G. P. G. Faylona, S. G. Padilla, J. Carlos, A. S. B. Mijares, B. Vallejo, M. Reyes, N. Amano, T. Ingicco and M. Porr

2014 Adaptation and foraging from the Terminal Pleistocene to the Early Holocene: Excavation at Bubog on Ilin Island, Philippines. *Journal of Field Archaeology* 39(3):230-247.

Pawlik, A. F., P. J. Piper, R. E. Wood, K. K. A. Lim, M. G. P. G. Faylona, A. S. B. Mijares and M. Porr

2015 Shell tool technology in Island Southeast Asia: an early Middle Holocene Tridacna adze from Ilin Island, Mindoro, Philippines. *Antiquity* 89:292+.

Paz, V.

2005 Rock Shelters, Caves, and Archaeobotany in Island Southeast Asia. *Asian Perspectives* 44(1):107-118.

Paz, V.

2012 Assessing past cosmologies through material culture and the landscape in the Philippines. In *Archaeology of spiritualities*, edited by K. Rountree, C. Morris and A. Peatfield, pp. 133-161. Springer New York, New York.

Pearson, C. E., R. A. Weinstein, S. M. Gagliano and D. B. Kelley

2014 Prehistoric Site Discovery on the Outer Continental Shelf, Gulf of Mexico, United States of America. In *Prehistoric Archaeology on the Continental Shelf: A*

Global Review, edited by A. M. Evans, J. C. Flatman and N. C. Flemming, pp. 53-72. Springer New York, New York, NY.

Peeters, H.

2011 How wet can it get—approaches to submerged prehistoric sites and landscapes on the Dutch continental shelf. In *Submerged Prehistory*, edited by J. Benjamin, C. Bonsall, C. Pickard and A. Fischer. Oxbow Books, Havertown.

Piper, P. J., J. Ochoa, V. Paz, H. Lewis and W. P. Ronquillo

2008 The first evidence for the past presence of tiger Panthera tigrs (L.) on the island of Palawan, Philippines: extinction n an island population. *Palaeoclimatology, Palaeogeography, Palaeoecology* 264(1):123-127.

Porr, M., A. S. B. Mijares, A. F. Pawlik, P. J. Piper and S. Padilla

2012 North of the Southern Arc – The Mindoro Archaeological Research Program: A summary of the 2010 and 2011 fieldwork activities. *Australian Archaeology* 75(1):110-117.

Rangin, C.

1991 The Philippine Mobile Belt: a complex plate boundary. *Journal of Southeast Asian Earth Sciences* 6(3):209-220.

Reich, D., N. Patterson, M. Kircher, F. Delfin, Madhusudan R. Nandineni, I. Pugach, Albert M.-S. Ko, Y.-C. Ko, Timothy A. Jinam, Maude E. Phipps, N. Saitou, A. Wollstein, M. Kayser, S. Pääbo and M. Stoneking

2011 Denisova Admixture and the First Modern Human Dispersals into Southeast Asia and Oceania. *The American Journal of Human Genetics* 89(4):516-528.

Rillera, F.

1995 Independent focuses Philippines exploration on Visayan basin. *Oil & Gas Journal* 93(34):68.

Roberts, P. and M. Petraglia

2015 Pleistocene rainforests: barriers or attractive environments for early human foragers? *World Archaeology* 47(5):718-739.

Roberts, R. G., M. J. Morwood and K. E. Westaway

2005 Illuminating Southeast Asia prehistory: new archaeological and paleoanthropological frontiers for luminescence dating. *Asian Perspectives* 44(2):293-319.

Robles, E.

2012 Estimates of Quaternary Philippine coaslines, land bridges, submerged river systems and mirgration routes: A GRASS GIS approach. *Hukay Journal of the University of the Philippines Archaeological studies program* 18:31-53.

Robles, E., P. Piper, J. Ochoa, H. Lewis, V. Paz and W. Ronquillo

2015 Late Quaternary Sea-Level Changes and the Palaeohistory of Palawan Island, Philippines. *The Journal of Island and Coastal Archaeology* 10(1):76-96.

Rocha, C., J. A. Peterson, A. Jalandoni, R. R. Chianelli and L. Ma

2017 Paleoenvironmental investigations, chemical analysis and characterization of underwater strata of Marigondon Cave. *Quaternary International* 431, Part B:223-231.

Ronquillo, W. and H. Ogawa

1996 The Calatagan Archaeological Report: a summary report. *journal of Southeast Asian Archaeology* 16:133-143.

Rosenthal, J. S., D. W. Oppo and B. K. Linsley

2003 The amplitude and phasing of climate change during the last deglaciation in the Sulu Sea, western equatorial Pacific. *Geophysical Research Letters* 30:1428.

Samanti, K., P. Nimal, U. D. Siran and P. Jude

2014 The Discovery and Excavation of a Human Burial from the Mini-athiliya Shell Midden in Southern Sri Lanka. *Ancient Asia* 5.

Santillan, J. R. and E. C. Paringit

2012 Hydrodynamic and Trajectory Modeling of the August 11, 2006 M/T Solar 1 Oil Spill in Guimaras, Central Philippines with Validation Using Envisat ASAR Data. *Proceedings of the Proceedings of the 33rd Asian Conference on Remote Sensing, ACRS 2012–Aiming Smart Space Sensing*:26-30.

Sathiamurthy, E. and H. K. Voris

2006 Maps of Holocene sea level transgression and submerged lakes on the Sunda Shelf. *The Natural History Journal of Chulalongkorn University, Supplement* 2:1-43.

Shen, G., W. Wang, Q. Wang, J. Zhao, K. Collerson, C. Zhou and P. V. Tobias

2002 U-Series dating of Liujiang hominid site in Guangxi, Southern China. *Journal of Human Evolution* 43(6):817-829.

Siringan, F. P., C.-C. Shen, K. Lin, M. I. T. Abigania and S.-Y. Gong

2016 Coral-based Holocene sea level of Paraoir, western Luzon, Philippines. *Journal of Asian Earth Sciences* 123:61-66.

Spoehr, A.

1968 *Archaeological survey of southern Zamboanga and the Sulu Archipelago*. University of Pittsburgh.

1973 Zamboanga and Sulu: an archaeological approach to ethnic diversity. In *Ethnology Monographs*. Department of Anthropology, University of Pittsburgh, Pittsburg.

Stein, J. K.

1986 Coring archaeological sites. *American Antiquity* 51(3):505-527.

Stewart, D.

1999 Formation processes affecting submerged archaeological sites: an overview. *Geoarchaeology: An International Journal* 14(6):565-587.

Stott, L., C. Poulsen, S. Lund and R. Thunell

2002 Super ENSO and global climate oscillations at millennial time scales. *Science (New York, N.Y.)* 297(5579):222.

Stringer, C.

2000 Coasting out of Africa. *Nature* 405:24-26.

Sutikna, T., M. W. Tocheri, M. J. Morwood, E. W. Saptomo, Jatmiko, R. D. Awe, S. Wasisto, K. E. Westaway, M. Aubert, B. Li, J.-x. Zhao, M. Storey, B. V. Alloway, M. W. Morley, H. J. M. Meijer, G. D. van den Bergh, R. Grün, A. Dosseto, A. Brumm, W. L. Jungers and R. G. Roberts

2016 Revised stratigraphy and chronology for Homo floresiensis at Liang Bua in Indonesia. *Nature* 532(7599):366-369N.

Szabó, K., M. C. S. Kelly, A. Peñalosa and V. Paz

2004 Prelminary results from excavations in the eastern mouth of Ille Cave, northern Palawan. In *Southeast Asian Archaeology. Wilhelm G. Solheim II Festschrift*, edited by V. Paz, pp. 209-224. vol. . University of the Philippines Press, Diliman.

Tizzard, L., P. A. Baggaley and A. J. Firth

2011 Seabed Prehistory: investigating palaeolandsurfaces with Palaeolithic remains from the southern North Sea. In *Submerged Prehistory*, edited by J. Benjamin, C. Bonsall and C. Pickard. Havertown : Oxbow Books, Havertown.

Turney, C. S., M. I. Bird, L. K. Fifield, R. G. Roberts, M. Smith, C. E. Dortch and R. Grün

2001 Early human occupation at Devil's Lair, southwestern Australia 50,000 years ago. *Quaternary Research* 55(1):3-13.

Uldum, O. C.

2011 The excavation of a mesolithic double burial from Tybrind Vig, Denmark. In *Submerged Prehistory*, edited by J. Benjamin, C. Bonsall, C. Pickard and A. Fischer, pp. 15-20. Oxbow Books, Havertown, UNITED STATES.

van Hengstum, P. J., D. B. Scott, D. R. Gröcke and M. A. Charette

2011 Sea level controls sedimentation and environments in coastal caves and sinkholes. *Marine Geology* 286(1–4):35-50.

Voris, H. K.

2000 Maps of Pleistocene sea levels in Southeast Asia: shorelines, river systems and time durations. *Journal of Biogeography* 27(5):1153-1167.

Waelbroeck, C., L. Labeyrie, E. Michel, J. C. Duplessy, J. F. McManus, K. Lambeck, E. Balbon and M. Labracherie

2002 Sea-level and Deep Water Temperature Changes Derived from Benthic Foraminifera Isotopic Records. *Quaternary Science Reviews* 21(1–3):295.

Wang, P., L. Wang, Y. Bian and Z. Jian

1995 Late Quaternary paleoceanography of the South China Sea: surface circulation and carbonate cycles. *Marine Geology* 127(1):145-165.

Ward, I., P. Larcombe and P. Veth

2015 A New Model for Coastal Resource Productivity and Sea-Level Change: The Role of Physical Sedimentary Processes in Assessing the Archaeological Potential of Submerged Landscapes from the Northwest Australian Continental Shelf. *Geoarchaeology* 30(1):19-31.

Westaway, M. C., A. C. Durband, C. P. Groves and M. Collard

2015 Mandibular evidence supports Homo floresiensis as a distinct species. *Proceedings of the National Academy of Sciences* 112(7):E604-E605.

Westley, K., T. Bell, R. Plets and R. Quinn

2011 Investigating Submerged Archaeological Landscapes: a search strategy illustrated wth case studies from Ireland and Newfoundland, Canada. In *Submerged Prehistory*, edited by J. Benjamin, C. Bonsall, C. Pickard and A. Fischer. Havertown: Oxbow Books, Havertown.

Whitty, T. S.

2015 Governance potential for cetacean bycatch mitigation in small-scale fisheries: A comparative assessment of four sites in Southeast Asia. *Applied Geography* 59(Supplement C):131-141.

Yender, R. and K. Stanzel

2011 *Tanker SOLAR 1 Oil Spill, Guimaras, Philippines: Impacts and Response Challenges-Chapter 38*. Elsevier Inc.

Yu, K. S., T. Thriveni, Y. Jegal and A. J. Whan

2017 A Brief Review on Limestone Sources and Oyster Waste Generation-Bantayan. *에너지공학* 26(1).

Yumul, G., N. Servando, L. Suerte, M. Magarzo, L. Juguan and C. Dimalanta

2012 Tropical cyclone–southwest monsoon interaction and the 2008 floods and landslides in Panay island, central Philippines: meteorological and geological factors. *Journal of the International Society for the Prevention and Mitigation of Natural Hazards* 62(3):827-840.

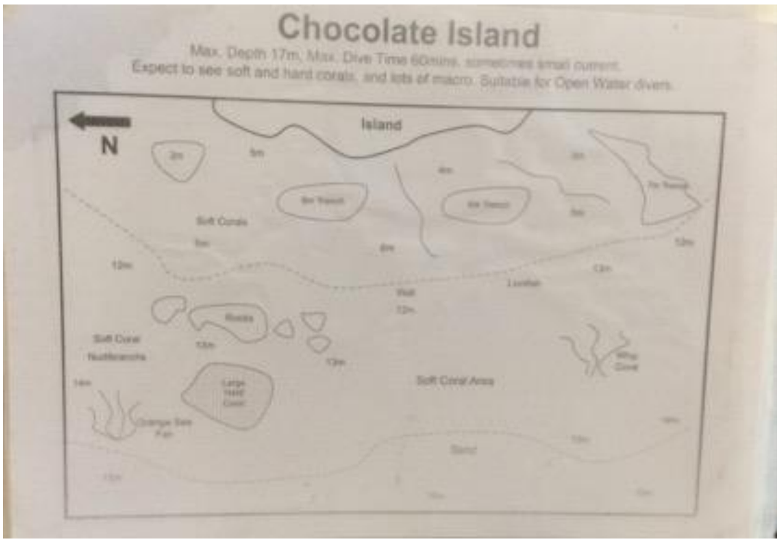
Yumul, G. P., C. B. Dimalanta, V. B. Maglambayan and E. J. Marquez

2008 Tectonic setting of a composite terrane: A review of the Philippine island arc system. *Geosciences Journal* 12(1):7-17.

8 APPENDIX

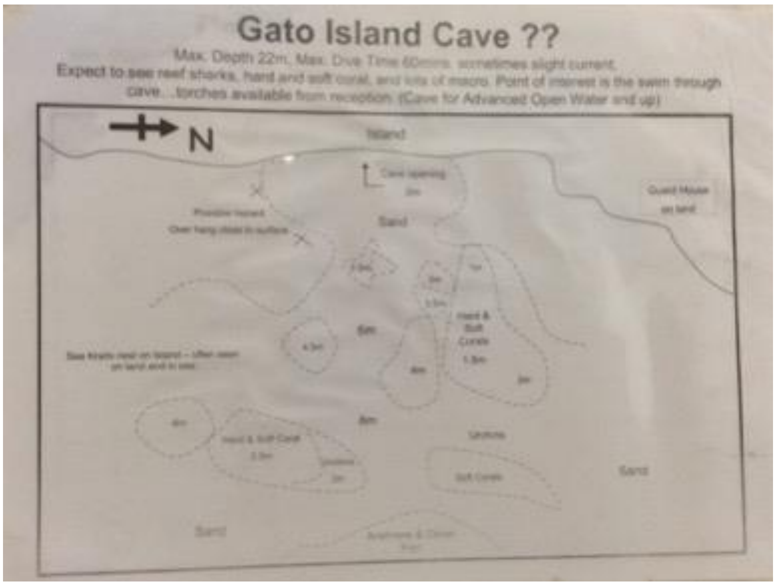
8.1 Dive Maps

8.1.1 Chocolate Island



8.1.2 Gato Island

8.1.2.1 Eastern Cave Entrance



8.1.2.2 Southern Cave Entrance