
Human History of Maritime Exploitation and Adaptation Process to Coastal and Marine Environments – A View from the Case of Wallacea and the Pacific

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Additional information is available at the end of the chapter

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Abstract

This chapter introduces the archaeological new findings and current outcomes for the past human marine exploitation and maritime or coastal adaptation particularly in the Wallacea region where I have studied for long time. One of the oldest and important data I discuss here is from Jerimalai Cave site from East Timor and Leang Sarru site from Talaud Islands. The finds from East Timor demonstrate the high level of maritime skills and technology possessed by the modern humans who colonized Wallacea. These skills would have made possible the occupation of the faunally depauperate islands of Wallacea and facilitated the early maritime colonization of Australia and Near Oceania. On the other hand, Leang Sarru site dated back to 35,000 years ago on Talaud Islands where located over 100 km away from neighbour islands. The site also produced large number of marine shells from the late Pleistocene via Last Glacial Maximum (LGM) to the early Holocene, then we can also discuss the past maritime exploitation and adaptation from the late Pleistocene to the early Holocene in the Talaud Islands, where located in Northern part of Wallacea. During the Holocene after 12,000 years ago, various capture technology invented, and great variety of fish and shellfish species had been exploited by modern human. Especially the fishing technology and Ocean navigation technology were developed after the Neolithic times in Wallacea to the Pacific. Most famous archaeological records related them are the Lapita migration and colonization to many islands in Melanesia to Western Polynesia where were mostly uninhabited islands before them. After the Lapita colonization, the Polynesians who are the descendant of Lapita people succeeded to colonize Hawaii, Easter Island, and New Zealand by the 12th to 13th centuries. The distance to these islands from their neighbour islands or continent is over 4000 km, hence the success of migration by the Polynesian clearly indicate their maritime adaption and navigation technology were highly developed. In fact, it is a dramatic event that modern human succeeded to migrate to all over the world except North and South Pole when the colonization to New Zealand was done by the Polynesians. It also shows that marine environment were our last target for migration and colonization in this world after the human birthed in and around inner forest environment over 600 million years ago. This chapter also discuss such developments of marine exploitation and maritime adap-

tation after the Holocene or Neolithic to modern times, then reviewing the human adaptation history to coastal and marine environments.

Keywords: Human history, maritime adaptation, fishing technology, Wallacea, Pacific

1. Introduction

Fish and shellfish are part of the major aquatic food resources and play significant role for human diet and tools for a long time, while its evolutionary process of exploiting such aquatic species by hominins who originally birthed in forest and terrestrial environments is yet unclear. The archaeological traces of the first human aquatic exploitation now back to over 2 million years ago, while the active use of marine resources including shellfish, fish, and other marine animals seems much later and possibly started by *Homo sapiens* known as modern humans. This chapter firstly introduces a brief history of marine use and maritime adaptation by early humans, including *H. sapiens*, and then discusses further maritime adaptation to Wallacea and Oceania, where the largest archipelago modern humans have migrated and lived after around 50 ka years ago up to now.

The term "Wallacea" came from Alfred Russel Wallace, who voyaged through the Malay Archipelago to recognize the zoogeographic divide running between Lombok and Bali, Borneo/Kalimantan Island, and Sulawes [1], now known as Wallace Line. The major factor to make such zoogeographic divide is the existence of deep sea between Lombok and Bali and the whole Wallacea Archipelago; hence, this line is defined for Wallace two natural provinces that had evolved during a long history of separation and isolation. Now we know Wallace Line is exactly running the past border of Sunda subcontinent coastline, and many Eurasian or Asian animals, especially mammals, could not or were hard to migrate into far east beyond the line in the past.

In terms of the past climate and wind water masses around Wallacea and Oceania, we should remember that the history of human migration mainly has corresponded to the Pleistocene to Holocene times. The Pleistocene is now estimated to have started around 2.6 million years ago corresponding to the glacial and interglacial cycles up to now in the latest interglacial period known as the Holocene. During the longer Pleistocene, the Earth's temperature had been cycled and separated into two stages as (1) cooler and dry period (glacial period) and (2) warmer and humid period (interglacial period). The average time-span of each stage was around 100 ka years. During the glacial period, huge ice sheets expanded in high latitude area and the world average sea level decreased down to 150 to 140 m when 6 million km³ water become ice sheet and more land area appeared. In the Southeast Asian region, Sunda subcontinent occurred as some major islands including Sumatra, Java, and Borneo (Kalimantan) were connected, while a huge Sahul Continent was formed by union of Australia and New Guinea in Oceania. Yet, the Wallacea region was never connected to these continents and formed as an archipelago even during the glacial period since their surrounding ocean is deeper than 150 m and hence become the water barrier to many animals for migration to Oceania.

However, Wallace recognized that it did not apply to the human occupants of the regions since he thought, “Man has means of transversing the sea which animals do not possess” [1:30]. Wallace inferred that maritime enterprise had allowed humans to travel between islands carrying with them their genes, language, cultural traits, domestic animals, and crops [2]. The current archaeological and anthropological evidences show that the earlier *Homo erectus* might not be able to go beyond the line. Only an exception is a human trace dated 84 ka in Flores Island, which is located in Wallacea. If this date is secure, the evidence shows that the later *H. erectus* might develop their maritime adaptation along the Sunda coast to cross the sea and migrate into islands in Wallacea.

However, all other archaeological traces of human maritime adaptation in Wallacea and Oceania are from the age of *Homo sapiens* and dated after around 50 ka years ago. One of the prominent evidences of our maritime adaption was the earlier modern human migration to Sahul Continent, since it was required to cross the sea over 80 km from Wallacea islands to Sahul even during the Late Pleistocene time with lower temperature and sea level. It also becomes the first migration to Oceania region by humans and long-distance ocean voyage in the world. Such archaeological evidences of modern human maritime adaptation far increased in both Wallacea and Oceania after the drastic sea rise and great increase of coastal distance during the Holocene with warmer temperature, which began around 12,000 years ago.

In Oceania, the islands in the South Pacific are used to be divided into (1) Near Oceania, which includes the past Sahul Continent and its neighboring islands between Bismarck Archipelago and Solomon Islands, and (2) Remote Oceania, which includes all other Melanesian Islands east beyond the Solomon Islands and whole Micronesia and Polynesian islands in the Pacific including Hawaii, New Zealand, and Easter Island (Rapa Nui). The highlight could be back to the first colonization by Austronesian-speaking people including Lapita people to the Remote Oceania Islands, which are located in remote and uninhabited islands before them around 3500 years ago. Some of their voyages for migration to new islands were required to cross the ocean over 800–2000 km; hence, they should have more sophisticated and high-level seafaring skills and maritime technology than their ancestors in the Late Pleistocene. In relation with the past climate and marine environment, the development of unstable sea conditions caused by ENSO from about 4–5000 years ago could be one of the factors for the development of more seaworthy craft and higher seafaring skills (e.g., [3]).

This chapter discusses such Holocene maritime adaptation and migration by modern humans based on our recent archaeological outcomes as well. With such discussions, we will see how the human maritime adaptation process has corresponded to the changes in the past marine environment including sea level, temperature, coastline, and marine resources.

1.1. Aquatic resource use by early hominins

Currently, the oldest trace of fish use by humans was found at the 1.95-million-year-old Oldowan site of FwJJ20 in Kenya (Fig. 1), and some early hominins possibly *Homo habilis* already exploited a varied diet including aquatic species such as freshwater fish singly occupied by catfish (*Clarias* sp.) family [4]. It is also reported that most of these catfish bones have cut marks and hence could be eaten by humans. However, most Oldowan-aged sites

including FwJ]20 produced only freshwater fish and over 80% of them were catfish, which could be captured by hand [5].

Although it is yet unclear whether these aquatic species were captured and discarded by humans or not, some early Rift Valley sites in East Africa have also produced the bones of aquatic animals, including crocodiles, fish, frogs, and shellfish, dated around 2.5 to 1.7 million years ago [6, 7]. Similarly, most of these fish are occupied by catfish species. On the other hand, some evidences of aquatic use by *Homo erectus* dated between 1.1 and 0.4 million years ago were also discovered in Africa and Southeast Asia. At Olduvai in Africa, Leakey reported that the bones of catfish and hippos are ubiquitous in artifact-bearing sediments [8], which also produced remains of crocodiles, aquatic turtles, and freshwater shellfish [7].

The relatively unambiguous use of aquatic resources, mainly freshwater shellfish by *Homo erectus* in Southeast Asia, comes from the site of Kao Pah Nam, a limestone cave in northern Thailand occupied about 700 ka [9] and the site at Trinil in Java, Indonesia, occupied around 500 to 400 ka (e.g., [10]). Based on these evidences, it is now acceptable that capture and use of freshwater fish and shellfish species possibly begun by early hominins (cf. *H. habilis* and *H. erectus*) could be the initial stage of human aquatic exploitation, since our ancient ancestors were originally birthed in mountain-forest environments in Africa back to over 6 million years ago.

After 400 ka during the stage of archaic *Homo sapiens*, archaeological evidences for aquatic resource use increases [7]. For instance, the Lower Paleolithic site of Hoxne in England produced numerous specimens of freshwater fish and beaver, smaller numbers of otter and waterfowl along with Clactonian artifacts dated 350 to 300 ka, which mainly correspond to an interglacial period [11]. Several North African Middle Paleolithic or Aterian sites, including Haua Fteah in Libya (e.g., [12]), Mugharet el'Aliya in Morocco [13], and several sites in Morocco and Algeria (e.g., [14, 15]) produced shellfish remains as well. Also in southern Europe, Monte Circeo [16] and Grimaldi caves [17] in Italy, Ramandils in France [18], and Devil's Tower Rockshelter [19], Gorham's Cave (e.g., [20]), and Vanguard Cave [21] in Gibraltar produced shellfish along with Mousterian stone tools assemblage.

Another archaic *Homo sapiens* site at Terra Amata along the Mediterranean coast of France also produced mussels and other marine shells about 300 ka, although their context and quantity are poorly documented [22,23]. If their context could be confirmed as really dated back to 300 ka, the use of marine shellfish by humans may possibly be started during the archaic *H. sapiens* species, including Neanderthals who occupied along the coastal area in Europe to Middle East. However, there is little evidence for the marine fish capture and use by Neanderthals or other archaic *H. sapiens* in the regions (e.g., [18]).

1.2. Development of aquatic and marine resource use by early modern humans

During Middle Stone Age (MSA) after 160 ka, aquatic resources become regularly visible in the diets of some groups of hominins, including modern humans (*Homo sapiens*), in Africa (Fig. 1). One of the early and solid evidences for marine shellfish consumption so far was found in Pinnacle Point in the south coast of South Africa dated around 160 ka (e.g., [24,25]). Klaises

River Cave (e.g., [26]) and Blombos Cave (e.g., [27,28]) in the South African coastal caves produced over 18 species of marine shellfish during the Middle Stone Age dated around 120 to 100 ka ([29]). Another early evidence for possible consumption of marine shells dated about 125 ka was also found near Abdur in Eritrea (Fig. 1) along the Red Sea coast ([30,31]). However, it is not clear whether these marine shells were consumed by modern humans or other hominids. It is also pointed that 10 km is the maximum transport distance for shellfish during the MSA stage (e.g. [32,33]).

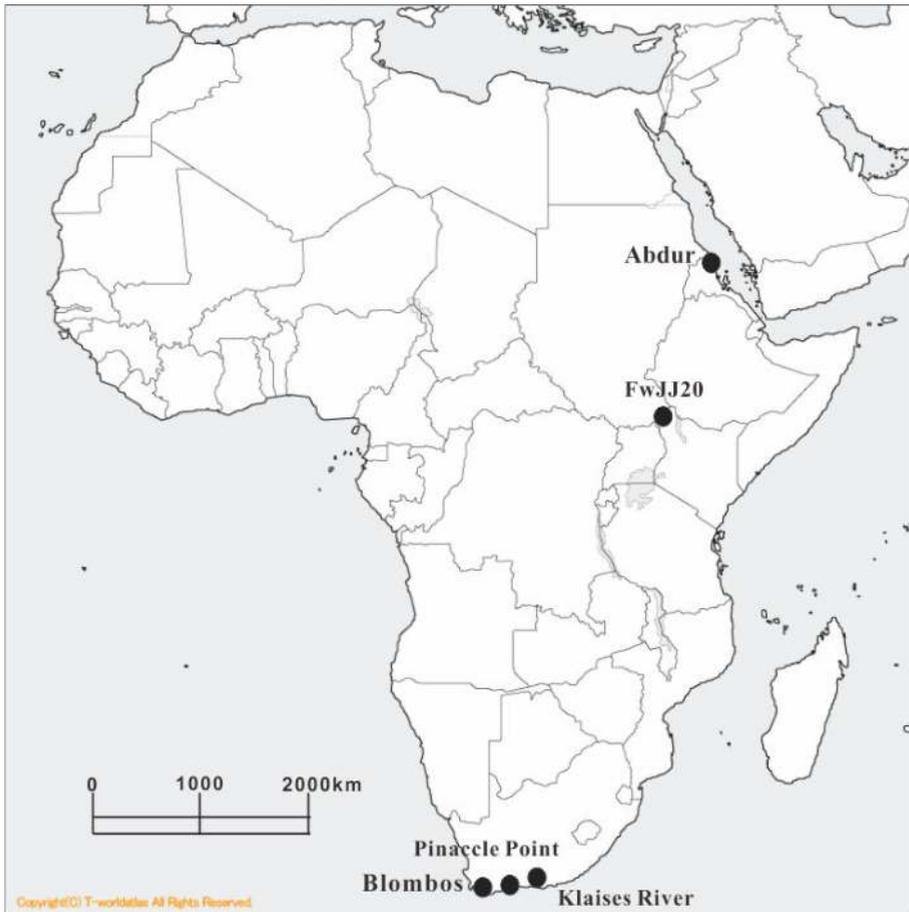


Figure 1. Locations of some important sites with traces of aquatic and maritime adaptation by early hominins and modern humans in Africa.

In terms of marine fish exploitation, one of the early evidences was also found at Blombos Cave. The site produced a number of marine-fish bones identified into 10 species of from MSA layers dated 100 to 70 ka years ago, yet inshore species were the majority [27]. Besides fish, the

site also produced fur seals, penguins, and marine birds. A number of bone spears estimated as fishing and hunting tools were also found in MSA layers in Blombos Cave [28]. In north and east Africa, the major captured fish species were catfish taken in lake or river environments.

The capture and use of catfish seems like similar practice with the earlier use by early hominins, although the capture technique or skill could be much developed during MSA. For example, a number of sophisticated barbed bone spears with amount of catfish remains found from Katanda (Fig. 1) on the Semliki River in Zaire (e.g. [34,35,36]) dated back to 90 to 80 ka in east Africa (Fig. 1). Such evidences indicate that early modern humans (*Homo sapiens*) already invented spear technology during MSA to catch both freshwater and marine fish.

During the same ages, production and use of more sophisticated shell tools and ornaments seem to have started. Blombos produced perforated *Nassarius* shell beads dated back to 75 ka [37], while Skhul in Israel and Oued Djebbana in Algeria also produced similar *Nassarius* beads back to 100–135 ka [38]. Since the Middle East including Israel to Europe was dominated by Neanderthals during this stage, these beads could be also made and used by them. Another evidence for use of shell tools by Neanderthals was also found at the Grotta Moscerini Cave in Italy dated 60–80 ka [16].

Recently, however, another new evidence of possible shellfish use for tool or ornament and engraving by *Homo erectus* at Trinil in Indonesia dated 540 to 450 ka was discovered [39]. According to their report, the well-preserved *Pseudodon* shells with a small hole (5–10 mm in diameter) around the anterior adductor muscle scar inside the shell (n=73) could be the ornament produced by *H. erectus*. Among them, five shells were dated by luminescence dating and back to around 500 ka. The finding of possible engraving by *H. erectus* may be a more surprising one, since the earliest previously known undisputable engravings are at least 300,000 years younger and by modern humans (cf. some engraved ochre pieces dated 70 ka at Blombos). If such evidence will be added, the possible use of shell tool and invention of engraving art could be traced back to later *H. erectus* level in near future. In any case, we shall consider that the use of shellfish for various tools could be another new tradition and technology occasionally practiced both by modern humans and Neanderthals rather than *H. erectus* so far.

In Late Stone Age (LSA) after 50 ka, further development of fish capture methods occurred during migration process by modern humans into Eurasia and via the Wallacea Archipelago to the Pacific. For example, the oldest trace of fast-swimming fish including tunas was found at Jerimalai Cave site on East Timor in Wallacea dated back to 42 ka. The site also produced shell fish-hooks after 23 ka [40]. Early fish-hooks appeared in Europe by Late to Final Palaeolithic around 20 ka [41] and East Asia to North Pacific after 10 to 8 ka. Beads or other ornaments made from marine shells or artistic depictions of aquatic animals were also produced from a number of coastal Upper Paleolithic sites in Europe and southwest Asia (e.g., [7, 18, 42, 43]).

All these evidence show that our adaptation to coastal and marine environments had been dramatically developed particularly after modern humans birthed in Africa and migrated into Eurasian continent and insular Pacific region including the Wallacea Archipelago (eastern Indonesia and East Timor regions). Based on such understanding, the next section introduces

the archaeological new findings and current outcomes for the past human marine exploitation and maritime or coastal adaptation, particularly in the Wallacea Archipelago, where the author has conducted archaeological fieldworks for over 10 years. One of the oldest and important data discussed here is from Jerimalai Cave site on East Timor and Leang Sarru Rockshelter site on Talaud Islands. The author also briefly introduces other important sites in and around Wallacea and the Pacific for comparative purpose to see the evidences of human use of marine resources and maritime adaptation in this region.

2. The late pleistocene marine exploitation and adaptation in Wallacea

2.1. Human migration and dispersal into Wallacea and the Pacific

A few million years later since humans birthed in African forest or subforest environments, a few groups of our ancestors succeeded out of the African continent and migrated into Eurasian continent or Old World during the stage of early hominins. One of the earliest hominins outside of Africa were recently found at Dmanisi Cave in the Republic of Georgia. The Dmanisi specimens dated 1.75–1.8 million years ago. Although they were reported to show clear affinities to African *Homo ergaster* rather than to more typical Asian *Homo erectus* or to any European hominid (e.g., [44, 45]), it is dominantly considered that Dmanisi men are the early type of *H. erectus* that possibly evolved from *H. ergaster*.

Other early hominin remains discovered outside of Africa are all identified as *Homo erectus*. The oldest aged *H. erectus* now is Sangiran 2 discovered in Java, Indonesia, and possibly dated around 1.66 to 1.49 million years ago (e.g., [46, 47]). Since the Java and Southeast Asian region is basically a tropic zone with rich floral and faunal resources for human food consumption, and Java (and also Sumatra and Borneo/Kalimantan Island) has been connected to the Asian mainland to form Sunda continent, except during the interglacial period like now in Holocene with much warmer temperature and higher sea level, early *H. erectus* might target this region soon after they left Africa for some reasons.

Following the current major hypothesis, *Homo erectus* possibly birthed around 2.4 million years ago and succeeded out of Africa around 2 million years ago into Eurasian continent, and they seemed to prefer the tropic or subtropic area in early stage. Their first migration into Java could be done during the glacial period when Java was connected to the Asian continent (Malay Peninsula), Sumatra, and Borneo/Kalimantan Island, which formed the Sunda subcontinent. They could disperse into Java by walking and without the need to cross ocean. In fact, all the old *H. erectus* bones and stone tools possibly made by them are only found in Java or in the islands that belonged to the last Sunda subcontinent but not in further eastern islands in Indonesia that are exactly located in the Wallacea Archipelago.

The earliest possible human trace in Wallacea so far is from Flores Island dated 840 ka. The evidence are some stone tools possibly produced by *Homo erectus*. Although the bones themselves are not discovered yet, if it could be the earliest human trace in Flores Island, it is the earliest evidence of sea crossing by humans in *H. erectus* level, since Flores Island is never

connected to the Sunda subcontinent or the neighboring islands. There have been at least 19 km distance of sea gap between Bali and Lombok even during glacial period, and they needed to cross this sea gap as well as other much shorter gaps to reach Flores Island. Therefore, the earlier human trace in Flores Island tentatively indicates the possible development of maritime adaptation by *H. erectus* or early hominins.

In terms of the Flores Island case, however, we should not forget the recent discovery of another new human species, *Homo floresiensis*, whose partial skeleton including a cranium, mandible, and several lower limb elements named as LB1 were excavated at Liang Bua in 2003 (e.g., [48, 49]). Although the direct dating of the bones only dated around 17 ka and surprisingly younger, the morphological character and size of cranial and other bones indicate that *H. floresiensis* could be one of the early hominin species and differs from the *Homo erectus* group (e.g., [50, 51]). Later excavations at Liang Bua added more bones possibly belonging to LB1 and also other individuals (LB2-6), while all of these bones could be identified as *H. floresiensis* (e.g., [52]). Among these bones, a few bones belong to LB 2 and 3 dated 74 ka, while this date is also much younger than other early hominin bones in the world.

In any case, if they are another early hominin species that differ from *Homo erectus*, there is another possibility that the Flores Island stone tools dated 840 ka can be also produced by *Homo floresiensis*, since they are only early hominins found in Flores Island so far, even their dates are very young. If so, this newly found human species might also develop maritime adaptation in the past to cross sea gaps and reach Flores Island. Although the truth is yet unclear, the Flores Island case tentatively shows that human maritime adaptation and migration could be developed in Wallacea since the early hominin age as far older than the age of modern humans (*Homo sapiens*). However, the possible evidences of human maritime adaptation and migration in early hominin level are yet limited and all the other evidences belong to the age of modern humans dated after around 50 ka in Wallacea.

The birth of modern humans in Africa is now estimated around 200 ka based on DNA model, past-environment changing model, and several archaeological traces in Africa (e.g., [30,42,53, 54,55]). As discussed in above, Middle Stone Age (MSA) after 160 ka may correspond to the age of modern humans, and their use of aquatic and marine resources became regularly visible in Africa, particularly in the coast of South Africa represented by some sites including Pinnacle Point, Klaises River Cave, and Blombos Cave.

After some extent of such maritime and aquatic adaptation, single or a few groups of modern humans succeeded to migrate into Eurasia possibly by the route of over the mouth of the Red Sea and subsequently dispersed into Arabia and Southern Asia. Possible dates for out of Africa by modern humans are now estimated around 100 to 60 ka (e.g., [30,56,57,58, 59,60,61]), and one of the oldest evidences for modern human migration out of Africa is from Australia dated back to 60 to 40 ka (e.g., [62,63]) but most potentially around 50 to 45 ka (e.g., [7,64,65]). Since Australia is located in Oceania further east from Eurasia, the existence of modern humans there clearly indicates that *Homo sapiens* should have migrated to Arabia, South Asia, and Southeast Asia, including the Wallacea Archipelago, before 50 to 45 ka.

It is also worth to mention that this earlier modern human migration to Australia, which was connected to New Guinea and formed the larger Sahul Continent, is so far the oldest evidence of human sea crossing over 80 km, since there had been over 80–100 km sea gap between Sahul or Australia and its neighboring islands in Wallacea including Timor or northern and southern Maluku Islands even during the Late Pleistocene at the last glacial period with much lower sea level and temperature (e.g., [65, 66,67,68]).

2.2. Major late pleistocene sites in Wallacea and the evidences

While the colonization of Sahul including Australia and New Guinea represents the earliest evidence of intentional and relatively long-distance seafaring in the world, there is relatively little known about the antiquity and nature of seafaring and coastal occupation in Wallacea, the nursery grounds for these early seafarers. However, recent excavations at Late Pleistocene sites in Wallacea provide evidence of early aquatic culture and marine exploitation. For instance, excavations in Maluku Islands, Aru Islands, and East Timor have uncovered evidence of modern human colonization dated 40 to 30 ka.

The major Late Pleistocene to Early Holocene sites in the Wallacea Archipelago (Fig. 2) are Jerimalai Cave, Lene Hara Cave, and Matja Kuru 2 Cave in East Timor (e.g. [40, 64,69, 70,71]), Golo Cave in northern Maluku Islands (e.g. [72-75]), Leang Sarru Rockshelter in Talaud Islands (e.g. [65,76,77,78]), Leang Burung 2 in southern Sulawesi (e.g. [79,80]), and Leang Lembudu Cave in Aru Islands (e.g., [71, 81]).

2.2.1. Evidence from Jerimalai cave site

Among them, the Jerimalai Cave site is currently the oldest prehistoric site by modern humans dated back to 42 to 38 ka in Wallacea. It is located at the eastern end of East Timor (see Fig. 2), where Pleistocene-raised coralline terraces run parallel to the present coastline with many caves and shelters. The site also plays significant roles as producing the oldest evidence of fast-swimming pelagic fish exploitation back to 42 to 38 ka and oldest shell fish-hooks possibly back to 23 to 16 ka [40]. The excavation was conducted by Sue O'Connor and her team from the Australian National University in 2005 and the author analyzed these excavated fish bones during 2009 and 2010.

Although Jerimalai Cave was excavated by only two 1×1 m test pits (squares A and B) in 2005, the site produced a rich assemblage of cultural material, including well-preserved faunal remains including marine fish and shellfish, marine turtles, murid rodents, bats, birds, and various terrestrial reptiles, as well as stone artifacts (n=9752), bone points, shell fish-hooks, and shell beads dated to the Terminal Pleistocene. The excavation encountered only three cultural layers in Jerimalai Cave [64].

The radiocarbon determinations on marine shell indicate that the lowest Layer 3 accumulated during the Late Pleistocene between 42 and 38 ka and the lower part of Layer 2 accumulated during the terminal stage of the LGM around 17 to 16 ka. Layer 1 with heaviest volume of sediment formed during the Early Holocene, around 10,000 to 5000 years ago. The site appears to have little evidence of occupation between ~38 and 24 ka. This may be due to sea-level retreat

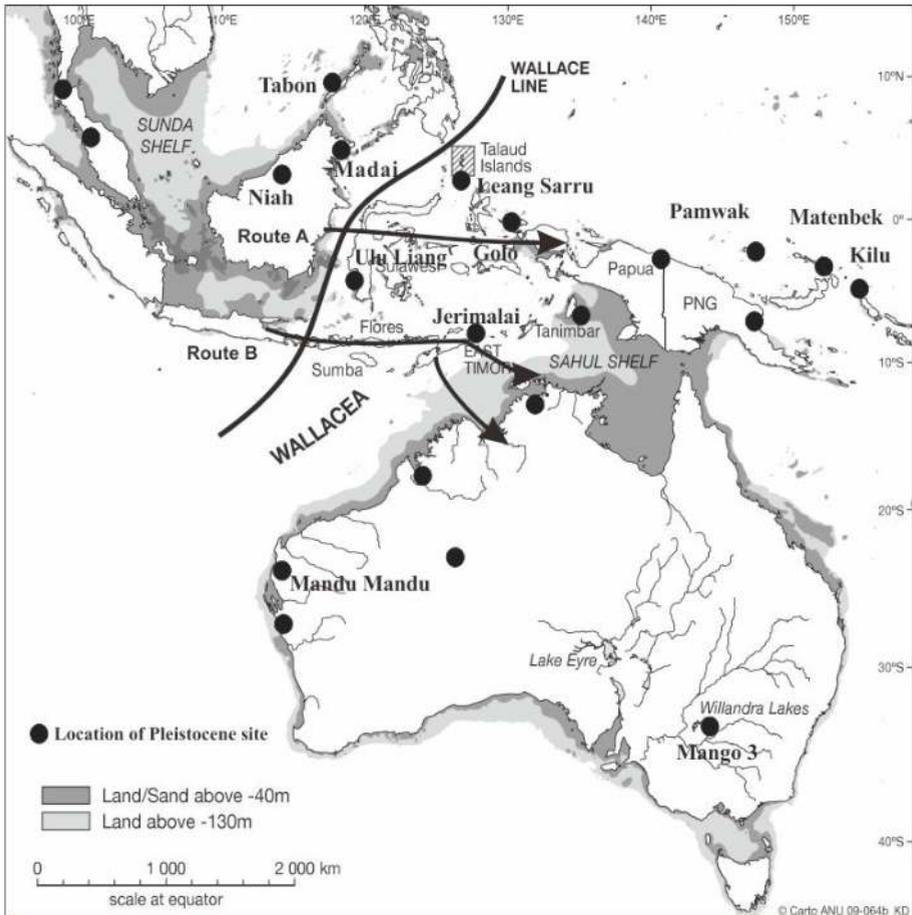


Figure 2. Map showing Sunda Shelf, Wallacea, and Sahul Shelf and major Pleistocene sites, with associated chronometric ages (after [65]).

rendering the shelter farther from the coast during this time; however, research at other nearby coastal sites such as Lene Hara Cave suggests that it more likely reflects limited sampling due to the small size of the excavation [40].

Among the faunal remains, the number and weight of fish bones far exceeds those of other fauna, averaging 56% by weight of the total vertebrate remains from the upper to lower layers. Especially, relatively larger bones from pelagic fish including tunas (Scombridae) and trevallies (Carangidae) compose almost 50% of the total fish assemblage in the earliest occupation levels. A total of 38,687 fish bones from square B and 23 taxa were identified. The total MNI (minimum number of individual) is 796 (= at least 796 fish were captured and discarded at the site) and the total NISP (number of identified specimen) is 2822 (= 2822 bones

were identified into family or species level). Twenty-three taxa were identified, including 22 families and 1 species as *Monotaxis granoculis* (see [40:1119]).

The MNI of Scombrids (mainly identified as yellow-fin tuna and skipjack tuna) is greatest in most of the spits down to the base of the site. Scaridae (parrotfish), Carangidae (trevallies), Balistidae (triggerfish), and Serranidae (groupers) fish families follow in MNI and NISP. These species make up about 12% to 15% of the total MNI. Other major fish families identified are Lethrinids (emperors), Lutjanids (snappers), Acanthurids (unicornfish), Labrids (wrasses), and Tetradontids (puffers). For Elasmobranchi (rays and sharks), both are recognized, and some shark vertebra were identified as Carcharhinidae (see [40: 1118-1119]).

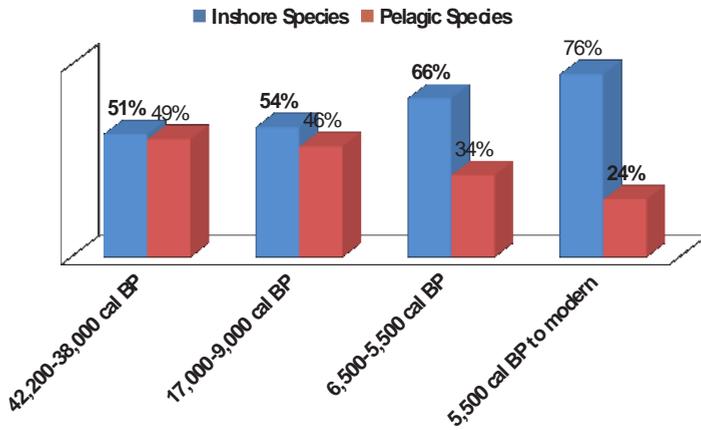
Among the three cultural layers in Jerimalai Cave, at least 15 fish taxa were exploited from the lowest layer (Layer 3), which may correspond to the earliest period of occupation, dated 42 to 38 ka, yet the quantity of fish bones from this layer is still limited. However, the tuna bones from this layer is so far the oldest evidence of human capture and use of tunas or fast-swimming offshore marine fish species in the world and tentatively indicates that modern humans migrated into Wallacea might have developed their maritime adaptation to have the high level of fish capture skills including hook and line fishing. Many of the current ethno-archaeological or fishery data in Wallacea to the Pacific islands (e.g., [65,82-91]) show the major fishing method to capture fast-swimming fish such as tunas are (1) fishing with hook and line or (2) trolling with lure (traditionally pearl shell lures have been used in the Pacific).

Since lure fishing could be developed in much later times possibly during the Neolithic times as discussed in below, it is highly plausible that hook and line fishing could be practiced to capture tunas at Jerimalai Cave. Yet, it should be noted that this evidence does not clearly show the modern humans at Jerimalai Cave practiced pelagic fishing in offshore sea zone with the use of a larger and faster boat or canoe as discussed by Anderson [92]. In fact, some tuna species including small-sized yellow-fin and skipjack tunas can also be captured near-shore or inside bay sometimes. However, wherever they caught tunas, they still might need to use hook and line for capturing tunas, as they are fast-swimming fish and hard to capture by other methods such as spearing, poisoning, trapping, and netting (see [93]). In recent or modern times, the large size of the net has been also used for capturing schools of tunas by large-scale motorized fishing vessel, although such modernized netting is hardly accepted in the prehistoric or even ethnographic fishing in Wallacea and the Pacific.

Therefore, the existence of tuna bones from Layer 3 in Jerimalai Cave shows the human use of fish hooks and line to capture marine fish dated back to around 40 ka, and the site also did produce some shell fish-hooks, although the oldest one from Layer 2 dated between ~23 and 16 ka, while later one in square A dated ~11 ka [40]. All are *Trochus* shell single-piece baited hooks and do not seem suitable for pelagic fishing. However, it is possible that other types of hooks were also developed at the same time. Bone points made on the spines of large fish first appear at Jerimalai Cave in Layer 2. Their function is uncertain, but they clearly represent a component of a composite tool, such as fine barbs for fish spears.

In terms of temporal change of marine fish exploitation in Jerimalai Cave, the prominent feature during this earliest occupation phase is the intensive focus on pelagic fish species,

particularly Scombrids (Fig. 3). The ratio of pelagic species (49%) and inshore species (51%) based on MNI is almost equal, and sharks and rays were also exploited in Layer 3. In Layer 2, the ratio of pelagic species in the total MNI still remained high (46%), but the number of Carangids (trevallies) dramatically increased, whereas the exploitation of Scombrids (tunas) remained similar. The exploitation of inshore fish species also shows the drastic changes, as parrotfish were still intensively exploited, but the number of groupers and triggerfish also increased in Layer 2, which possibly corresponded to LGM. In Layer 1 during the mid-Holocene time, the most prominent change is the dramatic increase (66–76%) in the total MNI and lower ratio of pelagic fish species (34–24%). Pelagic species were still targeted, but inshore fish dominate the assemblage. The increase of inshore species may reflect the stabilization of sea level, warmer temperatures, and the development of coral reef environment along the coast (see [40:1119]).



(Original map from Ono et al. 2010; Fig. 1)

Figure 3. Changing ratios of pelagic species vs inshore species in Jerimalai Cave (source: O'Connor et al. 2011; Fig. 2, which originally made by Ono).

The finds from East Timor demonstrate the high level of maritime skills and technology possessed by the modern humans who colonized Wallacea. These skills would have made possible the occupation of the faunally depauperate islands of Wallacea and facilitated the early maritime colonization of Australia and Near Oceania. Here, the author also introduces other archaeological evidences from Leang Sarru Rockshelter site, where the author re-excavated in 2005 and dated back to 35 ka in next.

2.2.2. Evidence from Leang Sarru Rockshelter site

Leang Sarru Rockshelter is a small limestone rockshelter located about 400 m from the eastern coast of Salibabu Island in the Talaud Islands, which is located over 100 km away from neighbor islands (see Fig. 1). It is situated in an uplifted coral limestone block about 15 m above

sea level in the middle of a clove plantation. The shelter faces northeast and is about 5×3 m in area. It has a curving ceiling about 2.5 m high at the drip line [65: 320].

The site was previously excavated by Tanudirjo [76, 77] in 1995, and he dug two 1 m² pits in 10 cm spits to a depth of about 80–90 cm below ground surface. This excavation revealed four sedimentary layers and unearthed thousands of chert artifacts and shell remains but no animal or fish bones. This excavation was relatively small, about 2 m² (1.8 m³), and the front area of the shelter was not examined. For this reason and to collect further archaeological data, Ono and Balai Arkeologi Manado (Institute for Archaeological Research in Manado) re-excavated the site in 2004 [65, 78, 94]. This excavation uncovered a further area of about 6 m² (3.6 m³) and comprised areas both inside and outside the shelter.

The excavation encountered three cultural layers (corresponding to Tanudirjo's Layers 1–3) before reaching the hard calcareous deposit (corresponding to Tanudirjo's Layer 4), and we inferred that the hard deposit shelved downward toward the back wall of the shelter where Tanudirjo had excavated. The radiocarbon determinations on marine shell indicate that Layer 3 (and Layer 4 in Tanudirjo's excavation) accumulated during the Late Pleistocene possibly between 35 and 32 ka, and the lower part of Layer 2 accumulated during the final stage of the LGM around 21 to 18 ka. The upper part of Layer 2 and possibly the lower part of Layer 1 formed during the Early Holocene around 10,000 to 8000 years ago [65: 322–323].

There were no conventional ¹⁴C or AMS determinations for the periods between 27–21 ka and 17 ka to 10,000 years ago; hence, it is possible that the shelter may not have been inhabited during these periods, other than perhaps very occasionally with little or no cultural discard. All the evidence possibly show the shelter had been occupied during at least three different periods in the Late Pleistocene and Early Holocene, an interpretation consistent with the tentative conclusion reached by Tanudirjo[77].

In total, 9465 stone artifacts, including flake tools, flakes, cores, chips, chunks, and hammerstones, together with 3371 NISP (number of identified specimen) of marine shell, land snail, crustacean, and sea urchin, and 580 earthenware sherds (only from the upper layer and top soil) were excavated. This range of cultural materials was generally similar to those from the 1995 excavation by Tanudirjo, with no fish or animal bones. The lack of animal bones possibly indicates that edible animals were scarce in the Talaud Islands. In fact, the Talaud Islands in modern times have no land mammals other than about 14 species of bat, 5 species of rat, 4 species of flying fox (*Pteropus* spp.), and 2 species of cuscus (*Ailurops ursinus* and *Strigocuscus celebensis*). Some introduced animals include chicken, dog, cattle (*Bos javanicus*), and pig (*Sus celebensis*) (see [95]). There is no archaeological evidence for the existence of large or mid-sized animals either [65: 323].

Shell remains are another major material from Leang Sarru Rockshelter. A total NISP of 3281 marine shell and land snail (26 kg) recovered from the excavation were sorted into 53 taxa: 23 of these taxa were identified to species level and the remainder to genus and family levels. One species each of crustacean (Brachyura) and sea urchin (*Heterocentrotus mammillatus*) were also identified as marine resources. With only minor differences, the shell density demonstrates a consistent pattern. When the 4135 in NISP and 15.2 kg/1.8 m³ of shell remains from

the previous excavation (identified as 40 taxa; see Tanudirjo 2001) are added, a grand total of 7416 (NISP) shell and land snail remains and 42.1 kg/5.4 m³ was retrieved from Leang Sarru Rockshelter [65: 325-326].

The analysis of the shell remains confirmed that *Turbo* spp. (e.g., *Turbo marmoratus* and *Turbo setosus*), *Nerita* spp. (e.g., *Nerita balteata* and *Nerita undata*), and *Trochus* spp. (e.g., *Trochus maculatus* and *Trochus niloticus*) were the predominant faunal species at Leang Sarru Rockshelter. Among them, *Turbo* spp. and *Nerita* spp. were the most abundant in number, whereas, in terms of size and actual meat value, *Turbo* spp. and *Trochus* spp., which were much larger than *Nerita* spp., were more important in terms of food and protein sources [65: 327]. These shell families are also the major exploited shells in other Late Pleistocene to Holocene sites in Wallacea and Near Oceanic islands (e.g., [64,96]).

In terms of temporal change of excavated shell and land snail, 33 species of them, with one species each of crustacean and sea urchin, were excavated from Layer 3 dated between 35 and 32 ka. The intertidal to subtidal rocky shore species such as Neritidae (*Nerita balteata*), Patellidae, Muricidae, Haliotidae, and Chitonidae were dominant, while *Turbo* spp., a subtidal species, were also exploited. The number of land snails such as Ellobiidae (*Pythia pantherina*) was also predominantly exploited during this period. However, the total amount of marine shell are yet small in number (NISP=859) during this early period.

In Layer 2B, dated between 21 and 17 ka, which corresponds to LGM, the total number and variety of species dramatically increased (NISP=1456; 42 species), as did crustacean and sea urchin (NISP=56 compared with NISP=12 in the earlier period). For instance, the major marine shell species of Neritidae, Turbinidae (Fig. 4A), and Trochidae (Fig. 4B) greatly increased in number (Fig. 4) and species variety, while the number of intertidal shell species such as *Haliotis varia* and land mollusc such as *Pythia* spp. slightly decreased. For *Nerita* spp., the number of *Nerita balteata*, *Nerita undata*, and *Nerita albicilla* dramatically increased, and for *Turbo* spp., the large to mid-sized species such as *Turbo setosus* and *Turbo marmoratus* also increased.

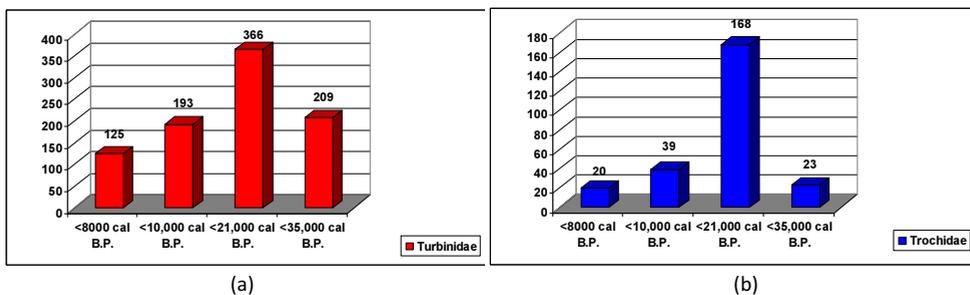


Figure 4. Number (MNI) of Turbinidae (a) and Trochidae (b) shell families in each layer/age at Leang Sarru Rockshelter.

For other species, shell belonging to Trochidae (particularly *Trochus maculatus*) and Fasciolaridae also dramatically increased. The increase in the total amount of shell remains in Layer 2B indicates more active exploitation of shell resources during the LGM. The exact reasons for

such an increase is not completely clear, although one of the crucial factors may have been a decline in the available food resources in the vicinity of the rockshelter during the LGM; alternatively, the site might have been more intensively used during this period.

However, the total amount of shell remains dramatically decreased in Layer 2A (NISP=516) and Layer 1 (NISP=450), which dated around 8000–10,000 years ago. In upper layers, however, some subtidal and coral rubble-dwelling species belong to Fasciolaridae (*Latirus nagasakiensis*) and Tridacnidae (*Tridacna maxima* and *Tridacna crocea*) increased. The increase of such coral rubble-dwelling species possibly indicates warming of sea and air temperatures and renewed growth of coastal corals after the Holocene. In contrast, the major subtidal species such as *Turbo* spp. and *Trochus* spp. as well as major intertidal species such as *Nerita* spp., *Cellana* spp., and *Chiton* dramatically decreased during this Early Holocene stage, although *Turbo* spp. were still dominant even in this stage. Regarding land snails, Ellobidae (*Pythia* spp.) and other snails (Zonitidae and Helicarionidae) increased, particularly in Layer 1, although it is unclear whether these were collected by humans or naturally accumulated in the sediments [65: 327-330].

2.3. Late pleistocene maritime exploitation and adaptation in Wallacea and adjacent regions

Previously excavated Pleistocene sites (Fig. 2) at the present coast of the former Sunda Shelf region reveal very little or no evidence for human use of marine resources during the Late Pleistocene, as all of these sites were located a considerable distance from the coast at that time. For instance, Lang Rogrien Rockshelter, which is currently located in the western coast of southern Thailand but was about 75–140 km from the coast during the Late Pleistocene (e.g., [97]), produced no marine faunal remains other than a single fish bone identified as a probable marine species [98].

Similarly, there are very little or no marine shell and fish remains in the cave sites of Niah (e.g., [99, 100]), Leang Burung 2 [80], and Tabon in the west coast of Palawan Island [101] (Fox 1970) or from the open-air site of Tingkayu in northeastern part of Borneo Island [102], all of which were a distance of 30–400 km from the coast during the Late Pleistocene; in general, these sites do have remains of freshwater mollusc and fish along with a variety of terrestrial animals (e.g., [101,103,104]).

Such archaeological results demonstrate the difficulty of investigating Pleistocene marine exploitation and adaptation in the Sunda Shelf region where former coastal sites are now submerged on the sea bed. On the other hand, island coasts in the Wallacea region were far less affected by the rapid rise in sea level since the Late Pleistocene, because they shelve steeply into deep water. For this reason, coastal sites in Wallacea provide good potential for identifying human exploitation of marine resources during the Late Pleistocene. For instance, Golo Cave, located 60 m inland from the northwestern coast of Gebe Island in Maluku Islands, produced shell tools and a variety (47 species) of marine shell that mainly inhabit rocky subtidal zones [75:703-704].

Similarly, in East Timor, Lene Hara Cave and Matja Kuru 2 Cave, located less than 10 km from the coast during the LGM, produced a larger amount of marine shell [70.72], while Jerimalai

Cave, located only a few kilometers from the shore, produced a number of *Nerita* spp., *Strombus* spp., *Trochus* spp., *Turbo* sp., and *Chiton* sp. as well as a large amount of fish remains including tuna and a variety of inshore fishes [64: 530].

In the Pacific region, next to Wallacea, Matenkupkum and Buang Merabak on New Ireland in the Bismarck Archipelago also produced amounts of marine shell, mainly rocky platform species such as *Strombus luhuanus*, *Trochus niloticus*, *Lambis lambis*, *Turbo* spp., *Nerita* spp., and *Chiton* dated around 40 to 32 ka (e.g. [105-108]). Wickler [109] noted a similar pattern at Kilu Cave on Buka Island, in which *Chiton* spp. comprised a relatively common component of the shell assemblages until the Early Holocene.

Although evidence for intensive marine exploitation in Australia during the Late Pleistocene is lacking, several sites in Western Australia have produced limited amounts of marine shell from strata dated between about 36 and 20 ka (e.g., [110-113]). For instance, at Mandu Mandu Creek Rockshelter (Fig. 2), located only about 4–5 km from the coast just prior to the LGM, a low-density midden deposit includes the remains of shell, crab, fish, and terrestrial fauna [110]. These sites could be interpreted as evidence for limited Pleistocene use of marine resources, but sea-level and shoreline reconstructions show a strong correlation between the presence and density of marine resources and the variable distance of each site from the sea [7:316].

These results tentatively indicate that coastal people in the Wallacea and Sahul regions (and probably in the Sunda Shelf region as well) actively exploited marine resources, especially shell, during the Late Pleistocene. The most important shell species exploited at these sites during the Late Pleistocene were *Turbo* spp., *Nerita* spp., *Trochus* spp., *Strombus* spp., and *Chiton*. In terms of actual meat value, *Turbo* spp. might have been the most important followed by *Trochus* spp. and *Strombus* spp. After 30 ka, the total volume and number of shell from Matja Kuru 2 Cave in East Timor dramatically decreased [72]. In contrast, the amount and variety of marine shell resources at Leang Sarru Rockshelter dramatically increased, especially during the LGM. These differences between the two sites may possibly relate to their distances from the coast.

The distance to the coast from each site was greater during the LGM. Even so, Leang Sarru Rockshelter was located within 2.5 km of the nearest coast [76:264], while Matja Kuru 2 Cave was over 10 km distant. Similarly, a heavy reliance on marine shell and other marine resources continued at Jerimalai Cave, which was located within 5 km of the coast during the Late Pleistocene [40:530]. The dramatic decrease in number and volume of marine shell in Matja Kuru 2 Cave during the LGM suggests the possible movement of the inhabitants to other locations closer to the coast or to other areas of the island. The absence of any human trace at most of LGM times during 24 to 17 ka in Jerimalai Cave also indicates the possible movement of inhabitants to other locations, but truth is yet unclear now with the very limited number of archaeological sites we have investigated.

In Sundaland, Niah and Tabon caves (Fig. 1) had been continually used, although their distances from the coast increased during the LGM, and very little or no marine shells were brought to these sites. Similarly, all other inland sites, such as Hagop Bilo Cave (17 to 12 ka) in northern Borneo and Ulu Leang Cave (Fig. 1) in southern Sulawesi, produce very little or

no marine shell but instead freshwater and land mollusc species. Overall, it is plausible that the access to marine resources depended on distance from the coast (see also [7]).

The fact that marine shell remains are abundant at Leang Sarru Rockshelter indicates that extensive marine exploitation was conducted by the people who lived close to the coast even during the LGM. Furthermore, the dramatic increase in volume and variety of shell species in Leang Sarru Rockshelter during the LGM strongly indicates that there was heavy reliance on marine and coastal resources particularly during cold conditions. It is possible that maritime and coastal adaptation in remote islands such as Talaud during the LGM was a consequence of very limited terrestrial resources.

For capture and use of marine fish, both pelagic and inshore species in the Late Pleistocene Wallacea, we only have a solid data from Jerimalai Cave so far. In the Pacific, a more convincing case for systematic fishing comes from Kilu Cave (Fig. 1) in the northern Solomon Islands dated 32 ka. Although Kilu Cave contains a larger quantity of fish bone, including some pelagic species, overall fishing at Kilu Cave seems to have been inshore fish species.

As similar to other early modern human sites in Africa, shellfish could be more important marine resources for human food consumption in Wallacea and the Pacific, and such possibility may be the main factor of very limited evidence of fish capture during the Late Pleistocene compared with the evidence of shellfish use. However, the Jerimalai Cave and Kilu Cave cases show that the modern humans migrated into the archipelagos also exploited fish and developed their fishing skills and techniques to capture both inshore and pelagic species far before the LGM, and the importance of marine resources as food and tool source should become much important after the Holocene with a dramatic rise of sea level and the coastal area and line far expanded as we see in next section.

Lastly, in terms of seafaring or voyaging skills as another aspect of maritime adaptation, the current archaeological evidences in Australia, New Guinea and Wallacea show that modern humans had ability to cross ocean over 80 km distance by 50 to 45 ka. Identifying evidence of early seafaring tradition can be difficult, yet evidence for the settlement of offshore inlands not connected to adjacent mainland tentatively indicates the use of watercraft by humans during the Pleistocene [114].

Although no evidence for reconstructing the early seafaring technology including their vessels is found yet, it is assumed that its progenitors arrived by raft possibly made of bamboo (e.g., [3, 115]). The trial by Thorne and Raymond [115] to build a 15×2 m bamboo raft with a 2 m² square sail of matting on a 2 m short mast revealed that such raft could travel 4–5 knots in a light breeze. It is reasonable to assume that bamboo rafts or rafts of other materials were the means of the earliest ocean passages [3, 66].

In any case, the fact is that modern humans could cross ocean to migrate into new lands or island with rather new environment and terrestrial resources from their home lands, including Africa. The exact departing location(s) where the earlier group(s) of modern humans tried to cross sea for migrating to Sahul is not sure, although it should be somewhere in the Wallacea Archipelago. In hypothetically, the two major migration routes from Sunda subcontinent via Wallacea to Sahul Continent are estimated (e.g., [81, 116]).

The first major route (Route A, see Fig. 2) is from Borneo/Kalimantan Island through Sulawesi, Sula and then into north or south Maluku Islands (e.g., Halmahera, Buru, and Seram) and into the Bird's Head in New Guinea or directly to Sahul Shelf where the present Aru Islands lie. The second one (Route B, see Fig. 2) is along the Lesser Sundas to Timor then via Maluku Islands to Aru Islands or directly onto the Sahul Shelf near the Kimberley region of Western Australia. When based on the current evidences as the oldest modern human sites located in East Timor, the direct migration from Timor is the most potential and supported route so far (e.g., [64,68,81]). However, the current archaeological evidences we have are yet very limited since many islands or area are not archaeologically investigated in Wallacea especially along the first route, and we need to increase more data to reconstruct the initial and past human migration route(s) in the near future.

After the initial migration(s) to Sahul (both Australia and New Guinea), the seafaring skills could be further developed during 35 to 20 ka in Wallacea and the Pacific. As already discussed, the excavations at Leang Sarru Rockshelter have shown that humans colonized the Talaud Islands by sea crossing of over 100 km at least by around 35 ka in Wallacea. Although the exact route of this migration to the islands is not known, it appears likely that many islands in Wallacea were already colonized by modern humans at the time the relatively remote islands of the Talaud group were settled.

Correspondingly, voyages to the Bismarck Archipelago and Solomon Islands from Sahul occurred after 40 to 30 ka (e.g., [108, 117,119]). While the initial settlement of New Guinea, New Britain, and New Ireland required voyages of up to 100 km, colonization of Buka Island in the Solomon Islands at least 28 ka required a minimum sea voyage of 140 km and possibly 175 km [67:20]. Furthermore, the archaeological evidences on Kilu Cave on Buka Island show the use and possible production of some plant food, including *Colocasia* taro and *Alocasia* taro. The residues of these plant species were discovered on the earliest stone tools from the site [120].

During the LGM, Pamwak site on Manus Island (Fig. 2) was newly settled around 21 ka. It should require at least 230 km voyaging to reach Manus and Admiralty islands from the north coast of New Guinea or the northwestern tip of New Ireland [120]. So the people's seafaring skills might be much developed by LGM around 20 ka. The Manus Island case is the earliest example of literally sailing into the unknown and beyond the range of one-way intervisibility [96]. Migration or movement to Manus Island required an uninterrupted voyage of 200–230 km, 60–90 km of which would have been completely out of sight of land [67:21].

Furthermore, the archaeological evidences at Matenbek and Buang Merabak on the New Island (Fig. 2) also show the intentional transfer of obsidian as tool material and cuscus as food source around 20 to 16 ka. Obsidian is mainly from the New Britain source of Mopir or Talasea, c. 55 km from Mopir [122]. Two quite different source distributions might imply different linkage between New Ireland sites and New Britain sources, with implications for canoe travel [96:154]. The cuscus is a kind of small- or mid-sized marsupial originally not habited in the Bismarcks; hence, they could be introduced by humans into these islands possibly from the main island of New Guinea as a half-dozen domesticated and nondomesticated animals. The cuscus might have been taken across the 30 km strait separating New Britain and New Island, while the direct distance between the obsidian sources and both sites could be around 300–350 km. It is

yet unknown whether the transfer of obsidian was done directly by crossing over 300 km sea or by hopping the coastal of New Britain to New Ireland coast. In the latter case, the maximum distance to cross sea could be about 30 km same as the estimated cuscus transfer.

It has often been argued that initial colonization of the many islands of Wallacea and its adjacent regions must have been facilitated by a maritime adaptation and that coastal lowland regions would therefore have been the logical focus of early settlement (e.g. [123, 124]). All of these evidences clearly show that the modern human seafaring skill did develop during the Late Pleistocene via LGM to Early Holocene in Wallacea and the Pacific.

However, as with the case of Leang Sarru Rockshelter, many of these early sites or remote islands were not continually used or habited during the Late Pleistocene, and it remains uncertain whether the early phase colonization of Talaud Islands was successful or not. The ^{14}C dates indicate that the initial occupation of the site was rather short, lasting only about 3000 years, from 35 to 32 ka. It is not known why people stopped using Leang Sarru Rockshelter after 32 ka. Did they move to other locations or islands to be close to better resources or did they just die out? Certainly, terrestrial resources were very limited in the Talaud Islands, as there were no land mammals, except for a few species of bat and rat, possibly with cuscus and flying fox (e.g., [95]). This paucity of terrestrial resources must be one of the major factors for the short occupation of Leang Sarru Rockshelter in the Late Pleistocene.

The Leang Sarru Rockshelter case tentatively shows that modern humans in Wallacea might not have had the strategies and skills prior to the advent of agriculture to sustain continual colonization of remote islands such as Talaud, which had limited terrestrial resources during the Late Pleistocene and Holocene. The difficulty of sustaining hunter-gathering subsistence in a remote island with limited natural resources has been discussed in relation to islands of the coast of southern Australia, such as Kangaroo Island (e.g., [125]) and Hunter Island (e.g., [126]), and Ryukyu (Okinawa) Islands (e.g. [127]) in south Japan.

On the other hand, in the Pacific, as with the case of Matenbek and Buang Merabak on New Island, people seemed to transfer animal resources and other materials from outside, possibly for supply of the limited resources in such remote islands especially during the LGM. However, the Matenkupkum site had been only occupied between 21 and around 14 ka, while Matenbek located 70 m south in the same cliff line had been occupied only between 20 and 18 ka and then abandoned. The site seems not re-occupied until 8000 years ago. Also, Buang Merabak on New Island and Kilu Cave on Buka Island were abandoned around 20 ka and re-occupied around Early Holocene. Therefore, the sites in Bismarcks and Solomon Islands were also not occupied continually the same as the sites in Wallacea.

The excavations of Golo Cave on Gebe Island (Fig. 2) in Maluku Islands (e.g. [74,75]) and Jerimalai Cave (e.g. [40,64]) in East Timor tentatively show that these sites also had not been used continually during the Late Pleistocene to Holocene. Golo Cave, for instance, was only occupied intermittently during the Late Pleistocene around 32 to 28 ka, and 21 to 19 ka, then later during the Holocene around 12 to 10 ka and possibly most recently during 7000 to 3000 years ago [74,75].

Similarly, Jerimalai Cave was occupied intermittently, during the Late Pleistocene from about 40 to 38 ka and again around 14 ka and during the Holocene around 6000 to 4000 years ago (see [64:528-529]). As with these sites, particularly Golo Cave in Maluku Islands, the second occupation phase of Leang Sarru Rockshelter occurred during 21 to 18 ka corresponding to the LGM. Although it is unknown whether people voyaged from other islands in the Talaud group or from adjacent regions such as the Sangihe Islands or Mindanao, it is clear that marine exploitation was practiced in the Talaud Islands during the LGM.

3. Holocene maritime exploitation and adaptation in Wallacea

3.1. The early to Mid-Holocene maritime exploitation and adaptation in Wallacea

After the LGM, the climate rapidly warmed and the sea level rose progressively until about 6500 years ago. The number of archaeological sites in Wallacea and adjacent regions postdating the Early Holocene dramatically increased. In East Timor, human habitation of Matja Kuru 1 Cave (e.g., [72]) and Uai Bobo 2 Cave [69] began at around 13 ka and there is evidence of increased human presence and activity from 8000 to 5000 years ago. During this latter period, human habitation of Bui Ceri Uato Cave in East Timor also commenced [69].

Matja Kuru 1 Cave and Bui Ceri Uato Cave, which are close to the coast, produced a variety of marine shellfish, while Uai Bobo 2 Cave, which is located in the inland hill country, has no marine shell. In northern Borneo, Hagop Bilo Cave was abandoned about 10 ka, while human activity at Madai caves is evident from 11 ka until 7000 years ago [102]. Madai caves produced a variety of fresh and brackish water shellfish but no marine shellfish. The distance of these caves from the coast during the Early Holocene was over 15 km, which, as for Uai Bobo 2 Cave in East Timor, would explain why marine shellfish are absent. Other sites such as Niah Cave, Lang Rogrien, and Leang Burung 2 were continually inhabited during the Early Holocene but no marine exploitation occurred there either.

On the other hand, total number and volumes of marine fish and shellfish remains dramatically increased at Jerimalai Cave during the Early to Middle Holocene dated around 6500 to 5500 years ago. For marine fish, numbers and percentage of inshore coral-dwelling fish species including Scarids (parrotfish), Balistids (triggerfish), and Serranids (grouper) increased. The heavy reliance on marine resources, especially shell, was continually evident in Lene Hara Cave [70] and Bui Ceri Uato Cave [69] in East Timor.

Similarly, some marine shellfish species increased in Leang Sarru Rockshelter during the Early Holocene. This is especially the case for Tridacnidae and Fasciolaridae, which are subtidal or coral rubble-dwelling species. As noted above, the increase of coral rubble-dwelling species such as Tridacnidae possibly relates to the rise in sea temperature and the growth of coral reefs. Similarly, at Golo Cave in Maluku Islands, the Holocene sediment prior to 3000 years ago contains a high density of shells [75:704]. In Buang Merabak on New Ireland, subtidal species such as *Trochus* spp. and *Limpet* suddenly increased after 10 ka, while the coral rubble-dwelling species, such as *Cypraea* spp. and *Strombus* spp., increased around 5000 years ago [106,128]. All

this evidence indicates that the possible change in target species corresponds to the development of Early Holocene coastal environments, although shellfish continued to be one of the major marine resources exploited by humans in Talaud Islands as well as in other island coasts in Wallacea and its adjacent regions.

In another aspect of maritime adaptation process during this age, the evidences both in the Wallacea Archipelago and the Pacific islands show a new tradition of shell use for tool and ornament. In Wallacea, Jerimalai Cave and Lene Hara Cave on East Timor produced some *Trochus* single-piece fish-hooks around 10 ka, especially the one from Lene Hara Cave [129], which is almost complete with a rather larger size possibly for capturing larger-sized fish. Although Jerimalai Cave has a possibly much older *Trochus* fish-hook as discussed above, much clear evidences are all after 11 to 10 ka during the Terminal Pleistocene to Early Holocene. Jerimalai Cave also produced a number of shell beads and ornaments during the Middle Holocene age around 6500 to 5500 years ago [40,64].

In northern Maluku Islands, Golo Cave produced a number of *Tridacna* shell adzes after 10 ka and *Cassia* shell adzes later around 6000 years ago [73,74], while the site also produced possible *Turbo* shell scrapers from the Late Pleistocene periods back to 35 ka [75]. The *Tridacna* and *Cassia* shell adzes from Golo Cave are so far one of the oldest shell adzes in the world. Since early modern humans in Africa and Arabia already produced and used marine shell ornaments and tools dated 130 to 70 ka (or possibly even *Homo erectus* after 500 to 400 ka), it is not so surprising that the modern humans migrated into Wallacea also used such shell tools from the initial stage during the Late Pleistocene. More visibility of shell use for tools and ornaments after the Holocene in the region might indicate that such use was more actively practiced during the Holocene.

In the Pacific, Pamwak site on Manus Island, stone and *Tridacna* shell edge-ground tools started to occur after 10 ka, while single edge-ground axe fragment, shark teeth, and cut *Trochus* shell occurred in Balof, another site at Manus Island from 10 ka as well. Matenbek on New Island produced a decorate shell bead, while Kilu Cave on Buka Island produced drilled shark teeth [96]. All of these archaeological evidences in Wallacea and the Pacific clearly show the human maritime adaptation and more elaborate techniques both for fishing and tool-making had been developed by this time.

Furthermore, some evidences of possible use of food plant resources in the Pacific may indicate that some kind of agricultural practices had been started during the Terminal Pleistocene to Early Holocene in the region. For instance, the analysis of plant residues on stone tools and shell scrapers from Balof on Manus Island indicates that these tools were used for processing starchy plants including yam (*Dioscorea* sp.), which are regarded as introduced plants from New Guinea after 14 ka [130]. For other evidences, *Canarium* nutshells, which are also estimated as introduced plants by humans from Wallacea or New Guinea, occur in Pamwak site before 11 ka and on Kilu Cave before 10 ka [131]. The fruit of such introduced trees has also been archaeologically presented on the north coast of New Guinea, where wild forms were endemic [132].

The possible development of agriculture or subsistent activities and technologies can be also supported by another evidence that human use of caves as habitation or camping site decrease after 6–5000 years ago. Both in Wallacea and the Pacific, most of the sites discussed here were abandoned by 5000 years and seemed to be seldom used as habitation sites, except for some case of use for secondly burial practices mainly after Metal Age in Wallacea or for temporal occupation in much later times (cf. use by Japanese soldiers during WWII). Possible development process of agricultural and subsistent technologies could correspond to the development process of people's maritime adaptation and seafaring skill during the ages, and then much-skilled colonizers known as Austronesian language group with their highly maritime and agricultural skills appeared in later times after around 3500 years ago in both Wallacea and the Pacific.

3.2. The Late Holocene marine exploitation and adaptation in Wallacea and Oceania

During the Late Holocene after 5000 years ago, various capture technology invented, and great variety of fish and shellfish species had been exploited by modern humans. Especially, the fishing and seafaring technology were further developed after the Neolithic times in Wallacea and the Pacific after the possible new migration by the Austronesian-speaking people who were originally birthed along the coast of southern China to Taiwan region before 5000 years ago and then dispersed into Southeast Asian islands including the Wallacea Archipelago and to the Pacific islands dated around 3500 to 2000 years ago (e.g., [73]). Since they had knowledge and skill of pottery production, animal husbandry of pig, dog, and chicken, as well as agriculture of some food plants, the early age of them is archaeologically recognized as Neolithic times.

In Wallacea and adjacent islands in Southeast Asia (Fig. 2), several major sites dated to this age are known as Leang Two Manae site on the Talaud Islands (e.g., [73,76]), Uattamdi site on Kayoa, northern Maluku Islands (e.g., [74, 133]), Bukit Tengkorak site on the eastern coast of Borneo/Kalimantan Island (e.g., [134,135,136,137,138]), Karumpang site on Sulawesi Island (e.g., [73]), and Duyong Cave on Palawan Island (e.g., [101]).

Among them, only two sites, including Uattamdi on Kayoa (e.g. [74,133,139,140]) and Bukit Tengkorak on Borneo/Kalimantan Island produced a number of marine fish and shellfish remains (e.g. [136-138]) and then have traces of modern human maritime exploitation and adaptation in the Neolithic times. Both sites had been mainly used during 3500 to 1800 years ago, although Bukit Tengkorak site was used more heavily during the Neolithic times dated 3400 to 2800 years ago [136]), while Uattamdi site was used as a habitation or camping site during Neolithic dated 3500 to 2800 years ago and as secondly burial site during Early Metal Age dated 2200 to 1800 years ago (e.g. [74,133,139,140]).

The Bukit Tengkorak site was first excavated by the Sabah Museum under the direction of Peter Bellwood in 1987 [134,141], and then by a joint team from the University of Science Malaysia and the Sabah Museum in 1994 and 1995 [135] and in 2001 [136,137,138,142]. The total area excavated during these investigations by 2001 was 10.5 m², and each excavation unearthed a number of fish remains. From these excavations, the author earlier analyzed fish remains excavated during 1994–1995 (from the southern part of the site) and in 2001 (from the northern



Figure 5. Major Neolithic sites in and around the Wallacea Archipelago.

part of the site), identifying a total of 28 fish taxa to family level (NISP=4132, MNI=1976) from 3 m² selected units [138,142].

Over 99% of the identified bones were inshore or coastal coral fish species such as groupers (Serranids), emperors (Lethrinids), parrotfish (Scarids), wrasses (Labrids), snappers (Lutjanids), and triggerfish (Balistids). The number of pelagic fish was very limited: only two bones (vertebrae) were identified as tuna (Scombrids) and one bone as barracuda (Sphyraenids). Although no materials related to fishing (cf. net sinker, hook, and lure) were recovered, the variety of excavated fish species and the author's intensive ethnoarchaeological study on recent Sama maritime people fishing around the site indicate that the Bukit Tengkorak people practiced netting, hook and line fishing, spearing, and possibly trapping and poisoning but possibly not trolling and offshore fishing [138]. Since the small peninsula, where the site is located, is surrounded by a large coral reef over a few kilometers, the heavy reliance on inshore fishing to capture coral-dwelling inshore fish species could be their strategic decision rather than lack of skills of offshore fishing.

On the other hand, the Uattamdi site is a complex of limestone rockshelters on a much smaller island but again fringing coral reef developed on the western coast where the site is located. The site was also excavated by Peter Bellwood and his team during the 1990s to find a number of potsherds, stone tools, shell tools or ornaments, glass beads, shellfish, and a few of fish,

animal, and human bones. Human bones and glass beads were only excavated from upper layers, which belong to Early Metal Age burial. Styles and types of potsherds also show the clear difference between upper Metal-aged layers and lower Neolithic layers [74,140].

However, the details of excavated shellfish and fish remains as well as shell tools are not fully reported and remain unclear. Ono and the National Archaeological Research Centre of Indonesia conducted new excavations in two rockshelters at Uattamdi in 2014 [133]. One of them is same larger rockshelter where Bellwood excavated. Our excavations also unearthed a number of potsherds, stone and shell tools, glass beads, marine fish, shellfish, animal bones, and human remains in both shelters at Uattamdi. Our excavations confirm over 150 species of shellfish mainly marine species, over 10 families of marine fish including tunas, groupers, emperors, parrotfish, wrasses, snappers, triggerfish, trevallies, unicorn fish, porcupine fish (*Diodontidae*), moray eels (*Muraenidae*), Haemurids, and sharks (mainly *Carcharhinidae*) as well as sea-turtle bones. A shark tooth from the Neolithic layers had a drilled hole and could be used as tool or ornament.

Although the total number and volume of fish remains is not so large like Bukit Tengkorak site, most of tunas mainly occupied by skipjack (*Katsuwonus* sp.) were only from Neolithic layers, and it seemed both offshore and inshore fishing were engaged in Uattamdi site during the Neolithic times. Also, we excavated over 20 specimens of possible shell fish-hook blanks both made from some bivalve species and gastropod species, mainly *Nerita* sp. Since they are all blanks and not complete hooks, it is yet unclear whether they are really hooks or not, although a number of tuna and grouper bones from the site tentatively show the Uattamdi people did hook and line fishing at least.

The location of Bukit Tengkorak and Uattamdi also indicate that these Neolithic people, possibly newly migrated into the region, developed maritime skills and knowledge and strategically selected such coastal environment with large coral reefs as one of their initial settlements. Such migration strategies and preference of coastal settlement can be seen much clearly in the case of Lapita sites in the Pacific.

Lapita people are usually identified as the early Austronesian-speaking people originally from Asian region with Neolithic material culture, including pottery making and using tradition and more systematic agriculture and animal husbandry practices, and migrated into the Pacific islands after around 3300 years ago. They migrated into many remote islands in Melanesia to Western Polynesia, which had been mostly uninhabited before them. Therefore, it is believed that the Lapita people are the first modern humans who succeeded to reach and migrate to these islands in Remote Oceania including Polynesia; hence, they are also estimated as the direct ancestors of Polynesians who migrated to most of all the islands in Polynesia including Hawaii, Rapa Nui (Easter Island), and New Zealand in later times.

However, the Lapita culture seemed not singly from the Asian region as well. One of the most specific materials that belong to Lapita is their pottery assemblage, which includes diagnostic motif of human face and geometric patterns made by dentate-stamping technique on its pottery surface and some of them are impressed by white-lime material. The technique of making pottery, dentate stamping, and lime impressing could have originated from Island

Southeast Asia or Taiwan to southern China since much older potteries made by such technique were found in these regions. However, when reducing pottery to a single element, there are 30 Lapita elements, of which 17 (57%) have been recovered from pre-Lapita Melanesian sites, 21 (70%) from Neolithic Southeast Asian sites, and only 8 (27%) from pre-Neolithic Southeast Asian sites [96,143].

Even for the pottery itself, the diagnostic motif of human face and mix of various patterns in one single pottery is a very specific character of Lapita pot and never seen in other regions including Wallacea yet. With such evidences, it is also believed that the Lapita is basically of Southeast Asian Austronesian origin, but with added elements innovated in pre-Lapita times in Melanesian Islands. If so, Lapita culture is more like a complex synergy involving both Austronesian immigrants and the Melanesian descendants of the Pleistocene colonizers of New Guinea and the Bismarcks (e.g., [96,144,145]). It also means that the Lapita people could be human group(s) mixed with both Asian originated newcomers and indigenous Melanesian islanders, yet the truth is unclear and we need more archaeological, anthropological, and genetic studies in the near future.

In terms of maritime exploitation and adaptation of the Lapita people, they seemed to have more developed maritime skills both for fishing and seafaring. Firstly, for fishing, most of the Lapita sites produced more inshore fish remains like in the Bukit Tengkorak site, including parrotfish, wrasses, snappers, triggerfish, groupers, emperors, unicorn fish, and porcupine fish. Although the number and volume are smaller, they also produced pelagic fish remains including tunas and barracuda (e.g., [83,136,137,145-151]).

Furthermore, several Lapita sites produced large to small-sized shell fish-hooks and *Trochus* lure shanks (e.g., [145,147,151,152]). Such lure shanks clearly show the possible employment of trolling offshore to catch skipjack tunas or other fast-swimming fish species, and the Lapita *Trochus* lure shanks are possibly the oldest evidence for such type of hook so far. Various sizes and styles of shell fish-hooks are another evidence of active line fishing. Most of these hooks are made from *Trochus* sp. or *Turbo* sp. shell, and the former could have been originally from the *Trochus* fish-hook tradition back to the Late Pleistocene to Early Holocene in Wallacea to the Pacific regions.

On the other hand, the absence of shell trolling lures and variety of fish hooks in Island Southeast Asia Neolithic sites, including Bukit Tengkorak and Uattamdi, implies a discontinuity between this region and the Pacific in the aspect of fishing technology. It is risky to make any conclusive statement at this stage, however, given the small number of investigated sites and paucity of data. Nonetheless, the present information could suggest that offshore fishing techniques with trolling lures might be an innovation of Lapita fishers in Melanesia where more islands are surrounded by deep sea.

Secondly, for seafaring skills, we do not have any archaeological evidences of vessels used by Lapita people, although it is estimated that their colonization could have been carried by outrigger canoes using a primitive Oceanic spritsail [3:38]. Outrigger canoes are major canoe types in almost the whole area where the Austronesian language dispersed from Islands Southeast Asia to the Pacific and also in Madagascar in Africa, where the later migrations by

the Austronesian-speaking people were done possibly from Indonesian islands somewhere after 2000 years ago. The only exception is Taiwan, which is considered as the potential original place of the Austronesian language group, and no outrigger canoes have been used in the island. It is yet unknown where the original outrigger canoes were birthed, but it is sure that they are the major type of canoe in the Austronesian-speaking area.

Another fact that the past Lapita colonization of the islands in Remote Oceania shows is that the capable distance of sea crossing by the Lapita people should be much longer than the modern human voyage during the Late Pleistocene to Middle Holocene. The Lapita successful migration beyond the sea gap in the Solomon Islands or between Near Oceania and Remote Oceania and then into many remote islands including New Caledonia, Vanuatu, Fiji, Tonga, Samoa, and so on sometimes need over 800 km navigation. Furthermore, the corresponding Austronesian migration into Mariana Islands in Micronesia dated about 3500 years ago possibly from the islands of the Philippines required over 2000 km navigation (e.g., [153,154]). Thus, the facts that these remote islands were colonized by the Austronesian including Lapita people clearly indicate that their seafaring technology and skills were developed around the Neolithic times.

After the Lapita colonization to Samoa, a western border of Polynesia dated around 2800 years ago, their migration movement seemed to stop in this volcanic island, and they did not try to migrate further east into a whole Polynesia. However, voyaging clearly continued between the known islands after the Lapita boundary was established and later reached several new islands to the east including Niue and perhaps Pukapuka by about 2000 years ago [3]. Similarly, after East Polynesia was reached, the Polynesians who are the descendants of the Lapita people also succeeded to colonize Hawaii, Easter Island, and New Zealand by the 12th to 13th centuries. The distance to these islands from their neighbor islands or continent is over 4000 km; hence, the success of migration by the Polynesians clearly indicate that their maritime adaption and navigation technology were highly developed.

In fact, it is a dramatic event that modern humans did succeed to migrate to all over the world, except for the North Pole and South Pole, when the colonization to New Zealand was done by the Polynesians. Such evidence also shows that marine environment could be our last target for migration and colonization in this world after the human birthed in and around inner forest environment over 6 million years ago. In this regard, the human history of maritime exploitation and adaptation process to coastal and marine environments in the Wallacea Archipelago and the Pacific islands should be important to think about the past relationships between coastal and marine environment and humans and thus is worth to be continually investigated by future studies as well.

4. Conclusion

This chapter overviews over 2 million years of aquatic and maritime adaptation history by human. It seems now that the early aquatic adaptation and fish use had been started in lake and river environments in Africa by early Hominins, while the maritime adaptation and marine use had been started much later by *Homo sapiens*. The progress of our maritime

adaptation had been far exceeded when *H. sapiens* reached various marine and coastal environments after out of Africa, particularly in Wallacea and Oceania islands dated around 50 ka years. Currently, the oldest traces of long-distance seafaring, possible pelagic fishing or line fishing, and use of shell fish-hooks by modern humans were all discovered in Wallacea and Near Oceania regions back to the Late to Terminal Pleistocene.

Such facts strongly indicate that their archipelagic environment with many small and remote islands in Wallacea and Near Oceania could be one of the major backgrounds for such high maritime adaptation of the people in this maritime world. Another possible factor is the effect of temperature and sea-level change in the past. In fact, many of the Late Pleistocene to Early Holocene sites in Wallacea and Near Oceania show the drastic change in the variety and volume of fish and shellfish for exploitation; usually, the high peak of shellfish use was possibly practiced during the LGM period with the coldest and driest times in the Late Pleistocene.

After the Holocene, modern human maritime adaptation had been accelerated as corresponding to warmer temperature, rapid rise of sea level, and expansion of coastal area including the possible development of coral reefs after around 6000 years ago. In Wallacea and Near Oceania, Austronesian-speaking people who were originally from Taiwan or Southern China having developed farming fishing and animal husbandry skills and knowledge newly migrated after 4000 years ago. Among these groups, Lapita people migrated to the remote islands in Near Oceania at first and then rapidly and firstly colonized into many Melanesian Islands in Remote Oceania east to Samoa and Tonga, while other groups migrated to Mariana or Palau Islands in Micronesia. Such new migration to these remote islands in Remote Oceania were required over 2000 to 500 km nonstop sea crossing; hence, these facts clearly show that modern human seafaring skills had been further developed. All of these cases discussed and introduced in this chapter tentatively indicate that the human maritime adaptation process has corresponded to rather long-term temporal changes in the past marine environment including sea level, temperature, coastline, and marine resources.

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