SOCIETY, SEAFARING AND WATERCRAFT IN PREHISTORIC OCEANIA*

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Lukáš PETRÍK
Institute of Oriental Studies, Slovak Academy of Sciences
Klemensova 19, 812 64 Bratislava, Slovakia
ORCID: https://orcid.org/0009-0001-2432-2608
kaorlpet@savba.sk

Many islands in the Pacific were settled as the last habitable parts of the Earth, with their size and distance being the primary reasons. The settlement of these islands required vessels capable of transporting a sufficiently large group of people and their provisions over distances of hundreds to thousands of kilometres. Numerous books and studies have been dedicated to watercraft and voyaging in prehistoric Oceania, aiming to provide detailed descriptions and reconstructions. However, technological innovations in any field are driven by a specific set of norms that reflect the adaptive strategies of local communities and interactions amongst them. Technologies themselves do not exist as material products in a social vacuum but are, to some extent, social constructs framed by the history, traditions, and cultural norms of societies and their intricate relationships. This article serves as a reflective exploration of the specific social, demographic, and cultural phenomena in prehistoric Oceania, predominantly within the context of the Lapita culture. It examines the potential correlations and influences of these phenomena on the types of watercraft used and the voyaging practices. The primary objective of this article is to highlight these correlations, which can serve as a basis for testable hypotheses and subsequent research. In the absence of concrete empirical data, such research holds the potential to enrich our knowledge of seafaring, navigational techniques, and canoe usage in prehistoric Oceania, mainly during the Lapita and subsequent post-Lapita periods.

Key words: Lapita, demography, watercraft, voyaging, migration, exchange links, social structures, kinship, residential patterns

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Introduction

Oceania, as a unique part of the world where the majority of islands were initially settled by inhabitants mostly speaking Oceanic languages, presented new opportunities, challenges, and threats to those who colonized the individual islands in this vast region. In what ways, if at all, did local environmental factors of the island habitats translate into technological innovations in the realm of watercraft and navigational techniques? Is it conceivable that this reflection also manifested itself in the social structure or cultural norms, remnants of which persist in contemporary, or at least historical, Oceanic communities? Furthermore, could the examination of indigenous boatbuilding technologies and navigation facilitate our understanding of prehistoric societies in this region?

Technological innovations have been an inseparable part of human society from ancient times to the present. Although the opportunities and repercussions of their utilization have evolved over time, their presence has empowered individuals in every epoch and within any setting to effect fundamental alterations, enhancing their ability to effectively address challenges across diverse conditions and life situations. It is apparent that the imperatives and potentials of technological innovations emanate from the conditions of the physical environment, which are, to a certain extent, modified by the outcomes of the technological innovation process. However, the domain of interrela-tionships is not solely delineated by technological innovations and the physical environment but is also co-shaped by social aspects that constitute the functionality of technologies while being amenable to modification under the impact of technological innovation. This phenomenon is exemplified, for instance, in the restructuring of social relationships, labour organization, and the formulation of new strategies for resource acquisition. Various scholars have proposed a theoretical framework delineating the relationship between society and technology (primarily pertaining to contemporary history) over the preceding half-century, predominantly within the domain of Science and Technology Studies (STS), such as Winner (1980), Bijker (1999), Jasanof (2004), Schiffer (2011) among others.

The study of prehistoric societies and certain phenomena within them is somewhat specific in this respect. It predominantly relies on material artefacts, the social context of which is often unknown to us and is subject to the interpretation of scholars. However, even these surviving artefacts constitute only a fraction of the complete range of objects utilized by people in prehistoric periods. In the context of prehistoric Polynesia, Kirch and Green (2001), calculate these figures within a range of only 14 to 23%, being represented by artefacts crafted from durable materials (p. 163). Direct empirical evidence is lacking for a wide range of artefacts that have not survived due to their material nature. Wood and plant fibres, which constitute the primary structural components of watercraft

in prehistoric Oceania, are susceptible to decomposition, and discoveries of such nature are typically very rare.

In instances where unpreserved artefacts are integral to the study of prehistoric societies and their technological phenomena, scholars usually face significant limitations not only in reconstructing the artefacts themselves but also in understanding their usage, functionality, and integration within the social context. Meanwhile, if surviving artefacts or associated phenomena enable us to infer the degree of social complexity and their specific characteristics, we can outline the trajectory of technological development or even attempt to reconstruct artefacts that have not survived due to their material composition. This approach, however, inherently has its limitations and suggests a form of universal determinism. In reality, the factors influencing technological innovations vary, exhibiting higher similarity in some contexts and lower in others (Downs & Mohr, 1976). Therefore, conclusions drawn from such methodologies should be approached with caution and employed only as supplementary arguments where other evidence is lacking. This article aims to outline some implications derived from demography, social complexity and residential patterns towards watercraft and voyaging in prehistoric Oceania, specifically in regions inhabited by the Lapita people during the relevant period and the subsequent era.

From an archaeological perspective, no evidence of watercraft has been uncovered so far from the Lapita period. However, it is known from other regions that people were able to construct dugout canoes long before the emergence of the Lapita cultural complex. For instance, the Kuahuqiao site near Hangzhou in China has yielded remains of a dugout canoe that is at least eight thousand years old (Jiang & Liu, 2005). From the Pacific region, the earliest archaeological evidence of canoes is dated to a period after 1000 AD, following the colonization of the Central and Eastern Polynesian islands. Among these discoveries, two provide insights into early Polynesian voyaging watercraft. One originates from Vaito'otia-Fa'ahia on Huahine (Carroll & Sinoto, 2005), the other is from Anaweka, New Zealand (Johns et al., 2014). Several rock art depictions of canoes are dispersed across the region inhabited by populations linguistically belonging to the Austronesian family, primarily in Island South-East Asia (ISEA) (Lape et al., 2007). While these depictions may offer some insights into the appearance of Austronesian watercraft from both historical and prehistoric eras, further research is required to accurately date these paintings and classify them within a broader framework to address existing gaps in knowledge. When drawing inferences about prehistoric watercraft, we typically rely on ethnographic comparisons and accounts dating from the period of European exploration of the Pacific up to the recent past, when traditional canoes were replaced by modern boats fitted with engines. In this context, the encyclopaedic work Canoes of Oceania (Haddon & Hornell, 1975) holds exceptional significance, as it outlines the typology of canoes from the early

historical period up to the time of its first edition in 1936–38 across the whole of Oceania. However, the diversity of canoes and their parts throughout the regions of historical Oceania, encompassing both functional and decorative elements, is so extensive that, coupled with the temporal distance of over three thousand years from the present era, it suggests significant changes over time.

An additional noteworthy source of insight lies in the reconstruction of relevant proto-language terminology for distinct regions or islands within Oceania. Indigenous languages spoken in the Pacific can be categorized into two primary groups – Austronesian and non-Austronesian (or Papuan). These languages exhibit substantial diversity, precluding their reconstruction to a unified Papuan proto-language level, given the gradual influx of ancestors of speakers of these languages into the Sahul region in multiple waves (Krupa, 2006). In this article, emphasis will be placed on terminologies derived from the reconstruction of the Proto-Oceanic language, specifically those pertaining to celestial bodies, the natural environment (Ross et al., 2007), societal structures (Ross et al., 2023), and components of watercraft (A. Pawley, 2007; A. Pawley & M. Pawley, 2015). Additionally, within the Austronesian languages of Oceania, there are languages that, although belonging to the Austronesian language family, do not align with the Oceanic language cluster, such as the Chamorro languages (Marianas) and indigenous Palauan languages (Krupa, 2006).

A relatively recent but fundamental aspect of research concerning indigenous watercraft in the prehistoric period has involved the integration of computer simulations. These simulations have the capacity to model potential scenarios based on designated parameters, such as weather conditions and ocean currents. While the initial simulations were conducted in the early 1970s (Levison et al., 1973), advances in data processing and computational capabilities have increased the sophistication of simulations in contemporary times. As a result, it is now feasible to simulate outcomes, tailored to the specific design of watercraft or their constituent parts, by inputting appropriate parameters, as seen in several more recent studies (e. g., Avis et al., 2007; Di Piazza et al., 2014; Irwin et al., 2023; Irwin & Flay, 2015; Montenegro et al., 2016).

The Lapita Context and the Spatial Mobility of the Lapita People

In the middle of the second millennium, some new cultural elements accompanied by finely decorated pottery began to emerge in the Bismarck Archipelago region. This culture, archaeologically represented by dentate stamped sherds was named Lapita after the discoveries of Gifford and Shutler (1956) at New Caledonian site no. 13 (as cited in Kirch, 1997). These emerging cultural elements indicate influences commonly linked to migration from Island

South-East Asia (e.g., Bellwood, 2006a; Carson, 2018; Pawley & Green, 1973 amongst others). However, it is noteworthy that the phylogenetic model positing a gradual cultural evolution originating from Island South-East Asia has faced criticism. Some scholars view the Lapita culture as an innovation in situ, influenced by cultural and biological interaction among local communities (e. g., Allen & Gosden, 1996; Terrell, 2014). Green (2000) proposed a hypothesis that offers a compromise between both perspectives, known as the "triple-I hypothesis" (after the initials of Intrusion-Innovation-Integration). This hypothesis suggests that the Lapita people resided in the Bismarck Archipelago region for several centuries before expanding into the areas of Remote Oceania and interacted with previously settled inhabitants.

The Lapita people primarily established settlements in coastal regions, predominantly on smaller islands, overlooking lagoons, where they constructed stilt houses directly above the water. An ongoing scholarly debate surrounds their subsistence practices, particularly the degree to which horticulture and domestic animal husbandry influenced their overall caloric intake, juxtaposed with hunting or foraging of wild plants.[1] Around 3300–3000 BP, the Lapita culture firmly established itself across the entire Bismarck Archipelago, with communities forming a network of exchange links and maintaining regular contacts based on kinship relations (A. Pawley, 2007). Towards the end of this period, the Lapita culture expanded beyond the previously settled areas in Oceania for the first time, into the realm of Remote Oceania.[2] The eastern boundary of Remote Oceania is approximately 350–450 kilometres of open sea between the south-eastern Solomon Islands and the Santa Cruz/Reef Islands. In a relatively short period, the remaining islands of Melanesia and western Polynesia were also settled. The colonization of Remote Oceania occurred gradually from north to south and west to east direction at a remarkable speed, following a line from the south-eastern Solomon Islands – Vanuatu – New Caledonia (Sand, 2001), and eastward to Fiji, Tonga, and Samoa. The chronology of settlements on the particular islands of Remote Oceania is documented in a table presented in the study by Rieth and Cochrane (2015), providing the following dates: Reef/Santa Cruz islands: 3185–2785 BP, Vanuatu: 3200–3000 BP, New Caledonia: 3050–3000 BP, Fiji: 3130–

[1] The Lapita culture is linked with a group of commensal animals, such as the chicken, pig, dog, and the Polynesian rat (*Rattus exulans*) along with other rat species. Archaeological evidence of these animals is found in Near Oceanic sites, although their presence is not uniformly documented across all islands in Remote Oceania.

[2] The terms *Near Oceania* and *Remote Oceania* were first proposed by A. Pawley and Green (1973) based on environmental and geological factors. Additionally, the region is characterized by the absence of settlements predating those that are associated with the spread of Austronesian languages.

3010 (older dates), 3010–2870 BP (newer dates), Tonga: 2846–2830 BP, Samoa: 2800–2400 BP (pp. 136-140).

The rapid spread of the Lapita culture, spanning a time frame of approximately 15–20 generations from the initial crossing of the boundary of Remote Oceania to Vanuatu, New Caledonia, Fiji, and subsequently to Tonga and Samoa — a distance of four thousand kilometres from the Bismarck Archipelago — was probably driven by various factors. In this context, scholarly debate continues among researchers, with several plausible models emphasizing societal structure and its core functions, particularly focusing on subsistence strategies and socio-economic dynamics. These models encompass the strandloper model, emphasizing mobility for procuring resources through the collecting of marine products and fishing (Groube, 1971), the trader model (Green, 1982), and the model emphasizing population growth and gradual settlement of neighbouring islands (e. g., Fort, 2003). Regarding the spread of the Lapita culture, it is notable that evidence of settlement from the Solomon Islands chain or the coast of New Guinea is absent from the phase of its dispersal into Remote Oceania, despite their potential as natural stepping stones for further eastward or southward island colonization.[3] This absence challenges the hypothesis of a gradual and slow spread. The rapid expansion following the boundary crossing of Remote Oceania is a remarkable prehistoric achievement, with distances covered sometimes exceeding 800 km across open ocean, such as the shortest possible distance from Vanuatu to Fiji. This fact implies that the use of relatively advanced and, at least to some extent manoeuvrable watercraft was probably an integral part of the colonization process, requiring a certain level of navigational expertise and an understanding of environmental factors such as wind patterns and swells.

Multiple lines of evidence point to the continued existence of active inter-community trade links between the regions of Near and Remote Oceania. This assertion is substantiated by the distribution of obsidian, predominantly sourced from the Willaumez Peninsula to the Santa Cruz/Reef islands (Tikopia) and Vanuatu (Makué, Teouma). Such distribution mechanisms were facilitated through direct imports or intermediation by a limited number of agents (Summerhayes, 2009). Of particular interest is the provenance of obsidian artefacts, with the majority of obsidian findings from the Santa Cruz/Reef islands (Green, 1987) and Makué in Vanuatu (Galipaud & Swete Kelly, 2007) believed to have been imported from New Britain, despite the Banks Islands being the closer obsidian source for both regions. Green (1987) suggests that these linkages to the Bismarck Archipelago reflect a deliberate strategy to maintain relations and

[3] Recent discoveries at Gutunka Bay on Brooker Island in the Louisiade Archipelago have unveiled an aceramic horizon of Lapita culture, consisting of pig and dog remains. These findings are dated to a period before 3200 BP (Shaw et al., 2022)

alliances through the importation of luxury commodities aimed at increase of social status (p. 246). Additionally, obsidian artefacts originating from the Bismarck Archipelago have been identified in Fiji, where the presence of three obsidian artefacts from two distinct sites – Naigani and Bourewa – has been documented (Best, 1987, as cited in Summerhayes, 2009). Contrarily, obsidian on Tonga comes exclusively from local sources.

In the subsequent phase of the Lapita cultural development, there was a notable shift in the distribution patterns of obsidian artefacts. While the early phase implied a symbolic exchange of volcanic glass items integral to the colonization process, in later stages it became evident that these exchanges were part of more spatially localized networks operating within a down-the-line exchange mechanism (Irwin, 1991, as cited in Gaffney & Summerhayes, 2019). The emergence of new stylistic motifs in dentate stamped sherds and pottery typology indicates a process of regionalization within the Lapita culture following the initial settlement of Remote Oceania. Despite the regional diversification, Summerhayes (2000) posits that these variations have a temporal rather than spatial significance. Furthermore, a detailed analysis of the stylistic components in decorative elements reveals the persistence of inter-regional trade networks and the adoption of novel decorative techniques across distinct territories (including the Bismarck Archipelago, island Melanesia in Remote Oceania, and western Polynesia). These innovations gradually supplanted the characteristic dentate stamping of the Lapita culture towards the latter stages of the Lapita era, with shell impressions and incisions emerging as the dominant decorative techniques across the diverse regions. This evidence underscores the coexistence of rapid demographic expansion and a remarkable degree of cultural homogeneity within the Lapita-inhabited regions during this epoch.

The settlements of Lapita culture were characterized by their relatively modest size. According to Kirch (2017), coastal settlements varied in scale from as few as 2-3 households to as many as 150 households, as exemplified by the site of Talepakemalai. The size of these settlements exhibited natural fluctuations over time (pp. 180, 191) It is apparent that initial settlements on newly discovered islands were typically smaller in scale and experienced growth through both natural demographic increase and migratory processes. The extent to which these demographic factors influenced the population dynamics of specific islands remains an issue requiring further investigation, as no definitive conclusions have been reached in this regard. A study by Di Piazza and Peartree (1999) employed a model incorporating three key variables – the size of the initial migrating population, natural population growth rates, and the proportion of individuals engaged in migration. Their findings suggest a probable trajectory for population size in newly settled regions over a span of 300–500 years, encompassing the dispersal of the Lapita cultural complex from the Reef/Santa Cruz islands to Samoa. This analysis offers insights into the colonization

of islands and the demographic dynamics within Island Melanesia and Western Polynesia. The simulation outcomes indicate a correlation between higher percentages of migrating populations and the eastward shift of more populous colonies. The variables employed in the study suggested a population growth rate of 4% per annum, while considering a migrant ratio ranging from 5% to 95% from already settled locations to the newly discovered ones. The suggestion of a 4% population growth rate, similar to trends observed in some preindustrial societies, raises questions about the subsistence capacity of coastal regions on predominately rather small islands, traditionally inhabited by the Lapita people. In contrast, Burley's (2007) examination of prehistoric Tonga proposes a more modest growth rate of around 0.8%.

The phenomenon of migration is also exemplified by archaeological evidence from the Teouma burial site in Vanuatu. A study conducted by Bentley et al. (2007) identified four individuals as immigrants out of a total of seventeen buried remains, but the analysis of isotopic signatures ($^{87}Sr/^{86}Sr$ and $\delta^{18}O$) derived from dental enamel, does not point to the precise origins of these migrants.

Social Aspects of Spatial Mobility during the Lapita Period

Even though it is not possible to exclude reasons that could potentially support the model of gradual dispersal to Remote Oceania from the perspective of the Lapita culture linked to the factors resulting in rapid population growth, for example, due to horticultural practices, it is evident that socio-economic relations played a significant role in this process. The Lapita society was not egalitarian; there were differences based on gender, age, or kinship, but according to Kirch (2017), it was probably not sufficiently stratified to be characterized as hierarchical. As Kirch further states, "in a heterarchical society, the fundamental social units (probably extended households) are in economic competition with each other, emphasizing minor distinctions in prestige or wealth, particularly as these are played out through formalized exchange" (p. 194). Bellwood (2006b) believes that the competitive environment was the main motivation for discoveries and settlement of new islands, resulting in the acquisition of prestige derived from pioneering, discovery and settlement of uninhabited territories. The rewards of such explorations and subsequent settlement guaranteed access to the most fertile lands, productive waters, and resources, which were subject to trade and ritualized exchange, while also conferring elevated status and prestige upon the descendants of the founder who became the ultimate ancestor in the lineage. In contrast to Kirch's perspective, Bellwood (2006b) suggests a more pronounced stratification within the social hierarchy, potentially manifested in the form of a hereditary chief. This concept may not necessarily have been imported from South-east Asia but could have

emerged as a consequence of the rapid colonization of previously uninhabited regions in Remote Oceania. It is plausible that younger siblings, driven by aspirations to establish new familial lineages, played a pioneering role in the settlement of new islands, hastening this process (pp. 31-32). Additional studies (Lin & Scaglion, 2019) propose that the concept of the hereditary chief did not evolve indigenously in Near Oceania but was imported as a result of earlier developments, already present in the Bismarck Archipelago region. A. Pawley (2020) proposes the evidence drawn from a distributional analysis of hereditary leadership in Near Oceania, a phenomenon absent in regions where non-Austronesian languages are spoken. The reconstruction of the Proto-Oceanic language suggests the term *ta(u)-lapat, as a chief or person of chiefly rank and potentially *riki (little, perhaps offspring) as an antecedent of Proto-Polynesian *qariki, with the meaning of chief. (Ross et al., 2023)[4]

Another societal aspect that needs to be examined in relation to the spatial mobility of the population involves family and kinship structures based on origin and inheritance. The reconstruction of this domain in prehistoric contexts is inherently complex and relies heavily on the analysis of ethnographic data, linguistic studies, diachronic analogies, and complex statistical models. Although several hypotheses have been proposed, a common feature among them is the tendency to conclude a general classification of kinship and structures based on origin and succession that were typical of Lapita society. Given the temporal distance to presence and the unavailability of empirically verifiable sources, research at this level of categories is naturally demanding, often leading to conclusions that may be inconsistent or even contradictory.

The issue of kinship in Lapita societies has been addressed in several studies. Hage (1998) provides a comprehensive overview of these studies in the introduction to his analysis. While bilineal systems are primarily supported by ethnographic comparisons, linguistic evidence favours unilineal systems. Based on these evidences, Hage concluded that Proto-Oceanic society was probably matrilineal. This conclusion was further corroborated by Marck (2008), who additionally posited that the society was matrilocal, providing new insights for understanding certain aspects of population mobility. Marck attributes this residential custom to a matri-oriented horticultural economy combined with frequent and extensive voyages conducted by men. This hypothesis is supported by findings from population genetics research (Kayser et al., 2006), which led Marck to estimate that, in the original pre-Austronesian population, one out of ten men and one out of a hundred women married into the Austronesian population (Marck,

[4] Opinions regarding the cognates of **qariki* in the Proto-Oceanic language vary. Additional references can be found in the Lexicon of Proto-Oceanic, Volume 6 (Ross et al., 2023).

2008). Contrarily, the conclusions drawn by Marck are contested by the results of a study by Jordan et al. (2009) which presents a statistically significant model supporting patrilocal residence within Proto-Oceanic society, while indicating matrilocal residence for Proto-Austronesian society.

Kinship and residential patterns are dynamic elements in society, subject to gradual changes with occasional rapid shifts influenced by external factors (Jones, 2011). Since the exploration of uninhabited territories was primarily, if not exclusively, carried out by men (as elaborated later in this article), the colonization of newly discovered islands, especially in Remote Oceania, in accordance with a founder-focused ideology mentioned earlier, necessitated the adoption of a neolocal residence system. This arrangement allowed male explorers to establish settlements with their partners, forming lineages of succession. Conversely, as noted by Marck (2008), a matrilocal system is beneficial in the absence of men due to extended voyages for trade and exchange, as was the case of the Lapita culture evidenced archaeologically in Lapita people-inhabited regions. It is important to emphasize that even within matrilineal societies, political power was often held by the mother's male descendants. Matrilocality thus would have been maintained after the establishment of each successor colony, with a possible gradual shift towards patricentric residence occurring very slowly. Additionally, residential patterns based on gender, seniority, or social status could be considered for Lapita society. Under such a scenario, patrilocal residence could have been part of influential lineages, while the rest of the society would have adhered to matrilocal residence, contributing to a process of social stratification in Lapita and post Lapita societies as elaborated further in this article. Although research on this topic is limited, similar systems are observed in contemporary Oceania, with Marck also proposing their presence in early Polynesian societies (p. 354).

Canoes and Voyaging in Prehistoric Oceania

The preceding sections of the article have examined the phenomenon of spatial mobility during the Lapita period and the social factors that influenced and facilitated this mobility. As Lapita people predominantly inhabited coastal regions of the Pacific islands, their primary mode of transportation was probably some form of watercraft capable of voyages lasting at least several days. While the distribution of obsidian in the pre-Lapita period suggests the existence of inter-island exchange networks, the distribution pattern underwent a significant change during the early Lapita era, with an increase in the overall trading distance across the Bismarck Archipelago (Fredericksen, 1997). This may indicate the use of more advanced watercraft, a topic that will be discussed in the following sections.

It is worth noting that the Lapita people were not the first group to venture beyond the boundaries of Remote Oceania. The settlement of the Mariana Islands, predating the colonization of Santa Cruz/Reef islands, or Vanuatu by the Lapita people by approximately 200-300 years, serves as the earliest documented example of island colonization in Remote Oceania. This historical event highlights the voyaging capabilities of Neolithic migrants, dating back to the period of the first settlements on the Mariana islands around 1500BC or possibly even earlier (Carson, 2014). Scholarly research suggests a potential colonization of the Marianas from the northern or central Philippines, entailing a voyage exceeding 2000 kilometres, challenging the prevailing trade winds (Blust, 2000; Hung et al., 2011). Linguistic analysis reveals that the inhabitants of the Marianas and Palau speak Western-Malayo-Polynesian languages, distinct from other Austronesian linguistic groups including that of the Oceanic branch, but sharing a common ancestry (Blust, 2000). Furthermore, the potential connection of prehistoric Mariana Islanders to Island Melanesia and subsequently the dispersal of Lapita people into western Polynesia is a plausible hypothesis, as posited by Carson (2018, p. 129). The research on skeletal remains from the Mariana islands dating back 2200 years confirms a genetic affinity between the original inhabitants of the Marianas and those unearthed at the Teouma or Talasiu Lapita burial sites (Pugach et al., 2021).

Contrarily, the hypothesis of a North or Central Philippine origin for the initial Marianas settlers has been opposed in a study by Winter et al. (2012), which proposes an alternative settlement origin from the Halmahera region or the Vogel Kop Peninsula. Their argument is underpinned by the technological constraints of watercraft, impeding sailing against prevailing trade winds over vast distances. However even a direct voyage from the Vogelkop Peninsula to the Marianas without intermediate stops at Palau or Yap would span approximately 2000 kilometres, a notable contrast to the maximal transport distances of obsidian within the Bismarck Archipelago during the pre-Lapita era.

The colonization of Near Oceania by Neolithic populations probably involved a transformation of the vessels and the improvement of seafaring skills, the full extent and nature of which remain unclear. Mahdi (2017) highlights a longstanding tradition of seafaring in the ISEA and Sahul region during the Pleistocene era, dating back to approximately 45 thousand years ago. However, most islands in this region were visible from other locations and the final destination of the voyages was known, although not all islands in Near Oceania conformed to this pattern. The visibility of specific islands was contingent upon factors such as elevation, distance, and the direction of the voyage. Manus, for instance, stands as an island that remains invisible under any conditions from any other island. Other potential exceptions include Bougainville and Buka (Irwin, 1994). Furthermore, the winds and ocean currents in Near Oceania exhibit a high

level of predictability that facilitates voyages along the principal chain of the Solomon Islands in both directions, depending on the seasons in the southern hemisphere.

There are two main schools of thought in academic discourse regarding the watercraft and maritime proficiency of the inhabitants of Remote Oceania, although pertaining specifically to a later period and navigation in Central and Eastern Polynesia. The traditionalists (Irwin, Horridge, Finney among others) regard these vessels as proficient instruments capable of navigating to a certain extent against the wind. The other academic group expresses scepticism towards the indigenous boats and the efficacy of colonization, rather attributing challenges to climatic variation during these epochs (Anderson, 2014). It is noteworthy that as the eastern islands were progressively settled, the likelihood of reaching these lands by simple drifting diminished, as evidenced by computational analysis conducted by Levison et al. (1973). For instance, out of ten thousand simulation trials aimed at reaching the Hawaiian archipelago, none successfully reached their target. This discrepancy prompted various scholars to embark on experimental voyages that demonstrated the navigational capabilities of traditional Polynesian canoes.[5] Drawing insights from the Polynesian canoe, scholars like Geoffrey Irwin (1994) or Adrian Horridge (2006) extrapolate the potential of Lapita watercraft not only to reach archipelagos within Island Melanesia but also Western Polynesia by strategically navigating against the prevailing winds to ensure a safe return. In contrast, several studies, primarily utilizing computational simulations, focus on the phenomenon of El Niño-Southern Oscillation (ENSO), considering extended periods of wind reversal during these episodes as a key factor (e. g., Anderson, 2002; Anderson et al., 2006; Avis et al., 2007; Montenegro et al., 2016; Winter et al., 2012). The ongoing debate between the two factions underscores the need for additional research to tip the scales in favour of either set of arguments. In the absence of robust empirical evidence, scholars must look to supplementary sources of information to gain further insights from which more conclusions can be drawn.

One plausible approach to gather evidence involves the reconstruction of terms pertaining to canoes and their parts, or their linguistic affiliations, in the

[5] One of the most prominent voyages in this context was led by anthropologist B. Finney, who embarked on a journey aboard the Hōkūleʻa, a traditional Polynesian double-hulled canoe, from the island Maui, Hawai'i to Tahiti and back in 1976. Subsequent voyages further demonstrated the vessel's proficiency in sailing against the wind. Noteworthy is the involvement of one of the few remaining traditional navigators named Mau Piailug from the Micronesian atoll of Satawal, who skilfully guided the ship during the expedition without the aid of modern navigational instruments.

Proto-Oceanic language and its potential predecessors, such as Proto-Austronesian and Proto-Malayo-Polynesian. The most reliable data in this field to date was provided by A. Pawley and M. Pawley (2015) in their reconstruction of terms for canoe parts in the Proto-Oceanic language. Important terms are listed in table 1 below.

Table 1. Comparison of constructible Proto-Austronesian, Proto-Malayo-Polynesian and Proto-Oceanic terms for canoes and sailing (A. Pawley, 2007)

1. *Terms continued from PMP*

	PAn	PMP	POc	PCP	PPn
prop, post, mast	*tuku	*tuku	*tuku	*tuku[1]	*tuku
boat rollers		*laɲen	*laŋon	*laŋo	*laŋo
outrigger canoe or hull[2]		*katiR	*kati(R)		
outrigger float		*(c,s)a(R)man	*saman	*ðama	*hama
sail	*layaR	*layaR	*layaR	*laða	*laa
steering oar, steer		*quli(n, ŋ)	*quliŋ	*quli	*quli
canoe paddle		*be(R)(c,s)ay	*pose	*voðe	*fohe
to paddle		*pa-luja	*paluca		
punting pole		*teken	*tokon	*(i)toko	*toko
bailer		*limas	*(l,n)ima(s)	*(i)nima	
anchor		*sauq	*jau(q)	*jau	*tau
channel in reef		*sawa(ŋ,q)	*sawaŋ	*sawa	*awa
make a sea voyage		*pa-lahud	*palau(r)	*volau	*folau
load a vessel; cargo		*lujan	*lujan	*uja	*uta
embark, ride on a vessel		*saŋkay	*sake	*ðake	
raft		*dakit	*raki(t)		

2. *Terms continued from POc, without known antecedents in PMP*

	POc	PCP	PPn
canoe, sailing canoe	*waga	*waga	*waka
topstrake	*(q)oRa	*(q)oa	*(q)oa
outrigger boom	*kiajo	*kiajo	*kiato
sticks attaching float	*patoto	*vatoto	*fatoto
side opposite outrigger	*katae	*katae	*katea
boom / yard of sail	*jila	*sila	*tila
bow of boat	*muqa	*muqa	*muqa
prow, end-piece of prow	*(i,u)cuŋ	*isu	*isu
stern	*muri	*muri	*muri
landing place	*mata-sawaŋ	*mata-sawa	
boat owner	*tau (ni) waga	*tau (ni) waga	*tau waka

Conclusion

The examples provided earlier illustrate how population expansion, socio-cultural, and economic aspects of the Lapita cultural complex were manifested through spatial mobility. The indigenous canoe, as previously described, served as the primary instrument of this mobility. This section aims to elucidate the influence of social and demographic factors on the evolution of the technologies linked to canoes and seafaring, particularly in peripheral regions such as the Tonga or Samoa archipelagos in the 9th century BC.

Voyaging to distant and unknown territories was undeniably a perilous endeavour, fraught with a high likelihood of casualties. Drawing on Finney's conservative estimates (as cited in Irwin, 1994, p. 43) approximately 10 canoes, each carrying 25 individuals, were lost at sea during the exploration and subsequent exchange-driven voyages in Central and Eastern Polynesia. It is conceivable that voyaging during the Lapita period was comparable in this regard, if not more hazardous, due to probable technological limitations. However, the shorter distances covered within Island Melanesia and Western Polynesia must be acknowledged in this assessment. The rapid dispersal of populations to the region of Remote Oceania occurred with remarkable speed. It is plausible to propose that the initial settlements on islands in Remote Oceania were modest in size, with some, like Nukuleka on Tongatapu, potentially evolving into larger villages over time. In such circumstances, both human labour and resources were relatively scarce in any single location. Irwin's theory of subsequent exploration and the strategic navigation against prevailing winds to ensure a safe return (Irwin, 1994) appears reasonable as a means to mitigate further workforce losses that could potentially jeopardize the survival of the community. In general, any strategy that could have reduced the frequency of such perilous expeditions or limited their distance appears feasible, unless other significant factors were at play.[6]

The exploration of unknown regions prior to subsequent migration was most probably an essential component of the colonization process as Irwin (1994) posits. As the manipulation of boats, paddles, and heavy sails, particularly when soaked, required a fair amount of strength, it is feasible to suggest, as previously mentioned, that exploration was predominantly, if not exclusively, the domain of men. Additionally, in the event of an outrigger canoe overturning, the combined bodyweight and strength of seafarers is necessary to restore it to its upright

[6] One such factor, especially in the principal phases of settlement, could have been an inter-island exchange to mitigate risks and foster mutual support and cooperation arising from potential environmental hazards, as was the case of the Sawei exchange system, within the Caroline islands of Micronesia.

position. Furthermore, as noted by Marck, the engagement in potential horticultural activities necessitated the presence of the female segment of the population on the land (Marck, 2008).

In order to effectively fulfil its intended function of transporting a sufficient number of individuals and supplies for the establishment of a new colony, as well as enduring prolonged voyages at sea, such as the journey from Vanuatu to Fiji, the requisite considerations included the appropriate dimensions and structural robustness of the voyaging canoe. The size of the canoe is evident in the reconstructed terms of the Proto-Oceanic language and also the Proto-Malayo-Polynesian language (A. Pawley, 2007). It was most certainly of such a size that in order to put into the water from the shore, boat rollers were required. The construction of such watercraft undoubtedly necessitated the collaborative efforts of multiple households and probably involved a significant amount of time to complete as observed by ethnographic research. In the documentary *Vikings of the Sunrise*, Siers (1977) documented a voyage from the Gilbertese island of Tarawa to Fiji. The baurua canoe, which he and his crew navigated, took six months to be constructed with the assistance of 14 men and their wives utilizing steel tools. One of the craftsmen emphasized that the construction of such a canoe would have taken a minimum of three years in ancient times without the aid of instruments made of modern materials. Nevertheless, the baurua crafted by the artisans of the village of Taratai represented a present-day vessel, built on the basis of knowledge acquired by generations of voyagers, and therefore cannot per se be applied to the watercraft of the Lapita era.

The evidence regarding whether the canoe was built using sewn planks, such as was the case of Siers' baurua, mentioned previously, is inconclusive. The reconstructed term *(q)oRa, as it appears in table 1, meaning top strake, offers some indication that this technique was known, but it remains uncertain whether it was applied to the key structural components of the canoe. No cognate for keel has been reconstructed in Proto-Oceanic. Constructing a large canoe during the prehistoric era with stone tools must have been a labour-intensive process requiring many skilled craftsmen. However, the availability of a sufficient workforce in certain locations is doubtful. Several indications suggest that, after the initial settlement in western Polynesia, population levels remained very low for several centuries, particularly in areas such as Samoa. Burley's (2007) estimations suggest that the initial settlement of Nukuleka, the first settlement within the Tonga-Samoa region, comprised no more than a hundred individuals. During the Lapita era, the population on Tonga is believed to have grown to approximately 600–700 people by the end of this period, with this population also spreading to other islands besides Tongatapu. In the case of Samoa, the demographic situation is even more pronounced. Only one locality with decorated Lapita sherds have been uncovered so far at Mulifanua, during pier

construction (Petchey, 2001). There are indications that some sites might have been abandoned after initial settlement with population exhaustion being the possible cause (Burley & Addison, 2014). Even genetic studies have concluded that the population of Samoans, scattered around the archipelago, was fluctuating between 700 and 3440 individuals until about 1000 AD (Harris et al., 2020, p. 9461).

Over the long term, a sparse population in terms of quantity or density prevents technological progress (i. e., Aiyar et al., 2008; Aiyar & Dalgaard, 2003; Klasen & Nestmann, 2006; Kremer, 1993 among others) occasionally even resulting in technological regression. Aiyar and collaborators (2008) have developed a model to elucidate technological regression in the preindustrial era, drawing upon the Malthusian and Boserupian frameworks.[7] The contemporary distinction between human capital and technology as two separate subjects does not align with preindustrial times. As the study further concludes: "…before the advent of the printing press and widespread literacy, technological knowledge would have to be embodied primarily in humans, and actively transmitted across generations in order to be preserved in society. This opens the possibility of technological regress" (Aiyar et all., 2008, p. 127). Could rapid expansion across extensive distances have led to a decrease in population density and subsequently resulted in the regression of boatbuilding technologies across successive generations? Evidence from both Island Melanesia and Western Polynesia (Burley & Addison, 2014; A. Pawley, 2007), confirms that exchange networks gradually underwent a process of regionalization and in many places also a diminishing intensity of contact, indicating a possible reversion of technological progress. After the cessation of decorative elements on pottery in the Samoa and Tonga region, Tongan and Samoan pottery display distinctions in typology. Samoan ware was primarily limited to bowls and cups, often characterized by crude production (Addison & Gurr, 2008, as cited in Burley & Addison, 2014). Contrarily, A. Pawley highlights unified language development in Tonga-Samoa area for millennia or more (Ross et al., 2023, p. 152) Further research can shed more light on the demographic dynamics of prehistoric Pacific societies in order to understand the processes behind technological advancement or potential regression. The positive correlation between population size and social complexity, as observed by Carneiro (1967), also suggests that the decrease in exchange activities in Western Polynesia at the end of the Lapita period and the onset of the Polynesian plainware phase may have been influenced by reduced

[7] Key references for these frameworks include the works of T. R. Malthus (2003), a distinguished 19th century English economist and scholar, and E. Boserup (1981, 2014), a renowned Danish economist known for her research on population dynamics and agrarian transformations.

demand stemming from a less competitive socio-cultural environment. Meanwhile, if the residential pattern of the founder shifted to a patrilocal arrangement, as posited earlier in this article, it would have resulted in the concentration of boat-building knowledge within the hands of such a lineage, given the male-dominated nature of seafaring, canoe construction, and related activities. With a gradual increase in population size and density in Tonga, peaking towards the end of the Polynesian plainware phase as noted by Burley (2023), a more pronounced social stratification emerged. Those who excelled as voyagers and boat-builders were positioned at the top of the social hierarchy, reflecting their elevated status obtained through the acquisition of larger quantities of redistributable goods during their voyaging expeditions. Contrarily, the practice of matrilocal residence facilitates a more evenly distributed boat-building and voyaging knowledge and contributes to a society characterized by a less hierarchical social system.

Final Remarks

The settlement of the Pacific islands during the Lapita period is a remarkable chapter in human history, filled with many unknowns yet to be explored. The exploration and colonization of these remote islands required suitable watercraft and navigational techniques, which were probably deeply intertwined with the social, demographic, and cultural contexts of the time. Despite the lack of direct empirical evidence due to the perishable nature of materials used in watercraft construction, the study of surviving artefacts, linguistic reconstructions, and ethnographic analogies provides valuable insights into the seafaring practices of prehistoric Oceania.

This article emphasizes the importance of understanding social factors, often overlooked in favour of environmental considerations, that influenced technological innovations in watercraft and navigation. It underscores the role of kinship structures, residential patterns, social hierarchy and demographic factors such as population mobility, size and density in shaping the evolution and dissemination of boat-building knowledge and navigational practices. The potential for technological regression due to sparse population density and the regionalization of exchange networks further emphasizes the complex interrelations between social dynamics and technological progress. The analysis in this article is based on theories proposed by recognized scholars, from which verifiable hypotheses will be formulated and tested in future research using concrete quantitative data. This research will be complemented by mathematical modelling and comparative analysis to deepen our understanding of the subject matter and reconstruct the intricate connections between technological and social

landscapes of early remote Oceanic cultures. Their adaptive strategies, achieved with the aid of technological innovations, finally led to the colonization of the Earth's last habitable environments in Central and Eastern Polynesia, starting approximately 1500 years after the initial settlement of the Western Polynesian islands of Tonga and Samoa.

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