Ancient Voyaging Capacity in the Pacific: Lessons for the Future

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We carry the cultural and historical inheritance of ocean navigators of peerless skill and their courageous kin who crossed vast distances before the tribes of Europe had ventured forth from their small part of the earth.

Sir Ratu Kamisese Mara, 1999[1]

Introduction

Some six to ten thousand years ago, humans migrated from Southeast Asia and populated the myriad islands of the vast Pacific Ocean. Their voyaging and maritime technologies were unique and unparalleled elsewhere, and evolved over time into specialised local knowledge.[2] While the catamaran-style vessels[3] of the eastern Pacific have received global exposure, the other remarkable and multiple vessel design evolutions that occurred across the Pacific are less well illuminated in

[1] Sir R. Mara, 'Opening address', *Pacific Vision Festival,* Auckland, New Zealand, 26 July 1999. http://dev.iwise.com/pVvWv accessed 2 July 2013

[2] The origins and chronology of settlement patterns of Pacific peoples is unclear. Archeological research in the area is hampered by the effect tropical conditions and changing coastlines have on remains. Contemporary research is bringing the conventional "out of Taiwan 3000 years ago" origin story into question, much as the single exit from Africa story of modern humans is currently in question. The authors remain agnostic on this subject as it has little bearing on the matters in discussions in this chapter. First colonists arrived in the north-west Pacific (now known as Micronesia) and Solomons/Vanuatu/New Caledonia chains, 3-4000 years ago, the central Oceania archipelagos (Fiji, Samoa, Tonga) over 3,000-years ago and from there throughout eastern Polynesia beginning some 2,000 ago, with the final outliers of Hawai'i, Rapanui and Aotearoa reached -700-1200 CE. Return, backwash and cross migration is assumed to be have occurred in many areas. See E. Matisoo-Smith and J. Robin, 'Origins and dispersals of Pacific peoples: Evidence from mtDNA phylogenies of the Pacific rat' *PNAS* 101 (24) (2004), 9167-9172; P. Sosres et al. 'Ancient Voyaging and Polynesian Origins', *The American Journal of Human Genetics* 88 (2011), 239-247; Y. Moodley, et al, 'The Peopling of the Pacific from a Bacterial Perspective', *Science* 23 January (2009) 323 (5913), 527-530; and P. Kirch, "Peopling of the Pacific: A Holistic Anthropological Perspective," by University of California, Berkeley, *Annual Review of Anthropology*, 39 (2010), 131-148.

[3] The signifier "canoe" has been used generically since European contact to describe Indigenous craft, sailed or paddled, and is now so ingrained in the literature to defy re-branding – even though the term implies insubstantial craft though they were often massive, blue-water, long-range, planked-hull sailing vessels. The terms "vessel" and "sailcraft" are used here rather than "canoe" where possible.

the literature. We use the examples of the *drua* class of vessel that emerged in central Oceania, including Samoa, Tonga and Fiji, and the *TePuke* of Taumako in the Solomon Islands to illustrate how technologies evolved and became attuned to various maritime and terrestrial environments, adapting to and exploiting local materials, tools, and weather and ocean conditions.[4]

Today, the ancestors of these master navigators and naval architects are facing the greatest threat to their existence, a growing global climate emergency. Contemporary Oceania is beset by challenges arising from an unfortunate trifecta: the decline of Indigenous practice and knowledge due to the arrival and subsequent colonisation by outsiders from the Western world over the last 400 years, a lack of adequate and affordable sea transport systems that support economic or sustainable development, and climate change. This chapter alerts readers to the urgency of rescuing and re-establishing Indigenous sciences, sailcraft design, seafaring traditions, and voyaging practices for reasons of both cultural preservation and future sustainability. In this troubled context, important lessons can be distilled from Pacific Indigenous maritime technologies to inform and inspire current and future generations as they seek to develop decarbonised shipping solutions to provide essential connectivity across atolls, islands and archipelagos in an increasingly climate challenged ocean.

Part I

Historical context

Sails are to the Pacific islands as the horse was to continents; the sailing vessel is as the wheel. A diverse variety of blue-water craft constructed entirely without metal and from a minimal resource base, and the capacity to navigate to far-flung islands *and return,* was developed by generations of shipwrights and master mariners. They settled every inhabitable island across the world's largest ocean, an exploratory and migratory feat unmatched in human history.[5]

[4] The term voyaging is often used to describe long distance and exploratory activities. We use the term "seafaring" to include *all* Indigenous practices of sailing, navigation, voyaging, and wayfinding.

[5] See for example K. Tu, 'Wa and Tatala: The Transformation of Indigenous Canoes on Yap and Orchid Island', unpublished PhD Thesis, Australian National University (2017), A. Couper, *Sailors and Traders: A Maritime History of the Pacific Peoples* (University of Hawai'i Press, Honolulu, 2009), P. D'Arcy, P, *The People of the Sea – Environment, Identity and History in Oceania* (University of Hawai'i Press, Honolulu, 2006), B. Finney, *Voyage of Rediscovery: A Cultural Odyssey through Polynesia* (University of California Press, Berkeley, 1994), K. Howe (ed)

The history of western maritime conquest, in the Pacific and elsewhere, is largely a history of searching for and controlling deep-water harbours. Modern naval ships have deep draughts[6] so they require safe depths of many meters. Pearl Harbour in Hawai'ian Islands, for example, was, and is, a strategic site precisely because it is a deep-water harbor with a deep entrance, that provides the nexus between the sea and the land for naval craft. Such harbours then become a bridgehead for land-based military, religious or economic conquest.

Indigenous settlement of the Pacific took a radically different pattern, their sailcraft could sail in a few inches of water and could be drawn up on the shore without falling over. Adapted to a world of reefs, shallow lagoons and estuaries, deep-water harbors were irrelevant. The first peoples of the Pacific were able to access and occupy the coasts of both mountainous volcanic islands and low-lying coral atolls.

As they pushed ever eastward from Asia into Oceania, the distances became greater, the islands smaller and more scattered and the biodiversity abundance declines rapidly. Evidence suggests that some groups reached South America, leaving behind the Polynesian chicken and bringing back the sweet potato, now a staple crop across the Pacific, and the bottle gourd.[7] By the time Europeans encountered the Pacific, only a brief few hundred years ago, the early sailcraft had evolved into a diverse range of sophisticated designs of multi-hulled and outrigger vessels.

The *Drua* vessel type that emerged in central Oceania around 350-500 years ago could carry well over 100 warriors and some sources credit with 200-300 capacity.[8] *Kalia* in Tonga were

Vaka Moana – Voyages of the Ancestors, (David Bateman, Auckland, New Zealand, 2006), and G. Irwin, *The Prehistoric Exploration and Colonisation of the Pacific* (Cambridge University Press, Cambridge, 1992).
Wangka: Austronesian Canoe Origins by Doran

[6] "Draught" is the depth of a vessel underwater.

[7] See D.E. Yen, *The Sweet Potato in Oceania: An Essay in Ethnobotany*, (Honolulu: Bishop Museum Press, 1974) and L. Roullier, et al, 'Historical collections reveal patterns of diffusion of sweet potato in Oceania obscured by modern plant movements and recombination', proceedings of the *National Academy of Sciences* 110(6) (2013), 2205–2210.

[8] Morphologically there is little design difference between the later vessels of Fijian, Tongan, and Samoan ownership (called *Drua* or *waqa tabu* in Fiji, *Kalia* in Tonga and *'alia* in Samoa). Where there is no necessity to distinguish between the country (or culture) of ownership, the class of *Drua/Kalia/`alia* collectively is referred to as *Drua* in this paper. See T. Williams, *Fiji and the Fijians and Missionary Labours among the Cannibals*, (Hodder & Stoughton, London, 1870); and W. Lawry, *Friendly and Feejee Islands: A Missionary Visit to Various Stations in the South Seas: in the year MDCCCXLVII*, (Mason, London, 1850), and P. Nuttall, et al (2014) 'Waqa Tabu – sacred ships: the Fijian Drua', *International Journal of Maritime History* (2014), 1-24.

built up to 118 feet, drew less than 3 feet and were capable of more than 15 knots of speed and reported to carry up to 50-ton burden.[9]

Pacific voyagers developed diverse sails designed to work with the wind, creating smooth airflows and aerodynamic curves which were efficient and refined to suit local operating conditions and the specifics of the transport work the vessel was employed on. The rigs favoured by European maritime engineers - massive spreads of canvas supported by enormous masts, and complex rigging - only sailed effectively downwind. Pacific seafaring designs resulted in highly efficient sail forms that allowed sailing much closer to the wind. They were also designed to spill excess wind in gusts and squalls.

Craft of diverse type and function were developed, from river, estuary and artisanal coastal fishing craft to fleets of long-range exploratory ships, for naval and trade missions. The more substantial polities developed large standing navies of massive battleships 30m and more in length and capable of carrying more than two hundred warriors at speeds of up to 15 knots and sailing as close to the wind as a modern racing yacht. The sheer volume of movement attests to islanders' willingness and ability to travel.[10]

Early European visitors encountering fleets of hundreds of vessels carrying thousands of people and were astonished by craft so fast and light, they outperformed any other vessel type known in the world. Affordable, accessible, appropriate, renewable-energy powered vessels ensured connectivity across the ocean and underpinned thriving local and regional trade and kinship networks. The sailing craft was the greatest asset a community could possess. It was a central aspect of all culture, imbued with sacredness. They belonged to chiefs and kings, rulers of high import, means, and political influence. Large voyaging vessels were symbols of statehood, power, military prowess, strength, and cultural pride.[11]

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[9] It should be noted that the Fijian term for a fleet is *bola*, meaning a hundred. Several Drua combined could easily carry the same load as the heavier displacement *Endeavour* or equivalent European ships. The invasion fleet of Kalia that Mariner reports travelling on in 1808 from Ha'apai to Vavau in Tonga could have been carrying as many as 2000 people and extensive provisions, see J. Martin *Tonga Islands: William Mariner's account: an account of the natives of the Tonga Islands in the South Pacific Ocean,*(Vava'u Press, 1981).

[10] D'Arcy, *The People of the Sea,* p. 64; E. Hau'ofa, 'Pasts to Remember,' paper delivered as an Oceanic Lecture, (USP, Suva, 1994), p. 54.

[11] M. Nickum, 'Ethnobotany and Construction of a Tongan Voyaging Canoe: The Kalia Mileniume', *Ethnobotany Research & Applications* 6 (2008), p. 233.

There can be no question that the Pacific Islanders were the greatest navigators ever known on any ocean and they built the fastest and most weatherly sailcraft made, until well into the twentieth century. Prior to external colonisation, every embayment in the Pacific would have its own fleet of carbon neutral vessels tailored to the local operating environment under a localised chiefly led system. A ship was always the greatest asset a chief could possess, house construction was an activity undertaken by shipwrights in their off-time. Sailing craft were the last line of defence to invasion by nature or rivals. The ability to point slightly higher to the wind, carry more people or cargo, or sail a knot faster than your foe could be the difference between survival or demise.

By 1,000 B.CE, the Pacific ancestors had arrived in the Marshall Islands to the north and the central Oceania archipelagos of Fiji, Tonga and Samoa, hundreds of open ocean miles east of Vanuatu, and were developing the outrigger and double-hulled "*vaka*" which would take them on to what is now known as the Cook Islands and the archipelagos of French Polynesia.[12] At about 1000 CE, Polynesians were already in Hawaii, over 2,000 nm north from the Marquesan Islands By 1200 CE they were settled in Aotearoa, 1600 nm to the south of Rarotonga. All known atolls and islands of the tropical north-west Pacific had long since been colonised. Five-hundred years ago, when Columbus sailed across the Atlantic, the Moriori had reached Rēkohu (Chatham Island), over 300 nm to the east of Aotearoa (New Zealand), and the colonisation of the entire Pacific Ocean was complete.

Indigenous Navigation: Colonisation & Renaissance

Pacific naval architecture was matched by outstanding navigational capacity. Captain James Cook's Tahitian guide, the *Arioi*[13] Tupaia, a master navigator, provided knowledge of 130 islands

[12] For examples see, J. Bentley, and H, Ziegler, *Traditions & Encounters: From the Beginnings to 1500*, (McGraw Hill, 2000), and L. Paine, *The Sea and Civilization: A Maritime History of the World* (Knopf, 2013).
[13] *Arioi* - artistic religious order.

to Cook's officers and George Banks, who recorded the names of seventy-four of them.[14] In Tupaia's time, the entire Pacific was an interlaced and interconnected network of locally-based knowledge of islands, seaways and weather patterns. Tupaia probably knew hundreds of routes between islands.

By that time almost all islands of the Pacific had been located and named, and Indigenous navigators had developed detailed and complex navigational systems based on intricate and intimate learned knowledge of celestial bodies, weather, wave and environmental indicators, passed between and handed down through generations of highly qualified navigators. These Indigenous systems were based in knowledge of universal environmental phenomena encountered on particular routes. – one learned the winds, seaway, and the starpath to a specific destination, then used reciprocal signs, to get back home. As Indigenous navigators undertook specific seaways, their experience of environmental phenomena increased, and the knowledge of interconnected routes developed into a rhizomatic network. At the edge of their range, navigators would exchange knowledge of local seaways with local navigators and share knowledge of universal navigational knowledge with their students.

These Pacific navigational systems (that we know of) are "deictic."[15] In this formulation, navigator is the (only) fixed point in the world, and *the world flows past* – a fitting conceptualisation for a maritime system.[16] Another quality of oceanic navigation is that there are rarely any landmarks, but there are birds, swell pattern, currents, clouds, and many other phenomena that an ocean-literate navigator can read. So, the idea of mapping the position of islands on a latitude/longitude grid so one can navigate by inferring one's position in relation to them is pointless.

In the 1970's, when Hawaiians were seeking to relearn their lost knowledge of navigation, Micronesian master navigator Mau Piailug was brought to Hawai'i from Satawal in the Federated States of Micronesia (FSM) to teach the future crew of the Hōkūle'a Indigenous navigation techniques.[17] But Mau's home, was over 3000 nm away, on a completely different latitude. So,

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[14] L. Eckstein, and A. Schwarz, 'The Making of Tupaia's Map: A Story of the Extent and Mastery of Polynesian Navigation, Competing Systems of Wayfinding on James Cook's Endeavour, and the Invention of an Ingenious Cartographic System' *The Journal of Pacific History, 54*(1) (2018), p. 15.

[15] "Deixis" is a term from linguistic, it refers to orientation centered on the perceiving subject, as opposed to an external reference system, e.g. "on my left" as opposed to "northwards."

[16] V. Diaz, 'Voyaging for Anti-Colonial Recovery: Austronesian Seafaring, Archipelagic Rethinking, and the Re-mapping of Indigeneity', *Pacific Asia Inquiry, 2*(1) (2011), p. 27.

[17] See L. Olopai, *The Rope of Tradition* (Saipan: The Northern Marianas Humanities Council, 2005).

islands, wind and swell patterns, and starpaths were different on a route to Tahiti in the southern hemisphere. Mau learned the rises and sets of celestial bodies for Hawai‘i by observing them and consulting with David Lewis about how the winds, seas, currents, and stars would change along the route to Tahiti.[18] Then he guided the first non-stop voyage of the 19 metre Hawaiian catamaran Hōkūle‘a from Hawaii to Tahiti in in 31 days without modern navigational tools, let alone compass, chart or sextant across open ocean using only learned oral knowledge.[19] This journey re-opened a traditional seaway of 2500 nautical miles (henceforth nm) that had been used between 400 BCE and 1400 AD.[20]

The arrival of Europeans as explorers and whalers, subsequently as colonists, missionaries and traders, led to the (often violent) suppression of Indigenous seafaring practices. Colonial governments – initially Spanish, British, Portuguese and French, and more recently including Russians, Germans, Japanese and Americans – often suppressed Indigenous seafaring by creating new and artificial political barriers between countries and communities and promoting and protecting their own trading interests over those of local populations. Through these 400 years, Indigenous seafaring, boatbuilding and navigation traditions in many Pacific Island cultures were lost. The knowledge of locally situated naval architecture and skills acquired and passed down through generations, is now all but extinguished, except in isolated pockets and fragile centres of cultural renaissance.

More than half a century of academic study and successful cultural revitalisation projects led out of Hawai‘i, Aotearoa/New Zealand and Tahiti have seen a global focus on the remarkable long-range exploration exploits of eastern Pacific navigators and voyagers as they completed the colonisation of the Pacific in the last millennia. Unfortunately, fascination with the long-range migrations to Hawai‘i, Rapanui/Easter Island and Aotearoa/New Zealand has overshadowed extraordinary history of Pacific maritime culture more generally. While the concept of the “Polynesian triangle” has become a culturally unifying idea for eastern Pacific Polynesians, it created false divisions between then and other Pacific peoples. Today, these people are the source of ancient seafaring practices that are long forgotten in the eastern Pacific.

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[18] See D. Lewis, *The Voyaging Stars: Secrets of the Pacific Island Navigators* (Collins, Sydney, 1978).
[19] K. Wilson, ‘Nā Mo’okū’auhau Holwa’a: Native Hawaiian Women’s Stories of the Voyaging Canoe Hōkūle’a’, unpublished PhD, University of Otago, New Zealand (2010). With more favourable wind on the return leg meant that the passage time was cut to only twenty-two days.
[20] Mimi George, Personal Communications with David Lewis and Mau Piailug (1992).

Part II

Pacific Design

Several thousand years of challenging blue-water passage-making in diverse marine environments resulted in design evolution toward the most efficient hull forms and wind powered propulsions of any blue-water craft. The outrigger and multihull designs of the Pacific offer a solution to the stability-under-sail problem that is utterly different from the Western solution. Rather than rely on a massive vertical lever-arm (ballast keel), islanders oriented that lever-arm horizontally. This not only solves the draft problem and the stability problem, it makes the craft much lighter, with much less volume and cross-sectional area to push through the water, making them inherently faster and nimbler. Their shallow draft allows them to sail over reefs, across lagoons, up shallow passages, and through estuaries. Shallow draught means the craft can be drawn up on land during storms and the rig can be dropped completely. If caught at sea, the buoyant wooden hulls can be flooded, and the vessel will sit semi-submerged until the waves subside. The materials for Indigenous craft are locally sources and inherently sustainable. These craft were finely wrought of local timber~~,~~ fashioned using tools of stone and bone, lashed together with sennit of coconut or other fibres, and flew sails of woven pandanus and other leaf crops. Timber is easily worked with stone and bone tools by skilled craftsmen. Sails of woven and sewn leaves are easily maintained and repaired. Cordage and lashings are made from coconut fiber, inner bark strips, or vines, which are easily severed and replaced allowing the vessel to be disassembled if needed. All replacement materials are easily sourced and installed.

Proa hull designs and rigs in particular had performance advantages undreamed of by Europeans. The asymmetrical hull combined with highly advanced sail shapes, movable spars and rigging resulted in energy efficient machines that paid dividends in speed and windward performance. No wonder early European explorers were aghast at the speed and agility of Pacific craft.

For any sail-powered vessel, there are two primary issues to resolve – how to ensure stability when there is wind pressure on the rig, ultimately avoiding a full capsize, and how to

capture the energy to drive the vessel upwind without the vessel sliding sideways (leeway). The conventional Western solution to the first problem is to create a counterweighted keel under the vessel, increasing the draught and providing a deeper keel to resist the boat sliding sideways. This often requires metal to achieve. Pacific ancestors developed a design philosophy based on working with the elements the vessel is constructed from and the environment the vessel would live in, rather than attempting to overpower them. Instead of rigid, immutable structures, they used lashings that allow the components of the vessel to flex with the waves. They built wide, multi-hull platforms to spread the load across the water. These shapes and structures were continuously refined.

Multi-hulls and outriggers have two performance characteristics that distinguish them from displacement mono-hull vessels. These are lower resistance to passage through the water and greater stability (initial resistance to capsize). Multi-hulls rely on form stability to resist heeling and capsize but need less driving power to go faster than deep draft vessels. The *TePuke* and *Drua* have mostly submerged hulls, which reduces wave-generating resistance by moving displacement volume below the waterline where waves have less effect. In modern naval architectural terminology, this is known as SWATH (small-waterplane-area-twin-hull). The larger wetted surface of a submarine hull causes some friction or 'drag', but there is less drag overall because the biggest cause of such drag is surface waves. The submarine hulls increase stability because they are not so affected by variations in wave heights that cause planing or wave-breaking vessels to pitch and heave.

Indigenous sailcraft: the evolution of the 'proa'

The epitome of Pacific naval design efficiency evolution is arguably the "flying proa" of the western Pacific. The Central Carolines *Wa,* Chamorro *Sakman,* Marshall Islands *Walap,* and Tongan *Kalia*, and Fijian *Drua are* all variants of the double-ended, shunting proa. The design diversity of sailcraft across the Pacific includes two different forms of shallow draft vessels with long fine hull lines, and a subsequent hybrid form. The catamaran has two equal hulls and a distinct

bow and stern. It is unidirectional and bilaterally symmetrical and like a modern western sailboat, it tacks through the eye of the wind. Tacking vessels present first one side of the craft to the wind, then, after tacking, the other. The proa, by contrast, is asymmetrical, with a single canoe main hull and either an outrigger or smaller second hull which is always keep to windward.[21] To change direction with respect to wind direction (as in tacking), the proa "shunts": the sail is removed from the front end (bow) and set up on the other end (the new bow) before sailing away. Shunting is a mode of sailing that is unique to Pacific and Indonesian craft.

One performance difference between different designs is how they sail to 'windward' – toward the direction where the wind is coming from. Sails cannot capture wind force when the vessel is heading directly toward the "eye" of the wind. So, sailing vessels must zigzag toward the eye of the wind at the best angle that they can while keeping the sails fully functional. On most early catamaran this meant a course at best of about 70 degrees off the wind can be maintained, whereas proa could achieve better than 50 degrees[22].

The axis of symmetry of the proa is lateral rather than longitudinal – one end is the mirror of the other. As with other Oceanic designs, the absence of a ballast keel means the underwater volume of the hull (to achieve floatation) is hugely reduced, resulting in a narrow, usually V-shaped hull of shallow draft that slices through the water. In many cases, the windward side of the hull is differently shaped from the leeward side, the former flat and the latter curved. This has the effect of hydrodynamically balancing the drag of the outrigger and of "crabbing" the hull to windward, increasing windward efficiency well beyond that capable in a catamaran design. As volume and cross-sectional area are reduced, drag is also reduced. In stronger winds, some proa can lift the outrigger entirely out of the water, further reducing drag.

The *Drua* of central Oceania, the *TePuke* of the Santa Cruz Islands, Solomon Islands, and related forms like the *Lakatoi* of Mailu Papau New Guinea, appear to be hybrid forms, with shunting rigs. *Drua* have two hulls, the leeward one slightly larger, with a shunting rig. Like catamarans, they are designed to sail level, the smaller hull being a true floatation hull and not a

[21] The term "proa" is thought to derive from "Parau/Prau" used for outrigger craft in parts of island SE Asia 1575–85; Malay "pərahu", "pərau", Kannada "paḍahu", or a cognate Dravidian word); probably influenced by Spanish or Portuguese "proa" meaning prow or bow.
[22] Sophisticated modern high performance sailcraft can point up to about 32.5 degrees off the wind.

windward counterweight. The *TePuke* of the Santa Cruz Islands, Solomon Islands has one hull and a massive outrigger with a variable number of floats, depending on the load.

The emergence of *Drua*

At some point after the migrations to the eastern Pacific, a new "racehorse" – the *Drua* class of true double-hulled proa battleships came to dominate in Samoa, Tonga, Fiji and surrounding islands.[23] There are three possible transition pathways; advances in western Pacific sails, rigging, and hull forms were transferred from the northwest to central Oceania via Tonga; the technology transfer occurred via Fiji and from there to Tonga and Samoa, or, much less likely, the design evolution occurred in Fiji with later transfer north and eastwards. While questions of origin are probably unresolvable, the design and construction innovation in disparate Pacific cultures is undeniable. The naval architecture excellence of the proa form, the maritime mechanics of Fiji, the navigation and seafaring expertise of Tonga and the seamless planking skills of Samoan shipwrights were combined to create a cross-cultural product that took Pacific sailcraft to a new zenith.[24]

The development of the *Drua* and their outrigger variation, the *Camakau*, depended on the *vesi loa* ((*Intsia bijuga*) resources of the southern Lau group between Tonga and Fiji. Described

[23] 'Alia (Samoa), Kalia (Tonga/Uvea), Drua (Fiji) are largely synonymous terms for the same vessel design. The documentation of the Drua/Kalia complex is restricted to a limited number of vessels examined by explorers of the Pacific in the late 1700s and 1800s (see for example J.C. Beaglehole, *The Exploration of the* Pacific, (A&C Black, London, 1934), J. Bulu, *Joel Bulu: The Autobiography of a Native Minister in the South Seas, Translated by a Missionary*, (Wesleyan Mission House, London, 1871); J. Twyning, *Shipwreck and Adventures of John P. Twyning Among the South Sea Islanders,* (London, 1850); C. Wilkes, *Narrative of the Unites States Exploring Expedition, During the Years 1838, 1839, 1840, 1841, and 1842. Vol. III*., (Lea and Blanchard, Philadelphia, 1845); Williams, *Fiji and the Fijians and Missionary Labours*, and a few ethnographies of the region in the late 1800's, early 1900's. See D. Toganivalu, "Canoe building," *Transactions of the Fijian Society for the Year* (1915) pp. 9-15; R. A. Derrick, *A History of Fiji*, (Suva, Fiji: Government Printer, 1946); A. M. Hocart, 'The Northern States of Fiji', *Royal Anthropological Institute of Great Britain and Ireland Occasional Paper No.11*, (Aleuin Press, Hertfordshire, 1952); A. Haddon and J Hornell, *Canoes of Oceania*, Vol. 1, Vol. 2, Vol. 3, (Bernice P. Bishop Museum, Honolulu, 1936); A. Krämer, *The Samoa Islands: An Outline of a Monograph with Particular Consideration of German Samoa (Auckland, New Zealand*, 1994 [1901]); L. Thompson, *Southern Lau, Fiji: An Ethnography,* Bernice P. Bishop Museum Bulletin No.162, (Bishop Museum Press, Honolulu, 1940). To this more recently can be added the treatises of A. Tippet, *Fijian Material Culture: a Study of Cultural Context, Function and Change,* Bishop Museum Bulletin No. 232, (Bishop Museum Press, Honolulu, 1968); F. Clunie, *Yalo i Viti. Shades of Viti: A Fiji Museum Catalogue,* (Fiji Museum, Suva, 1986), 'Drua and Kalia: the Great Tongan Voyaging Canoe', *Islands* (1987), pp. 11-16, and *Fijian Weapons and Warfare*, (Fiji Museum, Suva, 2013 and originally published as *Bulletin of the Fiji Museum* No. 2 1977); S. Rayawa, "Fijian Canoes," *Domodomo* XIII, 1, (Suva, 2001), pp. 30-36, 31.

[24] Nuttall et al, *Waqa Tabu – sacred ships,* pp. 1-24.

as “the titanium of the Pacific”, these massive greenheart timbers growing on limestone rock produced a marine construction material heavier, stronger and more rot and worm resistant than any other.[25] A complex ship building and export economy with permanent settlements of hereditary clans of Fijian, Tongan and Samoan expert shipwrights produced large fleets of such vessels for their overlords, in turn underpinning the trading economy of all of central Oceania. As Tonga expanded its influence, the Lau Islands became the hub of a complex maritime trade network centered on Tonga, Fiji, and Samoa. Tongans were the voyagers and the navigators, maintaining a monopoly over all exchange between these three archipelagos and outlying islands.[26] The maintenance of this exchange system depended on the *Drua* that could beat back into the wind when returning from Fiji.

Large scale construction of the *Drua* complex of vessels spanned at least the mid 1700’s CEto late 1800’s CE When the first prototypes were developed is unknown but is unlikely to have been earlier than 1600 CE[27] A little more than century ago such vessels were commonplace in Fiji’s waters and throughout central Oceania, underpinning a vibrant trading network within island groups but no longer allowed to practice international trade with their neighbouring countries.

While smaller, outrigger craft were used for fishing and other every day uses, the *Kalia* was clearly the ship of an empire, a political tool, and an instrument of power, war, and trade[28]. The majestic Tongan *Kalia* was a chiefly vessel, belonging to the most powerful nobility. In Fiji, the comparable *Drua* was called “*waqa tabu*,” or sacred canoe and manifested through rituals and protocols associated with drua culture.

The *Drua* home range included at least Fiji, Tonga, Samoa, Uvea, Rotuma and Futuna, and also likely found east to Tokelau and Niue, possibly even Rarotonga, and southwest to New Caledonia and north to Tuvalu. The *Drua* of central Oceania, as with all the great vessels of this ocean, were valuable and highly prized assets and major investments. “Great care was taken of them ... the construction and maintenance of canoes was a community effort. Only chiefs could

[25] S. Banack, and P. Cox, ‘Ethnobotany of Ocean-Going Canoes in Lau, Fiji’, *Economic Botany*, 41(2) (1987), pp. 148-162.

[26] N. Kaeppler, ‘Exchange Patterns in Goods and Spouses: Fiji, Tonga and Samoa’, *Mankind*, 11 (1978), 246-252.
[27] Derrick, *A History of Fiji* and B. Thomson, *The Fijians: A Study of the Decay of Custom* (Heinemann, London, 1908) both cite Kabara and Fulaga as centers of Kalia construction.
[28] Nickum, ‘Ethnobotany and Construction of a Tongan Voyaging Canoe’, pp. 129-253.

muster the manpower and resources needed to construct large voyaging canoes."[29] Construction could take up to seven years during which a skilled workforce would be employed. Only a chief of means could afford both the initial outlay and the continual maintenance a lashed vessel built of organic materials would require. Such vessels were not just physical assets; they were also symbols of community *mana* (respect). The completion of a large drua was a source of great pride.

Drua displayed better windward ability than any other double-hull Oceanic design. This reduced the uncertainty of return voyaging capacity (assuming the vessel itself withstood the rigours of the voyage), as well as giving increased speed and performance. Drua were the naval attack weapon of choice for any central Oceania naval commander, serving as blockade-runners and enforcers, landing craft, fleet battleships, troop and supply transporters and deadly effective rammers. There are graphic descriptions of the naval battles as a warship capable of slight extra speed or agility could be the difference between life and death, not only for the crew but also the community it protected.[30] In times of peace they served as merchant ships servicing established trade, kinship, and secular routes and performed as diplomatic missions, passenger carriers and cargo traders. They were used extensively in the service of the new Christian religion as essential transport for both European and local missionaries, especially by the Tongan teachers who used massive on regular conversion voyages from Tonga to Fiji via the Lau Islands. The vessel movements between Fiji and Tonga were almost certainly at their highest historical levels in the mid-nineteenth century CE

TePuke: The *Vaka o Lata* of Taumako, Santa Cruz Islands, Solomon Islands

Taumako is the furthest east of the far-flung islands of the Santa Cruz Group which are themselves regarded as a first outpost of "Remote Oceania" for voyagers heading east from the archipelago of

[29] D'Arcy, *The People of the Sea*; Haddon and Hornell, *Canoes of Oceania*, p. 319; Nickum, 'Ethnobotany and Construction of a Tongan Voyaging Canoe', p. 137; and Thompson, *Southern Lau, Fiji.*
[30] See Clunie, *Fijian Weapons and Warfare.*

thousands of islands stretching out to the east of West Papua/Papua New Guinea.[31] In 1996-97, the late Te Aliki Kaveia led his community in the thirty-step process required to build an ocean-going vessel (*vaka*) known as "*TePuke.*" It was the first to be built in sixteen years. Another was built by his grandchildren in 2016-17.

The designs, materials, methods and tools used by Taumakoans are an unparalleled window into ancient voyaging practice. The first step is planting gardens to feed the workers every day they work. Some days there are hundreds of workers. The organizational effort may involve ten years of planning prior to planting the gardens. During the first year, elders and children make the first few thousand meters of cordage, and plans are made to harvest each type of plant, tree, reef, and ocean resource that was used for each part and method of construction. The trees, leaves, vines, seaweeds, etc, to be harvested were planted and wild-crafted generations earlier. Women and children lead the gardening and food preparation, weave the sail panels, and make most of the cordage. They also help haul logs, forecast and modify weather, and negotiate for resources. Before WWII in the Southeast Solomon's there were Polynesian women navigating, owning, and leading voyages on TePuke. Small children gather and pound seaweed for paint, and carry messages, tools, and food. Men and boys do almost all the adzing, lashing, and sewing together of sail-panels. With steel blades in their adzes, a community of a few hundred people usually takes about two years to build a *TePuke*.[32]

Among Taumako people, as with many other Pacific cultures, the ancient story of Lata tells how the first person built and navigated a voyaging vessel (*vaka*) to distant islands.[33] It is not known how old the story of Lata is. But Taumako visitors to Hawai'i and Fiji recognised petroglyphs of Lata's sail as proof of Lata having been there.

At Taumako the story of Lata is a guide to life today, because they have an unbroken chain of practice of voyaging skills that Lata pioneered. Many of these skills are no longer practiced elsewhere and much knowledge has been extinguished. Each Taumako generation has its own

[31] Taumako is a fifteen km^2 island with large lagoons, fringing reef and an offshore deep reef that adds protection from the surge of cyclones. "Taumako" is also the ancient name for a group of five high islands plus outlying islets now called the Duffs Group. Sailing from ~~to~~ the closest big islands to the Santa Cruz Group at 10 knots speed takes at least two days in good conditions...then another day or so to the Duffs Group.Yet there is evidence that for about 3,000 years Taumako has been a crossroads of north/south and east/west voyaging. Duffs Group Islanders today are one of eighteen linguistically and culturally Polynesian communities in the far western Pacific.

[32] M. George, and K. Kaveia, 'The return of Lata: An authentic Polynesian voyaging canoe sails again', *New Zealand Sailing* (38) (1999), 49-53.

[33] Lata is known as "La'a," "Laka," "Rata," "Laa," and other names, among various peoples of Pacific and Indian Ocean Islands.

Lata; a person who achieves mastery in various areas of knowledge and experience. An experienced voyager is today referred to as a "Lata," and the crew treats that person, or those persons, like they would the original Lata. The lifestyle of oceanic people encourages youth to reach out over the ocean, engage with people of faraway islands, and seek and share resources that exist on some islands and not others. So voyaging vessel technology is key to creating and maintaining relationships between families, partners, networks, and eco-systems.

Lata's voyaging vessels were used for exploration, migration, and communications. Taumako has no anchorage for a ship, nor infrastructure for loading or unloading passengers and cargo. Lata's vessels can sail over the reef onto the beach. Those who sail Lata's vessels choose to voyage with fair winds, quickly and efficiently arriving at their destination, without unnecessary tacking or great risk of stormy seas.

Today, there are few products that Lata's descendants can afford to transport on a ship, and no paying jobs on the islands allowing people to buy goods from the ship's store or fares to travel aboard. Ships will not carry some natural materials and animals that islanders need. Only some ships carry petrochemical fuels that allow islanders to run their own engines. Ships do not come often to remote islands, and are usually in ill repair, lack safety gear, etc. Children who go to boarding schools and adults who take work on other islands must stay there many years. Without transport the social fabric is strained, proper cultural education is not possible, and there are no emergency services. In recent years movement between islands is urgently needed to adjust to rising sea levels and climate change.

Lata's *Vaka* Types

Voyagers of Taumako know that Lata's designs are more than two-hundred years old, but they could be very much older. "Vaka o Lata" (voyaging canoes of Lata) are double ended with proa rigs and sail with the outrigger to windward. According to Te Aliki Kaveia, *TePuke* (Figure 1 Cambridge U Press have ruled all illustrations must only be black and white. We can convert Figure 3 to black and white easily, but these two lack sufficient resolution. Can you substitute high resolution black and white, and if possible, make them one figure split into two panels or just use one as they are ruling 2 illustrations per chapter? If not, I am trying to get you three and may be

able to delete ones from my chapter to give you three) and *TeAlo* are the two main types of *vaka* that Lata created. Both are massively outrigged, but only *TePuke* have a riser box in between the main hull and the crossbeams. There are several types of *Te Alo*, with the biggest called "*TeAlo Lili*" made for offshore voyaging (Figure 2).

Figure 1. *TePuke* photo by M. George Copyright Vaka Taumako Project

Figure 2. *TeAlo Lili* photo by Wade Fairley Copyright Vaka Taumako Project

Ideally, *TePuke* and *TeAlo Lili* are trimmed to run with the hull almost submarine. The main hull of both sailcraft are hollowed-out logs with a narrow opening along the top. Coverboards are lashed on, and the seams sealed with a mastic made from breadfruit sap and shredded tree bark to keep water out. The outriggers are fitted with floats, that can vary in size and number as needed to suit loads and conditions. Lata's sail is a long-armed crescent shape, that is the image of Lata, with his arms raised overhead to grasp the wind. The woven Pandanus sail panels are sewn together with sennit. A well-maintained sail can last 10 years. The booms are grown to shape. The cordage of the running rigging is made from inner bark of *noa* (*Hibiscus tilaceous* or similar). Parts of the sail and booms change shape, flex, belly and return to shape in complex adjustments to wind conditions that enhance performance, and that modern materials cannot make.

TePuke are at minimum of six "*fadom*" in length.[34] The main hull of the *TePuke* is a heavy hardwood called Tamanu (*Callophylum inophylum*) that grows over 40m tall with few branches in the steep topography of Taumako. It is rough-cut in the forest, then moored in the lagoon for some weeks to season. It, and other major parts, are left to dry after layers of wood have been cut away as the parts are shaped. An internal lashing helps keep the ends of the main hull from splitting.

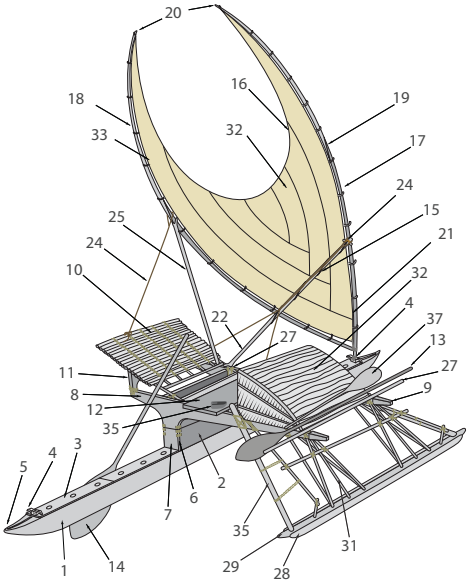
TePuke carry heavy loads, like trucks. The leeward edge of the leeward deck is mounted high on a large piece (*TeAlunga*), while the inboard edge is over a meter above the sea surface because it mounts at the riser box. This keeps the crew well above the seas. The name *TePuke* translates as "flood," and refers to the technique of floating the rough-cut of the main hull down to the sea (from higher altitude forest) when there is flooding from rain.

Up to three *TeAlo* can be carried on one *TePuke*. *TeAlo Lili* are like sports cars in being smaller, quick, and light, and carry only a few people and a little cargo. Their leeward deck (*TeKatea*), where most of the crew work or rest, is not as high off the water as it is on the *TePuke*. The main hull of *TeAlo Lili* are made from lighter, somewhat stringy, such as Breadfruit (Artocarpus altilis) or *PuloPulo (scientific name unknown*). *TePuke* have a shelter, but *TeAlo Lili* either have a shelter or not.

Marianne George has observed *TePuke* sailing at ~~better~~ less than 55 degrees off the wind. *TeAlo Lili* do not sail to windward quite as well. The cruising speed of *TePuke* in a 15 – 20 knots of wind was measured in 1980 at 10 knots. In 2013 a *TeAlo Lili* was clocked at over 15 knots in 30 knots of side-wind and a strong sea.[35]

Figure 3. Diagram of some of main parts of a *TePuke*:

[34] One "*fadom*" is the Solomons Pijin language name for a length from the fingertip of one hand to the fingertip of the other hand with arms stretched out fully from the side of the body. *TeAlo Lili* are usually no longer than 5.5 fadom.
[35] Challenges in measuring performance of the sail of Lata discussed in M. George, 'Te Laa o Lata of Taumako: Gauging the Performance of an Ancient Polynesian Sail,' *Journal of the Polynesian Society* 126 (4) (2017), 377-415.



1 Te Vaka - main hull
2 Te Hano Noho - riser box
3 Te Tau - coverboard
4 Te Moamoa -birds head shape at ends of vaka
5 Te Manumanu - Te Ube bird carving
6 Te Matai - the wooden planks that sit on the gunnels and form the sides of the riser box (not what is written there)
7 Te Taupua - the wooden planks that form the front and back of the riser box
8 Te Lakau halava - crossbeam
9 Te Pua'a - pig's head image
10 Te Katea - leeward platform
11 Te Alunga - "headrest" that supports the highest, leeward, end of the leeward platform
12 Te Pola - carved wooden plank that is the windward platform between riser box and shelter
13 Te Foe Ama - small steering blade used on the ama side of the vaka
14 Te Foe Vaka - large steering blade used on the vaka side of the vaka
15 Te Lele - lines that raise the mast
16 Te Laa = the sail that has the shape of Lata holding arms overhead
17 Te Lango Vaka = the two booms together
18 Te Manga Iti - leeward boom
19 Te Sila - windward boom
20 Te Ukui - top sections of booms
21 Te Kawolo - bottom section of boom
22 Te Hanaa - mast
23 Te Tata - halyard (to raise sail)
24 Te Haha - sheets (lines to control sail)
25 Te Kapemanga - reaching pole
26 Te Li'i - windlasses (there are 6 inside riser box, 3 forward and 3 aft)
27 Te Tokomanga - poling pole
28 Te Utongi - side float
29 Te Ama - central float
30 Te Hakatu - vertical connector
31 Te Haehale - half shelter
32 Nga Laula - woven sail panels
33 Te Hanga - boltrope inside sewn fold
34 Te Saa - oceanic bailer
35 Te Lou - main strut from crossbeam to end of middle float

Te Puke

Te Nohoanga Te Matangi (TNTM) – Lata's Navigation System

Indigenous navigation systems (introduced briefly above) complement the more tangible boatbuilding. Taumako is one of the few places in the Pacific where a relatively complete traditional navigation system is known. *Te Aliki* Kaveia of Taumako explained that Lata navigated by what is more accurately described as a complex knowledge system that is useful for gardening, weather prediction and modification, social planning, as well as navigation. That system is called *Te Nohoanga Te Matangi* (the wind positioning system), and it inter-relates wind positions with

celestial phenomena, weather and sea conditions, and many other environmental signs. [36] *Te Nohoanga Te Matangi* (*TNTM*) names thirty-two wind positions around the horizon of the navigator, who knows how each wind position correlates and calibrates with calendrics (seasons, solstices and equinoxes), the rises and sets of asterisms (stars, star groups, celestial bodies, dark shapes in the sky), swell patterns, appearances of light patterns that show the way to land routes between islands, special winds and weather, animal and plant behaviours, etc.[37]

Opposite pairings of wind positions, asterisms, routes, etc, are like the double-ended design of a *Vaka o Lata.* When sailing the vessels or observing the phenomena, one alternates looking forward and looking back, using one end as the bow of the vessel when heading one way, and then using the other end as the bow when heading the other way, and using one star(path), for example, going one way and its partner star(path), going back. So, Lata's navigation system is a systematic interrelationship of wind positions with all other observable phenomena.

Furthermore, the navigator's relationship with those phenomena is that of a descendent to ancestors and so the inter-relationships between the navigator and the ancestors is dynamic in the system. The voyagers are responsible to be respectful of all phenomena, and the phenomena are willing and pro-active in guiding the voyagers. The *TNTM* system of navigation is not only extensively specific about inter-relationships between phenomena, but it is an ontologically different way of knowing what to do, that requires the navigator to relate to phenomena as a subjective actor inside the system. From this point of view, one cannot abuse one's relationship with phenomena/ancestors, and sustainability is an operant value at all times.

Part III

Contemporary Realities: Shipping & Climate Change

[36] Traditional navigation systems are also still practiced in communities in the Republic of the Marshall Islands, the Federated States of Micronesia (FSM) and the Republic Palau. A circular representation of the so-called "wind compass" has been described all around the Pacific and in Indonesia. But Kaveia's detailed explanation of the inter-relationships of phenomena linked to wind positions, and how to use that knowledge, is unparalleled.

[37] M. George, 'Polynesian navigation and Te Lapa – The Flashing. *Time and Mind: The Journal of Archaeology, Consciousness and Culture* 5(2)(2012), 135–74.

Shipping in the Pacific at the time of sustained European contact was sustainable, largely locally owned and operated, and independent of external support. Sophisticated internal transport and trading systems were well-embedded prior to European contact. Across the Pacific, complex local trading chains operated through intermediate villages and even through professional middlemen.[38] Today, shipping remains the Pacific's lifeline through maritime connectivity and underpins all socio-economic activity of these islands. It is essential for all service delivery and societal functioning – health, education, governance, food procurement and security, trade, climate crisis and disaster response, kinship maintenance.

Sea transport in the Pacific is of four general types. The giant tankers, bulkers and container ships pass through on their trans-Pacific routes between Asia and America, entirely bypassing Pacific communities. A smaller class of ocean-going cargo ships bring (and take) goods from major Pacific ports, usually at the capitals of island nations that often comprise many islands and island chains. Secondary ports on these smaller islands allow transhipment and local trade with smaller craft and as noted, can only make landfall at specially constructed docks. Current domestic shipping options are often characterized by an aged fleet of mainly imported and fossil-fuel powered ships that service and underpin micro-economies at the end of long and narrow operating routes, with the consequence that sea transport within and between Pacific Island Countries is the most expensive per unit distance and per capita in the world. Finally, there are the largely outboard powered, wooden and fiberglass skiffs, open punts and small craft that serve as the primary village vehicle.

At the domestic level today, Pacific island shipping services are inadequate, aged, often inappropriate, sometimes unsafe, always expensive and usually poorly maintained. Domestic shipping is a marginally economic trade plagued with major financing and insurance barriers. Vessels are owned and operated from the urban centres with decision-making of frequency and type of service determined externally to the community of need. The sector is currently characterized by a range of challenges that enforce the prevalence of old, inefficient and undermaintained imported vessels. There is a general lack of adequate supporting infrastructure including modern ports, and facilities for bunkering, shipbuilding, maintenance, and repair in any but the major Pacific centres.

[38] Couper, *Sailors and Traders.*

The docks and jetties are often in a similar state of disrepair and are highly vulnerable to damage by tsunamis and sea-level rise as well as cyclones, now increasing in number and severity. Locations without docks for these smaller ships are most benighted in term of transport needs, goods rarely move in or out, and medical support is in many cases non-existent. All travel in an out is by open outboard runabout or canoe. It is in these contexts that a revival of working, traditionally based sail transport would be a huge asset. Revival of sailing would also support sustainable fishing and improve nutrition.

In belated reaction to the climate crisis, international shipping, a behemoth industry of giant vessels that enables 80% of world trade and globalised consumerism, is poised to start a decarbonisation transition that will see a revolution in shipping not witnessed since the shift from sail to fossil-fuel powered propellers over a century ago. In 2018, the International Maritime Organisation, the United Nations agency charged with regulating global shipping, agreed an initial decarbonisation target of at least 50% reduction of overall emissions by 2050. In the developed and large world economies, captains of the shipping industry and maritime innovators are now experimenting with new fuels – electricity, ammonia, methanol, hydrogen, advanced biofuels - and rediscovering innovation using wind-powered hybrid propulsion, advanced hull forms, battery and new generation computer technology and construction materials. While the linkages between locally controlled, appropriate shipping modalities and enhanced resilience and adaptations to a climate challenged future are easy to make, determining a future solution for Pacific islands is not so clear cut. Shipping, the conduit for 80% of world trade by volume, contributes about 3% of all global GHG emissions, equivalent to more than all of the emissions of the state of Germany. But it is the rate of increase that gives greats rise to concern. As global trade continues to expand, shipping emissions could rise by 50 to 250% by 2050[39]. This would make it an emitter on the scale of Europe. While it is unclear how quickly shipping can respond, it is poised at the brink of the greatest revolution since steam replaced sail in the late nineteenth century.

At the scale, cost and complexity that such innovation incurs, it is questionable how much of this benefit will eventually trickle down to Pacific island scale and practical application,

[39] T. Smith et al. *Third IMO Greenhouse Gas Study 2014*. Retrieved from: http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Documents/Third%20Greenhouse%20Gas%20Study/GHG3%20Executive%20Summary%20and%20Report.pdf

especially for the most remote and vulnerable communities. As the climate crisis deepens, as sea levels rise and extreme weather events intensify, the island communities of the Pacific will be increasingly reliant on inter-island maritime connectivity to survive. If the Pacific is not to be left behind as fuel and carbon prices rise, bespoke transition pathways to decarbonized modern shipping are urgently required given the uniqueness of the Pacific islands operating scenarios. Indigenous seafaring traditions provide a rich knowledge base that provide useful information and models for future development and sustainability.

Increasingly today these peoples, at the very front line of the increasing effects of anthropogenic climate change, are now describing themselves as Large Ocean States. The low-lying atoll states of Kiribati, Tuvalu, the Marshall Islands and Tokelau, after millennia of unbroken occupation in some of the most precarious and resource-thin inhabited places on the globe, now face a real and existential threat to their very physical survival. For almost all Pacific islanders, the scale of the crisis will adversely affect all to a greater degree than almost any threat in their history. Sadly, they have not contributed to the source of this threat. In the 2018 Boe Declaration, Pacific Forum leaders declared climate change to be the greatest threat to the region.[40] In 2019, Pacific leaders upgraded to a climate crisis, issuing the *Kainaki Lua Declaration for Urgent Climate Change Action Now.*[41] There is very little time available to strategize and implement survival pathways, the scope, scale and cost of defence and adaptation is greater than any needed previously.

As the outer islands across the ocean become ever more uneconomical to maintain and depopulate with increasing speed, the capacity of these remote communities to control their modes of physical connectivity by sea and therefore maintain their independence and localized control further diminish. A village (embayment/island) which controls its own sea-transport is a village with options and opportunity – its capacity to make its own decisions, and ability to enact its decisions, is enhanced. Conversely, a village that is reliant on externally controlled sea-transport is truly captive; dependent on decisions outside the immediate watershed.[42]

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[40] 1.(i) We reaffirm that climate change remains the single greatest threat to the livelihoods, security and wellbeing of the peoples of the Pacific and our commitment to progress the implementation of the Paris Agreement. https://www.forumsec.org/boe-declaration-on-regional-security/ accessed 12 Dec 2019.

[41] See: https://www.forumsec.org/statement-by-the-secretary-general-at-the-2019-united-nations-climate-change-conference/ accessed 12 Dec 2019.

[42] Nuttall (2013).

Conclusion

This chapter alerts readers to the urgency of re-establishing Pacific Indigenous sciences, sailcraft design, seafaring traditions, and voyaging practices for reasons of both cultural preservation and future sustainability. Important lessons can be distilled from Pacific Indigenous navigation and maritime technologies to inform and inspire current and future generations as they seek to develop decarbonised shipping solutions to provide essential connectivity across atolls, islands and archipelagos in an increasingly climate challenged ocean. Analysis of some pre-European sailcraft technologies; the "proa" from across present-day Micronesia, the Drua/Kalia/'alia of Fiji, Tonga and Samoa, and *Vaka o Lata* of Taumako in the Solomon Islands, serve as examples highlighting the Indigenous science behind the designs and demonstrate the voyaging capacity of traditional vessels. The three examples we have discussed – the various flying Proa, Drua, and *TePuke* – demonstrate some of the performance advantages and shallow sea access capabilities of asymmetric double-hull and outrigger designs, it is clear that there is much that the ancient vessels could do that modern vessels could not and some still cannot.

A living culture of sail can be lost in a generation, and much has already been lost. Extensive research is urgently needed regarding the designs, dimensions and performance of these vessels. Part of the genius of the Pacific traditions is their (obvious) ecological integrity: craft are made entirely from local and inherently sustainable materials. Different forms evolved as local needs and circumstances were creatively resolved under the constraints of available materials. Documentation of the materials, methods, and tools is required, along with the stories that explain how the vessels were used, what mistakes to not make, what weather and sea dynamics prevail in what places and times. With such data, information, and understanding, we could further appreciate the specific strengths of each design and material. The preservation of these traditions as human cultural treasures is crucial for several reasons: to maintain cultural coherence, to support further cultural renaissance, for the anthropological record, and to provide ancient and hard-won insights into sustainable seafaring and maritime practices for a new generation of sustainable sea transport. Assiduous study and revival of traditional practices is crucial. Viable solutions to

contemporary needs demand a syncretic design process that learns from traditional practices and sensitively leverages assets of contemporary science and technology.[43]

The global climate emergency impacts Pacific communities in specific and increasingly severe ways. When sea transport by unaffordable, unreliable and ecocidal ships breaks down completely, the ingenious and efficient designs of the ancients may be appreciated and put into service, but only by people who remember enough of what the seafaring ancestors knew.

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