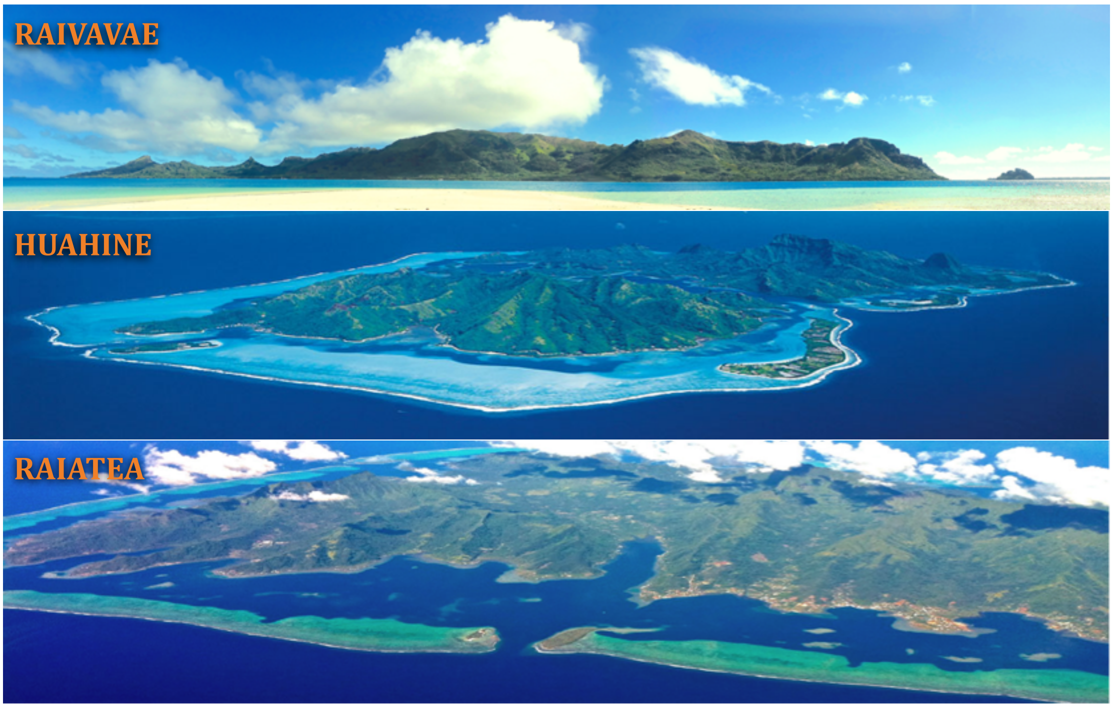
The Orientation of Sacred Sites on Raivavae, The Austral Islands, French Polynesia
(with a Brief Study of *marae* on Huahine & Raiatea)

By Edmundo Edwards and Alexandra Edwards



FLAG #83 EXPEDITION REPORT, MAY 2015

by Edmundo Edwards and Alexandra Edwards

An Explorer's Club Flag Expedition

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and private donations

Expedition Teams

Club Flag #83 Expedition Team 1 at Marae Maunga Oto or Ao'ahu on Raivavae

From left to right: Edmundo Edwards (Lowell Thomas Award FI '90), Michelle Zygielbaum, Alexandra Edwards, Paul Zygielbaum, Captain Lynn Danaher (FN '05), and Roger Crossland (MN '77)

Club Flag #83 Expedition Team 2 with Tiki on Raivavae

Clockwise from left to right: Alexandra Edwards, Brian Hanson (Edward C. Sweeney Medalist '84), James Alexander (MN '05), Dan Ward), Captain Lynn Danaher (FN '05), Edmundo Edwards (Lowell Thomas Award FI '90), and Linda Alexander

Raivavae and Our Project: An Overview

Raivavae is the southernmost high island in French Polynesia with a large enclosing coral reef. It is part of the Austral Islands group, lying 500 miles directly south of Tahiti, and in past times, the Australs formed a cultural continuum with the cultures of the Southern chain of the Cook Islands, spanning over 4,000 km of open Ocean. Raivavae was part of an extensive contact network and shared kinship alliances with the noble families of neighbouring Tubuai, and according to oral tradition, in the early IXX century double-outrigger canoes travelled regularly to make offerings at Marae Taputapuatea in Raiatea in the Society Islands over 950 km away.

It is not known when Raivavae was first settled, but it most probably correlates with the colonisation of the South Cook Islands sometime around 800 and 1,000 AD.[1] Raivavae is oriented east-west with a maximum length of 8.6 km by a maximum width of 3.4 km. Raivavae was densely populated in past times, considering its size, and by 1700 it likely had a population of about 3,000 inhabitants divided into 16 clans, living in different settlements around the coast of the island and pondfields, where taro was cultivated.

At the time of European discovery in 1775 by Spanish explorers Tomás Gayangos and José Andía y Varela, Raivavae had a flourishing culture that carved large stone statues and impressive altars with upright slab walled courts, reminiscent of those found in a few other Eastern Polynesian islands where stone statuary is common. The statues of Raivavae are some of the largest in Polynesia, measuring just as much as the tallest ones of the Marquesas, and second only to those of Rapa Nui. The statues of Raivavae represented goddesses and the deified ancestors of different clans.

By 1821 nearly everyone on Raivavae had converted to Christianity and interest in the ancient traditions, history, and lore waned until it was virtually forgotten. Nevertheless, in the late 1800s and early 1900s, several family heads recorded their genealogies and wrote down local traditions in well-ordered ledgers and notebooks, locally known as *puta tupuna*, in order to establish land rights before the French authorities who had colonised French Polynesia in 1842. Precious few of these notebooks have survived, constituting a very rich historical and ethnographic source.

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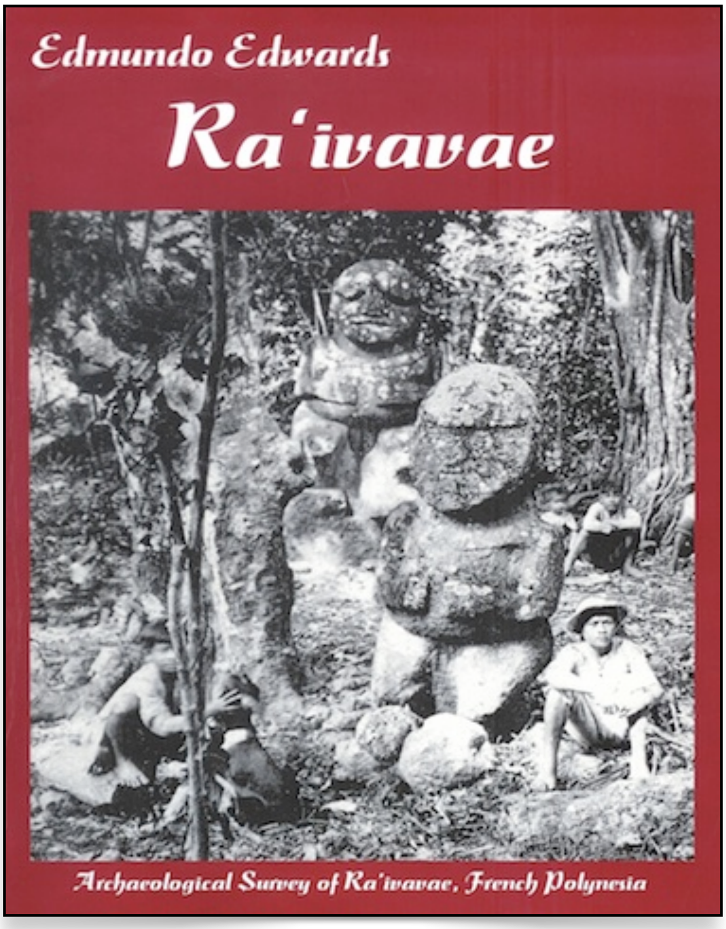
[1] The earliest radiocarbon dates of neighbouring Rapa indicate that it was settled by the year 1200 AD. (Atholl, et al 2006, pp 340-354)



Book cover of Edmundo Edwards' archaeological survey of Raivavae, 2003 (The Easter Island Foundation)

In 1987-1991, archaeologist Edmundo Edwards carried out the archaeological survey of Raivavae for the Department of Archaeology of the Territory of French Polynesia. In that time, his team recorded 610 archaeological structures in detail, and restored two *marae* or sacred religious structures. The publication of the archaeological survey which constitutes the most comprehensive archaeological work carried out on Raivavae to date, has given birth to several more specific research projects, because few archaeological excavations have been carried out on the island so far, and many aspects of Raivavae's cultural history remain a mystery.

In late 2005, E. Edwards returned to work on Raivavae, this time for the University Of Chile, and in 2006 he led a team consisting of Captain Lynn Danaher, Alexandra Edwards, and Rodrigo Navarro for the Explorers Club Flag #95 Expedition. They registered one previously unrecorded *marae* and shot a documentary that had a limited release in DVD form in 2007, which will finally premiere before audiences at the 2015 3rd Annual Friday Harbour Film Festival. Edmundo and Alexandra returned again in 2008 with field assistants Becky Cox and Margarita Riroroko. They mapped another *marae* that had not been registered before, and conducted test excavations at several sites, locating a few rich coastal middens, however these were not investigated further.

E. Edwards has spent the past 20 years studying the archaeoastronomy of different islands in Eastern Polynesia. The term "archaeoastronomy" was coined in 1973 by Elizabeth Chesley Baity to designate a fairly new field of study that blended the physical science of astronomy with the social sciences of anthropology, archaeology, and history to explain how ancient cultures interpreted astronomical phenomena. Considered a controversial field at times, only a handful of pioneers have ventured into the matter in Polynesia so far, and the subject remains obscure despite the fact that there is a fair amount of ethnographic information and archaeological evidence regarding the role of astronomical phenomena in Polynesian cosmogony, mythology, and religion, as well as its practical application in everyday life, particularly in navigation, time reckoning, and in the regulation of farming and fishing activities. "Star maps," "calendric calibration devices," observatories, and structures with astronomical alignments, have been found in several islands in Eastern Polynesia, such as Huahine, Mangareva, Raiatea, Raivavae, Rapa Nui, Rurutu, and Tahiti. Surely their number would increase considerably with a more comprehensive study of archaeological sites on these, and other, Polynesian islands, which is what E. Edwards has been trying to do for over a decade. Raivavae, represented an interesting challenge to archaeoastronomers since the subject has never been thoroughly researched there, yet their sacred architecture and their contact networks link them to islands with rich cultural traditions, thus a project in archaeoastronomy seemed promising.

The goal of our project was to locate, assess, and corroborate the astronomical function and ethnographic importance of sacred sites on Raivavae—and then to study the correlations that may have existed between Raivavaen archaeoastronomy and that of a few sacred sites on Huahine and Raiatea, which part of our team would also be visiting. We started by determining whether any of the main sacred sites connected to chiefly settlements on Huahine and Raiatea had any kind of astronomical orientation, and then did the same for the better-preserved sacred sites on Raivavae. In addition, we also searched for ethnographic information about the ancient cosmogonic beliefs and practices related to Raivavaen archaeoastronomy, from local informants, but also in extant *puta tupuna*. In addition, some of the sites surveyed by E. Edwards in 1987-1991 appeared to have measurements that needed to be confirmed with a more precise instrument than the one available to his team at that time, and this was a good opportunity to correct that.

The Milky Way over Aitutaki in the Cook Islands (Photo by David Rofall)

The Orientation of Sacred Sites on Raivavae, Austral Islands, French Polynesia (with a Brief Study of *marae* on Huahine & Raiatea) An Explorers Club Flag #83 Expedition Report

An Introduction to Polynesian Archeoastronomy

Some 3,500 years ago in a span of about 500 years, the Lapita, the ancestors of the Polynesians, used their knowledge of the stars to settle an area 4,300 km wide in what is considered one of the speediest human expansions of the pre-historic world. Their descendants, the Polynesians, eventually settled hundreds of islands crossing millions of square kilometres of water without navigational instruments, guided by nothing more than complex astronomical observations and an understanding of natural signs. These navigators, or wayfinders, as they are known today, were undeniably skilled specialists who passed astronomical information from one generation to the next for over three thousands years. However, the observation of astronomical phenomena was not limited to navigation and served a far more important function carried out by powerful astronomer priests: to establish a cycle of yearly activities, where the cosmic rising and setting of specific stars and asterisms determined when certain events took place. Depending on the timing of astronomical events, skywatchers announced when festivities, ceremonies, prohibitions, and the seasons started and ended. Astronomer priests studied the Sun, Moon, stars, and planets from special structures built in places with the best vantage point for each astronomic event, and ceremonial constructions were often aligned to astronomic phenomena. The observation of the sky was an important survival tool for Polynesians, while at the same time it reinforced some of their main religious precepts.

If the superb seafaring abilities of Polynesians are any indication, their knowledge of celestial phenomena was vast. In the 1940s, Anthropologist Maud Makemson recorded the names of 772 stars and constellations as well as several astronomical terms while working in different Polynesian islands. Polynesians did not make distinctions between planets and stars, or small star clusters and constellations, and the Sun (Ra'a) was usually far less important to Polynesians than the Moon and the stars and asterisms that were useful to them for calendrics and navigation. The Moon (Marama), was particularly important, primarily because of its influence on activities related to planting and fishing, drawing Polynesians to rely on lunar calendars to measure time.

Raivavaen Cosmogonic Traditions and the Polynesian Celestial Sphere

Like many other world cultures, Polynesians had Cosmogonic traditions that explained the origins of the universe and humankind's place in it. These precepts were passed down from one generation to the next in extensive chants, some of which were recorded by early missionaries and scholars, before it was lost after conversion to Christianity. Some of the chants are more complete than others, but in Eastern Polynesia, the universe is always seen as having been born from a void, where a sentient being awakens to thoughts that evolve into the creation of the Moon, Sun, stars and eventually an Earth mother and Sky father, who bear the pantheon of Polynesian gods; in turn, these gods create light by separating their parents, triggering an "explosion" of elements that copulated with each other, generating almost everything in existence. Humans, and a some other elements, were created by the gods themselves, usually Tane (a.k.a. Tiki) with a woman made out of earth called Hina. Raivavaen cosmogonic traditions reflect these important religious precepts, sometimes with a unique twist, such as that the gods Tane and Tangaroa are two sets of twins, living in the opposite worlds Ao and Po.[2]

According to Stimson's manuscript, the sky, generically called *rangi* or *ra'i* on Raivavae, was divided into at least 4 different regions. These were:

The Ao (The World of Light)

1. Rangi Tahi or Rangi Ta a Tahi (a dark netherworld)
2. Rangi Rua, Rangi Tu a Rua, or Rangi Ma (the second sky world)
3. Rangi Toru or Rangi Tu a Toru (the world of humankind)
4. Rangi Ha, Rangi Tu a Ha, or Rangi Ha Teatea (the fourth sky world)

Unfortunately the pages that correspond to the divisions of the underworld Po are missing from Stimson's notes, however four Po subdivisions are mentioned elsewhere in his manuscript:

Po (The Underworld)

1. Po hauriuri (a higher portion of the Po)
2. Rangi Ta'e (a lower portion of the Po)
3. Ta'ere o te Po (an even lower portion of the Po)
4. Pore o te Po (the lowest portion of the Po)

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[2] Stimson's manuscript mentions a supreme being called Io or Ia, one of two unnamable supreme gods and father of the major gods Tu, Tane, and Tangaroa. In Raivavaen tradition, the eldest two children of Io were the congenitally joined twin gods Tane Mata Ara i te Ao and Tane Mata Ara i te Po. One brother lived in the world of light (Ao), while the other was lord of the underworld (Po) and was the progenitor of humankind by copulating with a woman made out of a mound of earth called Hinga Ahu One. Similarly the twins Tangaroa-Tu Noa i te Ao (a.k.a. Hinga-Tu Runga) and Tangaroa Hi i te Po (a.k.a. Hinga-Tu *Nui?*) also lived in these opposite worlds. Interestingly, in Raivavaen lore the gods Tangaroa and Tu were sometimes combined in the form of the god Tangaroa-Tu Noa i te Ao, first assistant to Tane Mata Ara i te Ao. His counterpart Tangaroa Hi i te Po was superior to Tu Nui Tahi i te Po, the second assistant to Tane Mata Ara i te Po. (Informants Tauira'i and Ta'a Re Ari'i in Stimson, 1938)

For Polynesians, the sky was the abode of the gods of creation and it was often conceived as the roof of a house in the form of one or more domes. For Hawaiians it consisted of a series of concentric domes sustained by four pillars. In Tahiti the sky was "propped up" by 10 "columns" generically called *po'u o te ra'ai*.[3] Each pillar was marked in the sky by a particular star. The foundation of this "house" rested over a flat surface that extended the length of the earthly horizon. In most islands of the Society, Austral, and Cook Islands the sky consisted of ten surmounted domes, while the Maori had 12. Each of the domes were inhabited by different entities, and at least one strata was occupied by human ancestral spirits who could visit the land of the living during the Acronychal and Heliacal rising of the Pleiades.[4]

Ceremony in Tonga (Engraving by John Webber)

[3] The stars and asterisms that marked the pillars that held up the Tahitian sky were the following:

1. Antares (*Anamua*): Front pillar, parent pillar, entrance to the sky
2. Aldebaran (*Anamuri*): Rear pillar, the post of food, guiding post of god Rio fishing for tuna
3. Epi: Post of gods Tu and Ta'aroa
4. Duhbe (*Anatipu*): Highest post, the guardian post.
5. Alphard (*Anaheuheupo*): Shorter post, the post of speech
6. Articus (*Anatahu'ata Metua te Tupu Ma Vae*): The post to rise(?)
7. Procyon (*Anatahu'avahine a Toa te Manava)*: The post of knowledge
8. Betelgeuse (*Anavaru):* Post to sit upon
9. Phaeton (*Anaiva*): The exit post
10. Polaris (*Anani'a):* The post at the end of the sky

[4] Heliacal rising of a star is when it rises just before the sunrise. Heliacal setting is when it sets just after the sunset. Acronychal rising of a star is when it rises just after the sunset. Acronychal setting is when it sets just before the sunrise.

In most Polynesian cosmogonic traditions, the Moon is the progenitor of the Sun, the importance of the Sun being subordinate to that of the Moon. Although the Sun may have been observed during the solstices, it was primarily done for practical reasons: to adjust the local synodic lunar calendar since the solstices were preceded by the rising and setting of stars that were crucial in Polynesian calendrics, i.e. the Pleiades. The heliacal declination of this small yet conspicuous asterism is +24°, therefore its heliacal rise occurs very close to sunrise during the December solstice. Sites currently believed to be oriented to this azimuth may very well be oriented to the Pleiades or the Sun, but no Sun cults or any form of Sun worship have ever been identified in Polynesia.

Oral traditions explain the origins of the brightest and/or most useful stars and constellations in the Polynesian sky, but a great many of these were believed to have been placed there by the gods for the sole merriment of humankind. In some cases, stars were believed to be the left eye of an important deceased family member, which would explain why some star names include the word *mata* (eye). However, in the end, the importance of the Moon, stars, and constellations depended mostly on their practical use, in what the astronomer priests and navigators could gain from them observing them.

The 15 statues of Ahu Tongariki on Rapa Nui are aligned to the setting of the Pleiades over Rano Raraku, the place where the statues are quarried from volcanic tuff called maea Matariki or "Pleiades stone" (Photo by Pierre Lesage)

Raivavaen Calendrics

Raivavaens believed that everything in the universe was "alive" and "conscious," as different elements grew, reproduced, and died as a result of a supernatural power called *mana*, or supernatural force, one of the most important pan-Polynesian concepts. Since the chiefs were the medium by which deified ancestors provided for their descendants by making the plants grow and animals multiply, the entire clan ensured the success of their subsistence activities by making offerings and sacrifices to honour the gods in an agricultural cycle that in many Polynesian islands was called "The Work of the Gods." On Raivavae festivities, offerings, and even prohibitions were programmed to ensure the successful planting and harvesting of their most important food crops, mainly taro, but also sweet potato for the clans living on the dryer northwestern part of the island where taro was not well cultivated. The same as all Polynesians, the Raivavaen annual cycle was marked by the occurrences that determined what sort of chores and rituals people carried out during different times of the year. Evidently these responsibilities and events were directly linked to the weather and the availability of seasonal resources, which differed on each island. Celestial bodies disappear from the night sky sometimes for several months as their rotation course leads them to periodically rise at a time when they cannot be seen, such as the daylight hours. These events occur at the same time every year. Since the arrival of migratory birds, turtles, and pelagic fish, and the different seasons sometimes coincided with the appearance and disappearance of specific astronomical phenomena, the rising or setting of certain stars or constellations could be used to mark the arrival of migratory species, but also to measure time and establish an annual calendar of activities. Interestingly, several Polynesian languages share the same names for the months, the nights of the Moon, and important stars and asterisms, even on islands located at opposite ends of Oceania. Linguistic studies carried out by Patrick Kirch and Roger Green have demonstrated that these words date back to the ancestors of the Polynesians, the Lapita Culture, the same as the synodic lunar calendar the Polynesians used to measure time. Therefore, this information was not something that the Raivavaens had come up with on their own, but rather was part of a greater body of knowledge that had been passed down from one generation to the next over thousands of years. The Raivavaens adapted this information to the conditions specific to their island, yes, but they also shared many concepts with other Polynesians, not only in the vocabulary they used in their calendrical system, but also in the activities and festivities they celebrated throughout the course of a year.

In all of Polynesia, the annual cycle of activities were associated with a local subsistence system based on a horticultural cycle determined by wet and dry periods and the arrival of seasonal resources. The year, called *mata hiti* in the Raivavaen language, was divided into a season of plenty and of want, probably related to a time of rain and another of drought. In most of Polynesia, the wet season also is the time of cyclones and rough seas, but as these climatic changes affected all forms of life in the Eastern Pacific, it also served to predict the arrival of other seasonal food resources such as pelagic fish, turtles and migratory marine birds to the different island groups. One of the reasons why the Polynesians and their forefathers the Lapita so readily adopted a lunar-based calendar is that it was ideal for the marine environment that formed their habitat, as most ocean life, including seabirds, follow a lunar cycle, and therefore reproduce, lay their eggs, and migrate on fixed lunar dates each year. A list of the different Raivavaen terms for general periods of time can be seen in Table 1.

Table 1. Raivavaen Names for Seasons and Time Periods (Stimson, 1938)

Name	Moment or Time Period
Mauri	Mauri Morning of first day of the month
Marama	Name for a lunar month, also Moon
Ara'au / Ra'au	The name of certain lunar periods
Tau	A season, a period of time
Ma Tau	A short season (literally a partial season)
Tau Poa' Ai	The dry season
Tau Torotea	The season of food abundance
Tau 'Au Hune	The season of abundance

The Pleiades were the most important of the calendar stars throughout the whole Pacific area as Polynesians divided the calendar year in two seasons marked by the Heliacal rise of the Pleiades that occurs at about May-June in our calendar, and then on its Acronychal rise during the months of October-November.[5] The latter also corresponds with a change between the dry and rainy seasons in the Pacific region that generally produces severe meteorological changes affecting all islands ecosystems. It is important to note, however that since the islands are located in different latitudes, these events did not occur on the exact same dates among the different islands. As already mentioned, early settlers had to "tweak" their calendars to fit their new reality, thus although Raivavaens, used the same stars and asterisms that other Polynesians used to mark their annual cycle of activities, these stars could mark different events on different islands, or mark the same event on another date. Thus, in the Society Islands and on Hawaii the new year began the first full Moon after the Heliacal rising of the Pleiades in October-November, while on

[5] The Pleiades are visible year round except near May and June when they disappear below the horizon being in conjunction with the Sun. Although the Heliacal rising of the Pleiades occurs on set dates depending on latitude, their actual observance depends on local geographic and meteorological conditions that may impair visibility. In addition, the Pleiades should ideally be observed when the Moon is least visible, yet their rise may easily fall on a Full Moon night.

Rapa Nui, Pukapuka, Mangareva, and in the Marquesas and the Austral Islands, it was marked by the Heliacal rising of the Pleiades in May-June. According to Makemson, Antares, a red supergiant star in the western constellation of Scorpio and the sixteenth brightest in the night-time sky, was also a very important Polynesian calendar star. Although much information has been lost over the years, the stars that are known to have been used in Raivavaen calendrics are the following: the Pleiades (Matari'i), Antares, Aldebaran, Alpha Centauri A, Formalhaut, Orion´s Belt (Tautoru), Sirius (Mere), Vega, and the star-clusters of Zeta Scorpii (Pipiri Ma). In 1938, ethnologist Frank Stimson wrote a Raivavaen language dictionary that was never published. Unfortunately the whereabouts of the original manuscript are unknown today and the only available public copy, with hand-annotations by ethnographer Donald Marshall, is incomplete. The few Raivavaen names for different Celestial bodies collected by Stimson, appear in Table 2.

Table 2. Celestial Bodies on Raivavae (Stimson 1938; Paipaimoana 1903)[6]

Name	Celestial Phenomena
Feti'a	Generic name for star
Ma Rama	Generic name for Moon (not full, waning, etc.)
Matari'i (Anamoa*)	The Pleiades
Mere	Probably the name for Sirius
Pipiri Ma	Two star-asterism, probably the star clusters of Zeta Scorpii
Rangi or Ra'i	The sky
Ra'a	The Sun
Ra'a Poto / Po Roto	The Summer solstice when the Sun is south of the horizon
Ra'a Roa / Po Roa	The Winter solstice when the Sun is north of the horizon
Tautoru	Probably the name for Orion's Belt

* *Name in the notebook of Opeta Paipaimoana, 1903*

The information provided in the Table above is exceedingly poor, nevertheless, considering the history of Raivavae, the utmost importance of the stars whose names were not forgotten are confirmed by their very remembrance in these

[6] Although the star names Mere and Tautoru are not linked to any particular star in Stimson's manuscript, they respectively are the names for Sirius and Orion's Belt in several other islands, particularly the Cook Islands from where it is believed the Raivavaens originated (Williams 1933: 133). Star names tend to repeat themselves in the different Polynesian languages and it seems likely that Sirius and Orion's Belt are the unidentified stars in Stimson's work. The name Anamoa seems to be of a rather localised nature.

later times. In addition to the Pleiades, Orion's Belt and Sirius were also very significant throughout Polynesia and Micronesia in the past, and it is hardly surprising that the name of this asterism often translates as "The Beautiful Three", as is the case on Raivavae. Many traditions have been lost over the past 200 years as a result of the devastating impact of European contact, Christian proselytisation, and the introduction of deadly diseases. The Gregorian calendar was adopted and the traditional names for the months were replaced by those phonetically linked to their non-Polynesian counterparts (i.e. Tiunu for June); new religious festivals replaced the old and traditional astronomical knowledge was reduced to whatever elements were useful to fishing. However, by studying the principal astronomical events that may be observed on different archaeological sites on Raivavae it was possible to identify a few other important Raivavaen stars and asterisms, despite not knowing what they were called in the local language, such as: Canopus, Vega, and Alpha Centauri. In addition, the results of our survey coupled with the fact that Raivavaens had different names for each of the solstices depending on the position of the Sun, also indicate that contrary to common Polynesian practice, solar observation was being carried out on Raivavae.

Orion's Belt sets perpendicular to the axis of Ahu Akivi, Rapa Nui.
(Enhanced photo by José Antonio Belmonte)

Polynesians relied on a lunar calendar consisting of 12-13 lunations in which each month began on a full Moon and every night had a different name depending on the effects of the Moon on the tides, marine fauna, and agricultural cycle, thus designating the best time and places for fishing, coastal foraging, and planting for each night of the year, every year. Since Stimson's manuscript is incomplete, a reconstructed prototype of the names of the months collected by him in 1938, appears in Table 3 below, yet the names for March, June, and November, and possibly a 13th month (*marama*, also Moon), are missing. The same as elsewhere in Polynesia, on Raivavae the months were sometimes named after the celestial phenomena, or important activities and/or events that marked each lunation (see Table 3). Thus, July is named after a season of bounty, marked by the Heliacal rise of the Pleiades in late June, announcing the upcoming harvest of their staple crops, most likely taro and sweet potato. The same occurs in the month of October, close to the Acronychal rising of the Pleiades, which on other islands announces the opening of the deep sea fishing season after having been restricted for a number of months. (It is important to note that because Polynesian months started on the night of the new or full Moon they hardly coincide with their solar counterparts in the Gregorian calendar).

Table 3. Raivavaen Lunar Months (Stimson, 1938)

Name	Month (Approximately)
Pipiri	January (reference to Zeta (and Theta?) Scorpii
Manu	February (reference to the arrival of birds or a constellation of the same name?)
n/a	March
Paroro Mua	April
Paroro Muri	May
n/a	June
Ma Tau Ha'ahotu	July (lit. a short season of fructification)
Muri Aha	August
Hiringa	September
Ma Tau 'Auhune	October (lit. a short season of abundance)
n/a	November
Ha'a Ahu	December

Since Zeta and Theta in Scorpio are called Pipiri, which is also the name of the month that would approximately correspond to January, it seems likely that these stars also marked events occurring at that time, yet without further study, the specifics of these are unknown. Likewise, the name for the month of February, *Manu* (Bird), may mark the arrival of a certain bird during that time, or may be a reference to the Polynesian constellation of the same name, which represents a large bird and includes most of the brighter stars that fall within the constellations of Orion and Canis Major, including Sirius, Canopus, Procyon, Betelgeuse, and Rigel. (See Figure 1).

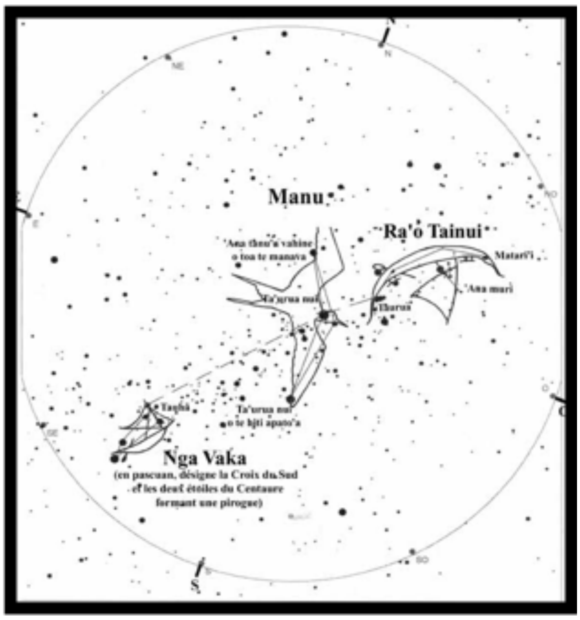

Fig. 1. The Manu constellation (Lewis 1974)

There are quite a few challenges to overcome when adopting a lunar calendar. A lunar year is approximately 11 days shorter than a solar one; not only that, but the Earth revolves around the Sun each 365,25 days, which explains why a day is added to February every four years in the Gregorian calendar. If not properly calibrated, this can add up to a noticeable discrepancy over observed equinox times and the seasons. Nevertheless, Makemson calculated that Polynesians added or subtracted a month every 3-4 years using the rise of the Pleiades as their guide; thus the Polynesian lunar year never exceeded the solar one by more than 19 days. (Makemson 1941: 94). Mataiki, Matariki, Matari'i, Mataliki, Matali'i, Makali'i are all Polynesian language variations of the same word meaning "chiefly eyes" or "eyes of the chief," the name for the foremost Polynesian asterism: the Pleiades. As elsewhere in Polynesia, the Raivavaen year probably began with the Heliacal rising of the Pleiades, and likely also used Antares to calibrate the lunar year with the solar one. The Pleiades were also the namesake of a Pan-Polynesian festival of renewal that began with the Heliacal rise of the Pleiades; the exact date of this event depends on longitude and the visibility of the Pleiades above the horizon at the time of its occurrence. The celebrations usually lasted several months. During these celebrations, normal labour was suspended and the first fruits of the upcoming harvest were offered to the chiefs; merry ceremonies were held to honour the deified ancestors and/or other deities whose generosity supported local subsistence activities.

As elsewhere in Polynesia, Raivavaens devised quite a complex calendric system with regards to the lunar month, depending on the activities that were best carried out on each date. The generic Raivavaen term for day was *mahana*, and night was *ru'i*, however, there were specific names for each of the 29 to 30 nights in a lunation. Using at least four calendars from different informants, Stimson collected 36 Raivavaen terms and their variations that refer to the nights in a lunation (see Table 4).

Table 4. Raivavaen Names for the Nights of the Moon (Stimson, 1938)

Name	Night in Lunar Calendar
Tireo	1st (1 informant) and/or 13th (1 informant)
Hiro / Hiro Hiti / Hiro Tu Hiti	1st or 2nd
Hoata	2nd (1 informant) or 3rd (1 informant)
Hamiama / Hamiama Tahi	3rd or 4th
Roto o Te Hamiama	4th or 5th
Ha’aoti o Te Hamiama	5th or 6th
Roto o Te ‘Ore ‘Ore	7th or 8th
Ha’aoti o Te ‘Ore ‘Ore / ‘Ore ‘Ore	8th or 9th, and 22nd or 23rd
Tamatea	9th (1 informant)
Ari / Oari	9th (2 informants) or 11th (2 informants)
Huna	10th (all informants)
Rapu	11th (1 informant)
Maharu	11th (1 informant) or 12th (1 informant)
Tireo	13th (1 informant) and/or 1st (1 informant)
Ohua	12 or 13th
Ma Aitu / Ma Atua	13th or 14th
Hotu	14th or 15th
Marangi	15th or 16th
Turu / Oturu	16th or 17th
Ti’a	17th
Ra'au Tahi	17th or 18th
Mua Ra'au	18th (2 cals)
Roto o Te Ra'au	18th or 19th
Ha’aoti o Te Ra'au	19th (1 informant) or 20th (3 informants)
Mua ‘Ore ‘Ore	21st (1 informant)
‘Ore ‘Ore	21st or 22nd
Ha’aoti o Te ‘Ore ‘Ore / ‘Ore ‘Ore	22nd or 23rd
Tangaroa Tahi	23rd or 24th
Mua Tangaroa	24th (2 cals)
Roto o Te Tangaroa	24th or 25th
Ha’aoti o Te Tangaroa	25th (1 informant) or 26th (1 informant)
Tane	26th or 27th
Rongo Nui	27th or 28th
Mauri Mate	28th or 29th
Rongo Ma Uri	29th (2 cals)
Motu / Mutu / O Mutu	29th or 30th

Raivavaens were well aware of the effects of the Moon on the tides, marine fauna, and planting, and this was reflected in the names of the days and nights, which often referenced the activities that were best performed at each time of the lunation. The five nights with names containing the word *'ore 'ore* were considered the best for fishing, and cognates of this term appear in several Polynesian calendars, sharing the exact same meaning. Although the the definition of many of the terms that appear in Table 3 is uncertain, we believe it may be possible to determine the significance of at least a few of these by comparing the names with those that appear in the Hawaiian, Maori, Mangarevan, Rapanui, Rarotongan, and Tahitian calendars. For example, Raivavaens grouped together the 14th-16th, and 27th-29th nights into at least two groups called Nga Po Atua and Nga Po Tane, presumably reflecting the activities that would best be performed on those dates (Stimson 1938). Similarly, the Maori were known for dividing a lunar month into groups of 2-4 days for specific activities while the remaining nineteen nights had independent individual names. The fact that several of the terms repeat themselves, sometimes consecutively, in all the calendars of the islands mentioned above not only indicates a common origin, but when they are placed in different parts of the Moon cycle, they suggest a local adaptation to the unique natural conditions and resources available on each island, thus shifting the activities that would be performed on a specific date.

Cook Islanders celebrating the rising of the Pleiades
(Illustration from the book Twenty Years Before the Mast by Charles Erskine, 1896)

Like most Polynesians, Raivavaens had many terms to designate the different times of a day, depending on the position of the Sun and the available sunlight. Not surprisingly, there are many more terms for the daylight hours than the nighttime ones (15 vs. 7) and some of them overlap, the same way 5 o'clock overlaps with afternoon. A list of the Raivavaen terms for the times of a day appears in Table 5.

Table 5. Raivavaen Names for the Different Times of the Day (Stimson,

Name	Time of Day
Tata i Ao	Brief period of light just before the first flush of dawn
Maru Ao	The first flush of dawn
Marehurehu Ao	Just before sunrise following the *maruao* and preceding the *'a'ahiata*
A'ahiata	Dawn
Aoranga or Aora'a	The appearance of daylight, the coming of dawn
Ngangahiata	Just prior to and following the dawn
Hiti Ranga Mahana	Sunrise
Pongi Pongi Roa	Very early morning, from sunrise to an hour later
Pongi Pongi	Early morning from an hour after sunrise until 10 am or so.
Ma'oro Ra'a Po	Morning
Avatea	Midday from about 10 am to 2 pm
Avatea Tuti'a	Noon
Ao	Open day
Tape Ranga Mahana	From about 2 pm to an hour and a half before sunset
To Iho Iho	The setting sun in the late afternoon, from about an hour and a half to a half hour before sunset
Ma'iri Ranga Mahana	Sunset
Marehurehu	Twilight, a period of faint light
Marehurehu Po	Dusk, the period from just after sunset until dark
Ahiahi Po	Nightfall
Ahiahi	Evening, an hour after sunset and lasting for an hour afterwards
Turua	Approaching midnight, from 10 pm until midnight
Totere'e Ranga Moa	Cock's crow, from 2:30 am to about one half hour before the first flush of dawn

Again, it is important to note that many of these terms repeat themselves from island to island, while at the same time there are nearly half as many names for the nighttime hours as the daytime ones. This not only indicates that fewer activities were performed at night, but it also perpetuates the commonly held Polynesian belief that the night was dangerous and to be feared, while daytime was associated with life and wellbeing.

The Skywatchers or Tohunga

The careful observation of celestial phenomena in order to correct the inherent seasonal and chronological shortcomings of a lunar calendar was essential but only part of the responsibilities of an astronomer priest; interpreting natural signs to predict the fluctuations in migratory resources, weather, and tides, that could be relied upon year after year, that was the actual point of having a calendar at all. In all Polynesia, these tasks were carried out by trained skywatchers—as astronomer priests are termed today—who were responsible for observing the movements of the stars and Moon, and accordingly adjusting the local lunar calendar with an intricate system of calculations to be keep it synchronised with the solar year. On most islands, this was done using only the Pleiades, but on Mangareva, Hawaii and most probably Rapa Nui and Raivavae, this was coupled with the observation of the solstice positions, and therefore the settlers of these islands had adopted a *luni-solar* calendar, adding or subtracting a few days or even inserting an entire month into a year, in a process known as intercalation.

Ethnographic information from other islands indicate that there were several different kinds of skywatcher, each with a specific skill and or duty, and that they were trained from infancy in specialised schools that were reserved for the elite. Some of them studied the tides and other meteorological phenomena, providing weather forecasts and predicting seasonal variations that benefited farmers and fisherman, and many of them used their skills to make predictions that went beyond the this practical scope, often delving into the realm of divination, as the relationship between celestial bodies was believed to announce future events.[7] The same as other Polynesians, Raivavaens probably called these astronomer priests by the term *tohunga*, the name reserved for priests and also a skilled professional class elsewhere in Polynesia. The function of astronomer priests and how celestial bodies were used in their predictions are detailed in Table 6.

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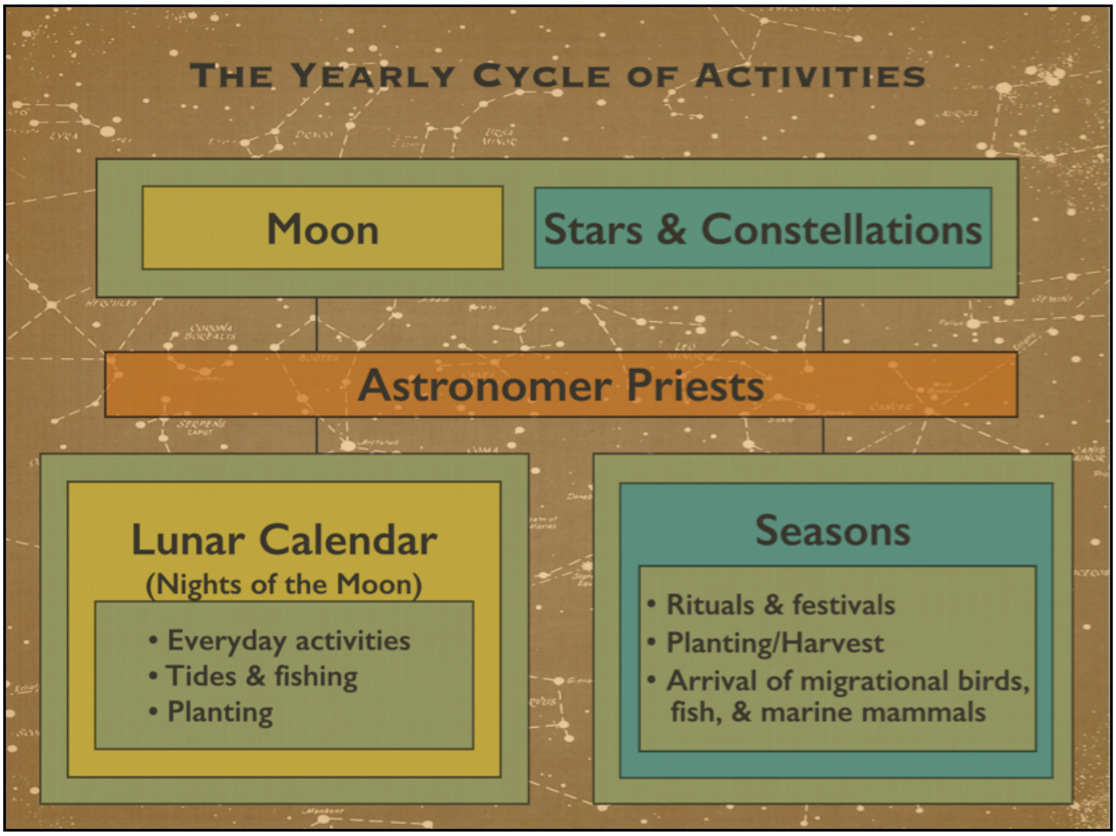
[7] Weather forecasts were made based on how specific stars looked when rising over the horizon. For example, for the Maori of New Zealand, if Rigel, Sirius, or Canopus appeared to have a light streak extending southwards it announced snow in the upcoming cold season. Predictions were also based on the position of the stars, planets, and the Moon relative to each other. On Rapa Nui, Mars passing near Orion's Belt brought bad tidings for fishermen who would fall victim to great ocean creatures called *niuhi*.

Table 6. Role of Celestial Bodies in Skywatcher Functions and Responsibilities



Skywatchers studied the night sky from the best point of observation for the specific phenomena they were looking for, and it must have taken much trial and error to find the most accurate location on each island. "Star maps," "calendric calibration devices," and observatories have been found in several Polynesian islands while ceremonial structures have been proven to be astronomically or topographically aligned on the islands of Hawaii, Mangareva, Rapa Nui, Rurutu, Tahiti and Tonga. It seems reasonable to infer that an important number of sacred sites, where specific ceremonies and festivities were carried out in the past, may have also functioned as observatories, where the astronomical phenomena that announced those very same activities might be recorded, particularly in the positioning or orientation of the structures themselves towards the rising or setting of one or more Polynesian calendar stars, or true north-south, or east-west. Indeed, this is not a novel concept in the interpretation of Polynesian archaeological sites and surely further studies will reveal many more such orientations elsewhere in the area.

Religious Architecture on Raivavae, Site Distribution, and *Marae* Types

The term *marae* originated in Western Polynesia and referred to an open space or meeting ground used for secular purposes, usually located in the centre of a settlement. *Marae* were the seat from which the chief exercised his political and economical control , where the clan convened to settle important matters, such as a declaration of war, or what measures to take to face a drought. In addition, *marae* marked land ownership and were where the chiefs and their families were buried. In time Eastern Polynesian religious structures called *ahu* (god-house) were combined with the secular *marae* to form a single structure (Bellwood 1975). Today, the term *marae* refers to any structure of a religious nature, including some structures that have uprights that were considered sacred boundary markers, and larger shrines. Many *marae* on Raivavae were vandalised in the past 200 years, statues were destroyed, and their component slabs were dismantled and reused elsewhere. Constrained by the uncertainty regarding the actual function of the structures, during the archaeological survey of Raivavae in 1987-1991, E. Edwards classified the sites according to the arrangement of their architectural components (court, god-house, etc) whose ground plan suggested they had a sacred use in the past. A few others that were completely destroyed by the time of E. Edwards' visit were identified as *marae* by archaeologists and ethnographers that had previously worked on Raivavae.

Religious structures vary between the Austral Islands group, even within an island itself, as the *marae* incorporate local characteristics that distinguish them from each other, they were ranked, and apparently their functions varied. Nevertheless, the same as their counterparts on other islands, there are certain patterns in the construction and distribution of *marae* on Raivavae that repeat themselves time and time again. E. Edwards identified 4 distinct types of Raivavaen *marae* based on their different ground plans and component parts. Included in our study were small square or rectangular enclosures that were identified as shrines during E. Edwards' survey of Raivavae. These were classified as B4 Type structures. The different religious constructions of Raivavae are listed in Table 7:

Table 7. Types of Raivavaen Religious Structures

Type	Number of Sites	Paved Open Court or Ramp	Unpaved Enclosed Court	Paved Enclosed Court	Ahu	Paved Approach
B1	7	X				
B2	9			X		
B3	34			X	X	
B3a	7			X	X	X
B4	6		X			

All *marae* have a court with an altar at one end, a raised platform to place offerings. However, Raivavaen religious structures can be divided into two general groups: open court religious constructions (B1) and enclosed court ones (B2, B3, B3a, B4). *Marae* types B3 and B3a have an *ahu,* that is, a god-house where the images of deified ancestors and other sacred objects were stored. The *ahu was* usually built into the hillside or the ended on a stone rectangular platform. In the case of B3a type *marae*, the court joined a paved approach flanked by a curbing of carved coral slab uprights absent in other types of *marae*. This approach was often built parallel to the right or to the left of the enclosed court of the *marae*. The approach of Marae Pomaovao (Type B3a) built by Chief Tutini circa 1720, had an "alleyway" that led to a paved enclosed court that served as a patio to a large house located on the upper part of the structure (see Figure 2). The house had three separate entrances: the one to the left was used by the warriors, the middle one by the chief, and the right one by the priests. Lastly, B4 Type structures were shrines with an unpaved enclosed court that usually measure less than 6 m in length or width.

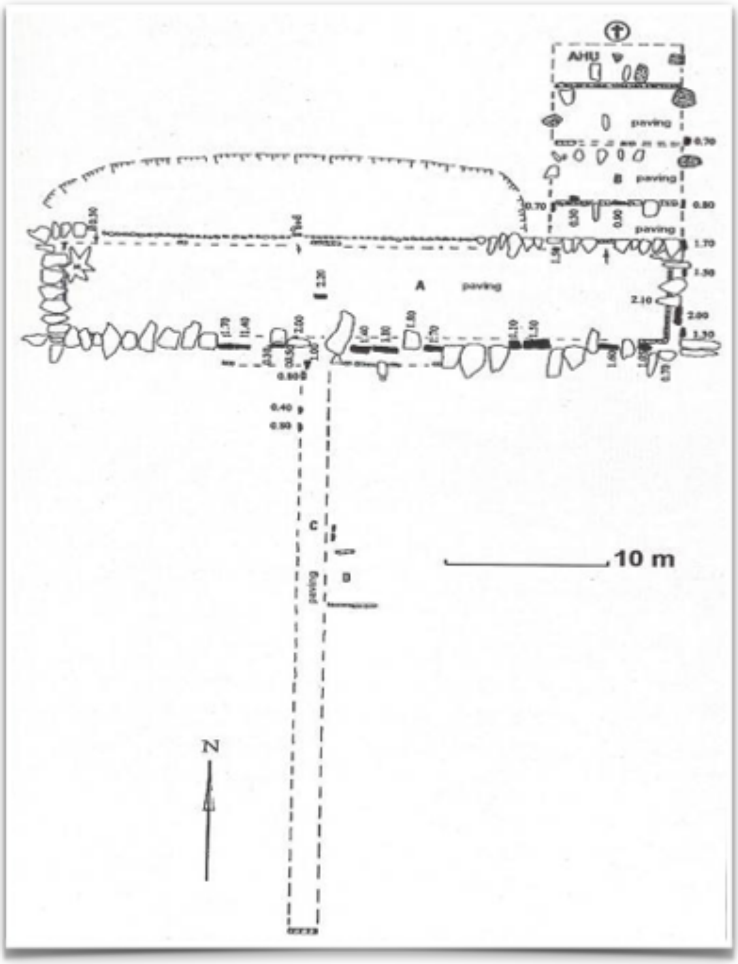


Figure 2. Marae Pomaovao (B3a) with its long paved approach, enclosed court, and *ahu* (Drawing by Edmundo Edwards)

According to ethnographic evidence, larger, later-period Raivavaen *marae*, belonging to high-ranking tribal chiefs, were part of an inter-island contact network between Raivavae, Tubuai, and the Society islands, regularly receiving visitors from those islands in the past. The alleyway of Marae Pomaovao extended several hundred meters, from the *marae* to a small pier built by the lagoon.

The most common type of religious structure by far, were *marae* type B3. Both B3 and B3a *structures* belonged to different family household heads and were located on the coastal plain, or behind the flood plain of the calderas of the island, overlooking the fields where taro was cultivated. These *marae* were always built within close proximity to a chiefly household or settlement and their related tombs. In addition, the *marae* also sometimes incorporated several statues made out of red volcanic tuff. The spatial distribution of many of the *marae* we studied during this expedition appear in Figure 3.

Figure 3. Spatial Distribution of Raivavaen Marae Studied in this Expedition

According to E. Edwards' survey, most settlements were located on hillside terraces near semi-permanent streams and along the coast, with access to the resources provided by the lagoon and the swamplands on the coastal plain. However, as occurs with most prolonged human settlements, a growing population forced people to move to secondary resource areas, away from the two fertile collapsed calderas of Vaiuru and Rairua that give Raivavae its distinct shape. Eventually the island was divided into at least 15 clans, allied into two opposing polities, with settlements delimited by boundary markers and large *marae* sprawled throughout the island, marking ownership of the land and the lagoon.

Methodology

This project was generated from the fact that when E. Edwards and his team surveyed the island between 1987-1991, they used a magnetic compass to register the sites, and although the measurements they collected were later calibrated for the declination of the instrument, the accuracy of the readings was questionable due to magnetic anomalies produced by interfering material in the substrata of the soil in some of the sites. A revision of the measurements was necessary and since E. Edwards was working in Polynesian archaeoastronomy at the time, it seemed appropriate to examine whether there were any more sites to add to the 9 that had been registered as having a N-S astronomical orientation.

Taking into account the conditions that have been found to have significance in sites of astronomical consequence on other Polynesian islands, for the purposes of this study we limited the scope of our investigation to Raivavaen religious structures. We considered only chiefly *marae* (those that could be traced to the head of a Raivavaen chiefdom) and shrines. We did not put any sort of restraint on the relative time of construction of the structures, therefore some were *marae* known to have been built in the late 1700s, while another one was purportedly the first *marae* of Raivavae.

Members of our team taking measurements at Marae Te Rae Rae (Photo by Alexandra Edwards)

During the archaeological survey of Raivavae and in subsequent expeditions to the island, E. Edwards classified more than 80 sites as having religious significance, however many of these were either so destroyed or in such a state of disrepair that no precise data could be obtained from their measurements, even more so today. Due to time constraints, we examined 48 sites out of the 69 we determined were in good enough condition to be part of this study. In one case (RRA 39) we used the measurements taken by John F. G. Stokes in 1921 since that site—now destroyed—was well-preserved at the time of Stokes' visit and we considered his readings to be reliable enough to be included here. Likewise, we used Edwards' previous measurements for sites VAI 325, 328, and 352 as well as RRA 67 since we were unable to obtain precise readings at these sites during our visit. We also included the measurements of 5 structures whose court dimensions could still be measured, but whose type could not be classified from the existing ground plan (RRA 35, RRA 74, VAI 81, VAI 149, and ANA 30). We also included one site that had been restricted to us in our previous visits (VAI 318), and another that had not been registered before (ANA 57).

Our measurements were taken with a Brunton high-quality magnetic compass with an up-to-date magnetic declination, as well as 3-4 digital giro compasses, a GPS, and an application called Spyglass on an iPhone 6 and 3 iPads, all equipped with the same application (see Figure 4). We felt these new instruments were capable of accurately reading the orientation of the selected archaeological sites. Once we had collected all the data, we presented it to astronomers Francisco Förster and Elise Servajean from the University of Chile and went over the readings together, considering both an ethnographic and astronomical interpretation of our findings. The results of our study, together with the corrected readings of the measurements taken in previous expeditions, are presented in the following section of this body of work. Due to the state of disrepair of some of the sites and other external factors, the margin of error of our measurements is estimated at ±5°.

Figure 4. Screenshot of a digital compass measuring the orientation of a alignment of stones at Marae Tarahu (Photo by Edmundo Edwards)

Project Results

Raivavaens undoubtedly had a great amount of knowledge regarding the natural world, the movement of celestial objects, and how these could be used to measure time and place man in the universe. The little information available regarding the subject on Raivavae today, stands in stark contrast with how things must have been just a few centuries earlier. Yet one must not forget the diseases that ravaged the population at that time. Although the days when these sacred *marae* with their great statues were feared and respected, have come and gone, these structures still hold an important key to Raivavae's past. The numbers speak for themselves: on the one hand, only 4 traditional star names were recorded by Stimson in 1938, on the other, a remarkable 44 structures, out of the 48 we studied, were built with an astronomical orientation. The fact that so many of the sacred sites on Raivavae were oriented to the same astronomical phenomena clearly indicated that these alignments had been made by choice.

The great majority of the structures we studied were aligned in a north-south direction, regardless of structure type. These numbered 29 total. Two *marae* were built on an east-west axis, the same as the rising and the setting of Orion's Belt, and another pair were aligned to the rising of the Pleiades, which is symmetrically opposite to the synchronous setting of Antares. Two other structures marked the rising of Aldebaran and the setting of Sirius, and only one structure was aligned to the rising of Vega and the Setting of Formalhaut. Five *marae* were built SE-NW, aligned to the rising of the star clusters of Zeta Scorpii and the setting of Vega. Certainly this orientation was not arbitrary, particularly when one considers that the Heliacal rising of Zeta Scorpii on Raivavae occurs in January and that it is the Raivavaen name of both Zeta Scorpii and that month. Three structures were found to be oriented to the rising of Alpha Centauri A and the setting of Alkaid. Lastly, the orientation of the remaining 4 sites could not be determined as one had a magnetic anomaly that interfered with our readings, while the others did not seem to be oriented to anything in particular. The detailed results of our findings appear in Table 8.

Table 8. Orientation of Raivavaen Sacred Structures

MARAE TYPE	SURVEY# & NAME	ORIENTATION	NOTES
Type B1	VAI 77	N-S	Facing ocean at S
Total: 7	VAI 154	N-S	Facing ocean at S
Checked: 5	VAI 325 Mahara I	62°-242°/ Pleiades + Antares	Edwards 2003 / In Disrepair
	VAI 328 Mahara II	76º-256° ±5° / Aldebaran + Sirius	Edwards 2003 / In Disrepair
	VAI 345	75º-255° ±5° / Aldebaran + Sirius	Edwards 2003 / Destroyed
Type B2	RRA 34 Taravao	88°- 268° ±3° E-W / Orion's Belt	Built circa 1780 AD
Total: 9	RRA 52 E'a or Vaitava'e	N-S	Facing South
Checked: 3	RRA 72	87°-267° ±3° E-W / Orion's Belt	
Type B3	RRA 1 Raupa	N-S	Facing Ocean at N
Total: 34	RRA 33 Utamae	N-S	Facing S / In Disrepair
Checked: 25	RRA 38 Te Umu Honu	N-S	Facing S
	RRA 39 Hu'urangi	128° - 308°	Stokes 1921 / Destroyed
	RRA 54 Puhau	N-S	Facing N
	RRA 55 Te Rena	SE-NW / Zeta Scorpii + Vega	Facing NW
	RRA 114 Hare 'Anuanua ('Anuanua II)	SE-NW / Zeta Scorpii + Vega	Facing SE
	RRA 115 Te Raerae	SE-NW / Zeta Scorpii + Vega	Facing NW
	RRA 122 Te Pua	45°-235° ±4° / Vega + Formalhaut	
	RRA 138 Atorangi or Angepua	N-S	Facing W
	RRA 162 Te Hau Rere Mata Riu	64°-243° ±3°/ Pleiades + Antares	
	VAI 111 Te Vairoa I	140°-320°, ˜SE-NW / Zeta Scorpii + Vega	Facing SE
	VAI 189 Urupuni	N-S	Facing S
	VAI 190 Ahaore	N-S	Facing S
	VAI 195 Mata o Hue	N-S	Facing S
	VAI 248 Te Rai st	53°-233°	Facing Southwards
	VAI 261 Maru Po	170°-350° ± 3°	
	VAI 281 Te Maihiku	154°-334° ± 4° / Alpha Centauri A+ Alkaid(?)	Built circa 1720 AD
	VAI 282 Mauna Oto or Aoahu	*Magnetic Variability*	Facing Ocean at S
	VAI 308 Ahe'e	N-S	Facing S
	VAI 314 Ahu Mate II	N-S	Facing S
	VAI 318 Pu'utoa	N-S	Prev. UnID / Facing S
	ANA 3 Urumanu	N-S	Facing N
	ANA 48 Te Tarahu	N-S	In Const. / Facing N
	ANA 57 Poihua	156°-330°±4° / Alpha Centauri A + Alkaid(?)	Prev. Unrec. / Facing N
Type B3a	RRA 6 Oro'oroputa / Tere te Hei Ra'u	N-S	Built circa 1780 / Facing N
Total: 7	RRA 18 Pomaovao	N-S	Built circa 1720 AD
Checked: 6	RRA 48 Unurau st	N-S	Facing S
	RRA 67 Moana Hei Ata	156° - 336° / Alpha Centauri A + Alkaid(?)	Edwards 2003 / In Disrepair
	VAI 76 Pua Pua Tiare	N-S	
	VAI 166 Pure Po	N-S	Facing S
Type B4	RRA 2	N-S	Facing N
Total: 6	RRA 51	N-S	Facing N /In Disrepair
Checked: 3	VAI 116 Te Vai Roa II	140°-320°, ˜SE-NW / Zeta Scorpii + Vega	
Type UnID	RRA 32	N-S	Prev. Unrec. / In Disrepair
Total: 17	RRA 35 Te Tahora	N-S	Facing N / In Disrepair
Checked: 6	RRA 74 Vai o Vihi	N-S	Facing N
	VAI 81 Tutemoata	N-S	Facing S
	VAI 149 Rapa Tanga	N-S	Facing S
	ANA 30	N-S	Facing N

Evidently, an overwhelming majority of structures pointed to different cardinal points. However, in subsequent analysis we found that more than a few structures were also aligned to important calendar stars—closer to what our team had theorised. As seen in the Table 9 below, there is no particular pattern or relationship between the geographic location or type of structure in relation to the astronomical phenomena the *marae* and shrines marked.

Table 9. Breakdown of Astronomically-Aligned Raivavaen Sacred Sites

Astronomical Alignment	Number of Structures	Orientation	Type	Location
Solstices	29	N - S	B1 (2) B2 (1) B3 (13) B3a (5) B4 (2) UnID (6)	RRA (13) VAI (13) ANA (3)
Zeta Scorpii Rising + Vega Setting	5	SE - NW ±5°	B3 (4) B4 (1)	RRA (3) VAI (2)
Orion's Belt Rising and Setting	2	E - W	B2 (2)	RRA (2)
Aldebaran Rising + Sirius Setting	2	75º-255° ±6°	B1 (2)	VAI (2)
Pleiades Rising + Antares Setting	2	64°-243° ±3°	B1 (1) B3 (1)	RRA (1) VAI (1)
Vega Rising + Formalhaut Setting	1	45°-235° ±4°	B3	RRA (1)
Alpha Centauri A Rising + Alkaid(?) Setting	3(?)	156°±7° - 334°±8°	B3 (2) B3a (1)	RRA (1) VAI (1) ANA (1)
Undetermined	4(?)	128° - 308° 53°-233° 53°-233° 170°-350° ± 3° Magnetic Variability	B3 (4)	RRA (1) VAI (3)

The fact that so many religious structures on Raivavae have a N-S orientation is very intriguing. The reason for this is unknown, but since Raivavae has a latitude of 23° 52′ S and the Earth is tilted 23°, it is possible to consider that the walls of the structures built with that orientation would cast no shadows on the days of the solstice, perhaps something of interest to the ancient Raivavaens. Nevertheless, the same orientation has been found to repeat itself on all other islands with astronomically aligned sacred sites in Eastern Polynesia and it seems to be the preferred alignment on Rurutu, Huahine, and Raiatea, all in different latitudes (Edwards 2003: 198-99). Not be ignored, is the fact that, together with an E-W alignment, N-S is one of the easier orientations to calculate.

With regards to the other orientations, the only two asterisms that Stimson mentions by name in his manuscript are the Pleiades, and Zeta and Theta (a.k.a. Sargas) in the constellation of Scorpio. If the name for the latter two was still remembered in 1938, then they must have been of importance to the people of ancient Raivavae. We do not know why Stimson believed Pipiri Ma probably referred to that two-star asterism, but the name is a compound of Pipiri (January) and Ma (-with family, -in a group, -with others). Stimson classified it as a mythological name and therefore there is reason to believe that it was narrated to him as part of an oral tradition where there were two protagonists who shared a relationship with each other, explaining why Stimson believed it was the joint name of those two stars. However, it is possible that the name refers to Zeta Scorpii and the conglomeration of stars immediately near it, together known as the "The False Comet" since it consists of three star clusters which to the naked eye look like a comet with its tail (see Figure 5). Zeta Scorpii is the brightest member in the "head" of the false comet and is also one of the brightest known in the galaxy. Since Pipiri means "January", which coincides with the Heliacal rising of this star cluster, this astronomical event must have marked an event in the Raivavaen calendar, however this information has been lost. Interestingly, Ms. Linda Tumarae White, from Raivavae, mentioned that the positioning of the "tail" of Scorpio was related to fishing, but we heard nothing more regarding the subject.

Figure 5. The The reddish nebulosity is star cluster IC 4628, while the bright concentrated cluster in the lower right is NGC 6321. Zeta Scorpii is the golden star group at the bottom. (Photo by NASA)

Both Zeta Scorpii and Vega are circumpolar stars, Vega rotating around the Northern Celestial Pole, Zeta Scorpii to the South. The same way Zeta Scorpii rises directly SE and settles SW, Vega, the brightest star in the constellation Lyra, rises due NE and settles NW (see Fig. 6). For this reason, Vega was an important calendar star for Micronesians, Melanesians, and Polynesians. The name for Vega is shared by close cognates in many Micronesian languages, meaning that its use in Polynesian navigation and calendrics dates back to their ancestors the Lapita. In the Puluwatese language of Micronesia, Vega and the the month of February share the same name, while at the other end of Oceania, on Rapa Nui, its Heliacal setting marked the start of the eel-fishing season, appearing briefly before at dawn on May 30th.

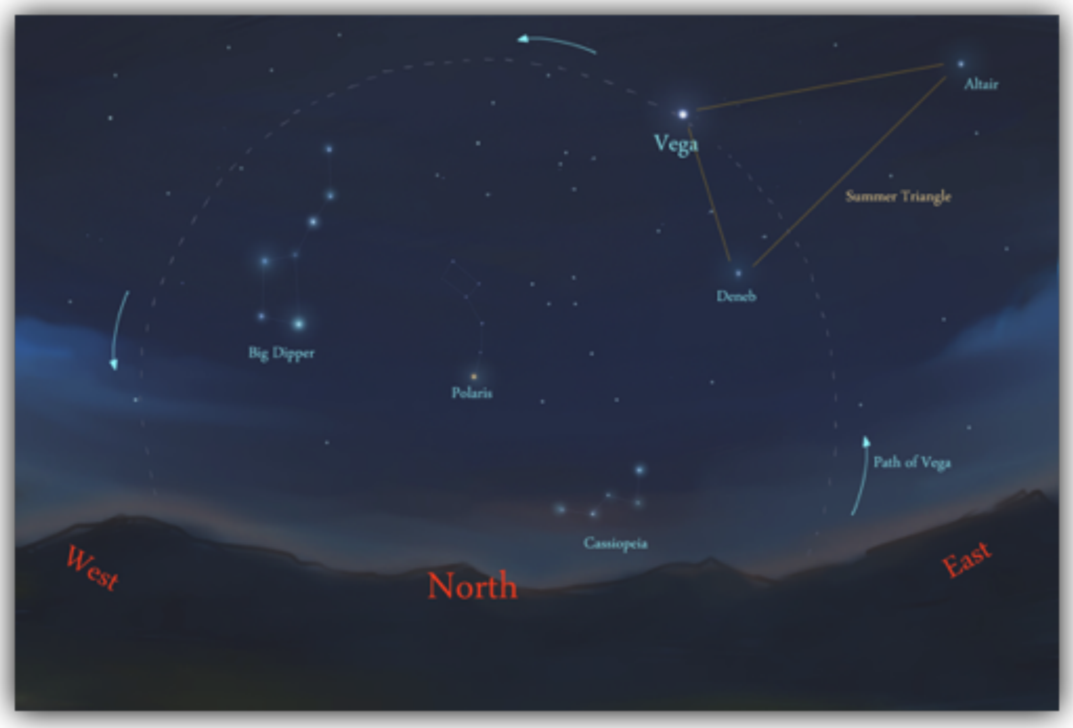


Figure 6. The night time path of Vega around the Northern Celestial Pole
(Image by Anonymous, Public Domain)

As mentioned previously in this report, the Pleiades were the foremost Polynesian calendar star and there is no question that Raivavaens, the same as Polynesians on all other islands would have set up a system to observe them. Antares ranks as the second most important star for the ancient Polynesians, for reasons of its own, but also in part because it lies symmetrically opposed to the Pleiades in the night time sky, so that when one is rising, the other is setting, and vice versa. This relationship was reflected obviously in the orientation of two chiefly *marae* on Raivavae.

Likewise it is not surprising to find Orion, Aldebaran, Sirius, and Formalhaut among the group of the stars to which the people of Raivavae chose to orient their sacred structures. As detailed previously in this report, Sirius and many stars in Orion were part of the great Manu constellation, and all of the aforementioned stars were of great cultural importance throughout the Pacific area, as "tools" for navigation, but also to calibrate their lunar calendars and mark different annual events. All of these stars are known as "alignment stars" since the relationship they share with each other, as well as with other stars, help mark direction (See Figures 7, 8, and 9). Like the Pleiades and Antares, Orion, Aldebaran, Sirius, and Formalhaut all played an important role in the mythologies, cosmogonic traditions, and cultural practices of the ancient Polynesians, and continue to do so to this day.

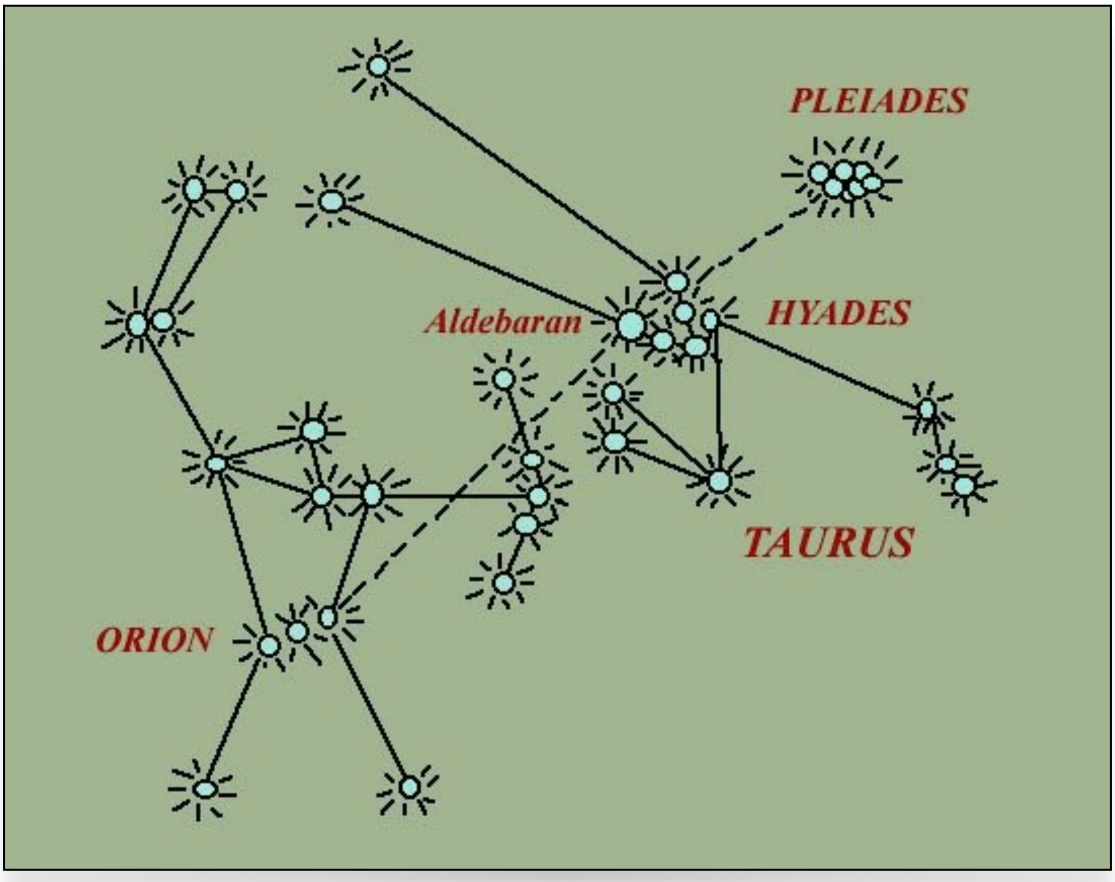


Figure 7. The three stars in Orion's Belt point to Aldebaran, which in turn point to the Pleiades. (Image by Anonymous, Public Domain)

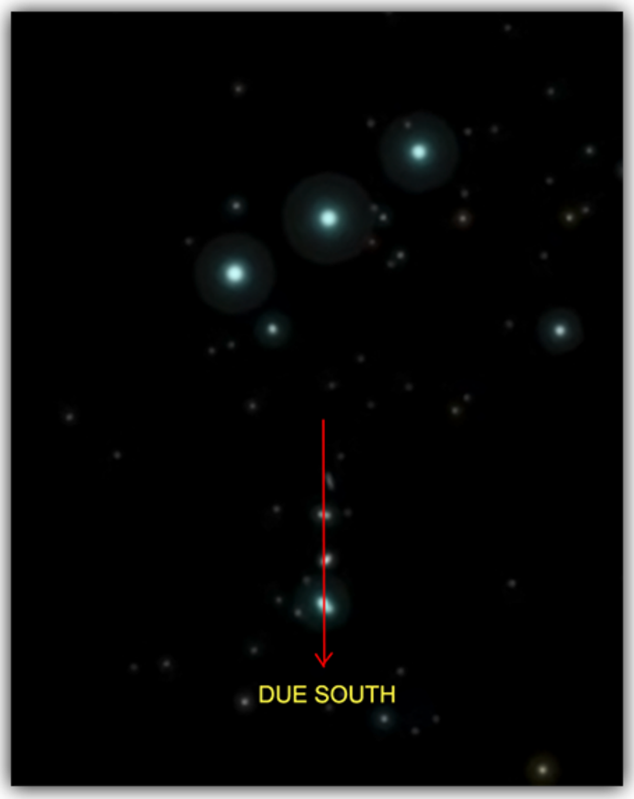


Figure 8. When the stars in Orion's Belt are positioned so that the "sword" is vertical, these stars point due South. (Image by Anonymous, Public Domain)

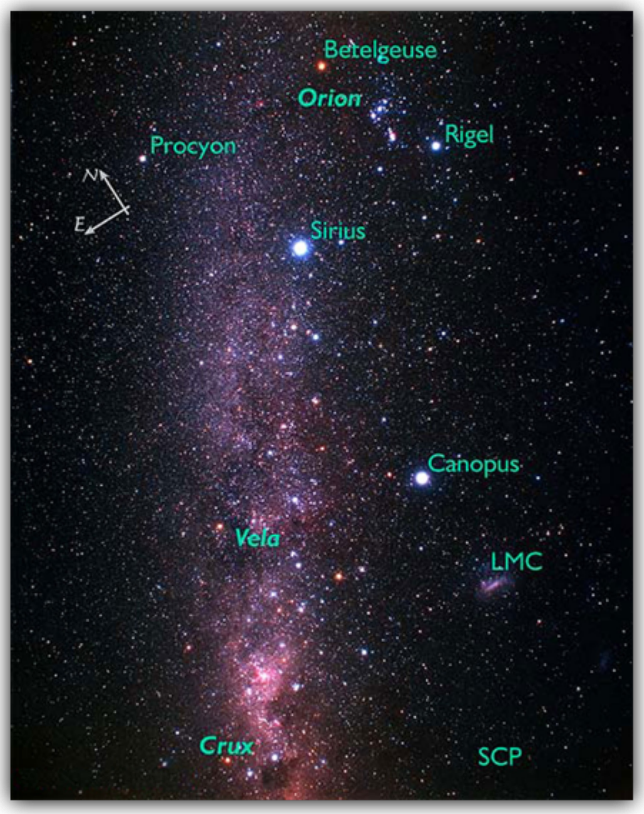


Figure 9. Sirius, the brightest star in the night sky, and its relationship to other important alignment stars. (Image by Anonymous, Public Domain)

Alpha Centauri A and B are two of the most notorious alignment stars in the night sky. They are commonly known as the pointers of Crux (a.k.a. the Southern Cross) and the same as the other stars mentioned here, they have been extensively used in Celestial Navigation, not just by Polynesians but by several other peoples throughout history, worldwide, to determine the location of the southern heavenly pole. In Micronesia these stars were known as “the two men”and on Rapa Nui they represented a mythological canoe, which together with Orion’s Belt, were used to announce the start of important Summer festivities. Alpha Centauri A is the 3rd brightest star in the night sky.

Figure 10. Alpha Centauri A and B, pointing to Crux.
(Image by Anonymous, Public Domain)

Of all the stars mentioned in this report, Alkaid is the one with least rank, which is not to say that it was not significant to Polynesians, but notably less so. Alkaid is the third brightest star in the great constellation of Ursa Major, and appears in the traditions of New Zealand and Tahiti, and even in the Hawaiian Creation chant as part of an asterism called Na Hiku ("The Seven”), which corresponds to the Big Dipper, with Alkaid as its easternmost star. Like its celestial counterparts mentioned here, Alkaid is useful in navigation and the Nautical Almanac lists it at number 34 out of 173 stars used for dead reckoning. In our study, we found three *marae* to be aligned with the rising of Alpha Centauri A and the setting of Alkaid. There is no question that Polynesians might choose to orient a *marae* to Alpha Centauri A, a star of great significance in Polynesian navigation, however there was some uncertainty regarding Alkaid, as it is a more obscure star in Polynesian lore.

Nevertheless, were it not for Stimson's manuscript, perhaps the same would have been said of Zeta Scorpii. It is possible to consider that Alkaid coincided with a local fluctuation of resources or celebration of events. The fact that so many structures on Raivavae have an astronomical orientation, coupled with the observation that as many as three *marae* found in all three districts of modern-day Raivavae share the same orientation, all points to this being a deliberate choice.

It is interesting to note that the orientation of chiefly *marae* on Raivavae usually also set the direction of the household of the head of the lineage to whom the *marae* belonged, and in most cases also several other structures in the settlement. The ground plan and orientation of these constructions must have been determined when their foundations were laid out, therefore this must have also been one of the responsibilities of the astronomer priests, but unfortunately we know nothing about the significance of this or the preparations and ceremonies that may have been related to that important occasion.

The *marae* today are surrounded by a dense growth of vegetation that interferes greatly with any kind of observation of the night sky. Undoubtedly, the area must have been kept clearer in the past, when these sites were in use. In addition, one must consider the possibility that the position of certain uprights that form the court of the *marae* itself, which are irregular in distribution, form, and height, may have served to indicate calendric events, such as the position upon which a certain star would rise or set behind the tallest slab or a pointed one; perhaps an upright on the approach to the *marae* had astronomical significance, but that would be impossible to know without the proper preservation and/or restoration of these sites.

Expedition Results

Part of the goal of our expedition was to verify the compass readings of the the religious structures that had been surveyed by E. Edwards in 1987-1991, and make corrections, if necessary. In addition, we took the measurements of some related structures, two house foundations, as well as the reading of two sites that have been identified as those belonging to the first two chapels built in Vaiuru, Raivavae shortly after the arrival of the first missionaries between 1819 and 1821. The previous measurements of a total 16 sites had to be rectified. The new readings appear in Table 10.

Table 10. Corrected Orientation of Selected Sites on Raivavae

Site	Orientation
VAI 75 Marae Puapua Tiare	N-S
VAI 69 House Foundation	N-S
VAI 166 Marae Pure Po	N-S
VAI 170 House Foundation	N-S
VAI 189 Marae Urupuni	N-S
VAI 190 Marae Ahaore	N-S
VAI 282 Marae Maunga Oto or Ao'ahu	Magnetic deviation
VAI 308 Marae Ahe'e	N-S
VAI 325 Marae Te Mahara I	Magnetic deviation
VAI 328 Marae Te Mahara II	Magnetic deviation
RRA 1 Marae Raupa	N-S
RRA 2 Shrine	N-S
RRA 18 Marae Pomaovao	N-S
RRA 38 Marae Te Umu Honu	N-S
RRA 52 Marae Te E'a or Vaitavae	N-S
RRA 162 Marae Te Hau Rere Mata Riu	64°-243° ±3°

With regards to sites VAI 61 and VAI 68, which correspond to the remains of the first chapels of Vaiuru, built in an area higher up and further inland of Vaiuru, we found that both were oriented N-S. This seems to indicate that the custom of building religious structures in this preferred position, continued even after the introduction of Christianity.

Modern-day Church of Vaiuru (Photo be Alexandra Edwards)

Collection of Ethnographic Data

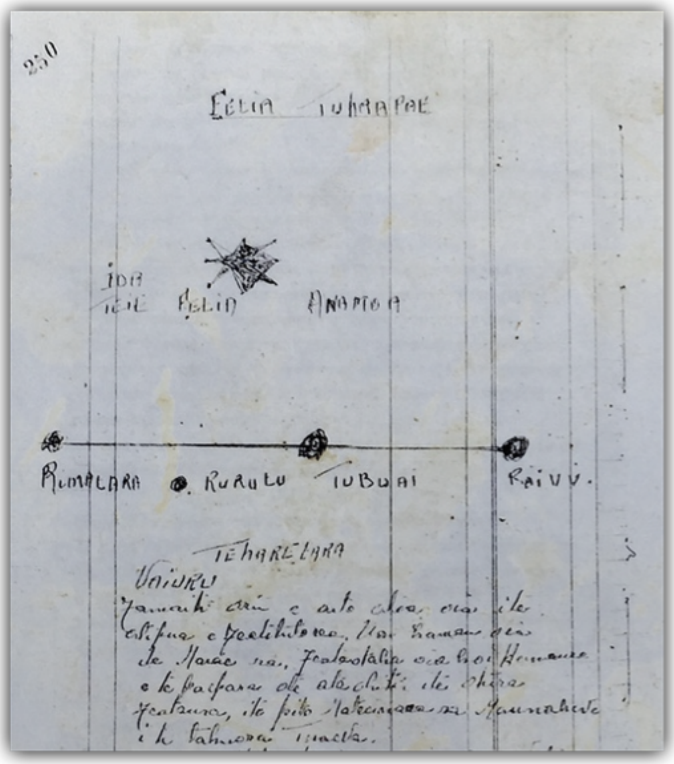
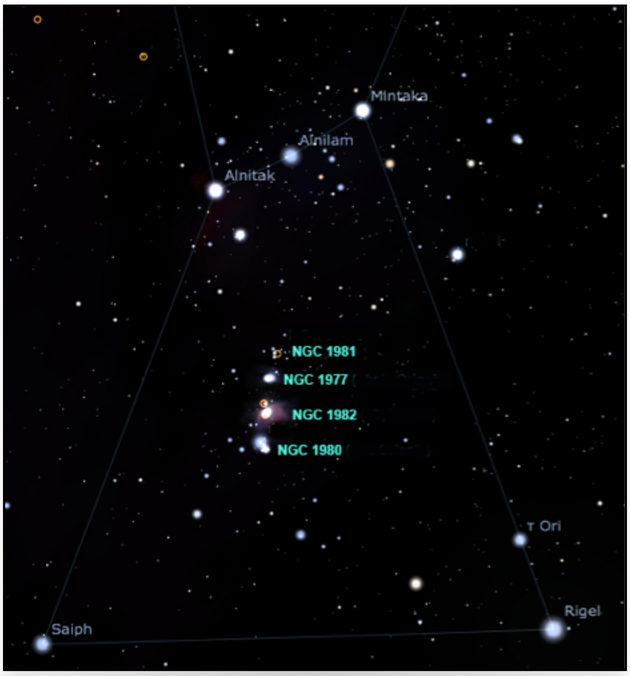


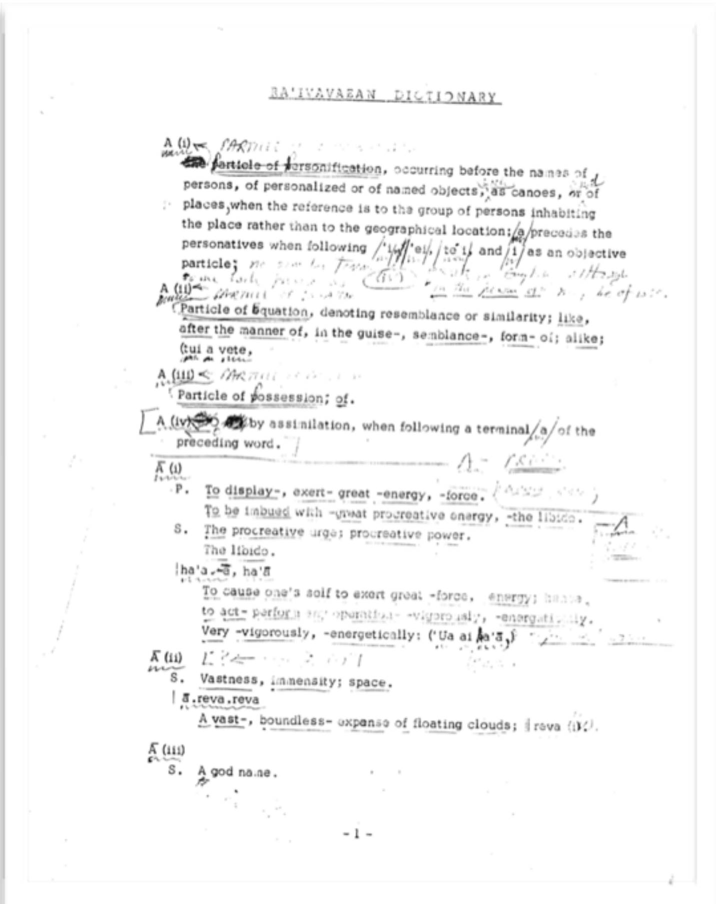
Figure 11. Copy of Opeta Paipaimoana's *puta tupuna*, showing information regarding Raivavaen stars (Photo by Edmundo Edwards)

As a corollary to the fieldwork our team carried out in Raivavae, we had also set it upon ourselves to collect ethnographic data in order to interpret our findings. Although we were unable to gather much information from the modern-day inhabitants of Raivavae, we were fortunate enough to have had access to copies of a *puta tupuna*, or ancestor book. These handwritten notebooks are zealously guarded by their keepers, and in most cases their contents are kept secret. Nevertheless, Mr. Haamai Tetaroi Uga, an acquaintance of Ms. Tumarae White, was generous enough to show us the photocopy of one that had been wrongfully sold to a foreign visitor to the island in 1965. The copy consisted of three volumes written by Opeta Paipaimoana between 1897 and 1903. The copy was illegible at times, and although parts were translated into French and English, most of it was written in native Raivavaen… Considering all this and the little amount of time we were allowed access to the notebooks, the information we were able to gather was limited. Nevertheless, the last page of the copy we saw had a drawing of what seemed to be the Pleiades with the inscription (in Raivavaen): "This star's name is Anamoa (Cave of Chickens)" and another unidentified asterism called "Tuha'a Pae" ("The Expelled Pieces," or "The Cast Away Pieces") consisting of four stars, which our informer believed was related to Orion's Belt (the three star clusters in Orion's Sword plus NGC 1981? — see Figures 11 and 12). These stars were supposed to represent Raivavae and its neighbouring islands Rimatara, Rurutu, and Tubuai, but today is used to refer to the Australs (incorporating further removed Rapa). Interestingly, "Anamoa" probably relates to a Raivavaen oral tradition explaining the origin of the Pleiades, a localised interpretation of the more common pan-Polynesian name of "Matari'i" recorded by Stimson in 1938.

Figure 12. The asterism known as Orion's Sword plus the loose star cluster NGC 1981 (Image by Anonymous, Public Domain, altered by Alexandra Edwards)



In addition, shortly after our expedition to Raivavae, A. Edwards met David Meyer who was kind enough to provide a link to the copy of Stimson's unpublished dictionary, which proved invaluable for this report (see Figure 13). Much of the ethnographic information collected here was gleaned from Stimson's manuscript, and for that we are greatly indebted to Mr. Meyer's generous assistance.



RA'IVAVAEAN DICTIONARY

A (i)
Particle of personification, occurring before the names of persons, of personalized or of named objects, as canoes, or of places, when the reference is to the group of persons inhabiting the place rather than to the geographical location; /a/ precedes the personatives when following /'i/, /'e/, /to'i/ and /i/ as an objective particle;

A (ii)
Particle of equation, denoting resemblance or similarity; like, after the manner of, in the guise-, semblance-, form- of; alike; (tui a vete,

A (iii)
Particle of possession; of.

A (iv) by assimilation, when following a terminal /a/ of the preceding word.

Ā (i)
P. To display-, exert- great -energy, -force.
To be imbued with -great procreative energy, -the libido.
S. The procreative urge; procreative power.
The libido.
ha'a.-ā, ha'ā
To cause one's self to exert great -force, energy;
to act- perform
Very -vigorously, -energetically: ('Ua ai ha'ā,)

Ā (ii)
S. Vastness, immensity; space.
ā.reva.reva
A vast-, boundless- expanse of floating clouds; reva (ii).

Ā (iii)
S. A god name.

- 1 -

Figure 13. The first page of the copy of Frank Stimson's unpublished dictionary from 1938, with handwritten notes by Donald Marshall (Photo by Alexandra Edwards)

The Orientation of Marae in Raiatea and Huahine

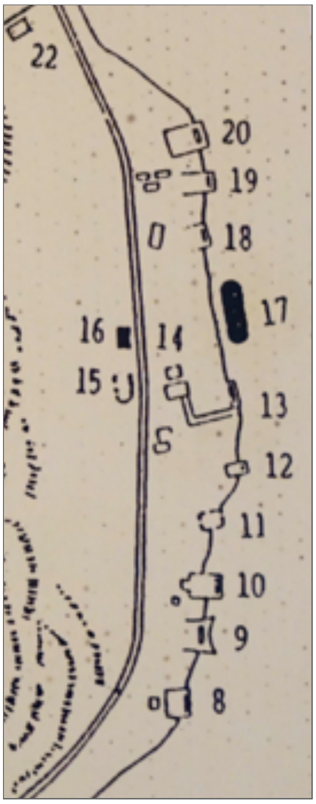
Previous archaeological surveys conducted on Raivavae and in the Northern group of the Society Islands indicate that several sacred sites on those islands were used to determine astronomical orientations. E. Edwards had previously recorded five *marae* with a North-South alignment on Rurutu and Raiatea (Edwards 1995; Edwards and Clarke 1986). In addition, two other *marae* on Raiatea pointed to local mountain peaks. These structures were distributed throughout Opoa valley, in four of the eleven ancient settlements of Raiatea. Again, in a preliminary survey conducted by E. Edwards on Huahine, 11 of the 47 *marae* on Matairea Hill were solstice-oriented, (Edwards n.d.). In nine of these 11 sites, the solstice direction was perpendicular to the *ahu* of the structures. This N-S orientation was found to repeat itself in *marae* found in both coastal and inland locations, indicating that the orientations were not arbitrary. Before parting to work on Raivavae for this expedition, Paul and Michelle Zygielbaum together with E. Edwards had the opportunity to measure the axes of 11 chiefly *marae* on Huahine, and three in the eponymous site of Taputapuatea on Raiatea. The selected *marae* corresponded to sacred sites of great magnitude, belonging to the head of an important lineage, and where visitors from other Polynesian islands gathered together to celebrate various ceremonies and festivities in the past. All of the *marae* we recorded on Raiatea and Huahine during this expedition, had a N-S orientation without exception (see Table 11).

Table 11. Orientation of Select Chiefly Marae on Raiatea and Huahine

Island	Site	Orientation
Raiatea	Taputapuatea (A)	North – South
	Taputapuatea (B)	North – South
	Taputapuatea 1	North – South
Huahine	Unurau	North – South
	Manunu	North - South
	Maeva Site, Sch2- 8 Nuumau	North – South
	Maeva Site, Sch2 -9 Oavaura	North – South
	Maeva Site, Sch2-10 Faretou	North – South
	Maeva Site, Sch2- 11 Avaroa	North – South
	Maeva Site, Sch2- 12 Orohahaa	North – South
	Maeva Site, Sch2- 13 Mata'itaria	North – South
	Maeva Site, Sch2-18 Manunu	North – South
	Maeva Site, Sch2-19 Matai're'arahi	North – South
	Maeva Site, Sch2 -20 Mata'ire'a	North – South

As seen in the table above, and from the information gathered in previous surveys to both islands, a N-S axis alignment seems to be the preferred orientation of chiefly *marae* on Raiatea and Huahine (there are several other sites that would have to be included to draw a complete comparative analysis), however, the results of our preliminary study is categorical: N-S is by far the most favoured alignment on Raiatea and Huahine, regardless of site location. Marae Taputapuatea and its two adjoining *marae* are located on the coast of Raiatea and together constitute the most sacred site in Eastern Polynesia, as well as one of the largest of its kind (see Figure 15 and 16). However, as mentioned previously five chiefly *marae* located further inland in Opoa valley were also oriented N-S. The counterpart of Taputapuatea on the island of Huahine is Marae Unurau, which the same as Marae Manunu, is located on the ocean side coast of Huahine. The remaining nine sites we registered on Huahine are by the shores of the interior lagoon of the island, in an area called Te Maeva (see Figures 17 and 18).

Figures 15 and 16. Marae Taputapuatea, the most sacred site in Eastern Polynesia, then and now (Engraving by John Webber; Photo by Anonymous, Public Domain)



Figures 17 and 18. Map of *marae* in the Maeva Site, Huahine, and an aerial shot of one of the same structures (Map CPSH Tahiti; Photo by Pierre Lesage)

It is interesting to note that several Raivavaen chiefly *marae* are estimated to have been built in the 1700s, a few as late as 1780. It is uncertain when the practice of orienting sacred structures to astronomical or cardinal directions began, but it seems to have been a later development, when inter-island voyaging between the Society and Austral Islands was frequent. According to Raivavaen oral tradition, people from Raivavae travelled regularly to Raiatea carrying offerings to Marae Taputapuatea, and Raivavae was included in a map drawn in 1776 by the renowned Raiatean wayfinder Tupaia who guided Captain James Cook to Tubuai in the Australs. Furthermore, Gayangos, the first European to stop at Raivavae, navigated there with the help of two wayfinders from the Society Islands. It is possible that the custom of building structures with a designated orientation may date back to a shared common ancestral tradition, however, it is also possible to consider that it was born from an external cultural influence.

Conclusions

The skill and knowledge involved in Polynesian archaeoastronomy was not learnt from one day to the next, indeed it involved centuries of information and experience passed from one generation to the next, until a specialised elite was able to establish seasonal patterns, keep track of time, and develop an agricultural cycle. It is easy to surmise that the heavens were the inspiration for cultural principles that were so significant that Polynesians saw in them the work of the gods. Nevertheless, Polynesian skywatching developed for very practical reasons, for agriculture and navigation (i.e. subsistence, immigration and trade), and was intrinsically related to almost every aspect of everyday affairs. Spearheaded by something as important as survival, population dispersal, and economic growth, people found a way to understand and use astronomical events for their own benefit, yet many concepts remained the same, year after year, century after century, from island to island. Examining the differences and similarities between Raivavaen archaeoastronomy and that of Raiatea and Huahine, undoubtedly offer great insight as to the nature of Polynesian inter-island migrations and contacts, as well as the unique evolution and cultural identity of these island-societies.

Studies have shown that Eastern Polynesians often oriented their sacred architecture to topographic and astronomical phenomena, often carving rock art in the vicinity of places where astronomical events were observed, yet the subject had never been investigated at length on Raivavae. In addition, there is also little information regarding ancient inter-island trade networks in the archipelago. None of these subjects have been adequately considered in the interpretation of archaeological data, nor have inter-disciplinary comparisons been systematised to clarify the nature and conditions of inter-island communication. Nevertheless, there are probably few areas in the world where the potential for studying the growth and development of complex stratified social and political systems is as great as among the islands of Polynesia. The analytical advantages of Polynesia are due to the often-cited "laboratory like" conditions of remote, isolated islands. A detailed study of the local calendric system and the orientation of sacred architecture would greatly contribute to our understanding of how Polynesians lived up until the time of European contact, in addition to fostering proper care and maintenance of valuable yet remote archaeological sites. The Raivavaen calendric system is evidently tied to that of other Polynesians, but it also includes uniquely local adaptations. That, and the overwhelming importance of the concepts of Cosmos and Time, place archaeoastronomy at the top of the list of valuable research topics in Polynesia today.

The common ancestry of Polynesians is evident in the many terms and practices shared by people settled on islands sometimes thousands of kilometres away from each other, yet the richness of this seafaring culture is manifest in the diversity found in settlements that are sometimes only a few valleys apart. Much can be learned by placing Raivavaen calendrics, within the context of greater Polynesia; while at the same time, the more we learn about Raivavaen archaeoastronomy, the more we will be able to understand the Polynesian view of the cosmos and the place humans occupied in the Polynesian universe. There is ample proof that Polynesians were exceptional navigators and that the wealth of information wayfinders commanded was an important factor in their success. With limited physical proof, mostly restricted to certain structures with an astronomical orientation, the expertise of Polynesian skywatchers is harder to grasp even though it almost certainly preceded Polynesian navigation and probably involved a much more extensive bank of knowledge regarding observation of the night sky. Hopefully the recent interest in Polynesian navigation will spark notice of other Polynesian achievements and expose one of the more extraordinary abilities of the ancient Polynesians.

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Expedition Timeline and Notes

The first part of our project was completed between April 21st and May 1st 2015 on the islands of Raiatea and Huahine, by Edmundo Edwards, Michelle Zygielbaum, and Paul Zygielbaum. They were joined by the other members of Team 1, working on Raivavae from May 1st until May 11th. A new team flew in on May 15th staying on Raivavae until May 25th. The expedition was led by Edmundo Edwards, archaeologist and co-founder of the The Pacific Islands Research Institute (PIRI) with the organisational expertise of Captain Lynn Danaher, president of PIRI. Alexandra Edwards helped with logistics and keeping a photographic record of the expedition. She has participated in three previous EC expeditions (Flag #95 Raivavae '06, Flag #83 Rapa Nui '10, Flag #56 Marquesas '13).

The Following is a list of the lectures that we offered during the expedition:

Expedition Lectures

"Wayfinders and Skywatchers: Polynesian Archaeoastronomy" by Alexandra Edwards

"The History of the Explorers Club" by Lynn Danaher

"Ancient Adventurers of Remote Polynesia: The People & Culture of Raivavae" by Alexandra Edwards

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(in alphabetical order)

Francisco Förster, Astronomer (Chile)
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Georges Mahaa, Guide and Translator (Raivavae)
David Meyer, Researcher and keeper of the copy of Stimson's manuscript! (U.S.A.)
Rodrigo Navarro, Biologist, Guide, and Translator (Tahiti)
Elise Servajean, Astronomer (Chile)
Haamai Tetaroi Uga, Ethnographic Informant (Raivavae)
Joachim Tevaatua, Mayor of Rairua (Raivavae)
Linda Tumarae White, Owner of "Pension Chez Linda" (Raivavae)

We also received support and collaboration from the staff at the town hall of Rairua, particularly from the substitute mayor when Mr. Tevaatua had to absent himself, and from the community of the Protestant Temple of Vaiuru.

We heartily thank them all for their counsel, assistance and generosity.

We dedicate this report to the fond memory of our dear friend and colleague Mr. Amedée Tevaatua, former mayor and team member of several previous archaeological expeditions to Raivavae.

We are greatly honoured that we were granted Explorers Club Flag #83 for our expedition to Raivavae, and we thank the Explorers Club for their support of this and other scientific missions around the world.