1. SCIENTIFIC STUDIES IN THE SOUTHERN COOK ISLANDS: BACKGROUND AND BIBLIOGRAPHY

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INTRODUCTION

The Cook Islands, in the centre of the Pacific (Figure 1), are remote from centres of recent reef studies in the Marshall Islands and the Tuamotus. The early work of Ladd in Fiji, Hoffmeister in Tonga, Mayor in Samoa, and Crossland and Setchell in Tahiti, served to indicate the existence of gradients of faunal and floral diversity across the central Pacific from west to east, a diversity reflected in the structure and composition of the reefs and also in terrestrial ecology, but in the absence of further detailed studies these gradients could be only loosely defined. The Cook Islands are of interest too, as Darwin and later workers recognised, for their combination of reef-encircled volcanic islands, almost-atolls, and atolls, and for the existence of several islands of elevated karst-eroded limestone locally known as makatea. These structures have implications for general theories of coral reef development, and they also promise new evidence on the problems of recent sea-level fluctuations in the open Pacific. It thus appeared timely to re-examine the Cook Islands, and the Cook Bicentenary Expedition in 1969, organized by the Royal Society of New Zealand, provided the opportunity to study shallow-water marine communities and some aspects of the terrestrial ecology of reef islands at Aitutaki and at Rarotonga.

These studies are reported in the present Bulletin, and this introductory paper describes the salient features of the southern Cooks, outlines the scientific work already carried out there, and presents a bibliography, by way of introduction to the more detailed papers which follow.

STRUCTURE AND TOPOGRAPHY

The southern Cook Islands (Figure 2) consist of a linear series of volcanic and limestone islands extending for 250 km from Mauke to Aitutaki, and the two more isolated islands of Rarotonga and Mangaia, all rising from the sea floor at depths of 4500-5000 m. A detailed chart of the area at 1:1,000,000 with contours at 1000 m intervals has been published by Summerhayes (1969), and an interpretation of the regional bathymetry has been provided by Summerhayes (1967). Robertson and Kibblewhite (1966) have drawn attention to the similarity of the submarine slope profiles of volcanic islands and of atolls with no volcanic rocks now exposed at the surface. The

southern Cook Islands appear to comprise a series of volcanoes of different ages, some recent, with narrow fringing reefs (such as Rarotonga), others capped with thickness of limestone and subsequently elevated to form a karst surface locally known as makatea. In the northern Cooks the process of atoll development by Darwinian subsidence has proceeded further, and true atolls such as Manihiki and Palmerston have been formed. There is no direct evidence of the depth to volcanic basement beneath these atolls, but seismic data at Manihiki indicates a dome-shaped basement with volcanic rocks at 0.5 km depth beneath the peripheral reef but at only 0.05 km in the centre of the lagoon. Aitutaki, as an almost-atoll, is presumably intermediate in age between the northern atolls and islands such as Rarotonga.

Rarotonga and Aitutaki form the summits of separate volcanic masses rising from depths of 4000 m, at which depth the cones are 45-55 km in diameter (Summerhayes and Kibblewhite, 1966, 1967). The lower slopes of the cones average 15-25°, increasing to 30° in the upper 750 m and becoming very steep as the surface reef is approached. The Mauke-Aitutaki line of islands is thought to be of early Tertiary age: the surface volcanics are much eroded, with a subdued topography, or are capped with limestones (Wood, 1967; Wood and Hay, 1970). On Rarotonga, where the relief is much stronger (maximum altitude 640 m), radiometric ages of 2.3-2.8 million years date the lavas as Pliocene (Tarling, 1967). Mangaia, with a cap of Oligocene-Miocene limestones, must be much older (Marshall, 1927). Evidence from the deep-sea drilling programme indicates that the ocean floor in the area of the southern Cooks is Paleogene (22.5-65 million years) in age (Winterer, 1973), thus providing a maximum age for the islands. It is probable that the gross history of the Cooks resembles that of other, better-known reef-capped Pacific volcanic cones known to have been initiated in the early Tertiary.

Aitutaki (lat. 18°51'45"S, long. 159°48'10"W), 225 km north of Rarotonga, is an almost-atoll with a total area of 106 km^2 (Figure 3). The main volcanic island, located excentrically on the northwestern reef rim, has an area of 16.8 km^2 and rises to a maximum height of 119 m. It is thus a much more extensive volcanic residual than that of the only other almost-atoll recently studied, Clipperton in the east Pacific (Sachet, 1962). In addition to the main volcanic island, basalts and agglomerates also outcrop on Aitutaki near the southern reef rim in the islets of Rapota and Moturakau. On the latter the agglomerates include coral fragments, indicating that the later stages of volcanism were contemporary with reef growth. A similar situation has been described for reef-edge volcanic islets at Mayotte in the Comores by Guilcher et al. (1965). The situation at Aitutaki thus contrasts with that in the other makatea islands of the southern Cooks, where vulcanicity had evidently ended before deposition of the limestone caps had begun. Age estimates of the Aitutaki volcanics range from

Eocene to Miocene-Pliocene (Wood and Hay, 1970, pp.36-40).

The peripheral reefs of Aitutaki are roughly triangular in shape, enclosing a lagoon with a total area of about 50 km^2 and with a maximum depth of 10.5 m. Detrital reef islands are concentrated along the eastern (windward) reef, and have a total area of about 2.2 km^2. Seismic refraction measurements by Hochstein (1967) indicate a thickness of coral limestone over basalt of 13-20 m in the Ootu Peninsula, adjacent to the main volcanic island, and of 150±30 m at Tavaerua Iti, midway along the eastern reef. Results of gravity surveys at Aitutaki are reported by Robertson (1970), and of magnetic surveys by Lumb and Carrington (1971).

Rarotonga (lat. 21°12'06"S, long. 159°46'33"W) is a larger and more deeply dissected mountainous island, 250 km^2 in area, with maximum dimensions of 8 x 11.5 km, and a maximum elevation of 652 m. The geology has been described by Marshall (1930) and by Wood and Hay (1970, 10-27). The Pliocene volcanic core is surrounded by Pleistocene gravels and sands of different ages, with remains of a slightly elevated coral reef. The modern reefs are fringing and of variable width. In the east, at Ngatangiia, the reef encloses a deeper channel and there are three small sand cays and a volcanic islet standing on it; these have been described elsewhere (Stoddart, 1972). In addition to the radiometric dating, geomagnetic studies have been reported by Woodward and Hochstein (1970) and gravity data by Robertson (1967).

CLIMATE

Aitutaki and Rarotonga both lie in the Southeast Trades, and are influenced by winds from the northeast, east and southeast throughout the year (Hydrographic Office, 1966). Maximum rainfall occurs during December-March, when the Trades are less steady, and squalls and northerly winds may occur (Figure 4).

Table 1 summarises rainfall data for Aitutaki: monthly rainfalls for 1930-1971 are given by Taylor (1973) and incomplete records for 1907-1911 by Hunt (1914, 255). Mean annual rainfall is 1984 mm, rather more than half of which occurs during December-March (Figure 5). This compares with 2103 mm at Rarotonga (where, however, there is considerable local variability because of orographic effects), 2482 mm at Manihiki, and 2984 mm at Pukapuka in the north. Figure 6 shows histograms of the annual rainfall distribution at these stations. All show a similar seasonal pattern, though the dry season is most marked at Aitutaki, especially in June-September. According to K.M. Johnston (1967, p.74), on occasions no rain may fall for over a month. Johnston calculated Thornthwaite potential evapotranspiration figures for Aitutaki, confirming the existence of the pronounced dry season.

Table 2 and Figure 7 give temperature records for Aitutaki. The mean annual temperature is 25.6°C. Mean daily maxima exceed 30° during January-April, and mean daily minima fall below 22° during June-October. The highest temperature recorded is 37.2° and the lowest 12.8°. The range in mean monthly temperatures is 3.4°, the daily temperature range is about 11°.

Table 3 gives relative humidity data for Aitutaki at 0900 and 1430. These show a similar seasonal trend to rainfall and temperature.

The main source for climatic data is in K.M. Johnston (1967, pp.71-75), based on 37 years of records maintained by the Meteorological Service, Wellington; Tables 2-4 are based on Johnston's data. Slightly different figures are given by Tamashiro (1964), particularly for rainfall and number of raindays. Summaries of climatic data for the Cook Islands, including the northern atolls, are given in Maps of the Cook Islands (Survey Department, Rarotonga), and for rainfall by Taylor (1973).

Hurricanes

The southern Cook Islands lie within the South Pacific hurricane belt, but because of the paucity of records and the scattered distribution of climatic stations, even compared with the area to the west, little is known of hurricane tracks or frequency. Most studies of south Pacific hurricanes concentrate on the southwest Pacific area and terminate at 160°W, the longitude of the Cooks. Hutchings (1953) contributes a general discussion of south Pacific hurricanes, but with few specific records. The fullest listing for the Cooks is still that given by Visher (1925, 40), but this omits a number of severe storms reported in the early missionary accounts. Table 4 lists the recorded storms, based on Visher's lists with additions; it is certainly incomplete, especially for the present century. It is, however, clear that storms of exceptional severity have occurred in the southern Cooks during the last 150 years. They occur mostly during January-March, and approach from the north-east, curving round to the south and the northwest. Being in the southern hemisphere the hurricane winds rotate clockwise about the centre.

MARINE ENVIRONMENT

According to standard sources on the oceanography of the South Pacific (Fiziko-Geograficheskiy Atlas Mira, 1964), the mean sea surface temperature in the southern Cook Islands ranges from 27.3°C in January to 25.5°C in June.

Table 1. Rainfall at Aitutaki

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean monthly rainfall, mm	228.9	286.3	242.3	157.7	141.5	104.6	79.8	79.5	82.0	133.9	188.2	259.3	1984
Mean number of rain days	13	14	10	10	9	8	9	7	8	9	11	13	120
Number of months with less than 61 mm (2.4 in) 1920-60	4	2	-	10	11	20	20	27	20	14	8	1	
Number of months with less than 61 mm as percentage	10	5	-	25	27.5	50	50	67.5	50	35	20	2.5	

Source: K.M. Johnston, 1967

Table 2. Temperature at Aitutaki (°C)

Month	Mean daily temperature	Mean daily maximum	Mean daily minimum	Highest recorded	Lowest recorded
Jan	27.2	30.6	23.9	35.0	17.8
Feb	27.2	30.6	23.9	35.6	17.8
Mar	27.2	30.6	23.9	34.4	20.0
Apr	26.7	30.0	22.8	33.9	16.1
May	25.6	28.9	22.2	31.7	16.7
Jun	24.4	27.8	20.6	31.7	15.6
Jul	24.4	27.8	21.1	31.1	12.8
Aug	23.9	27.2	20.6	31.1	15.0
Sep	24.4	28.3	21.1	31.1	15.0
Oct	25.0	28.3	21.7	37.2	14.4
Nov	26.1	29.4	22.8	32.2	17.8
Dec	26.7	29.4	23.3	33.3	17.8
Means	25.6	28.9	22.2		

Source: K.M. Johnston, 1967, p.71

Table 3. Mean relative humidity at Aitutaki (per cent)

Local time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
0900	80	83	82	81	80	80	79	78	77	75	77	80	79
1430	73	73	73	73	71	68	64	67	70	70	71	72	71

Source: K.M. Johnston, 1967, p.71

Table 4. Hurricanes in the Cook Islands

Date		Comment
1831	21 December	Rarotonga
1839	22 February/1 March	
1841	February	Rarotonga
1841	17 December	Rarotonga; "gigantic waves"
1842	15-18 December	
1845	16-17 January	
1846	16-18 March	
1848	24 December	
1854	6 February	Rarotonga; hurricane and earthquake (Gill, 1856, 224-5)
1865	25 January/3 February	
1869	4-5 April	
1877	24 February	Towards Austral Islands
1882	2 February	Towards Austral Islands
1882	18 March	Towards Austral Islands
1883	December	Palmerston Island
1887	10-11 April	Towards Austral Islands
1889	18 February	
1890	15 December	Towards Austral Islands
1897	10-11 February	
1923	8 March	Towards Kermadec Islands
1943	4 March	
1946	10 January	

Source: Visher, 1925, p.40; Hutchings, 1953; Gill, 1856

Tides are semi-diurnal and of small amplitude. At Aitutaki the range at springs is 0.49 m and at neaps 0.12 m, and at Rarotonga 0.82 m at springs and 0.24 m at neaps. There is no substantial inequality between successive high and low tides in the semidiurnal cycle.

Tsunamis occur in this area but no major ones have been recorded. Keys (1963) describes the tsunami of 22 May 1960, which was observable at Rarotonga. In this case the small effect may be attributed in part to the fact that the tsunami arrived at a stage in the tidal cycle when the sea was below the level of the reef flat. Tsunamis in the Cooks are much less important than hurricanes in causing coastal inundation.

RECENT HISTORY OF AITUTAKI

Human activities have clearly had a profound effect on the ecology of islands in the southern Cook Group, not only during the one and a half centuries of direct European influence, but also during the earlier period of Polynesian colonisation and settlement. No detailed studies have been made of these effects, and indeed the history of human occupation itself is known only in bare outline. The main sources for pre-Contact history are in oral tradition, initially collected by missionaries such as Wyatt Gill (1876, 1880, 1885, 1894), and accounts of the initial settlement of Rarotonga and Aitutaki from these sources have been provided by Best (1927) and Pakoti (1895). Archaeological work has been begun by Duff (1968, 1971) and Bellwood (1969, 1971, 1973). Beaglehole (1957), Crocombe (1964) and Curson (1973) have presented recent summaries of the pre-contact and early contact periods, and these serve as a basis for the present account.

Cook discovered Manuae during his second voyage in 1773, and Mangaia and Atiu during his third in 1777, but he did not locate either Rarotonga or Aitutaki. Aitutaki was discovered by Europeans on 11 April 1789, when Captain William Bligh arrived on H.M.S. Bounty, before the mutiny. Bligh (1792) briefly but recognisably described the island:

> "...on the 11th, at daylight, land was seen to the S S W, at about five leagues distance, which appeared to be an island of a moderate height. On the north part was a round hill: the northwest part was highest and steep: the southeast part sloped off to a low point. ...we tacked to the southward, and, as we advanced in that direction, discovered a number of low keys, of which at noon we counted nine: they were all covered with trees. The large island first seen had a most fruitful appearance, its shore being bordered with flat land, on which grew innumerable cocoa-nut and

> other trees; and the higher grounds beautifully interspersed with lawns. ... On the 12th ... at two in the afternoon, we were within 3 miles of the southernmost key. ...the name of the large island ... was Wytootackee.
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> The island of Wytootackee is about ten miles in circuit; its latitude from 18°50' to 18°54'S, and longitude 200°19'E. A group of small keys, eight in number, lie to the S E, 4 or 5 miles distant from Wytootackee, and a single one to the W S W; the southernmost of the group is in latitude 18°58'S. Variation of the compass 8°14'E" (Bligh, 1792; 1961 edition, 127-129).

The Pandora, Captain Edwards, called on 19 May 1791, while searching for the Bounty mutineers (Edwards, 1915), and on 25 July 1792 Bligh himself again passed by in the Providence. These early contacts can have had little direct effect on Aitutaki. After the Bounty mutiny, the ship, under Fletcher Christian, apparently called at Rarotonga in 1789; the missionary John Williams (1837) reported a tradition of this visit surviving in 1823, and Christian thus becomes the discoverer of Rarotonga. No other ships called there until 1813 and 1814. Captain Theodore Walker in the Endeavour sighted the island and Captain Goodenough in the Cumberland landed there, searching for sandalwood, and Goodenough is said to have cut a great deal of nono (Morinda citrifolia) in mistake for it at Ngatangiia (Gill, 1856; Gosset, 1940; Maude and Crocombe, 1952). Goodenough subsequently called at Aitutaki (August 1814) and set down a group of Rarotongans he had abducted. The Seringapatam also called at Rarotonga, on 23 May 1814, and was followed by other vessels (Coppell, 1973).

Effective contact began with the arrival on Aitutaki of the Rev. John Williams on 26 October 1821. He left native Tahitian missionaries there, and went on to do the same at Rarotonga, having learned of the existence of the latter island from Goodenough's Rarotongans. When Williams returned to Aitutaki in July 1823, the inhabitants had apparently been converted to Christianity. In 1827 he went back to Rarotonga, instituted a code of laws, and installed the first of a series of English missionaries - Charles Pitman at Ngatangiia (1827-1855), Aaron Buzacott at Arorangi (1828-1857), and William Gill (1839-1857). Narrative accounts of the early history of the Rarotonga missions are given by Buzacott (1866), Gill (1856, 1880), and Wyatt Gill (1876a, 1885). Much material on cultural change and the introduction of plants and animals is undoubtedly contained in archival material relating to these missions, notably the journals of Pitman (1827-42), Buzacott (1828-40) and Mrs Buzacott (1830-33), with a manuscript by the latter on life on Rarotonga in the 1830s, in the Mitchell Library, Sydney, and letters in the London Missionary Society archives, but it has

not been possible to explore this material in the present study. Beaglehole (1957, 45) has fully documented the progress of disease, occurrence of hurricanes, and social disruption during the first decades of European contact, which reduced the population from ca. 7000 in 1833 to about 2000 between 1845 and 1900: major factors in this decline were the new diseases of measles, whooping cough, mumps, influenza, jaundice and dysentery.

At Aitutaki the first English missionary, Henry Royle, arrived on 23 May 1839, by which time some European beachcombers were already living on the island. He remained there for about 35 years (Plates 1-2). The impact of contact was less catastrophic than on Rarotonga. Epidemics were less serious, though there were notable outbreaks of dysentery in 1843 and measles in 1854. The population declined from approximately 2000 when Royle arrived to less than 1200 in the forty years after 1880. In spite of the alleged early and complete conversion of the people, Royle had a difficult time: disturbances and arson in the early months were followed by serious hurricanes in February 1841 and again in December 1842. His problems were accentuated by the development of the central Pacific whaling industry, for which both Aitutaki and Rarotonga became important victualling stations: thus in 1843 no less than 35 ships called at Aitutaki, and 100 at Rarotonga. Numbers of islanders joined the vessels as crew members, and of course the whalers went ashore. Perhaps the most severe disturbance on Aitutaki, which Royle was powerless to control, occurred in 1847, when two whalers, one American, one French, were wrecked there, and 70 sailors spent a year on the island. It is not surprising that the missionaries took the view that "All runaway sailors were profligate, all Frenchmen licentious, all Roman Catholics venal and corrupt, all traders petty and dishonest" (Beaglehole, 1957, p.75). By the time that whaling declined in these waters in the 1860s, Peruvian slave vessels were cruising in the northern Cooks seeking guano workers, and Cook Islanders were leaving for Makatea and also for New Zealand. By this time the islanders were said to be all clothed, housed, and literate, and Royle was selling Testaments at Aitutaki at the standard rate of 18-20 lbs of arrowroot per copy.

The missionaries took a leading part in the introduction of economic crops and in the transformation of the indigenous economy. Cotton and the sweet potato were on Rarotonga before 1831: Buzacott introduced arrowroot, tapioca, rice and coffee, and also a weaver for cotton cloth. The cultivation of yams, bananas, pumpkins, pineapples and oranges, and the rearing of pigs and poultry were encouraged. Rum was introduced to Rarotonga in 1845, and methods of fermenting oranges, pineapples and bananas were known there by 1851. We have no details of the economic transformation at Aitutaki, but it presumably closely followed that at Rarotonga.

With the conclusion of the initial missionary phase and the economic development of the islands, and with increasing imperial interest in the Pacific, the political status of the Cook Islands required definition. A British Protectorate was therefore declared over Rarotonga, Aitutaki, Mangaia, Mauke, Mitiaro and Manuae on 22 September 1888 (Gilson, 1955). Administration was transferred to New Zealand in 1901. The main economic significance of the islands, linked by schooners, was as a source of copra and other coconut products, but the trade proved a highly variable one (Figure 8), being greatly affected by market fluctuations. After the initial missionary intervention, however, the second major event in the recent history of Aitutaki was the Second World War. When it began the island had a population of about 2000. In 1942 a party of 900 U.S. Marines, including 400 negroes, was established there, and remained until 1944 (K.M. Johnston, 1967). The present airstrip was built on the Ootu Peninsula. After the war a Solent flying boat service was operated by Tasman Empire Airways Ltd to Samoa, Tonga, Fiji and Auckland, and by UTA to New Caledonia and Tahiti. The landing area was in the southeast lagoon, with terminal facilities on Akaiami island, linked by launch with a mainland jetty at Tautu. This service was discontinued in 1960, but New Zealand military planes maintain a service from New Zealand via Rarotonga, using the Ootu landing facility. Marine communications were also improved during the war. The reef entrance at Arutanga was dredged and a stone jetty constructed. The jetty has now disintegrated, and the channel, 1.5 km long, carries less than 2 m water. No regular shipping service serves Aitutaki. Matson Line vessels callat Rarotonga, where a new commercial jet airfield has now been constructed. The increased accessibility and development of tourism which will result from this development will certainly lead to major changes in all aspects of life both on Rarotonga itself and on islands accessible from it, including Aitutaki.

It will be apparent that, in spite of the relatively short history of European contact, native life has been subject to major changes since the first missionaries arrived. Active anthropological and ethnological research, other than the often anecdotal records of the missionaries, did not begin until the 1920s: most of the studies, under the influence of Sir Peter Buck, concentrated on artefacts and material culture. In the southern Cooks, studies were made of Aitutaki (Buck, 1927) and Mangaia (Buck, 1934), and in the northern Cooks of Tongareva (Buck, 1932a), Manihiki and Rakahanga (Buck, 1932b), and Pukapuka (Macgregor, 1935; Beaglehole and Beaglehole, 1938). Summaries of the Cook Islands were proved by Buck (1944, 1945). Missionary accounts of Aitutaki traditions were supplemented by Low (1934, 1935).

In spite of these accounts, little is known of the economy and human geography of Aitutaki in pre-contact times. It is reported that villages were originally located at inland sites,

on hills, and only moved down to the coast under the influence of missionaries (Beaglehole, 1957, p.6). With the long history of Polynesian occupation, the size of the population in 1830, and the limited land area, it is clear that the landscape of Aitutaki must have been substantially influenced by man before the European discoveries. Population numbers provide a crude but effective index of the subsequent course of human activity. Table 5, based on McArthur (1968), gives census and pre-census population figures for Rarotonga and Aitutaki since 1821. The fall in numbers during the early years of missionary activity on both islands has already been noted. At the census in 1966 the population of Rarotonga was 9971, and of Aitutaki 2579. In the case of Rarotonga the total represents a density of approximately 780 per cultivated square mile, or 500 per mile of coast; in the case of Aitutaki, of 430 per cultivated square mile and 220 per mile of coast. Densely populated islands in the western Pacific, such as the Gilbert and Ellice Islands, the Carolines and Marshalls, have overall population densities of 160-180 per square mile. Largely because of migration the Aitutaki population has been stable over the last decade, whereas that of Rarotonga has increased since 1956 by over 50 per cent; that of atolls on the northern Cooks and of islands such as Mauke has decreased sharply (Curson, 1972). Concurrent changes in agriculture, with increasing emphasis on cash crops (citrus fruits, vegetables, tomatoes), have been treated in detail for Aitutaki by K.M. Johnston (1967).

The scale and intensity of these changes in the recent past must be remembered throughout the subsequent discussion of the vegetation and flora of Aitutaki, and of other aspects of the ecology of the Cook Islands. Remote and little studied as these islands are, they are in no sense unaffected by the work of man.

SCIENTIFIC STUDIES IN THE SOUTHERN COOKS

Though important observations were made by Cook and his companions, particularly on Palmerston Island in 1777 (Cook, 1967 edition, 92-96, 849-857, 1011-1012), little scientific work was carried out in any part of the group until more than a century had passed. Charles Darwin passed through the southern Cooks on the Beagle in 1835, but did not land. He sighted Aitutaki, and in a passage in his Diary (Darwin, 1933, 358-359), omitted in the published version in Journal and Researches (1839), notes:

> "December 3rd. After several days of light winds, we passed near to the island Whytootacke. We here saw a union of the two prevailing kinds of structure united. A hilly irregular mass was surrounded by a well defined circle of reefs, which in great part have been converted into low narrow strips of land, which as Cook calls them are half drowned, consisting merely of sand and Corall rocks heaped up on the dead

> part of a former reef. The inhabitants made a smoke to attract our attention."

Darwin was at this time drafting the first full statement of his coral reef theory, in which he mentions Aitutaki and speculates in which of his classes of reefs it should be placed (Darwin, 1962, p.7). In his Structure and Distribution of Coral Reefs (1842, pp.154-155), he discussed the matter more fully:

> "Aitutaki was partially surveyed by the Beagle, (see map accompanying Voyages of Adventure and Beagle); the land is hilly, sloping gently to the beach; the highest point is 360 feet; on the southern side the reef projects five miles from the land: off this point the Beagle found no bottom with 270 fathoms: the reef is surmounted by many low coral-islets. Although within the reef the water is exceedingly shallow, not being more than a few feet deep, as I am informed by the Rev. J. Williams; nevertheless, from the great extension of this reef into a profoundly deep ocean, this island probably belongs, on the principle lately adverted to, to the barrier class, and I have coloured it pale blue; although with much hesitation."

After Darwin's brief and distant observations, the only general scientific studies in the nineteenth century were the episodic and anecdotal notes made by the missionary Wyatt Gill. His "Notes on natural history" (Gill, 1877, pp.273-320) and "Zoological and botanical notes" (Gill, 1885, pp.125-210; also Gill, 1888) are, however, of little value. Otherwise the nineteenth century scientific literature is limited to an important paper on the land Mollusca by Garrett (1881), a description of two hydrozoans from Rarotonga by Quelch (1885), and a brief note on the marine algae of Mangaia by Dickie (1875).

Early in the present century, Marshall initiated a long series of studies of the volcanic rocks and elevated limestones of the southern Cooks, particularly of Rarotonga, Atiu and Mangaia (Marshall, 1908, 1909, 1912a, 1912b, 1927, 1930; Chubb, 1927). The reefs of Aitutaki were briefly visited by Alexander Agassiz (1900, 1903) in November 1899, though his observations proved to be characteristically unreliable. Crossland (1928c) and W.M. Davis (1928, pp.406-408) briefly described the reefs of Rarotonga. Crossland in particular published a long series of papers on Tahiti, several of which contain comparative comments on the reefs of Rarotonga (Crossland, 1927, 1928a, 1928b, 1928c, 1929, 1931a, 1931b, 1935, 1939). Agassiz, Davis and Crossland were all concerned with the geological relations of the reefs and their historical implications, rather than with reef biota and ecology: indeed no work seems to have been carried out on littoral marine ecology in the Cook Islands until recent years. Rather more work has been carried out on terrestrial

ecology. Floristic studies of Rarotonga were published by Luerssen (1873), Cheeseman (1903) and Wilder (1930, 1931), though no collections have been reported from Aitutaki or other islands in the southern Cooks. Taxonomic papers on the vascular flora have been published by Copeland (1931), Martelli (1932), Skottsberg (1933), Whitney (1937) and St John (1952), all based on Rarotonga material. Campbell (1932) has listed native names of Rarotongan plants. On other islands in the group, Hemsley (1884) named a few species collected by J.T. Arundel on Palmerston and Suvarov, and Cranwell (1933) gave a list of plants and Linton (1933) contributed brief notes on the vegetation of Manihiki. Lichens of Rarotonga are described by Jatta (1903-5) and Sbarbaro (1939) and Fungi by Karling (1968). The early literature on land animals is remarkably sparse, and with the exception of Garrett's work on land Mollusca and of Christian's (1920) paper on the birds of Mangaia is concerned with anthropods, especially mosquitoes of medical importance. Most of the studies are based on Rarotonga material, with some specimens from the northern Cooks, especially from Manihiki (Marks, 1951; Krauss, 1961; Taylor, 1967; Lieftinck, 1953; Laird, 1956; Tamashiro, 1964; Marples, 1960). The papers by Krauss (1961) and Laird (1956a) deal specifically with collections from Aitutaki. Solem (1972) has also recently published on a new land snail from Rarotonga.

The most important scientific studies in the Cook Islands in recent years have been those of the New Zealand Oceanographic Institute (Manihiki Expedition, 1960; Eclipse Expedition, 1965) and the Cook Bicentenary Expedition of 1969. The Eclipse Expedition carried out much bathymetric work throughout the group and established both regional and local data on submarine topography (Robertson and Kibblewhite, 1966; Summerhayes, 1967, 1969; Summerhayes and Kibblewhite, 1966, 1967, 1968, 1969). In addition E. Dawson and Summerhayes studied marine communities and bottom sediments at Aitutaki and Manuae (Summerhayes, 1971). Extensive collections were made during this expedition and are still being studied; the echinoderms have been listed by McKnight (1972). The results of the Manihiki expedition have been collected by Bullivant and McCann (1974).

The Cook Bicentenary Expedition of 1969 was a joint New Zealand and United Kingdom project working in the Cook Islands and Tonga (Fraser, 1971). The United Kingdom Marine Biology Party (Project 9) consisted of D.R. Stoddart, P.E. Gibbs, and H.G. Vevers. Its main project at Aitutaki concerned shallow water marine communities, geomorphology and sediments in reef, lagoon and beach environments, but it also extended to certain aspects of terrestrial ecology, notably the vegetation. A short supplementary study was also made of similar habitats at Ngatangiia Harbour, Rarotonga, with a subsequent reconnaissance of reefs and islands at Nuku'alofa, Tonga. The party worked on Rarotonga between 21 and 27 August 1969, and on Aitutaki between 27 August and 26 September 1969. A preliminary account of the

work was given by Gibbs, Stoddart and Vevers (1971). Gibbs (1972) has published on the polychaete annelids and Stoddart and Pillai (1973) on the corals collected. An account of the Rarotonga reef islands is given by Stoddart (1973), with a list of vascular plants by F.R. Fosberg. Ferns from these islands are included in Brownlie and Philipson's (1971) list of Cook Islands Pteridophyta. In addition to the papers in the present Bulletin, a more detailed account of the corals is in course of publication (Pillai and Stoddart, in press). A preliminary account of the terrestrial invertebrates of Rarotonga, Aitutaki and other islands has been given by Wise (1971).

Some of this work supplements the extensive studies of land geology carried out in August and September 1957 throughout the Group by B.L. Wood (1967; Wood and Hay, 1970). Work during the Cook Expedition on gravity and magnetics (Lumb and Carrington, 1971) also supplemented important recent geophysical studies: on magnetics by Woodward and Hochstein (1970) and Woodward and Reilly (1970), on gravity by Robertson (1970), on paleomagnetism on Rarotonga by Tarling (1967), and on seismic refraction studies by Hochstein (1967).

The soils of the southern Cooks have been studied by Grange and Fox (1953) and Stout (1971), and agriculture and land use by W.B. Johnston (1951, 1953a, 1953b, 1955, 1959), K.M. Johnston (1967), and Bassett and Thomson (1968).

Since the Cook Bicentenary Expedition the Group has been visited by the Westward Expedition from Honolulu, which spent 7-8 March 1971 at Aitutaki and 6-11 March at Rarotonga, making general collections and searching for the Crown-of-Thorns Starfish Acanthaster planci. Results of this survey, with information on the reefs, are presented by Devaney (1973) and Devaney and Randall (1973).

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Table 5. Population of Rarotonga and Aitutaki

Year	Rarotonga	Aitutaki
1821		ca 2000
1839		ca 2000
1845	3000	2000
1854-5	2374	1750
1871-2	1936	1450
1881	2000	1146
1902	2060	1170
1906*	2334	1154
1911*	2620	1221
1916*	2853	1277
1921*	3287	1343
1926*	3731	1417
1936*	4818	1707
1945*	5307	2332
1951*	5802	2358
1956	6417	2590
1961	8676	2582
1966*	9971	2579
1971*	11388	2854

*census return

Source: McArthur, 1968; New Zealand Official Yearbook (annual)

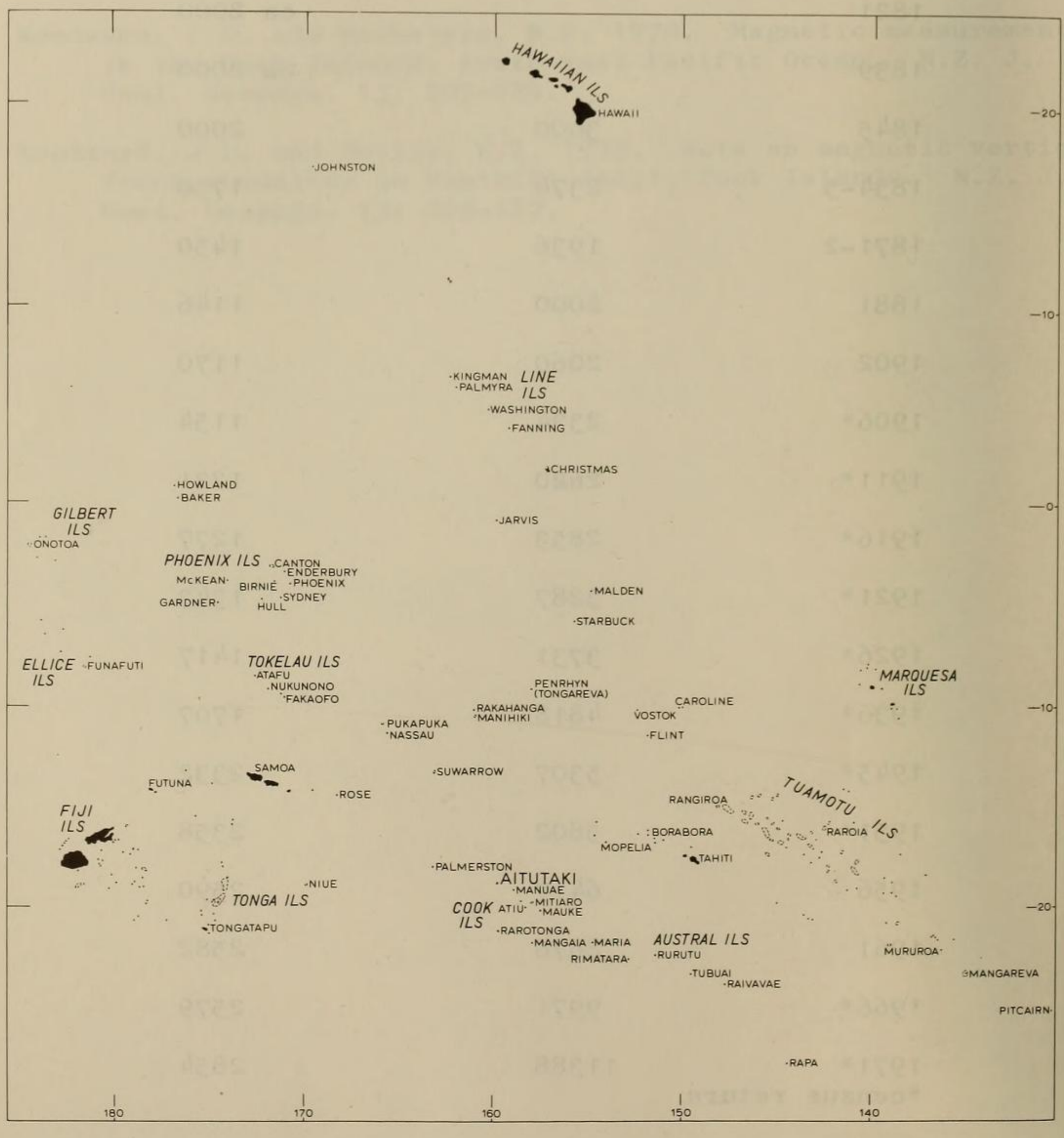


Figure 1. Location of Aitutaki in the central Pacific

Figure 2. Bathymetry of the southern Cook Islands, after Summerhayes (1967)

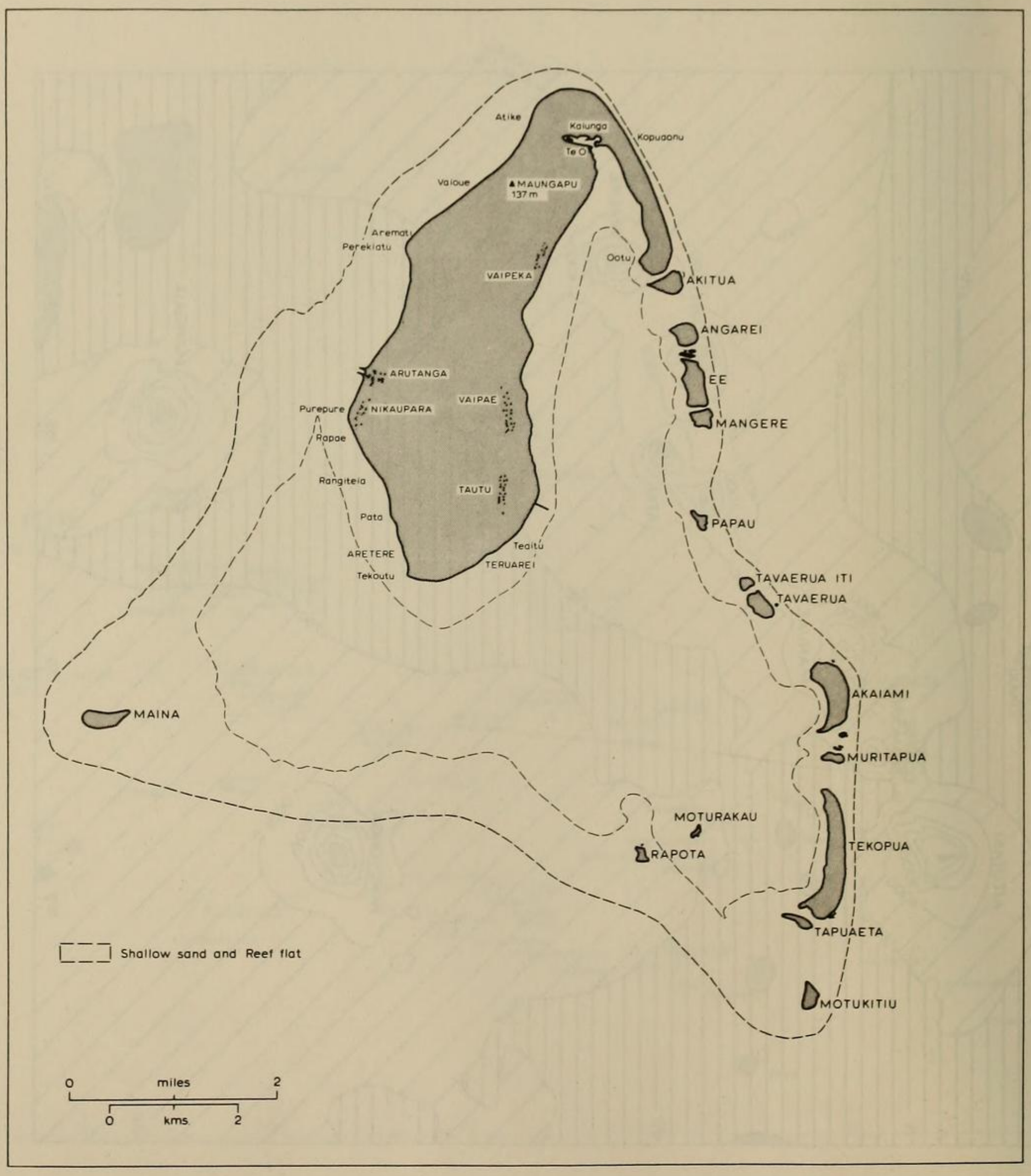


Figure 3. Aitutaki

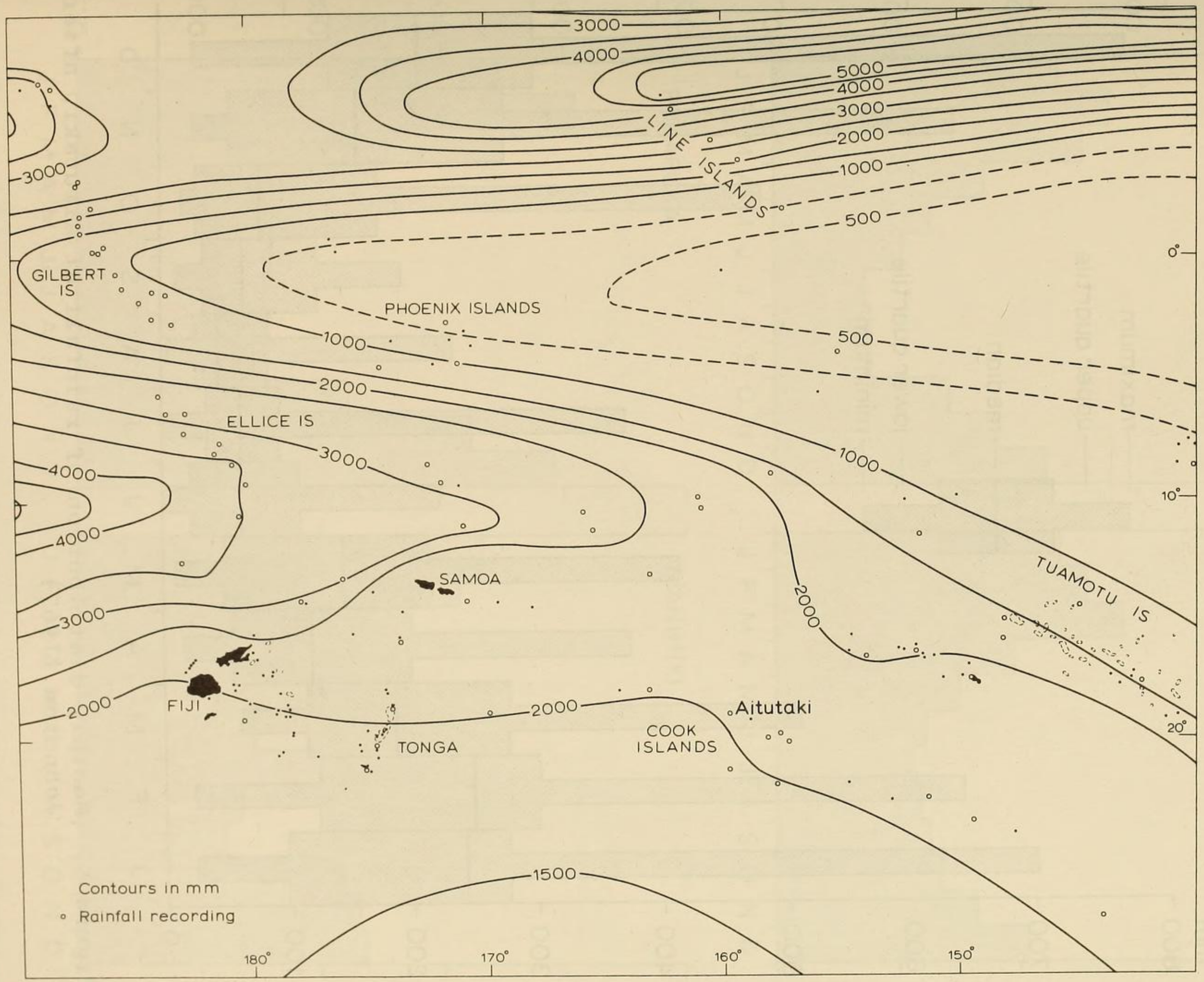


Figure 4. Rainfall distribution in the central Pacific, based on Taylor (1973)

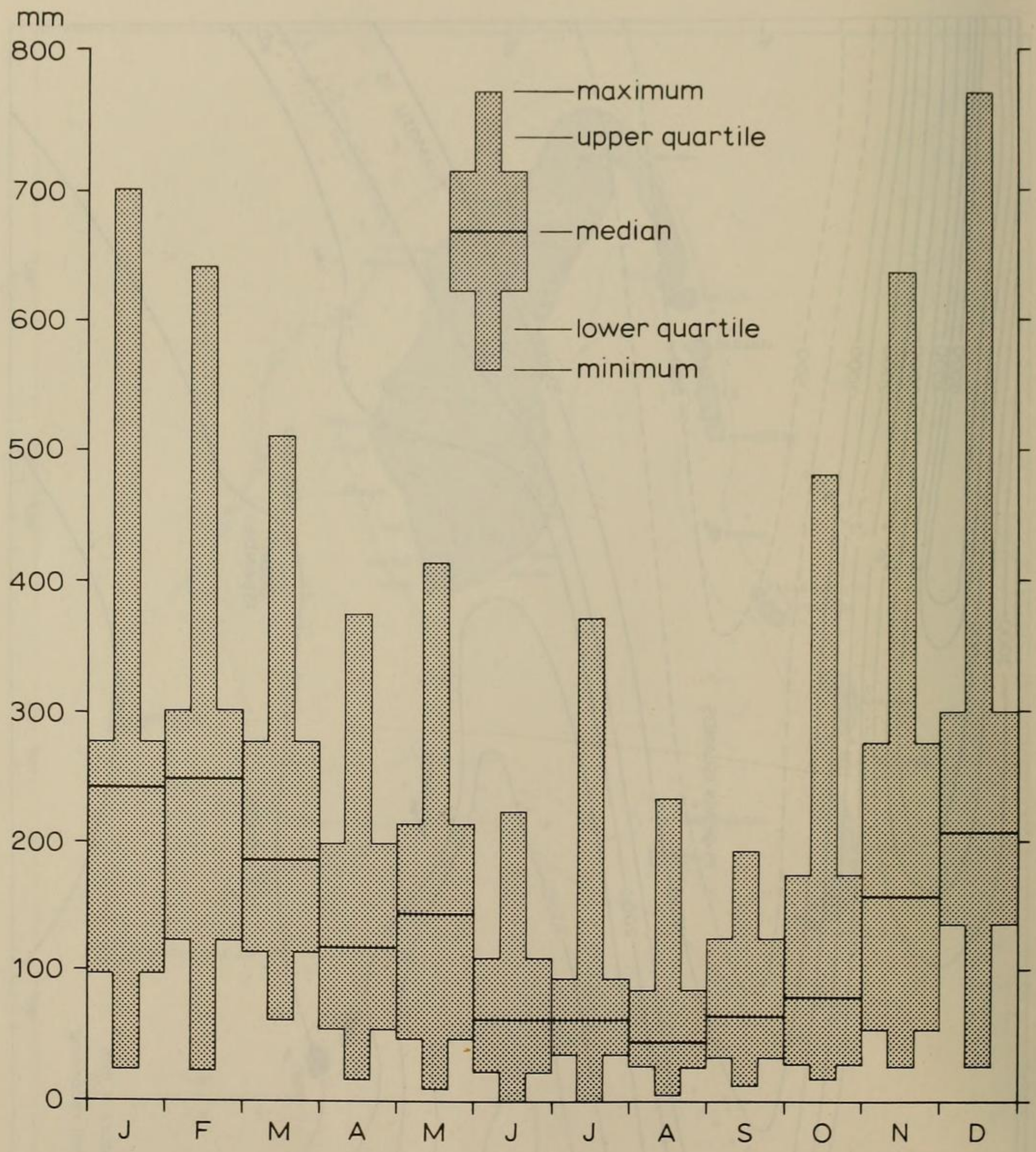


Figure 5. Monthly distribution of rainfall at Aitutaki, after Johnston (1967)

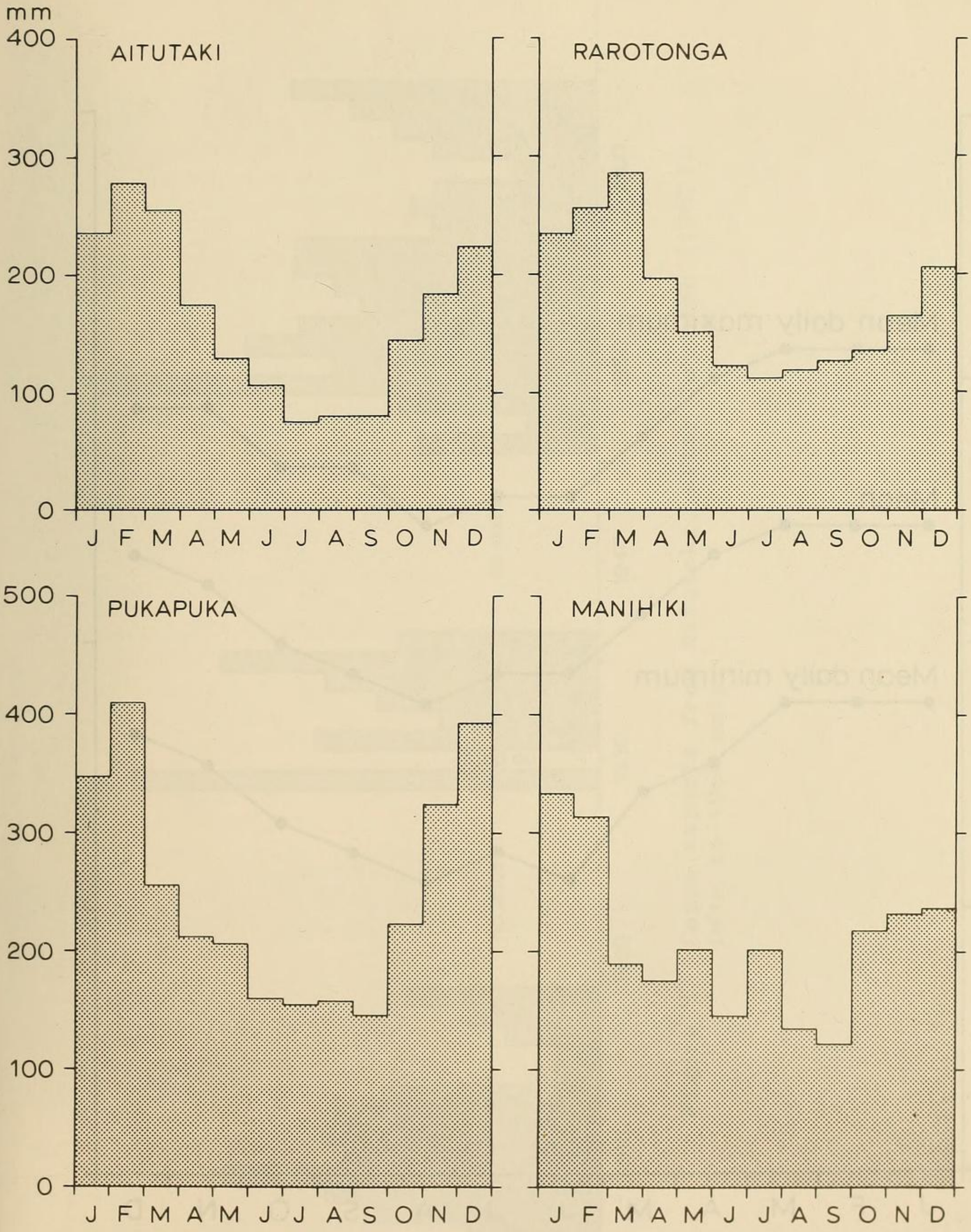


Figure 6. Monthly distribution of rainfall at Aitutaki, Rarotonga, Pukapuka and Manihiki

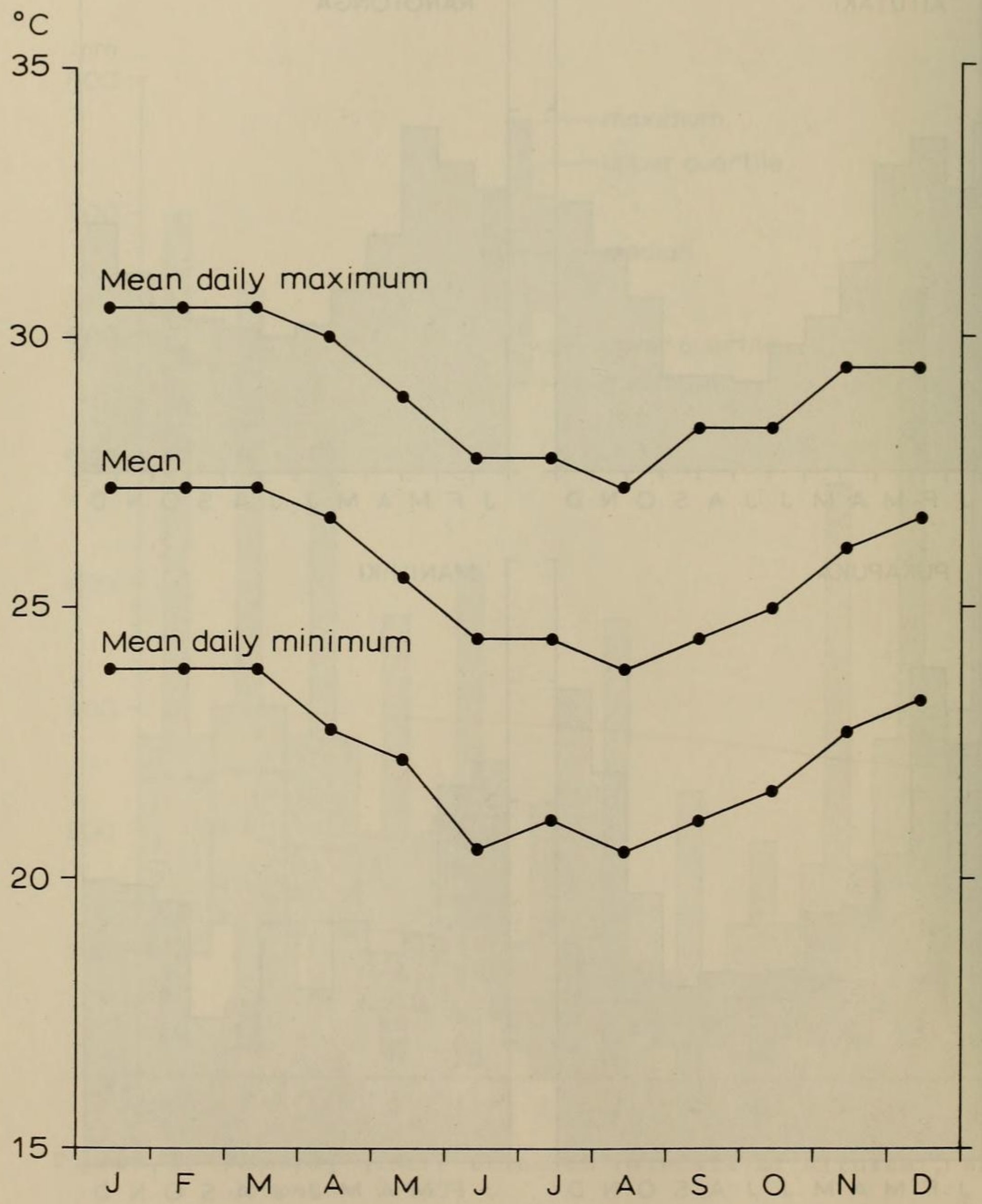


Figure 7. Monthly distribution of temperature at Aitutaki, after Johnston (1967)

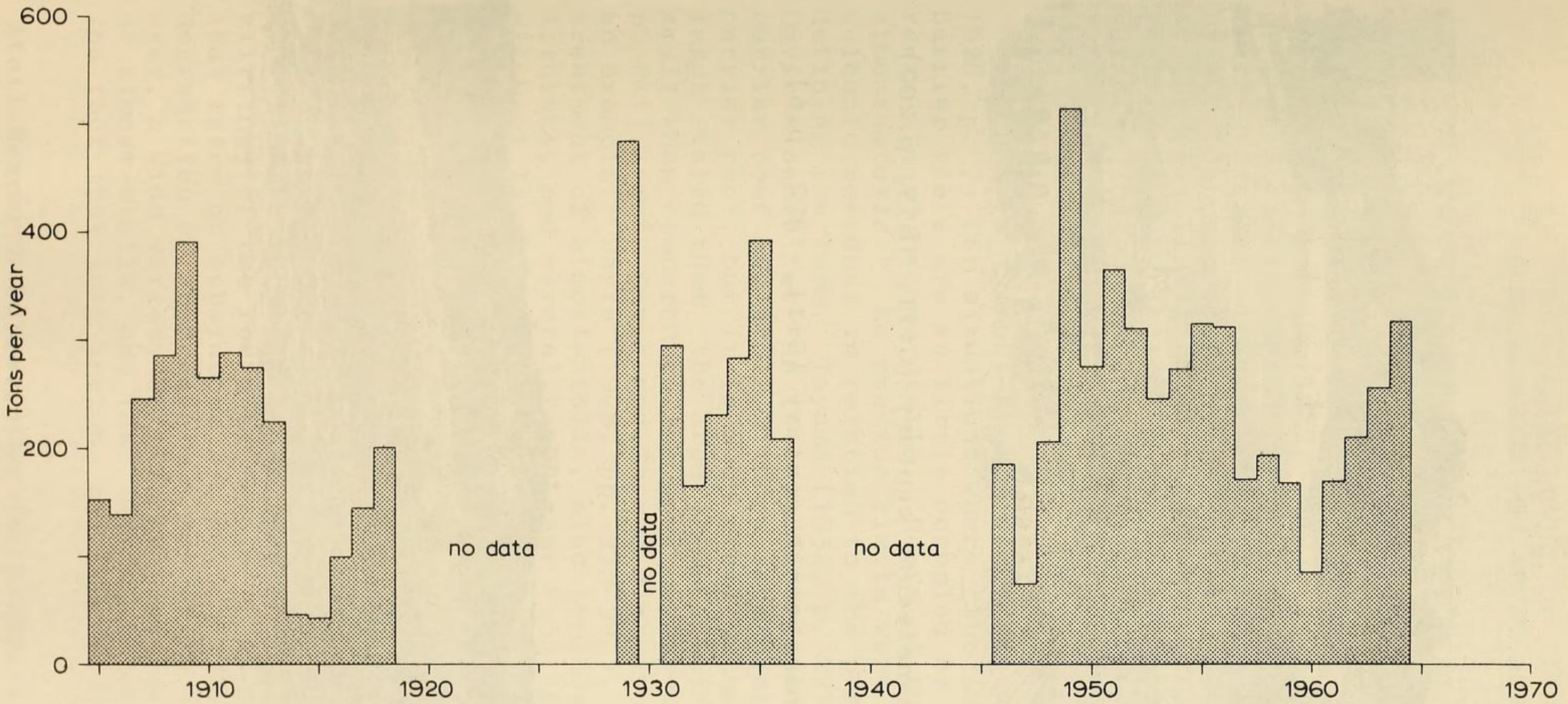
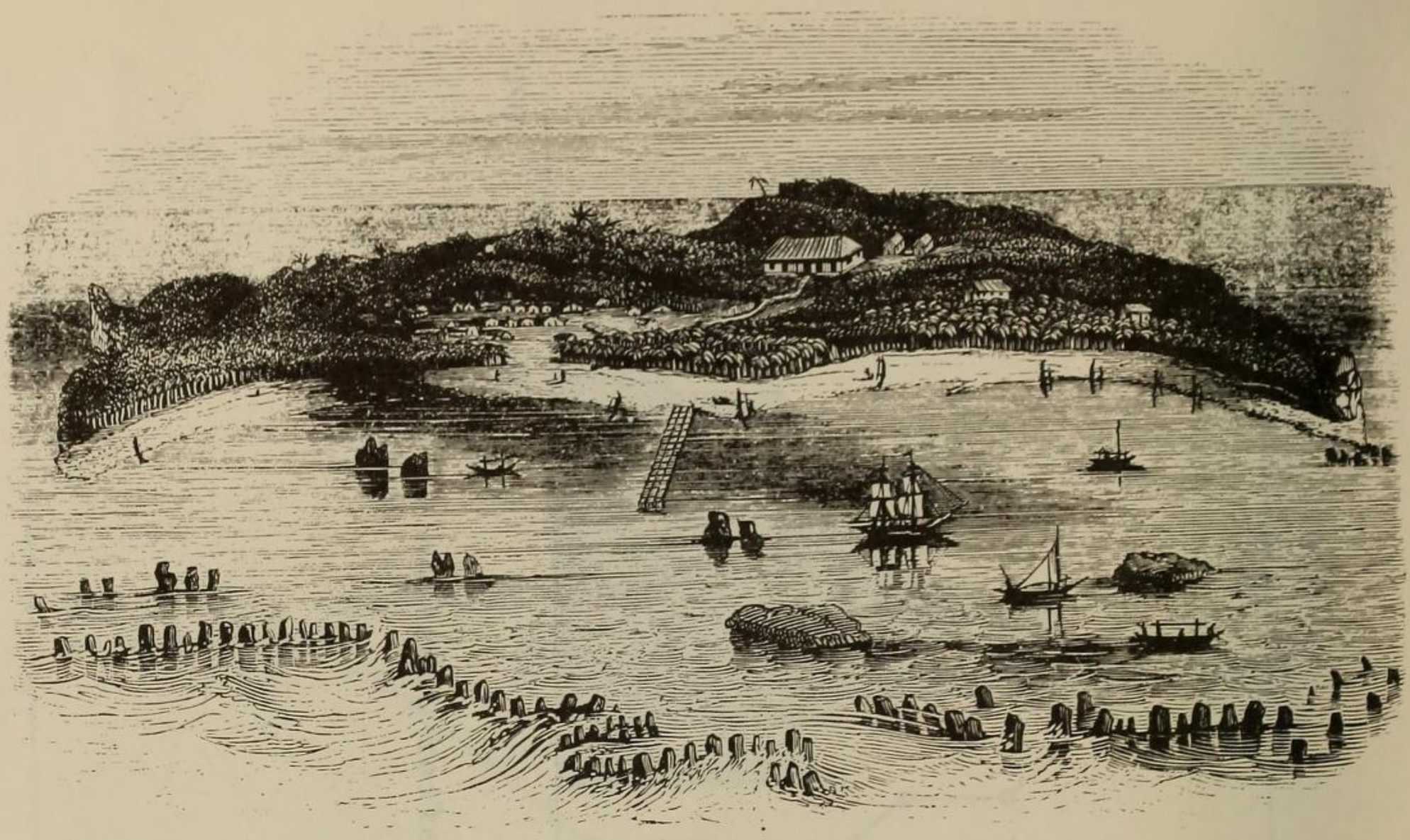
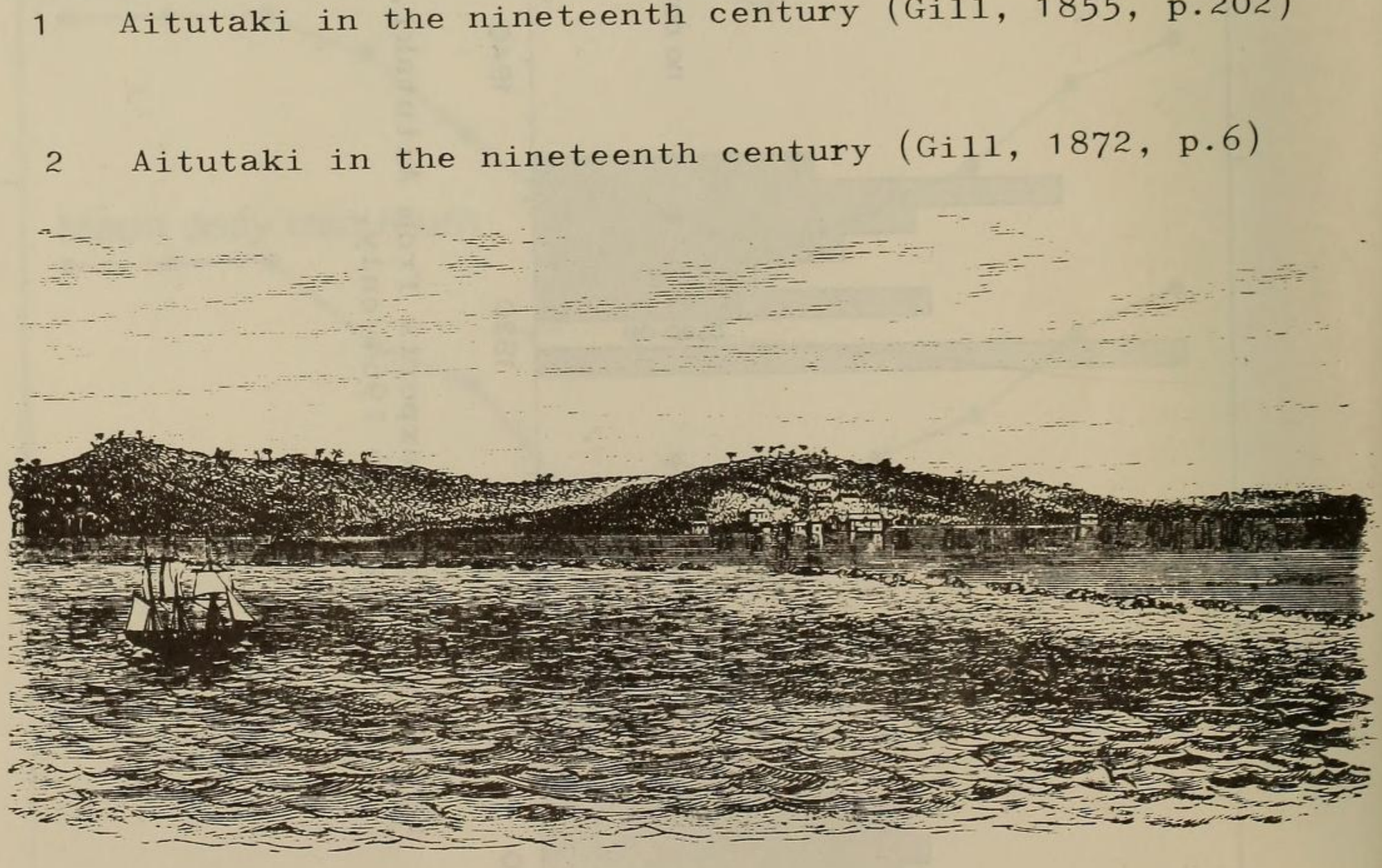


Figure 8. Copra exports from Aitutaki, after Johnston (1967). Date to 1964 only.



1 Aitutaki in the nineteenth century (Gill, 1855, p.202)



2 Aitutaki in the nineteenth century (Gill, 1872, p.6)