ATOLL RESEARCH BULLETIN

No. 116

Reef studies at Addu Atoll, Maldive Islands

Preliminary results of an expedition to Addu Atoll in 1964

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Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences--National Research Council

Washington, D. C.

March 31, 1966

CONTENTS

Illustrations

Following page

Following page

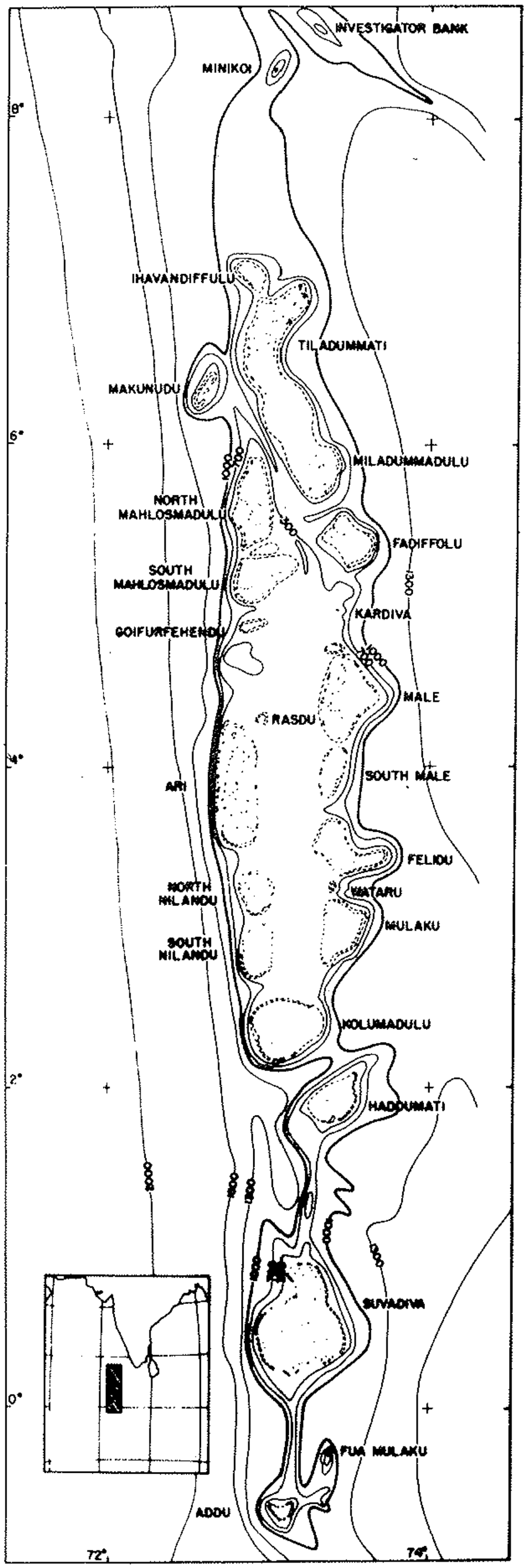

Fig. 1. The Maldive Islands, after Farquharson (1936).

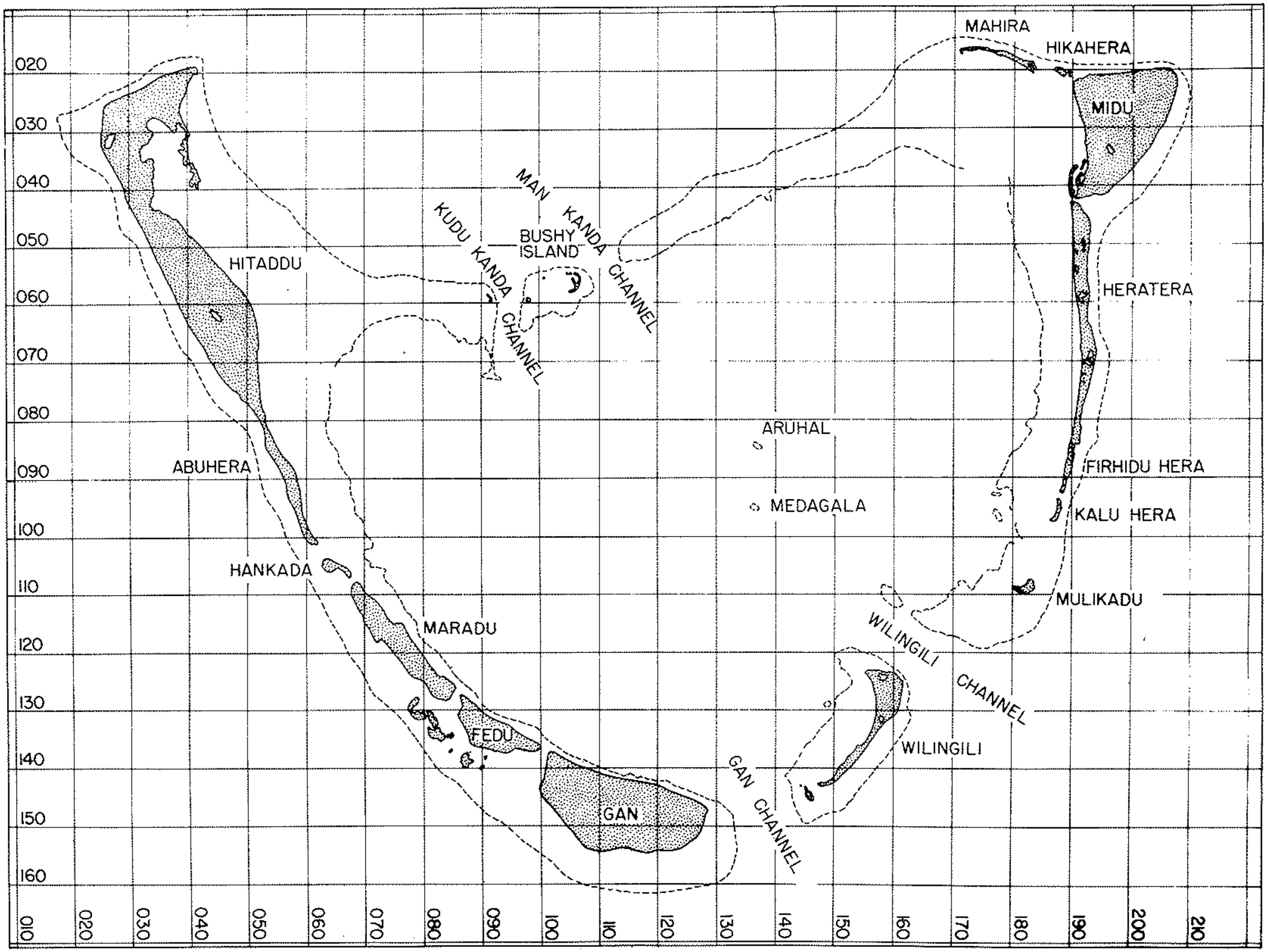

Fig. 2. Addu Atoll, based on Admiralty Chart No. 2067; 1 kilometre location grid overlay.

I. INTRODUCTION

The Maldive Islands

The Maldive Islands proper (Fig. 1), between Ihavandiffulu and Haddumati Atolls, form a double chain of atolls, rising from a submarine plateau or ridge, 150-210 fathoms deep, 350 nautical miles long, and up to 70 nautical miles wide. The atolls are separated by channels which are deeper than the general plateau surface, and at the edge of the plateau the sea floor falls steeply to between 1000 and 1400 fathoms on the east side, and to 1300-2000 fathoms on the west side. The main features of the bathymetry were first recognized by Gardiner (1902, 1903-6), and subsequently confirmed by Farquharson (1936).

Both to north and south of the main plateau the bottom topography is less clear. Minikoi, in the north, is linked to the main Maldive plateau by a shelf at 700-900 fathoms. In the southern Maldives, the plateau may be interrupted between Haddumati and Suvadiva Atolls at about 900 fathoms. Between Suvadiva and Addu Atolls the plateau does not seem to exist: the minimum sounding midway between the two atolls is 845 fathoms, rising to 654 fathoms 12 nautical miles north of Addu, and most of the soundings range from 1000 to 1200 fathoms. The existence of a deep ridge seems clear, however, for on either side of a line joining the two atolls, at depths of about 1000 fathoms, the floor falls to depths of 1300-1500 fathoms on the east side, and to 1400-2000 fathoms on the west. The relationship of Fua Mulaku Island, between Addu and Suvadiva, to this ridge is unknown.

South of Addu, between the Maldives and the Chagos Archipelago, soundings are few. Immediately south of Addu, depths of 1200 fathoms are recorded, increasing to more than 1800 fathoms at 3°S. This suggests that the Mid-Ocean Ridge, extending northwards to the Chagos at about 67°E longitude, and swinging northwestwards from there towards the Gulf of Aden, thus forming the Carlsberg Ridge with depths of about 1000 fathoms, does not continue uninterruptedly into the Maldives (Heezen 1962; Heezen and Ewing 1963, 396; Heezen and Tharp 1964). Recent work on the structure of the Indian Ocean has concentrated on the Carlsberg Ridge, and does not make its relationship with the Maldives ridge clear. At the 2000 fathom level the Maldive Ridge is continuous with the Carlsberg and Mid-Ocean Ridges: to the east of the Maldives Ridge the ocean floor lies at more than 2000 fathoms, between the Maldives and Carlsberg Ridges it averages 2400 fathoms (reaching 2600), and s.w. of the Carlsberg Ridge the floor averages 2700 fathoms and in places reaches more than 2800 fathoms. Farquharson (1936) uses the 1300 fathom isobath to delimit the Maldives Ridge, thus including Minikoi and Addu; most of the Maldives atolls are connected at the 300 fathom level.

Most observations on the structure of the Maldives have been speculative. Darwin (1842, 110), followed by Davis (1928, 527-532), suggested that subsidence of an island like New Caledonia, with reef upgrowth, could form such a double chain of atolls. Gardiner (1902, 1903) believed that the main Maldives plateau was formed by current erosion, and that the atolls themselves were subsequently formed by the growth of deep- and later shoal-water organisms on this formation. During the John Murray Expedition, Glennie (1936) made gravity readings at several stations, including Midu Island, Addu Atoll. These showed a strong negative anomaly along the whole Maldives ridge, which Glennie interpreted as indicating a thickness of several thousand feet of reef limestone. Magnetic anomaly studies carried out by H.M.S. Owen in 1962 demonstrated small field changes in the Maldives and Laccadives, which were interpreted as indicating the presence of a continental basement (Gaskell and others, unpublished data). In contrast to the mid-ocean ridge characteristics of the Carlsberg Ridge (high heat flow, seismicity, vulcanicity (Hill and others 1964)), the Maldives and Laccadives area is notably aseismic.

Reef studies in the Maldive Islands

Several large expeditions have visited the Maldive Islands reefs, yet paradoxically they remain one of the least known groups of atolls. Unlike Pacific atolls, the Maldive Islands have been known to the west since medieval times. Ibn Battuta visited the islands in 1327 and gave the first recognisable account of Maldivian life (Ibn Battuta 1829, 1854-8, 1890, 1929). In 1602 François Pyrard de Laval was shipwrecked in the Maldives, lived there for five years, and wrote a spirited account of topography, vegetation, and native life (Pyrard 1887-1890). At this time Portuguese influence in the islands was great, since the Maldives lay across the shipping route from Europe to the Far East. Scientific investigation properly began in the Maldives with Commander R. Moresby's hydrographic survey for the East India Company in the 1830s, a survey which for most atolls forms the basis of current charts. Moresby's remarkable survey of so large an area resulted in charts of great elegance, but his vessel carried no naturalist, and he does not appear to have concerned himself with reef physiography or fauna. Apart from his own brief memoir (Moresby 1835), and some botanical and general data by other officers (Christopher 1841, Horsburgh 1832, Owen 1832, Young and Christopher 1844), the only published conclusions on the reefs of the Maldives from this survey are those of Darwin (1842), based on communication with Moresby himself. Moresby's two nautical memoirs, on the islands of the Indian Ocean, and on the Maldives, remain in manuscript.

The major advance in scientific knowledge of the Maldive Islands dates from the expedition led by J. Stanley Gardiner of Cambridge University to the Maldives and Laccadives in 1899-1900. Gardiner's work was mainly zoological, and his collections, based on extended stays at Minikoi and South Male Atolls and brief excursions through the whole group, were published in two large quarto volumes and a series of papers. Gardiner himself contributed studies of reef and island physiography and speculated on the coral reef problem and the origin of the Maldives (Gardiner 1900a, 1900b, 1901b, 1902, 1903a, 1903b, 1906d, 1930, 1931), as well as working up some groups of scleractinian corals (Gardiner 1906b, 1906c, 1909, 1929). In spite of his reef experience in the Western Pacific, however, Gardiner was no physiographer, and many of his ideas on the Recent history and development of the reefs and islands must be discounted. His major contribution lies in the systematic lists of land and marine fauna (Gardiner 1903-6), and in his botanical collections (land flora: Willis and Gardiner 1903; marine flora: Foslie 1903, Barton 1903), which until recently remained unique. It is difficult to obtain from Gardiner's work any precise idea of the structure of modern Maldivian reefs, or of the distribution and relative importance of corals and other reef organisms. A number of groups, including the genus Acropora, also remained unmonographed. Without Gardiner's work, however, our knowledge of the Maldives would be sparse indeed. Gardiner was followed by Alexander Agassiz, who spent two months in 1901-2 cruising through the whole archipelago, making a large number of shipboard observations and deductions (Agassiz 1902a, 1903). Many of Agassiz's plates are of interest, but in general his work is of small value compared with that of Gardiner.

The major event of the inter-war period was the John Murray Expedition 1933-34, led by R. B. Seymour Sewell. Sewell, who had already published on the reefs of the Indian Ocean (Sewell 1932, 1935), carried out gravity surveys and deep soundings in the Maldives (Glennie 1936, Farquharson 1936) and published physiographic descriptions of Addu and Goifurfehendu Atolls (Sewell 1936a, 1936b). Like Gardiner, Sewell was a zoologist, not a marine geologist, and his chief work was on the Copepoda. His physiographic work, while of great value, contains many untenable speculations. Taken together, however, Gardiner's and Sewell's expeditions provide the greater part of our knowledge of the atolls and their reefs. Subsequently, Gardiner led the Percy Sladen Trust Expedition to the Indian Ocean in 1905, which, while not directly concerned with the Maldive Islands, led to Matthai's studies of the Indian Ocean corals (Matthai 1914, 1924, 1928), including many of Gardiner's type specimens from the Maldives. The reports of the Percy Sladen Expedition contain much material relevant to the study of the Maldive Islands (Gardiner 1907-1936).

The pre-1945 literature is largely completed by reference to a series of reports by H. C. P. Bell (1882, 1921, 1940) which, though largely historical, include much topographic data and information on flora and native names of plants. Gray (1878) compiled a vocabulary. A few expeditions touched at the Maldives, including the Deutschen Tiefsee Expedition (Chun 1905) and the S.M.S. Planet (Lübbert 1909). A full bibliography is given by Sachet and Fosberg (1955), and also in this paper.

The limitations of these data became apparent with the increasing number of Pacific reef studies after 1945. Emphasis in these on reef distribution, ecology and sedimentology, rather than on systematics, gave reef studies new impetus. When Wiens summarised postwar work in 1962, therefore, the reefs of the Indian Ocean received virtually no mention, although the Maldives include some of the largest atolls on earth, and many have unique characteristics unknown in Pacific and Caribbean atolls. The need for further studies of Maldivian reefs became more apparent, but for political reasons few scientists were able to visit the area. The Xarifa carried out systematic studies in 1957-8, under Hans Hass, which are in the course of publication (Hass 1961, 1965; Eibl-Eibesfeldt 1964); Hass's own contributions on marine geology (Hass 1962a, 1962b, 1963) are largely speculative. Fosberg (1956) briefly visited Male in 1956, and published a revised and augmented version of Trimen's (1896) and Willis and Gardiner's (1903) flora. Deraniyagala (1956) published the results of ecological collecting in 1932, and Kohn (1964a) has published molluscan and general notes following visits to the southern atolls in 1957. Both the Te Vega and the Anton Bruun have visited the Maldives in connection with the International Indian Ocean Expedition, but results have not yet been published, and in general political conditions made extensive work in the Maldives during this Expedition impossible.

Present expedition

An expedition was, therefore, first planned in 1962, to visit the Maldive Islands and to carry out on a small scale reef studies similar to those carried out in the Pacific since 1945, to provide data on topography, sedimentology, marine geology, and ecology of the reefs, reef flats, islands, and other environments. It was hoped to work at either Male or Kolumadulu Atolls, but this proved politically impossible, and finally permission was given for a small party to work at the Royal Air Force Staging Post at Gan Island, Addu Atoll, southern Maldives, in mid-1964. For political reasons work on islands other than Gan and part of Hitaddu was impossible, but traversing and sampling the lagoon and its reefs was allowed. The expedition thus came to concentrate on reef and island environments around Gan and, to a lesser extent, Hitaddu Islands.

The expedition was led by Dr. D. R. Stoddart, Department of Geography, Cambridge, who concentrated on topography, sedimentology and marine geology of reefs, reef flats and island beaches. Dr. P. Spencer Davies, Department of Zoology, Glasgow University, collected marine invertebrates and was in charge of aqualung work on the reefs. Mr. D. C. Sigee, Department of Botany, Cambridge University, collected land plants and marine algae, and Mr. A. C. Keith of the Department of Geography, Cambridge University, assisted with the surveying and sediment sampling programmes. The detailed reef transects were carried out jointly by all members under the direction of Dr. Davies. The party arrived at Gan on 1 July 1964, and remained until September 10. The collections and other data collected by the expedition will take some years to work out, and this report is hence of a preliminary nature. The main collections were sent for identification as follows: land plants, Dr. F. R. Fosberg; marine algae, Mr. R. Tsuda; stony corals, Dr. J. W. Wells.

Previous work at Addu Atoll

Being remote from the centre of Government in Male, Addu Atoll (Fig. 2) has been visited only briefly by most of the expeditions working in the Maldives. The first detailed examination of the atoll was made by Commander R. Moresby and Lieut. F. T. Powell in 1836, their small scale chart being published in 1839. Moresby's manuscript Nautical directions for the Maldive Islands (no date, c. 1837) contains an extended account of Addu (p. 39-46), reproduced here as Chapter VI. The first scientific account is that of J. Stanley Gardiner, who spent 11-15 April 1900 at Addu, making soundings, taking 14 dredge hauls in the lagoon, and collecting fauna and flora, chiefly at Midu and Maradu Islands. For Gardiner's description of Addu, with a sketch map, see Gardiner 1903a, 10; 1903b, 150-151; Willis and Gardiner 1901, 78-80; and other references cited in this report. Alexander Agassiz spent two days at Addu in January 1902, published brief notes on Midu, Wilingili and Gan Islands, and took issue with Gardiner on lagoon floor sedimentation (Agassiz 1903, 145-148). Subsequently H.C.P. Bell visited Addu in his third tour in the Maldives, spending 10-15 February 1922 at Gan and Hitaddu Islands, describing their historical remains (Bell 1940, 115-121).

During February-April 1923, Commander F. H. Daugleish, R.I.M.S. Investigator, carried out a survey of Addu Atoll at a scale of 1:18, 136, making approximately 18,000 soundings in the lagoon and the reef channels. Until the post-1945 work in the Marshall Islands this was the most detailed atoll chart in existence, but for military reasons it remained classified until 1964. The published chart of Addu remained that by Moresby, with some corrections, until the current Admiralty Chart No. 2067, based on Daugleish's but with a greatly reduced number of soundings, was published in 1957. Land topography on Daugleish's chart was sketchy, and in some cases had changed considerably since 1923, so that the Daugleish chart was republished in 1964, with land topography and outer reef detail from aerial photography of 1958 and 1960. With the establishment of the Gan Staging Post, a number of minor hydrographic surveys have been carried out to supplement Daugleish's chart.

Addu was visited by the John Murray Expedition 1933-34. Soundings (Farquharson 1936) and gravity profiles (Glennie 1936) were made at Addu, and Sewell (1936a) contributed a general account of the whole atoll. This for the first time described the reefs and reef-flats, added additional lagoon soundings to Moresby's and Gardiner's charts, and included notes on Midu, Heratera, and, more briefly, the other islands. There has been little opportunity for scientific work at Addu since Sewell's expedition. The ornithologist Phillips has recorded bats, amphibians and reptiles in the Maldives, including Gan (Phillips 1958a, 1958b, 1958c, 1958d, 1963; Phillips and Sims 1958a, 1958b). The conchologist Kohn, of the Yale Seychelles Expedition, spent a week at Addu in October 1957, visiting Gan, Hitaddu and Wilingili Islands, recording mollusca (Kohn 1964b). Hans Hass with the Xarifa Expedition visited Addu in early 1958 (Hass 1961, 34-63, 80-85; Eibl-Eibesfeldt 1964), and some systematic reports are being published (Scheer 1960a, Gerlach 1960, 1961).

Acknowledgments

For the opportunity to work at Addu Atoll we particularly wish to thank the Commonwealth Relations Office, London; the Ministry of Defence (Air), London (which also provided transportation to and from Gan for the four members of the party); and Wing Commander G. Moss, A.F.C., Royal Air Force, Gan, for his kindness in allowing us to work on the island, supplying us with quarters, and allowing us to use the facilities of the Officers' Mess. To many members of the Service and civilian personnel at Gan our debt is considerable, but we would like to thank especially Ft. Lt. D. Hunter and Mr. E. Denis of the Gan Sub-aqua Club for help in underwater work and for the use of the launch Victoria. The expedition was made possible by generous financial help from a variety of sources, much of which was sought at a very late stage. We wish to record our thanks to the following for help in this way: The Royal Society, the Goldsmiths' Company, Shell International Petroleum Limited, the Vaughan Lewis Fund of Cambridge University, the University of Glasgow, the Carnegie Trust for the Universities of Scotland, British Petroleum Company Limited, the Permutit Company Limited, Middlesex Education Committee, Glasgow Breweries Limited, and George Ballantine and Son Limited. We also thank the British Museum (Natural History) for the loan of collecting equipment, and the following organisations for supplying equipment at reduced rates: Rank Precision Industries Limited, Wallace Heaton Limited, Lillywhites Limited, Sangamo Weston Limited, Submarine Products Limited, and Kodak Limited.

We are most grateful to Rear Admiral E. G. Irving, Hydrographer, Royal Navy; Professor J. A. Steers; and Professor C. M. Yonge for their support at various stages; to Dr. F. R. Fosberg and Dr. M.-H. Sachet for their interest and work on the botanical side; and to the various specialists who are working on the collections.

Present report

This report can only be preliminary, since most of the collections have yet to be worked up. It is intended only as an outline of the work which took place, and to serve as a framework for future reports. The conclusions given here on the geomorphology and vegetation of Addu Atoll are, therefore, provisional. The report provides a general account of Addu Atoll, with a more detailed consideration of some aspects of its geomorphology and its vegetation. Work on the zoology of the reefs will be published at a later date.

II. CLIMATE AND MARINE ENVIRONMENT

Climate

This section briefly summarises data on climate and marine environment of Addu Atoll. Gardiner (1903, 20-21, 25) commented on the climate as observed in 1900, and stressed the variability of winds, Addu lying too far south for the monsoon reversals to be strongly felt. Gardiner estimated annual rainfall at 150 inches (too high, judging by recent records). Agassiz (1903, 145) and Sewell (1936a, 65) made similar observations. Addu differs from the northern Maldives (a) in its greater total rainfall, and its less seasonal nature; (b) in the weakened effect of monsoon wind reversals; and (c) in the absence of typhoons, which originate in the Laccadive area and travel northwards. The contrast with trade wind atolls in the Pacific and the Caribbean is marked.

Instrumental records began to be kept in the Maldive Islands during World War II. Wells (1948) reported 4 years of observations at Male, and Newnham (1949) compiled wartime records at Addu Atoll for the period September 1942 to December 1945. With the establishment of the R.A.F. Staging Post at Gan, recording was resumed in October 1957 for temperature and rainfall and in June 1960 for winds. The data to 1964 have been analysed by the Meteorological Centre at Gan, and the following account is abstracted from their summary:

"The weather experienced differs little from that of the surrounding Indian Ocean but the heating of the land by day and its cooling by night causes an average diurnal variation of temperature of around 10°F. Only small variations occur in the surface pressure and these are masked by the diurnal pressure variation which has a range of about 4 mb with pressure maxima at about 1000 and 2200 and minima at 0400 and 1600 hours local time. Temperature and humidity show also only a small annual variation being controlled largely by the warm water of the Indian Ocean. It is unusual for the sky to be either overcast or free from cloud for a day or more at a time, and much of the cloud is of the convectional type, ranging from fairweather cumulus to massive cumulonimbus. During rainier periods there is often a background of Altostratus and Cirrostratus. Rainfall averages around 90 inches per year, the highest total so far recorded being 118 inches and the lowest 74 inches. Visibility is usually very good except when rain is falling. Occasionally in very heavy rain it is reduced to less than 1000 yards. Strong winds or gales are relatively rare, although Westerly winds during a wet spell blow rather strongly for several days. However, during wet spells squalls of up to 70 kts have been experienced. Surface winds in January from between WNW and NNE become mainly North or Northeast in February (cf. Fig. 3, where wind data are plotted as monthly wind roses). In March winds are evenly distributed between WSW and NNE, but in April become mainly Westerly. The

Westerly winds persist throughout May, then change in June to blow from between Southwest and Southeast. Throughout July and August winds are between South and Southeast, then change to a more Southwesterly direction in September; October and November see the re-establishment of the Westerly, but in December winds become more variable, being distributed between WSW and NNE.

"The weather at Gan is controlled by the migration North and South with the sun of the belt of Equatorial Westerlies unique to this area of the Indian Ocean, which lie between the Northeast Trades of the Northern Hemisphere and the Southeast Trades of the Southern Hemisphere. Along the boundaries between these wind regimes lie zones of convergence which give rise to unsettled rainy weather. The boundary between the Westerlies and the Northeast Trades is called the Northern Shear Line, and that between the Westerlies and the Southeast Trades the Southern Shear Line. Almost invariably prolonged spells of unsettled weather are associated with oscillations north and south over Gan of one or the other of these shear lines.

"Roughly the weather at Gan divides into five main types, as follows:

Type 1. Northeast Trade type with the Northern Shear Line south of Gan. The surface wind is mainly northeasterly and the weather fair but sometimes showery.

Type 2. Disturbed Westerly Type A associated with the Northern Shear Line oscillating north and south over the area. The surface wind is mainly Westerly and the weather unsettled, with periods of heavy rain, accompanied at times with squalls of between 40 and 70 kts.

Type 3. Settled Westerly type with the shear lines well north and south of Gan. Surface winds are westerly and the weather is fine.

Type 4. Disturbed Westerly Type B associated with the Southern Shear line oscillating north and south over the area. The surface wind is westerly and the weather unsettled, with periods of heavy rain accompanied at times with squalls of between 40 and 70 kts.

Type 5. Southeast Trade Type with the Southern Shear Line north of Gan. Surface winds are southeasterly. The weather is mostly fair but spells of unsettled weather are also likely with periods of rain and fresh southeasterlies of up to 30 kts.

"January and February usually have either Type 1 or 2. March and April usually have either Type 2 or 3. May, June and July usually have Type 3, 4 or 5. August and September usually have Type 5. October and November usually have Type 2, 4 or 5. December usually has Type 2.

"To complete the summary mention should be made of periods of light and variable winds which occur from time to time in any month. They usually last from 2 to 5 days, but there have been exceptional periods of up to 12 days. The weather is fine but sometimes showery. Showers when they occur may be heavy and prolonged, but severe squalls of wind are usually absent."

Figure 4 shows annual temperature data at Gan, October 1957 - September 1962. The monthly figures vary less than 3°F throughout the year, which is considerably less than the diurnal variation. Figure 5 plots mean monthly rainfall at Gan for the period October 1957 - June 1964, together with the records for each month in this period and for the period February 1944 - February 1945. The figures show a considerable range in each month, from a monthly minimum of 0.60 inches to a monthly maximum of 18.75 inches (mean 7.91 inches). There is no clear seasonal pattern, except that February and March tend to be drier than the rest of the year.

Currents and tides

Marine currents in this area are variable with the monsoon circulation, but under the influence of the Equatorial counter-current the predominant current direction appears to be eastward of northeastward. "Current observations are, however, scanty in this region, but it is probable that marked variations of current direction occur" (West Coast of India Pilot, 1961, 57).

Tidal variations are referred to the standard station at Madras. Low water springs stand at 0.6 feet and high water springs at 3.8 feet, an extreme range of 3.2 feet. Low water neaps stand at 1.7 feet and high water neaps at 2.6 feet (Admiralty Tide Tables, 2 (1965), Atlantic and Indian Oceans). A predicted curve for part of 1964 is given in Figure 6. According to the <u>West Coast of India Pilot</u>, at Addu Atoll "the flood stream sets strongly into the lagoon through Wilingili channel and out of the lagoon through Gan channel, but the ebb stream sets out of the lagoon through both these channels; thus whereas in Wilingili channel there is a reversal of the tidal stream with the change of tide, in Gan channels the stream sets continuously out of the lagoon. In Kudu Kanda channel, the tidal streams set into the lagoon with the flood tide and out of it with the ebb, but in Man Kanda channel, the tidal streams set continuously out of the lagoon" (Hydrographic Department 1961, 61).

Continual wave action on the reef edge, together with tidal variation, sends a continuous sheet of water across the reef flats, particularly between islands. In the channel between Gan and Fedu Islands, on the Addu reef flat, current measurements with fluorescein and with floats at high water on 24 August 1964 gave values of 1-2 kts off the west end of the runway, and of 1.5 kts lagoonward of the causeway between the two islands.

Sea temperature and salinity

Sea temperatures are approximately 28-29°C (82.4-84.2°F) throughout the year. H.M.S. Owen recorded 28.1-28.8°C (82.6-83.8°F) in this area in early 1962, and Agassiz a surface temperature of 27.8°C (82°F) and bottom temperature of 27.8°C (82°F) at 22 fathoms in Addu lagoon in January 1902. Temperatures measured during the Gan lagoon reef transect work in 1964 varied from 27.0 to 28.0°C. On the lagoon reef slope temperatures were isothermal to depths of at least 80 feet, but they tended to be more variable on the reef flat. The following tables summarise temperature and salinity data recorded by Dr. Davies on the lagoon reef transect I in 1964:

(a) Variation in temperature and salinity with depth in lagoon reef transect I.

Depth ft	Temp. °C	Salinity °/oo
Surface	28.0	34.7
10	28.0	34.7
20	28.0	34.7
30	28.0	34.7
40	28.0	34.7
50	28.0	34.7
60	28.0	34.7
70	28.0	34.7
80	28.0	34.7

(b) Variation in temperature and salinity over the lagoon reef flat in transect I during one tidal cycle, after moderate rain with light wind from the north. Readings taken at surface and at bottom at inshore, mid-flat and reef edge locations at LWST and HWST on 23 August 1964.

0900 hrs, LWST

Zone	Sample	Temperature °C	Salinity °/oo
Inner	surface water	27.0	33.8
	bottom (2 ft below)	27.5	33.8
Mid-flat	surface	28.0	34.8
	bottom (3 ft below)	28.0	34.7
Reef edge	surface	27.5	34.7
	bottom (6 ft below)	28.0	34.4

1500 hrs, HWST

Zone	Sample	Temperature °C	Salinity ‰
Inner	surface	28.0	33.9
	bottom	28.0	33.9
Mid-flat	surface	28.0	34.1
	bottom	28.0	34.1
Reef-edge	surface	28.0	34.1
	bottom	28.0	34.1

These data show a slight salinity gradient across the reef flat from land to sea on the lagoon reef. A higher gradient was found on the seaward flat, particularly after heavy rainfall, as shown in the following determinations by Dr. Davies. They may be compared with normal sea salinities of 33.8-34.4 ‰ in this area, determined by H.M.S. Owen in 1962.

Sample (100 metre intervals from shore to seaward edge)	Salinity ‰ Shortly after LWST	Salinity ‰ Following heavy rain
1	26.3	16.7
2	31.7	31.5
3	30.8	31.5
4	31.2	31.5
5	31.0	31.6
6	30.8	31.6
7	34.1	32.0
8	34.3	33.8
9	34.4	34.7
10	34.5	34.7
11 (reef edge)	-	34.7

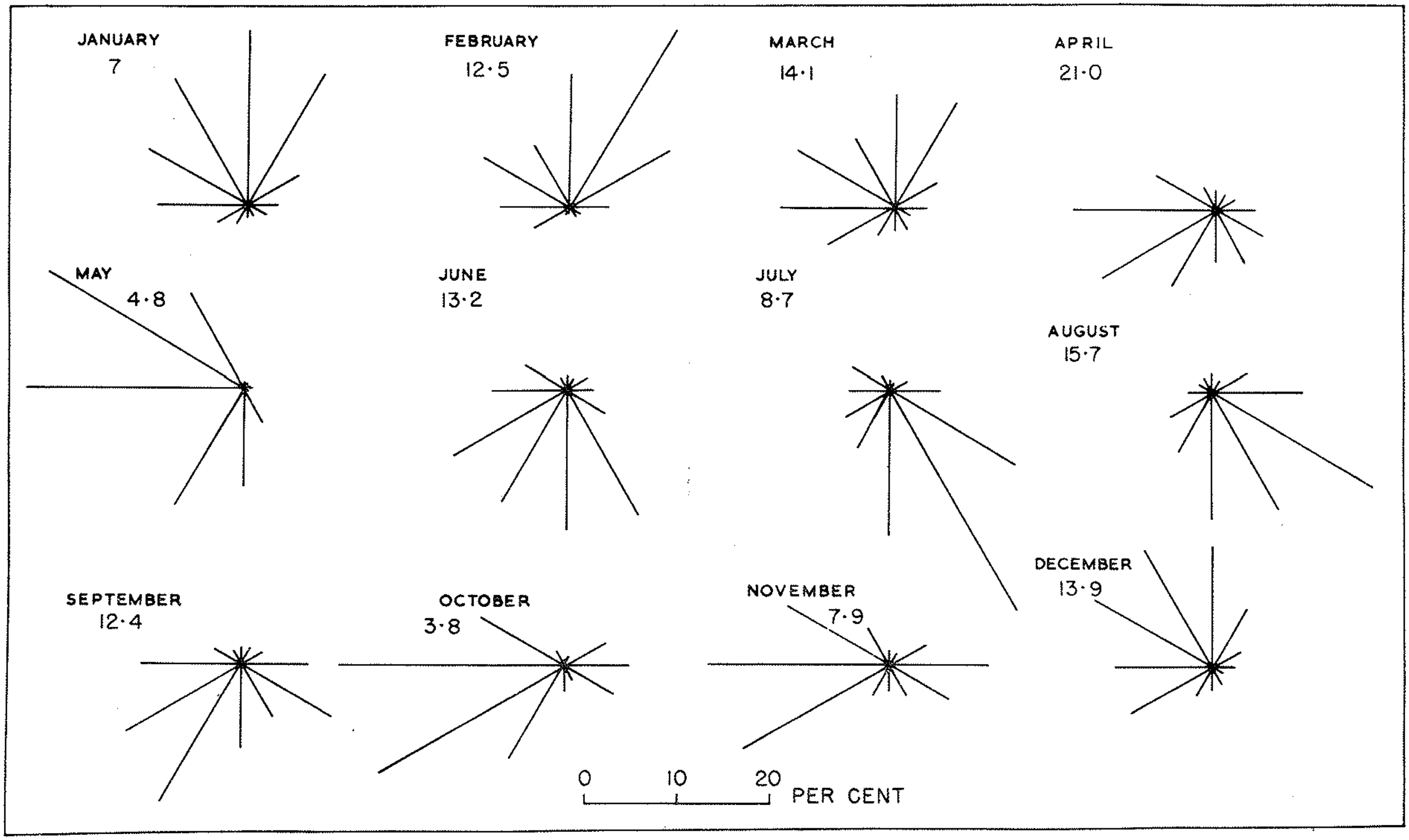

Fig. 3. Mean monthly wind directions at Gan Island, 1960-1964, based on data supplied by the Meteorological Service, Gan. Figures refer to percentage calms.

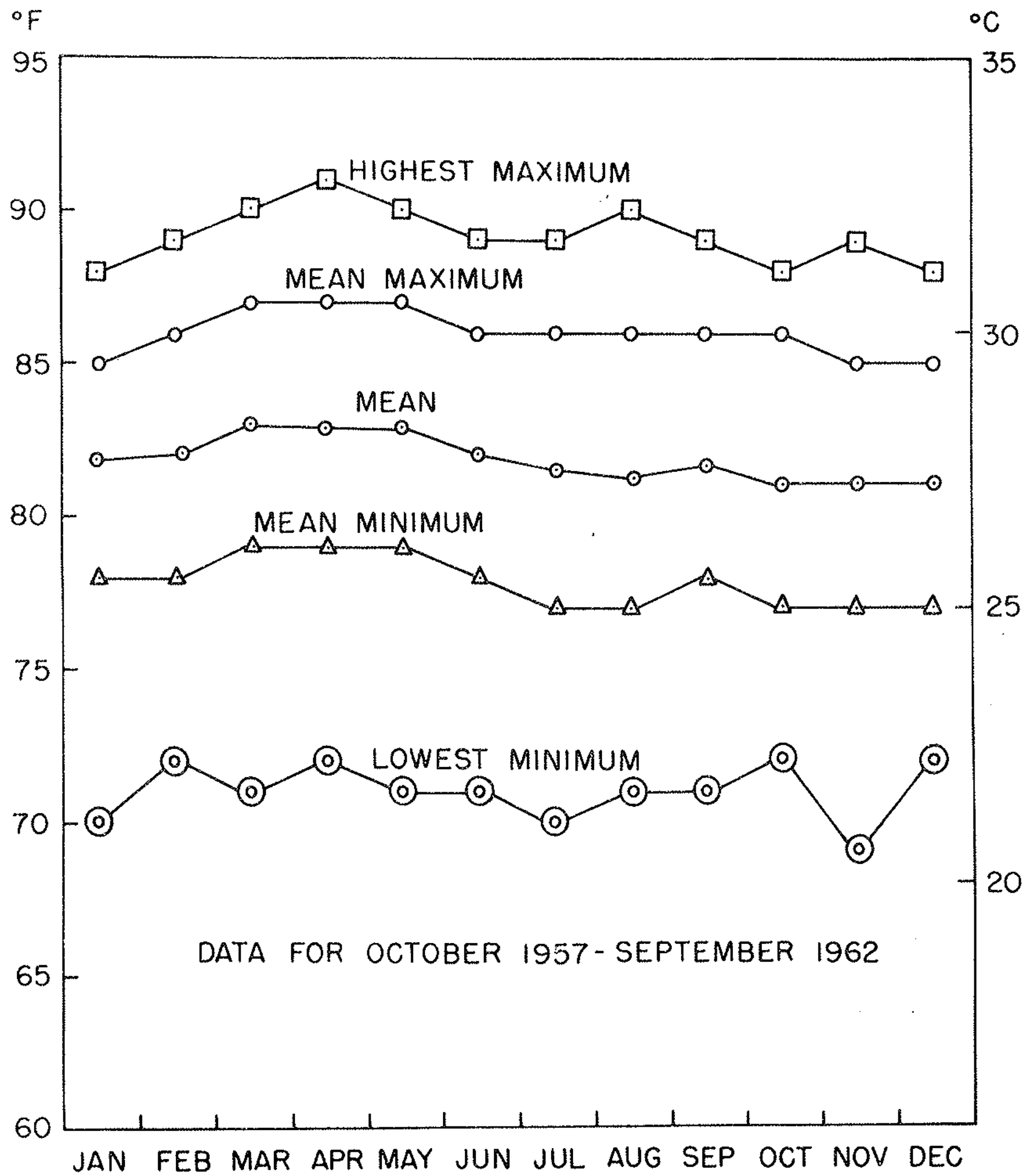

Fig. 4. Monthly temperatures at Gan, October 1957-September 1962, based on data supplied by the Meteorological Service, Gan.

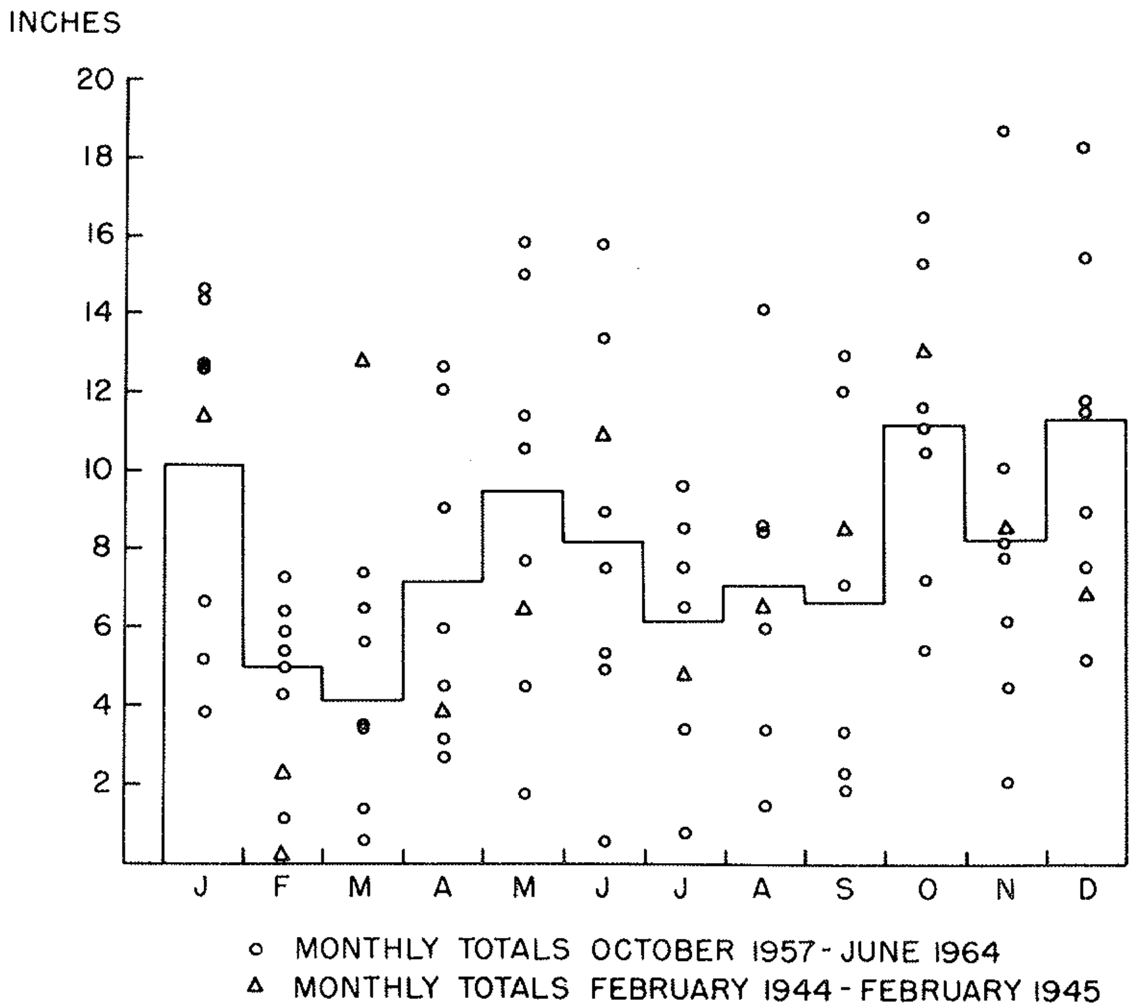

Fig. 5. Range of rainfall and mean monthly rainfall at Gan, October 1957-June 1964, based on data supplied by the Meteorological Service, Gan.

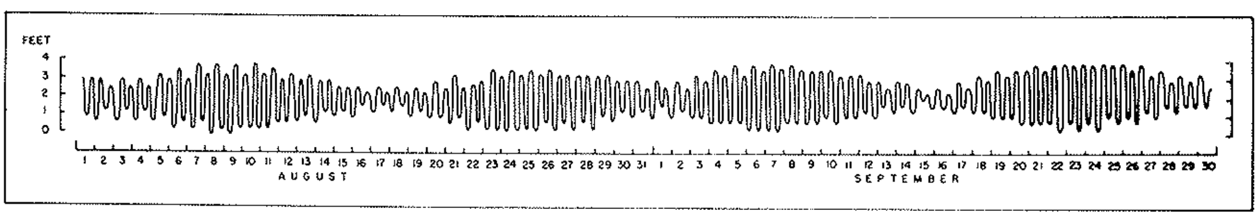

Fig. 6. Predicted tides for August and September 1964, based on data supplied by the Marine Craft Section, Gan.

III. GEOMORPHOLOGY OF ADDU ATOLL

by

D. R. Stoddart, P. Spencer Davies and A. C. Keith

A. General description

Addu Atoll, latitude 0°38' South, longitude 73°10' East, is the southernmost atoll in the Maldive Islands, separated from the next nearest atoll to the north, Huvadu or Suvadiva Atoll, by the 45 mile wide Equatorial Channel. The next nearest atoll to the south is Salomon Atoll, Chagos Arthipelago, 320 miles distant. Addu itself (Fig. 2) is one of the smallest of the Maldive atolls, measuring 28.4 km (17.6 miles) in maximum dimension (NW to NE points), and 16.5 km (10.2 miles) in the transverse direction. The atoll may be termed semi-circular or triangular: the south-facing reefs are broadly convex, the northern reef concave. The shape may be approximated to that of a triangle, apex southwards, with a base of 28 km between the northwest and northeast points, and sides of 25 km. Shape measurements by several methods give values for Horton's F number of 0,604, for Miller's Circularity Ratio of 0.754, for Schumm's Elongation Ratio E of 0.895, for Boyce and Clark's Radial Line Index of 28.54, and for the Ellipticity Index of 1.3 (Stoddart, in press).

The total area of the atoll is approximately 60 square nautical miles, or 6.5 on Haggett's G scale (Haggett et al. 1965). Of this, no less than 41% consists of reef flat and islands. The peripheral reefs of the atoll are broad, ranging from 700 metres on the north side to 1900 metres on the southwest; maximum widths of up to 2900 metres are found on the northwest projection. The reefs are continuous except for two gaps in the centre of the southern reef (Gan Channel, Wilingili Channel) and two in the centre of the northern reef (Kudu Kanda Channel, Man Kanda Channel). Gan Channel, which is buoyed, is 950 metres wide with a sill depth of 9-10 fathoms; Wilingili Channel, 750 metres wide, has a sill depth of 21-31 fathoms. In the north the channels are narrower: Man Kanda, which is buoyed, is 350 metres wide with a 13-18 fathom sill; Kudu Kanda is 250 metres wide, with a 13-19 fathom sill. All the peripheral reefs are of simple linear form, and lack the ring-shaped faros so well developed in the northern Maldives. Little is known of the detailed topography of the atoll slopes. The John Murray Expedition ran a profile from the northeast corner of the atoll, recording a depth of 1000 fathoms within 4.5 miles in the easterly direction (mean slope 14°10') and within 5 miles to the northeast. Their soundings also indicated a ridge extending northeastwards towards Fua Mulaku, shown by soundings of 590 and 654 fathoms (Farquharson 1936, Plate 6). H.M.S. Modesta, sounding out of Gan Channel in 1956, recorded 1069 fathoms 1.5 nautical miles southeast of the Wilingili reef edge, giving a mean slope of 35°.

The atoll lagoon is elliptical, with its axis trending ENE-WSW. It has a maximum length of 11.7 km and breadth of 9 km. Unlike the northern Maldive atolls, such as North Male and Ari, there are few knolls or patch reefs in Addu lagoon. The two most conspicuous patch reefs are near the lagoon centre, named Medagala and Aruhal, on which waves break even in calm weather. Medagala and two smaller patches near the west side of the lagoon are buoyed. Small reef patches and knolls are more profusely developed in the extreme northwest and northeast corners of the lagoon, but elsewhere the lagoon reef slope falls steeply to the lagoon floor. The maximum lagoon depth is 43 fathoms, comparable to that of the much larger Huvadu Atoll and considerably deeper than that of the larger atolls in the northern Maldives (cf. Biewald 1964, 354).

Islands occupy approximately 20% of the peripheral reef flat of the atoll by area, and no less than 65% of the seaward reef edge is backed by land. The only extensive reef sector without land is the concave northern reef. There are large villages on two of the islands, Midu and Hitaddu, and the settlement formerly located on Gan Island has been relocated on Fedu following the 1960 Agreement between Britain and the Maldivian Government. An airstrip was operational on Gan Island during the Second World War, when the deep channels and lagoon of Addu proved of naval value (the Queen Mary has anchored here). Following the Agreements of 1953 and 1960 the Maldivian Government has made certain scheduled territories (Gan Island and part of Hitaddu Island) available for use as a Royal Air Force Staging Post. Development of this Staging Post has involved the construction of a new runway and facilities, with personnel quarters on the northwest side of the island.

The population of the atoll was 4664 in 1931 and 5686 in 1946 (Didi 1949); in 1963 it was 8235. For a fairly detailed general account, see the West Coast of India Pilot, tenth edition (1961, p. 57-62), together with the more scientific papers cited in this report.

To aid in location an arbitrary 1000 metre grid was laid down on the Admiralty Chart (No. 2067) of Addu, related to the earth graticule in that the 0°40' S latitude line and the 12 km S grid line, and the 73°10' E longitude line and the 12 km E grid line are coincident. This basic 1000 metre grid shown in the figures in this report may then be subdivided to give locations to the nearest 10 metres, easting before northing in each point reference. The grid, with a 100 metre interval, was also superimposed on an enlarged vertical air photograph of Gan to aid location referencing in the field. All reef flat and lagoon locations were obtained by horizontal sextant angles on fixed island points, and then reduced to grid coordinates.

B. Peripheral reefs

The most detailed descriptions of the Addu reefs are those of Sewell (1936a, 69-72, 87-92), who divided the reef area into reef platform, outer reef and inner reef. Gardiner (1903, 317-321, 416) briefly comments on the reefs, stating that "the coral growth, taken as a whole, in Addu lagoon is most extraordinary, and in vigour quite surpasses anything in my experience elsewhere either in the Maldives or in the Pacific Ocean" (1903, 319). Most of his remarks on reef characteristics, however, are phrased in general terms. Agassiz (1903, 148) doubted whether the coral growth on the lagoon reef slopes of Gan was as vigorous as Gardiner implied. Kohn (1964a) gives a brief description of the reef flat and reefs at Hitaddu and Gan. Eibl-Eibesfeldt (1964, 38-39) gives a schematic section of the reefs of a Maldivian atoll, and his zonation is followed here (Fig. 7). Figure 8 gives in diagrammatic form cross-sections of the peripheral reefs at Gan (B) and Hitaddu (A) Islands, to show contrasting conditions at these two locations. Peripheral reef characteristics are treated under the following headings: (i) seaward reefs and slope, (ii) seaward reef edge (algal platform), (iii) seaward reef flat, (iv) northern reefs--Midu side, (v) lagoon reef flat, reef and slope.

(i) Seaward reefs and slope

Little is known of the seaward reefs of Addu, except from air photographs, though Davies and Keith inspected the seaward reef slope by diving at Gan and Bushy Island. The 1958 aerial photography shows spur-groove formation well-developed along the reef front along the whole of the convex southern reefs from Hitaddu to Midu, but not along the northern reefs, the lagoon reefs, or in the channels. Along most of the southwest reefs the lineations are approximately 100 metres long, or less; but off Wilingili they reach 250 metres, and off Mulikadu, north of Wilingili Channel, they reach a maximum length of 300 metres. The depth to which the lineations extend is unknown; Davies and Keith report no apparent trace of lineations on the seaward slope off Gan in depths of 7-16 fathoms. They also report a fairly gentle bottom slope, suggesting that at some point, perhaps 400-500 metres outside the breakers at Gan, the bottom slope increases rapidly and falls to great depths. Air photographs indicate that the reef front outside the breakers is steeper or the reef front terrace narrower round most of the rest of the atoll perimeter than at Gan. There is no data on the area immediately outside the breakers, which Wells (1957, 618) terms the innominate zone.

Hass (1961, 60) and Eibl-Eibesfeldt (1964, 37) describe an abrupt increase in bottom slope to form a "reef wall" at the foot of the more gentle reef slope outside the breakers on the seaward sides of Maldivian atolls. Undercutting at the base of this reef wall forms "Grotte" or "Höhle" at depths of 25-135 metres (14-19 fathoms). Hass ascribes this undercutting to low-level marine erosion during a Würm glacial low sea level at -30 metres (16.4 fathoms). Main Würm sea levels, however, were probably in excess of -100 metres (Donn, Farrand and Ewing 1962), and stillstands at the -30 metre level may be connected with the Allerød or similar oscillations. Whether these brief Holocene stillstands (Fairbridge 1961) were long enough to cut Hass's features is debatable. Similar undercutting was unfortunately not observed during the 1964 expedition.

An attempt was made by Davies and Keith to investigate the structure of the seaward reef slope at Gan at a distance of approximately 150 metres from the reef edge, using SCUBA apparatus, but the high bottom surge made working conditions too dangerous for more than a brief examination. Here the depth was approximately 35-40 feet and the seaward beginnings of the surge channels were discernible. Corals, particularly massive palmate Acroporas were present on the areas corresponding to the base of the spurs and reached a height of no more than 4 feet above the general level of the bottoms of the groove areas. In the bases of the groove channels there was a continuous back and fore surge corresponding to the passage of each wave above, of approximately 15-20 feet. Coarse sand and fine gravel are kept in suspension in these areas, often rising to heights of 4-5 feet above the level of the floor of the surge channel. The backwards and forward motion of the bottom water was discernible to depths of approximately 70 feet on the seaward terrace.

At a distance of 200-250 metres from the reef edge a more thorough examination of the structure of the seaward reef slope was made. At this point the seaward terrace had a depth of 40 feet and sloped gradually seawards at about 10°. At a depth of 70 feet there is a slight increase in the steepness of the slope to 30-40°, extending to a depth of 130 feet and the bottom then appears to flatten out again. At 200-250 metres from the reef edge, there is little trace of the groove and spur system. The corals nevertheless appear to be in bands of approximately 10 feet wide, normal to the reef edge. Between the bands are areas of dead coral fragments, rounded and largely covered with calcareous algae though still mobile. Sand is present in places amongst the dead coral. The living coral is of three dominant types 1) a much branched twig like _Acropora_ similar to that growing on the lagoon reef slope at Gan, 2) _Echinopora_ and 3) a massive palmate _Acropora_ whose growing points all pointed in the direction of the reef edge. Occasional small colonies of _Pocillopora_ were present but there were few encrusting corals. This was in marked contrast to that seen at equivalent depths on the lagoon reef where encrusting corals were common. The calcareous alga _Halimeda_ was to be found, particularly amongst the first mentioned type of _Acropora_.

At 60 feet coral growth gave way to a zone of Alcyonarians often forming masses of up to 4 x 5 feet in area. There was no sign of any banding of corals and the few small coral colonies present were randomly dispersed amongst the Alcyonarians, with areas of sand and small coral fragments between. There was no evidence here of any cementing action by calcareous algae. At a depth of 120-130 feet the bottom flattens out and is comprised largely of gravel and sand.

(ii) Seaward reef edge

Seaward reef edge features at Gan are comparable to those described in the Marshall Islands (Ladd and others 1950). The outermost zone, between the reef flat and the breakers, is formed by a platform of encrusting and nodular red and purple calcareous algae, forming a rough and irregular surface. Unlike some areas in the Marshall Islands, where the algal zone forms a high ridge, at Gan it is less distinctive topographically, forming a zone 30-50 metres wide, rising 0.5-1 ft above the level of the reef flat immediately to landward, and drying at extreme low water but not at other low tide stages. Between islands, where the level of the reef flat is lower, the relative height of the algal platform is correspondingly greater. At low tide stages, waves break outside the algal platform, where its crest begins to curve down towards the reef slope, and each breaker sends a sheet of water over the platform, the higher parts of which remain emerged. At higher tides the platform may be covered with 3-4 ft of water, and breaking of waves takes place over a wider area on the platform itself.

In places the seaward slope lineations extend through the breaker zone into the algal platform. At Gan, long sectors of the reef edge lack algal-platform channels, and often poorly and irregularly developed channels can only be seen where the platform descends beneath the breakers at low tide. At certain points, however, as at 093150 and particularly 115161, the channels cut back into the platform for 25-35 metres, forming deep, steep-sided gullies, with vertical or overhanging sides and floors 6 ft or more below the level of the intervening ridges. The channels are narrow, often less than 2 metres wide, and the ridges are wider. The sides of the channels and the intervening areas are covered with encrusting nodular and papillose brownish-red algae and other non-calcareous colonial organisms. Small colonies of Acropora are found on the channel walls and are exposed at low tide during backwash, when water level in the channels may vary vertically 3-5 ft with each wave advance. During backwash the channels act as drainage lines for water on the reef flat, which cascades over the channel lips and attached small corals; during swash, water surges up the channels and spills over the brim onto the flat, where it joins with the slower water flow over the platform surface to form a translating wave 1-2 ft deep. No signs of channel roofing or tunnel formation were seen, and no observations were made on the channels during higher tidal stages.

The Gan reef edge may be compared with that in the Northern Marshalls described by Emery, Tracey and Ladd (1954, 24-26), except that reef blocks lodged by extreme storm action are not found. At Gan the reef edge falls into the Northern Marshalls Class I, strongly grooved, Sub-type A, ridge low and uncut by grooves. In this type the algal zone is described as forming "a broad arch, sloping gently seaward and rising only 6 inches to 1 foot above the main reef flat. With rare exceptions, the grooves, though well developed, are limited to the seaward slope beyond low-tide level" (Emery, Tracey and Ladd (1954, 25). Their Type I-B, with an algal ridge 2-3½ feet above the reef flat and deeply cut by surge channels, is apparently absent at Addu. The northern reefs at Addu, not investigated in detail, appear to belong to their Class II, grooves weak or absent, Sub-type A, reef edge straight or smoothly scalloped.

(iii) Seaward reef flat

Precise levelling was carried out on the seaward reef flat, from Fedu to Gan Channel, a distance of 5 kms. Landward of the algal platform is a deeper area, or moat, 20-70 metres wide, and generally 9-12 inches lower than the highest part of the algal platform. It lacks encrusting red algae of the reef-edge type, is floored with rubble coated with filamentous algae and occasional massive Halimeda, with occasional flattened coral colonies. This moat carries a few inches of water even at lowest low tides. Landward it is succeeded by a rubble zone of small boulders, usually less than 1 ft in diameter but exceptionally up to 3 ft, and smaller rubble. This zone is as high as the reef edge platform and is exposed at lowest low water. Gravel and cobbles form irregular tongues extending lagoonward from the rubble zone across the reef flat, with maximum lengths off the southeast shore of Gan of 250 metres. Generally these debris tongues are about 50 metres long and only a few inches thick, fingering out lagoonward; there is some indication in vegetation patterns on the flat of the existence of tongues of several ages, suggesting that they may be mainly formed periodically during storms.

The reef flat itself (Fig. 9) is a rock platform thinly veneered with sand and some coarser debris, partly in transport and partly held by vegetation. The width of the reef flat varies widely round the atoll, and the width of the seaward flat depends largely on the relative location of islands on it. At Gan the total width of the reef flat is 1500-2000 metres, and of the seaward flat 600-750 metres. Most of the islands are situated closer to the seaward reef, and between Hitaddu and Hankada and Mahera and Mulikadu the seaward flat is 50-300 metres wide; the mean width of the whole reef flat round the atoll is approximately 1000 metres (cf. Section E below). The flat also varies in height. Off the central part of Gan (115-120 easting), where the flat is 750 metres wide, it stands at a relatively high level, is thickly covered with marine grasses, and dries completely from the shore to the algal platform at lowest low tides. Between Gan and Fedu, by contrast, the flat is at a lower level, carries 1-3 ft of water even at lowest tides, lacks a vegetation mat, and is covered with sand in transport. These reef flats on the southern side of the atoll differ considerably from those on the north side, and may be distinguished as windward reef flat types. They differ from many described elsewhere in the Pacific and the Caribbean chiefly in the lack of coral growth on the seaward flat itself (cf. Emery and others 1954, 27; Wells 1954, 396-398). This apparently results from the high level of the flat and its regular drying. Where the level is lower on the Gan flat, growing corals are found. This occurs in three main areas: (a) the Gan-Fedu channel, (b) the lobe-shaped inlet of deeper water at the reef edge at 106158, and

(c) on the flat near the Gan channel (130153). A few very small and scattered corals are also found in the moat and in deeper parts of the algal platform round the reef edge. These consist mainly of corymbose Acropora and small nodular Porites, tightly cemented to the flat, together with small patches of Heliopora. In the three deeper areas, carrying at least 1 foot of water at lowest tides, the dominant corals are widely scattered colonies of Heliopora and Porites, the latter forming "micro-atolls" the top surface of which often supports a growing mass of Turbinaria. In the Gan-Fedu channel, where coral growth is scattered in spite of adequate water depth, coral growth is probably restricted by the amount of sediment in transport across the flat into the lagoon: in the case of many Porites colonies this is indicated by scouring on the upstream face and construction of a sand tail on the lee side, which creeps up the face of the colony killing the polyps which it buries.

At Hitaddu where the seaward flat is narrower and thus more characteristic, the seaward edge is also formed by an algal platform, but the seaward flat itself is rocky, 100-200 metres wide, and 18-24 inches deeper than at Gan (precise comparison is difficult in the absence of a common datum). No part of the seaward flat dries at any time. From the algal platform to within a few metres of the shore the flat is covered with coral rubble and blocks, with scattered small colonies of Heliopora, Porites and Acropora. Heliopora nowhere reaches the importance described at Funafuti and Onotoa Atolls (Cloud 1952), but it is certainly one of the more successful colonisers on shallow seaward flats at Addu.

(iv) Northern reefs - Midu side

The northern reef flat at Addu is quite different from those described above. It is likely that it carries 1-2 feet of water over almost its whole extent at lowest tides, and circulation of water is not inhibited by the presence of islands. Considerable coral growth is found both along the seaward edge of the flat, and on the lagoon side, and the sand-floored area between is patterned by growing corals. Similar conditions are found on the flats at the northwest and northeast corners of the atoll lagoon. The patterns of coral growth on these flats resemble at a small scale those described by Kornicker and Boyd (1962, 643) at Arrecife Alacran, Gulf of Mexico. This reef flat type may be termed the leeward type.

Lagoon reefs (approximate grid ref. 045130)

The northern reefs are considerably narrower than those at the south end of the atoll and differ in morphology and species composition of the corals. The lagoon reef slope is less steep and has an estimated angle of approximately 40°, merging with the lagoon floor at a depth of approximately 80 feet. The cessation of coral growth is not so distinct and patches of coral growth are found to depths of 100 feet on the gradual slope of the lagoon floor. Chute formations were not observed. The reef edge does not form a distinct zone and the outermost area of the reef top merges with the upper area of the lagoon slope, being dominated by palmate Acroporas, although some Pavia, Galaxea and Porites are also present.

The reef flat or reef top is characterized by the very low growths of coral which rise no more than 1-1.5 feet above the level of the surrounding sand. The area between corals is typically composed of a coarse sand rather than of coral fragments. The area occupied by living coral decreases towards the centre of the reef top and in some areas 90% of the surface of the reef is covered by the sand. Corals of the genus Acropora are dominant and comprise an estimated 95% of the total coral population. There are probably five or six species of this genus present, all tending towards a rather heavy, massive growth form. Other corals observed included Millepora, Pocillopora but Echinopora and Goniastrea did not appear to be present and massive cerioid and meandroid corals were not found.

Seaward reefs (approximate grid ref. 037133)

The centre of the reef top was not observed directly but aerial photographs indicate that there is little or no coral growth and that this area is carpeted with a layer of sand. Towards the reef edge, coral growth increases in abundance. Acropora spp. are again the dominant corals, particularly A. palifera and a branching species resembling A. formosa. Altogether there appears to be about six or seven species of Acropora composing this community but occasional colonies of Millepora and Pocillopora eydouxi are also present. The only common alga is a species of Halimeda. There are very few massive or cerioid corals. The area between corals is again filled by sand which here shows evidence of sorting and is typically of large flake-like form, from 1 to several millimeters in diameter and probably derived from the breakdown of Halimeda. Towards the edge of the reef the corals form a very close community with very little non-living areas between the colonies. Where these are present they are filled by small Acropora fragments cemented together with encrusting calcareous algae. The dominant corals here are A. palifera and a massive bracket type of Acropora. These corals are actively growing and probably do not break surface at low water spring tide.

The reef edge is not distinct, but at a depth of approximately 10 feet the zone of luxuriant growth gives way to a barren zone which is characterized by the lack of vigorous coral growth. Here, instead is an area of broken coral fragments cemented into a stable structure by the growth of encrusting red calcareous algae. Very small colonies of Acropora and Pocillopora of 6-9 inches diameter make up 10-15% of the bottom cover. This zone slopes gradually seawards to a depth of approximately 20 feet and then gives way to a steeper sloping zone (slope approximately 30°) of very luxuriant coral growth. Acropora species are again dominant but Favia spp., Seriatopora, Millepora and occasional fungiids are also found. Occasional massive upgrowths, rising up to 20 feet above the general surface of coral growth were observed and these provided ecological niches for the establishment of several encrusting and nodular form corals which were not otherwise in evidence.

At a depth of approximately 80 feet a break occurs in the slope, forming a fairly distinct edge and from here the reef falls away at a slope of about 50-60° to the depths of the Equatorial Channel. Beginning at depths of 40 feet in the zone above, the area between corals is filled by a coarse sand similar to that on the seaward region of the reef flat above. The relative area occupied by the sand increases with increasing depth as the number of corals and coral species decreases. At a depth of 150 feet there are very few corals still present but small Porites colonies are of sporadic occurrence. The hermatypic corals are gradually replaced by large branching colonies of Dendrophyllia and by large gorgonian sea fans and sea whips. Algae are still present at depths of 150 feet, attached to the larger coral fragments.

The northern reefs were visited at a time of year when the predominant wind is from the southeast so that the seaward reefs were therefore in the lee of the atoll. At midday, depths in excess of 150 feet were visible from the surface and water clarity was greater than that experienced in any part of the lagoon or on the seaward reef at Gan. Morphologically the seaward reef of the northern reef system differs from that of the southern reef in:

a) the absence of a distinct reef edge breaking surface at low tides

b) absence of a groove and spur system

c) the absence of a 10-fathom terrace although it is possible that the barren calcareous algae zone is the morphological equivalent of this

d) the presence of delicate weak-framed corals and gorgonians

e) the almost total domination of the surface reef by species of Acropora, including species which were not observed at the south of the atoll.

The windward reef flats at Addu are further distinguished by the presence of areas of relict "reefrock" standing (at Gan) up to 4 feet above the general level of the reef flat. In the Gan-Fedu channel the largest of these patches are found 300 and 400 metres respectively from the reef edge, and measure 140 x 30 and 140 x 60 metres. Smaller patches are found up to 700 metres from the reef edge near the Fedu shore. At Hitaddu similar rock platforms outcrop at the foot of the seaward beach, at a distance of 100-200 metres from the reef edge. The distribution of this rock and its origin are discussed under Section G below.

At Gan there has been considerable human interference with the condition of the seaward flat. Several of the areas of exposed reef-rock have been damaged by military vehicles and by excavation, and areas of the reef flat near the Gan shore have been used as a source of reef-rock for construction purposes, particularly in the construction of the runway, leaving a pattern of excavation hollows; the approximate extent of these is given in Figure 9.

(v) Lagoon reef flat and slope

Like the seaward flat, the lagoon reef flat varies widely in character in different parts of Addu. At Gan it is narrow (100-140 metres wide) and slopes from the shore to the lagoon reef edge. Most of the flat carries more than 1 ft of water at low tide, and except for the tips of some corals none of it dries. It is divisible into an inshore sandy zone with breaking waves, a zone of rubble and dead coral from 25-60 metres from the shore, and a zone of living reef from 60 metres to the edge and down the lagoon slope. The break of slope marking the edge of the flat has depths, between coral heads, of 10-15 ft at Gan. At Hitaddu the leeward flat is much wider (reaching 1000 metres), has a depth of 1-2 fathoms, and for most of its width is sandy, covered with marine grasses, and lacking in growing corals. The reef itself appears to be similar to that at Gan. It is possible, especially at Gan, that military activity has led to increased sediment disturbance on the lagoon reef flat, with the death of nearshore corals; certainly the extent of coral growth, while comparable to that on Caribbean reefs, falls short of Gardiner's description. Detailed transects were made on the lagoon reef at Gan, and some geological aspects of these are discussed in Section D below.

The lagoon slope at Gan has a gradient of 60° from the reef edge to a depth of 14 fathoms, and is coated with growing corals. At 14 fathoms the slope angle decreases to less than 10°, and begins to merge with the lagoon floor. Coral growth in this zone is restricted to patches of *Leptoseris*, together with scattered Alcyonarians.

The nature of the lagoonward reefs is subject to modification between islands, where water flowing across the reef flat carries a considerable load of debris. Thus between Gan and Fedu, Fedu and Maradu, Maradu and Hankada, and elsewhere, through-flowing currents have incised deep channels into the upper part of the lagoon reef edge and slope, concentrating flow across the reef flat into narrow streams with speeds of 2-3 knots, and resulting in the growth of sand deltas at the foot of the lagoon slope.

C. Addu Lagoon

Lagoon topography

Information on lagoon topography is derived almost entirely from Daugleish's 1923 survey, in which the density of soundings exceeds even that at Eniwetok (Table 1). Since location-finding methods were less refined in 1923, however, and since the soundings were all lead-line soundings corrected for tide and not reduced from echosoundings, the accuracy at Addu may be less than in the Marshall Islands.

Table 1. Sounding density in selected atolls

Atoll	Lagoon area[1] sq.miles	Number of soundings[1]	Soundings per sq.mile
Addu	30	18,000	600
Eniwetok	360	180,000	500
Bikini	259	38,000	146.7
Rongelap	396	14,550	36.7
Rongerik	57	1,640	28.8

1. Emery, Tracey and Ladd 1954.
2. Estimated from sample counts.

The Daugleish chart has been supplemented by ten echo-sounding profiles made with a Marconi Ferrograph Offshore 500 echosounder in 1964; these have been replotted on rectangular coordinates in Figures 12-15 and the location of the echo-sounding tracks is shown in Figure 11. The Daugleish chart has been contoured and redrawn to include land topography derived from aerial photography and included on Admiralty Chart 2067 of 1964; it is included here as Figure 10.

Addu lagoon is deepest in the east and northeast, and shoals towards the north and southwest. The 30 fathom isobath delimits a basin of irregular outline, which includes a number of isolated deeper basins and a few upstanding knolls. The lagoon reef slopes are steep (Profiles 1-4, 6-7, 9-10) and extend from the lagoon reef edge at 5-15 ft to the lagoon floor at depths of 85-100 ft, where the slope angle decreases and the slope becomes a flatter apron. Chart inspection suggests that much of the lagoon floor is fairly flat at depths of 25-29 fathoms, particularly in the south and northwest parts of the lagoon, and this is also suggested by several of the profiles. Profile 1, between Gan and Man Kanda Channel, shows a distinct level at 20-25 fathoms, with deeper central areas down to 33 fathoms below this level. Similar features are shown in Profile 9. The deepest parts of the lagoon (more than 40 fathoms) lie in the south-central sector, where nine small areas fall below this level. Most of these are narrow and aligned east-west on Daugleish's chart, in the direction of sounding, suggesting systematic variation in sounding accuracy between successive lines of soundings. Hence the absolute depths of these basins may be unreliable. The maximum charted depth is 43 fathoms (258 ft).

To determine the reality of the apparent floor flattening between 20 and 30 fathoms, Daugleish's chart at 1:18,360 was contoured, and the areas between successive contours were measured using a Stanley Precision Disc Planimeter. The areas of reef flats and islands were obtained in the same way from the published Admiralty chart at 1:25,000, in which these features are plotted from aerial photography. The results of these measurements are given in Table 2.

Table 2

Depth fathoms	Area sq. yds	Cumulative area shallower	Per cent shallower	Cumulative area deeper	Per cent deeper
Islands	13,419,197				
Reef flat, 0-1 fathom, inc.islands	65,987,766				
Reef flat, 0-1 fathom, exc.islands	52,568,569				
1 - 14	12,110,207	12,110,207	13.20	91,750,231	100.00
15 - 20	11,815,554	23,925,761	26.08	79,640,024	86.80
21 - 24	19,085,942	43,011,703	46.88	67,824,470	73.92
25 - 29	22,353,011	65,364,714	71.24	48,738,528	53.12
30 - 34	14,153,743	79,518,457	86.67	26,385,517	28.76
35 - 39	11,553,133	91,071,590	99.26	12,231,774	13.33
40 - 43	678,641	91,750,231	100.00	678,641	0.74
Total lagoon area, inc. gaps	91,750,231				
Total atoll area	157,737;997				

The data in Table 2 are plotted as a histogram in Figure 16, which shows the large area of reef flat and also the dominant lagoon floor area at 25-30 fathoms. The hypsometric curve for the whole atoll (bounded by the outer reef edge) in Figure 17 gives a graphic idea of the wide shallow reef flats, the steep lagoon floor slopes between 1 and 15 fathoms, the slope foot apron at 15-21 fathoms, the wide flatter area between 21 and 30 fathoms, and the smaller extent of deeper holes in the main lagoon floor level. A percentage hypsometric curve may be constructed for the lagoon data only, and directly compared with percentage hypsometric curves constructed for the better sounded lagoons of the Northern Marshall Islands (Fig. 18), where the curves were obtained by cutting out and weighing depth zones on contour maps. The similarity between the curves for Eniwetok, Rongelap and Bikini Atolls and Addu Atoll is striking, at depths shallower than 28 fathoms, though Addu lagoon floor reaches greater depths than those in the Marshalls. The curve for Rongerik is of different form, and a curve for Johnston Island published by Emery is not really comparable because of the absence there of an enclosed lagoon (see Emery, Tracey and Ladd 1954,55; Emery 1956).

The infilling controversy

Using Daugleish's chart it is also possible to resolve the controversy between Agassiz, Gardiner and Sewell over possible aggradation or degradation of the lagoon floor. Gardiner (1903, 317-321), comparing Moresby's 1836 chart with the soundings made by his colleague Forster Cooper, argued for "a decrease in depth of from 1 to 8 fathoms, the general reduction being 2 or 3 fathoms" on the lagoon floor proper, at the same time as the encircling reefs were growing rapidly into the lagoon. He concluded that "in the 65 years between Moresby's visit and my own there has been at the least a decrease in depth of 2 fathoms over the whole area of the lagoon proper, i.e. about 15 square miles....To suppose, therefore, for the 60 odd years since the survey, a deposit or filling in by coral growth of $2\frac{1}{4}$ inches a year over an area of 22 square miles does not seem to me to be excessive" (Gardiner 1903, 320). Lagoon infilling was the reverse of the process which Gardiner thought was general in the Maldive Islands lagoons: in the case of Addu he attributed lack of solutional deepening to the landlocked nature of the lagoon, its small size, supposed lessened rate of water circulation through the reef gaps, and high rates of coral growth. Agassiz (1903, 148) questioned whether Forster Cooper's soundings were close enough to Moresby's to allow Gardiner to draw any conclusions, and emphasized the difficulty of accurate location within the lagoon. Subsequently Sewell made several more soundings (Sewell 1936a, 64), and calculated that while the "average depth" of the lagoon, excluding shoal areas, was on Moresby's chart 24.4 fathoms and on Cooper's 21.5 fathoms, Cooper's and Sewell's soundings together made it 24.5 fathoms. He hence concluded that no change had taken place. Sewell's contoured chart bears a tolerable resemblance to Daugleish's, from which the median depth read from the hypsometric curve (including shoal patches) is found to be 25.5 fathoms. The maximum depths in the lagoon were charted by Moresby as 36 fathoms, by Cooper as 32 fathoms, and by Daugleish as 43 fathoms. Subsequently Gardiner (1931, 141)ceased to stress the supposed infilling of Addu lagoon. As Sewell observed and Daugleish demonstrated, the bottom topography of the lagoon is sufficiently complex to require precise sounding location before conclusions on depth changes can be made.

Lagoon reef patches and knolls

By comparison with other atoll groups, and with the northern Maldive atolls, there are few reef structures within the Addu lagoon. Arbitrarily defining a patch reef as a structure rising more than 10 fathoms above its base and capped with wave-breaking corals, Addu lagoon patch reefs total 3. Defining knolls as structures rising 10 fathoms or more above the floor, denoted by two or more closed contours on the bathymetric chart, but failing to reach the surface, Addu lagoon knolls total 22. The total of 25 lagoon reef structures may be compared with nearly 2300 at Eniwetok, over 900 at Bikini, and 700 at Glover's Reef, British Honduras. Daugleish's density of sounding was such that it is unlikely that any major structures were unrecorded.

The knolls and patch reefs are located and given index numbers in Figure 19. Two in the centre of the lagoon, Aruhal (13, at 137084) and Medagala (14, at 136094), have living reef caps, and are normally marked by breakers, peaking up to 6 ft in height even in calm water. Of the rest, numbers 3, 23 and 24, on the west side of the lagoon, have growing coral on their summits and reach to within 2½ fathoms of the surface; number 4, reaching 4 3/4 fathoms, also has growing coral, but Davies and Keith report much dead coral also. Whether any other knolls support growing coral is not known.

Chart inspection suggests that of the knolls which fail to reach the surface there is a dominant summit level at 15-25 fathoms. The Stanley Precision Disc Planimeter was used to measure the basal area (lowest closed contour) and summit area (highest closed contour) of all 25 knolls and patches: their depth-area distribution is shown in Figure 21. Apart from Aruhal (13) and Medagala (14) all of the patches which reach within 10 fathoms of the surface are small and steep sided: the mean ratio of basal area and summit area is 7.6 and the median 4.6. None of the other knolls rises above 12.5 fathoms; six reach to between 12.5 and 17.5 fathoms; and five to between 20 and 25 fathoms. With one exception (21) the knolls rising to 12.5-17.5 fathoms all lie in the northeast part of the lagoon (numbers 7, 9-12). Those rising to 20-25 fathoms all lie in the centre of the lagoon. The mean ratio of basal to summit area of knolls rising to 12.5-25 fathoms is 24.4 and the median 9.1; the mean ratio for Aruhal and Medagala is 14.6. Of the knolls rising above 20 fathoms some show apparent terracing at the 20-25 or 25-30 fathom levels, as in numbers 12 and 21.

Comparison may again be made with the Marshalls. At Eniwetok the greatest frequency of knoll summits is at 16-20 fathoms, with few rising to 0-8 fathoms. At Bikini the greatest frequency of summits is at 4-12 and 20-24 fathoms (Emery, Tracey and Ladd 1954, 96). The concentration of the larger Addu knolls at similar depths, and the contrast between these and the smaller, steeper surface patches, suggests that the deep knolls have not been formed by reef growth in the Holocene. The echo-sounding profiles of two different types of knoll may be compared in Figure 15 (number 24) and Figure 12 (number 20). The apparent bevelling of the lower knoll summits may possibly be correlated with the apparent lagoon floor flattening shown by the depth-area histogram, and with the reported erosional undercutting of the seaward reef wall described by Hass and Eibl-Eibesfeldt, both at 25-30 fathoms. It is possible, as shown by the distribution diagram, Figure 20, that the knolls fall into two groups, one rising to about 12.5 and the other to about 20 fathoms. If these knolls are indeed older features, then they may have lost both height and steepness during karst erosion at the time of glacial low sea levels: it would be extremely valuable to have data on the nature of the knoll surfaces, and whether coral growth occurs on them. The small size of the sea-level patches (numbers 1-4, 6, 22-24) may indicate that they are wholly Holocene reef constructions. Of the larger knolls only Aruhal and Medagala reach the surface, and it is possible that they have been the only older knolls on which Holocene reef growth was established, and that the fairly small area of surface reef growing on much larger foundations represents an amount of Holocene reef growth comparable to that of the other near-surface patches. Such interpretations must be speculative until more data are available on the knolls themselves.

Notes on the structure of "Five Fathom Shoal" (095095)

Underwater observations were made on the leeward, northwestern side of this structure (no. 4, fig. 19) to a depth of 140 feet. The surface of the knoll lies at a depth of approximately 30 feet, is flat topped and is characterised by almost complete lack of coral growth. There are occasional small colonies of *Pocillopora*, *Porites*, *Galaxea* and *Acropora* but most of the surface comprises loose, uncemented skeletons of a branched *Acropora* with individual pieces of up to 2 feet in length and of plate-like fragments probably derived from *Echinopora*. The whole is carpeted with a fine leafy alga.

Below approximately 45-50 feet on the northwest side, the dead coral is replaced by fine sand and the slope is very steep to a depth of 80 feet. The sand is very tightly packed, cannot be scooped into with the hands and superficially resembles a soft sandstone. Occasional coral colonies are found in this area, with a density which rarely exceeds one per 10 square metres. A loosely branching bracket form of *Acropora* is the most common of these but *Favia* and *Porites* were also observed.

Below a depth of approximately 80 feet the slope begins to level off and at a depth of 140 feet the bottom is almost flat. Between these two depths reef building corals are very infrequent although one large colony of *Porites* was present. Small colonies of *Dendrophyllia* and occasional gorgonian sea whips were observed.

D. General Reef Characteristics

The main reef work of the expedition was concentrated on two lagoon reef transects at Gan (locations: 108140, between the jetties, and 113143, east of the oil jetty). Recording and collection of corals and algae in 10 feet quadrats from the shore to the foot of the lagoon slope was carried out continuously along a steel chain laid on the sea floor. Within each quadrat an effort was made to collect a specimen of every species of corals and marine algae present, and estimates were made of total percentage cover and of relative importance of particular species. Details of these transects will be published when all the determinations are available, but certain features are of geological interest and are discussed here. Figure 21 shows relative abundance of corals across each transect in terms of total number of species per quadrat; the species themselves were separated in the field and their identity will be subject to revision. Figure 22 shows the distribution of these species roughly classified by growth form. In both transects coral growth begins at about 30 metres from the shore, though scattered small colonies may be found closer, and rapidly increases to form a rich reef association at about 70 metres from the shore. From here to the reef edge at 112 metres, the abundance of species increases (Figure 21), from about 10 species per 100 sq. ft. to about 20 species per 100 sq. ft. From the reef edge to the foot of the lagoon slope the number of species remains approximately constant (10-17 per 100 sq. ft. in Transect I, 12-29 per 100 sq. ft. in Transect II). Abundance of species itself is not necessarily of geological importance, however, for many are small and often insignificant reef builders. A rough division was therefore made into species of the genus *Acropora*, those of the family Fungiidae, and the cerioid corals (those with adjoining polygonal calices such as *Favites*). Both transects show regularity in the distribution of these admittedly rather diffuse groups. The cerioid corals are important on the reef flat, forming 25-35% of the species present, but are less so on the reef slope, particularly with increasing depth. The fungiid corals are not important on the flat, but form a minor constituent on the slope. The Acropora spp. form one of the most important and cosmopolitan groups, generally accounting for 25-50% of the species present on the flat, and continuing to the base of the reef slope.

A rough classification of species was also made into growth form (Fig. 22), distinguishing foliaceous corals (e.g. Pachyseris and Echinopora), meandroid corals, branching corals (e.g. Acropora, Pocillopora, Euphyllia, and the superficially meandroid Lobophyllia), and the non-meandroid massive corals, many of cerioid form (e.g. Astreopora, Favites, Hydnophora, Porites, and many others). The contribution of the massive corals appears exaggerated, for many of the species represented form only small colonies. Attention may be drawn (a) to the importance of branching corals over the whole transect, and (b) to the importance of foliaceous corals on the outermost flat and particularly on the reef slope. Estimates of cover of different corals give a similar picture, particularly reinforcing the importance of reef flat Acroporas: on the outer part of the flat many quadrats show 50% of the area of living coral to be Acropora, and one shows 85%.

By comparison with Caribbean reefs there are certain major differences, with geological implications, in these reef assemblages. These may be summarized as:

(a) the virtual absence in the Maldives of the massive meandroid frame-building corals, such as the Diploria spp., and the greatly reduced significance of other massive frame-builders corresponding to the Caribbean Montastrea and Siderastrea species.

(b) the greater diversity in species and the greater area covered by Acropora. Branching and plate-like Acropora spp. are the most important corals on the Addu lagoon reefs, and most of the species present are of light and open growth form, rather than heavy and massive. On lagoon patch reef 24 the diversity and luxuriance of the Acropora, especially the flat, plate-like species, is remarkable, compared to the abundance of other species and to the Atlantic Acropora. Massive Acropora, comparable to the Atlantic A. palmata, are less common.

(c) the importance of foliaceous corals, particularly Echinopora on the slope, and of other open-branched, weak-framed, and often unattached corals (such as Fungia, Herpolitha and Halomitra) in similar situations.

It is probably reasonable to conclude from this that the Maldivian lagoon reefs are formed of much faster growing species than the Caribbean reefs, but that the reef framework formed is less rigid and more unstable than that in the Caribbean. There is, as a result, evidence of reef instability at Gan. The lagoon slope is exceptionally steep, and must approach the limits of cohesion of weak-structured corals. On the Gan lagoon slope coral growth is frequently interrupted by dead areas of broken coral and rubble, often extending from the top of the slope to the bottom, which are clearly slide scars. At times small scale sliding was seen taking place down the slope, raising turbid clouds of finer material. The reef structure, as Hass (1962) observed, is certainly a fragile and delicate one, at least near the surface, but the conclusions which Hass drew from this on the question of atoll origins misconceive the space and time scales involved. It is also possible that some at least of the larger slides have been triggered by military activities at the Gan Staging Post. Nevertheless, the evidence indicates major differences in the nature of reef growth between the Maldives and the Caribbean, and the implications of this might well be explored further.

E. Islands

Types of islands

Twenty per cent of the reef flat area at Addu is covered by islands, and the proportion would be higher if it were not for the almost island-less northern reef. The three largest islands are Hitaddu, Gan and Midu: six other islands have areas in excess of 100,000 sq. yds. The planimetric area of the islands is given in the following table:

Table 3. Areas of Addu Islands

Island	Area, sq. miles
Hitaddu	1.3943
Gan	0.8711
Midu	0.7913
Maradu	0.3118
Heratera	0.2965
Wilingili	0.1989
Fedu	0.1588
Abuhera	0.1399
Mahira	0.0464
15 small islands	0.1132
Total	4.3222

Many of the islands have only been sketchily studied, but fairly full accounts exist for Midu, Hitaddu, and particularly Heratera (Putali), and Gan and Hitaddu were visited during the 1964 expedition. The characteristics of the islands vary with size and with position on the reef flat. There are two extreme cases of island types: those formed close to the seaward reef edge, and those formed close to the lagoon reef edge (Fig. 8).

(a) Seaward-edge islands.

The seaward beach of these islands characteristically lies 45-180 metres from the algal platform, and may adjoin the rubble zone. The seaward beach is steep and high, and generally built of coral debris coarser than gravel, though in more protected areas it may be largely or wholly sand. According to Gardiner (1903, 146) raised reef-rock outcrops on the seaward beach, underlying beach sediments, where-ever the shore lies within 230 metres of the reef edge, though this is by no means a general rule (Section G below). At Wilingili the seaward beach lies only 90 metres from the reef edge, is built of shingle, and was reported by Agassiz (1903, 146) to be "the highest in the Maldives". At Hitaddu the seaward beach is sandy with patches of shingle at a distance of 180 metres from the reef edge, and rises 10-12 ft above the flat; but at Abuhera, 45 metres from the edge, the beach is built of shingle and is steeper. The lagoonward beach on these islands may be 450-1000 metres from the lagoon reef edge, and is usually low and sandy, with vegetation reaching close to high tide level.

(b) Lagoon-edge islands.

In this class the island lies close to the lagoon reef edge, and correspondingly farther from the seaward reef. The distance between the lagoon reef edge and the lagoon beach ranges from 45-180 metres, and between the seaward reef edge and seaward beach from 180-1000 metres. Beaches facing the wide and often high-standing seaward reef flat are thus relatively more protected than those facing the narrow lagoon reef flat. At Gan, which falls in this class, the seaward beach is flat and narrow, and the lagoon beach high, steep and wide. Gravel and coarser debris is rare on both seaward and lagoon beaches, which are mostly sandy.

The characteristics of the larger islands thus depend to a considerable extent on relative location on the reef flat, and this varies in a fairly systematic fashion round the atoll rim. Smaller islands such as Bushy and Mulikadu are simple ridges of coral shingle and sand lodged on the reef flat by waves, and they do not show the more complex features of the larger islands. The following table classifies the Addu islands into three types: A, seaward-edge islands, B, lagoon-edge islands, and C, intermediate islands, and gives distances measured from air photographs between the seaward and lagoon reef edges and beaches.

Table 4

Island	total width of reef flat, metres	width seaward flat, metres	width lagoon flat, metres	Island type
Hitaddu	900-1350	90-180	900 +	A
Abuhera	820	45	640-900	A
Maradu	1040	600-690	180-320	C
Fedu	1130-1350	600-1350	160-180	B
Gan	1350-1800	550-690	70-90	B
Wilingili	730	90	460-550	A
Midu	300-400	90-180	-	A
Heratera	820-1260	70-90	550-900	A
Firhidu Hera	900-1000	90	730-820	A
Kalu Hera	1130	90	1000	A
Mulikadu	450	135-275	90-180	C

Island beaches

151 beach profiles were surveyed at Gan Island and 30 at Hitaddu, using a tripod quickset level and staff. Profiles were carried from the beach crest (or where vegetated the outer edge of the vegetation hedge) to a point 15-30 metres seaward of the foot of the beach. The foot of the beach is defined on most profiles by a sharp concave break of slope where the beach face meets the horizontal reef flat. In the field it is delimited by a more or less abrupt transition between white beach sands and the rocky, vegetated flat. Beach profiles may be slightly convex or concave, but most are straight with a summit convexity, except where erosion has led to scarp formation at the beach crest. A distinction may be made between (a) rough water beaches, where the foot of the beach forms a step up to 1 ft in height immediately below low tide level, often with an area of strongly rippled sand to seaward, and (b) calmer water beaches, where this step is absent. Beach profiles were measured over a period of weeks, but always at similar tidal stages, i.e. during the 4-5 days of exceptionally low low tides occurring at fortnightly intervals. Gan profiles 1-5 were also repeated at a medium high tide (profiles 6-10).

Considerable differences were found in beach angle in areas with different exposure to wave activity. At Gan the profiles were grouped into beach sectors (Fig. 23), separated by areas unsurveyed because of human interference or other reasons. Within each sector, beach angles tend to be tightly clustered about a mean value (except on the east shore, where values are more widely scattered), but there are considerable differences between beach sectors. Mean beach angles for Gan beach sectors are as follows:

Table 5

Beach sector	Number of profiles	Mean angle
East shore	10	5.75°
North shore (east)	10	7.95
North shore (centre)	56	8.30
North shore (west)	15	8.07
West shore	14	4.18
Southwest shore	36	5.77
Total and Mean	151	7.01

These beach angles correlate directly with exposure. Wave activity is most intense on the lagoon shore between the two jetties; it is high along the whole lagoon shore, and much less on the east and west shores where the reef flat is wider and shallower. On the southwest shore the beach is rather more exposed to waves in the wide and deeper Gan-Fedu channel, and beach angles are correspondingly higher. The steepest beach angle recorded at Gan is 11.5° in profile 58. The south shore of Gan, facing the exceptionally wide seaward flat, is most protected from wave action: the beaches are low and flat, and vegetated almost to high tide level; this, together with the fact that this shore has been used since World War II as a rubbish dump for military debris, made profiling impossible.

At Hitaddu similar contrasts are found in beach angles, again co-relating with wave energy, but whereas at Gan the steepest beaches are on the northern lagoon shore, at Hitaddu they face the narrow seaward reef flat, and the more protected lagoon beaches are lower and flatter.

Table 6

Beach sector	Number of profiles	Mean angle
Seaward shore	19	9.5°
Lagoon shore	11	5.2

The steepest beach angle measured at Hitaddu was 13° on seaward shore profile B9.

Inspection of the Gan profiles shows that the width of the beach tends to be fairly constant between the sectors measured (not including the south shore): width averages 14-16 metres, and varies extremely from 7 to 23 metres. The height of the beach above the immediate offshore flat (i.e. above the concave break of slope at the beach foot) is more variable, and is directly related to beach angle. On beaches with a mean angle of 5° or less, the height of the beach is 5 ft or less. On steeper beaches (angle greater than 8°) beach heights are greater than 5 ft and range up to 10.5 ft. Steep, high beaches are built in exposed areas where rapid swash builds the beach face above still high-water level. The most sheltered beaches have heights approximately equal to the tidal range. Median beach heights for different beach angles at Gan are as follows:

Table 7

Beach angle, deg.	3	4	5	6	7	8	9	10
Median height, ft.	3	4	5	4	5	6	7	8

Similarly at Hitaddu, the width of the seaward beach averages 15 metres, varying from 13 to 20 metres, and that of the lagoon beaches averages 13-14 metres, varying from 10-15 metres. Main variability is in beach height, which again directly correlates with angle:

Table 8

Beach angle, deg.	5	5.5	8	9	10	11	13
Median height, ft.	4	4	7*	7	7	8*	10*

(* single cases only)

Plotting median height and height range against beach angle in Figure 24 indicates the range and variability of these beach characteristics; the regression line is fitted by eye.

Interior topography

Most of the Addu islands consist of seaward and lagoonward ridges, separated by a lower area, in places occupied by water. The eastern islands consist of a rocky seaward ridge and sandy lagoon ridge, separated by freshwater lakes or kuli (Willis and Gardiner 1901, 78). Air photographs show a large interior lagoon at Hitaddu, but this could not be visited. Much of the central part of southern Hitaddu was covered with standing water 6-24 inches deep in August 1964, under a vegetation of sedges and Pandanus thicket. At Gan the interior topography has been considerably altered by construction work, but in the centre of the island the soil is black and mucky, with the water table at or within an inch or two of the surface. Excavation at several places showed a clear distinction between soils derived from peripheral sand ridge sediments, and those formed under high water table conditions in the centre of the island. Unlike many Pacific and Caribbean islands, mantles of coarse sediments ("rampart wash") in the interiors of islands, resulting from exceptional storm activity, seem to be absent at Addu.

The height of the water table is such that after heavy rain fresh water may stand on the island surfaces for several days, and in places permanently. This is the case at Gan, where levelling of the surface has added to drainage difficulties, but also at Hitaddu. Gardiner described similar conditions at Maradu (Willis and Gardiner 1901, 80). Rainwater replenishment of the Gan freshwater lens is sufficient to supply all freshwater requirements for the R.A.F. Staging Post established there.

Minor changes in Addu island topography

The records of 1836, 1900, 1934 and 1964 show that some features of the Addu islands are subject to minor alteration, particularly where gaps between islands are narrow and shallow. Islands charted as separate by Moresby and even by Gardiner may now be joined; and some small islands may have disappeared. Sewell has chronicled the changing numbers of small islands off northwest Midu: 6 in 1836, 7 in 1900, 5 in 1934 (Sewell 1936a, 73-74); in 1964 there were three, two small, and one (Mahira) long and narrow. Heratera and Firhidu Hera were separate in 1836, joined in 1900 (Gardiner 1903, 318), separate in 1934 (Sewell 1936, 74), and joined in 1964. Wilingili, charted as two islands in 1836, had become one by 1900 (Gardiner 1903, 418), and remains so. In 1836 Abuhera was continuous with Hitaddu, and remained so in 1900 (Gardiner 1903, 415). By 1934 the two were separated (Sewell 1936a, 84), but were again joined in 1964, by a sandy area with continuous vegetation cover, standing 3.5-4 ft above the level of the reef flat immediately to seaward, with a seaward sand and shingle ridge 2.5 ft higher (Profile B19). The series of small islands on the seaward side of Fedu and Maradu, uncharted in 1836 but recorded by Gardiner, were probably omitted in error by Moresby; they are discussed by Gardiner (1903, 419) and Sewell (1936a, 80-81). The scrub vegetation described by Sewell has now been replaced by coconut thicket with trees 45-50 ft tall.

According to Agassiz (1903, 147-8) and Kohn (1964b) the lagoon and southwest shores of Gan are being eroded, while Sewell (1936a, 80) inferred aggradation. Evidence for beach retreat is given by the beachrock at the northwest point, which is now being actively undercut by throughflowing water in the Gan-Fedu channel; by the exposure of cay sandstone on the beach face on the southwest, west, and to a lesser extent the northern shore; and occasional undermining of trees at the eastern end of the north shore. Retaining walls have been built to stabilise the shore on parts of the west and north shores. For details of the beachrock and cay sandstone exposures, see Section G(iii) and (iv). Local aggradation is taking place at the northeast point of Gan, where a fresh sand spit extends 60 metres from the main beach crest.

F. Sedimentary environments

The main aim of the geomorphic work was the sampling of sediments in a variety of atoll environments, to demonstrate (a) how sediment characteristics varied between environments within the depositional framework of the atoll, and (b) how sediment characteristics (mechanical and organic composition) vary on the beach face and the immediate nearshore area in a number of beach sectors subject to differing wave intensities at Gan and Hitaddu Islands. The main sedimentary environments sampled were (1) island beaches, (2) reef flat, (3) lagoon reef slope, and (4) lagoon floor. On beaches sampling was carried out at the same time as beach profiling, on a total of 250 beach profiles. Samples were collected at 5 metre intervals on each profile, measured from the beach crest, and the profiles were generally spaced at 25 metre intervals along the beach. Generally 5-6 samples are available per profile: the profiles are located in Figure 23. The total number of beach face and immediate nearshore samples collected at Gan numbered 950, and at Hitaddu 99. Sampling of reef flat environments was carried out on the seaward flat at Gan, and in the Gan-Fedu channel, concurrently with levelling. Location of the reef flat samples, totalling 127, is shown in Figure 25. On both beaches and reef flat sampling was carried out with a simple scoop sampler holding approximately 300 grams. On the lagoon reef slope 5 samples were collected by Keith using SCUBA apparatus. On the lagoon floor sampling was carried out using a bronze grab sampler which closed automatically on striking the bottom. Recovery of samples was poor because of frequent malfunction of the release, and the total number of samples collected was 42; their location is given in Figure 26. Processing of these samples for machine computation of mechanical characteristics is continuing, and this section simply records some gross characteristics of reef flat, beach and lagoon floor sediments, on the basis of preliminary data for 350 samples. As measures of sediment characteristics, cumulative percentage curves were drawn from sieve data and used to derive phi median diameter (ϕM_d) and sigma phi ($\sigma\phi$), the latter giving a simple measure of sorting (ϕ [$\phi 84 - \phi 16$] / 2).

Using these parameters clear distinctions may be made between reef flat, beaches and lagoon floor environments (Fig. 27). In the reef flat sediments as a whole the mean ϕM_d is about 0.5, a coarse sand, with a range from -1.3 to +1.7 ϕ (very fine gravel to medium sand). Taking the Gan beach sediments as a whole, mean ϕM_d size is about 0.85, a less coarse sand, with a range from -0.2 to +2.1 ϕ (very coarse sand to fine sand). The lagoon floor sediments are highly variable in size composition, ranging from less than 1.0 to more than 4.0 ϕM_d (coarse sand to coarse silt). There is therefore some distinctiveness in size range between the three environments (note that no attempt was made to sample beach sediments coarser than fine gravel, such as the shingle or rubble sediments on the seaward beach of Hitaddu). Taking median size characteristics alone, however, there is considerable overlap, particularly between reef flat and beach sediments. Sorting is more discriminatory. Although the sorting measure used here is rather inefficient and was chosen for ease in calculating, it is clear that considerable differences in sorting exist between environments. Beach sorting values are almost all less than 1.0, except where the sediment sampled is obviously bimodal; the peak frequency of beach sorting values is 0.5-0.6, i.e. beach sediments are very well sorted. By contrast, reef flat sediment sorting values range from 0.7 to 2.1, with a mean value of about 1.5, i.e. sorting is much poorer. Lagoon floor samples have similar or higher sorting values than those on the reef flat. Plotting of median size against sigma phi in Figure 28 shows that reef flat and beach sediments are clearly distinguishable in terms of size and sorting; data are too few to accurately define the range of lagoon floor characteristics. In summary:

(1) beach sediments are moderately fine sands and very well sorted;
(2) reef flat sediments are coarser and poorly sorted;
(3) lagoon floor sediments are coarse to very fine, and poorly sorted.

There is in addition considerable variation within the major environments. The beach sampling programme was designed to assess changing sediment characteristics normal to the shore, particularly in the light of Miller and Zeigler's (1958) model of beach sediment characteristics. Preliminary results indicate that sediments are coarsest at the foot of the beach, at the "step" on rough-water beaches, and become finer in median diameter both to seaward of the beach foot and up the beach face. Sorting is also best in the lower part of the beach, and decreases to seaward of the beach foot and up the beach face. Much work needs to be done on the data, however, before conclusions can be drawn. Similarly on the reef flat, a distinction can be made between flats backed by islands and channels, since considerable sediment transport and sorting occurs through the Gan-Fedu channel, by comparison with more stable conditions on the vegetated flat south of Gan.

G. Lithified sediments

Lithified sediments of various types have been described from the Maldive Islands by Moresby, Gardiner, Agassiz and Sewell, and Gardiner in particular has used the present distribution and height of lithified sediments on the atolls as evidence for considerable shifts of sea level in Recent times. In many discussions of lithified sediments, genesis has been deduced only from the gross topographic characteristics of the outcrop, and it has then been assumed that similar outcrops have a similar composition. Few discussions of atoll rocks consider lithology and mineralogy as well as topography and distribution, and many of the earlier deductions on rock origin and its implications in terms of geomorphic history are purely speculative.

Gardiner (1903) and Sewell (1935a, 500-512) distinguished three main types of rock on atolls: reef rock, beach sandstone or beachrock, and cay sandstone. All these types are found at Addu Atoll, but a further distinction must be made between reef rock underlying the modern reef flat, and raised or relict presumed "reefrock" of uncertain status. This account is purely descriptive, and no attempt is made to describe the mineralogy or origin of the rocks, or their bearing on atoll history at this stage.

(i) Reef rock

Wherever investigated the reef flats of Addu atoll consist of a more or less regular rock platform, veneered with loose sediment. This is particularly so south of Gan, on the wide seaward reef flat, which is wholly a rocky feature, lacking any considerable relief, and giving no indication of subsurface structure in the form of either curvilinear fracturing or of truncated and relict coral heads described from such flats elsewhere. Samples of reef rock were obtained by blasting on the seaward reef at Gan, location 115159, through the courtesy of Mr. J. Woodward. The rock is a toughly cemented rock of coral fragments in a limestone matrix, with abundant Heliopora fragments which have lost their blue colour and turned brown. The constituents indicate a reef community similar to that now found on deeper flats than the present Gan flat. It is difficult to see how such rock could form at the present level of the flat off central Gan.

(ii) Relict "reef rock"

Several of the seaward-edge islands have low rock platforms at the foot of their seaward shores. Gardiner (1903, 416) described this as occurring wherever part of the island lies within 230 metres of the seaward reef edge; at Hera, north of Midu, he described emerged reef-flat rock masses standing up to 6 ft above high water and 10 ft above the flat. At Midu, rock is described along the east shore, reaching 5 ft above high water (Gardiner 1903, 417; Sewell 1936a, 73, Plate 1ii). Seaward-beach rock masses are also described at Heratera (Sewell 1936a, 75, Plate 3ii), Firhidu Hera and Kalu Hera (Sewell 1936a, 79), Mulikadu (Sewell 1936a, 79), and Maradu (Sewell 1936a, 82). Sewell also describes it between the seaward shore and the reef edge at Maradu, forming "coral horses" (Sewell 1936a, 83, Plate 3i), and in the small islands between Fedu and Maradu (Sewell 1936a, 81).

"Reef rock" of similar type is present on the seaward shore of Hitaddu, where it was surveyed in beach profiles B1, B12, B14 and B15.

In profile B1 the highest point of the reef rock outcrop, which is 4 metres wide, reaches 4.3 ft above the general level of the reef flat, but only 3 ft above the level of the flat immediately seaward of the rock. It outcrops at the foot of the beach, which here rises 6 ft above lowest low water, and the rock itself dries at least 1.5 ft at this stage. Other profiles show similar characteristics, except that the beach face above the rock is only 3-4 ft high. In places the upper surface of the rock shows a distinct seaward gradient (4.5^{o} in B1, 3^{o} in B12), but this is clearly erosional: elsewhere the surface is rough but horizontal. The structure of this relict rock is not easily discernible, but at places on the southernmost part of the Hitaddu seaward shore and the northernmost part of Abuhera the coral slabs forming the rock are clearly imbricated, dipping seawards, which might indicate a subtidal reef flat rather than a beach environment.

Several patches of rock, mentioned by Gardiner and Sewell, are found in the reef flat embayment between Gan and Fedu Islands, and on the wide reef flat to the south of Gan. The patches are as follows: (1) A rock platform marked on charts as Addu Island, south of Gan, location 1048/1536-1550, measuring 140 x 30 metres, the highest part rising 5.1 ft above the deepest part of the seaward flat between it and the reef edge, and 3.45 ft above the level of the reef edge algal platform. (2) A large patch 800 metres to the northwest, 220 metres from the seaward reef edge, location 0958-0966/1486-1500, rising at its highest 4.3 ft above the surrounding reef flat. (3) Two small patches of rock, the largest 35 x 23 metres, approximately the same distance from the reef edge, with a similar height, location 091143. (4) A small patch of rock standing 3 ft above the reef flat approximately 30 metres to the northwest. (5) A much larger patch, the first of a series, location 089142, which continue towards the northwest and form the basis of several of the small islands on the seaward side of Fedu, as described by Sewell. (6) Two small patches, location 095139, close to the southeast shore of Fedu, drying up to 2 ft at low water, marked on the Admiralty chart as "drying 4 ft." In all these cases the rock surface is deeply pitted and eroded, and in cases 1 and 2 it has also been damaged by military activity. The rock is formed of coral fragments in a coral sand matrix, and in places is dominantly sandy.

(iii) Cay sandstone

The Maldive Islands form a classic area for the description of cay sandstone. Moresby (1835, 398) described subsurface induration of sands at a depth of 3-4 ft, forming a layer 2 ft thick overlying unconsolidated sands, at the freshwater table, at Miladumadulu Atoll. Sewell (1935a, 502-3) described a similar occurrence at Maradu Island, Addu Atoll, and also figured a section at Fehendu Island, Goifurfehendu Atoll (cf. Sewell 1936b), where a layer of sandstone 1½ ft thick underlies 2-3 ft of surface sands and soil, well above high water level.

Cay sandstone is well exposed on the west and southwest shores of Gan, where it forms a nearly horizontal ledge or platform several feet wide on the upper part of the beach. The rock is generally 1-2 ft thick:

its base is dry at low water, but its upper surface is covered by swash at high tide. Its seaward edge forms a vertical or overhanging scarplet, which is being eroded by transverse gullying, by local undermining and wave action, and by the dislodgment of sections several metres long because of longitudinal fracturing. Inland the rock passes under the beach, and at one point outcrops in the eroded beach face to a height 9 inches higher than the platform, suggesting that the upper surface of the rock may itself be erosional. The rock is poorly bonded and may generally be crumbled in the fingers at fresh sections; at the outcrop it is casehardened and tougher. It lacks internal structures in bedding or grain size sorting, and is essentially horizontal.

Cay sandstone outcrops on the west shore, as recorded in beach profiles 76, 77, 78 and 79. These are all low-angle beaches (gradients 1 in 10 to 1 in 15), the beach crest rising 5 ft above the immediate offshore flat. Cay sandstone outcrops 1.3-2.5 ft below the beach crest, forming a platform 2.3-5.6 metres wide, and 1-1.5 ft thick. On the southwest shore, cay sandstone outcrops are shown in beach profiles 92, 95, 96, 98, 99 and 100. Beach gradients here range from 1 in 5 (where there has been considerable steepening as a result of erosion) to 1 in 16. The height of beach crests above the flat ranges from 5 to 9 ft. The sandstone outcrop is 1-6.4 metres wide; it passes landward beneath unconsolidated beach sands which form a vertical scarplet up to 2.5 ft high. The outer edge of the rock platform forms a scarplet 0.5-2 ft high. The height difference between the sandstone platform and the beach crest depends on the amount of human interference with the latter: at its greatest, where the erosional sand scarp is highest, the platform is 3.3-4 ft below the beach crest. Elsewhere it may be only 1-2 ft. Profile 99 shows the rock with a maximum thickness of 3.4 ft; generally it is 0.5-2 ft. The surface of the platform is often tilted slightly seawards, but at a very much smaller angle than intertidal beachrock.

No outcrops of cay sandstone were seen at Hitaddu, but Sewell describes outcrops of similar rock on the lagoon beach at Heratera (Sewell 1936a, 76, Plate 4iii).

(iv) Beachrock

Intertidal beachrock has been classically described from the Maldive Islands by Gardiner (1903, 341-346, Plate 16), and its characteristics are now well known. Gardiner insisted on its intertidal character (1903, 343), and this appears to be a useful field criterion for beachrock identification. Beachrock is uncommon on Addu beaches, where it must not be confused with outcropping beach sandstone on the upper beach face, exposed by beach retreat. Outcrops of beachrock are found in two places on the Gan beaches, the largest being at the northwest point (1014/1367). Three lines of beachrock continue the trend of the north shore towards the deeply scoured Gan Channel. The rock is eroded and discoloured by algae, the outer line blackened, the inner lines grey and brown, but by contrast with the Caribbean, larger algae such as *Turbinaria* are absent, doubtless because of the high tidal range. The beachrock is shown in beach profiles 72 and 73. The lowest seaward part of the beachrock stands 1.5 ft above the level of the lagoon reef flat, at this point a hard planed rock floor; the highest landward part of the beachrock stands 4 ft above the flat and 3.5 ft below the beach crest. Low tide level approximates to its lowest extent, and the rock is submerged at high tide. The three lines of beachrock all dip seawards: the innermost at 3°40', the second at 5°36', and the outermost at 6°30'. They are separated by scarps 1-1.4 ft high. At its westernmost extent the beachrock is being undermined by current scouring in the Gan channel, and several slabs have been broken transversely and have fallen into scour holes. At the end of the beachrock the channel floor lies 4 ft below the beachrock surface, and as a result of this scouring there is a secondary longitudinal tilt in the exposure.

Possible massive beachrock outcrops on the north shore of Gan, (a) immediately west of the marine jetty (1060/1394), where it has been much altered by man, and (b) in four small patches at the eastern end of the north shore (124144), where it is difficult, however, to distinguish it from possible cay sandstone on morphologic grounds. Similar difficulty is also experienced with some of the outcropping rocks figured by Sewell at Goifurfehendu Atoll (Sewell 1936b). Unmistakable beachrock was not seen at Hitaddu, though a lagoon beach exposure south of the jetty may be so classed. Gardiner also reports beachrock on the seaward beach at Midu (Gardiner 1903, 417).

The Gan beachrock consists of sedimentary particles similar to those of the adjacent beach, showing vertical sorting into distinctive layers dipping seawards, which helps to differentiate it from cay sandstone. The constituent particles show evidence of solution, and the rock has been secondarily cemented to an extremely tough and hard character.

Problems

The problems posed by the Addu lithified sediments may be briefly stated. The nature of the relict "reef rock" is of critical importance in the geomorphic history of the atoll. Gardiner and Sewell supposed it to be a true submarine reef rock exposed by relative elevation, but it is also possible that it has been formed by lithification of coarse island clastic sediments at its present elevation and exposed by beach retreat, as Newell suggests in the Tuamotus (Newell 1961). Bearing on this problem is the generally unsorted nature of the constituents and the imbrication of coral slabs at Hitaddu. Even though there is no evidence of corals being found in the rock "in the position of growth", as Gardiner observed at Minikoi and elsewhere, this seems to indicate a subtidal origin, implying a relative shift of sea level. The widespread nature of similar exposures elsewhere in the Maldives and in the Indian Ocean generally (Sewell 1935a, 474-479; 1932, 1928) would also lend support to a negative eustatic shift in explanation of these raised features. It is interesting in this connection that Shepard (1963, 5) has obtained a radiocarbon date of 2990 ± 220 yrs B.P. from a raised reef 2-3 ft above low tide level in Ceylon, although comparable Pacific and Australian features have yielded considerably older dates. At Gan the rock has been subject to considerable alteration by erosion, and is probably undatable. However, samples of reefrock underlying the present flat should give significant results: if near-surface samples are very old, they may indicate antiquity and subsequent planation of the flat, from which the higher fragments of reefrock rise as erosional remnants; but if young, it will be difficult to attribute the relict rock to any major eustatic shift of sea level.

The nature of the cement in the cay sandstone and the intertidal beachrock is of interest. If, as seems likely, the cay sandstone is a freshwater rock and the beachrock marine, the primary cements should be calcite and aragonite respectively (Stoddart and Cann 1965). In the case of the Gan beachrock, however, solution may have gone too far for the primary cement to be determined. Alternatively, if the beachrock cement is calcite, this will add further evidence to Russell's theory of beachrock origin at the freshwater table under beaches (Russell 1962). A major problem is why rock of one sort is developed on a particular island, rather than another. At Gan, cay sandstone is the dominant lithified material, whereas at Cocos-Keeling Russell and McIntire (1965) report massive beachrock.

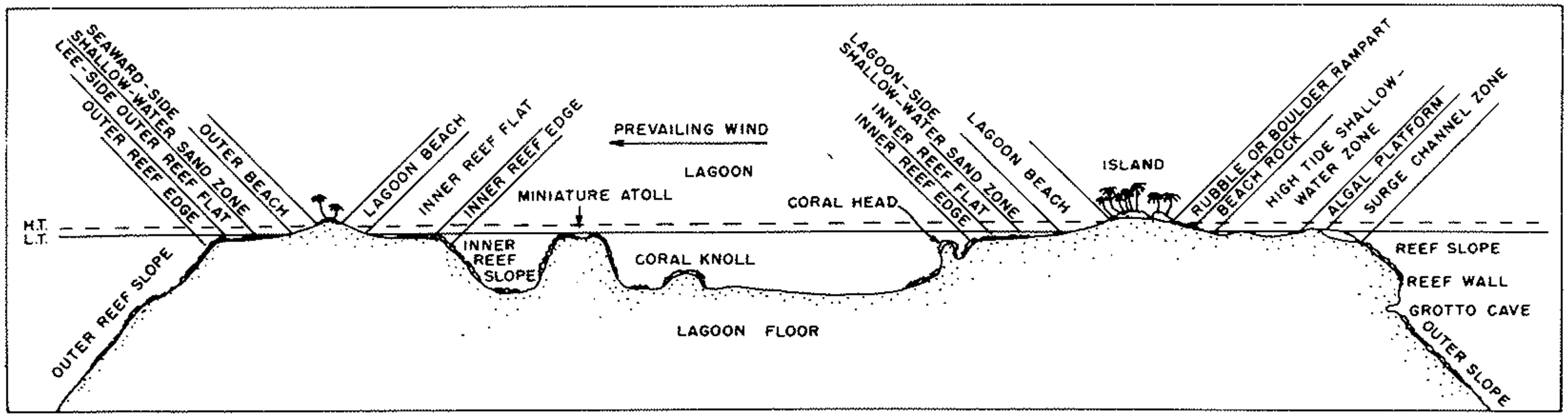

Fig. 7. Zonation of Maldivian reefs, after Eibl-Eibesfeldt (1964).

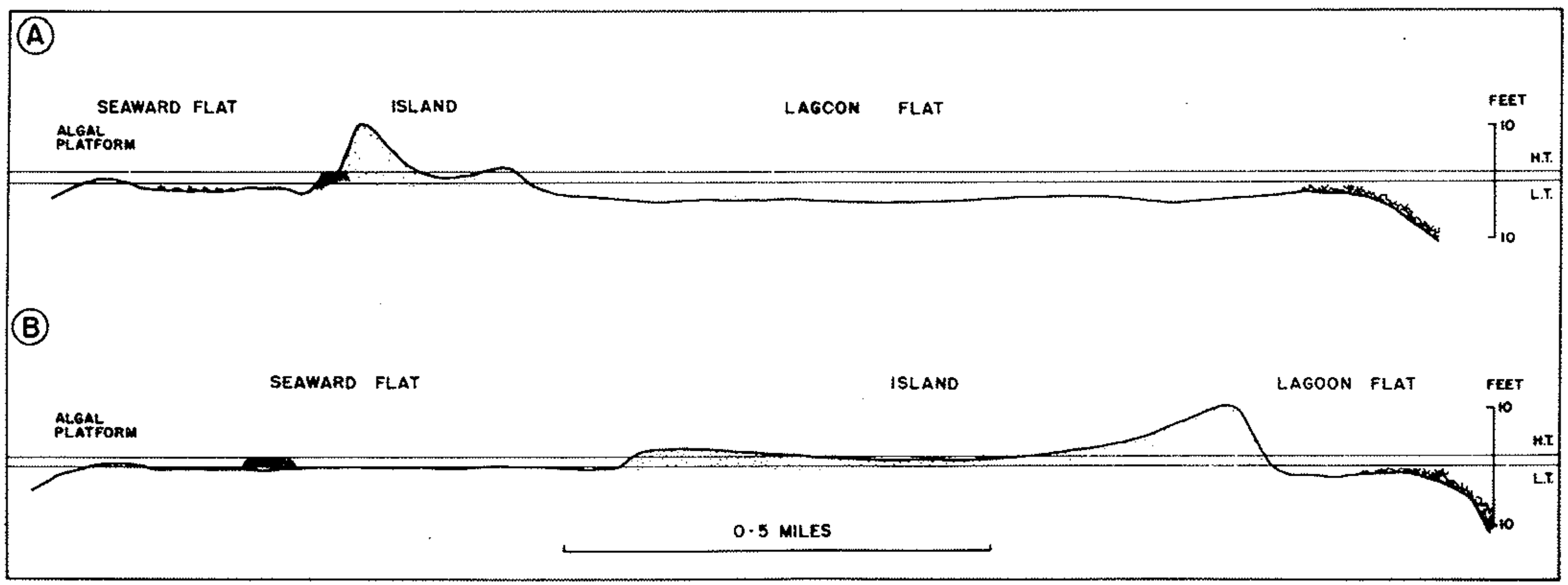

Fig. 8. Diagrammatic cross-section of peripheral atoll reefs at (A) Hitaddu and (B) Gan Islands, Addu Atoll.

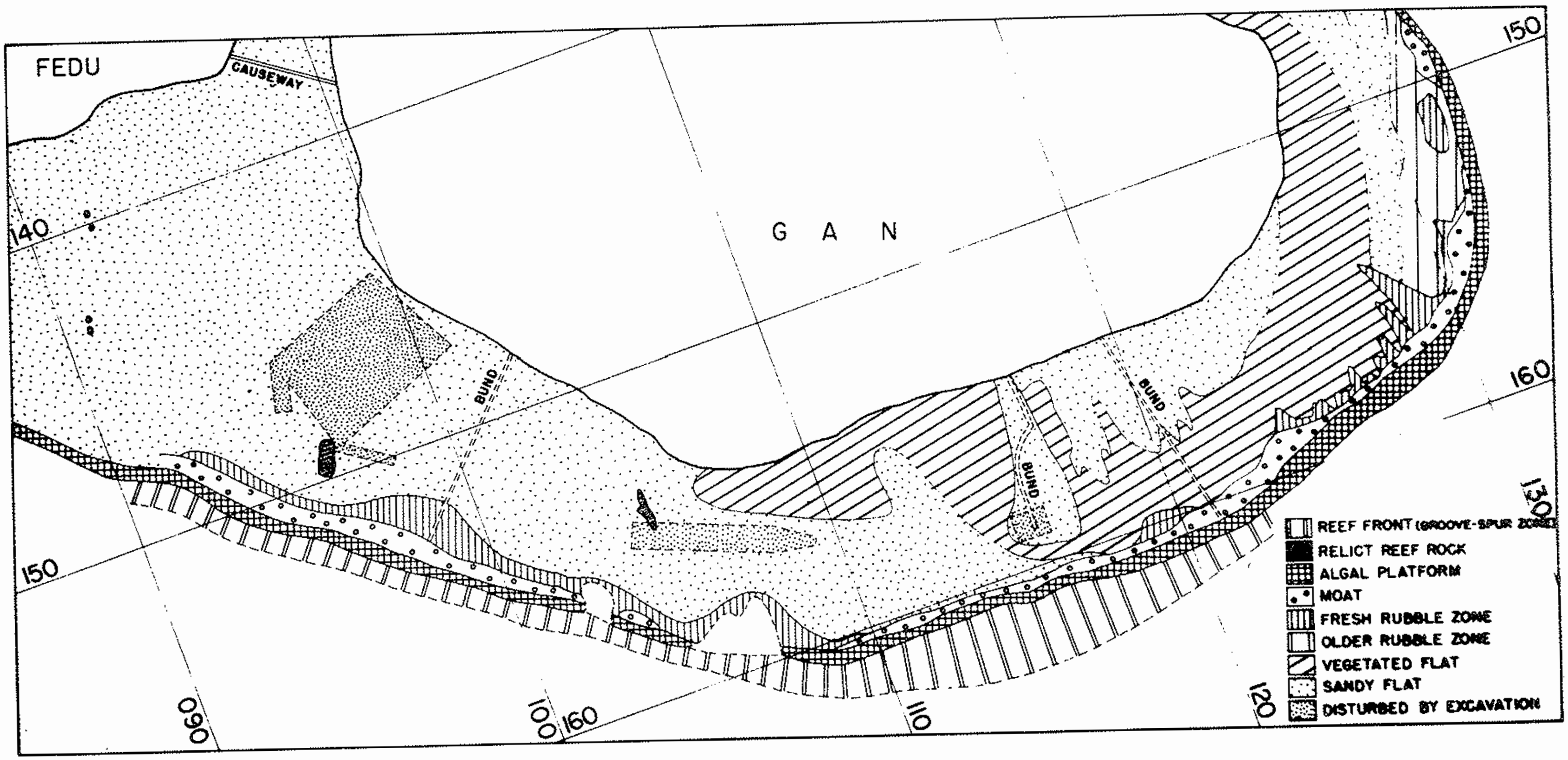

Fig. 9. Ecological zonation on the seaward reef flat at Gan Island

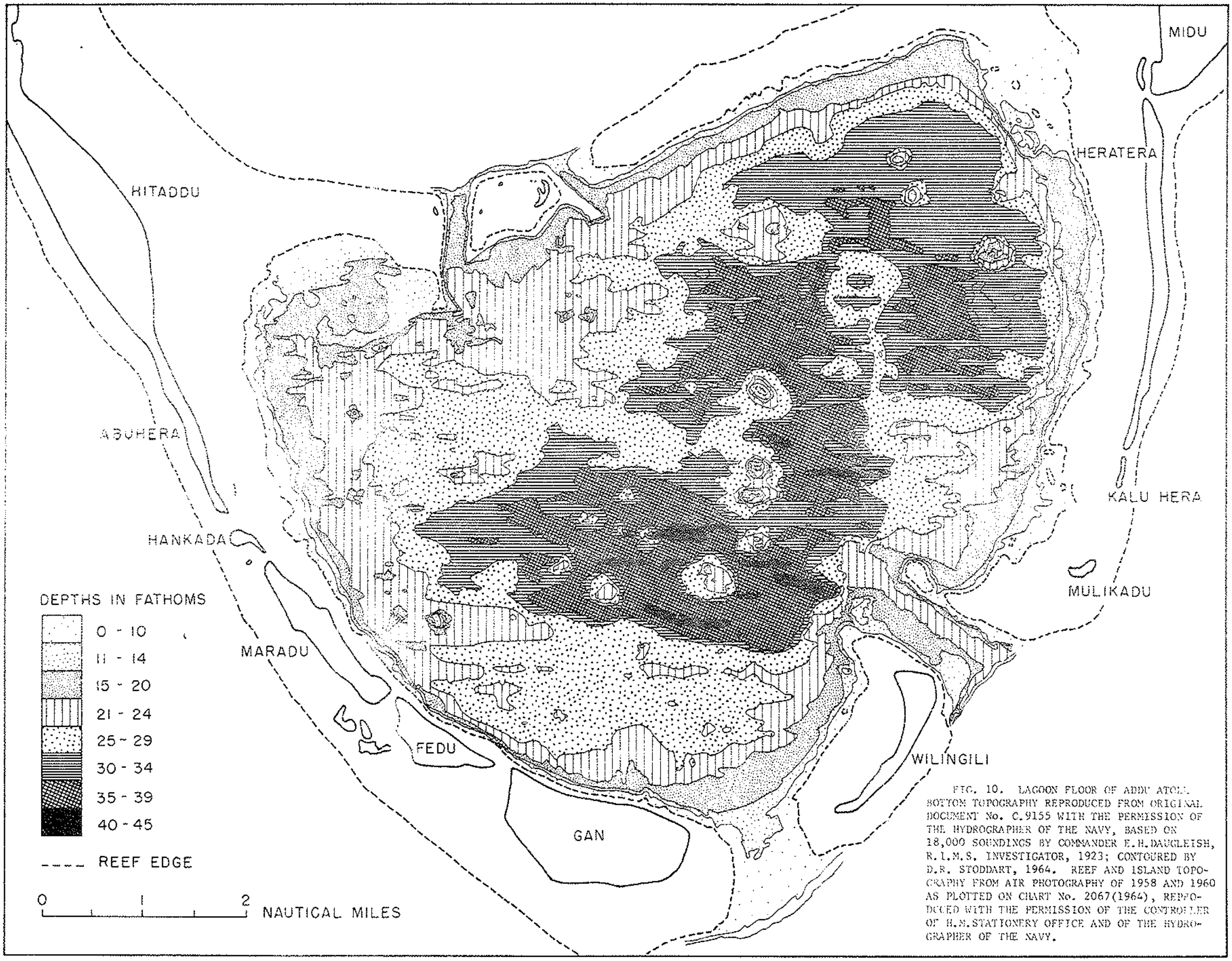

FIG. 10. LAGOON FLOOR OF ADDU ATOLL. BOTTOM TOPOGRAPHY REPRODUCED FROM ORIGINAL DOCUMENT No. C.9155 WITH THE PERMISSION OF THE HYDROGRAPHER OF THE NAVY, BASED ON 18,000 SOUNDINGS BY COMMANDER E.H.DAUGLEISH, R.I.M.S. INVESTIGATOR, 1923; CONTOURED BY D.R. STODDART, 1964. REEF AND ISLAND TOPOGRAPHY FROM AIR PHOTOGRAPHY OF 1958 AND 1960 AS PLOTTED ON CHART No. 2067(1964), REPRODUCED WITH THE PERMISSION OF THE CONTROLLER OF H.M.STATIONERY OFFICE AND OF THE HYDROGRAPHER OF THE NAVY.

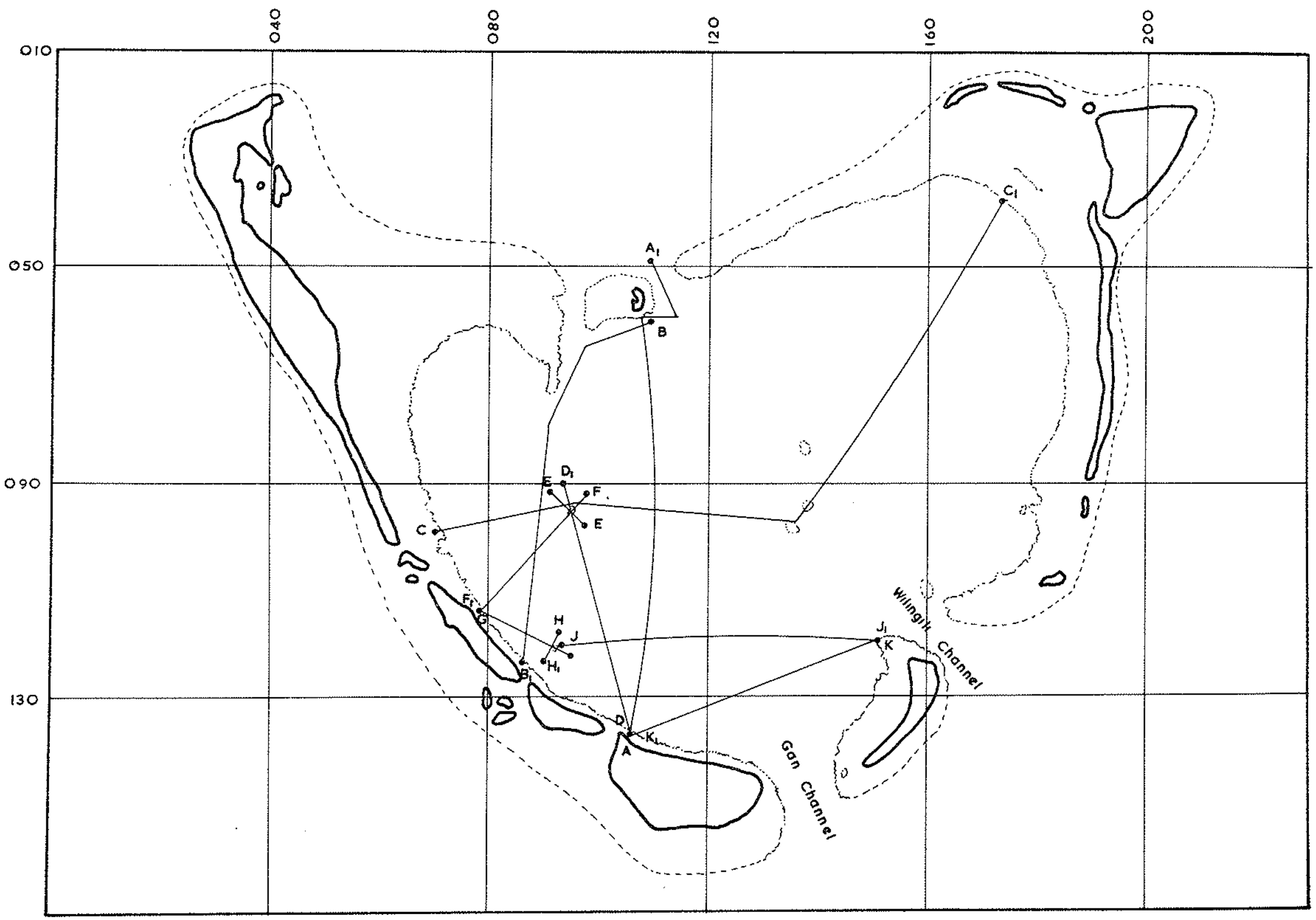

Fig. 11. Location of echosounding profiles in Addu Atoll lagoon.

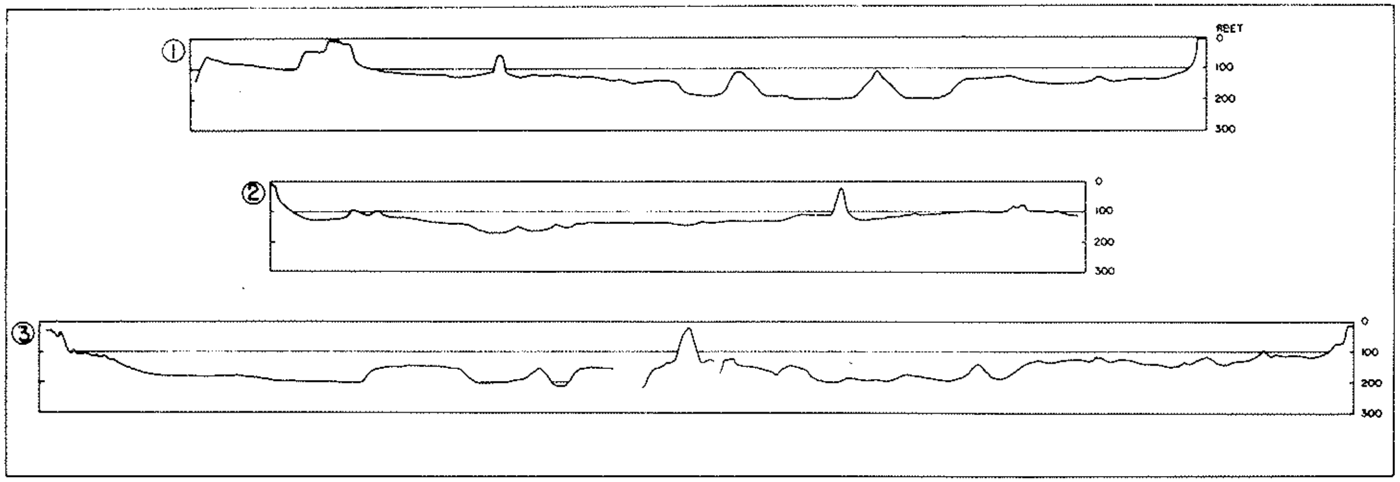

Fig. 12. Addu Atoll lagoon echosounding profiles 1-3; for location, see Figure 11, 1: A-A_1; 2, B-B_1; 3, C-C_1. Horizontal scale approximately 1:55,000

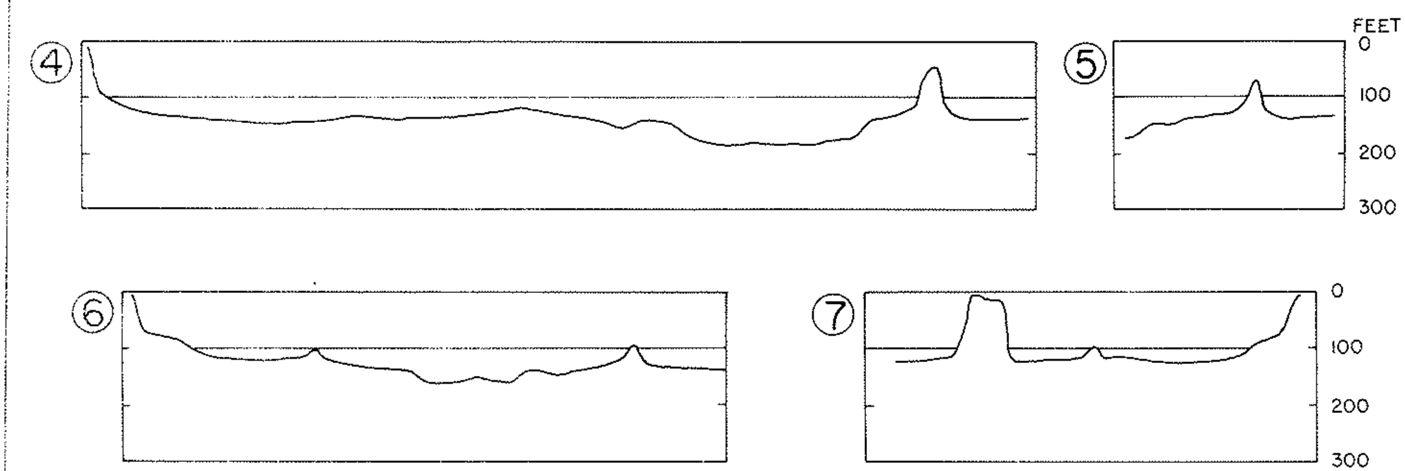

Fig. 13. Addu Atoll lagoon echosounding profiles 4-7; for location, see Figure 11, 4: D-D_1; 5: E-E_1; 6: F_1-F; 7: G_1-G. Horizontal scale approximately 1:28,000

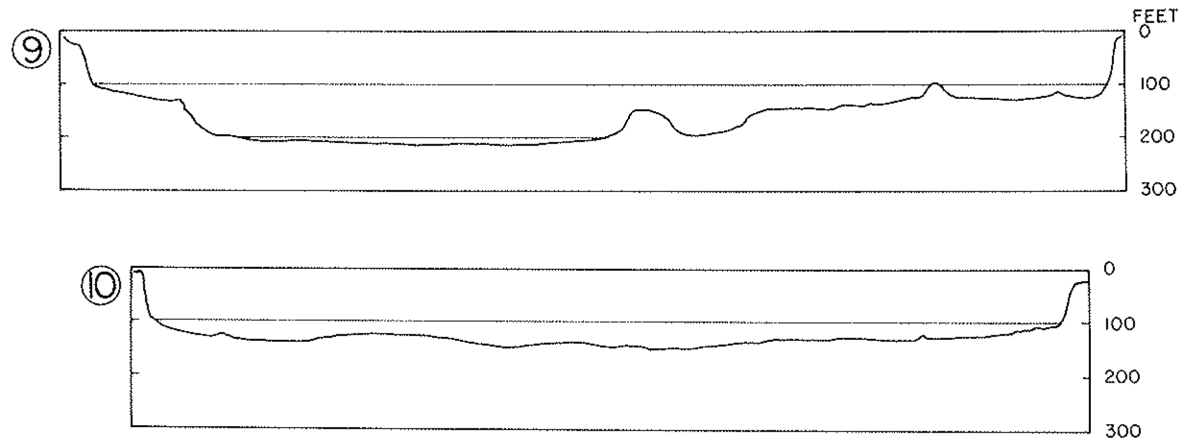

Fig. 14. Addu Atoll lagoon echosounding profiles 9-10; for location, see Figure 11, 9: J_1-J; 10, K_1-K. Horizontal scale approximately 1:27,000

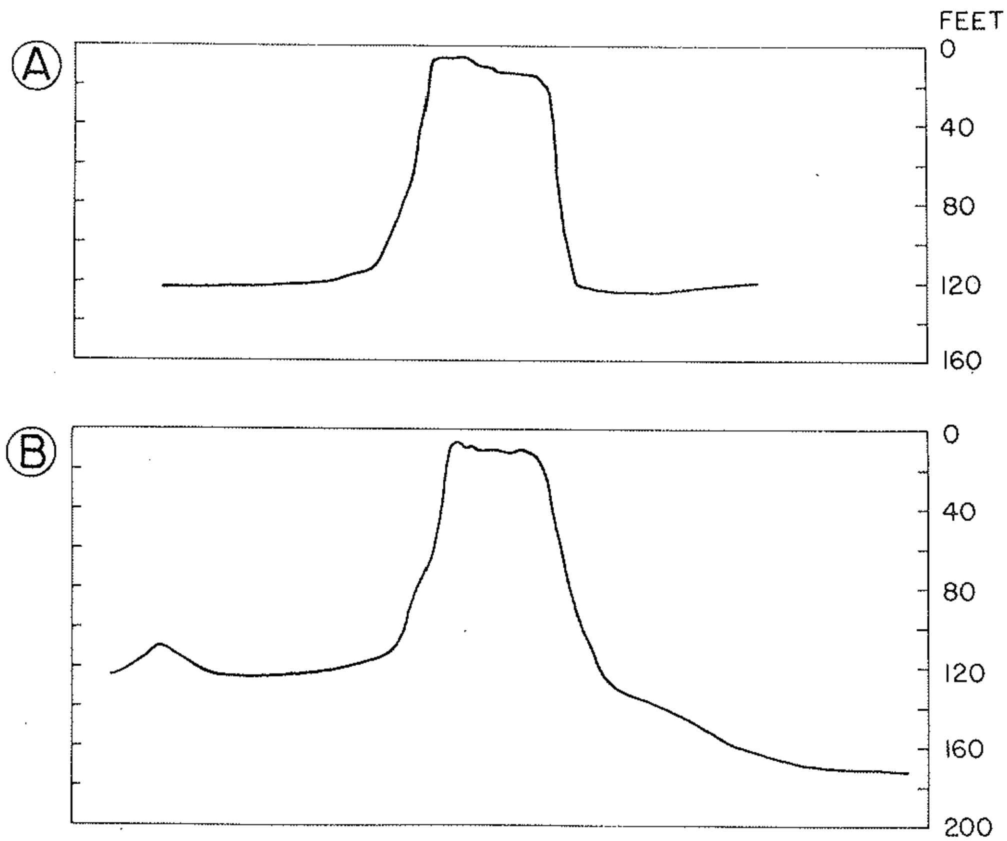

Fig. 15. Echosounding profiles of lagoon patch reef 24: (A) from profile 7, (B) from profile 8. For location, see Figure 11, A: G_1-G; B: H-H_1. The diameter of the summit is approximately 220 metres.

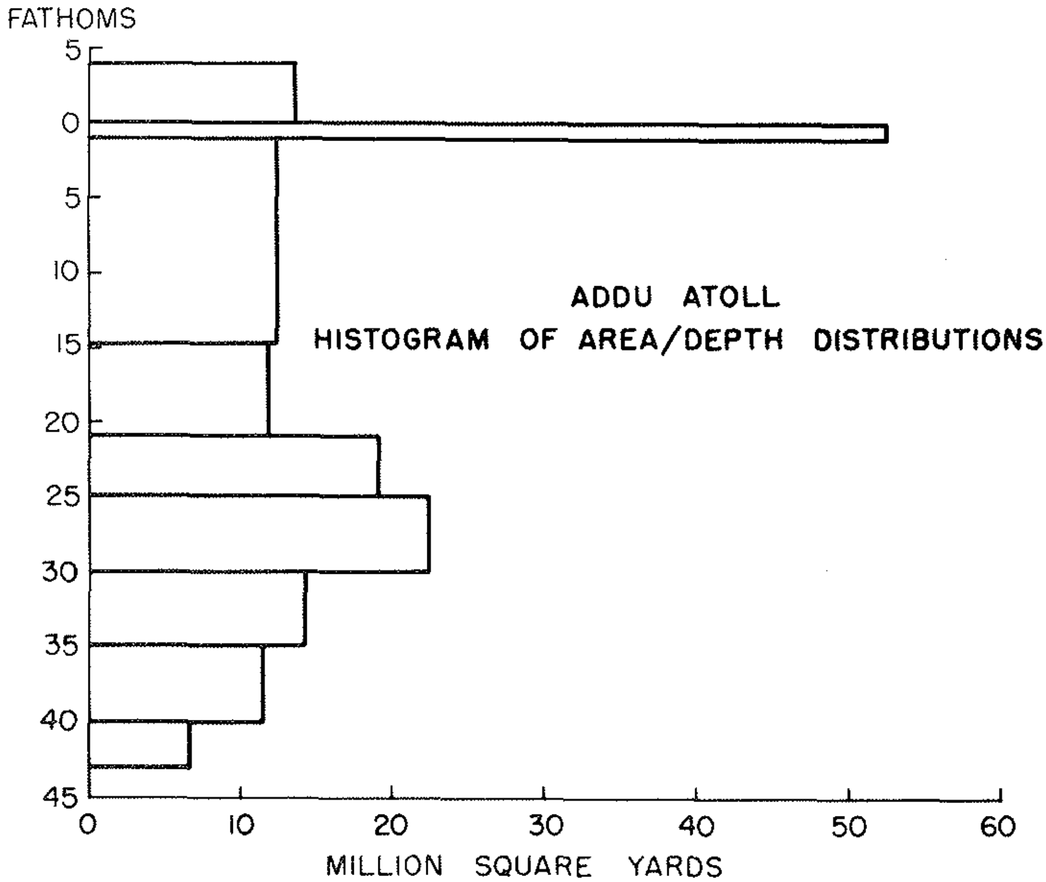

Fig. 16. Histogram showing area-depth distributions in Addu Atoll lagoon and peripheral reefs.

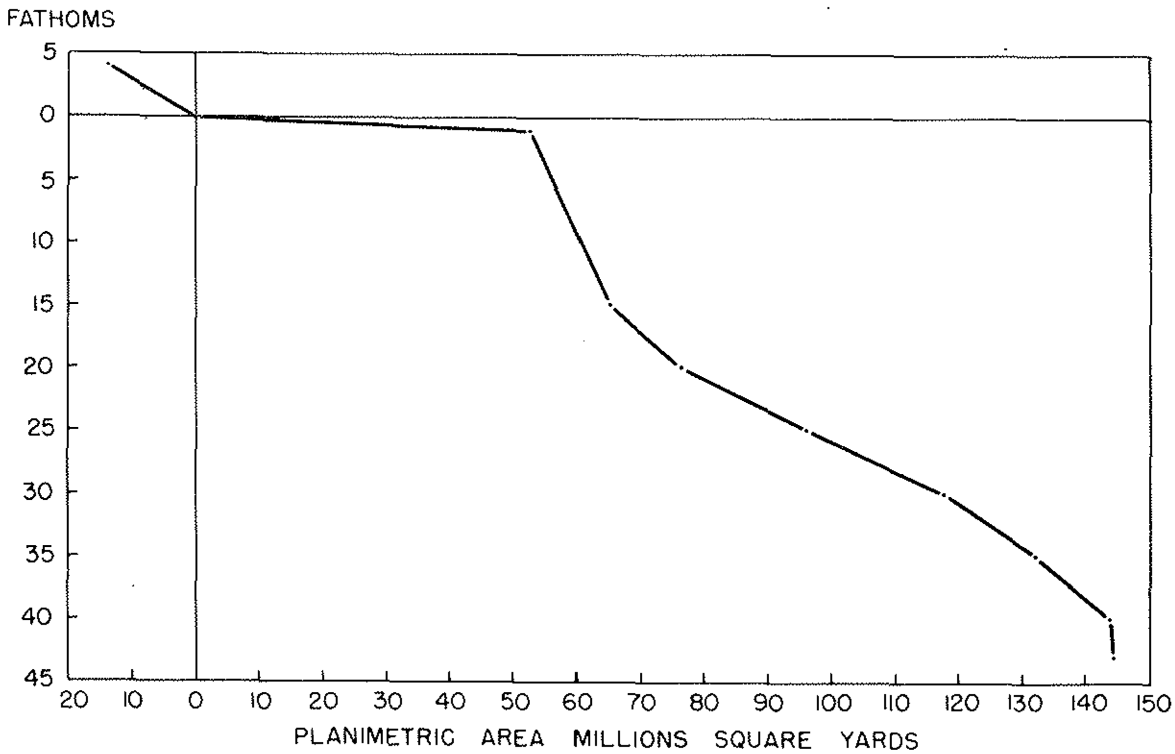

Fig. 17. Hypsometric curve for Addu Atoll lagoon and peripheral reefs.

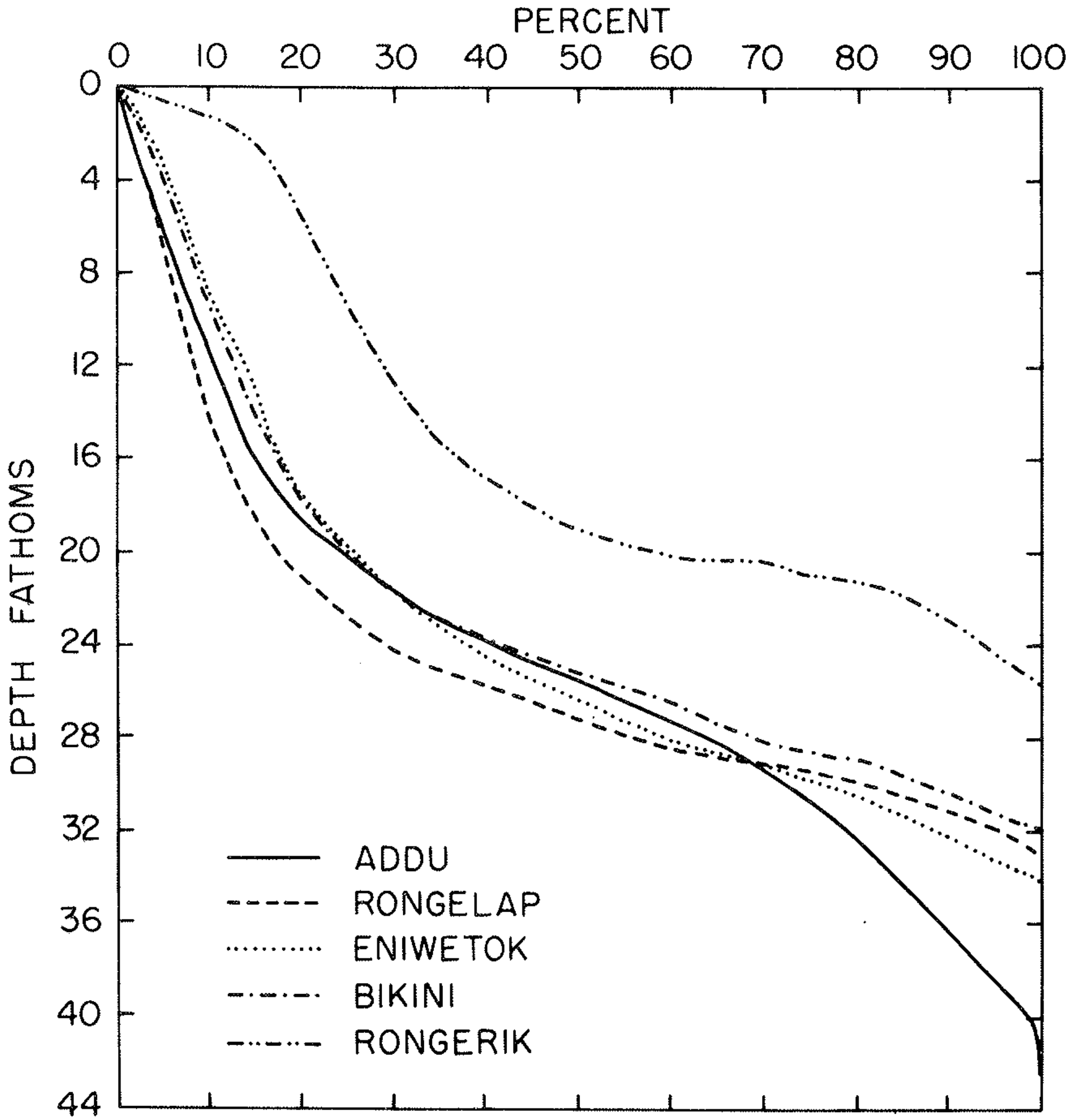

Fig. 18. Percentage hypsometric curves for Addu, Rongelap, Eniwetok, Bikini and Rongerik Atolls. Data for the Marshall Islands from Emery, Tracey and Ladd (1954).

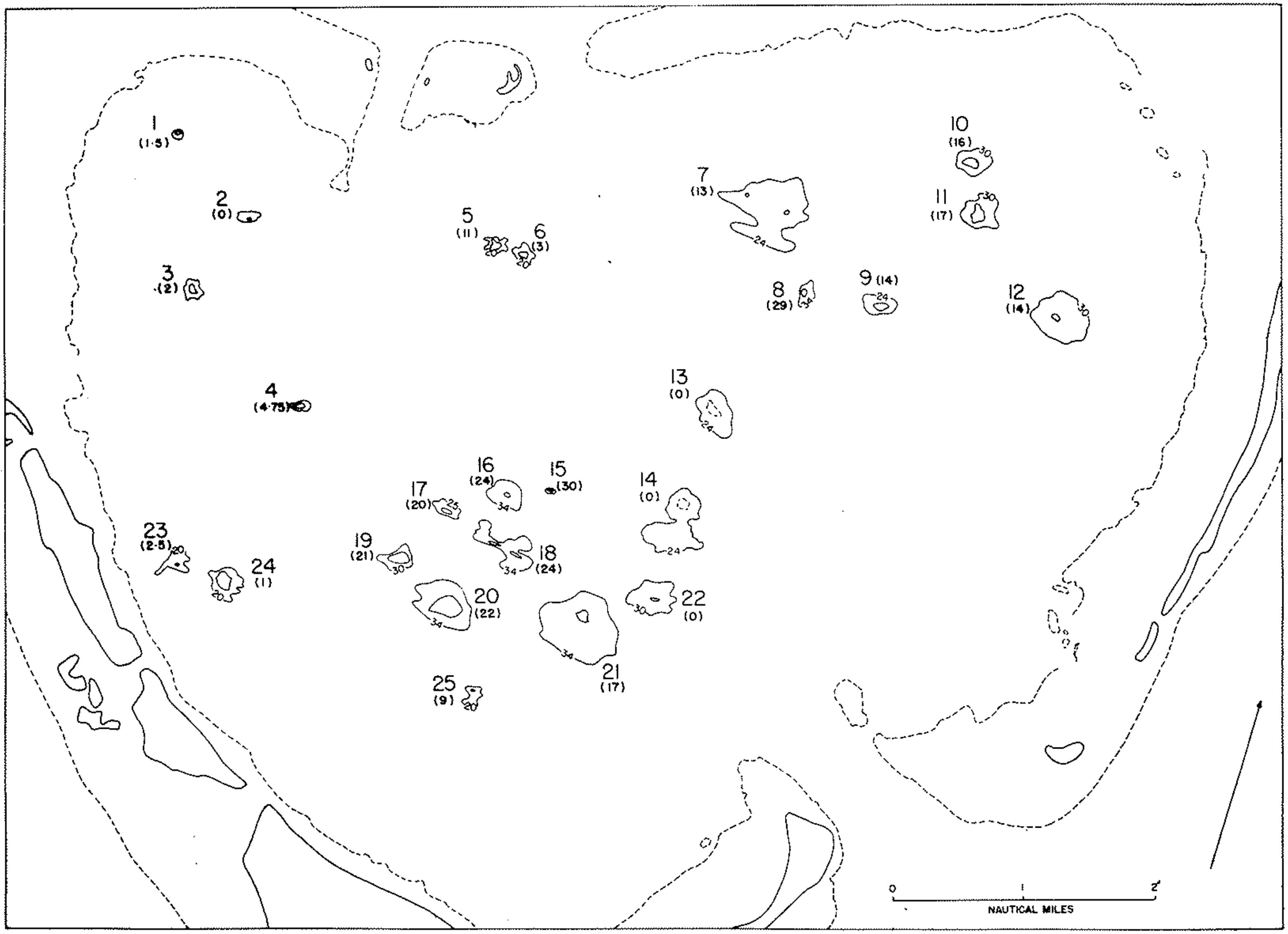

Fig. 19. Location and index numbers of Addu Atoll lagoon patch reefs and knolls, defined by their lowest closed contour. The small figure in brackets is the minimum recorded summit sounding. Based on the chart by Daugleish (1923).

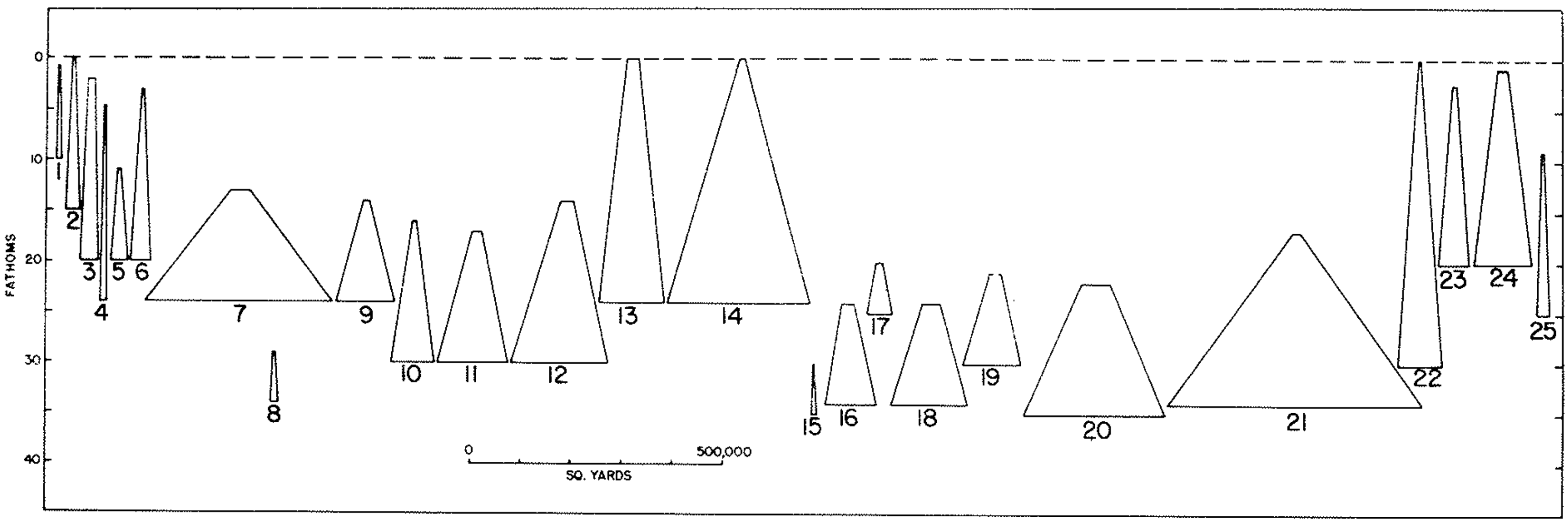

Fig. 20. Depth-area distribution of Addu lagoon patch reefs and knolls.

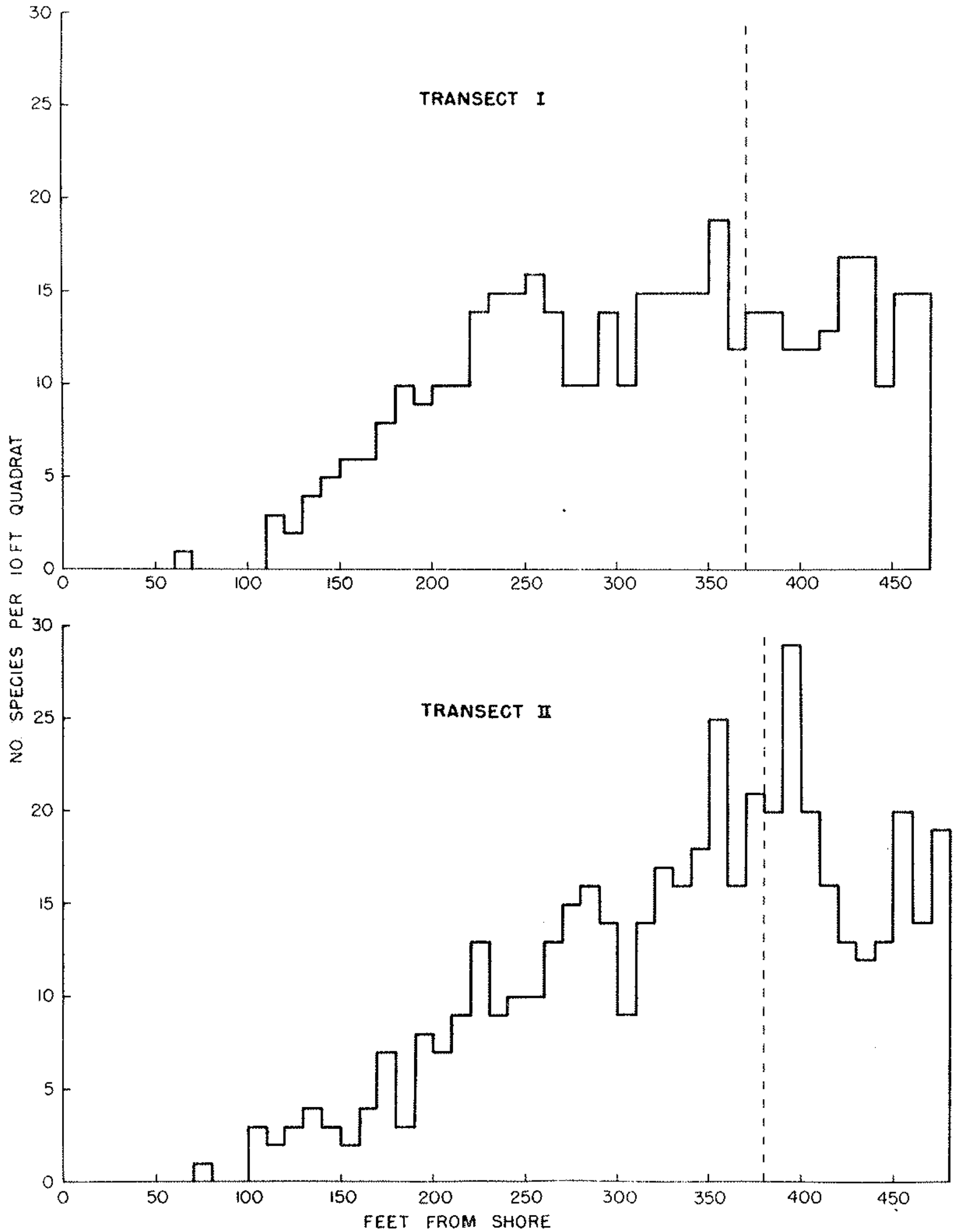

Fig. 21. Distribution of number of coral species across Gan lagoon reef transects I and II, based on field determinations of species collected in 10 ft quadrats.

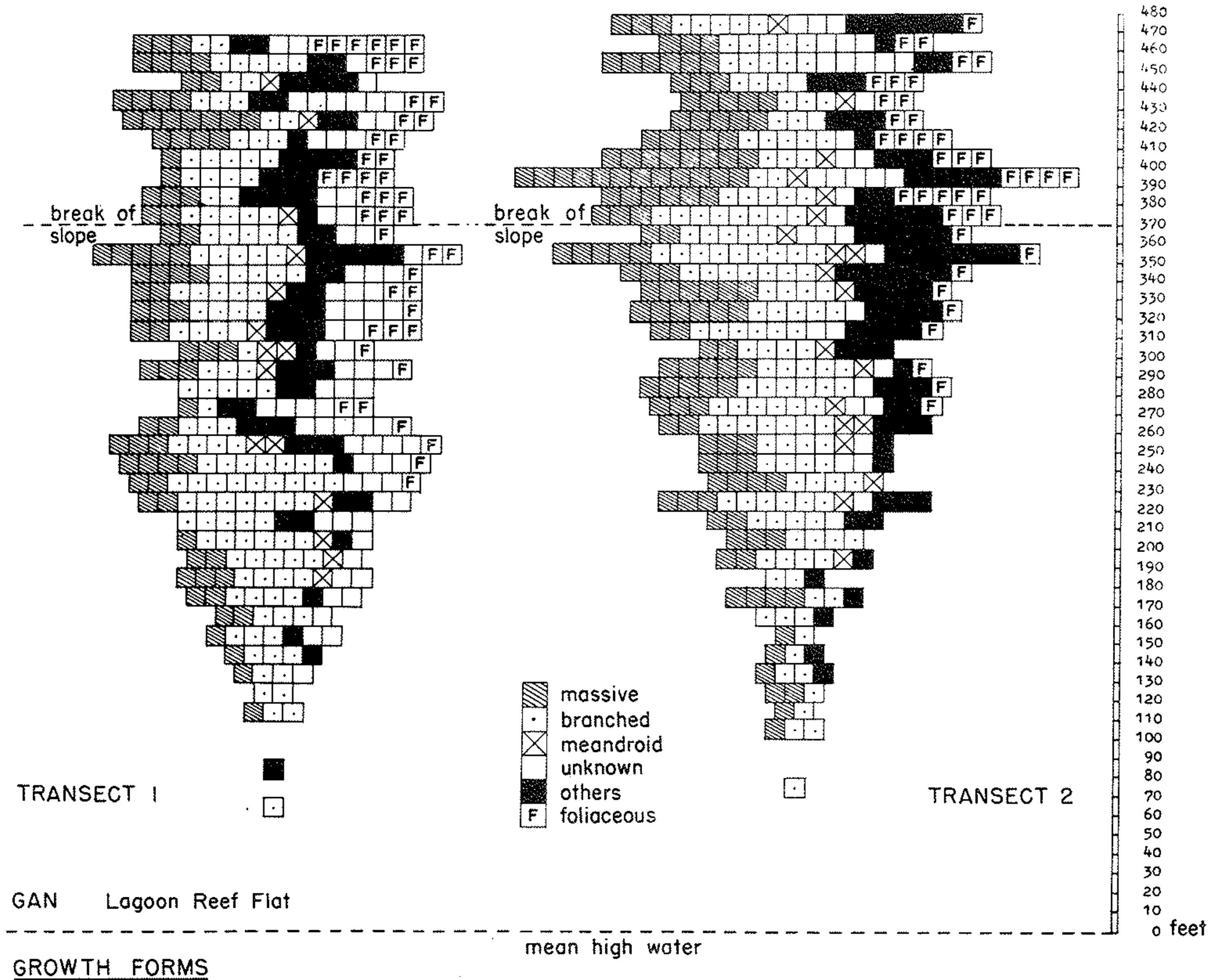

Fig. 22. Distribution of growth form of corals across Gan lagoon reef transects I and II.

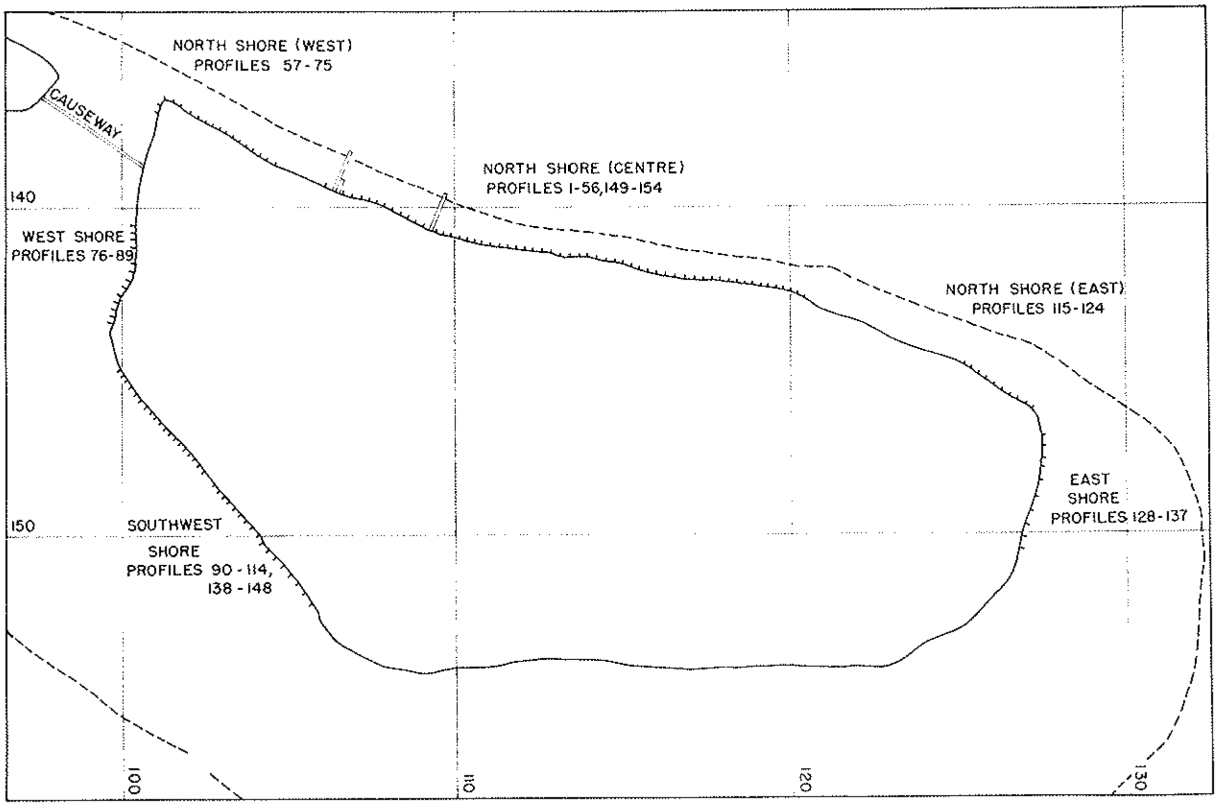

Fig. 23. Location of beach sectors and beach profiles at Gan Island.

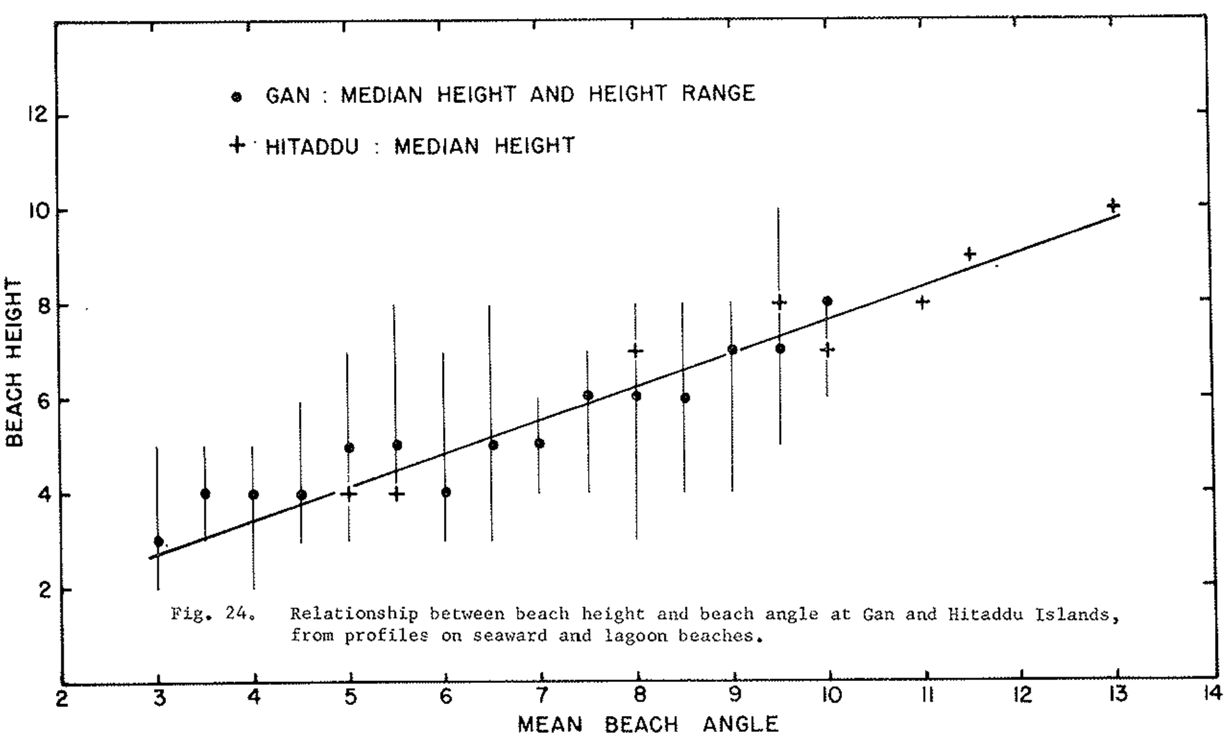

Fig. 24. Relationship between beach height and beach angle at Gan and Hitaddu Islands, from profiles on seaward and lagoon beaches.

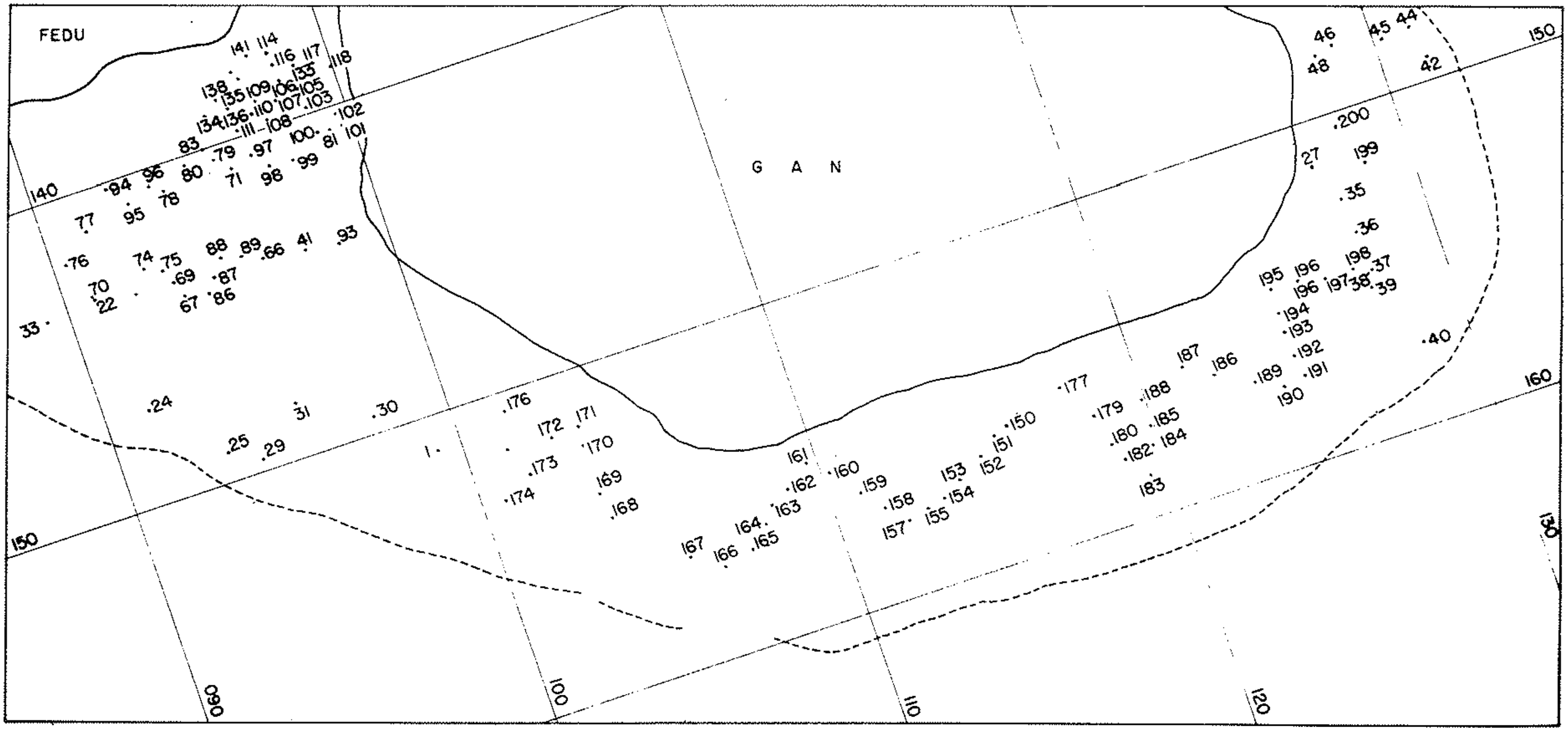

Fig. 25. Sediment sampling stations, seaward reef flat, Gan Island.

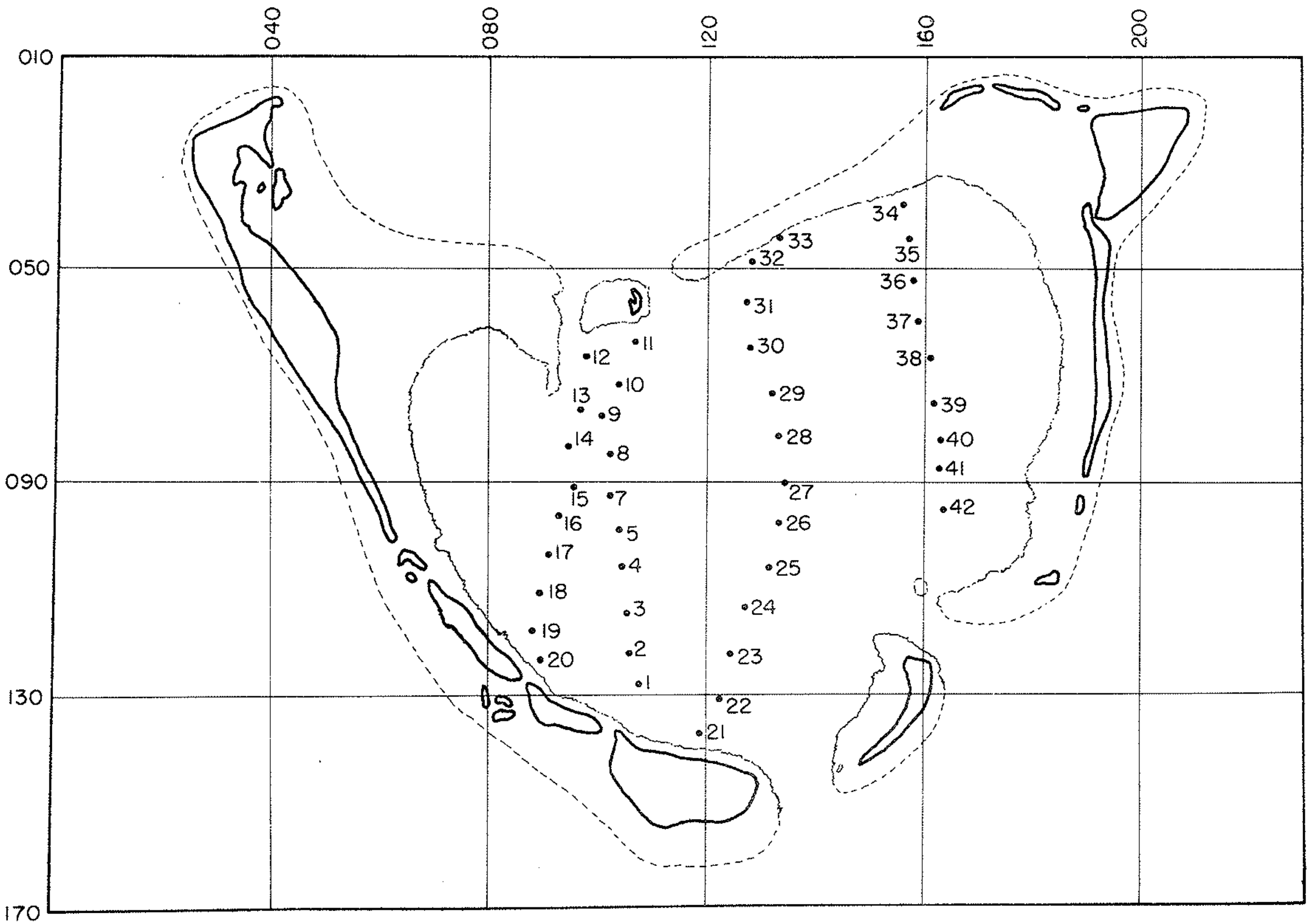

Fig. 26. Sediment sampling stations, lagoon floor, Addu Atoll.

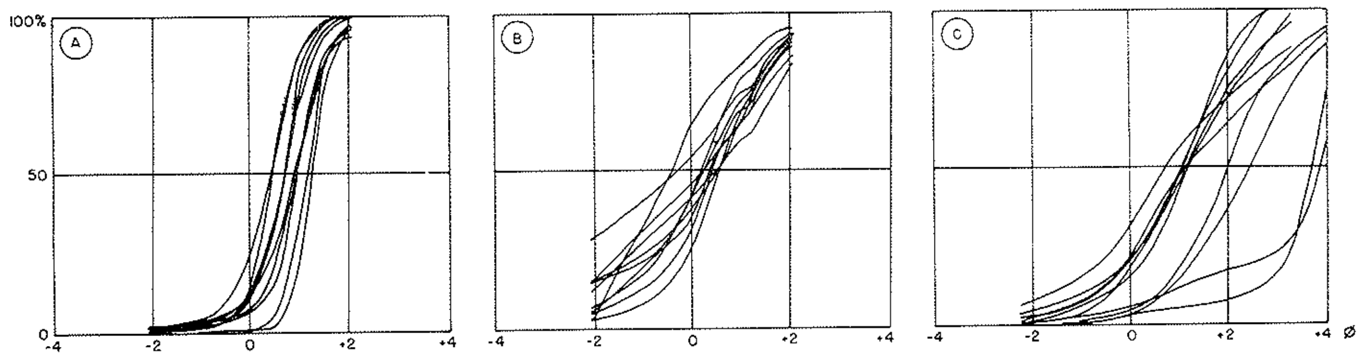

Fig. 27. Sample cumulative frequency curves for (A) Gan beach, (B) Gan seaward reef flat, and (C) Addu lagoon floor sediment samples.

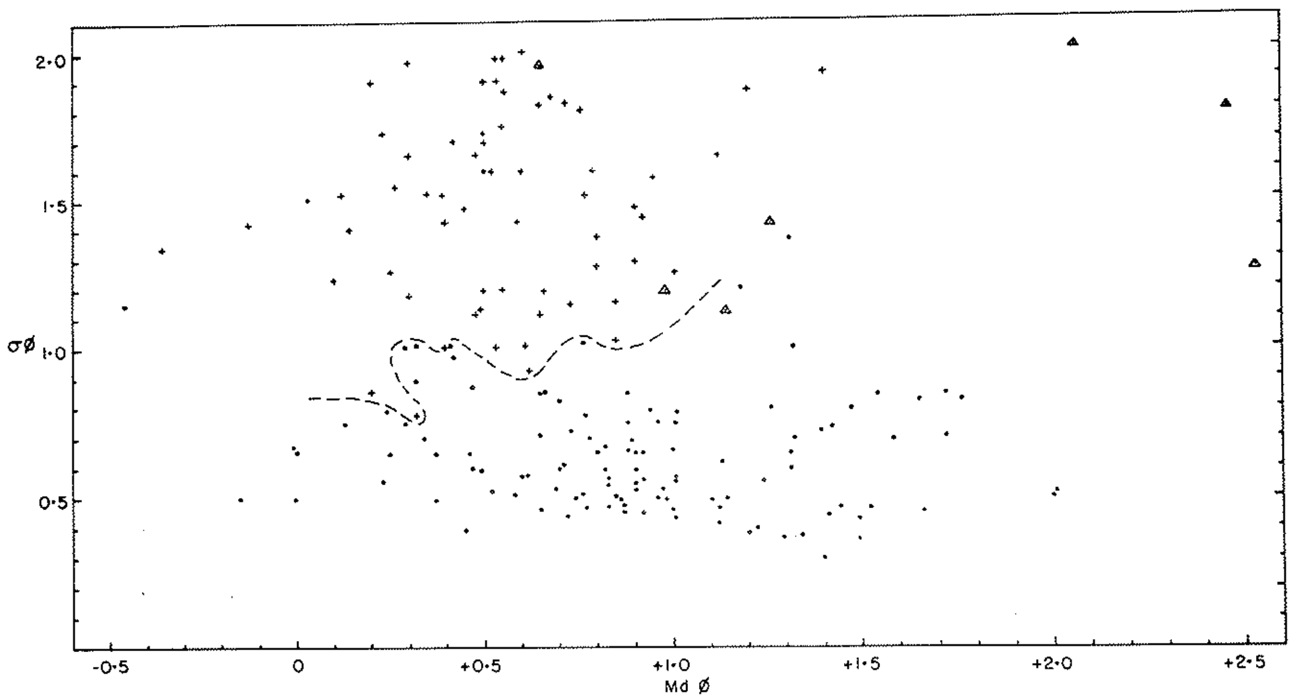

Fig. 28. Relationship betwen median size and sorting in sediment samples from Gan beaches (dots), Gan seaward reef flat (crosses), and Addu lagoon floor (triangles).

IV. PRELIMINARY LIST OF STONY CORALS FROM ADDU ATOLL

by

J. W. Wells and P. Spencer Davies

During the course of the quadrat transect surveys on the lagoon reef at Gan (see p. 28) a collection of corals was assembled. The method adopted was as follows: Each coral specimen removed and recorded from each quadrat was given a number to form the nucleus of a type collection. Subsequent corals were then compared with the types and assigned the relevant number. Any showing morphological differences from the type were given a new number and incorporated in the collection; this involved some duplication and the assemblage of a number of what later turned out to be growth forms and varieties of the same species. In this way it was possible to pinpoint the distribution of all corals collected along transects from the shore to the base of the lagoon slope. Collections were also made in a non-systematic manner whenever any corals were recognized as being not represented in the type collection. The collection therefore includes a few species which were collected on a shoal in Addu lagoon (no. 4, fig. 19) and on the seaward reef slope of the reefs to the north of the atoll.

Distribution has been related in the list to the reef terminology adopted by Tracey *et al.* (1955). On the lagoon reef flat, the area of living coral (which commences approximately one-third of the distance to the reef margin from the shore) has been divided into three arbitrary zones, *viz.*: *inner*, *mid* and *outer*. These have no ecological significance and are used solely to give greater precision in describing distribution.

Subclass	ZOANTHARIA
Order	SCLERACTINIA
Suborder	ASTROCOENIINA
Family	ASTROCOENIIDAE
Subfamily	Astrocoeniinae

Genus STYLOCOENIELLA

1) *Stylocoeniella guentheri* (Bassett-Smith)
    Lagoon slope, Gan. 20 to 80 ft.depth

Family THAMNASTERIIDAE

Genus PSAMMOCORA

1) *Psammocora nierstraszi* v.d. Horst
    Outer zone of lagoon reef flat, Gan.

2) *P.* (*Stephanaria*) *folium* Umbgrove
    Outer zone of lagoon reef flat, Gan.

3) P. (Stephanaria) togianensis Umbgrove
Lagoon slope, Gan. 20-70 ft. depth

4) P. (Stephanaria) sp. cf. P.(S). digitata M.E. & H.
Lagoon reef flat, Gan.

5) P. (Plesioseris) haimeana M.E. & H.
Outer zone, lagoon reef flat, Gan. Common.

Family POCILLOPORIDAE

Genus STYLOPHORA

1) Stylophora pistillata (Esper)
Mid to outer zone, lagoon reef flat, Gan.

2) Stylophora mordax (Dana)
Seaward reef slope, off Bushy Island, N. Addu. Depth 20 ft.

3) Stylophora subseriata (Ehrenberg)
Lagoon slope, Gan. Depth 70-80 ft.

Genus SERIATOPORA

1) Seriatopora angulata Klunzinger
Seaward reef slope off Bushy Island, N. Addu. Depth 20 ft.
Not recorded from reefs at Gan.

Genus POCILLOPORA

1) Pocillopora eydouxi M.E. & H.
Lagoon reef margin, Gan. Common.

2) Pocillopora meandrina Dana var. nobilis Verrill
Outer zone of lagoon reef flat and lagoon slope to 60 ft., Gan. Very common.

3) Pocillopora damicornis (Linn.)
Very common over whole of lagoon reef flat, Gan. One of the first corals found on the landward margin of growing coral on the reef flat.
P. sp. cf. P. damicornis (Linn.) - Stunted growth form.
Inner zone of lagoon reef flat, Gan.

4) Pocillopora ligulata Dana
Lagoon slope, Gan. Depth 10-90 ft.

5) Pocillopora acuta Lamarck
Lagoon slope, Gan. Depth 40-90 ft.

Family ACROPORIDAE

Genus ACROPORA

1) Acropora convexa (Dana)
   Found over whole surface of lagoon reef flat, Gan.
   Particularly abundant at lagoon reef margin.
   A. sp. cf. A. convexa (Dana)
   mid zone of lagoon reef flat, Gan.

2) Acropora intermedia (Brook)
   Mid zone lagoon reef flat, Gan.

3) Acropora humilis (Dana)
   Very common on whole of lagoon reef flat and to 15 ft. on lagoon slope, Gan. Also found in shallow pools behind algal pavement seaward reef flat, Gan and Hitaddu.

4) Acropora hemprichi (Ehrenberg)
   Lagoon reef margin and to depth of 20 ft on lagoon slope, Gan. Common at depths of 20 ft on seaward reef slope of Northern reefs, Addu.

4a) Acropora abrotanoides (Lamarck)
   Outer zone of lagoon reef flat, Gan.

5) Acropora formosa (Dana)
   Very common. Forms a distinct zone between mid and outer zone of lagoon reef flat. A similar species, tentatively identified as Acropora sp. cf. A. formosa is dominant over large areas of the lagoon slope, between 20 and 70 ft. Gan.

6) Acropora hyacinthus (Dana) "cytherea" form
   Lagoon reef margin, Gan.

7) Acropora forskali (Ehrenberg)
   Lagoon reef margin, Gan.

8) Acropora palifera (Lamarck)
   Not recorded on Gan reefs but abundant, in places dominant, on reef top and seaward margins of Northern reefs, Addu.

9) Acropora eurystoma (Klunzinger)
   Mid zone, lagoon reef flat, Gan.

10) Acropora variabilis (Klunzinger)
   Lagoon slope, Gan. Depth 50-80 ft.

11) Acropora corymbosa (Lamarck)
   Lagoon reef margin and lagoon slope to 50 ft. Gan.

12) Acropora syringodes (Brook)
   Lagoon reef margin and lagoon slope to 80 ft. Gan.

13) *Acropora* sp. cf. *A. conigera* (Dana)
Outer zone, lagoon reef flat, Gan.

14) *Acropora rotumana* (Gardiner)
Outer zone, lagoon reef flat, Gan.

15) *Acropora hystrix* (Dana)
Lagoon slope, Gan. Depth 80 ft.

16) *Acropora squarrosa* (Ehrenberg)
Lagoon slope, Gan. Depth 30 ft.

17) *Acropora* n. sp. ?
"Five Fathom Shoal", Addu Lagoon. Depth 70 ft.

Genus ASTREOPORA

1) *Astreopora myriophthalma* (Lamarck)
Lagoon reef flat and lagoon slope to 35 ft, Gan. Also recorded from "Five Fathom Shoal", Addu Lagoon. Depth 50 ft.

2) *Astreopora ocellata* Bernard
Lagoon reef flat, mid zone to reef margin and to depth of 20 ft on lagoon slope. Gan.

3) *Astreopora listeri* Bernard
Lagoon slope, Gan. Depth 15 ft.

4) *Astreopora* sp. cf. *A. gracilis* Bernard
Lagoon slope, Gan. Depth 65 ft.

5) *Astreopora* sp. cf. *A. incrustans* Bernard
Lagoon slope, Gan. Depth 40 ft.

Genus MONTIPORA

1) *Montipora sinensis* Bernard
Lagoon reef margin, Gan.

2) *Montipora danae* M.E. & H.
Lagoon slope, Gan. Depth 90 ft.

3) *Montipora pulcherrima* Bernard
Lagoon slope, Gan. Depth 90 ft.

4) *Montipora* sp. cf. *M. foliosa* (Pallas)
Lagoon slope, Gan. Depth 50 ft.

Suborder FUNGINA
Superfamily AGARICIICAE
Family AGARICIIDAE

Genus PAVONA

1) Pavond gardineri v.d. Horst
Lagoon slope, Gan. Depth 15 ft.

2) Pavona clavus (Dana)
Lagoon slope, Gan. Depth 20-60 ft.

3) Pavona varians Verrill
Widely distributed. Mid to outer lagoon reef flat and lagoon slope to depth of 80 ft. Gan.
var. "repens"
Lagoon slope, Gan. Depth 60-80 ft.

4) Pavona (Polyastra?) acuticarinata (Umbgrove)
Lagoon slope, Gan. Depth 50 ft.

5) Pavona (Polyastra) sp. cf. P. (P.) planulata (Dana)
Lagoon reef margin to 80 ft on lagoon slope, Gan.

6) Pavona (Polyastra?) ponderosa (Gardiner)
Seaward reef slope, Bushy Island. Depth 30 ft.

7) Pavona (Polyastra?) n. sp.
Lagoon slope, Gan. Depth 50 ft.

8) Pavona (Polyastra) sp.
Lagoon slope, Gan. Depth 60 ft.

9) Pavona (Pseudocolumnastraea) sp. cf. P. maldivensis Gardiner
Lagoon slope, Gan. Depth 60 ft.

Genus LEPTOSERIS

1) Leptoseris gardineri v.d. Horst
Forms large colonies in sand at base of lagoon slope, Gan. Depth 90-100 ft.

2) Leptoseris incrustans (Quelch)
Lagoon slope, Gan. Depth 60 ft.

Genus PACHYSERIS

1) Pac yseris speciosa (Dana)
Lagoon reef margin and lagoon slope to 60 ft. Gan.

2) Pachyseris levicollis (Dana)
Lagoon slope Gan. Depth 40-70 ft.

3) Pachyseris valenciennesi M.E. & H.
Lagoon reef margin and lagoon slope to 30 ft. Gan.

Family SIDERASTREIDAE

Genus COSCINARAEA

1) *Coscinaraea monile* (Forskaal)
"Five Fathom Shoal", Addu Lagoon. Depth 50 ft.
Mid zone, lagoon reef flat, Gan.

Superfamily FUNGIICAE
Family FUNGIIDAE

Genus FUNGIA

1) *Fungia scutaria* Lamarck
Lagoon reef margin to 50 ft on lagoon slope, Gan.

2) *Fungia repanda* Dana
Lagoon reef margin to 90 ft on lagoon slope. Gan. Common.

3) *Fungia echinata* (Pallas)
Lagoon slope, Gan. Depth 70-90 ft.

4) *Fungia fungites* (Linnaeus)
Very common on whole of lagoon reef flat, Gan, attached stage commonly on *Acropora formosa*. Not recorded from lagoon slope.

Genus HERPOLITHA

1) *Herpolitha limax* (Esper)
Lagoon reef margin to 60 ft on lagoon slope, Gan. Common.

Genus POLYPHYLLIA

1) *Polyphyllia talpina* (Lamarck)
Lagoon floor at base of lagoon slope, depth 80-100 ft.
Gan and Northern reefs, Addu. Tentacles extended during day.

Genus HALOMITRA

1) *Halomitra philippinensis* Studer
Lagoon slope, Gan. Depth 50-90 ft. Common.

Superfamily PORITICAE
Family PORITIDAE

Genus GONIOPORA

1) *Goniopora minor* Crossland
Lagoon reef margin to 80 ft on lagoon slope, Gan.

2) Goniopora sp. aff. G. planulata (Ehrenberg) cf. Klunzinger
Seaward reef slope, Bushy Island. Depth 30 ft.

Genus PORITES

1) Porites solida (Forskaal)
No distribution data available.

2) Porites lutea M.E. & H.
Lagoon slope, Gan. Depth 10-100 ft.

3) Porites lichen Dana
Lagoon slope, Gan. Depth 90 ft.

4) Porites sp. cf. P. alveolata
Outer zone, lagoon reef flat, Gan.

5) Porites (Synaraea) monticulosa (Dana)
Lagoon slope, Gan. Depth 15-90 ft.

6) Porites (Synaraea) n. sp.? aff. P.(S.) horizontalata Hoffmeister
Lagoon slope, Gan. Depth 70 ft.

7) Porites sp. (cf."P. mauritius 5" Bernard)
Seaward reef edge, Gan.

Genus ALVEOPORA

1) Alveopora sp. cf. A. viridis (Quoy & Gaimard)
Lagoon slope, Gan. Depth 70 ft.

Suborder FAVIINA
Superfamily FAVIICAE
Family FAVIIDAE
Subfamily Faviinae

Genus CAULASTREA

1) Caulastrea furcata Dana
Mid zone of lagoon reef flat, Gan.

2) Caulastrea tumida (Matthai)?
"Five Fathom Shoal", Addu Lagoon. Depth 50 ft.

Genus PLESIASTREA

1) Plesiastrea versipora (Lamarck)
Lagoon slope, Gan. Depth 80 ft. "Five Fathom Shoal", Addu Lagoon. Depth 70 ft.

Genus FAVIA

1) *Favia valenciennesi* (M.E. & H.)
Lagoon reef flat, Gan.

2) *Favia rotumana* (Gardiner)
Lagoon reef flat, Gan.

3) *Favia stelligera* (Dana)
Lagoon reef margin, Gan.

4) *Favia favus* (Forskaal)
Inner zone of lagoon reef flat to 40 ft on lagoon slope, Gan. Also mid zone, lagoon reef flat, Gan.

5) *Favia pallida* (Dana)
Mid zone of lagoon reef flat to 30 ft on lagoon slope, Gan.

6) *Favia hululensis* Gardiner
Mid zone, lagoon reef flat, Gan.

7) *Favia speciosa* (Dana)
Lagoon reef flat, mid zone, to 80 ft on lagoon slope, Gan. Also at depth of 60 ft on "Five Fathom Shoal", Addu Lagoon.
F. speciosa Dana "clouei" form
Lagoon slope 80 ft, Gan.
F. sp. cf. *F. speciosa* Dana
"Five Fathom Shoal", Addu Lagoon. Depth 60 ft.

Genus FAVITES

1) *Favites melicerum* (Ehrenberg)
Mid zone of lagoon reef flat, Gan.

2) *Favites halicora* (Ehrenberg)
Lagoon slope, Gan. Depth 50-80 ft.
F. sp. cf. *F. halicora* (Ehrenberg)
Lagoon reef margin and to 80 ft on lagoon slope, Gan.

3) *Favites ehrenbergi* (Klunzinger)
Lagoon slope, Gan. Depth 50-60 ft.

4) *Favites hemprichi* (Ehrenberg)
Mid zone of lagoon reef flat, Gan.

5) *Favites complanata* (Ehrenberg)
Lagoon reef margin, Gan.

6) *Favites pentagona* (Esper)
Lagoon slope, Gan. Depth 80 ft.

7) *Favites abdita* (Ellis & Solander)
Mid and outer zone of lagoon reef flat and to 70 ft on lagoon slope, Gan.

8) Favites flexuosa (Dana)
Lagoon slope, Gan. Depth 15-90 ft.

Genus OULOPHYLLIA

1) Oulophyllia crispa (Lamarck)
Lagoon reef margin, Gan.

Genus GONIASTREA

1) Goniastrea retiformis (Lamarck)
Middle to outer zone, and reef margin of lagoon reef flat, Gan.
One of the commonest massive corals on this reef.
G. retiformis (Lamarck) var. parvistella (Dana)
Mid to outer lagoon reef flat and to 20 ft on lagoon slope, Gan.

2) Goniastrea pectinata (Ehrenberg)
Lagoon slope, Gan. Depth 15-80 ft. Also recorded from "Five Fathom Shoal", Addu Lagoon. Depth 50 ft.

Genus PLATYGYRA

1) Platygyra lamellina Ehrenberg
Outer zone, lagoon reef flat, Gan.
P. lamellina Ehrenberg forma sinensis (M.E. & H.)
Outer zone of lagoon reef flat, Gan.
P. lamellina Ehrenberg forma rustica (Dana)
Mid to outer zone of lagoon reef flat, Gan.
P. lamellina Ehrenberg forma astreiformis (M.E. & H.)
Outer zone of lagoon reef flat, Gan.

Genus LEPTORIA

1) Leptoria phrygia (Ellis & Solander)
Mid zone to reef margin of lagoon reef flat, Gan. Very common.

Genus HYDNOPHORA

1) Hydnophora exesa (Pallas)
Mid zone, lagoon reef flat, Gan.

2) Hydnophora microconos (Lamarck)
Outer zone, lagoon reef flat, Gan.

Subfamily Montastreinae

Genus DIPLOASTREA

1) Diploastrea helipora (Lamarck)
Lagoon slope 60 to 100 ft, Gan and Fedu. Forms massive sheets at base of lagoon slope. One such mass measured approximately 15 x 20 ft.

Genus LEPTASTREA

1) Leptastrea transversa Klunzinger
Mid zone, lagoon reef flat, Gan.

2) Leptastrea purpurea (Dana)
Mid zone, lagoon reef flat to 30 ft on lagoon slope, Gan.

Genus CYPHASTREA

1) Cyphastrea microphthalma (Lamarck)
Mid zone, lagoon reef flat to reef margin and to depth of 90 ft on lagoon slope, Gan.

Genus ECHINOPORA

1) Echinopora lamellosa (Esper)
Outer zone of lagoon reef flat to 40 ft on lagoon slope. Dominant coral in places at lagoon reef margin at Gan; less frequent at Fedu.

Family OCULINIDAE
Subfamily Galaxeinae

Genus GALAXEA

1) Galaxea fascicularis (Lamarck)
Mid to outer zone, lagoon reef flat, Gan. "Five Fathom Shoal", Addu Lagoon, depth 40 ft.

2) Galaxea clavus (Dana)
Mid zone of lagoon reef flat, reef margin and lagoon slope to 80 ft, Gan. Very common.

Genus MERULINA

1) Merulina ampliata (E. & S.)
Outer zone of lagoon reef flat and to 90 ft on lagoon slope, Gan.
M. sp. cf. M. ampliata (E. & S.) (M. regalis Dana?)
Lagoon reef margin to 40 ft on lagoon slope, Gan.

Family MUSSIDAE

Genus ACANTHASTREA

1) Acanthastrea echinata (Dana)
Lagoon slope, Gan. Depth 60 ft.

Genus CYNARINA

1) Cynarina lacrymalis (M.E. & H.)
Lagoon slope 80-100 ft, Gan.

Genus LOBOPHYLLIA

1) *Lobophyllia corymbosa* (Forskaal)
   Outer zone of lagoon reef flat to 20 ft on lagoon slope, Gan.

2) *Lobophyllia costata* (Dana)
   Lagoon reef flat and to 30 ft on lagoon slope, Gan.

3) *Lobophyllia* sp. cf. *L. hemprichi* (Ehrenberg)
   Lagoon slope, Gan. Depth 100 ft.

4) *Lobophyllia* sp. cf. *L. fistulosa* (M.E. & H.)

Genus SYMPHYLLIA

1) *Symphyllia radians* M.E. & H.
   Mid to outer zones of lagoon reef flat and to 80 ft on lagoon slope, Gan.

2) *Symphyllia* sp. cf. *S. nobilis* (Dana)
   Mid zone of lagoon reef flat and to 40 ft on lagoon slope, Gan.

3) *Symphyllia valenciennesi* M.E. & H.
   Lagoon slope, Gan. Depth 90 ft.

Family PECTINIIDAE

Genus ECHINOPHYLLIA

1) *Echinophyllia aspera* (E. & S.)
   Lagoon slope, Gan. Depth 20-90 ft.

Genus PECTINIA

1) *Pectinia alcicornis* (Saville Kent)
   Lagoon slope, Gan. Depth 60-80 ft.

Genus OXYPORA

1) *Oxypora lacera* (Verrill)
   Lagoon slope, Gan. Depth 15-80 ft.

Genus MYCEDIUM

1) *Mycedium tubifex* (Dana)
   Lagoon slope, Gan. Depth 50-80 ft.

Suborder CARYOPHYLLIINA
Superfamily CARYOPHYLLIICAE
Family CARYOPHYLLIIDAE
Subfamily Eusmiliinae

Genus EUPHYLLIA

1) *Euphyllia glabrescens* (Chamisso & Eysenhardt)
   Mid to outer zone, lagoon reef flat, Gan.

2) Euphyllia fimbriata (Spengler)
Lagoon slope, Gan. Depth 60 ft.

Genus PLEROGYRA

1) Plerogyra sinuosa (Dana)
Lagoon slope, Gan. Depth 30-90 ft.

Suborder DENDROPHYLLIINA
Family DENDROPHYLLIIDAE

Genus DENDROPHYLLIA

1) Dendrophyllia micrantha (Ehrenberg)
In sand at base of lagoon slope, Gan. Depth 100-110 ft.

Genus TUBASTRAEA

1) Tubastraea aurea (Quoy & Gaimard)
Beneath overhangs, in shade on dead boulders, lagoon reef margin, Gan.

2) Tubastraea diaphana (Dana)
Similar distribution to T. aurea.

Genus TURBINARIA

1) Turbinaria peltata (Esper)
From wrecked ship, Addu Lagoon. Depth 110 ft.
"Five Fathom Shoal", Addu Lagoon. Depth 90 ft.

2) Turbinaria n. sp. ?
Lagoon slope, Gan. Depth 50 ft.

Subclass ALCYONARIA
Order COENOTHECALIA
Family HELIOPORIDAE

Genus HELIOPORA

1) Heliopora coerulea (Pallas) var. meandrina Dana
Inner reef zone, lagoon reef flat, Gan.

Class HYDROZOA
Order MILLEPORINA
Family MILLEPORIDAE

Genus MILLEPORA

1) Millepora latifolia Boschma
Outer zone of lagoon reef flat, and to 20 ft on lagoon slope, Gan.

2) <u>Millepora tenera</u> Boschma
Lagoon reef margin and to 80 ft on lagoon slope, Gan.

Order	STYLASTERINA
Family	STYLASTERIDAE
Subfamily	Distichoporinae

Genus DISTICHOPORA

1) <u>Distichopora fisheri</u> Broch
In shaded areas on dead coral boulders, lagoon reef margin, Gan.

V. VEGETATION AND FLORA

A. A brief history of botanical observations and collections made in the Maldive Islands, Indian Ocean

by E. W. Groves */

Although the earliest known account of the Maldives is that given by the Moorish traveller, Ibn Batutah (1829, 1853-59) who was in the islands in 1343-44 and briefly mentioned pomegranates (Punica granatum L.) in cultivation there, it was not until nearly 300 years later that the first description of any of the vegetation was made. This was recorded by a Frenchman, Pyrard de Laval, who whilst travelling to the East Indies in the barque "Corbin", was shipwrecked on one of the northern islands of the group during July 1602. He stayed on in the Maldives from 1602 to 1607 and it was during this period that he made notes for an account of the islands which he subsequently published on his return to France (Pyrard, 1679). His references to the vegetation were, however, confined to describing plants that he had noticed either in cultivation or being put to some domestic use.

The first collection of plants, albeit somewhat fragmentary and few in number, was made by H.C.P. Bell, a Ceylon Civil Servant, during the first of his visits to Malé (the capital of the Maldives) in 1879. The few specimens he brought back from this trip were examined by W. Ferguson of Colombo. Bell incorporated Ferguson's determinations along with other of his observations on plants seen in cultivation (amounting to 39 species in all) in his excellent account of the Maldive Islands and its people which was published by the Ceylon Government a few years later (Bell, 1883).

Capt. A. C. Christopher, serving in a British Naval warship, visited Malé in 1888 making a collection of flowering plants (both wild and cultivated) amounting to 73 species of which 44 were new to Bell's previous list. A few more additions were discovered later by a Mr. Haly, at that time Director of the Colombo Museum, visiting the same island in 1893. Both collections were reported upon by Henry Triman (1896). In 1896, Mohammed Ibrahim Didi, then Prime Minister to the Sultan of the Maldives, despatched to the Peradeniya Gardens herbarium a collection he had made of some 174 numbers including many cultivated species. These he had collected probably all from Malé or Funadu islets, both on Malé atoll and included 100 species new to the Maldive list. Three further brief visits to the same atoll were made during the next few

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years: the first by J. J. Thorburn in Aug. 1901 when he made notes of some of the economic plants under cultivation there; the second by Capt. Simons of the British warship "Pomone" who recorded another three new species; and the third by F. Lewis of the Ceylon Forestry Dept. who visited Malé and two adjacent islands in Oct. 1901 and was able to add yet a further seven records. All these additions were taken into account in the Willis and Gardiner paper mentioned below.

The first widely gathered botanical collection was not made in the Maldives until the visit of the J. Stanley Gardiner expedition*/ to Minikoi and the Maldives during 1899-1900. In the course of this expedition, the primary purpose of which was to study the reef formations and their associated fauna and flora, collections were made on 19 atolls from Ihavandifulu in the north to Addu in the south. About 212 different species including flowering plants and ferns were collected and presented to the herbarium at Peradeniya Gardens, Ceylon. The marine algae that were collected were brought back to England and presented to the herbarium at Cambridge University. They were determined and published upon as follows: the calcareous algae 9 species belonging to 4 genera were dealt with by M. Foslie (1903) and the remainder which included 4 species from Suvadivan waters and 2 species from Addu Atoll were written up by Miss E. Barton (1903). The vascular plants were determined in Ceylon by W. de Alvis and J. C. Willis and were written up, along with those smaller collections mentioned above, in an excellent account by the latter in conjunction with J. Stanley Gardiner (Willis & Gardiner, 1901). Thus by the end of 1909 the vascular flora list for the islands had risen to 284 species.

Although a few visits were made to the islands between the two World wars the only known reference to any plants is that given by T.W. Hockley in his book (1935) which gives an account of his trip, to Male in particular, in 1926. He mentions some of the species grown or used economically but all of these had already been mentioned by earlier authors. During World War II the present author (E. W. Groves) was stationed at Addu Atoll from 1943 to 1945 during which time he made a small collection of flowering plants and some notes of some of the species seen growing on Gan and a few on Fedu and Hittadu. Owing to insect ravage two specimens only survived to be determined but these together with those identifiable from his notes amounted to 18 species of which 3 species were new Maldive records. These were Canavalia cathartica,**/ Commelina suffruticosa and Cyanotis axillaris, all from Gan island.

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*/ J. S. Gardiner was a Fellow of Cambridge University and his expedition, consisting of himself as leader, with L. A. Borradaile from June-July 1899 and C. Forster Cooper from Oct. 1899-April 1900, was under patronage from the Royal Society and the British Association.

**/ Seeds of Canavalia cathartica were brought back to England in 1945 and taken to the Chelsea Physic Garden, London. These were germinated in 1946 under tropic heat and by that midsummer two vines at least were trailing along beams of the glass house for about 15 ft. Unfortunately a countrywide fuel shortage the following winter prevented the stoves being maintained at the necessary temperature and the Canavalia, along with many other plants that were in the tropic house at the time, perished.

In April 1956 F. R. Fosberg paid a short visit to Malé atoll and whilst there made a good collection of flowering plants both on Malé island itself and on two adjacent islands (Kudos Bados and Furannafuri). In addition notes were made of species identified in the field but not actually collected, especially of plants in cultivation in gardens on Malé. A later assessment of specimens both collected and identified on sight indicated a further 44 species not already known from the Maldives. These were listed together with a detailed ecological account of the islands visited in a paper published by Fosberg (1957). W. W. A. Phillips who was in the Maldives first at Malé, Nov. 1956-Feb. 1957, and then on Gan island, Addu Atoll, May 1958-April 1959, made a small collection during his first stay which he sent for identification to A.S.A. Packeer (Asst. Warden, Dept. of Wild Life) in Colombo. The list of 12 species was included in Fosberg's paper just mentioned.

During Sept. and Oct. 1957 the Yale University Seychelles expedition en route there from Colombo visited North Malé, Fadiffolu, South Mahlosmadulu and Addu atolls. At a prior request W. D. Hartman, one of the zoologists on the expedition, collected as many different _Pandanus_ spp. as he encountered and as a result a small but excellent collection was brought back to the Arnold Arboretum herbarium for Dr. H. St. John to study. After evaluation 4 species new to science and to the Maldive list were described (St. John, 1961).

As far as known, the next and most recent collections made in the Maldives are those of the 1964 expedition, reported upon below in parts C and D.

B. Preliminary account of the land and marine vegetation of Addu Atoll

by D. C. Sigee

There are few studies of the vegetation of the Maldives, and even less attention has been paid to that of Addu Atoll. Earlier papers were mostly systematic lists of plants. In addition to such a list, Willis and Gardiner (1901) include much information on plant distribution, economic uses and vegetation of the Maldive Islands. Gardiner (1903, p. 25) noted that the luxuriance of the vegetation of the Maldives tended to increase with rainfall from North to South. Both Agassiz (1903, p. 146) and Sewell (1936a) comment on Addu vegetation.

During the 1964 expedition, collections of land and marine flora and notes on the vegetation were made at Gan and Hitaddu Islands. The other islands could not be visited, but Midu and Maradu are described in some detail by Willis and Gardiner (1901, p. 78-80). Gan was described as "well-wooded" by Sewell (1936a, p. 80), and remained so at least until 1940 (West coast of India Pilot, 1961, p. 58). During World War II, much of the vegetation was removed when an airstrip and installations were built, and a second major phase of clearing took place in 1957, when the present staging post was established. There is little undisturbed vegetation left at Gan therefore, but in recent years there has been considerable opportunity for additions to the flora of imported species, both weeds and cultivated plants. Similar, though less extensive, clearing has taken place on the southern part of Hittadu. Conditions are therefore comparable with those of other airstrip atolls in the Pacific, such as Midway and Wake. About 142 species of land plants were collected at Addu Atoll in 1964, and these are reported in Chapter V, part C. About 100 species of algae were collected and were identified by R. Tsuda and J. Newhouse (Chapter V, part D).

Land vegetation of Gan Island

Much of the original woodland vegetation of Gan has disappeared with recent clearing, and most of the island is now covered with open grassland, with a little open woodland in the centre of the island, and some coastal shrubs and trees. The water table is high over the whole island surface, resulting in the formation of a zone of marshland at the southeast end (Figure 29).

The open grassland is continually cleared of bushes and tall herbs by hand and mechanical activity, and is continually sprayed with tar sprays to reduce the breeding of mosquitoes. Where the water table is highest, sedges form the sward completely, *Cyperus rotundus*, *C. polystachyos* and *Fimbristylis cymosa* being very common. Grasses are commoner in the drier regions, comprising largely *Panicum repens*, *Digitaria timorensis* and *Dactyloctenium aegyptium*. In some parts, where the ground is very dry, with bare patches of earth, *Sida humilis*, *Tridax procumbens*, *Corchorus aestuans* and *Thuarea involuta* are typical.

A variety of weeds occur in this open grassland. Celosia argentea, Cassia occidentalis, Cyperus melanosperma, Physalis angulata and Cleome viscosa seem particularly characteristic of this habitat.

Areas near roads and buildings are also kept clear of tall herbs and shrubs. A few trees have been left standing near the staging Post buildings at the northwest point: these include various coconut palms 30-67 ft. tall, Terminalia catappa 50 ft tall, Artocarpus altilis 35 ft tall, and Delonix regia. In the northern part of the island, at the site of the former Maldivian village, is an old graveyard. This contains a a single specimen of Moringa oleifera, and adjacent to a nearby Mosque a single large tree of Erythrina variegata.

In the centre of the island is a zone of woodland. Part of this is fairly dense and is probably regenerating after clearance. The woodland has well developed tree, bush, and herb layers. The tallest tree was Eugenia cumini averaging 44 ft in height but reaching 50 ft. Hibiscus tiliaceus is very common, the mature trees reaching 14-16 ft. Other trees include Morinda citrifolia up to 9 ft tall and Pandanus up to 26 ft. The shrub layer consists mainly of juvenile Hibiscus tiliaceus, Morinda citrifolia and Pandanus. There is little light penetration to the herb layer, where the ferns Thelypteris goggilodus and Nephrolepis hirsutula cover the ground in a dense layer. Cyanotis axillaris is found at the edge of the woodland, and in sunny clearings. South of the main woodland is an area of younger woodland largely consisting of juveniles reaching a height of 9 ft. Hibiscus tiliaceus is widespread, with Morinda citrifolia and Eugenia also occurring. Ixora coccinea is common. The fern layer is well developed, with the grass Apluda mutica occurring in the more open conditions of regenerating woodland.

In the southern part of the island, in the marshland and open scrub, clearing is not as rigorous as in the northern end. The grass Apluda mutica occurs extensively over the whole area, with many bushes. Many plants are found here that do not occur in the open grassland, including Ricinus communis, Hedyotis brachiata, Ammania baccifera, Passiflora foetida, Ipomoea tuba, Gloriosa superba.

Much of the marshland consists of sedges, Cladium jamaicense, Cyperus ligularis, and C. javanicus, to a height of 2-3 ft. Other sedges present are Cyperus rotundus and C. polystachyos and the two species of Fimbristylis. In the wetter areas, Lippia nodiflora, Eclipta alba and Bacopa monnieri are plentiful, the latter two species being found only in this region. Apluda mutica occurred over the whole marshland, and patches of Thelypteris goggilodus in the drier areas.

Around the edge of the marshland, and scattered sparsely throughout, are small shrubs of Scaevola taccada, Hibiscus tiliaceus, Pandanus and a few specimens of Morinda citrifolia and Tournefortia argentea. The first three are characteristically found under fairly open conditions in a successional stage to forest.

It is convenient to consider the vegetation at the periphery of the island as comprising a shoreline community, reached by the tide and directly exposed to sea winds, and a coastal scrub community immediately behind this.

The most common shoreline shrubs at Gan are Scaevola taccada, and Tournefortia argentea. On the lagoon side, these are frequently covered with the vines of Canavalia cathartica and Vigna marina. Where the shoreline has been cleared, Launaea pinnatifida and Ipomoea pes-caprae cover the ground around the hightide line. Cocos nucifera occurs at the shoreline near the staging post, and single specimens of Cordia subcordata and Hernandia sonora on the lagoon shore. Behind the shoreline, Hibiscus tiliaceus, Pandanus and Wedelia biflora characteristically form a dense coastal scrub. This also includes bushes of Morinda citrifolia, Carica papaya, Scaevola taccada and Tournefortia argentea, and a variety of herbs, including Ipomoea pes-caprae, Apluda mutica, Boerhavia diffusa. A few specimens of Pemphis acidula and a single specimen of Suriana maritima were found on the south shore.

Land vegetation of Hitaddu Island

The area occupied by the staging post at Hitaddu is extensively cleared of vegetation. Many of the herbs seen at Gan are also found here, with a few additions, such as Stachytarpheta indica.

Immediately surrounding the buildings is an area of open grassland which is completely free of shrubs. Tridax procumbens covers the ground extensively, with much Cassytha filiformis and patches of Launaea pinnatifida and Apluda mutica.

North of this area, clearance is not so vigorously maintained, and there is open scrubland. Apluda mutica is very common, and a variety of bushes occur; Scaevola taccada, Dodonaea viscosa occur in the drier areas. The scrub is densest on the seaward side with Tournefortia argentea, Pandanus juvenile shrubs and tall stands of Wedelia biflora. In the centre of the open scrub, much of the ground is open and covered with trailing plants, Cucumis melo, Jacquemontia paniculata, Passiflora suberosa, Cassytha filiformis and Boerhavia diffusa being common. Other common herbs are Cleome viscosa, Corchorus aestuans, Nothosaerva brachiata. In the extreme northern part of the scrub is a small area of open marshland. At the edge of the water, Scaevola taccada, Morinda citrifolia and Muntingia calabura are typical. Where the water table is at ground level an extensive carpet of Lippia nodiflora occurs. Large tussocks of Cyperus javanicus form islands, with Cyperus polystachyos. Blumea sinuata occurs here in shallow water and was not found elsewhere.

Woodland is found to the north and south of the cleared area. To the south, the undergrowth had been cleared beneath the coconuts on the lagoon side, and Apluda mutica and Wedelia biflora were especially common. To the north, pathways have been cut through the coconuts, and plants such as Apluda mutica and Vernonia cinerea introduced.

In the midst of the northern forest, parts have been cleared for banana plantation, with a number of original trees such as Artocarpus altilis, Terminalia catappa and small groves of Pandanus left standing. With the opening up of the forest, Apluda mutica, Vernonia cinerea and Euphorbia cyathophora occur as common weeds. Kalanchoe pinnata and Turnera ulmifolia were common in this area of cultivation, but not seen anywhere else at Gan or Southern Hitaddu.

A transect was taken through the woodland at the northern boundary of the staging post area. Seven zones may be distinguished: (1) on the eastern lagoon side, the soil is dry and under woodland. The main pathway along the island runs along this shore, and there is probably periodic clearing of shrubs. The main trees are Cocos, with Hibiscus tiliaceus and Guettarda speciosa as both trees and shrubs. The herb layer includes Apluda mutica, Launaea pinnatifida, Striga asiatica, and Tacca leontopetaloides. Scaevola taccada is occasionally found on bare ground in clearings.

(2) About 245 metres from the shore, the bush layer becomes much denser, with Guettarda speciosa and Morinda citrifolia more frequent.

(3) About 260 metres from the shore, the ground surface is lower and covered with a mosaic of pools. These are surrounded with bushes of Hibiscus tiliaceus and Guettarda speciosa, and with palm trees separated from each other by distances of 9-12 metres. The ground surface lies 2.4-3 ft. below the crest of the lagoon beach ridge. On the bases of the palm trunks, which are usually surrounded by water, Asplenium pellucidum and Psilotum nudum are found. Moss is also found on the bases of the trunks and in the pools. The pools contain several inches of water, with decaying palm leaves and other debris forming a soft layer a foot or more thick. Two species of sedge grow in the centre of the pools, Fimbristylis sp. projecting 6 inches or more above the surface, and Eleocharis geniculata 2-3 inches. No clearing of vegetation takes place in this marshland, and there is no obvious sign of human interference.

(4) Between 280 and 425 metres from the shore of the lagoon, this marshland vegetation changes into one with Pandanus as the dominant tree, and Cladium jamaicense forming a tall stand below it. The forest is still fairly open. The Pandanus at Hitaddu is of different growth-form from that at Gan. At Gan, mature Pandanus has an erect main stem, with stilt roots leading from the lower part and branches from the upper, to form a fairly compact dense canopy. The Pandanus at Hitaddu in the mature state has thinner, decumbent stems with foliage not in a dense canopy but produced at all levels. At Hitaddu, the Pandanus foliage seems lighter in color and more yellow. Where Cladium jamaicense occurs in a dense stand, no other herbs are seen, and open water is restricted to narrow channels.

(5) At 450 metres from the lagoon shore, the marsh disappears and the ground is covered with dense Pandanus woodland. This was the densest and most impenetrable woodland encountered. It is almost entirely Pandanus, with a little Hibiscus tiliaceus included. The Pandanus trees grow with stems spreading out in groves, and when a certain age is reached a clearing forms in the centre, and Scaevola taccada invades as temporary coloniser. The Pandanus regenerates from the fruit and several seedlings were seen where fruit had fallen to the ground. The ground is covered with a dense mat of dead Pandanus leaves, and there is no herb or shrub layer. There is no evidence of human interference. The small number of species in the mature undisturbed woodland is of interest.

(6) Toward the shore on the seaward side, a dense coastal scrub of Hibiscus tiliaceus, Scaevola taccada, Morinda citrifolia, and Pandanus is found. Scaevola taccada occurs in woodland clearings and margins, together with Wedelia biflora and Pemphis acidula. Terminalia catappa is also found in this zone.

(7) On the seaward shore itself, Pemphis acidula is common all along the crest of the shingle ridge, with Scaevola taccada and Tournefortia argentea immediately behind. Scaevola frequently shows leaf stripping along the shore, and many nearest the sea are dead. Suriana maritima is also frequent, particularly in exposed conditions. Ipomoea pes-caprae and Launaea pinnatifida are not seen on the beach itself, growing only well back from the shoreline, but the grass Lepturus repens does occur in these exposed situations and was not seen elsewhere.

In the central part of North Hitaddu there is a large area of open marshland. This appeared from the edge to be largely Cladium jamaicense, traversed by frequent channels.

On the lagoon shore at Hitaddu, the vegetation is similar to that at Gan. Scaevola taccada is the commonest shoreline shrub together with some Tournefortia argentea and Hibiscus tiliaceus. To the south, where the island narrows towards Abuhera, both Pemphis acidula and Suriana maritima are common on the lagoon shore. Behind the shore occurs an open scrubland of Wedelia biflora, Apluda mutica, Scaevola, Guettarda speciosa, Tournefortia argentea and others.

Coastal scrub on the lagoon side is much less dense than on the seaward--presumably due to the establishment of a major pathway, a few houses and general clearance of vegetation on this side.

Comment: Human activity has thus considerable effects on the vegetation of Gan and Hitaddu. The result of clearing, if only partially, of the mature woodland, is to allow the introduction of many new species, including pantropic weeds, and to increase the number of species per unit area, which probably accounts for the large number of species collected at Gan and Hitaddu. In this connection, comparison with the vegetation of an uncleared Maldivian island would be valuable.

At both Gan and Hitaddu many of the plants are diseased or damaged. This is particularly the case along the shore. Chlorosis was often seen in Ipomoea pes-caprae and other herbs. The most serious damage, however, was inflicted on foliage by insects. This is seen in nearly all the shrub and ground-level foliage along the shore, but is especially severe on Scaevola taccada and Ipomoea-pes-caprae. Grasshoppers particularly occur in vast numbers in the Ipomoea. Many trees, shrubs and herbs are also overgrown by creepers, particularly by Cassytha filiformis. Several specimens of Scaevola are completely smothered by Cassytha, with much dead foliage where the Cassytha is most abundant.

Marine algae of Gan and Hitaddu Islands

Collection of marine algae at Gan and Hitaddu was carried out either along line or quadrat transects, or by traversing on the reef flats, fixing location with horizontal sextant angles. The latter method was useful in covering large areas rapidly; the transect method gave detailed observations in smaller areas, and was useful in studying zonation. Under difficult conditions no record of precise location was made. The algae were collected in polythene bags, examined fresh, and then transferred to alcohol-formaldehyde preservative, to which metaldehyde had been added as a neutralising agent. Species distribution along transects, Figs. 30-32.

Out of 61 marine species and varieties, 18 were most common in or restricted to the seaward reef, 31 to the lagoon reef, and 15 occurred equally on both. Three species were found only on Hitaddu.

Lagoon reef, Gan

Charts of algal distribution show that for most algae, there was no strict zonation across the reef, but considerable variation along the reef, so that distribution over most of the reef flat was mosaic.

On the basis of algal distribution, it was possible to divide the lagoon reef from the shore to the base of the reef slope, into three major zones. Distance on the lagoon reef were measured from a sand ridge which was presumably high tide line.

(1) An inshore zone (20-60 ft). Algae found here were specific to this zone, characterised by a loose sand substratum, continuous water motion, and high turbidity. Chaetomorpha brachygona, C. crassa and Enteromorpha sp. occurred very close inshore, attached to stones and pieces of coral lying in the sand. Just beyond this, Padina commersonii formed a very characteristic zone.

(2) An inshore zone (60-150 ft) between the zone of turbulence and the beginning of the large dead coral masses. The substrate was mainly sand patches with much dead coral litter.

Beyond the Padina zone, Dictyota sp. and Jania capillacea covered the ground in large patches. Intergrading with, and beyond this, Halimeda incrassata was common on sand and coral fragments. Halimeda discoidea and Boergenesia forskii were also common in this zone along parts of the reef. Caulerpa lentillifera and C. racemosa var. macrophysa were especially luxuriant here.

(3) From about 150 ft to bottom of the reef slope. The whole of this zone is characterised by an abundance of dead and living corals. Both the completely dead corals, and the dead parts of living ones were covered by epiphytic algae. The epiphytic habit was thus the predominating one in this part of the reef.

Common epiphytic algae included Hypnea sp., Jania capillacea and Lophosiphonia villum which formed a mat-like covering over the coral. Lyngbya majuscula occurred as a mass of threads attached to the coral. Most of the algae seen in zone 3 on the reef flat also occurred on the reef slope, e.g. Dictyota sp., Caulerpa lentillifera, Gelidium divaricatum. Exceptions to this were few, and included Lyngbya majuscula and Polysiphonia ferrulacea which were rare on the reef slope, and Symploca hydnoides and Pocockiella variegata which were common on the reef slope but not on the flat. Pocockiella was a very common epiphyte on dead coral on the reef slope and represented the most significant difference between it and the reef flat.

Seaward reef, Gan

The seaward reef profile was divided into two major areas, separated by the rubble or boulder zone.

(1) Shore-boulder zone, a shallow zone of little water movement and exposed to sun and rain. Algae were not plentiful in this zone. Much of the reef was covered by Thalassia and Cymodocea, with patches of sand and marine grass forming a mosaic. Cladophora sp. was common over the whole of the reef as free floating or loosely attached to the marine grass. Jania capillacea and Boergenesia forskii were common in the sand between and within patches of marine grass.

(2) Boulder zone to surge channels. Between the boulder zone and the surge channels there were 3 main zones:
a. In the region of the surge channels, towards the edge of the reef, the coral rock was almost entirely covered by encrusting red algae.
b. At the ends of the surge channels, and for a distance up to 30 ft, the growth of algae was luxuriant. A few algae were restricted to this zone, Caulerpa racemosa var. peltata, Codium arabicum and Valonia utricularis. Algae which were particularly common included Codium edule, Halimeda opuntia and Jania capillacea which formed compact bunches, with strong attachment to the coral rock. Pocockiella variegata was luxuriant on rock surfaces between algal clumps.
c. Between zone b and the boulder zone, algal growth was not so luxuriant. This was a zone of algal pavement with clumps of Halimeda opuntia, H. discoidea and Jania capillacea distributed over it. Turbinaria ornata occurred towards the sea end, as small rosettes covering much of the ground. Pocockiella variegata, Schizothrix calcicola and Cladophoropsis sp. occurred on rock surfaces.

Seaward reef, Hitaddu

The seaward reef at Hitaddu was narrow compared with Gan, a width of about 250 yards as against 900, distances measured to beginning of surge channels. The physical appearance of the reef is very like the outer part of the seaward reef at Gan, consisting over nearly the whole surface of hard coral pavement, with a boulder ridge on the shore in places. The transect taken across the reef at Hitaddu was divisible into 2 distinct algal regions:

(1) An outer zone, about 60 ft offshore to the surge channels. The number of algae was large over the whole of this zone comparable with the outer reef zone at Gan. The force of wave action seemed less at the edge of the reef at Hitaddu than at Gan, and there was no zone of marked algal abundance as at Gan close to the surge channels.

The algae over the whole zone were comparable to those seen at Gan, Caulerpa racemosa var. peltata and Valonia utricularis occurred in the outer zone. Halimeda opuntia, H. discoidea, Jania capillacea, Pocockiella variegata, Turbinaria ornata, Boodlea composita, Cladophoropsis sp., and Dictyosphaeria intermedia var. intermedia were recorded as occurring over most of the reef. Neomeris mucosa occurred mid-reef at Hitaddu, and was only seen elsewhere in strong current on the far seaward side of the Gan-Fedu gap.

(2) An inshore zone within about 60 ft from the shore. This was a zone of continual water motion, and was closely similar to the inshore zone at Gan lagoon reef. Two algae were recorded, Padina commersonii forming a distinct zone, and inshore to this, Chaetomorpha gracilis growing on stones and loose coral rock.

Notes on occurrence of algae collected*/

Myxophyceae

Anacystis montana

Gan, seaward reef. Covered the surface of low lying beachrock in the Gan-Fedu gap. Periodically submerged and exposed by the tide.

Calothrix pilosa

Gan, seaward reef. Found in association with A. montana on beach rock.

Hormothamnion enteromorphoides

Gan, lagoon reef: found in inshore zone, within 100 ft from shore. Seaward reef: fairly common over most of the reef flat between the shore and the boulder ridge, appearing as a brown-golden covering on stones and dead coral.

Lyngbya aestuarii

Appeared as a greenish felt of projecting filaments on dead coral. Gan, lagoon reef: fairly rare on dead coral from about 100 ft to the reef edge.

Lyngbya majuscula

Gan, lagoon reef: common, especially from about 100 ft to reef edge. Uncommon in the inshore zone, and a few specimens were found on the reef slope. Seaward reef: quite rare between the shore and boulder ridge, becoming slightly more frequent between the ridge and the surge channels.

Schizothrix calcicola

Gan, seaward reef: very common as a covering on stones and rocks, between the shore and boulder zone.

Symploca hydnoides

Wide variation in external appearance, collected as 7 different forms. Gan, lagoon reef: uncommon over the whole of the reef flat, but becoming fairly common near the reef edge, and common on the reef slope. Seaward reef: uncommon, occurring in the shoreward half of the reef flat, between shore and boulder zone.

*/ The data on occurrence were received too late to be of use to the algologists who identified the collection, and even to be incorporated in their systematic list below (Tsuda and Newhouse, Chapter IV, Part D). Their identifications, however, are utilized in the present enumeration, but see last paragraph on p. 93 [ARB Eds.]

Chlorophyceae

Boergesenia forbesii

Gan, lagoon reef: occurring at the western end of the island, on the reef between about 100-150 ft from shore, where it was common on a substratum of sand and dead coral fragments. Seaward reef: seen over a wide area of reef flat, between shore and boulder zone, where it was locally common. It was not common between the boulder zone and surge channels.

Boodlea composita

Gan, lagoon reef: common and restricted to outer zone of the reef, from about 200 ft to the reef edge. Seaward reef: not common, occurring between the boulder zone and the surge channels.

Boodlea sp.

Gan, lagoon reef. A few specimens were found on the reef slope, at a depth of about 60 ft.

Bryopsis pennata

Gan, lagoon reef: common in mid-reef zone, between 100-200 ft, found occasionally over most parts of the reef. Seaward reef: generally uncommon, occurring occasionally over the greater part of the reef.

Caulerpa lentillifera

Gan, lagoon reef, western end. Common in the middle of the reef, from 100-200 ft, uncommon on the lagoon edge and on the reef slope.

C. racemosa var. macrophysa

Habitat closely similar to that of C. lentillifera.

C. racemosa var. peltata

Gan, lagoon reef: uncommon, occurring locally in the mid-reef zone, 100-200 ft from shore, with a few specimens occurring either side of this. Seaward reef: uncommon, between the boulder ridge and the surge channels. Hitaddu, seaward reef: not common, occurring toward the seaward edge of the reef.

C. serrulata var. typica

Gan, Gan-Fedu Gap: common and restricted to this area, on the seaward side between islands. Occurred on sand substratum, as small colonies, with a distinctly yellowish appearance.

C. taxifolia

Gan, lagoon reef: uncommon, occurring at the western end of the island, 40 to 250 ft from shore.

Chaetomorpha brachygona

Gan, lagoon reef: uncommon, occurring locally along the reef. A filamentous green alga living on dead coral fragments, it occurred close inshore, 20-50 ft from high tide line.

C. crassa

Gan, lagoon reef: uncommon, restricted to a zone 20-100 ft from shore.

C. gracilis

Hitaddu, seaward reef: common and restricted to close inshore zone, 0-20 ft from tideline.

Cladophora sp.
Gan, lagoon reef: uncommon, attached to rocks and dead coral, occurring between 20-250 ft from shore. Seaward reef: common between shore and boulder zone.

Cladophora sp.
Gan, lagoon reef: uncommon, attached to stones and coral, inshore zone 20-250 ft.

Cladophoropsis sp.
Gan, seaward reef: uncommon, occurring between the boulder ridge and the surge channels, where it was attached to coral pavement and loose rocks. Hitaddu: common over the whole of the seaward reef from 60 ft to edge.

Codium arabicum
Gan, seaward reef: not common, but found several times in the dense algal growth near to the surge channels.

C. edule
Gan, lagoon reef: a few specimens only were found in one locality, attached to dead coral about 250 ft from shoreline. Seaward reef: fairly common, between the boulder zone and the surge channels, attached to the underside of rocks near the boulder zone and to the surface and cavities of the porous rock at the surge channels.

Dictyosphaeria intermedia var. intermedia
Gan, seaward reef: occurring only very occasionally between shore and boulder zone, but fairly common between boulder zone and surge channels. Hitaddu, seaward reef: fairly common over a wide area of reef from about 50 ft from shore to the reef edge.

Enteromorpha sp.
Gan, lagoon reef: strictly an inshore alga on the reef flat, where it occurred 20-50 ft from high tide line. It was attached to stones and dead coral lying loose in the sand. A few specimens were also found on the reef slope on dead coral at about 50 ft depth.

Halimeda discoidea
Gan, lagoon reef: uncommon, locally common along the reef. It occurred between 50 and 200 ft from shore, attached to sand or loose lying rocks. Seaward reef: common in the boulder zone to surge channels. Hitaddu, seaward reef: quite common within 130 ft from the surge channels at the edge of the reef.

H. incrassata
Gan, lagoon reef: common inshore, the inner limit being fairly sharp at 60 ft from high tide line, the range extending lagoonwards to about 150 ft;beyond this the alga was uncommon. Seaward reef: found occasionally attached to rubble and coral pavement in the boulder zone and up to halfway between this and the surge channels. A few specimens were also found between the shore and the boulder zone.

Halimeda opuntia

Gan, lagoon reef: as with H. incrassata, common between 60 and 150 ft from shore. Seaward reef: very common between the boulder zone and the surge channels. It was the species of Halimeda extending farthest seaward, almost up to the channels, where it had a very compact growth form. Hitaddu, seaward reef: fairly common in the mid part of the reef.

Neomeris mucosa

This had the appearance of small bunches of bright green fingers, and occurred in conditions of good water flow. Gan, seaward reef: uncommon, between boulder zone and surge channels, and found only at the Gan-Fedu Gap. Hitaddu, seaward reef: a few specimens were found in the mid part of the reef, attached to the coral pavement.

Tydemania expeditionis

Gan, lagoon reef: very characteristic of the outer reef zone, 200 ft to edge, where it was sparsely distributed. Common also on the reef slope to depths of 60 ft. A few specimens were attached to coral brought up from a knoll in the lagoon, depth 30 ft.

Udotea orientalis

Gan, lagoon reef: occurrence very sporadic, specimens were collected from inshore, mid reef and outer reef. Seaward reef: a single specimen was collected during traverses between the shore and the boulder zone. The species was quite common between the boulder zone and surge channels opposite the Gan-Fedu Gap. Hitaddu, seaward reef: fairly common in the middle part of the reef.

Valonia utricularis

Occurred as a dense mat of green vesicles, well attached to the rocky substratum. Gan, seaward reef: uncommon, between the boulder ridge and the surge channels. Hitaddu, seaward reef: common at the edge of the reef, within 150 ft of the surge channels.

V. ventricosa

Solitary, olive green vesicles, concealed within coral masses, or in crevices in rocks. Gan, lagoon reef: fairly common on reef slope, to depth of about 30 ft, less common over most of the reef flat. Seaward reef: a few specimens were found in the porous coral near the surge channels.

Phaeophyceae

Dictyota friabilis

Gan, lagoon reef: not common, found mainly on the inshore part of the reef in patches at about 40-60 ft.

Dictyota sp.

Gan, lagoon reef: common over the whole of the reef. Especially common in an inshore zone at about 50-150 ft, where it formed a carpet on the sand. Common in other parts of the reef on dead coral, occurring on the reef slope to a depth of 70 ft. Seaward reef: uncommon on the reef flat between shore and boulder zone, common between boulder zone and surge channels. Hitaddu, seaward reef: common over the whole of the reef except the inshore 50 ft, and the surge channel zone.

Hydroclathrus clathratus

Gan, seaward reef: not common, seen on the coral pavement midway between the boulder zone and the surge channels, and in the boulder zone itself. Gan-Fedu Gap: quite common in the sand on the seaward side of the channel between the two islands.

Padina commersonii

Gan, lagoon reef: very characteristic as an inshore alga, between 30 and 50 ft from shore. Gan, seaward reef: rare, a few specimens were found between the shore and the boulder ridge. Hitaddu, seaward reef: very characteristic inshore plant, occurring within 60 ft of the shore.

Pocockiella variegata

Gan, lagoon reef: common on the reef slope, where it formed a common covering over dead coral to a depth of 70 ft. Uncommon on the reef flat, occurring as occasional specimens. Seaward reef: abundant covering on rocks and coral pavement between the boulder zone and the surge channels. Hitaddu, seaward reef: abundant over most of the outer zone of the reef, especially so within 100 ft of the surge channels.

Sphaceleria sp.

Gan, lagoon reef: uncommon in the mid part of the reef.

Turbinaria ornata

Gan, lagoon reef: occurred very infrequently in the middle of the reef flat, attached to coral. Seaward reef: common between the boulder ridge and the surge channels, as small, rosette-like plants attached to the coral pavement. It occurred between the shore and the boulder zone as an occasional find, and was of moderate size (3 inches long). In the area shore to boulder zone at the eastern end of Gan, the *Turbinaria* was of large size, and attached to coral microatolls in the swiftly flowing current. Gan-Fedu Gap: large well developed specimens attached to microatolls in the strong current. Hitaddu, seaward reef: abundant over the whole of the reef flat except the close inshore zone, as small compact rosettes.

Rhodophyceae

Antithamnion sp.

Gan, an epiphytic pink alga, occurring on *Caulerpa* and associated algae and on dead coral. Lagoon reef: fairly common on the reef flat in the mid and outer zones of the reef.

Botrycladia skottsbergii

Gan, lagoon reef: generally uncommon over the reef flat, most frequent in the mid zone of the reef, occurring on the underside of dead coral rock. Seaward reef: a few specimens were found in cavities in the porous coral rock in the surge channel region.

Ceramium fimbriatum

Hitaddu, seaward reef: restricted to the close inshore zone (0-60 ft), where it was common.

Ceratodictyon spongiosum

Gan-Fedu Gap: occurred as a spongy, olive brown thallus on the seaward side of the gap, on a sand substratum.

Champia parvula
Gan, lagoon reef: fairly common in close inshore zone, on sand.

C. salicornoides
Habitat closely similar to that of C. parvula

Dasya sp.
Hitaddu, seaward reef: common in the mid region of the reef, attached to the coral pavement and to coral rocks.

Dictyurus purpurescens
Gan, lagoon reef: a pink alga, which occurred only in the mid region of the reef flat as a few specimens along one of the transects (200-250 ft from shore).

Galaxaura marginata
Gan, a massive pink alga. Lagoon reef: rare, only a few specimens found, attached to coral heads in the mid-outer region of the reef flat.

G. rudis
Gan, lagoon reef: not common, occurring locally along the reef; most frequent in the mid reef zone; specimens also found inshore, and on the reef slope.

Gelidium divaricatum
Gan, lagoon reef: occurred on the surface of stones, dead coral and living Halimeda. Occasional over the whole of the reef flat, and on the reef slope to a depth of 40 ft. Seaward reef: single specimen seen near reef edge. Lagoon knoll: specimens brought up on dead coral from surface of knoll, 30 ft below surface.

Griffithsia sp.
Gan, lagoon reef: rare, occurring from about 250 ft to edge.

Herposiphonia sp.
Commonly occurred as an epiphyte on Halimeda. Gan, lagoon reef: uncommon, occurring mid reef at 200-270 ft, also infrequently found on reef slope, depth 30 ft. Hitaddu, seaward reef: a few specimens occurred at mid reef.

Hypnea sp.
Gan, seaward reef: rare, occurring between boulder zone and reef edge. Another form occurred as thick brown filaments twining through cavities in the coral rock. Gan, seaward reef: fairly common near the surge channels, uncommon between boulder zone and shore. Hitaddu, seaward reef: common over middle part of reef. Gan, lagoon reef: another form common on dead coral, 40 to 250 ft from shore. Seaward reef: common between shore-boulder zone. Gan, lagoon reef: still another form common on dead coral from 80 ft to reef edge, and on upper part of reef slope (to depth 40 ft).

Jania capillacea

This was the most common alga observed at Addu atoll in marine habitats. Gan, lagoon reef: common over the whole reef flat except the close inshore zone, from 40 ft to near the bottom of the reef slope at 80 ft depth. It was especially common in the midreef zone, where it formed clumps on the sand and rock substrate, and was also common attached to dead coral. Seaward reef: locally common between the shore and the boulder zone, having a patchlike distribution over the whole area. Abundant between the boulder zone and the surge channels, occurring near the channels as especially compact masses with high calcification. Hitaddu, seaward reef: common over the whole of the reef except the inshore 150 ft, occurring in masses on the coral pavement.

Lophosiphonia villum

Occurred as a reddish, velvet-like covering on stones and dead coral. Gan, lagoon reef: common on dead coral in the midreef zone, between 150 to 300 ft, less common to the reef edge, and rare on the reef slope. Gan, seaward reef: rare, a few specimens were found near the surge channels. Hitaddu, seaward reef: rare, a few specimens about 30 ft offshore. Lagoon knoll: fairly common on dead coral brought up from the summit of the knoll, depth 30 ft.

Polysiphonia ferrulacea

Gan, lagoon reef: common on outer part of reef, from 140 ft to reef edge, where it occurred on sand and rock substratum. Seaward reef: rare, between shore and boulder ridge. Gan-Fedu Gap: common, on sand, midway between islands.

Spyridea filamentosa

Gan, seaward reef: occurred as a mass of pinkish filaments, close to the shore at the eastern end. Very local.

Tolypiocladia glomerulata

Gan, lagoon reef: quite common, and local, at the western end of the island, forming dark red clumps on dead coral masses. Most frequent from 100 to 200 ft from shore.

Viadlia serrata

Gan, lagoon reef: locally fairly common, 150 to 200 ft from shore.

Freshwater and terrestrial algae

Nostoc commune

Gan, locally common on open waste ground with grassland, where the water table was high. Formed olive green masses, which under wet conditions, as just after a rain shower, became swollen and apparent.

Pithophora oedogonia

Gan, found floating on the surface of fresh water in an old well at the centre of the island.

ACKNOWLEDGMENT: I am very grateful to Mr. R. Tsuda and Mr. J. Newhouse for undertaking the identification of the collection. Also to Dr. D.R.Stoddart as leader of the expedition, and to Dr. P. Spencer Davies and Mr. A. Keith for collecting specimens from the reef slope and the lagoon knoll.

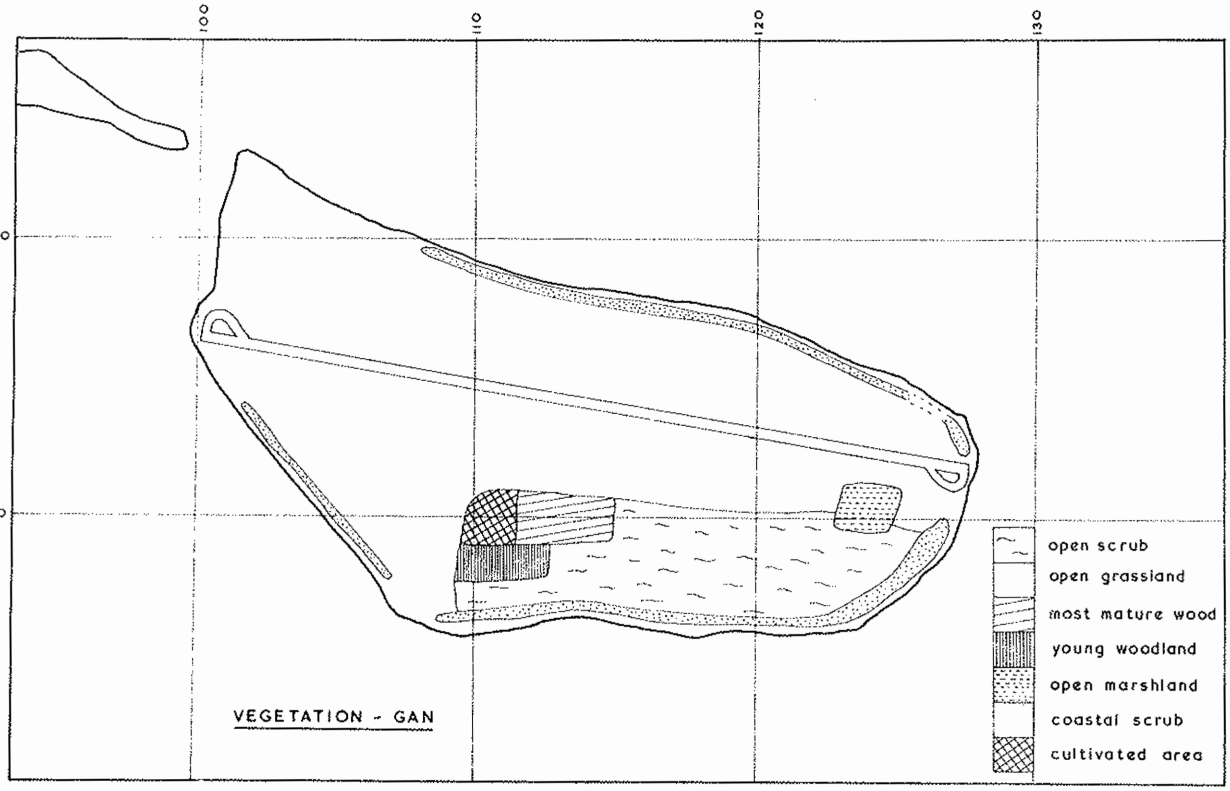

Fig. 29. Vegetation of Gan Island, 1964.

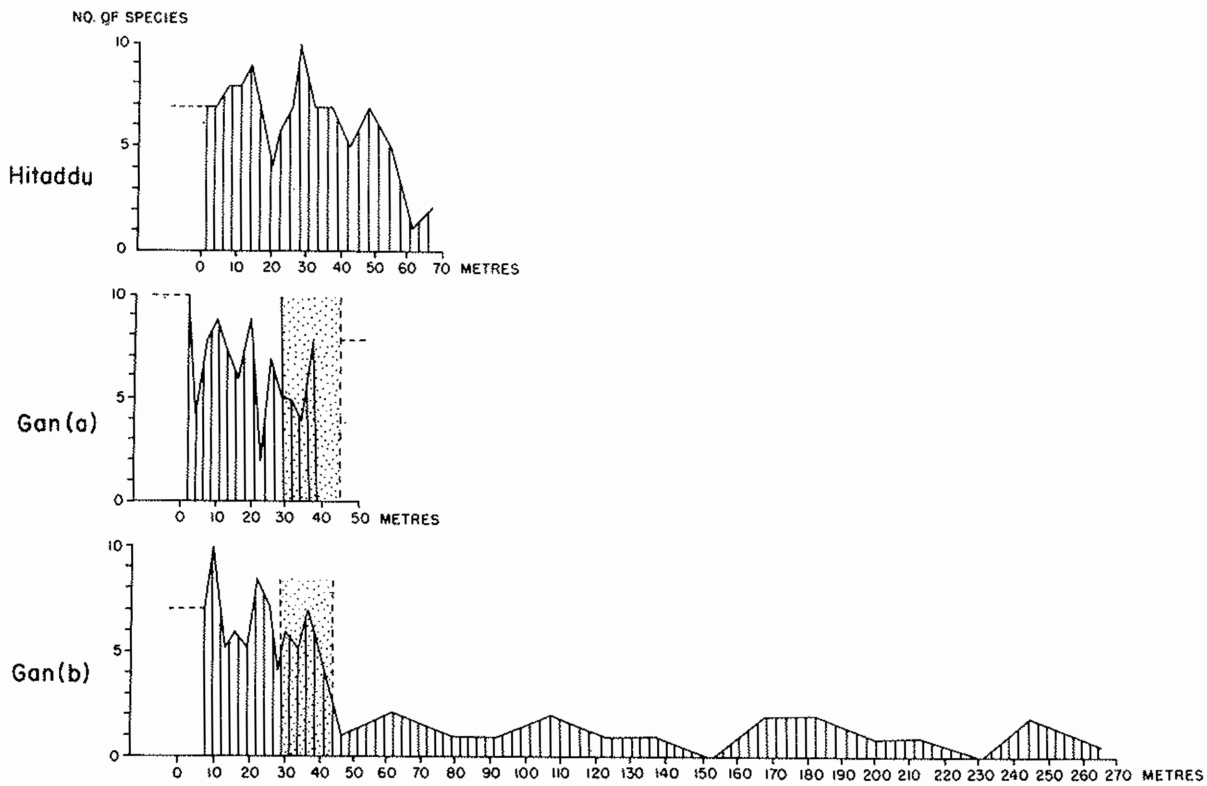

Fig. 30. Distribution of number of algal species collected in 10 ft quadrats on the seaward reef flat in transects at Hitaddu and Gan Islands. Transect Gan (a) is incomplete.

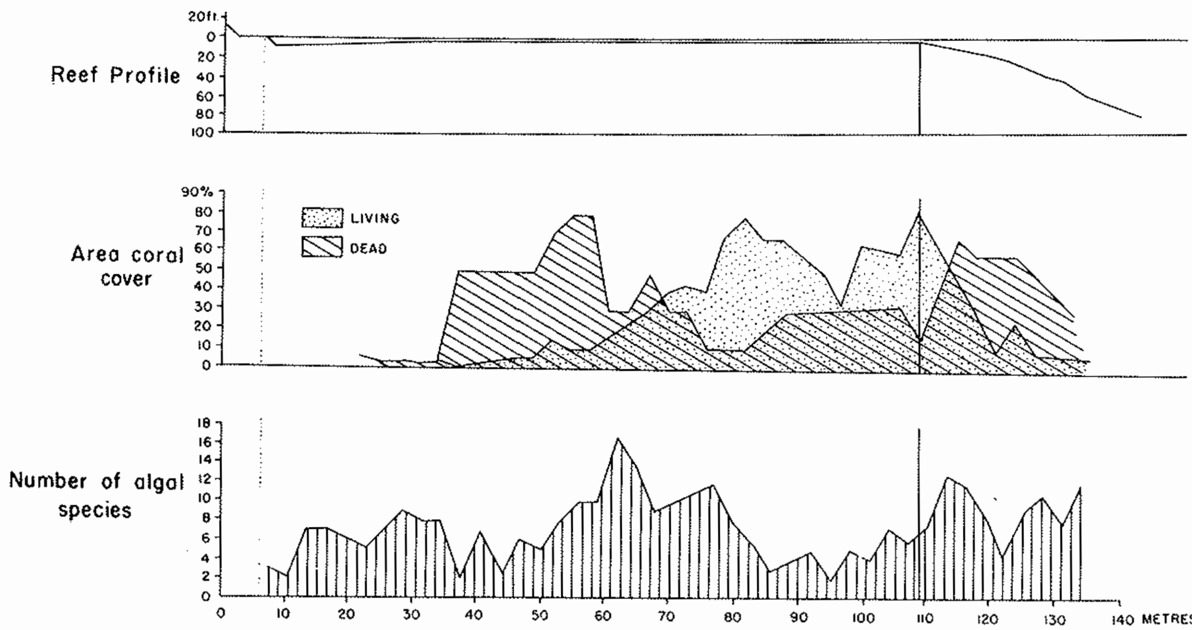

Fig. 31. Distribution of number of algal species and percentage coral cover in Gan lagoon reef transect I, based on 10 ft quadrats.

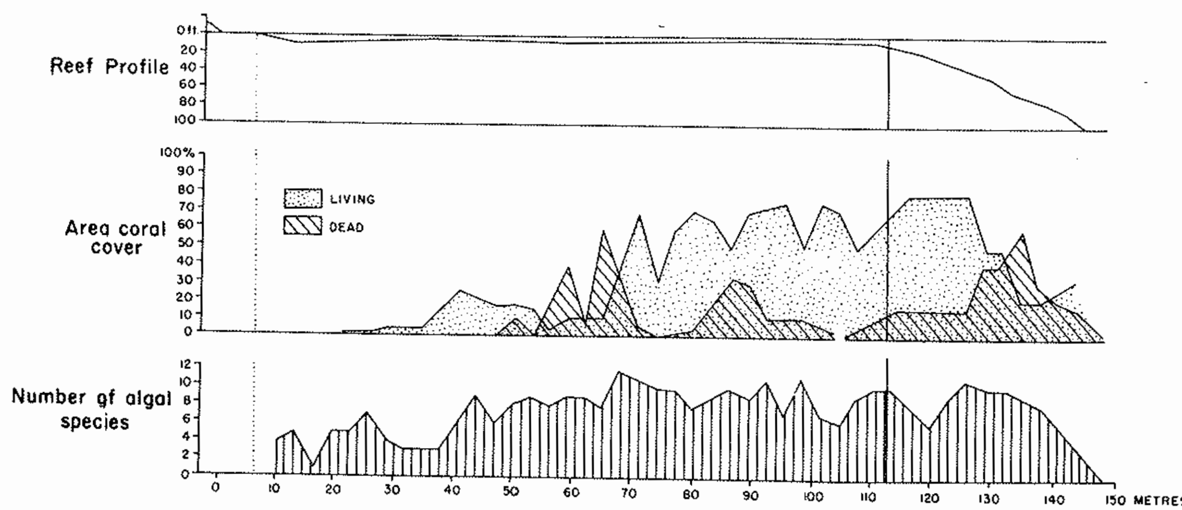

Fig. 32. Distribution of number of algal species and percentage coral cover in Gan lagoon reef transect II, based on 10 ft quadrats.

C. List of Addu vascular plants

by F. R. Fosberg, E. W. Groves and D. C. Sigee

The vascular plants collected by Mr. Sigee were independently identified by Fosberg and Groves, and the resulting lists combined and the differences reconciled. 145 specimens, in all, were collected, representing 142 species. Of these 57 (marked with an asterisk *) were clearly exotic, 33 of them cultivated or immediately persisting from cultivation; 32 are widespread maritime species. Most of the remainder are widespread species that occur in tropical Asia, some pan-tropical. Some of them may well be indigenous, but this is difficult to be certain of, one way or the other. There are no local endemics, unless the *Euphorbia* sp. should turn out to be one, and it seems likely that it is an Indian species that has been commonly, but erroneously, regarded as a variety of *E. hypericifolia*. Further study of more ample material may determine this. The *Pandanus* sp. (sterile) may well belong to one of the local populations that have been regarded as species in this perplexing genus. The *Fimbristylis* sp. may possibly be new and local, but is more likely an extreme or variant form of a known species.

This collection illustrates very well the state of our knowledge of the floras of the islands that are a little off the beaten track. In the 145 specimens, representing 142 species, there are 40 newly recorded from the Maldive Archipelago. 105 species are clear new records from Addu. 23 more are possibly new records, as they are plants mentioned by Willis and Gardiner (Ann. R. Bot. Gard. Peradeniya 1(2): 45-164, 1901) as occurring generally throughout the group, but not specifically mentioned by them from Addu. This is a large proportion of new records, found in spite of (in certain cases possibly because of) the almost total destruction of the natural and planted vegetation by the construction of an air base. It seems clear that a great deal of careful collecting still must be done before we can claim anything like an adequate picture of the floras of the world's islands.

In addition to the bare records of species collected, Sigee's notes on their occurrence on the three islets visited have been added. The observations placed *after* the citation of the collection number do not necessarily apply strictly to the local population from which the specimen was collected. The notes *before* the citation presumably apply to the plant actually collected.

Since the list of Maldive plants was published (ARB 58) in 1957, there have been certain changes in our understanding of some of the species included in it, and certain changes in nomenclature. A list of these has been added at the end of this paper, whether or not they apply to Addu species.

PDERIDOPHYTA

Psilotaceae

Psilotum nudum (L.) Beauv.
Hitaddu islet, in water, in forest area north of staging post, in closed forest where water table was at ground level, Sigee 90.

Polypodiaceae

Asplenium pellucidum Lam.?
Hitaddu islet, common in northern forest area, on tree stumps, around open pools, Sigee 105. New record for the Maldives.

Nephrolepis hirsutula (Forst. f.) Presl
(Possibly the plant recorded as N. exaltata (L.) Schott by Willis & Gardiner; see ARB 58).
Gan islet, abundant, forming dense stands in the dense central woodland, Sigee 57. Also found in regenerating woodland nearby; on Hitaddu I., found only in the northern forest area, associated with Psilotum and Asplenium.

Thelypteris goggilodus (Schkuhr) Small
Gan islet, in open woodland with high water table, Sigee 41. Very common in open scrubland at the S.E. end. Fairly common also in central dense woodland, S.E. marshland and roadsides. New record for the Maldives.

SPERMATOPHYTA

Cupressaceae

*Juniperus sp. ?
Gan islet, Sigee O. Recent introduction, cultivated bush along roadsides near RAF buildings. New record for the Maldives.

*Thuya orientalis L.
Gan islet, in village near Officers' Mess, Sigee P. Recent introduction, cultivated to form low sparse hedge. New record for the Maldives.

Pandanaceae

Pandanus sp.
Gan islet, common in coastal scrub along margin of island, Sigee 76. Some trees also in the central dense woodland, in open scrub, and a few juvenile plants in the S.E. marshland. On Hitaddu islet, abundant in coastal scrub on seaward side of island, also in seaward half of northern forest area. Juvenile specimens occurred infrequently in staging post area.

Potamogetonaceae

Cymodocea ciliata (Forsk.) Asch.
Gan islet, on submerged reef, between shore and boulder edge of reef, Sigee 25. On lagoon and seaward reef flats on both Gan and Hitaddu

islets. Common and widespread on seaward flat, occurring in conditions of continuous, moderate water flow; localized on the lagoon reef to an inshore zone. New record for the Maldives.

Hydrocharitaceae

Thalassia hemprichii (Ehrenb.) Asch.

Gan islet, between boulder ridge and reef edge, Sigee 26. On lagoon and seaward reef flats of both Gan and Hitaddu islets. Distribution generally similar to Cymodocea. New record for the Maldives.

Gramineae

Aeluropus littoralis (Gouan) Parl.

Hitaddu islet, lagoon side, sand-coloniser, Sigee 93. Seen only along lagoon shore, on beach, where it was fairly common. New record for the Maldives.

Apluda mutica L.
(A. varia var. aristata L.)

Gan islet, on top of sand bank 20 yards from sea, with Ipomoea and on bare sand, Sigee 13. Abundant on both islets (Hitaddu and Gan), where there has been a clearance of vegetation. Common throughout Gan, except in the central dense woodland area and in the grassland surrounding the runway. On Hitaddu islet, abundant in the staging post scrub, and common on the lagoon side of the forest north and south of this.

Bambusa multiplex (Lour.) Rausch ?

Gan islet, in gardens, Sigee X. Recent introduction.

Cenchrus echinatus L.

Gan islet, near huts, Sigee 82. Uncommon in open grassland in the immediate vicinity of RAF buildings. New record for the Maldives.

Chrysopogon aciculatus (Retz.) Trin.

Gan islet, in grass wasteland, near buildings, Sigee 80. Common in open grassland, also occurring along roadsides. New record for Maldives.

*Dactyloctenium aegyptium (L.) Willd.

Gan islet, in wasteland near buildings, Sigee 81. Common in open grassland and along roadsides. Hitaddu islet, common in staging post area. New record for the Maldives.

Digitaria timorensis (Kunth) Balansa

Gan islet, common in the open grassland and along roadsides, Sigee 62. New record for the Maldives.

*Eleusine indica (L.) Gaertn.

Gan islet, east end, lagoon side, in wasteland, in shade, in patches on bare ground, Sigee 19. Common in the open grassland and along roadsides. Hitaddu islet, in staging post area.

*Eragrostis tenella (L.) Beauv.
(E. amabilis (L.) W. & A.)
Gan islet, near east end, lagoon side, in wasteland, Sigee 18.

Lepturus repens (Forst. f.) R. Br.
Hitaddu islet, coloniser, on seaward shore, Sigee 91. New record for the Maldives.

Panicum repens L.
Gan islet, Sigee 64. New record for the Maldives.

Paspalum commersonii Lam.
Gan islet, fairly common in open marshland at S.E. end, Sigee 89. New record for the Maldives.

*Sorghum bicolor (L.) Moench
Gan islet, sporadic in open grassland at N.W. end of airstrip, Sigee 74.

Thuarea involuta (Forst. f.) R. & S.
Gan islet, eastern tip, shoreline, in open, near sea, covering ground with Cassytha, Sigee 27; also common in open grassland at N.W. end, surrounding runway and along roadsides. Hitaddu islet, common in staging post area.

Cyperaceae

Cladium jamaicense Crantz var. chinense (Nees) Koyama
Hitaddu islet, in marshland, by side of open water, Sigee 97. Locally common in marshland of northern forest, and also observed covering a wide area of open marshland north of the staging post area, in the midst of the forest. On Gan islet, seen only in small amounts in the S.E. marshland.

Cyperus brevifolius (Rottb.) Hassk.?
Gan islet, single colony found in open scrub at S.E. end, forming lush stand on wet ground, Sigee 84. New record for the Maldives.

Cyperus conglomeratus Rottb. f. pachyrrhizus (Nees) Kük.
Hitaddu islet, only a few colonies observed, lagoon shore, just south of staging post area, Sigee 102.

Cyperus javanicus Houtt.
Gan islet, common in the S.E. open marsh area, and scrubland, Sigee 24. On Hitaddu islet, fairly common in the staging post area.

*Cyperus ligularis L.
Gan islet, grassland, Sigee 4; common in the S.E. marsh area. On Hitaddu islet, common in staging post area. New record for the Maldives.

Cyperus melanospermus (Nees) Sur.
Gan islet, near airstrip, grassland, Sigee 66. Uncommon in the open grassland and roadsides, where the ground has had free surface water. New record for the Maldives.

Cyperus polystachyos Rottb.

Gan islet, east end, south of runway, in marshland (high water table), Sigee 38. Common in the wetter zones of the open grassland surrounding the runway, and in the S.E. marshland. On Hitaddu islet, fairly common in staging post area, in the marshland adjacent to the northern boundary.

*Cyperus rotundus L.

(But spikelets very pale)

Gan islet, behind oil tanks, in grassland, dense forest, Sigee 17. Common in S.E. marshland, open grassland, and along roadside. On Hitaddu islet, fairly common in staging post area.

Eleocharis geniculata R. and S.

Hitaddu islet, northern forest, in open pools, just projecting above water surface, in open woodland area, Sigee 106. New record for the Maldives.

Fimbristylis cymosa ssp. spathacea (Roth) Koyama

(A slender form with unusually small spikelets)

Gan islet, Sigee 40. Common in S.E. marsh area, uncommon in scrub and along roadsides.

Fimbristylis sp.

Gan islet, in marshland, Sigee 39. Common in southern marsh area. On Hitaddu islet, seen only in the northern forest area, where it was localized in open pools.

Araceae

*Colocasia esculenta (L.) Schott

Gan islet, center, in dense fern stand, Sigee 59. Mature plants occurred in the gardens, where they were obviously cultivated. A few mature specimens were also seen in the scrub in the centre of the island, and juvenile forms occurred in clearings in the central woodland.

Palmae

Cocos nucifera L.

Gan islet, common around RAF buildings, and along the lagoon shore at the northwest tip of the island. Hitaddu islet, common in the forest north and south of the staging post. The lagoon side of the forest comprised open coconut woodland. Not collected.

Commelinaceae

Cyanotis axillaris (L.) D. Don

Gan islet, center, in open fern land, Sigee 78. Seen only at edge of clearings in central woodland. New record for the Maldives, first found there by Groves in 1943-45.

Cyanotis cristata (L.) D. Don
Hitaddu islet, north part, in clearing, Sigee 113. A single colony was seen in a dense area of the northern forest in a clearing near an old native dwelling.

Liliaceae

*Gloriosa superba L.
Gan islet, southern side, in bush scrub, Sigee 53. Uncommon, found in open scrubland in the centre of the island adjacent to the woodland.

Amaryllidaceae

Crinum asiaticum L.
Gan islet, in gardens, Sigee AD. Hitaddu islet, planted in rows by the wayside adjacent to the RAF buildings, Sigee L, south side in clearing, Sigee 101. The Hitaddu specimens are leaves only, so the determination is uncertain.

*Zephyranthes rosea Lindl.
Hitaddu islet, Sigee K. Planted as ornamental along roadsides near RAF buildings.

Taccaceae

Tacca leontopetaloides (L.) O. Ktze.
Hitaddu islet, in clearings in woodland, Sigee 96. Occurrs in the northern forest on the lagoon side, where conditions are fairly open.

Musaceae

*Musa sp.
Hitaddu islet, seen only in banana plantation north of trading post area. Gan islet, small plantation seen near the Pakistani village, just south of the runway. Not collected.

Casuarinaceae

Casuarina equisetifolia L.
Gan islet, single tree in village near Officers' Mess, Sigee Q.

Moraceae

*Artocarpus altilis (Park.) Fosb.
Gan islet, Sigee 60. A few trees were left standing near the RAF buildings. Hitaddu islet, a few specimens seen in the banana plantation north of the staging post.

Urticaceae

Pouzolzia indica Gaud.
Hitaddu islet, north, in clearing, Sigee 114. Gan islet, a few specimens seen on a bank in the southeast scrub.

Nyctaginaceae

Boerhavia diffusa L. ?

Gan islet, east end of island, Sigee 46. A few specimens were seen near the RAF buildings, and in the scrub at the southeast end. Hitaddu islet, commonly found in the staging post area, where it spreads across open ground.

*X Bougainvillea buttiana Holttum & Standley

(Perhaps the plant recorded as B. spectabilis Willd. in ARB 58)

Gan islet, in hedgerow, Sigee I. Recent introduction, cultivated near the RAF buildings.

*Bougainvillea glabra Choisy

Gan islet, Sigee J. Recent introduction, cultivated near RAF buildings.

Amaranthaceae

Alternanthera sessilis (L.) R. Br.

Gan islet, center, in scrub on rough ground, Sigee 73. Not common, typically found at the edge of the grass verge near to the road. New record for the Maldives.

*Celosia argentea L.

Gan islet, behind oil tanks, on grassy wasteland, Sigee 16. Widely scattered over the open grassland surrounding the runway, and in the scrub.

Nothosaerva brachiata (L.) Wight

Gan islet, roadside rubble, Sigee 75. Common in scrub, by roadsides and near buildings. Hitaddu islet, infrequently found in the staging post area.

Portulacaceae

*Portulaca oleracea L.

Gan islet, near oil drums, on bare waste ground, Sigee 42. Uncommon in open grassland. Hitaddu islet, infrequent in the staging post area.

Lauraceae

Cassytha filiformis L.

Gan islet, eastern tip, Sigee 28. Common in open grassland near buildings, and found in all open habitats over the island. Hitaddu islet, very common in the scrub of the staging post area, and frequent in the open woodland on the lagoon sides of the southern and northern forest.

Hernandiaceae

Hernandia sonora L.

Gan islet, near oil tanks, on bank, 10 yards from sea, Sigee 14. Single tree on the lagoon shoreline, and a few trees inland in the scrub area south of the central woodland. Hitaddu islet, seen as an infrequent tree or bush on the lagoon side of the northern forest.

Capparidaceae

Cleome viscosa L.
Gan islet, on roadside, Sigee 34 (glabrous form), Sigee 34b. Common in dry, open habitats such as roadsides and open grassland. Hitaddu islet, common in dry areas of the staging post scrubland, particularly on the seaward side. Specimens on Hitaddu were more pubescent than those on Gan.

Crassulaceae

*Kalanchoe pinnata (Lam.) Pers.
Bushy islet, in clearing on rough ground, Sigee 70. Common in the clearings in the wooded area. Hitaddu islet, seen only in the banana plantation north of the staging post.

Moringaceae

*Moringa oleifera Lam.
Gan islet, Sigee 107. A single tree in the graveyard of the Mosque, adjacent to the Pakistani village.

Leguminosae

Canavalia cathartica Thou.
Gan islet, lagoon shore, climbing on Scaevola in shade of palm tree, Sigee 6. Common on lagoon and southeast coastal scrub. New record for the Maldives, first found there by Groves in 1943-45.

*Cassia occidentalis L.
Gan islet, south end of island, east side, in open wasteland, Sigee 48. Uncommon, individual plants were scattered over open grassland and by roadsides. Hitaddu islet, uncommon, seen only in dry parts of the staging post scrub.

*Clitoria ternatea L.
Gan islet, in gardens, Sigee T.

Crotalaria retusa L.
Gan islet, eastern tip, in scrub, near sea, Sigee 29. Fairly common along roadsides and in scrub at the southeast end of the island.

*Delonix regia (Boj.) Raf.
Gan islet, Sigee 32. A few trees lined the roadway along the northern perimeter.

*Dolichos lablab L. ?
Hitaddu islet, in Scaevola-Tournefortia hedge, lagoon side, Sigee 92. A few plants seen along the lagoon shore at the northern end of the staging post area.

Erythrina variegata L.
(E. indica L.)
Gan islet, Pakistani Camp, near graveyard, near wall of buildings, Sigee 108. A single large sterile tree occurred on the southern side of the Mosque, near the Pakistani village.

Sesbania bispinosa (Jacq.) F. W. Wight
Gan islet, golf links, grass stand, Sigee 65. Uncommon, seen in open grassland and by roadsides. New record for the Maldives.

Vigna marina (Burm.) Merr.
Gan islet, west of promontory, east end, lagoon; coloniser, on sand banks near sea, Sigee 21. Common along lagoon shoreline.

Surianaceae

Suriana maritima L.
Gan islet, at edge of Scaevola bush, south side of island, Sigee 49. Single plant found near the seaward coast. Hitaddu islet, common along parts of the seaward shore, a few specimens found on the lagoon shoreline.

Euphorbiaceae

Acalypha indica L.
Hitaddu islet, in scrubland, centre of island, Sigee 103. Common in dry parts of staging post scrub. Gan islet, common in dry scrub and by waysides.

Acalypha lanceolata Willd.
Gan islet, waste ground, on coral pile, Sigee 83. An uncommon plant, found in open grassland, roadsides and scrub.

*Acalypha wilkesiana M.-A.
Gan islet, in gardens, Sigee Y.

Agyneia bacciformis (L.) Juss.
Gan islet, in very wet area, Sigee 112. Common in the southeast open marsh area.

*Codiaeum variegatum L.
Gan islet, Sigee F. Cultivated as an ornamental by the side of buildings.

Euphorbia cyathophora Murray
(E. heterophylla L. of ARB 58)
Gan islet, near oil tanks, at back of Ipomoea zone, Sigee 11. Common plant in scrub, and wasteland near buildings. Hitaddu islet, fairly common in banana plantation, also infrequent in staging post scrub.

Euphorbia hirta L.
Gan islet, wayside, Sigee 88. Common in scrub at southeast end of island, and along roadsides. Hitaddu islet, common in staging post scrub.

Euphorbia sp.
(Probably undescribed, of E. atoto-E. chamissonis group, but conspicuously pubescent; requires further study)
Gan islet, east end, lagoon side, in wasteland, bare open ground, Sigee 20.

*Manihot esculenta Crantz
Gan islet, Sigee N.

*Pedilanthus tithymaloides (L.) Poit.
Gan islet, in wayside, border, Sigee C. Common wayside ornamental. Recent introduction.

Phyllanthus madraspatensis L.
Gan islet, near oil tanks, on top of loose sand bank, 20 yards from tideline, Sigee 12. Common in all wasteland-scrub, roadsides and land near buildings. Hitaddu islet, common in staging post scrub.

*Phyllanthus urinaria L.
Gan islet, away from sea, near oil tanks, in wasteland, Sigee 23. Distribution as with P. madraspatensis: common in all wasteland-scrub, roadsides and land near buildings.

*Ricinus communis L.
Gan islet, rifle range, in open ground, near wayside, Sigee 44. Fairly common along roadsides and in dry areas of the scrub at the south-eastern end. Hitaddu islet, a few plants seen in the scrub around the staging post.

Malpighiaceae

Tristellateia australasiae Richard
Gan islet, in gardens, Sigee AC, U. New record for the Maldives.

Sapindaceae

Allophylus cobbe Bl.
Hitaddu islet, in woody clearing in woods, Sigee 95 (sterile). An infrequent plant, seen only in the lagoon northern forest area.

*Cardiospermum halicacabum L.
Gan islet, grass sward, Sigee 33. Common in scrub, and occasionally seen in open wasteland around buildings.

Dodonaea viscosa L.
Hitaddu islet, in wasteland, Sigee 99. Common in coastal scrub south of the staging post. Gan islet, a few bushes seen in the central scrub.

Tiliaceae

Corchorus aestuans L.
Gan islet, in grassland near buildings, Sigee 61. Common in open grassland and along roadsides. Hitaddu islet, common in staging post scrub.

*Muntingia calabura L.
Gan islet, west marsh, in tree-scrub woodland, small thicket, Sigee 43. Uncommon, bordering the marsh at the southeast end. Hitaddu islet, common in parts of the staging post area, where it was restricted to the marsh near the northern border.

Malvaceae

Abutilon indicum (L.) Sweet
Gan islet, south side, east end, Sigee 47. Uncommon, found in central scrub.

*Hibiscus rosa-sinensis L.
Gan islet, Sigee M. Solitary bush, at northwestern tip of island.

Hibiscus solandra L'Her.
Gan islet, grassland, Sigee 72. Uncommon, occurring along roadsides and in open grassland. Hitaddu islet, uncommon in staging post area.

Hibiscus tiliaceus L.
Gan islet, seashore, lagoon side, very near to tide-line; a dense tree with no associated herbs but often with Scaevola, Sigee 5. Abundant along the shoreline and in the regenerating woodland in the centre of the island; common also in the central dense woodland. Hitaddu islet, common tree, growing in the coastal scrub on the seaward side south of the staging post area, and in open woodland on the lagoon side north and south of this.

Sida humilis Willd. ?
Gan islet, on mown grassland, Sigee 109. Common in open grassland and along roadsides, very widespread. Hitaddu islet, common in staging post scrub.

Guttiferae

Calophyllum inophyllum L.
Gan islet, south side, scrub, Sigee 56. A few trees in the area of regenerating woodland.

Turneraceae

*Turnera ulmifolia L.
Bushy islet, clearing on rough ground, Sigee 68. Common in clearings in the centre of the woody area. Hitaddu islet, seen only in the banana plantation.

Passifloraceae

*Passiflora foetida var. hispida (DC.) Killip
Gan islet, grassy scrub, Sigee 63. Common along roadsides and in the scrub. Hitaddu islet, uncommon, in the staging post scrub. New record for the Maldives.

*Passiflora suberosa L.

Gan islet, south side, scrub, Sigee 55. Not common, but seen in the scrub, along roadsides, and clearings in the regenerating forest. Hitaddu islet, common in open, dry areas of the staging post scrub. New record for the Maldives.

Caricaceae

*Carica papaya L.

Gan islet, in open wasteland, Sigee 50. A few trees occurred in the southern coastal scrub, and around the buildings at the northern end.

Cucurbitaceae

*Cucumis melo L.

Gan islet, on rough ground, concrete rubble, between oil tanks, Sigee 15. Common in the grass verge by roadsides, and in the scrub clearings. Hitaddu islet, common on bare ground in staging post area, seaward side. New record for the Maldives.

Lythraceae

Ammania baccifera L.

Gan islet, near coral heap, wet ground, Sigee 86. Uncommon in the scrub, and localized in a small marsh area. Hitaddu islet, uncommon in the staging post scrub, where it was localized in the marsh at the northern boundary. New record for the Maldives.

Pemphis acidula Forst.

Gan islet, lagoon shore, in open, about 2 yards from high tideline, among Ipomoea, Sigee 7. Uncommon; a few specimens seen in the seaward coastal scrub. Hitaddu islet, common as the shoreline shrub along parts of the seaward coast, and in the coastal scrub behind the shoreline. A few specimens were also seen on the lagoon side. Bushy islet, rock spits going out to sea on ocean shore, Sigee 69. A common shrub, occurring along the whole periphery of the island, and in places washed by the tide.

Rhizophoraceae

Bruguiera gymnorhiza Lam.

(B. conjugata (L.) Merr. of ARB 58)

Hitaddu islet, south end, lagoon side, Sigee 110. Single specimen seen on the lagoon shore, south of the staging post, in an area of local surface water.

Combretaceae

Terminalia catappa L.

Gan islet, Sigee 71. A few trees seen in the area of buildings at the northwest end. Hitaddu islet, uncommon, occurring in the northern forest near the seaward coast.

Myrtaceae

*Eugenia cumini (L.) Druce
Gan islet, center, Sigee 77. The tallest tree on the island, dominating the central woodland; also occurring as juvenile specimens in the regenerating woodland nearby. New record for the Maldives.

Apocynaceae

*Catharanthus roseus (L.) Don
Gan islet, in wayside border, Sigee A. Recent introduction, very common along the wayside border as an ornamental.

*Nerium indicum Mill. ?
Gan islet, bush, wayside, Sigee B. Recent introduction, very common along wayside border.

Ochrosia oppositifolia (Lam.) K. Schum.
Gan islet, along eastern end, near road, solitary in scrub, Sigee 45. Uncommon, seen only in regenerating woodland.

*Plumeria obtusa L.
Gan islet, Sigee H. Recent introduction, wayside shrub.

*Plumeria rubra f. acutifolia (Poir.) Woods.
Gan islet, Sigee G.

Concolvulaceae

*Argyreia nervosa (Burm. f.) Bojer
Gan islet, Sigee E. Single specimen seen, cultivated as a creeper on an erected cane framework. New record for the Maldives.

Ipomoea littoralis Bl.
Hitaddu islet, in clearing in woodland, Sigee 115(sterile). A single colony seen in the northern forest, near a disused native dwelling.

Ipomoea pes-caprae (L.) R. Br. ssp. pes-caprae
Gan islet, seashore, in dense mats about 20 yards from sea, Sigee 1. Abundant on the lagoon shoreline, and behind the coastal shrub on the seaward side. Hitaddu islet, abundant on the lagoon shoreline, occurring also in parts of the open woodland on the lagoon side. A few plants seen in clearings in the seaward coastal scrub.

Ipomoea tuba (Schlecht.) G. Don
Gan islet, south of runway, east end, almost marsh (high water table), Sigee 37. Common in southeast open marsh area, and also in scrubland at that end of the island. Hitaddu islet, uncommon, in northern forest.

Jacquemontia paniculata (Burm.f.) Hall. f.
Gan islet, south side, scrub, grass, with Ipomoea vines, Sigee 54. Generally uncommon, seen in open grassland, roadsides, and scrubland near the regenerating woodland. Hitaddu islet, common in the scrub of the staging post, where it covered local areas of otherwise bare ground.

Boraginaceae

*Cordia curassavica (Jacq.) R. & S.
Gan islet, in gardens, Sigee 23a, Z. New record for the Maldives.

Cordia subcordata Lam.
Gan islet, end of island, Sigee 79. Uncommon, occurring near buildings.

Tournefortia argentea L.f.
(Messerschmidia argentea (L.f.) Johnst.)
Gan islet, seashore, lagoon, 5 yds from tide-line; open habitat, Sigee 8. Common along shoreline, and in coastal scrub at southeast end of island. Scattered as an infrequent shrub in the scrub farther inland, and a few colonising bushes seen in the open marsh area. Hitaddu islet, common along parts of seaward coast as shoreline shrub, and also in the coastal scrub behind the shoreline. Common also in the staging post area on the seaward side. Not common on the lagoon coast.

Solanaceae

Physalis angulata L.
(This specimen would correspond to P. minima L., which is probably just a reduced form of P. angulata L.)
Gan islet, near airstrip, grassland on disturbed area, Sigee 67. Common herb by the side of roads, occurring also in dry areas of the open grassland, and scrub. Hitaddu islet, fairly frequent in the dry areas of the staging post scrub.

Verbenaceae

*Lantana camara L.
Gan islet, Sigee S. Recent instroduction. A few bushes seen planted as wayside ornamentals at the northern end. New record for the Maldives.

*Lippia nodiflora L.
Gan islet, almost marsh (high water table area), Sigee 36. Seen only in the open marsh area at the southeast end, where it was common. Hitaddu islet, restricted to the marsh area at the northern boundary of the staging post, where it was locally common.

Stachytarpheta indica Vahl
Hitaddu islet, south end, on wasteland and in open forest, Sigee 100. Locally common in open grassland at the southern boundary of the staging post. New record for the Maldives.

Labiateae

Ocimum sanctum L.
Gan islet, near coral heap, dry waste ground, Sigee 87. Uncommon in central scrub. Hitaddu islet, uncommon in staging post scrub.

Stachys sericea Wall. ex Benth.
Hitaddu islet, north, in clearings, Sigee 116. Common in central staging post scrub, also found on the lagoon side of the northern forest. New record for the Maldives.

Scrophulariaceae

*Angelonia salicariaefolia H. & B.
Gan islet, in gardens, Sigee AB. New record for the Maldives.

Bacopa monnieri (L.) Wettst.
Gan islet, in water in marshland, Sigee 111. Restricted to the southeast marsh, where very common.

Striga asiatica (L.) O. Ktze.
Hitaddu islet, north part, in forest clearings at lagoon side, Sigee 94. Localized in a small area on the lagoon side of the northern forest, near the northern boundary of the staging post. New record for the Maldives.

Bignoniaceae

*Spathodea campanulata Beauv.
Gan islet, in gardens, Sigee AA. New record for the Maldives.

*Tecoma stans L.
Gan islet, in gardens, Sigee V.

Acanthaceae

*Pseuderanthemum carruthersii var. atropurpureum (Bull) Fosb.
Gan islet, Sigee R. Recent introduction. Planted as wayside bush.

*Pseuderanthemum carruthersii (Seem.) Guill. var. carruthersii ?
Gan islet, in wayside, Sigee D. Recent introduction. Occurring in garden and as wayside bush near buildings.

Rubiaceae

Guettarda speciosa L.
Gan islet, lagoon side, on shore, Sigee 10. Common in the coastal scrub, and occurring frequently in the open scrub, and regenerating woodland. Hitaddu islet, common in the coastal scrub on the seaward side, and in the open forest on the lagoon side north of the staging post. Fairly frequent in banana plantation.

Hedyotis brachiata Wight
Gan islet, near coral heap, waste ground, Sigee 85. Restricted to a small area of open scrub at the southeastern end of the island. New record for the Maldives.

Hedyotis corymbosa (L.) Lam.
Gan islet, southern end, along wayside in rocky dust, Sigee 51. Commonly found by waysides, also seen in the scrub. Hitaddu islet, common in the staging post area.

Ixora coccinea L.
Gan islet, southern part of island, in bush scrub, Sigee 52. Locally common shrub, seen only in the regenerating woodland south of the central dense woodland.

Morinda citrifolia L.
Gan islet, Sigee 58. Hitaddu islet, common in the coastal scrub on the seaward side, and occurring also as a frequent shrub in the open woodland on the lagoon side of the northern forest.

Goodeniaceae

Scaevola taccada (Gaertn.) Roxb.
(S. sericea Vahl)
Gan islet, Sigee 9. Common along the shore as a shoreline shrub, and also in the coastal scrub. Frequent in the open scrubland in the regenerating woodland. A few bushes occurred as primary colonisers in the southeast marsh area. Hitaddu islet, abundant on the seaward coast both as a shoreline shrub, and in the dense coastal scrub behind the shoreline. Also common in the staging post scrub, and on the lagoon shoreline. A frequent bush in the open forest, north and south of the staging post; was a coloniser in clearings in the dense Pandanus forest on the seaward side north of the staging post area.

Compositae

*Bidens pilosa L.
Hitaddu islet, in clearings in woodland, lagoon side, Sigee 98. Common on the lagoon side of the northern forest. New record for the Maldives.

Blumea sinuata (Lour.) Merr.
Hitaddu islet, in scrubland in open swampy area, Sigee 104. Uncommon, a few specimens found in the marsh area at the northern boundary of the staging post. New record for the Maldives.

*Conyza floribunda Kunth
[This species seems to me insufficiently distinct from C. bonariensis (L.) Cronq. FRF.]
Gan islet, east end of island, just south of airstrip, in open scrub, Sigee 30. Seen only as a few clumps near the coastal scrub at the eastern end of the runway. New record for the Maldives.

*Eclipta alba (L.) Hassk.
Gan islet, almost marsh (high water table), Sigee 35. Common in the southern marsh area, uncommon along roadsides and in scrub.

Launaea pinnatifida Cass.
Gan islet, seashore, Sigee 3. Common as a shoreline plant on lagoon side, also fairly frequent inland on bare ground. Hitaddu islet, common along the lagoon shoreline, spreading across bare sand.

*Tridax procumbens L.
Gan islet, east end, just south of airstrip, on bare ground, open, Sigee 31. Common in parts of the open "grassland", roadsides, scrub and on the shoreline. Hitaddu islet, abundant in parts of the staging post area, near buildings, where it formed a compact turf.

Vernonia cinerea var. parviflora (Bl.) DC
(V. cinerea (L.) Less. of ARB 58)
Gan islet, away from sea, near oil tanks, in wasteland, more or less shady, Sigee 22. Common by roadsides, in scrub, and near buildings. Hitaddu islet, common in scrub of staging post area.

Wedelia biflora (L.) DC.
Gan islet, seashore, not normally washed by tide, Sigee 2. Abundant in open coastal vegetation, occurring just inland from shoreline. Also common in dry inland scrub. Hitaddu islet, abundant herb, forming complete ground layer in places, in the lagoon side open forest, north and south of the staging post. Also common in clearings in coastal scrub on seaward side, and common in open scrub of staging post area itself.

Name changes required in the Systematic list of plants of the Maldive Islands (ARB 58: 8-36, 1957)

Apluda varia var. aristata L. = Apluda mutica L.

Bambusa arundinacea Willd. = Bambusa spinosa Roxb.

Bambusa vulgaris Schrad. = Bambusa arundinacea Willd.

Eragrostis amabilis (L.) W. & A. = Eragrostis tenella (L.) Beauv.

Paspalum vaginatum Sw. = Paspalum distichum L.

Cladium jamaicense Crantz = Cladium jamaicense var. chinense (Nees)Koyama

Areca cathecu L. = Areca catechu L.

Rhoeo discolor Hance = Rhoeo spathacea (Sw.) Stearn

Cordyline terminalis (L.) Kunth = Cordyline fruticosa (L.) Goepp.

Ficus retusa L. = Ficus microcarpa L. f.

Gynandropsis gynandra (L.) Briq. = Cleome gynandra L.

Albizzia lebbek L. = Albizia lebbeck (L.) Benth.

Erythrina indica L. = Erythrina variegata L.

Triphasia trifoliata DC. = Triphasia trifolia (Burm. f.) P. Wils.

Euphorbia heterophylla L. = Euphorbia cyathophora Murr.

Phyllanthus nivosus Bull = Breynia nivosa (Bull) Small

Abroma augusta L. = Ambroma augusta L. f.

Eugenia jambolana Lam. = Eugenia cumini (L.) Druce

Ipomoea turpethum (L.) R. Br. = Operculina turpethum (L.) Manso

Messerschmidia argentea (L. f.) Johnst. = Tournefortia argentea L. f.

Physalis minima L. = Physalis angulata L.

Borreria ocymoides (Burm. f.) DC. = Spermacoce ocymoides Burm. f.

Scaevola sericea Vahl = Scaevola taccada (Gaertn.) Roxb.

Adenostemma viscosum Forst. = Adenostemma lavenia (L.) O. Ktze.

D. Marine benthic algae from Addu Atoll, Maldive Islands[1/]

by Roy T. Tsuda[2/] and Jan Newhouse[2/]

The following is an annotated list of the marine benthic algae that were sent to the senior author by Mr. David C. Sigee. One terrestrial and one freshwater alga are also included in this paper. All collections were made in the proximity of three islands--Gan, Hitaddu, and Fedu on Addu Atoll, July to September, 1964.

Past published listings of the algae from the Maldive Islands are based solely on the collections from two expeditions--the J. S. Gardiner Expedition, 1892-1900, and the J. Murray Expedition, 1933-34. Barton (1903) describes 6 species, including 4 forms, 3 of the species from Addu Atoll; while Foslie (1903) enumerates 9 species of melobesioid algae, containing various forms, 2 of the species from Addu Atoll. Newton (1953) records one alga, Microdictyon pseudohapteron f. luciparense Setchell, collected by the J. Murray Expedition from Mulakadu Atoll. To the authors' knowledge, only these three papers treat the marine benthic algae from the Maldive Islands.

HABITAT DATA

The following is a list of habitats on Addu from which the collections of algae were made or observed by Mr. Sigee.

A. Gan Island - lagoon reef flat, shoreline to 100 feet.
B. Gan Island - lagoon reef flat, 100 feet to 250 feet.
C. Gan Island - lagoon reef flat, 250 feet to reef edge (360 feet).
D. Gan Island - lagoon reef slope, to depth of 90 feet.
E. Gan Island - seaward reef flat, shoreline to boulder zone.
F. Gan Island - seaward reef flat, boulder zone to reef edge.
G. Hitaddu Island - seaward reef flat, shoreline to 20 feet.
H. Hitaddu Island - seaward reef flat, 20 feet to reef edge.
I. Gan-Fedu Gap.
J. On knoll in lagoon, 30 feet below the surface.

MARINE ALGAE

In the list of species below, the letters representing the habitats above refer both to the site where the species were actually collected and where the species were only observed. Where more than one habitat is listed for a species, there is no available information indicating which was the actual site of collection. It must be assumed that the collector was sufficiently competent to judge critical differences between the specific entities represented. All specimen numbers

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1/ Technical Report No. 8, Hawaii Institute of Marine Biology, University of Hawaii, Honolulu, Hawaii 96822.

2/ Department of Botany, University of Hawaii, Honolulu, Hawaii.

cited here are those of the collector, and the specimens are deposited in the herbarium of Dr. Maxwell S. Doty, University of Hawaii.

Those five species which are recorded from Addu Atoll in both Barton (1903) and Foslie (1903) are incorporated in this listing and preceded by an asterisk.

Myxophyceae

Anacystis montana (Lightf.) Drouet & Daily
Habitat: E, Sigee 120.

Calothrix pilosa Bornet & Flahault
Habitat: E, Sigee 120.

Hormothamnion enteromorphoides Bornet & Flahault
Habitat: A, E, Sigee 86.
This species determination was made by Dr. Francis Drouet.

Lyngbya aestuarii Gomont
Habitat: B, C, E, Sigee 26, 79, 87.

Lyngbya majuscula Gomont
Habitat: A-F, Sigee 16.

Schizothrix calcicola (Ag.) Gomont
Habitat: E, Sigee 88.

Symploca hydnoides Gomont
Habitat: A-F, Sigee 42, 46, 61, 71, 79, 84, 85.

Chlorophyceae

Boergesenia forbesii (Harvey) Feldmann, 1938: 588, figs. 3-5.
Habitat: A, B, E, F, Sigee 6.
The elongated vesicles are in groups of 10-20. The bases of the vesicles in this collection are tapered with attached septate rhizoids.

Boodlea composita (Harv.) Brand, 1905: 187; Egerod, 1952: 362, figs. 6a, pl. 32a.
Habitat: B, E, F, H, Sigee 94.
Both specimens seem to fall within the limits of this species. No. 7 is much coarser with the main axis about 300 μ in diameter, while the main axis of No. 94 is about half that diameter.

Boodlea sp.
Habitat: D, Sigee 63.
The collection is a fine spongiose mass about a centimeter in diameter, with the presumed older portions of filaments approximately 25 μ in diameter and the younger portions as fine as 7 μ.

Bryopsis pennata Lamx., 1809: 134, fig. 1a-b, pl. 3; Egerod, 1952: 370, fig. 7.
Habitat: A-F, Sigee 14, 54, on coral.

Caulerpa lentillifera J. Ag., 1837: 173; Eubank, 1946: 418, fig. 2L; Taylor, 1950: 67.
Habitat: A-D, Sigee 8b.
This specimen, which is 5 mm high from the prostrate axis, does not fall within the size range as described by Eubank (1946) or Taylor (1950), but is placed here because of its distinct constrictions at the points of attachment of the pedicels to the terminal heads.

Caulerpa racemosa var. macrophysa (Kütz.) Taylor, 1928: 101, pl. 12 (fig.3) and pl. 13 (fig. 9).
Habitat: A-D, Sigee 8a.

Caulerpa racemosa var. peltata (Lamx.) Eubank, 1946: 421, figs. 2r-s.
Habitat: A-C, F, H, Sigee 9, 13.
Distinct peltate ramuli are present on both specimens.

Caulerpa serrulata var. typica (Weber-van Bosse) Tseng, 1936: 178, pl. 1.
Habitat: I, Sigee 47.

Caulerpa taxifolia (Vahl) Ag., 1822: 435; Eubank, 1946: 417, fig. 2f-g.
Habitat: A-C, Sigee 10.

Chaetomorpha brachygona Harvey, 1858: 87; Taylor, 1960: 70, pl. 2(fig.9).
Habitat: A, Sigee 66.
The filaments are about 150 µ in diameter and slightly constricted at their septa. The cells are less than two times as long as their diameter.

Chaetomorpha crassa (Ag.) Kütz., 1845: 204; Taylor, 1960: 72.
Habitat: A, Sigee 106.
The filaments, including the cell wall, are about 420 µ in diameter with the cell length less than twice their diameter. The thick cell wall is approximately 75 µ in diameter.

Chaetomorpha gracilis Kütz., 1845: 203; Taylor, 1960: 70.
Habitat: G, Sigee 105.
These filaments are about 45 µ in diameter with the length of the cells about two to four times as long as their diameter.

Cladophora sp.
Habitat: B-E, Sigee 38, 55.
These intertangled filaments are light brown in color with their cells about 120 µ in diameter. The length of each cell is about seven to eight times their diameter. The lateral branches usually occur on one side of the main filament.

Cladophora sp.
Habitat: A-B, Sigee 73.

Cladophoropsis sp.
Habitat: F, H, Sigee 99, 118.
The lateral filaments are spaced irregularly along the main filament in a verticillate manner. The diameter of the main filament is about 550 µ.

Codium arabicum Kütz., 1856: 35, pl. 100 (fig. II).
Habitat: F, Sigee 123.

Codium edule Silva in Egerod, 1952: 392, fig. 18, pl. 35b.
Habitat: B, F, Sigee 22.

A branching repent specimen with the thalli not secondarily attached to each other. The size and shape of the utricles are very similar as those described in Egerod (1952).

Dictyosphaeria intermedia var. intermedia Weber-van Bosse, 1905; Taylor, 1950: 42.
Habitat: E, F, H, Sigee 40.

Two morphologically different thalli are included in this collection--a solid, pseudoparenchymatous cushion and a hollow monostromatic bladder. Both thalli lack trabeculae. The latter thallus also falls within the circumscription of D. cavernosa (Forsskål) Boerg. Egerod (1952) comments on these species saying that D. intermedia, in the later stages of development, is almost indistinguishable from D. cavernosa. Since these two thalli appear under the same collection number, it may be possible that these represent the young and old stage of D. intermedia. A more critical study of the haptera of both species is needed.

Enteromorpha sp.
Habitat: A, D, Sigee 68.

These thalli are about 7 cm high with branching occurring near the base. Both cylindrical and compressed branches arise from the base, with the former type about 150 µ in diameter and the latter type about 1 mm in diameter. The cells appear in longitudinal rows with two to four pyrenoids in each cell.

Halimeda discoidea Decaisne, 1842: 91; Hillis, 1959: 352, pl. 2 (fig. 5), pl. 5 (fig. 11), pl. 6 (fig. 11), pl. 7 (figs. 9-10), pl. 8 (figs. 5-8), pl. 11.
Habitat: A, B, F, H, Sigee 1.

The secondary utricles are very conspicuously inflated.

*Halimeda incrassata (Ellis) Lamx., 1812: 186; Hillis, 1959: 365, pl. 4 (figs. 1-2), pl. 5 (fig. 21), pl. 6 (figs. 21-24), pl. 12.
Habitat: below 25 fathoms and on hard bottom outside atoll, Barton, 1903; A, B, Sigee 75; A, B, F, Sigee 2b; F, Sigee 103.

The habitat data for these three specimens are listed here separately since the specimens appear morphologically dissimilar, but all three seem to fall within the circumscription of this species when examined anatomically. The surface utricles of specimen No. 2b are round in appearance and not angular as described by Hillis (1959). Aside from this, it seems to fall within this species.

*Halimeda opuntia (L.) Lamx., 1812: 186; Hillis, 1959: 359, pl. 2 (figs. 7-8), pl. 5 (figs. 3-4), pl. 6 (fig. 6), pl. 7 (fig. 3), pl. 10.
Habitat: below 25 fathoms and on hard bottom outside atoll, Barton, 1903; A, B, E, F, H, Sigee 2a, 3, 4.

These thalli are about 4-5 cm high with no specific holdfast present. The medullary filaments are fused in twos but occasionally may be seen in threes, with the points of fusion about 1-1.5 times as long as the diameter of the filaments. The primary utricles adhere to each other even after decalcification. These individual utricles are about 17 μ in surface diameter.

Neomeris mucosa Howe, 1909: 84, pl. 1 (fig. 5) and pl. 5 (figs. 1-14); Dawson, 1956: 42, fig. 30c.
Habitat: F, H, Sigee 102.
Of the seven species in this genus, these thalli agree with the description and figures of this species as described in Howe (1909).

Tydemania expeditionis Weber-van Bosse, 1901: 139; A. & E. S. Gepp, 1911: 66, fig. 153-154; Taylor, 1950: 73, pl. 38 (fig. 1).
Habitat: B-D, J, Sigee 32.
Only the distinct glomerular form of this species is present in this collection.

Udotea orientalis A. & E. S. Gepp, 1911: 119 and 142; Taylor, 1950: 74, pl. 38 (fig. 2).
Habitat: A-F, H, I, Sigee 15.
The thalli are small, about 3-4 cm high including the stipe, and anatomically similar to the description in Taylor (1950).

Valonia utricularis (Roth) C. Ag. 1822: 431; Taylor, 1950: 41.
Habitat: F, H, Sigee 103, 111.
The vesicles are irregularly shaped with no organized pattern of branching.

Valonia ventricosa J. Ag., 1887: 96: Egerod, 1952: 347, pl. 29a.
Habitat: B-D, F, Sigee 52.
These vesicles are solitary, about one centimeter in diameter.

Phaeophyceae

*Dictyota bartayresiana Lamx., 1809: 43.
Habitat: in passage below 25 fathoms and on hard bottom, Barton, 1903.

Dictyota friabilis Setchell, 1926: 91, pl. 13 (figs. 4-7) and pl. 20 (fig. 1).
Habitat: A-F, H, J, Sigee 5a, 70.
Both collections form prostrate clumps, with the thalli about 1-2 cm long. Most of the thalli of No. 70 are less than 2 mm broad, whereas the thalli of No. 5a are about 5 mm broad. For the present, both of these sterile specimens are tentatively listed here.

Dictyota sp.
Habitat: A-F, H, J, Sigee 5b.
This collection consists of prostrate clumps with the thalli up to 3 cm long. The margins of the thalli are serrated as in Dictyota patens J. Ag., but do not conform to the growth habit and size of this species.

Hydroclathrus clathratus (Bory) Howe, 1920: 590; Taylor, 1950: 96.
Habitat: E, F, I, Sigee 45.

Padina commersonii Bory, 1828: 144; Okamura (Icones VI): 89, pl. 295.
Habitat: A, B, E, G, Sigee 17.

These thalli are about 5 cm high and arise from a common holdfast. The thalli are two to three cells thick, about 90 μ in thickness at the apical portion and enlarging to 120 μ in thickness below. The oogonia are in concentric rows on the upper surface above every hairline, with no inducium present.

Pocockiella variegata (Lamx.) Papenfuss, 1943: 469, figs. 1-14.
Habitat: B, D-F, H, Sigee 50.

The thalli were growing prostrate on fragments of coral. Although the anatomical sections as well as habit are similar to those described in Papenfuss (1943), there is still some doubt as to the legitimacy of the generic name.

Sphacelaria sp.
Habitat: A, B, Sigee 28.

These thalli are about 1-2 mm high. Since all of the thalli were without propagulae, no specific epithet can be designated here.

Turbinaria ornata (Turner) J. Ag., 1848: 266; Taylor, 1950: 101, pl. 53 (fig. 2) and pl. 55 (fig. 2)
Habitat: B, F, H, I, Sigee 20.

Rhodophyceae

The melobesioid corallines of the present collection are not reported here because of the authors' unfamiliarity with this group. However, two species described in Foslie (1903) are listed here.

Antithamnion sp.
Habitat: B, C, F, Sigee 25.

The branches on the main axis are either opposite or verticillate with the terminal branches tipped with a single acute shaped cell.

*Archaeolithothamnion schmidtii Fosl.
Habitat: below 25 fathoms of water in lagoon, Foslie, 1903.

Botryocladia skottsbergii (Boerg.) Levring. 1941: 645; Dawson, 1956: 52, fig. 48.
Habitat: A-C, F, Sigee 23.

Ceramium fimbriatum Setchell & Gardner, 1924: 777, pl. 26 (figs. 43 & 44); Dawson, 1944: 317; Dawson, 1950: 123.
Habitat: G, Sigee 105.

The mature portions of the thalli are approximately 70 μ in diameter, with the corticating bands divided into two distinct parts at about the lower third. Short thick apically rounded, unicellular hairs are present at the nodes. The tetrasporangia are involucrate.

Ceratodictyon spongiosum Zanard., 1878: 36; Okamura, 1909 (Icones II): pls. 51-52.
Habitat: I, Sigee 69.
The thalli are very sponge-like in appearance.

Champia parvula (Ag.) Harvey, 1853: 76; Boerg., 1915-20 (Danish West Indies): 407.
Habitat: A, Sigee 122a.
The thalli are intertangled and form small clumps about 2 cm across.

Champia salicornoides Harvey, 1853; Taylor, 1960: 491, pl. 61 (fig. 5).
Habitat: A, Sigee 122b.
The thalli are about 3 cm high and appear erect from a basal disk. Anatomically, the walls of the thalli consist of a single layer of large cells, 25-50 μ in diameter, interspersed with smaller cells about 7-14 μ in diameter. The medullary filaments are seen running throughout the length of the thalli. The sessile pericarps are conical in shape and scattered on the thalli.

Dasya sp.
Habitat: H, Sigee 112.

Dictyurus purpurascens Bory in Belanger & Bory, 1846: 170, pl. 15 (fig. 2); Taylor, 1950: 143, pl. 78 (fig. 1).
Habitat: B, Sigee 24.
This collection is similar to the description and photograph in Taylor (1950).

Galaxaura marginata (Ellis & Solander) Lamx., 1816: 264; Kjellman, 1900: 77, Tab. 20 (fig. 44).
Habitat: B, C, Sigee 104.
The thalli are composed of flattened branches throughout. Terminal cells of the cortical filaments are spherical in shape.

Galaxaura rudis Kjellman, 1900: 43-44, Tab. 2 (figs. 1-9) and Tab. 20 (fig. 11).
Habitat: A, B, D, F, Sigee 21.
The thalli are 3-4 cm high and are bushy in appearance. Anatomically, the thalli consist of long assimilatory filaments with swollen cells at the basal portion of these filaments.

Gelidium divaricatum Martens, 1866: 30, pl. 8; Tseng, 1936: 36, figs. 18a-b, pl. 4.
Habitat: A-D, F, J, Sigee 72.

Griffithsia sp.
Habitat: C, Sigee 80.
The thalli are sterile and about a centimeter long.

Herposiphonia sp.
Habitat: B, D, H, Sigee 78.
These thalli were growing as epiphytes on Halimeda opuntia.

Hypnea spp.
Habitat: E, Sigee 91; E, F, H, Sigee 93; A, B, E, F, Sigee 18; B-D, Sigee 12.

Four species are represented in these collections of Hypnea. Due to the taxonomic difficulties encountered by the senior author in this genus, they cannot be named at present but are listed separately above with their respective habitats.

Jania capillacea Harvey, 1853: 84; Boerg., 1917: 198-199, fig. 188.
Habitat: A-F, H, Sigee 11.

The thalli appear as intertangled masses, with the branches seldom forming obtuse angles at the dichotomies. The diameter of the branches is approximately 120 u, with the length of the segments 6-8 times as long as the diameter.

*Lithothamnion fruticulosum (Kütz.) Fosl.
Habitat: below 40 fathoms, Foslie, 1903 (cited as an uncertain determination).

Lophosiphonia villum (J. Ag.) Setchell & Gardner, 1903: 329.
Habitat: B-D, F, H, J. Sigee 29, 98.

Polysiphonia ferulacea Suhringar in J. Ag., 1863 (Spec. Alg. II): 980.
Habitat: A-C, E, F, I, Sigee 35a.
Species determined by Dr. Hollenberg.

Spyridea filamentosa (Wulf.) Harvey in Hooker, 1833: 337; Taylor, 1950: 139; Dawson, 1954: 444, fig. 54i.
Habitat: E, Sigee 97.

The main axis is similar to the illustration in Dawson (1954). The determination branchlets are tipped with a single spine.

Tolypiocladia glomerulata (Ag.) Schmitz in Schmitz and Hauptfleisch, 1896-97: 441; Dawson, 1954: 452, figs. 59b-c.
Habitat: B, C, Sigee 44.

Vidalia serrata (Suhr.) J. Ag., 1863: 1125.
Habitat: B, Sigee 19.

The thalli are about 2 cm high with the stichidia present on the blades, just inside of the marginal serrations.

FRESHWATER AND TERRESTRIAL ALGAE

Nostoc commune Bornet & Flahault
Habitat: Terrestrial, Gan Island, Sigee 119

This blue-green alga was reported to be especially evident in wet weather.

Pithophora oedogonia (Mont.) Wittrock, 1877: 55, pl. 6 (figs. 1-6); Collins, 1909: 363.
Habitat: Freshwater, Gan Island, Sigee 114.

The filaments of this green alga are branched with cells about 60 µ wide and the cell length about ten times as long as the diameter. Both intercalary and terminal akinetes are present.

Summary of Algal Collection

Excluding the four tentative species of *Hypnea*, this paper lists 63 species or varieties of marine benthic algae from Addu Atoll, 58 of them reported here for the first time from this atoll. These new records consist of 7 in the Myxophyceae, 25 in the Chlorophyceae, 7 in the Phaeophyceae, and 19 in the Rhodophyceae. One terrestrial alga and one freshwater alga are also included in this paper.

It is of great interest to note that the species represented here from Addu Atoll in the Indian Ocean are very similar to the marine flora that occurs on many of the atolls in the Pacific Ocean.

Acknowledgment

The authors are grateful to Dr. Maxwell S. Doty, who critically read the manuscript and who gave them free access to his personal library. They are also indebted to Mr. H. E. Hackett, Department of Botany, Duke University for his unselfish help in furnishing the authors with the necessary references to past literature on the marine benthic algae of the Maldive Islands; to Dr. Francis Drouet, Academy of Natural Sciences, Philadelphia, who provided the determination of *Hormothamnion enteromorphoides* Bornet & Flahault; to Dr. George J. Hollenberg, Professor Emeritus of Biology, University of Redlands for his determination of *Polysiphonia ferulacea* Suhr.; and to Mr. Gavino Trono, Jr., Department of Botany, University of Hawaii, who helped with the determinations of the two species of *Galaxaura*.

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VI. ADDU ATOLL IN 1836

The following text is taken from an unpublished manuscript by Commander R. Moresby, "Nautical directions for the Maldive Islands", written following the first hydrographic survey, and preserved as MS 55 in the India Office Records, Commonwealth Relations Office, London, by whose permission it is reproduced.[1/] Excerpts from Moresby's work have been previously published (Moresby 1835, 1844), and his officers also published early descriptions (Christopher 1841, 1844; Young and Christopher 1844), but Moresby's full memoir has not previously been published, though Darwin (1842) drew on it, and it is briefly mentioned by Gardiner. The original forms a volume of 98 manuscript pages, of which pages 39-46 deal with Addu Atoll.

Addoo Atoll

Addoo Atoll erroneously called by former Navigators Phoohah Moloque
Atoll, this Atoll being rich, well inhabited, and available for Ships,much
in want of supplies; I shall be particular in describing it. This Atoll
terminates the South extreme of the Maldive chain of Islands, is the small-
est of all the Atolls; being only 10 Miles from East to West. and 7 miles
from North to South, it is of a half Moon Shape, the concave side facing
the north, and the convex side the South. The NW Point is in Lat^{de} 0°35'
South. Long^{de} 73°6½ East. The NE Point in La^{de} 0°35 South and Long^{de}
73°10½ E. there are nine larger and several smaller Islands; the two prin-
cipal Islands lay, one on the NW point; the other on the NE^{n} point; that
on the NW^{n} part of the Atoll, is named Hit-ta-doo. and extends to the SSE
39 5 miles, its breadth from ¼ to ½ of a mile; next to the South of it is / is
40 Merra-doo. about one Mile in extent; then Faidoo which is smaller, next
to the south is Gung, which is 1½ Mile in extent, and is the most South-
ern and centre Island of the Group; all these Islands four in number, lay
on the Western side of the Atoll, and are connected by a barrier reef.
of coral, dry at low water, with no Soundings outside of them.

There are four Channels leading into this Atoll; two in the Centre,
on the North side, and two in the centre on the South side; the Southern
channels are the largest., and may be used at night time; the Northern ones
are not so broad; yet are safe. and available for vessels coming from the
North^{d} with northerly winds, or leaving the Atoll with Southerly winds.
a vessel could not work through the Northern Channels, but with a fair
tide it could be don through the Southern ones; the best way is to adopt
that channel through which a vessel will have a fair wind; the Northern
40 Channels are not easily seen by a vessel coming from the Northward./as
41 the Northern barrier at some distance appears like one unbroken Reef; on
a nearer approach and almost in the centre of this barrier, between the
East and Western Islands, lay the channels; which will be known by a small
bushy Island and a high Bank of Coral Stones; both on the Same Reef; on

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either side of them is a channel leading into the Atoll, the eastern
Channel is the largest being 4 or 500 yards broad, having not less than
6 & 7 fms, its direction NW and SE^{n}; the Western Channel is narrower yet
longer, and its direction North and South, the depths are from 10 to 12
fms; in both these channels the tides and currents are strong. as also in
the Southern ones; the Flood tide sets into the Northern Channels; the
Ebb sets into the Southern ones, rise and fall of the tide about 4 feet,
high water at 1 hour full and change of the moon. The Southern Channels
41 lay on the East side of Gung Island the Southern Island of the / the Atoll;
42 this I shall call Gung Channel and is formed between Gung Island. and two
small Islands to the ENE of Gung, called Willing-gilly Islands. Gung
Channel is half a mile broad, having no dangers in it. and the depths are
from 13 to 17 fms. it is convenient for any Ship entering the Atoll. The
other Channel I shall call the Willing-gilly Channel is on the East side
of the Willing-gilly Islands, formed between them and the South Point of
the dry coral reef bounding the East Side of the Atoll; this channel is
one mile broad and has from 17 to 20 fms water in it; deepening as a Ship
enters the Atoll; the direction of this Channel is about NW & SE about
one mile inside the entrance, on the NE side, there is a small Coral reef,
and as a Vessel proceeds on to the centre of the Atoll, 3 coral patches
will be observed on which the sea breaks at times; but these are easily
avoided by a common look out; the deepths in the centre of the Atoll are
42 from 25 to 35 fms sand and clay; the most convenient anchorage for com-
43 munication with the Natives is near the Islands on the West side all / all
of which are inhabited; from the Willing-gilly channel round the NE^{n} Side
of the Atoll; to the Centre on the North side, is one continued barrier
reef, on which are several Islands, the only large one of two miles in
extent, is on the NE^{n} part of the Atoll this is well inhabited and an in-
teresting Island it is called Mee-doo and Hoo-loo-doo from two villages
situated in its Centre.

This Atoll is clear of Reefs except in the Centre, the three small
patches as formerly mentioned; and which are easily avoided; 30 & 35 fms
is the depth of water in the Centre. Near the Islands on the East and
West sides, are 20 & 25 fms. a vessel may Anchor as Most convenient, ac-
cording to the Seasons; during the NE^{n} Monsoon on the north or Weather
side, and in the other Monsoon on the West side. The Islands afford a
few Supplies, of Fruit - limes. Poultry Eggs. Water and Firewood in abun-
dance. the Natives are very civil and obliging, and will exchange their
articles either for Money or Rice, Biscuits, Sugar. Salt. Onions. Garlic.
43 they are extremely lazy / lazy and indolent and very timorous fearful of
44 strangers, and will not be induced to assist a Ship in Wooding, and Water-
ing, unless paid for it, and obliged to work; they are under the Govern-
ment of the Sultan at Male, or King's Island; and the Atoll-Warree or
Chief of the Atoll is the person Strangers ought to apply to, for assis-
tance in getting Supplies; Some of the Natives speak the Indostannee
language; their principal occupation is making cotton Cloths, of White,
Red, and Black colours mixed; all of which they dye themselves. and sell
at a good price in the other Atolls; they are not allowed by their Govern-
ment to trade with Foreigners, not even with the English their Allies;all
this produce must be sold at the King's Island Male. They seldom visit
Ships passing, from fear of molestation; and it would be wrong any Ships

stopping at these Islands; to allow their Crew to intrude into the privacy of their houses, among their females, or wantonly and without
44 permission to take their fruit. coconuts. fowls &c. they are poor, and
45 inoffensive, and have reason / to regret the visits of some Merchant
Ships; in Religion they are all Musselmen. the Atoll contains about 500 inhabitants and in appearance they are like the Natives of India on the Malabar coast.

There are no soundings outside of this Atoll close to the barrier reef. and being to the South^{d} of the line or Equator. is almost without the influence of the Monsoon: the Winds and Weather being very variable. subject to Squalls. and Rain. The NE^{n} Monsoon is felt in Jan^{ry} Feb^{y} & March. and Westerly winds more in July August & Sept^{r}. the currents about this Atoll are very Strong, for six months they set to the West^{d} and then back again to the East^{d} according to the Monsoons. but are subject to checks from variable winds. They commence to set to the West about January and to the East^{d} about June. their velocity from 40 to 50 Miles per day. decreasing considerably in strength 40 or 50 Miles from the Islands. there was in 1836 no variation of the Magnetic.

45 I have been thus particular as so many Ships pass this place on
46 their way to & from India. /

I have also recommended it as a Coal Depot for Steamers.

VII. BIBLIOGRAPHY OF THE MALDIVE ISLANDS

This bibliography covers the reefs, islands, zoology, botany, and peoples of the Maldive Islands. A basic source is the bibliography by Sachet and Fosberg (1955), together with the references listed by Haas (1961) and Eibl-Eibesfeldt (1964). Dr. Sachet verified or corrected some of the entries, and added a large number from her unpublished bibliographies. Her help is gratefully acknowledged. The bibliography also includes some items not specifically concerned with the Maldive Islands, but referred to in this report; these are noted with an asterisk.

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