Reports

OF THE

Great Barrier Reef Committee

VOLUME III.

ISSUED 13th JANUARY, 1931.

FREDERICK PHILLIPS, Government Printer, Brisbane.

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With Ten Plates.

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Contents.

No. 1.

The Great Barrier Reef Expedition, 1928-1929.

By C. M. Yonge, D.Sc., Ph.D., Leader; late Balfour Student in the University of Cambridge.

(Plates I.–VI.)

Introduction.

This paper, written at the request of the Barrier Reef Committee, contains a general account of the nature and activities of the Great Barrier Reef Expedition. In view of the fact that, for obvious reasons of convenience, the great part of the results of the expedition will be published in Great Britain, it is only fitting that such a paper as this should appear in the Reports of the Great Barrier Reef Committee in Australia. A short general account of the expedition will form the introduction to the full series of scientific reports. While the present paper must inevitably cover the same ground, it will do so in more detail and also include summaries of the purely scientific and economic work as well as recommendations for future work. In this way it is hoped to gratify the natural desire of members of the Great Barrier Reef Committee and the Australian public generally for a full account of the work of the expedition which they invited out from Great Britain, for which they provided nearly half the funds, and the success of which was largely due to their continued interest and co-operation.

Genesis of Expedition.

In his account of "Scientific Investigations on the Great Barrier Reef, Australia," in volume ii. of these Reports, Professor H. C. Richards has outlined the events which led to the formation, at the Leeds meeting in 1927, of a British Association Committee for the purpose of organising an expedition to the Great Barrier Reef of Australia. This Committee, which consisted of members of the Sections of Zoology, Botany, Geography and Geology, with later co-opted members, was made up as follows:—

Rt. Hon. Sir M. Nathan, Chairman; Prof. J. Stanley Gardiner and Mr. F. A. Potts, Secretaries; Mr. E. Heron Allen, Dr. E. J. Allen, Prof. J. H. Ashworth, Dr. G. P. Bidder, Dr. R. N. Rudmose Brown, Dr. W. T. Calman, Sir G. Lenox Conyngham, Sir T. W. Edgeworth David, Mr. F. Debenham, Admiral Douglas, Capt. Edgell, Prof. F. E. Fritsch, Prof. E. J. Goddard, Prof. W. T. Gordon, Sir S. F. Harmer, Sir Frank Heath, Mr. A. R. Hinks, Dr. Margery Knight, Prof. H. C. Richards, Prof. A. C. Seward, Dr. Herbert Thomas, Dr. C. M. Yonge. The Agent-General for Queensland, the Hon. John Huxham, kindly agreed to act as Treasurer, being succeeded in 1929 by the new Agent-General, the Hon. E. H. Macartney.

The Committee decided to send out a large-scale expedition to work for at least a full year on the Barrier, and set to work immediately to raise the necessary funds and assemble a suitable party.

Finance.

The following contributions were received towards the expenses of the expedition:—

	£	s.
Commonwealth Government	2,500	0
Empire Marketing Board	2,500	0
Great Barrier Reef Committee	1,000	0
Royal Society of London	950	0
Dr. G. P. Bidder	500	0
British Association for the Advancement of Science	400	0
Australasian Association for the Advancement of Science ..	200	0
Mr. E. Heron Allen	100	0
Mr. Edward T. Browne	100	0
Dr. W. S. Colman	100	0
Rt. Hon. Lord Glendyne	100	0
Zoological Society of London	100	0
Rt. Hon. Sir Matthew Nathan	25	0
Mr. J. R. Eccles	5	5
Total	£8,580	5

The Royal Geographical Society undertook full financial responsibility for the Geographical Section of the expedition. The Balfour Fund of the University of Cambridge, the British Museum, and the Carnegie Trust for the Universities of Scotland were responsible for the payment of salaries to Dr. Yonge, to Mr. Tandy, and to Miss Marshall and Mr. Orr respectively. Valuable concessions on steamer fares and freight were given by the Australian and New Zealand Passenger Conference. The Queensland Government provided free rail transport for personnel and equipment (the total value of which approached £1,000), and also paid the salary of Mr. Moorhouse, while the Commonwealth Government allowed all equipment to be imported duty-free. Great assistance was also afforded by the Navy Department and the Navigation and Lighthouse Service in the loan of instruments, transport, and other facilities for work at Low Isles, as will be acknowledged later.

The financial assistance thus received proved sufficient for the completion in full of the programme drawn up before the expedition left Great Britain, and a small sum remained in hand after its return.

Personnel.

The party, which left London on the R.M.S. "Ormonde" on 26th May, 1928, consisted of Miss S. M. Marshall, Mr. A. P. Orr, Mr. G. W. Otter, Mr. and Mrs. F. S. Russell, Dr. and Mrs. T. A. Stephenson, Mr. G. Tandy, and Dr. and Mrs. C. M. Yonge. They arrived at Brisbane on 9th July and, accompanied by Mr. F. W. Moorhouse of Brisbane, proceeded north two days later to arrive at Low Isles, the headquarters of the expedition, on 16th July. They were joined two days later by Mr. A. G. Nicholls of Perth. Subsequently additional members came out from England, while some of the original party left. The camp at Low Isles was evacuated on 28th July, 1929, after being occupied for exactly one year and twelve days. A detailed list of the members of the expedition, the nature of their work, and the period each of them spent on Low Isles, is given below:—

		Months.
C. M. Yonge, Esq., D.Sc., Ph.D. (Edin.)	Leader of Expedition; Physiologist	$12\frac{1}{2}$
F. S. Russell, Esq., D.S.C., D.F.C., B.A. (Cantab.)	Second in command; in charge of Boat Party; Zooplankton worker	5
J. A. Steers, Esq., M.A. (Cantab.)	Leader, Geographical Section	4
T. A. Stephenson, Esq., D.Sc. (Wales)	In charge of Shore Party; Zoologist	$11\frac{1}{2}$
A. P. Orr, Esq., M.A., B.Sc., (Glasgow), A.I.C.	Chemist and Hydrographer	$12\frac{1}{2}$
Miss S. M. Marshall, B.Sc. (Glasgow)	Phytoplankton worker	$12\frac{1}{2}$
F. W. Moorhouse, Esq., B.Sc. (Q'land)	Economic Zoologist	$12\frac{1}{2}$
A. G. Nicholls, Esq., B.Sc. (W. Australia)	Assistant to Leader	$12\frac{1}{2}$
G. W. Otter, Esq., B.A. (Cantab.)	Zoologist	11
Mrs. G. Russell, M.B.E.	Assistant to Mr. Russell	5
Mrs. A. Stephenson	Honorary Zoologist	$11\frac{1}{2}$
G. Tandy, Esq., B.A. (Oxon.)	Botanist	5
Mrs. M. J. Yonge, M.B., Ch.B. (Edin.)	Medical Officer; Assistant to Leader	$12\frac{1}{2}$
J. S. Colman, Esq., B.A. (Oxon.)	Zooplankton worker	$10\frac{1}{2}$
Miss E. A. Fraser, D.Sc. (Lond.)	Zoologist	4
Miss S. M. Manton, M.A., Ph.D. (Cantab.)	Zoologist	4
C. E. Marchant, Esq., B.A. (Cantab.)	Geographer	3
M. A. Spender, Esq., B.A. (Oxon.)	Geographer	11

The Trustees of the Australian Museum, Sydney, very kindly agreed to five members of their scientific staff assisting the expedition for periods of between four and six weeks during the latter part of 1928. Mr. W. Boardman, Mr. T. Iredale, Mr. A. A. Livingstone, Mr. F. A. McNeill, and Mr. G. P. Whitley all visited Low Isles and made valuable collections on that and neighbouring reefs. Mr. Iredale later spent a second period with the expedition, assisting in the ecological survey of Three Isles, and his collections of reef molluscs and his exceptionally wide knowledge of these animals were of the greatest help to the work.

Low Isles were visited during the course of the expedition by a number of visitors with scientific interests, and they were especially welcome since one of the main aims of the expedition was the encouragement of marine zoology in Australia. A list of these visitors, in the order they visited the expedition, follows:—

Charles Barrett, Esq., of the *Melbourne Herald*.

T. C. Roughley, Esq., Economic Zoologist of the Technological Museum, Sydney.

Professor H. C. Richards, D.Sc., Chairman, Great Barrier Reef Committee.

Dr. E. O. Marks, Hon. Secretary, Great Barrier Reef Committee.

H. A. Longman, Esq., Director of the Queensland Museum.

H. S. Mort, Esq., Sydney.

Miss Freda Bage, M.Sc., F.L.S., Principal of the Women's College, The University of Queensland.

Miss H. F. Todd, Assistant Secretary, Great Barrier Reef Committee.

E. A. Briggs, Esq., D.Sc., Zoology Department, University of Sydney.

Dr. and Mrs. P. D. F. Murray, Zoology Department, University of Sydney.

Professor G. E. Nicholls, D.Sc., Biology Department, University of Western Australia.

Miss M. D. Glynne, of the Rothampstead Experimental Station, who did valuable work on the distribution of Lithothamnia on Low Isles Reef, and made collections of fungi and lichens

Mrs. A. C. Wishart, of Brisbane.

Dr. Gwyneth Buchanan, Zoology Department, University of Melbourne.

F. N. Ratcliffe, Esq., M.A., special investigator of the flying fox pest for the Commonwealth Government.

On 15th March, 1929, we had the especial pleasure of a short visit from Dr. Schmidt and the scientific staff of the "Dana," at that time en route from Brisbane to Thursday Island and the East Indies.

A group showing the majority of the members of both sections of the expedition, leading members of the Great Barrier Reef Committee, and members of the staff of the Australian Museum, is shown in Plate I., fig. 1.

FIG. 1.—PARTY ON LOW ISLES, 3RD NOVEMBER, 1928.

Names from left to right.

Back row, standing: H. C. Vidgen, F. A. McNeill, J. A. Steers, A. P. Orr, H. S. Mort, H. A. Longman, E. O. Marks, M. A. Spender, J. S. Colman, G. Tandy, C. E. Marchant, A. A. Livingstone, T. Iredale.

Front row, seated: F. W. Moorhouse, A. C. Wishart, Miss S. M. Marshall, F. S. Russell, Mrs. Russell, Professor H. C. Richards, Mrs. Yonge, C. M. Yonge, Mrs. Stephenson, T. A. Stephenson, A. G. Nicholls.

Seated on ground: Master Iredale, G. W. Otter.

[*Photo., M. J. Yonge.*

FIG 2.—KITCHEN, LABORATORY, AND EASTERN END OF MARRIED QUARTERS FROM SOUTH. The sea-water tank with the anemometer above it is in the foreground and the lighthouse behind.

[*Photo., G. W. Otter.*

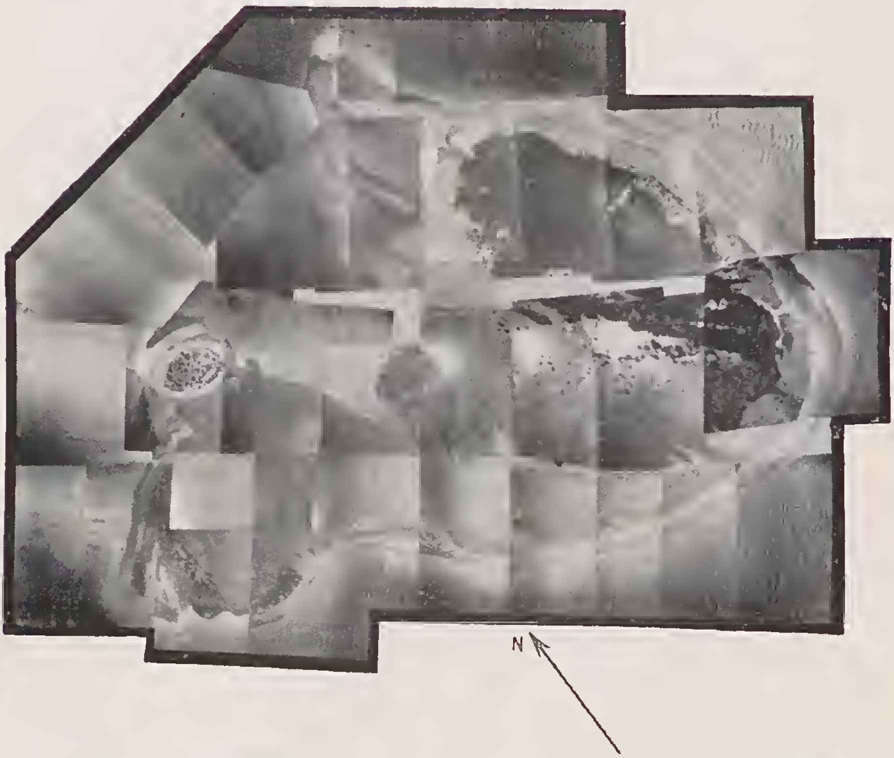

FIG. 3.—MOSAIC PHOTOGRAPH OF LOW ISLES REEF FROM HEIGHT OF 2,000 FEET.

[*Photo., Royal Australian Air Force.*

Fig. 4.—Sand Cay from the South.
Shingle rampart in the foreground, reef flat in middle distance; photograph taken at low water.
[*Photo., G. W. Otter.*

Fig. 5.—Central Lagoon within the Mangrove Swamp at Low Isles.
[*Photo., G. W. Otter.*

Fig. 6.—Library occupying North-Eastern Corner of Laboratory Hut.

[*Photo., M. J. Yonge.*

Fig. 7.—Western Half of Laboratory Hut.

Showing plankton bench on left, chemical bench in centre, and physiological bench on right.

[*Photo., M. J. Yonge.*

Fig. 8.—The "Luana" lying at Anchor between Snapper Island and the Mainland. [*Photo., M. J. Yonge.*

Fig. 9.—Experimental Area on the Reef Flat. [*Photo., M. J. Yonge.*

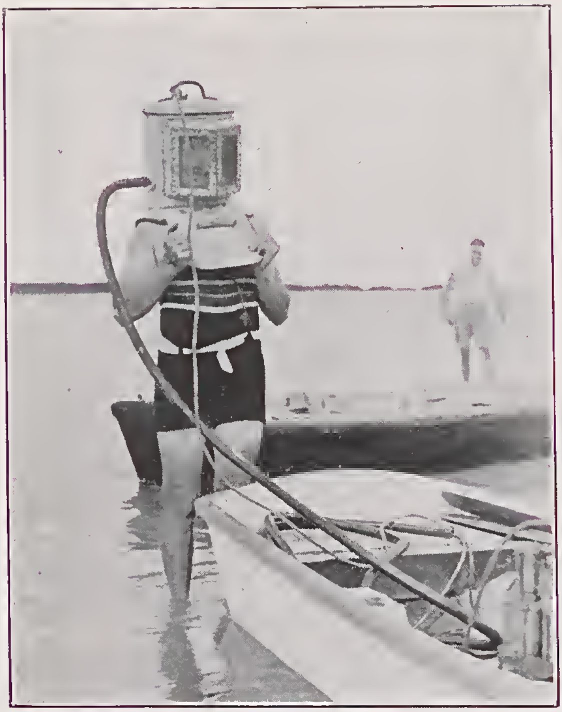

FIG. 10.—DIVING OUTFIT.

[Photo., H. C. Vidgen.

FIG. 11.—MR. F. S. RUSSELL WITH A TOW-NET AND THE DEPTH RECORDER ON THE "LUANA."
The boom with the metre wheel seen above.

[Photo., H. C. Vidgen.

FIG. 12.—BRINGING IN THE DREDGE FROM THE HALIMEDA BOTTOM NEAR LIZARD ISLAND DURING THE MAGNETA CRUISE.

[Photo., M. J. Yonge.

Low Isles.

After much consideration the Great Barrier Reef Committee in Brisbane recommended Low Isles, forty-five miles north of Cairns in Lat. 16° 23′ S., Long. 145° 34′ E., as the headquarters of the expedition. Events showed that no better site could have been chosen. It was central, about midway up the Barrier, equidistant from the coast and the inner side of the Barrier, here fourteen miles apart, conveniently near a base of supplies in Port Douglas only seven miles distant, and in regular communication with Cairns and the south of Queensland, and possessed a good anchorage.

Low Isles consist of two islands arising from a common coral formation. The reef itself has the shape of a somewhat compressed crescent, with the convex side pointing south-east and the concavity—the anchorage—north-west. The general plan will be realised most easily by reference to Plate II., which is a reproduction of a mosaic photograph taken at a height of 2,000 feet by an amphibian flying boat belonging to the Royal Australian Air Force. This machine, under the command of Lieutenant Packer, was sent north from Bowen by the Air Force authorities, the great assistance to the expedition thereby rendered being here most gratefully recognised. The dark area on the eastern edge of the reef is the mangrove swamp, of considerable area but almost entirely awash at high water. It consisted of an almost impenetrable forest of *Rhizophora mucronata* fringed, on a slightly higher level, with *Avicennia officinalis.* Within were several open areas covered with thick mud and the stumps of dead trees (Plate III., fig. 5). The presence of this mangrove and the very different flora and fauna it supported gave an added interest to ecological work on the reef.

The second island (Plate III., fig. 4), on the north-west of the reef formation, is an oval sand cay covered with bushes with several coconut palms, casuarinas, and *Terminalia Catappa.* At low water it was some 700 ft. long and 16 ft. above water level, and had a total area above the beach of some 3 to 4 acres. The reef flat cannot here be described in detail. It was about 4 ft. above datum line, and bounded on the convex side by a shingle rampart, which was most strongly developed at the south-eastern point, where it was 60 yds. wide and 7½ ft. above datum, gradually decreasing in height and width towards the horns of the crescent. This rampart enclosed a shallow moat, never completely dry at the lowest tides and containing much living coral. Behind this stretched the reef flat, which varied greatly in character in different parts. It consisted largely of dead coral on the south-western side, of sand in the region south of the cay, and of mud and sand with much weed and isolated mangroves in the mangrove "park" to the west of the swamp. The margin of the reef between the western horn of the crescent and the sand cay was marked with a conspicuous tract of dead coral boulders, small examples of the large "nigger-heads" typically found on the lee sides of reefs in the cyclone belt. The northern shores of the sand cay, about low-water mark, were strengthened with a broad area of beach rock, a little of which was also present on the south shore. The anchorage formed the concavity of the crescent, being bounded to the west by the sand cay and to the east by a long shingle spit. It had a sandy bottom with many patches of growing coral, exposed only at the lowest tides. On this, the lee side of the reef, the bottom shoaled very gradually, but on the south-eastern, weather side, the coral descended at a comparatively steep angle to some 12 fathoms.

Accommodation.

The small sand cay was the only inhabitable part of the reef complex. The position of the reef, in the middle of the steamer channel, caused a lighthouse to be erected here between forty and fifty years ago. Centrally situated, 65 feet high and painted white, it is a conspicuous object. Around it are grouped the houses of the three lightkeepers.

The huts belonging to the expedition were arranged in a line along the top of the beach on the south side of the cay, as will be seen in Plate II., fig. 2. After the details of requirements of the expedition had been received at Brisbane, the Committee there were so fortunate as to receive the offer of the services of Mr. J. E. Young, a prominent Queensland naturalist, as director of the constructional work. As a result of Mr. Young's great experience in camp life and of his energy and ability, the members of the expedition on their arrival at Low Isles found all the huts completed and all necessary furniture and stores provided. The expedition owes a great debt to Mr. Young. Scientific work was begun almost immediately after arrival, instead of being delayed for many weeks pending the completion of constructional work.

There were six huts consisting, in order from east to west, of the following:—

1. Kitchen, 10 ft. by 12 ft. Of galvanised iron throughout, and connected with a covered passage-way with—

2. Laboratory and dining hut, 35 ft. by 18½ ft. Of wood with galvanised iron roof, the framework of this hut was that of the hut used on Michaelmas Cay. There were doors at the end adjoining the kitchen and in the middle of the two long sides, and four windows on either side. The east end contained a working bench used by the shore party on the south, and on the north the dining table and the library (see Plate IV., fig. 6). The west end contained three working benches; on the south that of the plankton workers, in the centre the chemical bench, and on the north the physiological bench. The general appearance is shown in Plate IV., fig. 7.

3. Married quarters, 49 ft. by 12½ ft. Divided into five rooms, that at the east end forming the store, the others being used

by the married members and the lady members of the expedition. There was a wide veranda on the south side, the whole being of wood with a galvanised iron roof.

4. Single quarters, 40 ft. by 12½ ft. Similar to the last, but divided into two rooms for the use of the unmarried male members.

5. Lavatory and bathroom. Behind the single quarters and of galvanised iron throughout. Bathroom contained a hip bath and shower and also a "fountain shower" kindly provided by the makers. Also occupied by the still for the preparation of distilled water, and by the steriliser.

6. Aboriginal quarters. A small hut similar to No. 4, and divided into two rooms for the use of the aboriginal servants.

After the arrival of the party, much additional furniture constructed from packing cases, kerosene boxes, &c., and draped with cretonne, was made. Every available space on the walls of the laboratory hut was covered with shelves and an additional bench constructed. Mr. Young made stools, of exemplary rigidity, and added a small dark-room on the east end of the married quarters. Later an additional store for the housing of boat's gear was constructed on the north side of the kitchen. A meteorological hut, constructed according to specifications supplied by the Commonwealth Meteorological Bureau, was erected on the north side of the island.

A sea-water tank of wood (see Plate I., fig. 2), and standing on stout wooden supports some 8 ft. high, had been erected on the south side of the laboratory. The supports were boarded in on three sides and shelves constructed within so as to form an aquarium. Later two further aquaria were constructed for use by Dr. Stephenson and Mr. Moorhouse respectively, also between the laboratory and the beach. There was also endless constructional work for experimental purposes.

Food and Supplies.

Food and other supplies were obtained from Port Douglas seven miles away. The lighthouse supply boat came out every other Wednesday; the expedition had the use of this but supplemented the service by its own boat, the "Luana," in the alternate weeks, and often more frequently. The bulk of the tinned goods, fresh vegetables, and fruit came from Cairns, the remainder from Port Douglas itself. Fresh meat was thus obtained once a week and lasted about two days, after which tinned goods had to be relied on. Fortunately fresh fruit and vegetables could usually be kept the entire week. Fish were scarce around the island, and even the erection of a fish-trap near the mangrove swamp did not greatly increase the supply.

During November an "Electrolux" refrigerator, supplied by the makers at very generous terms, was received. The sea-water tank, pumped full daily by the aboriginal servants, provided the necessary circulation of water, and an "Aladdin" kerosene lamp the heat. This machine worked admirably, and made a very great difference in the comfort of life during the summer months.

Water was a serious problem. A fortunate shower immediately after the tanks—situated at either end of each of the main huts—were erected carried the party over the first few weeks. After then it was necessary to obtain water from the mainland, it being brought in large tanks by the M.L. "Daintree" from the Daintree River and then carried up the beach in pails and kerosene tins. On two occasions water was obtained from the lighthouse steamers "Cape York" and "Cape Leeuwin" and pumped directly into the tanks. For this and many other services thanks are due to Captain Roskruge and the Commonwealth Navigation Department at Brisbane. After the beginning of the rains in November there was no further anxiety about water, and the supply received during the summer, with the addition of the contents of one of the lighthouse tanks kindly supplied by Mr. O'Meara, the head light-keeper, proved sufficient for the remaining period of the expedition.

Mrs. Yonge acted as housekeeper, receiving much help from the other lady members. The original cook, Gracie Dabah, remained for four months and was succeeded by Minnie Connolly, who remained for the concluding eight months. Both were half-caste aboriginal and white, and came from the Anglican Mission to the Aboriginals, at Yarrabah near Cairns.

Camp Arrangements.

Rough work about the camp was carried out by the aboriginal servants. Andy and Claude, husbands of the two cooks, acted as house-boys, keeping the huts tidy and attending to the sanitary arrangements. Harry Mossman and Paul Sexton, both from Yarrabah, remained with the expedition for the full period of its work, and formed the crew of the "Luana" and did rough work about the camp, and assisted the scientific staff in various ways. All the aboriginal servants did excellent service to the expedition, and by their cheapness and efficiency contributed very materially to its success.

The work of the aboriginal servants was supervised and directed by Mr. H. C. Vidgen, of Brisbane. Mr Vidgen sailed up with Mr. A. C. Wishart on the "Luana," and the expedition was fortunate in securing his services for the full period of its work. Mr. Vidgen assisted Mr. Wishart on the boat but at all other times worked on the island. It is impossible to speak too highly of his ability and unfailing good humour. By invariably working with the aboriginals he was able to infect them with something of his own industry. His knowledge of Australian business methods was also of great help, and he was of great help to the leader personally in transacting business at Port Douglas and Cairns. No one contributed more to the success of the expedition.

For a short period near the conclusion of the expedition a third aboriginal boy, Stephen Dabah, was engaged to assist Dr. Stephenson and the Shore Party.

In addition to their regular scientific work, all the members of the expedition had certain duties allotted to them, such as care of the library, tools, smaller boats, supervision of pumping, &c.

Equipment.

The programme of the expedition involved the erection and equipment of a modern marine biological laboratory on Low Isles. The great bulk of the equipment was purchased in Great Britain and brought out on the R.M.S. "Ormonde." Out of a total value of some £1,200 not more than 10s. worth of damage was done, in spite of transhipment at Brisbane and again at Cairns.

Large stocks of standard laboratory glassware and chemicals were brought from Great Britain, replacements and additional supplies being purchased in Australia. Petrol bunsens were used with success, also primus stoves and "Colman" petrol vapour lamps and stove, the two latter became especially valuable. Rain-water was used, distilled water being prepared by means of a small "Griffin's" still housed in the bathroom. The centrifuge used in the phytoplankton work was supported on a special staging sunk deep into the sand beneath the laboratory, so that it could be worked at maximum speed without shaking the floor and benches. The delicate balance was housed in the lighthouse, owing to the absence there of vibration.

A very serviceable scientific library was collected, containing standard works on zoology and marine biology, especially with reference to tropical conditions and coral reefs. Much assistance was rendered in this connection by a number of individuals and institutions, notably Professor J. Stanley Gardiner, the Royal Society and the Linnean Society of London, the Australian Museum, the British Museum, the Indian Museum, Calcutta, and the Carnegie Institution and the Smithsonian Institution of Washington, all of whom made valuable gifts of books and journals.

Standard hydrographic and plankton apparatus was used. There were two Knudsen insulating water-bottles and a metre wheel, all made at the Laboratoire Hydrographique of Professor Dr. Martin Knudsen at Copenhagen. Standard international pattern tow-nets of coarse and fine silk were used (Plate VI., fig. 11), also metre stramin nets, and Apstein and Nansen silk nets. A depth recorder (Plate VI., fig. 11) was loaned to the expedition for the first five months by the Marine Biological Association of the United Kingdom, and an Eckmann current metre was lent by Professor J. Stanley Gardiner. Rectangular and triangular dredges were used (Plate VI., fig. 12), several being supplied by the British Museum, who also provided the net for one of the two Agassiz trawls. A Petersen grab was borrowed from the Zoological Department of the University of Cambridge, two small vacuum grabs of the Bidder and Hunt pattern being also used. The Royal Australian Navy gave great assistance by the loan of a Lucas sounding machine, sounding lines and leads, binnacle compass, station pointer, sounding sextants, Douglas protractor, patent log, Admiralty charts, and much other material. A friction winch and small motor were purchased, and proved of inestimable value in open sea work on the larger vessels hired for cruises.

For reef work baskets and collecting jars of the various standard sizes used by the Marine Biological Association of the United Kingdom at the Plymouth Laboratory were employed. Absolute and commercial alcohol were obtained duty-free through the kind offices of the University of Queensland. Several members of the expedition brought their own microscopes, but the great bulk of those used, both monocular and binocular, were lent by the Zoological Department of the University of Cambridge. Through the kindness of Acting Professor Briggs, two additional monocular microscopes were obtained from the Zoological Department of the University of Sydney. A "Watson" half-plate camera, two stands, and all accessories were lent by Mr. Watson Baker, of London. A valuable part of the collecting apparatus consisted of a diving helmet (Plate VI., fig. 10) of the type originally employed by Dr. Mayor at the Carnegie Laboratory at Tortugas, and recently made popular by the writings of Dr. Beebe.

The Commonwealth Meteorological Bureau supplied standard instruments of the following types: barograph, thermograph, hygrograph, sunshine recorder, anemometer, and maximum and minimum and wet and dry bulb thermometers. The Geographical Section of the expedition brought with them a Bauch and Lomb recording tide gauge, which was erected on the western side of the anchorage during February.

Boats.

The provision of a suitable boat was one of the first considerations, and the Committee at Brisbane were most fortunate in obtaining the services of Mr. A. C. Wishart and his motor launch the "Luana" for the full period of the expedition. The expedition is also indebted to the Brisbane Newspaper Company for granting Mr. Wishart the necessary leave of absence. The "Luana" (Plate V., fig. 8) was a ketch-rigged yacht, 39 ft. long, with a draught of 3 ft., and with a 26 h.p. Kelvin sleeve valve engine, extremely reliable and economical in fuel. This fact, together with the most generous terms on which Mr. Wishart provided his services and those of his boat, was another important factor in the financial solvency of the expedition. Mr. Wishart's pleasure and interest in the work of the Boat Party contributed greatly to its success.

Mr. Wishart was assisted by Mr. Vidgen, and the two aboriginal men, Paul and Harry, acted as crew when the boat stations were made. Regular weekly stations for hydrographic and plankton work were made throughout the year with hardly a break, at a position midway between the island and the inner side of the Barrier. A series of more distant stations outside Trinity Opening were also worked, while many visits to neighbouring reefs and the mainland about Snapper Island and the Daintree River were made. Regular communication was maintained with Port Douglas at fortnightly and often more frequent intervals, and occasional visits paid to Cairns and Yarrabah Mission. Although, of course, never built for marine biological work, the "Luana" did all and more than could have been expected of her, and Mr. Wishart and the "Luana" played a great part in the scientific success of the expedition.

The original policy of the expedition had been to engage two launches, but on arrival in North Queensland inquiries about boats proved largely unsuccessful. The alternatives were a somewhat expensive boat of the same general type but a little smaller than the "Luana," and a 20-ft. whaleboat. The latter was finally purchased, being intended as an auxiliary to the larger boat, and for dredging and trawling around Low Isles. She gave unceasing trouble, both her hull and engine requiring extensive repairs. She carried out all necessary dredging and trawling about the island but was otherwise of little use. Events showed that a second boat was unnecessary, and consolation is provided in the fact that the larger boat was not engaged. A new 12-ft. dinghy and a 2½ h.p. Johnson outboard motor for use with her were purchased, and proved of the greatest use both for independent use around Low Isles and for towing behind the "Luana." A small flattie, originally used by the first expedition on Michaelmas Cay, was very useful, especially as a diving barge and lighter.

For long cruises for plankton and hydrographic dredging or reef work, the "Luana" had neither the accommodation nor the power, and, with the exception of the visit of the Shore Party to Three Isles, and a short visit to Michaelmas Cay and Pixie Reef, larger boats with greater accommodation and more powerful engines were hired on these occasions. Details of these cruises and the boats used are given later in this paper.

Health.

The health of the party remained exceptionally good throughout the year. There is, fortunately, no malaria in North Queensland and no tropical disease other than dengue fever, which, with one doubtful case, all members escaped. The danger of sunburn was avoided by the appropriate precautions by the original members of the expedition, though several of the members who came out later from England suffered considerably from it. The worst trouble was septic cuts, scratches on the feet and legs with coral or any other agency invariably going septic and usually failing to respond to treatment unless the patient kept scrupulously away from sea-water until the wound had completely healed. During the summer the effect of the humid heat was felt keenly, particularly towards the end of March, and the majority of the remaining members of the original party were exhausted physically by the end of the year, both Miss Marshall and Mrs. Yonge having, unfortunately, to spend short periods in Port Douglas hospital near the conclusion of the expedition. Both in my capacity as leader of the expedition and personally I have to acknowledge the great help and kindness shown by Dr. and Mrs. Sword, of Port Douglas.

Excursions.

During the summer months all members of the expedition made visits of about a fortnight to the Atherton Tableland behind Cairns, where, at an elevation of between 2,000 and 3,000 ft., the excessive heat of the coastal region could be avoided. Whenever possible, Sunday excursions were made to Snapper Island, the Daintree River, or other places on the mainland.

Organisation of Scientific Work.

The expedition was subdivided into sections and parties, each having its own sphere of work which it carried out largely independently of the others. This policy worked well, the work of each section or party being such that it could co-operate with the others without in any way overlapping. The organisation of the expedition was as follows:—

A.—Biological Section.

The work of this section was, with the exception of the hydrographic and chemical work, exclusively biological in character. It was subdivided into the following three parties:—

1. *Boat Party.*—This consisted of F. S. Russell, leader and in charge of work on Zooplankton; A. P. Orr, leader after the departure of Mr. Russell in December and in charge of chemical and hydrographic work; S. M. Marshall, in charge of work on Phytoplankton; J. S. Colman, assistant to Mr. Russell and in charge of his work on Zooplankton after his departure; G. Russell, assistant to Mr. Russell in laboratory work. The work of this party consisted of quantitative and qualitative work on the animal and plant plankton and its variations in space and time throughout the year and diurnally, and correlated work on the physical and chemical conditions in the sea. Intensive work was carried out at the regular station between Low Isles and the Barrier and over the reef at Low Isles, and many isolated stations both within and without the Barrier worked. Mr. Orr and Miss Marshall also carried out work on sedimentation over the reef at Low Isles and its effect on the corals, and Miss Marshall did work on the oxygen exchange of coral planulæ.

2. *Shore Party.*—This consisted of T. A. Stephenson, leader and chief zoologist; G. Tandy, botanist; F. W. Moorhouse, economic zoologist; A. Stephenson, honorary zoologist and assistant to Dr. Stephenson; E. A. Fraser, zoologist; and S. M. Manton, zoologist. The principal work of this party as a whole consisted of a detailed ecological survey of Low Isles reef, of Three Isles, and of sectors of the Outer Barrier. In this work it had the valuable collaboration of M. A. Spender, of the Geographical Section. In addition Dr. and Mrs. Stephenson, assisted later by Dr. Fraser and Dr. Manton, worked on the breeding of a series of corals and other representatives of the reef fauna; Dr. Stephenson worked on the development of corals, and carried out a large-scale

experiment on the rate of growth of corals, Dr. Manton also carrying out work in this connection. Mr. Moorhouse worked with the Shore Party for the first few months but later devoted his entire time to problems of direct economic importance. He was also responsible for the collection of temperature data from the anchorage twice daily.

3. *Physiological Party.*—This consisted of C. M. Yonge, leader and physiologist; A. G. Nicholls, assistant physiologist; M. J. Yonge, chemical assistant; G. W. Otter, zoologist. The main work of this party consisted of a thorough research into the feeding, digestion, absorption, excretion, respiration, and metabolism generally of corals, paying especial attention to the zooxanthellæ and the part these algæ play in the life processes of corals. Similar work was also done on *Tridacna*, the clam, which also contains zooxanthellæ, and observations made on the feeding and digestion of other reef molluscs. Mr. Nicholls also did work on the breeding and growth of the pearl oyster and, with the assistance of Mr. Orr, on calcium metabolism in corals and other reef animals. Mr. Otter worked on boring organisms. In addition to physiological and general zoological work, this party was also responsible, with much assistance from Mr. Moorhouse, for dredging, trawling, and bottom collections generally.

B.—Geographical Section.

This section consisted of J. A. Steers, leader; M. A. Spender and C. E. Marchant, geographers. During the period that Mr. Steers was in Australia this section worked quite independently of the Biological Section. The M.L. "Tivoli," belonging to Mr. G. Butler, of Townsville, was chartered, and a cruise made from Townsville north as far as the Flinders Group, beyond Cape Melville, returning thence past Townsville to Mackay. Mr. Steers then left on his return to England, having been able to gain a general impression of the geographical problems presented by the Barrier Reef and the coast of Queensland which it borders. Mr. Spender and Mr. Marchant (the latter of whom had joined the "Tivoli" at Cooktown on her northern cruise), came on to Low Isles at the beginning of December, Mr. Marchant remaining for some six weeks and Mr. Spender for the remaining period of the expedition, when he carried out a detailed survey of the reef and also of Three Isles and of sectors of the Outer Barrier, all in conjunction with the Shore Party.

Scientific Excursions.

Little work was carried out away from headquarters at Low Isles for the first six months of the expedition. The policy adopted was to set up all detailed experimental work as soon as possible and to concentrate upon this and upon obtaining a thorough understanding of conditions on Low Isles reef and in the adjacent waters before going farther afield. This policy undoubtedly worked well, for when more extended work began, in the early part of 1929, the fullest possible advantage could be taken of the comparatively short visits made elsewhere. In the case of the Shore Party this policy was doubly necessary because good day low tides were experienced only during the winter months, and by the time the conditions on Low Isles reef had been studied during the first few months the tides were already so poor as to render extended reef cruises of little value. The fullest advantage was, however, taken of the low tides during May, June, July, and August of 1929.

Details of the various scientific excursions made are given below:—

I.—20/10/28. The M.L. "Merinda" of Townsville hired. The Boat Party with Dr. Yonge, Mr. Moorhouse, and Mr. Nicholls carried out plankton and hydrographic work outside Trinity Opening.

II.—23–24/11/28. "Merinda." Same party as before with the exception of Mr. Moorhouse; plankton, hydrographic, and dredging work outside Trinity Opening.

III.—25/2/29–2/3/29. The M.L. "Magneta" of Townsville hired. The Boat Party with Mr. Spender cruised as far north as Lizard Island and back, working a series of hydrographic and plankton stations within the Barrier and one outside Cook's Passage. A series of bottom samples were also taken.

IV.—6–14/3/29. "Magneta." A second cruise with Dr. Yonge, Mr. Moorhouse, and Mr. Vidgen on board was undertaken, proceeding this time some distance farther north still to the Howick Group. Dredging, trawling, and other bottom work was carried out at a series of stations, one of them outside Cook's Passage.

V.—17–18/3/29. "Magneta." The Boat Party with Mr. Moorhouse and Mr. Nicholls carried out plankton, hydrographic, and dredging work outside and inside Papuan Pass, some fifty miles north of Low Isles.

VI.—19–30/4/29. S.S. "Cape Leeuwin." Mr. Orr and Mr. Otter were absent from Low Isles for this period in connection with a visit to Willis Island undertaken at the invitation of the Commonwealth Lighthouse Service. Hydrographic work was carried out en route.

VII.—23/4/29–27/5/29. A party consisting of Dr. and Mrs. Yonge, Mr. Nicholls, and Mr. Moorhouse were absent from Low Isles for this period during a visit to Torres Strait. The voyage from Cairns to Thursday Island was made in the s.s. "Taiping," the return journey being made on the same vessel, when the party with great consideration were dropped at Low Isles, thereby saving much time and expense. The purpose of the visit was largely the inspection of the economic products and possibilities of the Torres Strait. The pearling and other industries at Thursday Island were inspected, also the work of Papuan Industries at Badu, where excellent work in training the natives in boat-building and in the exploitation of marine products is being carried on, and the various fishing activities at Murray Island. A fortnight was spent on the last-named, the site of the Carnegie expedition under the leadership of the late Dr. Mayor in 1913. The voyages to and from Thursday Island were made in the Papuan Industries' launch "Goodwill."

VIII.—1–16/5/29. "Luana." A party consisting of Dr. and Mrs. Stephenson, Mr. Colman, Mr. Spender, and Mr. Iredale of the Australian Museum visited Three Isles a little distance north of Cooktown, an ecological and topographical survey being made.

IX.—31/5/29–13/6/29. The M.L. "Tivoli" of Townsville, originally used by the Geographical Section, was hired, assistance also being given by the M.L. "Merinda." A party consisting of Dr. and Mrs. Stephenson, Dr. Fraser, Dr. Manton, and Mr. Spender established a camp on Lizard Island and carried out surveys of neighbouring sectors of the Outer Barrier.

X.—5–6/6/29. "Luana." During the absence of the Shore Party on cruise IX., a party consisting of Dr. and Mrs. Yonge, Miss Marshall, Mr. Orr, Mr. Moorhouse, Mr. Colman, and a visitor, Dr. G. Buchanan of Melbourne, visited Michaelmas Cay and Pixie Reef on the inner side of Trinity Opening, during the extremely low day tides then prevailing.

XI.—5–8/7/29. The M.L. "Daintree" of the Daintree River Settlement hired. A party made up of Dr. Yonge, Mr. Orr, Mr. Moorhouse, Dr. Manton, Mr. Nicholls, Mr. Colman, and Mr. Spender visited Ruby and Escape reefs of the Outer Barrier, respectively north and south of Papuan Pass, and also Undine reef of the Inner Barrier. Valuable information was obtained in spite of very stormy weather.

XII.—2–5/8/29. The M.L. "Athlone" of Gladstone hired. After the conclusion of the expedition, a party consisting of Dr. and Mrs. Yonge, Miss Marshall, and Mr. Orr stopped at Gladstone on their way south, and a visit was paid to the Capricorn Group, a visit which fortunately coincided with good low tides and excellent weather. Three nights were spent on Heron Island, the reef and the turtle-canning factory being examined, and a cruise made around the other islands, some time being spent on North-west Island.

Resume of Work Accomplished.

This may most suitably be presented under the four general headings of Observational and Routine, Experimental, Collecting, and

Economic Work, a classification of work done which, while it cuts somewhat across the allocation of work to the various parties, does perhaps give the clearest general statement of the scope and nature of the work carried out.

I.—Observational and Routine Work.

(*a*) Weekly plankton stations between Low Isles and Barrier; all catches sorted and a proportion counted.

(*b*) Weekly hydrographic stations, regular estimations of temperature, pH, salinity, phosphate, oxygen, and silica content made. Turbidity or otherwise of water tested with Secchi Disc.

(*c*) Series of plankton hauls made over Low Isles reef, treated as (*a*).

(*d*) Hydrographic conditions over Low Isles reef and in mangrove over high and low tides and over day and night.

(*e*) Plankton and hydrographic work at various stations within and without the Barrier.

(*f*) Vertical distribution of plankton in day and night.

(*g*) General ecological survey of Low Isles.

(*h*) Detailed quantitative survey of distribution of corals and algæ along two narrow strips of ground, with additional surveys of smaller patches.

(*i*) General survey of Three Isles.

(*j*) General survey of Jukes reef, Outer Barrier.

(*k*) Survey of patch of Batt reef.

(*l*) Topographical surveys accompanying the ecological surveys.

(*m*) Daily meteorological data consisting of barometric pressure, humidity, temperature (Mr. Tandy in charge for first five months, later Mrs. Stephenson and Mr. Spender), sunshine (Mrs. Yonge), and wind (Mr. Nicholls).

(*n*) Temperature of water in anchorage at surface and depth of one metre taken twice daily (Mr. Moorhouse).

(*o*) Continuous tidal data from February onwards (Mr. Spender).

II.—Experimental Work.

(*a*) Feeding and food of all available genera of corals.

(*b*) Digestion in *Fungia* and *Lobophyllia.*

(*c*) Absorption in *Lobophyllia, Galaxea, Pocillopora,* and *Psammocora.*

(*d*) Excretion in *Lobophyllia* and effect on this of zooxanthellæ

(*e*) Nature and distribution of zooxanthellæ in corals, &c.

(*f*) Oxygen production by zooxanthellæ of corals, &c.

(*g*) Oxygen exchange of coral planulæ.

(*h*) Effect of starvation and darkness on algal content of corals.

(*i*) Calcium metabolism of corals and *Holothuria*.

(*j*) Nature and rate of fall of sediment on reef under various conditions, and effect of this on the life of corals.

(*k*) Study of the life-history of *Pocillopora* and *Porites*.

(*l*) Study of the life-history of the hydroid *Eudendrium*.

(*m*) Investigation of the breeding seasons of the common animals on Low Isles, including several corals and a variety of common reef invertebrates.

(*n*) Large-scale experiment on the growth-rate of corals, supplemented with the marking of corals *in situ* under water by means of the diving helmet, and the collection of young coral colonies on clean surfaces put out for that purpose.

(*o*) Feeding of *Tridacna*, and effect of the presence of zooxanthellæ on this and the general metabolism of the clam.

(*p*) Feeding and digestion in the reef gastropods *Lambis* and *Vermetus*.

(*q*) Study of the distribution, nature, and mode of boring of the boring organisms on the reef at Low Isles.

III.—Collecting Work.

(*a*) *Plankton.*—Weekly collections throughout the year within the Barrier with fine and coarse silk nets and with stramin nets. Many isolated hauls elsewhere up and down inside the Barrier and at several places outside. This represents probably the richest and most complete collection of plankton ever made in coral seas.

(*b*) *Dredging.*—General dredging and trawling around Low Isles reef; in this region, however, the bottom is of mud with very little contained life of any kind. A series of twenty-seven dredging stations worked between Trinity Opening in the south and the Howick Group in the north, a stretch of some 200 miles. Several stations worked outside the Barrier, but a large ocean-going vessel is necessary for this type of work.

(*c*) *Reef Collections.*—Exhaustive collections were made by the Shore Party during the course of their ecological surveys; collections which are, of course, accompanied with very valuable and complete data. Collections of great value were also made by the five members of the staff of the Australian Museum on Low Isles and Batt reef. These collections were later incorporated with the collections made by the Shore Party, amplifying and completing them.

IV.—Economic Work.

Work on animals of direct economic importance was carried out by Mr. F. W. Moorhouse, the work on the black-lip pearl oyster being carried out by Mr. A. G. Nicholls—

(*a*) A detailed investigation on the rate of growth, breeding period, and habits of *Trochus niloticus.*

(*b*) Similar work on the black-lip pearl oyster, *Pinctada margaritifera.*

(*c*) Spawning of bêche-de-mer.

(*d*) Spawning of the rock and mangrove oysters.

(*e*) Experiments on the propagation of commercial sponges by means of "cuttings."

(*f*) Observations on the nature, quantity, and fluctuations of the edible fish about Low Isles and the region between Cairns and Cooktown generally.

(*g*) Observations on the sardine fishery at Maer Island, Torres Strait, and the collection of information as to the occurrence of shoals elsewhere.

(*h*) The collection of information as to the nature and prospects of the turtle fishery (both edible and tortoise-shell), and of the dugong fishery, in various regions of the Barrier and in the Torres Strait.

Conclusion of Expedition.

The camp on Low Isles was evacuated on 28th July, 1929, one year and twelve days after the expedition arrived there. The remaining members—Dr. and Mrs. Yonge, Miss Marshall, Mr. Orr, Mr. Colman, and Mr. Spender—with the luggage, specimens, and apparatus on loan from England, were transported to Cairns in the M.L. "Merinda." Mr. Moorhouse accompanied Mr. Wishart on the "Luana." The bulk of the apparatus and gear was stored in the rooms comprising the married quarters, full inventories being taken and handed to Mr. Moorhouse, who, with Mr. Orr and Mr. Vidgen, was chiefly responsible for the packing. Delicate apparatus, books, and cases containing apparatus on loan from Australian sources were packed and stacked ready for transport to Brisbane by the lighthouse steamer "Cape Leeuwin." All cases for England were deposited at Cairns, whence they were despatched direct by sea to England. The collection of corals was sent to Professor G. Matthai at Lahore, India. Mr. Vidgen remained on Low Isles until 31st July to complete the clearing of the camp and lock up the huts.

Every member of the expedition left with the feeling that the year on Low Isles had been well spent and that something of real scientific value had been accomplished.

Formation of the Queensland Marine Station.

The most fitting conclusion possible to the work of the expedition was the formation by the Queensland Government of a permanent Marine Biological Service, having as its object the investigation and development of the resources of the Great Barrier Reef and adjacent regions. Mr. F. W. Moorhouse has been placed in charge of this work, a position for which his natural aptitude, industry, and unceasing interest in all the activities of the expedition well fit him. He has the assistance of a junior naturalist. The huts on Low Isles, all equipment (other than that on loan), and the scientific library were handed over to the Queensland Government, and thus form the nucleus of the first permanent marine laboratory to be established in Australian waters.

Economic Prospects.

The exhaustive programme of pure research carried out by the expedition provided the essential background for future work of a more directly economic character. So little is known of the conditions of life in tropical seas, of their relative fertility, and of the annual cycle of marine "crops," that such preliminary work was essential. The work of Mr. Moorhouse and that of Mr. Nicholls on pearl-shell initiated what it is hoped will prove to be long-continued work on the economic products of the Great Barrier.

The greatest need of all is for fuller information about the economic possibilities of all regions of the Barrier. To this end it is recommended that a thorough survey from the biological—especially economic—standpoint should be undertaken. Information should be collected from every possible source, and, when it appears to be of sufficient interest and potential value, this should be confirmed and extended by qualified investigators. For example, reputed good fishing grounds, or sponge beds (such as are stated to occur off Bowen and in the Torres Strait), should be thoroughly investigated. The information so collected could suitably be incorporated in maps showing the fishing grounds of all types, and which could be revised from time to time for the benefit of all interested. Information could with advantage be collected as to the best type of fishing gear for the various fisheries, while the questions of curing, freezing, and marketing of fish and turtle in particular require detailed study.

Investigations should have the dual aim of conserving the older fisheries, some of which show danger of being overfished, and of developing new ones. Exact knowledge of the life-history, breeding, and growth of *Trochus* (information already largely supplied by Mr. Moorhouse's work), pearl-shell, bêche-de-mer, and turtles (which has been commenced recently by Mr. Moorhouse), would enable legislation to be framed for the conservation of these valuable fisheries. The possibility of farming in the case of the first two is not to be neglected. Edible oysters are abundant on all the islands and along the coast; as the population develops these will become of increasing importance, and the question of cultivation, already practised near Brisbane, will in time come to the fore. The sponge investigated by Mr. Moorhouse at Low Isles, and common on all the reefs, is of medium quality suitable for industrial use. Further experiments on propagation, and the selection of the best sites for such, would probably be of ultimate value. Further dredging on suitable bottoms can alone decide the vexed question of the presence of valuable sponge beds within the Barrier.

The true fisheries are certain to develop in importance as the population increases, but they could be considerably developed immediately if suitable methods of fish preservation which would enable fish to be sent to the back country and even exported were adopted. Here again the first problem is the discovery of the best grounds for edible fish. Methods of fishing may be improved, but fishing within the Barrier will have to be largely by line, seine, or cast net. Trawling on a coral bottom is out of the question, and indeed the quantities of demersal fish probably would not warrant it. The pelagic "kingfish," "Spanish mackerel," or "bonito" (*Scomberomorus* sp.) and its relatives, and the sardines, are probably the most important food fish. The thorough investigation of their life-histories, especially the range and nature of their migrations of which nothing is known, is a problem of the first importance.

The question of fish curing and freezing, with especial reference to the hot, humid climate, should be thoroughly investigated. The establishment of curing factories at convenient fishing centres along the coast is the ideal to be aimed at. There is a big potential market in the back country, and the existence of a steady market for their fish would be of the greatest help to the fishermen. At present the local markets are so small that they are soon glutted and the fishermen receive no adequate return for the good catches they make, for example in the height of the kingfish season. An export trade in cured fish to the Far East would appear a very probable development in the Torres Strait area.

Finally a big market is always open for the sale of fish meal, though for the development of such a trade a large supply of raw material is necessary.

Summarising, the immediate problems of fishery research are—

1. Quality of fishing grounds, in different areas and at different seasons;

2. Methods of fish preservation and utilisation;

3. Nature, accessibility, and development of markets.

Sharks are abundant wherever fish are numerous. There is a good market for shark products—leather, oil, and dried fins—while fish meal could be manufactured from the carcasses. Powerful boats would be needed in such a fishery, which has undoubted potentialities.

There remain finally dugongs, especially from the Torres Strait and the Gulf of Carpentaria, which yield meat and oil, but of which the fishery would need to be carefully controlled owing to the ease with which such animals may be exterminated; and large crustaceans, such as the blue mudcrab (*Portunus pelagicus*), the mangrove crab (*Sylla serrata*), and the crawfish (*Palinurus* sp.), all of which are edible and might eventually form the basis of a canning industry.

In conclusion, the desirability of employing in the marine industries the Torres Strait Islanders and the aboriginals of the coastal regions of Queensland must be pressed. They provide an efficient and cheap form of labour, and their employment would enable them to play their part in the economic development of the regions they inhabit.

Recommendations for Future Work.

It cannot be too often emphasized that fuller knowledge of everything to do with the Barrier is the first thing to be aimed at; developments will follow in proportion to the speed with which this knowledge is gained.

The functions of the Government Committee and its scientific officers may be summarised as follows:—

I.—Survey of the Barrier with especial reference to the distribution of rich fishing grounds.

II.—Investigation of the life-history and habits of all animals of economic importance; this with a view to the further development of the fisheries and their effective control; legislation to be recommended where it is deemed necessary.

III.—Investigation into any and every avenue of further economic development, e.g. sponges, fish curing, &c.

IV.—Experiments having as their object the further development of the established marine industries, e.g. cultivation of pearl-shell and of *Trochus*.

V.—Work of purely scientific interest, in collaboration with the Great Barrier Reef Committee and other interested bodies or individuals.

VI.—The formation of a central bureau supplying information about the Barrier to—

(1) Fishermen of all kinds;

(2) Individuals or collections of individuals desiring to found companies for the economic exploitation of the marine resources of the Barrier;

(3) Scientists desiring information, specimens, or opportunities of working on the Barrier;

(4) Tourists and the public generally.

VII.—The bringing together of all institutions, companies, and individuals interested in the scientific investigation of the Great Barrier Reef or in its commercial exploitation, for their mutual advantage and the promotion of knowledge, and the fuller reaping of the harvests of the sea.

While Low Isles, on account of the buildings, equipment, and knowledge of the conditions, must naturally remain the site of the marine station, the presence of the lightkeepers enables the buildings to be left with safety. The staff would thus be at liberty to carry out work in the two important centres of the Torres Strait and the Capricorn Group, as well as at intermediate places when necessity arose. It is very sincerely to be hoped that visiting scientists will be attracted in increasing numbers to the marine station at Low Isles, which provides such ideal conditions for work on Indo-Pacific corals and the fauna and flora associated with them.

Publication of Results.

In addition to this paper, the economic work of Mr. Moorhouse and the paper on the Breeding and Growth of the Black-lip Pearl Oyster by Mr. Nicholls will be published in the Reports of the Great Barrier Reef Committee.

The great bulk of the work will be published in Great Britain. The trustees of the British Museum have very generously undertaken the publication of the results of the Great Barrier Reef Expedition, which will appear in some five quarto volumes. The following list, though liable to revision, indicates the scope and nature of the papers which will be published:—

I.—1. Origin, Organisation, and Scope of the Expedition. (C. M. Yonge.)

II.—Hydrography and Plankton—

2. The Physical and Chemical Conditions in the Sea inside and outside the Barrier Reef. (A. P. Orr.)

3. The Physical and Chemical Conditions on Low Island Reef. (A. P. Orr.)

4. Sea Temperature in Low Isles Anchorage throughout the Year. (F. W. Moorhouse.)

5. Report on the Microplankton of the Waters inside and outside the Barrier. (S. M. Marshall.)

6. Seasonal Abundance of Zooplankton in Coastal Waters between the Great Barrier and the Mainland, with comparison with data obtained in more oceanic water. (F. S. Russell and J. S. Colman.)

7. Presence of Plankton Organisms in Waters bathing a Coral Reef as shown by collections taken over a Reef at High Tide. (F. S. Russell and J. S. Colman.)

8. The Vertical Distribution of Plankton in Tropical Waters. (F. S. Russell and J. S. Colman.)
9. A Comparison between the Abundance of Zooplankton in Tropical Waters and that of Temperate Regions as shown by Vertical Hauls with the Nansen Net. (F. S. Russell and J. S. Colman.)

III.—Nature and Bionomics of the Reefs—

10. General Account of the Coast of Queensland and of the Great Barrier Reef. (J. A. Steers.)
11. Detailed Account of the several Types of Reef, with conclusions as to their Foundations and Origin. (M. A. Spender.)
12. Brief Description of the several Types of Coral Reefs, with a preliminary account of their Natural History. (T. A. Stephenson and G. Tandy.)
13. An Account of Quantitative Surveys carried out on restricted Areas on several Reefs. (T. A. Stephenson, S. M. Manton, and E. A. Fraser.)
14. An Account of the Growth-rate of Corals and Alcyonaria on the Low Isles Reef. (T. A. Stephenson.)
15. An Account of the Breeding Seasons of Marine Organisms on the Low Isles Reef. (T. A. Stephenson, A. Stephenson, and G. Tandy.)
16. An Account of the Development of two species of Coral. (T. A. Stephenson and S. M. Manton.)
17. An Account of the Development of a species of *Eudendrium*. (E. A. Fraser.)
18. An Account of the Ecology of Low Isles and other Reefs. (T. A. Stephenson and G. Tandy.)
19. Observations on Organisms which bore into Coral Rock. (G. W. Otter.)

IV.—Physiological and Experimental Work—

20. Effect of Sediment on Corals. (A. P. Orr and S. M. Marshall.)
21. Calcium Metabolism in Corals and other Reef Animals. (A. G. Nicholls and A. P. Orr.)
22. The Gas Exchange of Coral Planulæ. (S. M. Marshall.)
23. Feeding Mechanisms and Food of Corals. (C. M. Yonge.)
24. Digestive Processes in Corals (C. M. Yonge). With Notes on the Speed of Digestion (A. G. Nicholls).

25. Structure of the Gut in Corals, Assimilation and Excretion. (C. M. Yonge.)

26. Symbiotic Algæ of Corals, their Structure, Distribution, and Physiology. (C. M. Yonge and A. G. Nicholls.)

27. The Effect of Starvation and Darkness on the relationship between the Algæ and the Corals. (C. M. Yonge and A. G. Nicholls.)

28. Oxygen Production by Algæ and its Significance in the Life of the Corals. (C. M. Yonge, M. J. Yonge, and A. G. Nicholls.)

29. Feeding and Significance of Symbiotic Algæ in *Tridacna*. (C. M. Yonge.)

30. Notes on Feeding and Digestion in the Reef Gastropods *Lambis* and *Vermetus*. (C. M. Yonge.)

31. Discussion and Conclusions on work on the Physiology of Corals and Reef Animals and the Significance of the Symbiotic Algæ. (C. M. Yonge.)

V.—Systematic Work—

This will consist of systematic accounts of the plankton, reef and bottom collections of animals and plants, carried out by specialists in Australia, Great Britain, and elsewhere.

VI.—Geographical Work—

The papers of the Geographical Section are being published by the Royal Geographical Society in their Journal, and consist of—

1. The Queensland Coast and the Great Barrier Reefs. (J. A. Steers. The Geographical Journal, vol. lxxiv., Nos. 3, 4, September and October 1929.)

2. A Paper dealing with the Topography of Low Isles, Three Isles, and of certain Outer Barrier Reefs, with remarks on their Origin and Formation. (M. A. Spender, appearing shortly.)

ACKNOWLEDGMENTS.

The expedition received generous assistance from very many sources, and its members will always remember the hospitality with which they were received in Australia. In addition to the acknowledgments made in the course of this paper, thanks in special measure are due to the following:—The officers and members of the Great Barrier Reef Committee, especially Professor H. C. Richards (the Chairman), Dr. E. O. Marks (the Hon. Secretary), Mr. H. A. Longman (the Director of the Queensland Museum and the Deputy Chairman), Mr. W. M. L'Estrange (the Treasurer), and Miss H. F. Todd (the Assistant Secretary, whose efforts on behalf of the expedition were untiring); Mr. J. B. Henderson, Government Analyst, Brisbane; the Councils of the Scottish Marine Biological Association and of the Marine Biological Association of the United Kingdom, for granting the necessary leave of absence to Miss S. M. Marshall and Mr. A. P. Orr and to Mr. F. S. Russell, members of their respective staffs; the Trustees of the British Museum for providing leave of absence to Mr. G. Tandy; the various lightkeepers on Low Isles for much practical assistance; Mr. A. J. Moran of the Strand Hotel, Cairns, for advice and help of all kinds; Messrs. C. and A. Osborne, the owners of the motor launch "Daintree," for their willing co-operation, and Captain D. Moynahan for assisting in the piloting of that vessel during the cruise within the Outer Barrier; Messrs Hayles for providing free transport for the party and luggage from Low Isles to Cairns on 28th July, 1929, and to Captain R. Hall and Mr. C. Hall, skipper and engineer respectively of Messrs. Hayles's launch "Magneta," for their great help during the four weeks during which that vessel was hired by the expedition; Mr. G. Butler, owner and skipper of the motor launch "Tivoli," for his invaluable help to the Geographical Section and later during the visit to Lizard Island; Mr. and Mrs. B. Allen, of Port Douglas, for their continual help and hospitality; the District Main Roads Officer, Mr. Milligan, for escorting a section of the expedition around the Atherton Tableland as a result of the courtesy of the Commissioner; Mr. C. O'Leary, Protector of Aboriginals at Thursday Island, Mr. D. C. Harman, Managing Director of Papuan Industries Ltd., and Mr. G. Agnew, Government Teacher and Administrator of Murray Island, all of whom rendered great assistance to the party who visited the Torres Strait; the Rev. Mr. Schwarz, the Superintendent of the Cape Bedford Mission, for hospitality and help given to the party which visited Three Isles; Mr. W. W. McCullough, Superintendent of the Yarrabah Mission, and Mrs. McCullough, for the very great assistance they rendered by supplying the native labour without which the expedition could not have carried out its work with the money available; Mr. H. Friend, of Gladstone, for making all arrangements for the visit to the Capricorn Islands; and Amalgamated Wireless (Australasia) Ltd., for the loan of a wireless outfit.

Finally it is fitting to acknowledge the encouragement which the expedition, and particularly its leader, received from the continued interest in its work of the Australian public, even in States remote from the Barrier.

No. 2.

ON THE BREEDING AND GROWTH-RATE OF THE BLACK-LIP PEARL OYSTER (PINCTADA MARGARITIFERA).

By A. G. Nicholls, B.Sc.

(Plates VII.–VIII.)

The life-history of the Black-lip has been investigated by Herdman,[1] so that work on Low Isles was confined to observations on spawning periods and a comparison of habits with those of the species found at Ceylon, with notes on the rate of growth of young specimens.

At Low Isles the Black-lip is found distributed over the reef flat attached to rocks, clam-shells, and shells of other molluscs, frequently to those of its own species; whereas the species investigated by Herdman occurs, where suitable "culth" is available, in large submarine beds at a depth of some fathoms. In the neighbourhood of Low Isles the sea floor is covered with a deposit of soft mud, which does not offer a suitable surface for the attachment of the young. On one occasion, however, a few small specimens were dredged in Penguin Channel, between Snapper Island and the mainland, where mud cannot settle owing to the scour of the tides.

It was decided to discover whether these animals could be farmed along lines similar to those employed in the cultivation of the edible oyster. To this end an area was marked out on the reef flat just above low spring-tide level in a situation typical of that in which the Black-lip is usually found—that is, amongst flat, weed-covered rocks lying more or less embedded in sand. Around this area was built a wooden fence. Stakes cut from young mangroves were driven vertically into the sand about 3 ft. apart and amongst these were woven more flexible saplings, forming a substantial and close-set fence about 3 ft. high and providing plenty of clean surface upon which the spat might settle. In addition rocks and empty clam-shells were distributed over the enclosed area and placed around the base of the fence. (Plate VII.)

From the reef flat over 400 adult specimens of the Black-lip were collected and placed within the pen, which enclosed an area of about 30 square yards, and about fifty specimens were brought from Batt reef on the inside of the Outer Barrier where they grow under similar conditions. The majority reattached themselves within a week of being transferred, while a small percentage died. In one corner of the pen were placed over fifty clam-shells each containing a young Black-lip for observations on the rate of growth.

Spawning Periods.

Herdman found that the pearl oyster of Ceylon spawned twice a year, once in May and again in November, each period extending over a few days. In order to compare conditions at Low Isles with those of the Ceylon beds, twelve specimens were examined twice a month, at the new moon and full moon. The sex and extent and condition of the gonad were noted along with the size of each individual.

As regards sex it was found that males were more numerous than females in the proportion of five to three. When empty the gonad is a loose, flaccid, colourless sac covering the digestive diverticula; as maturity approaches and the sac becomes filled with germ cells it becomes more turgid and, in the case of the male, takes on a creamy white colour, the female being slightly yellower, while at the same time the sac extends round both sides of the retractor muscle. The eggs prior to maturity are small and round and there is a large amount of interstitial material in the ovary, which decreases as maturity approaches, the eggs themselves becoming pyriform.

When the examination of the gonads was started in September (1928) the products in each specimen examined were immature though the gonads were moderately full. At the end of September and during October they were obviously approaching maturity, and by 12th November spawning had occurred. As at that time heavy south easterly weather was prevailing, the chances of the spat settling in the vicinity of the pen were very small and it was not expected that many would be found. In January two small specimens were found in the pen attached to other individuals, and from their size it was obvious that they had resulted from the November spawning. Though a thorough examination of the fencing and surrounding rocks and shells was made, no more young were discovered.

Through the subsequent months recovery from spawning proceeded slowly, and it was not until 11th March that the gonads were observed to be filling again; from then onwards the gonads filled gradually and it was expected that by the end of April they would be fully mature. Towards the end of that month, however, I accompanied Dr. Yonge on a visit to the Torres Strait to see the pearling industry at Thursday Island, going thence to the Murray Islands. It was hoped to get specimens for examination while at Thursday Island but the tides were too poor, so that the second examination in April was missed. On 10th May when at the Murray Islands, specimens were obtained and the gonads found to be mature. Six more specimens were examined on 12th May, of which two were spent and the others fully mature and ready to spawn at any moment. On our return to Low Isles on 27th May, all the specimens examined were in the spent condition, and examination of the pen revealed the presence of a few young individuals with very thin shells resulting from the spawning earlier in the month.

The summarised result of each fortnightly examination will be found in Table No. 1.

Rate of Growth.

In order to form some estimate of the rate of growth of the young Black-lip under conditions found on a reef flat, some fifty clam-shells were placed in one corner of the pen described above. These were numbered by means of silver discs, upon which the numbers were stamped, cemented on to the outside of the clam-shells. A single young Black-lip was placed in each shell, measurements having been made in two directions—one, dorsi-ventrally, from the centre of the hinge line at right angles across the shell, and called, for the sake of simplicity, the width; the second being the greatest measurement antero-posteriorly, parallel with the hinge line and called the length. This latter measurement was not very reliable and difficulty was experienced in all measurements owing to the presence of numerous finger-like processes projecting from the margin of the valves and usually indicative of the flourishing condition of the animal. All measurements of young and adult specimens were taken as stated above and in no case were these processes included.

As soon as these specimens had become established, measurements were made at monthly intervals starting in October and continuing through the summer to midwinter of the following year, the last measurements being made in July. From time to time odd specimens were lost from one cause or another, and in Table No. 2 will be found figures showing the growth of some of the survivors, from which it will be seen that the average width in October was 28 mm. and the length 27 mm., which, nine months later, had increased to 43 mm. and 42.6 mm. respectively, or an addition of about 20 mm. per annum to the diameter. A few specimens practically doubled their original size, while for one an even greater increase was recorded.

Habits.

As mentioned above, the adult Black-lip can be found anywhere on the reef flat exposed at low water, but they occur also below low water, attached to big coral boulders, whence they can be obtained only by wading or diving. When the valves are shut the animal is not easily observed, the outside being frequently covered with plant and animal growth. Those situated in slight depressions where water has remained will be found with their valves agape, their coloured mantle edges rendering them conspicuous. The mantle is usually red, less frequently black; it does not protrude beyond the valves. Attached to the substratum by means of a strong byssus, they are able to withstand any normal force brought to bear upon them, but a continued twisting in one direction soon separates them from their attachment.

Young specimens under six months were always found submerged, none being found on the fencing or shells above low-water level, and the presence of specimens of six months or more on rocks exposed at low tides on the reef flat is accounted for by the fact that they retain powers of locomotion for some months after first settling, and by the time that they have attained a diameter of two centimetres they are sufficiently hardy to withstand exposure for some hours. Moreover, during the months following the November spawning when the heat from the sun is at its maximum, the tides are such that the reef is exposed only for short periods, if at all, during the day, and the very low tides are at night; while after the May spawning when the very low tides occur during the day and the reef is exposed for hours at a stretch, the weather is much cooler, so that the question of desiccation does not concern the young Black-lip to any great extent.

There is evidence of a decided preference on the part of the young specimens for shells of their own species as a preliminary if not a permanent home, as many as five having been found together; one adult of over three years bearing two small specimens about eighteen months old, these in turn each having a newly settled specimen.

In conclusion I would draw attention to the temperature of the sea at the time of spawning. Nelson[2] has collected the spawning temperatures of a number of lamellibranchs from the works of various authors, supplemented by his own observations. He says: "One is impressed by the fact that these spawning temperatures fall into groups which differ by approximately 5° C. Setchell, studying the temperature limits for growth and fructification of marine algæ, marine spermatophytes, and land plants, has been led to assign as critical temperatures for the initiation of these processes: 5°, 10°, 15°, 20°, and 25° C. Crozier has brought together a large amount of data on the temperature characteristics of vital processes of the most diverse sorts, and from these and other data he determines the critical points to occur most frequently in the neighbourhood of 4.5°, 9°, 15°, 20°, 25°, 27°, and 30° C. As he points out, the agreement of these figures with those of Setchell can hardly be accidental."

Plate VIII. is a copy of the chart constructed by Mr. F. W. Moorhouse, from readings taken at the surface in the anchorage at Low Isles twice daily, from which it will be seen that in the early part of November the temperature varied between 26.2° and 28.4° C., ignoring the outstanding peaks, which are due to the coincidence of low tide with the time of taking the temperature. It will be apparent that these peaks can be neglected because at low tide the reef flat was denuded of water. At the end of April and in the early part of May the temperature varied between 27° and 25° C.

Since the actual time of spawning was not discovered, I would merely point out that the temperatures in the early part of November and of May coincide approximately, overlapping to the extent of about 1° C between the temperatures 26° and 27°.

I should like to take this opportunity of expressing my thanks to Dr. C. M. Yonge for his help and advice, and to other members of the Barrier Reef Expedition for much assistance.

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2. NELSON, T. C., 1928: On the Distribution of Critical Temperatures for Spawning and for Ciliary Activity in Bivalve Molluscs. Science, vol. lxvii., No. 1730, pp. 220-221.

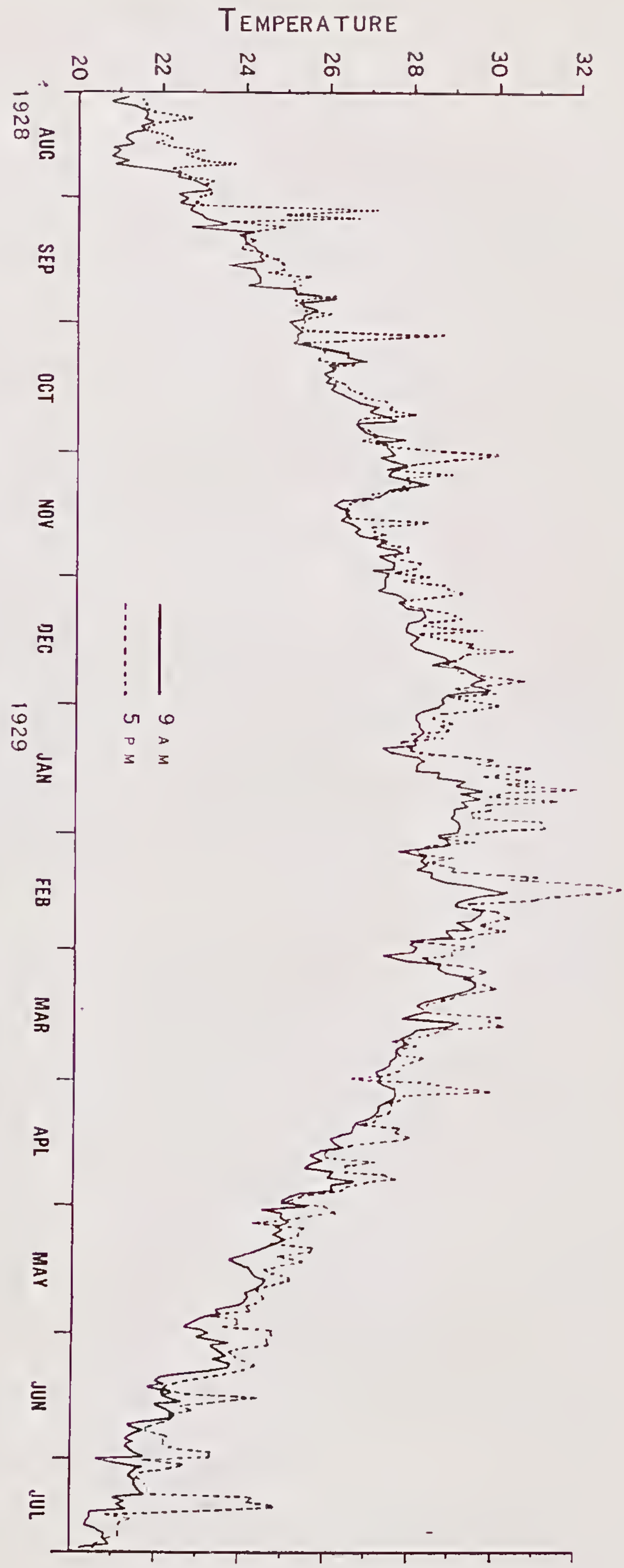
TABLE No. 1.

SUMMARY OF CONDITION OF GONADS IN P. MARGARITIFERA DURING THE YEAR 1928-29.

Date.	Number of Males with Gonad.					Number of Females with Gonad.				
	I.	N.M.	M.	S.	E.	I.	N.M.	M.	S.	E.
17/9/28	6	..	..	..	..	6	..	..	..	..
28/9/28	3	2	..	..	..	3	3	..	..	..
11/10/28	2	3	..	..	..	..	6	..	..	..
28/10/28	4	1	..	..	..	1	6	..	..	..
12/11/28	..	..	1	7	..	..	..	..	4	..
27/11/28	..	..	..	..	4	..	..	..	..	6
12/12/28	..	..	..	..	8	..	..	..	..	4
28/12/28	7	..	..	..	..	5	..	..	..	..
12/1/29	8	..	..	..	..	4	..	..	..	..
25/1/29	4	1	..	..	..	2	2	..	..	..
10/2/29	7	..	..	..	1	..	..	..	..	1
23/2/29	6	..	..	..	..	1	..	..	..	..
11/3/29	1	3	..	..	..	5	..	..	..	..
25/3/29	4	1	..	..	..	1	..	..	..	..
11/4/29	8	..	..	..	2	1	..	..	..	..
10/5/29	1	..	1	..	..	..	1	..	..	..
27/5/29	..	..	..	1	..	..	..	..	1	..

In the above table the different states of the gonad are indicated as follows :—
I, for immature ; N.M., nearly mature ; M., mature ; S., spent ; E., empty.

Breeding Pen, Black-lip Pearl Oyster.



TEMPERATURE CHART, BLACK-LIP PEARL OYSTER SPAWNING.

TABLE No. 2.

SHOWING GROWTH RATE OF YOUNG P. MARGARITIFERA.

No.	October 1928.		July 1929.		Increase.		Increase %.	
	Width, mm.	Length, mm.	Width, mm.	Length, mm.	Width, mm.	Length, mm.	Width.	Length.
4	47	43	73	64	26	21	55·3	48·8
9	23	22	44	43	21	21	91·3	95·5
12	33	32	40	44	7	12	21·2	37·5
15A	25	24	33	35	8	11	32·0	45·7
18	26	23	33	31	7	8	26·9	34·8
22A	25	26	35	36	10	10	40·0	38·5
24	35	34	55	58	20	24	57·1	70·6
25	45	45	60	61	15	16	33·3	35·6
42	21	19	35	34	14	15	66·7	78·9
43	21	19	34	35	13	16	61·9	84·2
52	33	33	48	48	15	15	45·5	45·5
53	21	26	30	33	9	7	42·9	26·9
54	18	16	35	32	17	16	96·6	100·0
55	18	19	45	43	27	24	150·0	126·0

Average increase in width, 15·0 mm. or 53·6 per cent.

Average increase in length, 15·5 mm. or 57·2 per cent.

No. 3.

A REPORT ON SAMPLES OBTAINED BY BORING INTO MICHAELMAS REEF, ABOUT 22 MILES N.E. OF CAIRNS, QUEENSLAND.

By Frederick Chapman, A.L.S., F.G.S., F.R.M.S., &c., Commonwealth Palæontologist, National Museum, Melbourne.

(Plates IX.–X.)

At the request of Professor H. C. Richards, D.Sc., I have undertaken to examine material and to furnish a report, chiefly on the foraminiferal contents, of the present boring into the Great Barrier Reef.

It was decided in August 1925, by a party of inspection consisting of Professors H. C. Richards and E. W. Skeats, Dr. P. Clarke, and Messrs. Chas. Hedley, W. B. Alexander, G. A. V. Stanley, and P. C. Morrison, to bore into a sand cay on Michaelmas Reef, about 22 miles N.E. of Cairns (Lat. 16° 36′ S., Long. 145° 59′ E.).

The boring was carried out by the Goldfields Diamond Drilling Co., with a Victorian calyx drill loaned by the Victorian Government. The bore extends from the surface down to 600 ft.

Note.—In view of the fact that the earlier samples of the boring were in solid coral rock, these were not forwarded to me for examination.

The material was received about the latter end of June 1927.

I would here express my thanks to Mr. W. J. Parr, F.R.M.S., for his assistance in examining several of these samples, and to my daughter, Winifred M. Chapman, for help in drawing the plates.

SYSTEMATIC EXAMINATION.

Depth, 32 to 42 Ft.

General Characters of the Sample.

A cream-coloured, shelly, and foraminiferal sand of medium coarseness. It contains numerous waterworn tests of foraminifera, joints of the calcareous seaweed *Halimeda*, alcyonarian spicules, echinoid spines, polyzoa, gasteropoda, and occasional claws of crabs.

The commonest foraminifera found in this sample are—*Textularia rugosa*, *Eponides repandus*, *Calcarina hispida*, *Baculogypsina sphærulata*, and *Amphistegina lessonii*.

List of Foraminifera.

(Families arranged according to Brady's Classification.)

Family Miliolidæ—

Quinqueloculina lamarckiana d'Orb. Very rare.

Quinqueloculina lamarckiana (reticulate var.). Rare.

Quinqueloculina polygona d'Orb. Very rare. A short form.
Triloculina reticulata d'Orb. Frequent.
Triloculina cf. *linneiana* d'Orb. Very rare.
Triloculina trigonula (Lam.). Very rare.
Massilina durrandi (Millett). Very rare.
Marginopora vertebralis Quoy & Gaimard. Rare.
Alveolinella quoii (d'Orb.). Rare.

Family Textulariidæ—
Textularia rugosa (Reuss). Common.
Textularia trochus d'Orb. Rare.
Textularia gramen (d'Orb.). Very rare.
Gaudryina siphonifera (Brady). Very rare.

Family Lagenidæ—*Siphogenerina raphanus* (P. & J.). Very rare.

Family Rotaliidæ—
Planorbulinella acervalis (Brady). Very rare.
Anomalinella rostrata (Brady). Frequent.
Eponides repandus (F. & M.). Common.
Calcarina spengleri (Linné). Rare.
Calcarina hispida Brady. Common. Often much rolled.
Gypsina globulus (Reuss). Rare.
Baculogypsina sphærulata (P. & J.). Common.

Family Nummulitidæ—
Elphidium craticulatum (F. & M.). Rare.
Amphistegina lessonii d'Orb. Common.

Depth, 90 to 93 Ft.

General Characters of the Sample.

A moderately coarse coral sand, creamy-white in colour. Although some separated tests occur in this sample, the main mass of the material is a broken-down foraminiferal limestone. Besides the foraminifera, there occur fragments of echinoid spines and united valves of the ostracod *Bairdia amygdaloides* Brady. The commonest foraminifera found here are *Calcarina spengleri* and a dome-shaped variety of *Amphistegina lessonii*.

List of Foraminifera.

Family Miliolidæ—
Hauerina ornatissima (Karrer). Very rare.
Marginopora sp.

Family Rotaliidæ—
Planorbulinella acervalis (Brady). Very rare.
Calcarina spengleri (Linné). Common.
Eponides repandus (F. & M.). Rare.

Family Nummulitidæ—

Elphidium crispum (Linné). Very rare.

Amphistegina lessonii d'Orb. Common.

Depth, 104 to 113 Ft.

General Characters of the Sample.

A brown earthy marl, containing fragments of hard foraminiferal limestone. The foraminifera in this sample are rare and small. An example of the cyclostomatous polyzoan *Crisia macrostoma* MacGill. is found here; also a large massive *Cellepora*.

List of Foraminifera.

Family Miliolidæ—*Marginopora vertebralis* Q. & G.

Family Rotaliidæ—

Cibicides refulgens Montf. Rare.

Eponides repandus (F. & M.). Rare.

Family Nummulitidæ—

Elphidium crispum (Linné). Very rare.

Amphistegina lessonii d'Orb. Rare.

cf. *Heterostegina*. Very rare.

Depth, 113 to 115 Ft.

General Characters of the Sample.

A cream-coloured to pinkish dolomitic sand, with moderately coarse, sharply crystalline grains. Foraminifera are scarce; alcyonarian spicules occasional.

List of Foraminifera.

Family Rotaliidæ—*Calcarina defrancii* d'Orb. Rare.

Family Nummulitidæ—*Amphistegina lessonii* d'Orb. Rare.

Depth, 115 to 123 Ft.

General Characters of the Sample.

A pinkish, comminuted, calcareous sand, with fragments of clear calcitic particles and obscure foraminifera. Organic particles appear to be encrusted and corroded.

Depth, 113 to 210 Ft.

General Characters of the Sample.

Yellowish to pink calcareous sand, with fine dusty particles. When washed clean, the residue is seen to contain obscure foraminiferal tests. A fragment of the shell of *Pinna* was also noticed.

Depth, 211 to 212 Ft.

General Characters of the Samples.

(1) Pinkish yellow sand, consisting largely of rolled foraminiferal tests, indeterminate ; also numerous fragments of echinoid spines and some shell-fragments.

(2) A fine brown earthy sand, containing a large proportion of limonite.

Depth, 214 to 220 Ft.

General Characters of the Sample.

A comminuted sand of a cream colour, with large and small particles intermixed. There are no determinable foraminifera in this sample, but washings seem to indicate that they are present. Organic particles encrusted and obscure.

Depth, 220 to 227 Ft.

General Characters of the Sample.

A cream-coloured and comminuted sand with organic particles of obscure origin. The only foraminifer that could be determined was *Epistomina elegans*, although in all probability a fair percentage of the material is of foraminiferal origin.

Depth, 239 Ft. 6 In. to 241 Ft.

General Characters of the Sample.

This sample consists of two large fragments of cream-coloured coral rock, with moulds and casts of mollusca, indet.

Depth, 241 to 308 Ft.

General Characters of the Sample.

A cream-coloured foraminiferal sand. The organic particles are much rolled, but washings show the following to be present :—

Foraminifera—

Anomalina ammonoides (Rss.).

Elphidium advenum (Cushman).

Also numerous fragmentary spines of echinoids and some small gasteropod shells, indet.

Depth, 241 Ft. 6 In. to 249 Ft.

General Characters of the Sample.

An ochreous calcareous sand, with numerous organic fragments. The only recognisable foraminifer is *Calcarina hispida* Brady.

Depth, 245 to 248 Ft.

General Characters of the Sample.

Rubbly coral rock of a pale cream colour, with some large fragments of consolidated reef material. Organisms indeterminate, except for a few fragments of echinoid spines.

Depth, 248 to 250 Ft.

General Characters of the Sample.

A pale cream-coloured coral sand; fragments worn or comminuted. No recognisable foraminifera. Several moulds and casts of small gasteropods present.

Depth, 308 to 322 Ft.

General Characters of the Sample.

Pale cream-coloured coral sand, with fragments of echinoid spines, small gasteropods, and foraminifera (*Calcarina hispida*).

Depth, 322 to 338 Ft.

General Characters of the Sample.

White coral sand, consisting of subangular and rounded fragments. No recognisable foraminiferal remains.

Depth, 338 to 348 Ft.

General Characters of the Sample.

A cream-coloured to pink coral sand, consisting chiefly of small rolled fragments. Foraminifera are present but not determinable. A carapace of an ostracod was found here, viz., *Cythere ovalis* G. S. Brady.

Depth, 348 to 363 Ft.

General Characters of the Sample.

Coral sand of a pale cream colour, rich in foraminifera. The species determined are—

Quinqueloculina lamarckiana d'Orb. Very rare.
Elphidium craticulatum (F. & M.). Very rare.
Operculina bartschi Cushman. Frequent.
Amphistegina lessonii d'Orb. Common.

Depth, 363 to 378 Ft.

General Characters of the Sample.

Pale-yellow coral sand, with numerous foraminifera and a few ostracods. The determinable species are as follows:—

Foraminifera—

Guttulina lactea (W. & J.). Very rare.
Calcarina hispida Brady. Common.
Elphidium advenum (Cushman). Rare.
Amphistegina lessonii d'Orb. Common.
Operculina ornata Cushm. Common.

Ostracoda—

Bairdia australis Chapm.
Cythere spp.
Loxoconcha sp.

Depth, 405 to 441 Ft.

General Characters of the Sample.

A bluish foraminiferal marl, with a large proportion of terrigenous material present, including glauconite. Besides the foraminifera there are small mollusca (*Cerithiopsis*) and worm-tubes, and, more rarely, ostracoda.

The determinable species are as follows :—

Foraminifera—

Quinqueloculina reticulata d'Orb. Very rare.
Lenticulina cultrata (Montf.). Very rare.
Calcarina defrancii d'Orb. Very common.
Eponides punctulatus (d'Orb.). Very rare.
Rotalia calcar (d'Orb.). Very rare.
Elphidium crispum (Linné). Very rare.
Elphidium advenum (Cushman). Very rare.
Elphidium craticulatum (F. & M.). Common.
Amphistegina lessonii d'Orb. Rare.
Operculina granulosa (Leymerie). Frequent.

Ostracoda—*Bairdia foveolata* G. S. Brady.

Depth, 441 to 476 Ft.

General Characters of the Sample.

Quartz sand of a greenish-grey tint, with numerous foraminifera and shell-fragments. Foraminifera determined as follows :—

Quinqueloculina kerimbatica (H. A. & E.), var. *philippinensis* Cushman. Very rare.
Sigmoidella elegantissima (P. & J.). Common.
Rotalia schroeteriana Parker & Jones. Rare.
Elphidium craticulatum (F. & M.). Rare.
Amphistegina lessonii d'Orb. Common.
Operculina ammonoides (Gron.). Frequent.
Operculina bartschi Cush. Frequent.
Operculina granulosa (Ley.). Rare.

Depth, 476 to 480 Ft.

General Characters of the Sample.

A greenish-grey sandy mudstone; residue on washing consisting of small angular quartz grains, numerous glauconitic grains (sometimes as foraminiferal casts) and occasional foraminifera, such as *Amphistegina* and *Eponides*. Alcyonarian spicules also present, as well as small, water-worn, indeterminate gasteropods.

The species are as follows :—

Foraminifera—

Rectobolivina bifrons (Brady), var. *striata* (Cushm.). Very rare.
Discorbis vesicularis (d'Orb.). Very rare.
Cibicides culter (P. & J.). Rare.
Calcarina defrancii d'Orb. Common.
Calcarina spengleri (Linné). Very rare.
Rotalia calcar d'Orb. Rare.
Rotalia beccarii (L.). Very rare.
Rotalia schroeteriana P. & J. Rare.
Elphidium craticulatum (P. & J.). Rare.
Amphistegina lessonii d'Orb. Common.
Operculina ammonoides (Gron.). Frequent.

Ostracod—*Bairdia australis* Chapm. Very rare.

Depth, 480 to 514 Ft.

General Characters of the Sample.

Greenish-grey terrigenous sand, containing much clear angular quartz and numerous glauconite grains, some of which are perfect casts of foraminifera. Also numerous shell-fragments and tests of foraminifera. with some polyzoa.

The determinable species are as follows :—

Foraminifera—

Bolivina limbata Brady. Very rare.
Guttulina communis d'Orb. Very rare.
Guttulina gibba d'Orb. Very rare.
Cibicides refulgens Montf. Common.
Cibicides culter (P. & J.). Frequent.
Rotalia schroeteriana P. & J. Very rare.
Rotalia beccarii (Linné). Very rare.
Elphidium crispum (Linné). Rare.
Elphidium advenum (Cushman). Rare.
Elphidium craticulatum (F. & M.). Very rare.
Amphistegina lessonii d'Orb. Very common.
Operculina ammonoides (Gron.). Frequent.
Operculina granulosa (Ley.). Common.

Polyzoa—*Nellia oculata* (Busk.). Rare.

Depth, 514 to 540 Ft.

General Characters of the Sample.

A grey, terrigenous sandy mud, with glauconite grains and many foraminifera. The quartz grains are sharply angular to partially rounded. Perfect casts in glauconite are found here.

The organisms identified are as follows :—

Foraminifera—

Quinqueloculina vulgaris d'Orb. Very rare.
Triloculina subrotunda (Mont.). Very rare. (Cast in iron pyrites.)
Alveolinella quoii (d'Orb.). Very rare. (Cast in glauconite.)
Bulimina pupoides d'Orb. Very rare.
Bolivina limbata Brady. Very rare.
Sigmoidella elegantissima (P. & J.). Frequent.
Guttulina oblonga (d'Orb.). Very rare.
Guttulina regina (B. P. & J.). Rare.
Guttulina gibba d'Orb. Very rare.
Guttulina sororia (Reuss). Very rare.
Guttulina lactea (W. & J.). Very rare.
Globigerina triloba Reuss. Frequent.
Discorbis pileolus (d'Orb.). Very rare.
Cibicides refulgens Montf. Rare.
Cibicides lobatulus (W. & J.). Very rare.
Cibicides mundulus (B. P. & J.). Very rare.
Eponides punctulatus (d'Orb.). Very rare.
Cancris oblongus (Will.). Very rare.
Calcarina defrancii d'Orb. Very rare.
Calcarina hispida Brady. Rare.
Rotalia schroeteriana P. & J. Frequent.
Rotalia calcar d'Orb. Rare.
Rotalia beccarii (Linné). Very rare.
Elphidium advenum (Cushman). Frequent.
Amphistegina lessonii d'Orb. Common.
Operculina granulosa (Ley.). Common.
Operculina ammonoides (Gron.). Common.
Operculina bartschi Cushman. Frequent.

Polyzoa—*Acropora gracilis* (M. Edw.). Very rare.

Ostracoda—

Cythere crispata G. S. Brady. Very rare.
Loxoconcha australis G.S.B. Rare.
Xestoleberis foveolata G.S.B. Very rare.

Depth, 540 to 561 Ft.

General Characters of the Sample.

Coarse, grey shelly sand with foraminifera ; *Operculina* especially abundant. Much terrigenous material in this sample, including a large proportion of quartz grains, angular to sub-rounded. The molluscan shell-fragments are comminuted and indeterminable. The foraminifera identified in this sample are as follows :—

Lenticulina orbicularis (d'Orb.). Very rare.
Lenticulina papillosa (F. & M.). Rare.
Guttulina oblonga (d'Orb.). Very rare.
Guttulina lactea (W. & J.). Very rare.
Globigerina triloba Reuss. Very rare.
Globigerina dubia Egger. Very rare.
Cibicides præcinctus (Karrer). Very rare.
Rotalia schroeteriana P. & J. Common.
Rotalia papillosa Brady. Common.
Nonion depressulus (W. & J.). Very rare.
Elphidium crispum (Linné). Very large.
Elphidium advenum (Cushm.). Very rare.
Elphidium aff. *striatopunctatum* (F. & M.). Very rare.
Elphidium craticulatum (F. & M.). Frequent.
Amphistegina lessonii d'Orb. Common. Specimens very small and depressed.
Operculina bartschi Cushman. Common.
Operculina bartschi var. *plana* Cushman. Common.
Operculina granulosa (Ley.). Common.
Operculina ammonoides (Gron.). Frequent.
Also alcyonarian spicules, common.

Depth, 561 to 582 Ft.

General Characters of the Sample.

Fine grey sand with foraminifera and much terrigenous material. A large proportion of angular quartz. Material cemented in places by ferruginous clay. The following is a list of the species determined :—

Foraminifera—

Bolivina lobata Brady. Very rare.
Cassidulina subglobosa Brady. Very rare.
Frondicularia advena Cushman. Very rare.
Lenticulina papillosa (F. & M.). Frequent.
Lenticulina rotulata Lam. Rare.
Guttulina regina (Brady, Parker, & Jones). Very rare.
Guttulina gibba (d'Orb). Very rare.
Guttulina lactea (W. & J.). Very rare.
Sigmoidella elegantissima (P. & J.). Frequent.
Globigerina subcretacea Chapman. Very rare.
Globigerina triloba Reuss. Rare.
Discorbis circularis (Sidebottom). Very rare.
Anomalina ammonoides (Rss.). Very rare.

Cibicides lobatulus (W. & J.). Common.
Eponides karsteni (Rss.). Frequent.
Globorotalia tumida (Brady). Very rare.
Rotalia papillosa Brady. Frequent.
Rotalia papillosa var. *compressiuscula* Brady. Rare.
Rotalia schroeteriana P. & J. Common.
Elphidium advenum (Cushman). Rare.
Elphidium crispum (Linné). Very rare.
Elphidium craticulatum (F. & M.). Common.
Operculina granulosa (Ley.). Very common.
Operculina bartschi Cushman. Frequent.
Operculina bartschi var. *plana* Cush. Very common.

Anthoza—Alcyonarian spicules, indet.

Echinoderma—Echinoid spine, indet.

Polyzoa—
Amphiblestrum sp. indet.
Schismopora sp. indet.
Bipora philippinensis (Busk.). Rare.

Ostracoda—
Macrocypris setigera (G. S. Brady). Very rare.
Bairdia foveolata G.S.B. Very rare.
Cythere scabrocuneata G.S.B. Very rare.
Xestoleberis nana G.S.B. Very rare.
Loxoconcha australis G.S.B. Very rare.
Cytheropteron sp. nov. Very rare.

Depth, 562 to 600 Ft.

General Characters of the Sample.

A gritty foraminiferal sand of a greyish to fawn colour, containing a large proportion of subangular and rounded quartz grains, glauconite grains, and jasperoid particles. The sand is found in places accreted by a fine mud cement. The foraminiferal fauna is largely operculine and rotaline. The polyzoa are rare and somewhat broken and corroded. List of species determined :—

Foraminifera—
Guttulina communis d'Orb. Very rare.
Sigmoidella elegantissima (P. & J.). Very rare.
Cibicides refulgens Montfort. Rare.
Rotalia papillosa var. *compressiuscula* Brady. Very rare.
Rotalia schroeteriana P. & J. Common.
Elphidium crispum (Linné). Rare.
Elphidium craticulatum (F. & M.). Rare.

Amphistegina lessonii d'Orb. Common.
Operculina bartschi Cushm. Frequent.
Operculina granulosa (Ley.). Common.
Operculina cf. *gaimardi* d'Orb. Frequent.

Polyzoa—*Bipora philippinensis* (Busk.). Rare.

Scaphopoda—*Dentalium* sp. indet. Very rare.

Ostracoda—*Bairdia amygdaloides* G.S.B. Very rare.

EXPLANATION OF PLATES.

PLATE IX.

(All figures magnified 37 diameters.)

Fig. 1.—*Quinqueloculina kerimbatica* (Heron, Allen, & Earland), var. *philippinensis* Cushman. 441–476 ft.

Fig. 2.—*Massilina durrandi* (Millett). 32–42 ft.

Fig. 3.—*Hauerina ornatissima* (Karrer). 90–93 ft.

Fig. 4.—*Rectobolivina bifrons* (Brady), var. *striata* Cushman. 476–480 ft.

Fig. 5.—*Guttulina regina* (Brady, Parker, & Jones). 514–540 ft.

Fig. 6.—*Polytrema miniaceum* (Pallas). 32–42 ft.

Fig. 7.—*Eponides punctulatus* (d'Orbigny). 405–445 ft.

PLATE X.

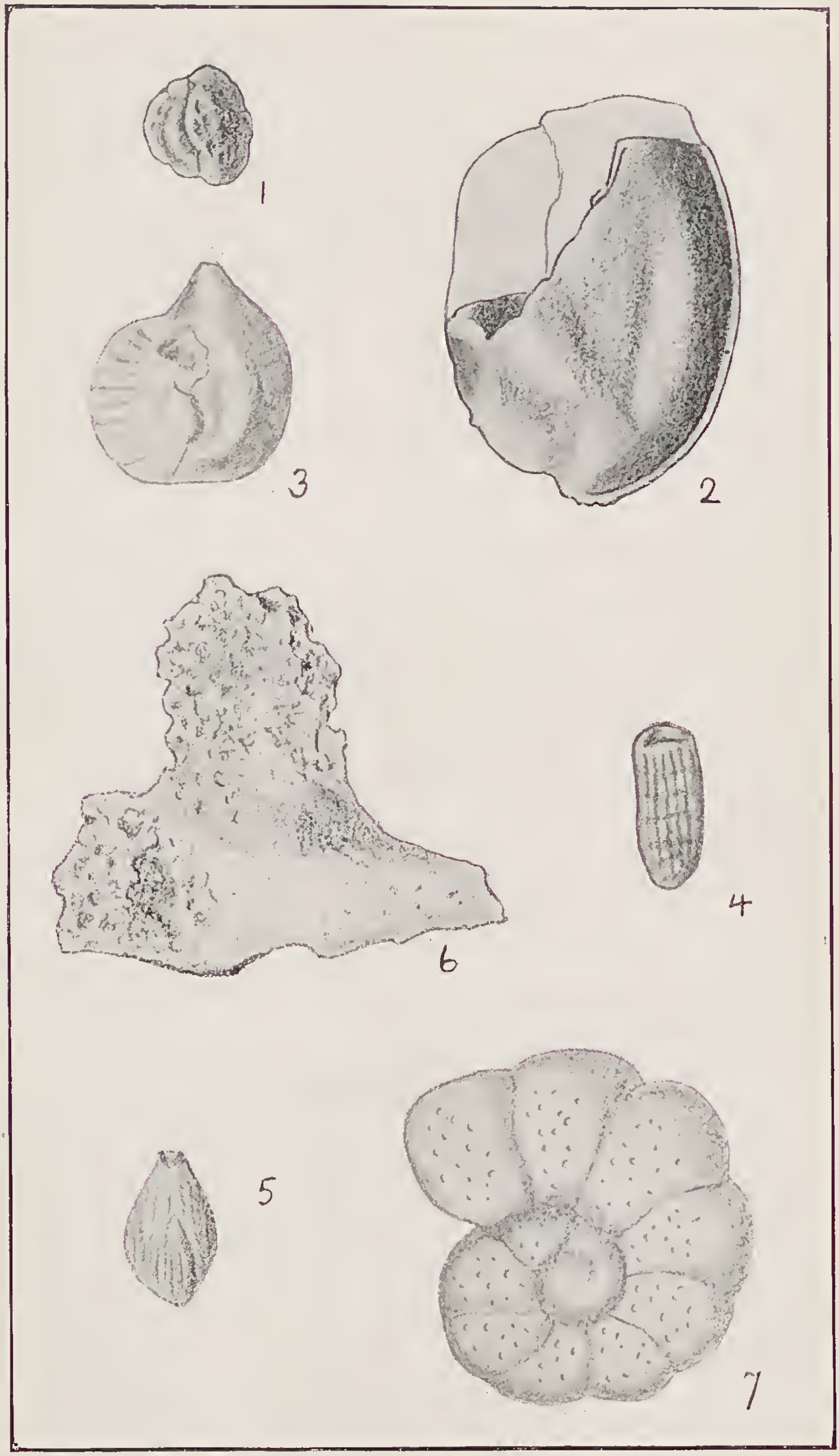
Fig. 8.—*Frondicularia advena* Cushman. 561–582 ft.

Fig. 9.—*Discorbis circularis* (Sidebottom). 561–582 ft.

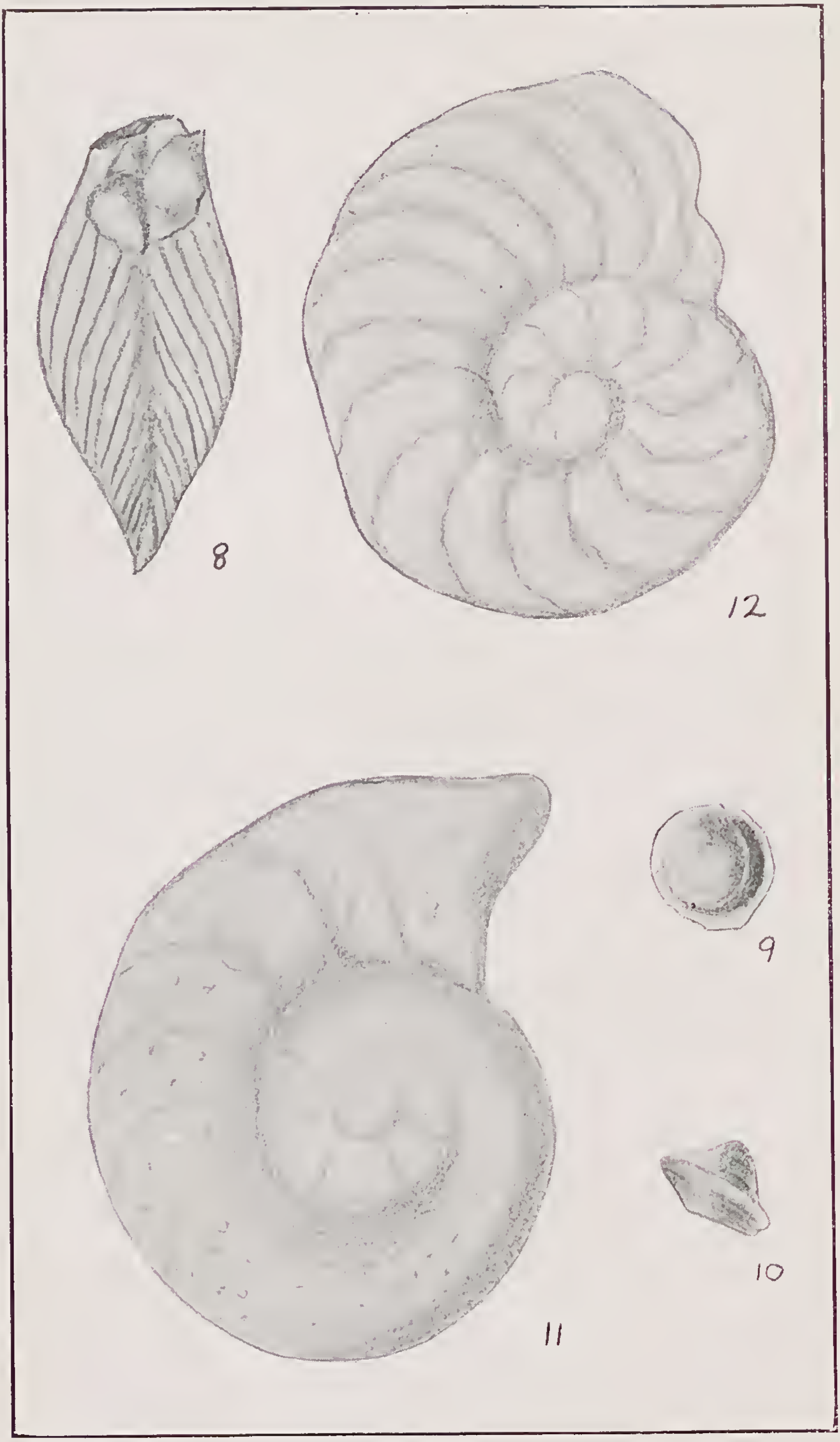
Fig. 10.—*Discorbis circularis*. Profile.

Fig. 11.—*Operculina bartschi* Cushman. 441–476 ft.

Fig. 12.—*O. plana* Cushman. 540–561 ft.



W.M.C. et F.C. del.]



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No. 4.

SUBSIDENCE OF THE CONTINENTAL SHELF NORTHWARD OF SANDY CAPE.

By Commander D. A. HENDERSON, O.B.E., R.N. (Acting).

(Text-figure 1.)

The soundings obtained from time to time in the eastern approach to the Curtis Channel have been for some years a matter of considerable interest to scientists quite apart from their practical utility to the mariner.

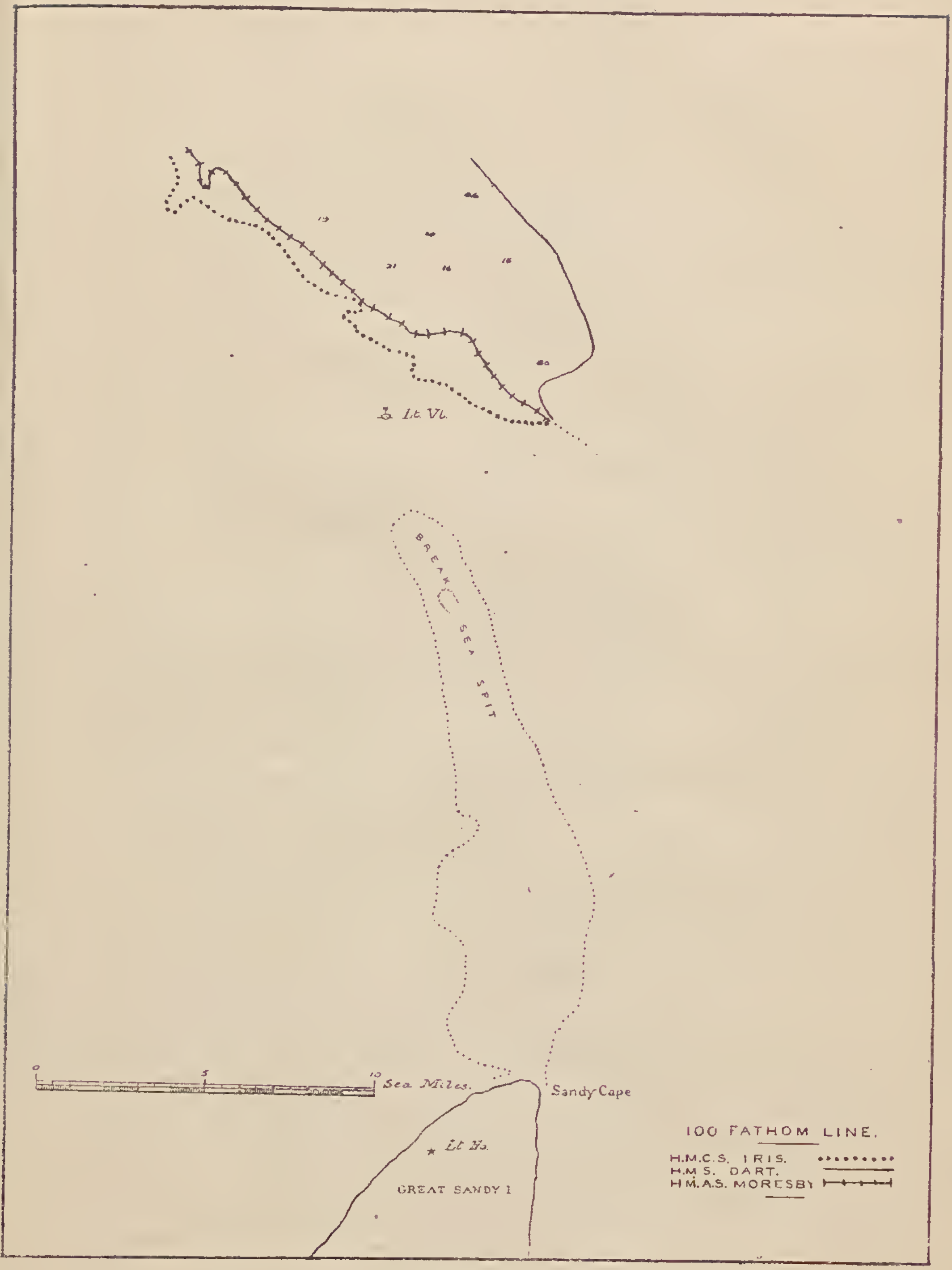
Referring to the vertical movement of the Earth, the late Charles Hedley, in his presidential address before the Linnean Society of New South Wales in 1911, drew attention to this area as a position of special unrest, and the locality has been further noted for the same reason in an article entitled "The Rate of Movement in Vertical Earth Adjustments connected with the Growth of Mountains," by William Herbert Hobbs, contained in the "Proceedings of the American Philosophical Society," vol. lxii., 1923, No. 2. Both these articles referred to the varying depths that have appeared from time to time in this vicinity, and it is now proposed to give a short summary of the surveys carried out in this area, so that a comprehensive view may be obtained of the investigations up to the present time.

The earlier navigators, including Captains Cook and Flinders, reported that the water northward of the Breaksea Spit was of moderate depth; it is presumed that this would indicate a depth of, at most, less than 20 fathoms. In 1879 the first detailed survey of these parts was made by Staff Commander Bedwell, R.N., and the soundings obtained were in general agreement with those of the pioneers. The next survey to be carried out in the locality was by H.M.S. "Dart" in 1898, and a comparison of this survey with that of Commander Bedwell indicated that there had been a considerable shifting of the position of the 100-fathom line to the south-westward during the period between these two surveys. The submarine cable (now abandoned) between Bundaberg and New Caledonia passed through this area, and in effecting repairs to the cable Captain Sharp, of H.M.C.S. "Iris," obtained soundings during 1904 and 1911; a further comparison of these with those taken by H.M.S. "Dart" revealed another marked change in the fathom line in the same direction, though both the surveys by "Iris" were substantially the same.

As the previous investigations detailed above had proved to be of more than ordinary interest to scientists in various countries, the Australian Naval Board, at the request of the hydrographer of the Navy, gave instructions to H.M. Australian surveying ship "Moresby" to rechart the position of the 100-fathom line in this locality, and the examination was carried out in May 1927. The attached tracing from Admiralty Chart No. 345 shows the position of the 100-fathom line as revealed by the surveys of H.M.S. "Dart," H.M.C.S. "Iris," and H.M.A.S. "Moresby"; the position of this line as charted by Commander Bedwell is unavailable at the time of writing, and it is regretted that it cannot be included in the tracing as its insertion would much increase the interest. The few soundings shown indicate the depths in fathoms as found by H.M.S. "Dart"; it should be noted that in these positions the depth now exceeds 200 fathoms.

An examination of this tracing will show the very considerable change in the position of the 100-fathom line that took place at some time between 1898 and 1904. Further, despite repetition, it must be remembered that a previous alteration in the position had occurred between the years 1879 and 1898 although this is not included in the tracing. The 100-fathom lines of "Iris" and "Moresby" will be seen to be in close agreement both as regards position and shape of contour; it would therefore appear that no further breakages of the Continental Shelf have occurred since 1904.

It is not within the province of the present writer to advance any theory for this phenomenon, but it would seem that these investigations show clearly that there are considerable breakages of the Continental Shelf in the locality, and that these are non-periodic but of very considerable violence and extent when they occur. A further examination in a few years' time should prove of more than ordinary interest.



Text-figure 1.

No. 5.

MORINDA SHOAL.

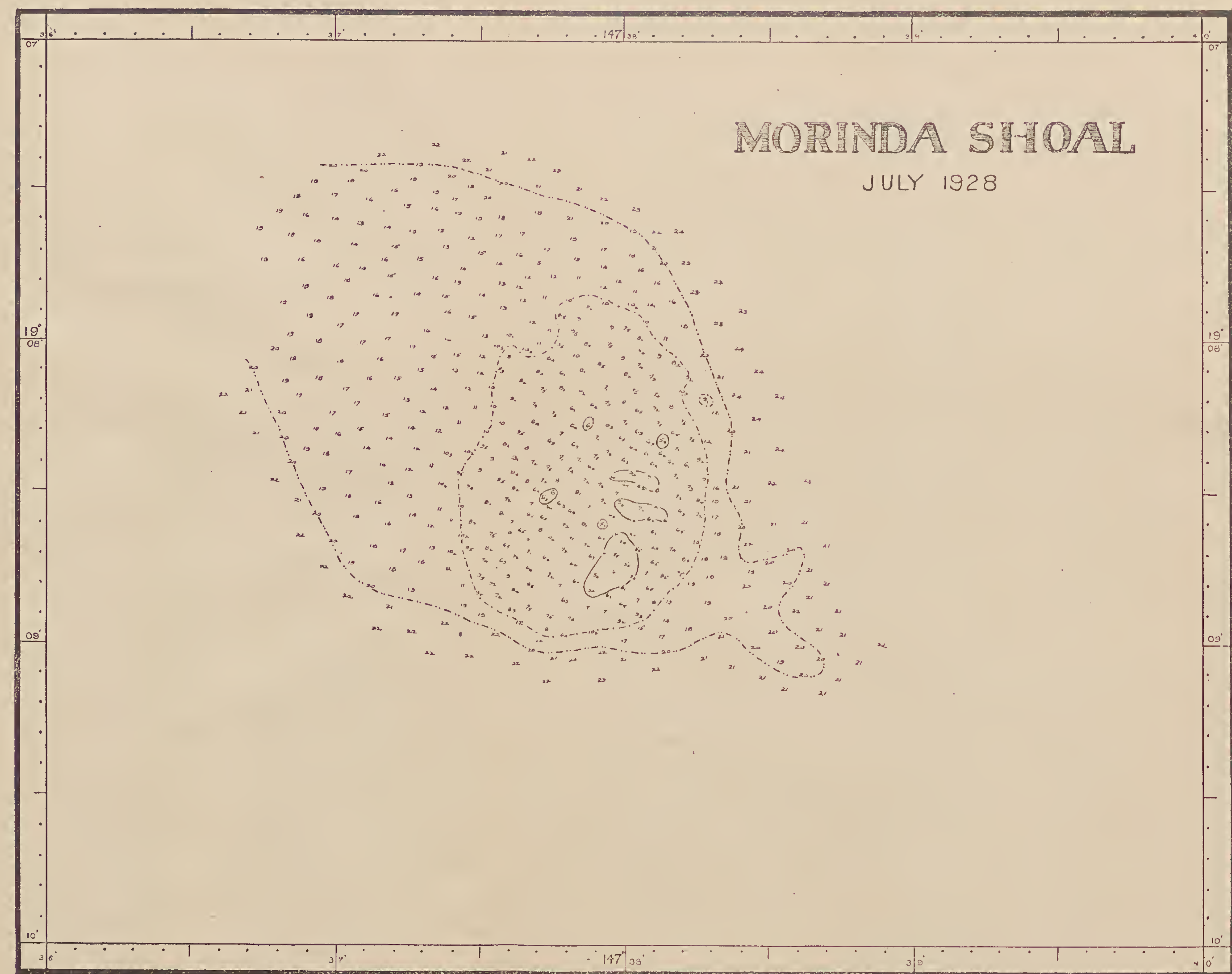
By Commander D. A. Henderson, O.B.E., R.N.

(Text-figure 1.)

A shoal reported by the S.S. "Morinda" was examined by me in July 1928. This shoal lies about 18 miles to the westward of the southern end of Flinders Passage, in Lat. 19° 08½′ S., Long. 147° 37½′ E.

The shoal bears all the characteristics of a typical atoll formation; it is roughly circular in form, steep to the eastward and southward with a more gradual slope to the north-westward. The shortest soundings obtained are somewhat towards the edges of the shoal. The bottom appears to be entirely live coral with patches of coarse coral sand.

It seems to me that in future years this formation might well prove a useful point for investigation into coral growth, &c. It would seem possible that in the course of years the reef will reach the low-water level; if this should occur, a future generation may find my examination of some interest, and the tracing (Text figure 1) shows some of the soundings obtained. With a view to clearness the majority of soundings are omitted, those shown being picked to show the general nature of contour. The soundings are in fathoms and feet, i.e., 6.2 indicates 38 ft. It will be seen that the least water is 23 ft. (3.5).


MORINDA SHOAL
JULY 1928

No. 6.

THE MARINE ALGÆ HITHERTO RECORDED FROM NORTH-EAST AUSTRALIA.

By A. H. S. Lucas, M.A., B.Sc.

The region considered includes the whole of the tropical coasts of Queensland, from Keppel Bay to the Gulf of Carpentaria.

This List of the Marine Algæ known from Tropical Queensland has been drawn up from the following data :—

(1) Dr. W. Sonder's "Die Algen des tropischen Australiens," 1871, Hamburg. Sonder's chief collectors were Dæmel at Cape York, and Kilner and Fitzalan at Port Denison.

(2) Collections sent to myself from Dr. G. H. Vernon, M.C., Thursday Island ; Rev. Percy Hubbard, Hudson I., North Barnards ; Messrs. T. Iredale and G. P. Whitley, of the Australian Museum, Michaelmas Cay ; Rev. Canon Norman Michael, Ayr ; Mr. E. H. Rainford, Bowen, Port Denison, and Stone Island.

(3) Plants forwarded by the former Government Botanist, Mr. F. M. Bailey, to Kew, England, and determined by Mr. A. D. Cotton. They were recorded by Mr. Bailey in his various "Contributions to the Flora of Queensland."

CHLOROPHYCEÆ.

Order CONFERVOIDEÆ.

Family ULVACEÆ (Lamouroux) Rabenhorst.

Ulva Linnæus.

U. lactuca Linn. Rockingham Bay (Dallachi).

U. reticulata Forsk. Toud I. (D'Urville) ; Cape York (Dæmel).

Enteromorpha Link.

E. intestinalis (Linn.) Link. Cape York (Dæmel).

E. compressa (Linn.) Grev. Cape York (Dæmel) ; Bowen (Rainford).

Family CLADOPHORACEÆ.

Chætomorpha Kuetzing.

C. coliformis (Mont.) Kuetz. Toud I., Torres St. (D'Urville).

C. tortuosa (Dillw.) Kuetz. Cape York (Dæmel).

C. crassa (Ag.) Kuetz. (Okamura.)

Rhizoclonium Kuetzing.

R. riparium (Roth.) Harv. Dunk I. (Banfield). Determined by A. D. Cotton.

CLADOPHORA Kuetzing.

C. anisogona (Mont.) Kuetz. Toud I., Torres St. (D'Urville).

C. gracilis (Griff.) Kuetz. Cape York (Dæmel) = *C. cristata* Zan.

C. ægiceras (Mont.) Kuetz. Toud. I. (D'Urville).

SPONGOCLADIA Areschoug.

S. vaucheriæformis Aresch. Dunk I. (Banfield). Determined, A. D. Cotton; Bowen (Rainford).

BOODLEA Murray & De Toni.

B. coacta (Dickie) Murray and De Toni. Thursday I. (Vernon); Michaelmas Cay (Iredale and Whitley); Bowen (Rainford). A. D. Cotton records *Boodlea* sp. from Dunk I. (Banfield).

STRUVEA Sonder.

S. delicatula Kuetz. Cape York (Dæmel). = *Cladophora anastomosans* Harv.

ANADYOMENE Lamouroux.

A. brownii (Gray) J. Ag. Bowen (Kilner, Rainford).

DICTYOSPHÆRIA Decaisne.

D. favulosa (Mert.?) Dcne. Michaelmas Cay (Iredale and Whitley); Bowen (Rainford).

VALONIA Ginnani.

V. forbesii Harv. Michaelmas Cay (Iredale and Whitley).

V. ægagropila (Roth.?) Ag., var. *australis* J. Ag. Dunk I. (Banfield). Determined by A. D. Cotton.

V. confervoides Harv. Stone I. (Kilner); Bloomfield R. (Miss Bauer).

V. fastigiata Harv. Endeavour R. (teste F.v.Mueller).

Order SIPHONEÆ.

Family DASYCLADIACEÆ (Endl.) Cramer.

DASYCLADUS C. Agardh.

D. australasicus (Sond.) Cramer. Cape York (Dæmel).

NEOMERIS Lamouroux.

N. dumetosa Lamour. Bowen (Rainford).

Rather slenderer than Harvey's Friendly Island examples.

BORNETELLA Munier-Chalmas.

B. nitida (Harv.) Mun.-Chalm. Edgecombe Bay (fide Sonder).

ACETABULARIA (Tournefort) Lamouroux.

A. kilneri J. Ag. Port Denison (Kilner).

Family CAULERPACEÆ Reichenbach.

CAULERPA Lamouroux.

C. biserrulata Sond. Cape York (Dæmel).

C. taxifolia (Vahl) Ag. Cape York (Dæmel). Albany I. (fide F.v.Mueller); Port Denison (Kilner).

C. plumaris Forskaal. Port Denison (Kilner).

C. falcifolia Harv. Port Denison (Kilner).

C. freycinetii Ag. Recorded from Australia by De Toni. Probably will be found in the North-east.

C. cupressoides (Vahl) Ag., var. *lycopodium* Weber de Bosse. Cape Gloucester (Kilner); Dunk I. (Banfield). Determined by A. D. Cotton.

C. thujoides J. Ag. Port Denison (Kilner).

C. tristicha J. Ag. Bowen (Rainford).

C. fontinaloides J. Ag. Port Denison (Kilner).

C. complanata J. Ag. Port Denison (Kilner).

C. lætevirens Mont. Toud I. (D'Urville); Port Denison (Kilner, Rainford).

C. racemosa (Forsk.) J. Ag., var *lætevirens* Weber de Bosse. Can this be the same plant as the preceding ?

C. clavifera (Turn.) Ag. Gulf of Carpentaria (F.v.Mueller); Thursday I. (Vernon); Bowen (Rainford); Islands of Torres St. (Hedley).

C. sedoides (R.Br.) Ag. Cape York (Dæmel); Bowen (Rainford).

C. kilneri J. Ag. Whitsunday I. (Kilner).

Family CODIACEÆ (following A. and E. S. Gepp).

Chlorodesmis Bailey and Harvey.

C. comosa Bail. & Harv. Port Denison (fide Sonder).

Avrainvillea Decaisne.

A. papuana (Zan.) Murray & Boodle. Bowen (Rainford).

Penicillus Lamarck.

P. nodolosus Blainville. Toud I. (D'Urville).

Udotea Lamouroux.

U. glaucescens Harv. Cape York and Torres St. ("Challenger" Expedition).

U. orientalis A. & E. S. Gepp. Cape Flattery (Algæ Muellerianæ); Cape Gloucester (fide Sonder); Bowen (Rainford); Dunk I. (Banfield).

U. argentea Zan. Dunk I. (Banfield); Bowen (Rainford).

U. flabellum (Ellis & Soland.) Howe. Cooktown (fide Sonder); Dunk I. (Banfield); Port Curtis (Macleay).

Halimeda Lamouroux.

H. Tuna (Ell. & Soland.) Lamour. Cape York (Dæmel); Bowen (Rainford).

H. macroloba Lamour. Gulf of Carpentaria (fide Sonder).

H. opuntia (L.) Lamour. Rockingham Bay (fide Sonder); Islands of Torres St. (Hedley); Bowen (Rainford); Michaelmas Cay (Iredale and Whitley).

H. incrassata (Ell.) Lamour. Cape York (Dæmel); Albany I. (F.v.Mueller); Port Denison (Fitzalan, Kilner).

H. polydactylis J. Ag. Bowen (Rainford).

H. cuneata Hering. Dunk I. (Banfield). Determined by A. D. Cotton.

CODIUM Stackhouse.

C. harveyanum W. A. Setchell. Bowen (Rainford).

Prof. Setchell considers this plant to be a new species of the *Adhærens* group, and employs the above name tentatively.

C. sp. Rockingham Bay (Dallachi); Dunk I. (Banfield); Bowen (Rainford). The plants formerly assigned to *C. tomentosum* (Huds.) Stackh. have been later placed under *C. muelleri* Kuetz. but the northern forms are quite distinct from the true *C. muelleri*.

C. lineare Ag. Bowen (Rainford).

C. decorticatum (Woodw.) Howe. Dunk I. (Banfield), determined by A. D. Cotton.

Schmidt and Setchell have thrown much light on the species of Codium, but our Australian species are not yet finalised.

PHÆOPHYCEÆ.

Order CYCLOSPORINÆ.

Family SARGASSACEÆ (Dcne.) Kuetz.

SARGASSUM C. Agardh.

S. peronii (Mert.) Ag. Edgecombe Bay and Port Denison (Alg. Muell.); Port Denison (Fitzalan).

S. decurrens (R.Br.) Ag. Cape York (Dæmel); Port Denison (Fitzalan).

S. boryi Ag. (fide J. Agardh.).

S. scabripes J. Ag. (fide J. Agardh.).

S. fallax Sond. Rockingham Bay (Dallachi).

S. angustifolium (Turn.) Ag. Port Denison, Goode I., Edgecombe Bay (fide J. Agardh).

S. carpophyllum J. Ag. Goode I., Edgecombe Bay (fide J. Agardh.).

S. flavicans (Mert.) Ag. Port Denison, Hervey Bay (fide J. Agardh.).

S. fissifolium (Mert.) J. Ag. Hervey Bay (Kilner).

S. swartzii (Turn.) Ag. Trinity Bay, Whitsunday I., Goode I. (Alg. Muell.).

S. binderi Sond. Port Denison (Fitzalan).

S. berberifolium J. Ag. Port Denison (Fitzalan).

S. microcystum J. Ag. Port Denison (Fitzalan).

S. biserrula J. Ag. Goode Island (fide J. Agardh.)

S. cinctum J. Ag. Rockingham Bay (Dallachi).

S. claviferum J. Ag. Port Denison (fide J. Agardh.).

S. opacum J. Ag. (fide J. Agardh.).

S. parvifolium (Turn.) Ag. Port Denison (Fitzalan).

S. filifolium Ag. Port Denison (fide J. Agardh.).

S. stenophyllum J. Ag. Edgecombe Bay, Whitsunday I. (Kilner). Between Capes Upstart and Bowling Green (Rev. Canon Michael).

S. lanceolatum J. Ag. Bloomfield R. (Miss Bauer).

S. desvauxii Ag. = *S. simulans* Sond. Cape York (Dæmel).

S. torvum J. Ag. (fide J. Agardh.).

S. leptopodum Sonder (? = *S. leptopodum* J. Ag.). Rockingham Bay (Dallachi).

S. spinuligerum Sonder. Cape York (Dæmel); Port Denison (Fitzalan).

S. cystocarpum Ag. Rockingham Bay (Dallachi).

S. granuliferum Ag. Cape York (Dæmel); Port Denison (Kilner).

S. gracile J. Ag. Cape York (Dæmel); Port Denison (Kilner).

S. polycystum Ag. Toud I. (Hombron); Cape York (Dæmel).

S. baccularia (Mert.) Ag. (Fide J. Agardh.)

S. plagiophyllum (Mert.) Ag. Port Darwin (fide J. Agardh.).

S. godeffroyi Grunow. Port Mackay (fide J. Agardh.).

TURBINARIA Lamouroux.

T. conoides Kuetz. Gulf of Carpentaria (F.v.Mueller); Torres St. (Haddon); Cape York (Dæmel).

T. decurrens Bory. Torres St. (Haddon).

T. ornata J. Ag. Toud I. (D'Urville); Port Denison (Kilner).

CYSTOPHYLLUM J. Agardh.

C. muricatum (Turn.) J. Ag. Gulf of Carpentaria, Cape York, Port Denison, Rockingham Bay (fide Sonder); between Capes Upstart and Bowling Green (Rev. Canon Michael).

Family FUCACEÆ (Lamouroux) Kjellman.

HORMOSIRA Endlicher.

H. articulata (Forsk.) Zan. Bowen (Rainford).

Order TETRASPORINÆ.

Family DICTYOTACEÆ (Lamour.) Zan.

GYMNOSORUS J. Ag.

G. nigrescens (Sond.) J. Ag. Cape York (Dæmel); Bowen (Rainford).

TAONIA J. Ag.

T. australasica (Sond.) J. Ag. Port Denison (Kilner).

PADINA Adanson.

P. commersonii Bory. (Fide De Toni.)

P. australis Hauck. Cape York (Dæmel).

P. fraseri (Grev.) J. Ag. Thursday I. (Vernon); Bowen (Rainford).

HALISERIS Targioni-Tazzetti.

H. woodwardia (R.Br.) J. Ag. Cape York (Dæmel); Rockingham Bay (Dallachi).

H. acrostichoides J. Ag. Bowen (Rainford).

H. australis Sond. Port Denison (Kilner).

SPATHOGLOSSUM Kuetzing.

S. macrodontum J. Ag. Port Denison (fide J. Agardh.).

DICTYOTA Lamouroux.

D. bartayresiana Lamour. Cape Flattery (fide J. Agardh.).

D. sandvicensis Sond. Gulf of Carpentaria (F.v.Mueller); Cape York (Dæmel).

D. radicans Harv. Port Denison (Fitzalan).

D. ciliata J. Ag. Port Denison (Kilner).

D. bifurca J. Ag. Port Denison (Kilner).

D. alternifida J. Ag. (fide De Toni).

D. furcellata Ag. Port Denison (Kilner).

DILOPHUS J. Ag.

D. fastigiatus (Sond.) J. Ag. Rockingham Bay (Dallachi).

Order PHÆOZOOSPORINÆ.

Family CHORDARIACEÆ (Ag.) Zan.

EUDESME J. Ag.

E. virescens (Carm.) J. Ag. Albany I. (F.v.Mueller); Cape York (Dæmel); Port Denison (Kilner, Rainford).

Family ARTHROCLADIACEÆ (Chauvin) Hauck.

CHNOOSPORA J. Ag.

C. obtusangula (Harv.) Sond. Port Denison (Kilner); Dunk I. (Banfield); Bowen (Rainford).

Family ENCŒLIACEÆ (Kuetz.) Kjellm.

COLPOMENIA Derbes and Solander.

C. sinuosa (Roth.) Derb. & Soland. Gulf of Carpentaria (fide Sonder).

HYDROCLATHRUS Bory.

H. cancellatus Bory. Gulf of Carpentaria (F.v.Mueller); Thursday I. (Vernon); Cape York (Dæmel); Michaelmas Cay (Iredale and Whitley); Bowen (Rainford).

Family SPHACELARIACEÆ (Dcne.) Kuetz.

SPHACELARIA Lyngbye.

S. furcigera Kuetz. Cape York (Dæmel); Port Denison (Kilner).

Family ECTOCARPACEÆ (Ag.) Kuetz.

ECTOCARPUS Lyngbye.

E. sp. Cape York (Dæmel).

RHODOPHYCEÆ.

Order NEMALIONINÆ.

Family HELMINTHOCLADIACEÆ (Harv.) Schmitz.

LIAGORA Lamouroux.

L. leprosa J. Ag. Cape York (Dæmel).

Family CHÆTANGIACEÆ Schmitz.

GALAXAURA Lamouroux.

G. umbellata (Esper) Lamour. Port Denison (Fitzalan).

G. fragilis (Lamck.) Kuetz. Rockingham Bay (Dallachi); Dunk I. (Banfield).

G. rugosa (Soland.) Lamour. Cape York (Dæmel); Port Denison (Kilner).

G. elongata J. Ag. N.E. (Kilner); Bowen (Rainford).

G. lapidescens (Soland.) Lamour.

ACTINOTRICHIA Decaisne.

A. rigida (Lamour.) Dcne. Cape York (Dæmel).

Family GELIDIACEÆ (Kuetz.) Schmitz.

WRANGELIA C. Agardh.

W. penicillata Ag. Cape York (Dæmel).

GELIDIUM Lamouroux.

G. rigidum (Vahl) Grev. Toud I. (D'Urville); and Cape York (Dæmel).

Family GIGARTINACEÆ Schmitz.

DICRANEMA Sonder.

D. filiforme Sond. Port Denison (Fitzalan).

Family RHODOPHYLLIDACEÆ Schmitz.

RHODOPHYLLIS Kuetzing.

R. blepharicarpa Harv. Cape York (Dæmel).

ERYTHROCLONIUM Sonder.

E. sonderi Harv. Dunk I. (Banfield). Known as a Western species. Determined by A. D. Cotton.

EUCHEUMA J. Agardh.

E. spinosum (L.) J. Ag. Gulf of Carpentaria (F.v. Mueller); Thursday I. (Vernon); Cape York (Dæmel).

E. gelatinæ (Esp.) J. Ag. (fide De Toni).

THYSANOCLADIA Endlicher.

T. densa Sond. Cape York (Dæmel).

T. laxa Sond. Gulf of Carpentaria (Alg. Muell.).

Order RHODYMENINÆ.

Family SPHÆROCOCEACEÆ (Dumort) Schmitz.

CERATODICTYON Zanardini.

C. spongiosum Zan. Dunk Island (Banfield).

GELIDIOPSIS Schmitz.

G. acrocarpa (Harv.) Schmitz. Gulf of Carpentaria, Cape York, Port Denison (fide Sonder).

SARCODIA J. Agardh.

S. palmata Sond. Cape York (Dæmel).

GRACILARIA Greville.

G. lichenoides (L.) Harvey. Cape York (Dæmel); Port Denison (Fitzalan).

G. tænioides J. Ag. Cape York (Dæmel).

G. polyclada Sond. Port Denison (Fitzalan).

G. canaliculata (Kuetz.) Sond. Cape York (Dæmel).

CORALLOPSIS Greville.

C. minor (Sond.) J. Ag. Cape York (Dæmel).

C. urvillei (Mont.) J. Ag. Gulf of Carpentaria (F.v.Mueller); Thursday I. (Vernon); Cape York (Dæmel); Toud I. (D'Urville); Dunk I. (Banfield).

HYPNEA Lamouroux.

H. musciformis (Wulf) Lamour. Toud I. (D'Urville); Dunk I. (Banfield).

H. seticulosa J. Ag. Port Denison (Kilner).

H. valentiæ (Turn.) Mont. Port Denison (Kilner).

H. cornuta (Lamour.) J. Ag. Port Denison (Kilner).

H. nidifica J. Ag. Port Denison (Fitzalan).

H. cervicornis J. Ag. Cape York (Dæmel); Port Denison (Fitzalan).

H. pannosa J. Ag. Port Denison (Fitzalan).

H. rugulosa Mont. Toud I. (D'Urville); Port Denison (Fitzalan).

Family RHODYMENIACEÆ (Naeg.) J. Ag.

SEBDENIA Berthold.

S. ceylanica (Harv.) Heydr. Port Denison (Kilner); Bowen (Rainford).

S. maculata (J. Ag.) De Toni. Dunk I. (Banfield); a form known from Mauritius. Determined by A. D. Cotton.

CHRYSYMENIA J. Agardh.

C. uvaria (L.) J. Ag. Cape York (Dæmel).

CHAMPIA Desfontaine.

C. parvula (Ag.) J. Ag. Cape York (Dæmel).

PLOCAMIUM Lamouroux.

P. leptophyllum Kuetz. Rockingham Bay (fide Sonder).

P. angustum (J. Ag.) H. & H. Rockingham Bay (Dallachi).

Family BONNEMAISONIACEÆ (Trev.) Schmitz.

DELISEA Lamouroux.

D. pulchra (Grev.) Mont. Rockingham Bay (Dallachi).

Family RHODOMELACEÆ (Reichb.) Harv.

LAURENCIA Lamouroux.

L. filiformis (Ag.) Mont. Toud I. (D'Urville).

L. nidifica J. Ag. Gulf of Carpentaria (F.v.Mueller); Bowen (Rainford).

L. dendroidea J. Ag. Cape York (Dæmel); Port Denison (Kilner, Rainford).

L. rigida J. Ag. Gulf of Carpentaria (F.v.Mueller); Thursday I. (Vernon).

L. papillosa (Forsk.) Grev. Toud I. (D'Urville); Cape York (Dæmel).

L. obtusa (Huds.) Lamour. Toud I. (D'Urville); Cape York (Dæmel); Dunk I. (Banfield)

L. concinna Mont. Toud I. (D'Urville).

ACANTHOPHORA Lamouroux.

A. muscoides (L.) Bory. Cape York (Dæmel).

A. orientalis J. Ag. Cape York (Dæmel); Port Denison (Kilner); Dunk I. (Banfield). Sometimes recorded as *A. thierii* Lamx., most abundant in the West Indies.

CHONDRIA C. Agardh.

C. rainfordi Lucas. Bowen (Rainford).

POLYSIPHONIA Greville.

P. amœna Sond. Cape York (Dæmel).

DIGENEA C. Agardh.

D. simplex (Wulf) Ag. Cape York (Dæmel); Dunk I. (Banfield); Bowen (Rainford).

TOLYPIOCLADIA Schmilz.

T. glomerulata (Ag.) Schmilz. Gulf of Carpentaria (F.v.Mueller); Cape York (Dæmel); Bowen (Rainford).

POLLEXFENIA Harvey.

P. lobata (Lamx. ?) Falk. Dunk I. (Banfield). A remarkable occurrence. A Banks Straits and Southern form. Determined by A. D. Cotton.

DICTYMENIA Greville.

D. tridens (Mert.) Grev. Toud I. (D'Urville).

LEVEILLEA Decaisne.

L. jungermannioides (Mart. & Hering) Harv. Cape York (Dæmel),; Michaelmas Cay (Iredale and Whitley); Port Denison (Kilner, Rainford).

AMANSIA Lamouroux.

A. glomerata Ag. Cape York (Dæmel); Port Denison (Fitzalan, Kilner).

A. dietrichiana Grun. Port Mackay (Amalia Dietrich).

A. dæmelii (Sond.) J. Ag. Cape York (Dæmel); Bowen (Rainford).

A. pumila (Sond.) J. Ag. Cape York (Dæmel); Dunk I. (Banfield).

VIDALIA Lamouroux.

V. fimbriata (R.Br.) J. Ag. Toud I. (D'Urville); Cape York (Dæmel); N. E. Australia (R. Brown); Dunk I. (Banfield).

V. spiralis Lamx. Dunk I. (Banfield). Determined by A. D. Cotton.

NEURYMENIA J. Ag.

N. fraxinifolia (Mert.) J. Ag. Cape York (Dæmel, "Challenger" Expedition); Dunk I. (Banfield).

LENORMANDIA Sonder.

L. spectabilis Sond. Dunk I. (Banfield). Determined by A. D. Cotton.

DASYA C. Agardh.

D. elongata Sond. Port Denison (Kilner).

D. cuspidifera Sond. Cape York (Dæmel).

HETEROSIPHONIA Montagne.

H. multiceps (Harv.) Falk. Cape York (Dæmel).

Family CERAMIACEÆ (Bonnem.) Naeg.

HALOPLEGMA Montagne.

H. duperreyi Mont. Cape York (Dæmel).

SPYRIDIA Harvey.

S. breviarticulata J. Ag. Cape York (Dæmel).

CERAMIUM Wiggers.

C. pygmæum (Kuetz.) Hauck. Cape York (Dæmel).

C. clavulatum (Mont.) Ag. Cape York (Dæmel); Port Denison (Kilner).

Order CRYPTONEMINÆ.

Family GRATELOUPIACEÆ Schmitz.

HALYMENIA C. Agardh.

H. lacerata Sond. Cape York (Dæmel).

H. floresia (Clem.) Ag. Dunk I. (Banfield). Determined by A. D. Cotton.

PRIONITIS J. Agardh.

P. obtusa Sond. Cape York (Dæmel).

CARPOPELTIS Schmitz.

C. capitellata (Sond.) Schmitz. Cape York (Dæmel).

CRYPTONEMIA J. Agardh.

C. undulata Sond. Cape York (Dæmel).

THAMNOCLONIUM Kuetzing.

T. tissotii, Weber. Dunk I. (Banfield).

Family RHIZOPHYLLIDACEÆ (Mont.) Schmitz.

CHONDROCOCCUS Kuetzing.

C. hornemanni (Mert.) Schmitz. Port Denison (Kilner).

C. kilneri (J. Ag.) De Toni. N. E. (Kilner).

Family SQUAMARIACEÆ (Zan.) J. Ag.

PEYSSONNELIA Decaisne.

P. sp. Port Denison (Fitzalan).

Family CORALLINACEÆ (Gray) Harvey.

LITHOTHAMNION Philippi.

L. membranaceum (Esp.) Foslie. Cape York, Port Denison (fide Sonder).

MELOBESIA Lamouroux.

M. farinosa Lamour. Cape York (Dæmel).

MASTOPHORA Decaisne.

M. plana (Sond.) Harv. Cape York (Dæmel).

AMPHIROA Lamouroux.

A. anceps (Lamck.) Dcne. Rockingham Bay (Dallachi).

METAGONIOLITHON Weber de Bosse.

M. graniferum (Harv.) Weber de Bosse. Dunk I. (Banfield). Determined by A. D. Cotton.

CHEILOSPORUM Areschong.

C. sagittatum. Port Denison (fide Sonder).

JANIA Lamouroux.

J. micrarthrodia Lamour. Cape York (Dæmel).

J. rubens Lamour. Cape York (Dæmel); Port Denison (Kilner).

CORALLINA (Tournefort) Lamouroux.

C. cuvieri Lamour. Port Denison (Fitzalan).

No. 7.

PLANTS ON ISLANDS OF THE BUNKER AND CAPRICORN GROUPS.

By W. D. K. MacGillivray and F. A. Rodway.

One of us had collected 27 species of plants on North-west Island in 1925, which were identified by Mr. C. T. White, Queensland Government Botanist. This series was used as a basis for identification on the present excursion. Specimens were taken of anything not readily identifiable. Several of these were determined by Dr. Rodway and all finally submitted to Mr. White for his authoritative opinion.

We left Bundaberg with Mr. E. F. Pollock's party for the islands on the 16th November, 1927, landing on the evening of that day on Lady Musgrave Island, one of the Bunker Group. Five days were spent on this island, during which time excursions were made to Hoskyn and Fairfax Islands of the same group. These visits were necessarily short, and, as one of us devoted most time to bird observation and photography and the other to collecting insects, not much time was left for gathering plant specimens.

On the 22nd we went on to North-west Island, where we remained for a week, one day of which was set apart for a visit to Tryon Island. We moved our camp to Heron Island on the 1st December, and from this as a base two visits were made to Masthead Island, one to Wilson Island, and one to One-tree Island. We left Heron Island on the 9th December for Gladstone, having spent twenty-two days on the islands.

Lady Musgrave Island was found to be tenanted by a large herd of goats, 200 to 300 in all—the increase of a few left there many years ago. These animals have cleared off all small trees, shrubs, herbage, and grasses with the exception of a few sessile species which grow too close to the ground to be grazed. Only four species of tree, *Pisonia brunoniana, Ficus opposita, Casuarina equisetifolia,* and *Pandanus pedunculatus,* with one shrub, *Tournefortia argentea,* have so far withstood their onslaught. Of the Tournefortia only two miserable specimens are living. The goats have started to eat the bark from the Pisonias, and as these trees have a spongy and succulent stem it will not be long before the hungry animals will have made serious inroads into the numbers of this species. All trees are browsed to a height of about 4 ft. The animals seem now to be dependent upon the dead leaves that fall from the trees (the few that they can still reach) and the seaweed on the beach.

White-capped noddies were busily engaged in building their nests in the trees in countless numbers at the time of our visit and were using the fallen Pisonia leaves for that purpose, and there was keen competition for every leaf that fell, so that the goats were being deprived of this source of food supply. It seems a pity that these animals should be left on the island to turn it into a barren waste, as they serve no useful purpose whatsoever. They have also been introduced to Hoskyn Island, Fairfax Island, and North-west Island. Fresh water does not seem to be essential to their existence, as there is only a small supply of brackish water on Lady Musgrave Island, another on Fairfax Island, and none at all on Hoskyn or on North-west Island.

Hoskyn Island consists of two portions connected at low tide by a reef. The western portion is the larger and, like most of these islands, consists of a central forest of *Pisonia brunoniana, Ficus opposita, Pandanus pedunculatus,* and a tangled undergrowth of *Ipomœa grandiflora, Wedelia biflora, Abutilon indicum,* and *Cæsalpinia bonducella,* with a bordering of *Scævola Koenigii, Tournefortia argentea, Suriana maritima,* all shrubs, and a ground vegetation of grasses and herbage, with Casuarinas growing on the outer edge. On the second island the trees were more stunted. This island is about 13 miles from Lady Musgrave.

Fairfax Island, only 3 miles away, consists of three portions, all wooded, and connected by reef at low tide. We landed on a long narrow sandbank topped with the sand-binding grasses *Thuarea sarmentosa* and *Spinifex hirsutus,* and a few Tournefortias with a small colony of Casuarinas at the free end. We followed it up to the main island, which is colonised by the usual association of Pisonia, Ficus, and Pandanus, with an undergrowth of trailers, climbers, and herbaceous plants, and the bordering shrubs Tournefortia, Scævola, and others.

The second portion was reached by a long walk across rough and crumbly reef and had a steep shingly beach. When this was surmounted it was found to be divisible into two portions, a western forested one with a large central waterhole, and an eastern half, which had at some prior time been worked for guano, leaving a large amphitheatre of tumbled coralline rock. This was covered with trailing herbaceous plants and grasses. The Ragweed (*Erigeron linifolius*), Nightshade (*Solanum pterocaulon*), and *Gnaphalium luteo-album* were conspicuous plants, and there were patches of Mexican poppy (*Argemone mexicana*); a few stunted bushes of *Ficus opposita* were struggling for existence amongst the rocks. On Lady Musgrave Island most of the centre is occupied by this fig, the trees being up to 15 or 20 ft. high, rounded and bushy with a single trunk. It does not send down aerial roots and is consequently not buttressed. The fruit, green at first, becomes red and purple and soft when ripe. "Silver-eyes" feed on it and probably disperse the seed from island to island.

We increased the list of plants for North-west Island to 29, adding three to the 1925 list, without counting *Ximenia americana,* which was missed this time. This is the largest island of the two groups, about 400 acres in extent, and has a dense forest of *Pisonia brunoniana,* some being majestic trees up to 50 or 60 ft. There are also fine specimens of the fig *Ficus platypoda* var. *petiolaris,* with large buttressed trunks and many aerial roots. These trees seem to favour the more rocky areas of the island, whereas the Pisonia prefers to grow in the loose floury soil, a mixture of coral, sand, and guano. On the rocky areas one also finds *Capsicum fastigiatum* and *Plumbago zeylanica.* The fruit of *Ficus platypoda* turns from green to yellow, and finally bright red when ripe and soft.

Celtis paniculata makes a bushy, green-foliaged tree, growing mostly at the edge of the forest. In 1925 only foliage was secured, but several specimens bore green fruits on the present visit.

Ipomœa grandiflora, with a large purple flower and leaves often a foot in diameter, grows luxuriantly in the forest, climbing high up on the trees, draping them and making fine panels of vegetation. It interlaces the smaller trees and with the trailing composite *Wedelia biflora* and the rankly growing Abutilon forms a tangle through which one finds it difficult to make one's way. An annoying plant with small clinging seeds is *Achyranthes aspera,* growing on all the islands except Lady Musgrave.

Scævola Koenigii and *Suriana maritima,* shrubs of the outer zone, were flowering freely and attracting numbers of insects. *Tournefortia argentea* was in flower and berry, and the latter was a favourite food of the "Silver-eyes."

Pipturus argenteus, a prettily foliaged small tree, was in much better condition than in 1925—not so insect eaten. It grows in the forest to about 15 ft. and flowers in an inconspicuous way.

A trailing pea, *Canavalia obtusifolia,* growing rankly with purple inflorescence, was found on the outer islands, preferring those of a rocky or shingly nature.

Ipomœa grandiflora was growing as a trailer on One-tree Island, where its flowers were pure white, opening in the evening and closing after the sun rose in the morning, probably being fertilised by some night-flying moth.

On One-tree Island there is a central pool of brackish water in which mosquitoes were breeding, the only instance on these islands. This pool is surrounded by a green carpeting of a succulent plant, *Sesuviam portulacastrum,* with a pretty pink flower. This was recorded by Jukes in 1843. He also mentions that the island was named before they landed from "The Fly" on account of the one conspicuous tree on it. On landing the one tree resolved itself into a clump of Pandanus, which supported the large nest of some bird of prey, probably an osprey. The clump of Pandanus is still there and also the nest, which we found in possession of a fine pair of white-breasted Sea Eagles. On this island were two clumps of stunted Pisonia, not noted by Jukes. Have they grown up since his visit eighty-four years ago?

The vegetation on Heron Island differs little from that on North-west Island. Here, however, we found a small tree with pretty green foliage and conspicuous orange-coloured flowers, *Cordia subcordata,* which was only noted elsewhere on Wilson Island. On Wilson Island the dominant plant was *Pandanus pedunculatus,* nearly the whole of the centre being colonised by this plant. Two young coconut trees were growing in the centre of this island, possibly planted by someone. Coconuts were found washed up on the shores of most of the islands but all too decayed to germinate. On Wreck Island a tall coconut palm overtopped the other vegetation. These three were the only coconut trees seen by us.

Sophora tomentosa, the sea-coast laburnum, grows freely on Mast-head Island, but is not found on any of the others. This island has also a pea with yellow inflorescence, *Vigna lutea,* trailing on the outer border. *Castanospermum australe* was recorded from Masthead Island by H. A. Longman on the strength of a seedpod found on the beach. I came across several seeds germinating on Masthead Island, and one small plant about 6 in. in height; it is to be hoped that this fine tree will establish itself. The pods were found washed up by the tide on nearly all the islands, but most of the seeds were decayed. Mangrove seeds were also frequent on the beaches but the tree had not established itself on any of them. A prickly-pear was found flourishing on one end of Masthead Island, but was pulled up and cast into the sea. A bean of the climber *Entada scandens* also floated ashore on North-west Island.

LIST OF PLANTS COLLECTED OR NOTED ON THE ISLANDS OF THE BUNKER AND CAPRICORN GROUPS.

Papaveraceæ—

Argemone mexicana Linn., var. *ochroleuca* Bail. Prickly or Mexican Poppy. Fairfax Island.

Cruciferæ—

Senebiera didyma Pers. Wart Cress. Lady Musgrave and Fairfax Islands.

Senebiera integrifolia DC. Lady Musgrave and Fairfax Islands.

Mr. White adds: "Your specimens represent the form named by Bailey in Queens. Agric. Journ. xxv., 234, 1910, as var. *scaber*; the plant, however, has a very wide geographic range and possibly varies somewhat as to vestiture."

Portulaceæ—

Portulaca oleracea Linn. Pigweed. Lady Musgrave, Hoskyn, and One-tree Islands.

Malvaceæ—

Abutilon indicum G. Don. Hoskyn, Fairfax, Tryon, North-west, Wilson, and Heron Islands.

Zygophyllaceæ—

Tribulus cistoides Linn. North-west, Masthead, Heron, and Tryon Islands.

Geraniaceæ—

Oxalis corniculata Linn. Wood, Sorrell, Lady Musgrave, and Fairfax Islands.

Simarubeæ—

Suriana maritima Linn. North-west, Heron, Wilson, Tryon, and Hoskyn Islands.

Leguminosæ—

Canavalia obtusifolia DC. McKenzie Bean. Fairfax, Hoskyn, and One-tree Islands.

Vigna lutea A. Gray. Masthead Island.

Sophora tomentosa Linn. Sea-coast Laburnum. Masthead Island.

Cæsalpinia bonducella Flem. North-west and Hoskyn Islands. Seeds on Lady Musgrave Island.

Castanospermum australe A. Cunn. Moreton Bay Chestnut. Masthead Island.

Cactaceæ—

Opuntia sp. Masthead Island.

Ficoideæ—

Tetragonia expansa Murr. New Zealand Spinach. Hoskyn and One-tree Islands.

Sesuvium portulacastrum Linn. One-tree Island.

Umbelliferæ—

Hydrocotyle hirta R. Br. Lady Musgrave Island.

Compositæ—

Erigeron linifolius Willd. Ragweed. Fairfax Island.

Gnaphalium luteo-album Linn. North-west, Heron, Masthead, Wilson, Tryon, One-tree, Fairfax, and Hoskyn Islands.

Wedelia biflora DC. All islands visited except Lady Musgrave.

Goodenovieæ—

Scævola Koenigii Vahl. North-west, Heron, Wilson, Fairfax, and Hoskyn Islands.

Plumbagineæ—

Plumbago zeylanica Linn. North-west Island.

Boragineæ—

Cordia subcordata Lam. Heron and Wilson Islands.

Tournefortia argentea Linn. All islands visited.

Convolvulaceæ—

Ipomœa grandiflora Lam. North-west, Heron, Wilson, Tryon, One-tree, and Hoskyn Islands.

Ipomœa pes-capræ Roth. Goat's-foot Convolvulus. North-west, Heron, Wilson, Masthead, Tryon, and One-tree Islands.

Solanaceæ—

Solanum pterocaulon Dunal. Hoskyn, Fairfax, North-west, Heron, One-tree, and Tryon Islands.

Capsicum fastigiatum Blume. Chilli. North-west Island.

Nyctagineæ—

Boerhaavia diffusa Linn. Hogweed or Tar Vine. North-west, Heron, Wilson, One-tree, Hoskyn, and Fairfax Islands.

Pisonia brunoniana Endl. All islands visited.

Amarantaceæ—

Achyranthes aspera Linn. All islands except Lady Musgrave.

Chenopodiaceæ—

Salsola Kali Linn. Prickly Saltwort. One-tree Island.

Laurineæ—

Cassytha filiformis Linn. North-west, Masthead, Heron, and Tryon Islands.

Euphorbiaceæ—

Euphorbia atoto Forst. All islands except Lady Musgrave.

Euphorbia eremophila A. Cunn. Caustic Plant. All islands except Lady Musgrave.

Casuarineæ—

Casuarina equisetifolia var. *incana*. Coast Oak. All islands.

Urticaceæ—

Celtis paniculata Planch. Investigator Tree. North-west, Tryon, and Masthead Islands.

Ficus platypoda A. Cunn. var. *petiolaris*. North-west, Heron, Masthead, and Tryon Islands.

Ficus opposita Miq. All islands except One-tree Island.

Pipturus argenteus Wedd. North-west, Heron, and Tryon Islands.

Palmeæ—

Cocos nucifera Linn. Coco Palm. Wilson and Wreck Islands.

Pandanaceæ—

Pandanus pedunculatas R. Br. All islands.

Cyperaceæ—

Cyperus rotundus Linn. Nutgrass. Lady Musgrave Island.

Gramineæ—

Spinifex hirsutus Labill. Masthead, North-west, One-tree, Fairfax, and Hoskyn Islands.

Stenotaphrum subulatum. Masthead, Tryon, and Heron Islands.

Thuarea sarmentosa Pers. Beach Grass. North-west, Masthead, Heron, Fairfax, and Tryon Islands.

Sporobolus virginicus Kunth. Masthead, North-west, Heron, Tryon, Wilson, and Fairfax Islands.

Eleusine indica Gært. Crow's-foot Grass. North-west and Heron Islands.

Lepturus repens R. Br. Coast Grass. North-west and Heron Islands.

No. 8.

CORAL REEFS—ROUGH-WATER AND CALM-WATER TYPES

By P. MARSHALL, M.A., D.Sc., F.G.S., F.N.Z., Inst., Department of Scientific Research, Wellington, New Zealand.

STRUCTURE OF CORAL REEFS.

Although geological literature contains much information about coral reefs, there is still little to be found about the actual composition and structure of these remarkable physiographic features. In Darwin's original description mention is made of the frequent occurrence of a raised rim on the edge of a reef; and it is stated that on the raised rim, "where the waves beat the surface is covered with a Nullipora." "The extreme verge of the reef which was visible between the breaking waves at low water consisted of a rounded, convex, artificial-like breakwater entirely coated with Nulliporæ."[1] The authors of "The Atoll of Funafuti" (Royal Society, London, 1904) found that the outer rim of that atoll was of a similar nature, and for that reason it was dubbed by them "The Lithothamnion rim." Wood-Jones confirms the statements of previous observers that the outer rim of the Cocos Keeling Atoll has a similar nature. Mayor, in his excellent description of the reef of Maer Island in the Murray Group, states that a Lithothamnion rim is found on the outer edge of the reef on the south-east side of that island.[2] There are but very few accounts of the outer edge of the Great Barrier Reef of Australia. In the voyages of Cook and of Flinders, however, it is stated that here also the outer rim is visible between the successive breaking waves at low water.

It appears, then, that it has been recorded that a number of the coral reefs in the Pacific Ocean are bordered on their outer side by a raised rim. The surface of this is slightly above the level of the sea at low water, but it is violently washed by each succeeding wave. Over all its area the rim is well covered by a growth of Lithothamnion, and related types of algæ, and is actually the nullipore rim or zone of Darwin's description. On the surface of this rim the growth of actual coral is restricted to a few colonies which, with a flattened corallum, maintain a precarious existence in the raging surf. Corals, however, abound on the landward side of the reef flat, which is a relatively even area, that extends from the Lithothamnion rim to the beach. The reef

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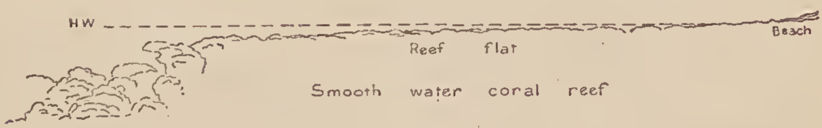
[1] Darwin, C.: Geological Observations, Smith Elder, 1851, pp. 24, 42.

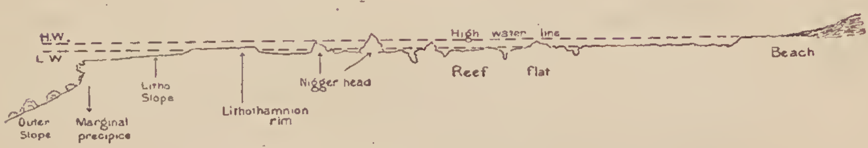
[2] Mayor, A. G.: Papers from Dept. of Marine Biology, Carnegie Inst. of Washington, vol. 9, p. 15, 1918.

flat may thus be at times a few yards only in width and at others as much as a mile or more. It is barely covered with water at low tide, but at high water and in rough weather it is traversed by waves of considerable power. Corals are numerous also on the ocean slope outside the Lithothamnion rim and in the numerous crevices that penetrate the very irregular outer border of the rim.

If a naturalist makes his first coral landing on a reef of this type he experiences a deep disappointment for a moment. On the limestone rock around him he can see none of those wonderful visions of beauty that have been described and pictured time and again by travellers as the normal appearance of a coral reef.

The thousands of Queensland coral reefs which flourish within the placid coastal waters, which are protected from the Pacific Ocean swell by the protecting line of the Great Barrier, are wholly different in their appearance and formation from the reef structure that has been described. Here the reef has no outer rim raised above its inner part. Its surface rises slowly, but continually, from its outer to its inner limit, really the beach of the island, which is usually present within it. Where it passes into the beach, however, it is only at low tide that any part of it is above the sea-level. On these reefs coral colonies without end grow and flourish in every conceivable form, and in colour of every hue, and





Rough water coral reef

constitute practically its whole mass. A stone flower-garden indeed, crowded with an infinite variety of plants. Some of them are delicately branching, others sturdy shrubs, some mushroom-shaped, some a thin sheet of lace. Each tip is crowned with blossom of the most appropriate tint, and seen through a film of the transparent water the whole field is truly a vision of delight. Lithothamnion has no place here, or it is restricted to mere incrustations on some of the older coral branches.

Here are two contrasted types of coral reefs—the one encircling islands in the open ocean; the other occurring where waves are small and conditions relatively quiet. It is thought that this distinction is really a natural one, imposed by nature in response to the conditions that affect vitality, and that it justifies the classification of coral reefs in the two divisions of *rough-water* and *calm-water* reefs.

Calm-water Coral Reefs.

The remarkable variety and the great luxuriance of the growth of coral colonies is the most striking feature of this type of reef. Of other growth there is little to be seen. At Beaver reef, Otter reef, and doubtless most, if not all, of those that lie within the shelter of the Great Barrier, *Acropora* is perhaps the prevalent genus of corals, though large heads of *Porites* are always present. The same is true of the reefs in the Bay of Batavia, where no long ocean swell beats on the reefs. At the outer edge of a reef of this type the tops of the heads of coral are only just exposed at the lowest water, but the surface rises a little towards the beach, where the highest coral heads may be exposed for an hour or so near low water. Quite a considerable number of molluscan shells are to be found here, and included among them species of *Hippopus* or other large clams are usually conspicuous. Sea urchins are frequent, especially the striking Diadema (Star) fish. Brittle stars, sea anemones, worms of many types are all to be seen here in their appropriate places in huge numbers. The reef, and the reef flat regions, cannot be distinguished from one another in these calm-water reefs. The edge of the reef merges into the reef flat without any distinguishing difference. The corals and other organic structures merely become less luxuriant and varied as the beach is approached.

The wave action is gradually decreased as the waves extend over the reef, and finally sand and coral fragments are deposited on the beach, if there is any central rock-mass around which the reef extends. Often between tide levels there is a formation of beach breccia or coquina—a solid resistant rock formed by the cementation of sand and coral fragments. Percolating rain-water flowing outwards is probably responsible for this cementation.

In these regions where wave action is particularly slight, banks of coral débris and sand often accumulate on the reefs themselves, and islands may be formed on their surfaces. At first such an island may change its form and even its position, from time to time, as wind and sea change and fluctuate. As accumulation becomes greater a more pronounced permanency results and vegetation may become established, and a stable island will result. Such an island will take a form in consonance with the action of sea and wind; and if the reef lies transverse to the wind an atoll-shaped island may result. It is certain that these calm-water reefs may arise on a muddy sea-floor, as has been clearly shown by borings. The most successful of these was made by the Great Barrier Reef Committee on Oyster Cay, within the relatively calm-water conditions of the Australian Great Barrier region. Other borings have been made in the Bay of Batavia, and some of the reefs there have been found to consist of even thinner masses of limestone than that of Oyster Cay. In some cases it has been found that the base of these reefs lies at a slightly lower level than that of the sea-floor around them. This of course can readily be explained by one of two lines of reasoning. Either the weight of the limestone reef has caused it to sink slightly into the soft muddy floor of the sea around it, or sedimentation has raised that floor since the growth of the reef began.

This calm-water form is the prevailing type of reef found on the Australian coast and in the waters of the East Indies generally. Many observers have naturally formed all of their ideas on coral reef growth and development from observation of the structures that they have seen in the large numbers of reefs and islands arranged in battalions along so many hundreds of miles of the length of the Australian coast.

It is probable that many people, the world over, have formed their ideas of coral reefs from seeing the striking and beautiful photographs in Saville Kent's book on the Great Barrier Reef of Australia. Several of these wonderful pictures are entitled "The Outer Barrier." This may lead to the conclusion that the photographs represent that portion of the reef on which the great surges of the Pacific Ocean are arrested, and on which they smash in might. The structure and features of the reef shown in the photographs, however, indicate that this is not the case.

The staghorn coral (*Acropora*), which is the main organism in many of the photographs, could not grow there. There is no sign of broken water or of waves. All is calm and serene. It may be asserted that the phrase "Outer Barrier" is used by Saville Kent in the sense of the outer portion of the area that is protected by the Great Barrier Reef; not the outer edge of the reef itself, on which the great waves of the Pacific Ocean spend their force. These illustrations can be taken as showing the features of calm-water reefs in their most highly developed and characteristic form.

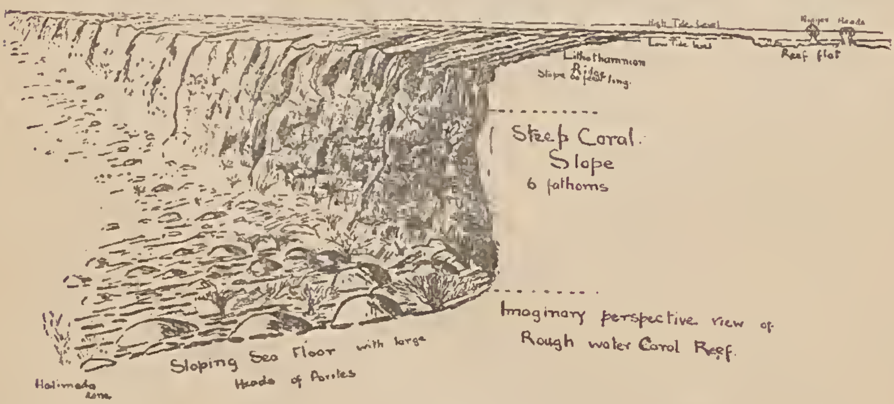
It is interesting to recall that Mayor, in his complete account of Maer Island, particularly records that a Lithothamnion rim edges the reef on the south-east side where the heavy sea breaks, but not elsewhere. In this island, therefore, both rough-water and calm-water reefs occur in appropriate places.

The Rough-water Coral Reef.

As is well known, the skeleton of a colony of coral polyps is composed of carbonate of lime, hard and resistant in its nature; and at first sight it seems as though these structures in their serried ranks could withstand the onslaught of the most furious waves. Yet the force of the league-long swell of the Pacific Ocean is too mighty for them. A single wave may throw a weight of 40,000 tons of water on to a strip of reef no more than 20 yards long, and this heavy mass has a velocity of 40 miles per hour. This mighty onslaught is repeated five times each minute. Hour after hour, day and night, this battering continues. The relatively frail coral growths are unable to stand up against it. Some more effective structure must take the place of the coral on this front line where the greatest stress of the battle between land and water is endured.

It may seem ridiculous to state that seaweed is found to be sufficient to withstand the burden of this onslaught. Yet in all the oceanic coral reefs that have been closely examined this has been found to be the case. Darwin long ago recognised that the nullipores constituted the dominant growth at the Cocos Islands and of the reefs of some Pacific Islands. Dana almost at the same time emphasized their importance. At Funafuti, David and others found these plants the dominant organisms on the reef of that atoll. It is now recognised that there is quite an alga flora on the coral reefs of this type. Most common usually is a species of Lithothamnion—if one uses this term in the most general sense. Where the surf is heaviest there is a lichenous species; where quieter there is a knobbly type. Nearly everywhere there is also a coralline alga or *Lithophyllum,* often *Acetabularia, Bornetella,* or *Amphiroa.* All of these algæ have the power of abstracting carbonate of lime from sea-water.

It is either their structure or their habit of growth that enables these humble organisms to flourish under these strenuous conditions, which are fatal to practically all organic growth besides. Some of them are lichenous in form and adhere closely to the surface of the reef rock;



others are jointed, and flexuous, and give way to every movement of the water, and by yielding survive, under conditions which are fatal to the strong but overmatched growths of hard coral.

The actual material of this resistant mass on which the waves break is a compact dense white rock in which no structure can be seen even with an ordinary lens. It is hard at first to believe that this rock has any real relationship to the somewhat flimsy Lithothamnion that grows on it. Microscopic preparations, however, show at once that this dense white rock is mainly composed of the thallus of Lithothamnion and of other genera of algæ. The cell-walls have been completely covered with a thick covering of carbonate of lime. If a chip of this rock is treated with some dilute acid, the calcium carbonate dissolves out, and the colourless delicate cellular structure then is left. With the algæ a few free foraminifera are to be found in this rock now and again; while encrusting forms such as *Polytrema* and *Carpenteria* are frequent.

When the covering coat of Lithothamnion and other algæ on a reef is closely examined it is always found that some fine sand is embedded in the small crannies between the different organisms. In the felted mat of *Corallina* and *Amphiroa* that is often found in association with the Lithothamnion, fine sand-grains are always found entangled in large numbers. The accumulation of these grains together with the growth of the algæ enables the reef to increase in size gradually, in spite of the violence of the surf and the constant solvent action of the circulating sea-water. The sand, of course, is formed by the action of wave action on some of the organisms that grow on the surface of the reef and on the sea-floor which lies outside of it; as well as the tests of some foraminifera. In the calmer weather the sand accumulates on the sea-floor outside the reef; but in heavy weather when the wave action becomes strong some of it is thrown on to the surface of the reef, and the finer grains are caught among and between the algal growths.

At first it seems absurd to suppose that such incoherent material could form rock with sufficient resistance to withstand the fury of the surf. If cementing action did not come to its aid the combination of alga and sand would certainly soon be washed away. It is found that carbonate of lime is deposited in the small spaces between these materials and unites the grains and algæ together into a solid rock. The deposition of cement takes place so quickly, and so strong is the resulting rock, that with a geological hammer it is found to be more difficult to detach fragments from it than from the surface of ordinary hard rocks; yet when this cemented and resistant limestone is treated with dilute acid the cellulose of the algæ is still distinct. The source of the cementing carbonate of lime is hard to decide. That it is derived directly from the sea-water is certain. While in many rock-masses the deposition of carbonate of lime can be ascribed to the effect of chemical reactions or to a simple evaporation of the solvent, it is evident that in this case the latter action at least is hardly possible. The reef is washed by each successive surf even at low tide at the least ten times in a minute, while at all other states of the tide it is constantly covered with water. It can be asserted that there is no possibility that the deposition of the calcareous cement is in this case due to the evaporation of the solvent water. It is well known that the very life of Lithothamnion is dependent on the alga being kept constantly wet: drying at once kills it. If evaporation were the cause of the cementation, it would surely be the case that all the sand on coral beaches would at once be cemented into solid masses; whereas it is well known that the loose sand of which they consist is one of their most attractive features.

Two explanations of cementation suggest themselves:—The algæ may abstract, for their growth, carbonic acid gas from the small amount of bicarbonate of lime that is in solution in sea-water. The carbonate of lime that would result, being insoluble, would then be precipitated. Against this explanation the fact must be remembered, that the algæ themselves use a great deal of carbonate of lime in building up their own structure, and it is not clear that there would be any carbonate of lime in excess of this requirement, for the cementing process. Insistence may be laid on the fact that the coral rock is perforated through and through with living organisms. The respiration of these organisms must liberate a great deal of carbonic acid gas, and at night time, when no part of this would be utilised by the chlorophyll of the algæ, there would be a considerable excess of this substance in solution in the sea-water. It is conceivable that carbonic acid gas thus generated might act upon the calcium sulphate that is actually in solution in sea-water in relatively large quantity. This suggestion, however, involves chemical reactions which appear to be improbable.

Examination of the reef rock convinces an observer that the cementing action takes place very rapidly, for the cemented rock is actually in contact with the living thallus of Lithothamnion. In a microscopic preparation the cementing matter has a characteristic appearance; for it has the form of parallel, columnar, minute crystals of calcite, which are arranged with their longer axes at right angles to the walls of the small cavities between the sand-grains.

The cementation that has taken place in these rough-water reefs is here considered to be of the greatest importance. It is this cementation alone which gives to this recent rock of organic origin, from its very birth, the strength and solidity which enables it to resist the league-long swells of the Pacific Ocean. Consideration of the conditions convinces one that, if this process of cementation did not take place, the coral reefs of the open ocean could not exist above the level at which the heavy waves that roll across it break. The islands of volcanic origin would then be without their protecting border of coral reefs and would be vigorously attacked by marine abrasion.

It is therefore in all probability no exaggeration to assert that, but for this chemical action that causes cementation, none of the smaller islands of the tropical Pacific would now exist, and that shoals alone would mark the site that they had occupied.

The striking feature of the Lithothamnion rim is not the only one that distinguishes the rough-water coral reef from the calm-water type. Both seawards and shorewards there are other differences. The Lithothamnion rim is flat on the top, and thirty or forty yards in width, and its surface is perhaps two feet above low tide level; though the constant break of the surf in all weather makes it impossible to measure this height in any exact manner. The surface of this rim, while in general very uniform, is most irregular in detail. It is surprisingly knobbly, and, where it is free from man's disturbing hand, each of the depressions is occupied by an echinoid. These organisms are so firmly fixed in the pits by their strong spines that the sides of the cavities have to be broken open by chisel and hammer before the animals can be extracted. Since they form a favourite article of food for the natives, these organisms are not plentiful on those portions of the reef which are near villages, and are on the sheltered side of the island. On the weather side of the island and in localities remote from a village the echinoids are found in countless numbers in these nooks on the surface of the Lithothamnion rim. The actual seaward edge of the reef is most irregular. Projecting buttresses extend as much as ten or twenty feet beyond the usual line, and on the other hand deep narrow ravines penetrate far into the reef. Occasionally these are covered over, and their existence may be known only by the presence of a blow-hole thirty or forty yards from the edge of the reef.

The gradual seaward slope of the Lithothamnion rim extends outwards to about three or four feet below the level of low water. The reef edge then descends rapidly for four or five fathoms. The upper part of this small submarine precipice is covered with a growth of Lithothamnion, while on the lower part where wave action is less pronounced corals of many species grow luxuriantly. Many corals grow also within the ravines that penetrate the rim, and in all places where wave action is not vigorous enough to destroy them. From the foot of the small precipice the sea-floor slopes away rather rapidly, and it is seldom that anchorage can be found for even small steamers at a reasonably safe distance from the margin of the reef. The surface of this exterior slope is mainly covered with sand, the grains of which consist of the remains of plants and animals that grow on the reef. Near the base of the small precipice coral heads grow in large numbers and in profusion; but as one proceeds outwards the patches of sand get larger, and the coral heads fewer, and at the depth of about fifteen fathoms it seems that a growth of *Halimeda* covers the sea-floor. A curious feature is often to be noticed. Among and between the coral heads on this outer slope rounded cobbles are often to be seen in large numbers. At first one is inclined to ascribe them to the effect of wave action near the base of the reef. It is well known, however, that the cobbles are due to human activity. Native fishermen gather the stones whenever obtainable on the beach, and attach them to fishing lines as sinkers. They are, however, fixed in such a way that as soon as the line is being drawn up they become detached. In time portions of the outer slope become almost covered with these discarded sinkers.

The top of the Lithothamnion rim is almost flat for thirty yards or more. On its landward edge there is then a sudden descent of two feet and again a flat surface extends more or less continuously to the beach. This is the reef flat. Its floor is on the average a few inches below the level of low tide. There are many coral heads on it—often depressions or pot-holes—and, not infrequently, large nigger-heads. These are large masses of limestone that have been swept on to the reef during hurricanes. All of those that I have closely examined are actually heads of *Porites*. It seems that they had been gathered by the force of the heavy waves from the slope outside the reef and cast on to it during hurricanes. In places there are large numbers of nigger-heads on the reef flat; but many of these are probably of considerable age. The most severe hurricane for twenty years at Rarotonga and Aitutaki Islands in 1925 added but few nigger-heads to those that had been on the reef flat previously and were easily recognised because of their black colour, which is always assumed by coral limestone after long exposure. The rough-water coral reef is then naturally formed of several well-marked and easily distinguished portions—the outer slope, the reef precipice, the Lithothamnion slope, the Lithothamnion rim, the reef flat, and the beach.

These different portions are clearly to be recognised in each type of reef fringing, barrier, and atoll; and can be easily recognised, whether there is a beach or island within them or not; though of course different portions, notably the reef flat, may vary to an immense extent in dimensions. When viewed from a height, colour alone affords the easiest way of recognising the different parts. There is the deep azure of the open sea, the startling line of white where the surf breaks on the Lithothamnion rim, while at low tide its maroon-coloured surface may be distinguished, between the successive waves. The reef flat is always coloured a bright emerald green, and in many cases there is the deep prussian blue of the lagoon within the reef, with its fringe of white sand. Veritably a feast of colour.

In numerous instances it has been found that the mineral matter of coral reefs has undergone considerable change in addition to that involved in the cementation of the material of the Lithothamnion rim. Notable amongst these are the deposition of secondary aragonite in some of the coral skeletons and the subsequent change of the aragonite to calcite. But by far the most important change is the formation of dolomite. Descriptions and discussions of these chemical changes are to be found in the volume on the Funafuti Atoll which was published by the Royal Society of London. The chemical composition of coral limestones has also been discussed by Professor Skeats, and some further information will be found in the Geology of Rarotonga and Atiu Islands by P. Marshall.

It may be stated briefly that the Funafuti report lays emphasis on the occurrence of magnesium carbonate in the hard parts of many marine organisms, especially the algæ of coral reefs, and suggests that the dolomite is merely a residue which remains after much of the calcium carbonate of organic remains has been removed by solution. The authors suppose that this solution would take place at considerable depth.

Professor Skeats subsequently examined raised reef limestones from many of the Pacific Islands. He concluded that the action of dolomitisation is relatively superficial and takes place at the depth of about thirty feet. He suggests that it is due to a chemical reaction.

The conditions of the occurrence of dolomite in the raised reef at Atiu Island in the Cook Group show that the formation of this mineral is due to a partial substitution of magnesium for calcium which appears to require a great lapse of time, but actually takes place on or near the surface of the reef rock, at a time when it was washed by lagoon water.

Whether the material of smooth-water coral reefs ever undergoes a change to dolomite cannot be said. The only raised reef of this type that was seen in Java, on the north coast near Tandjoeng, had undergone no dolomitisation.

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Frederick Phillips, Government Printer, Brisbane.