The Nature of the Coast

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(Plates I–II)

Nearly the whole of the coast of Christmas Island is formed of steep limestone cliffs, usually ranging in height from thirty to fifty feet. At infrequent intervals the line is broken by small beaches or coves. Above these cliffs is a terrace, of slightly varying width, which runs almost completely round the island[1]. The outer edge of this, where the brown booby, *Sula leucogaster*, generally nests, is for the most part devoid of soil and consists of bare, jagged pinnacles of limestone. The vegetation, except along the north coast, where the jungle continues right to the edge, is low and often thinly scattered. It consists of bushes of *Pemphis* and *Scaevolo*, with thicker belts of *Pandanus*. On the

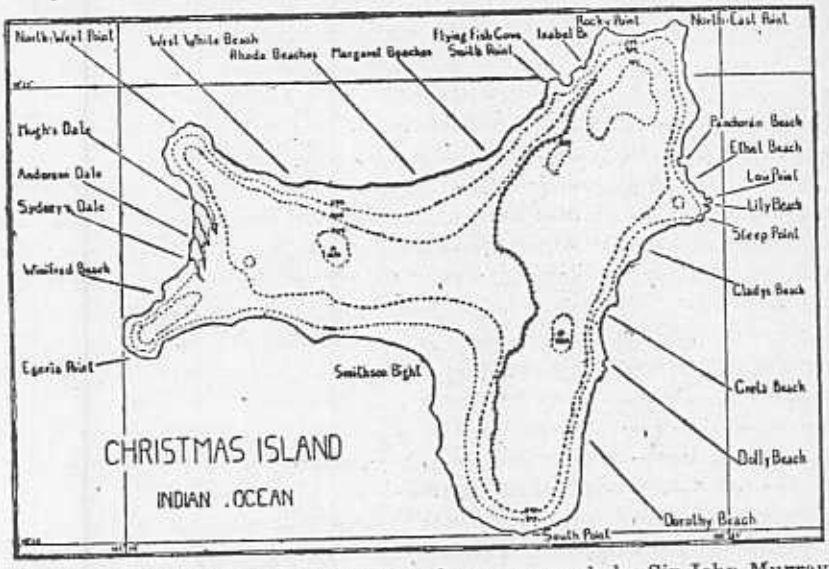
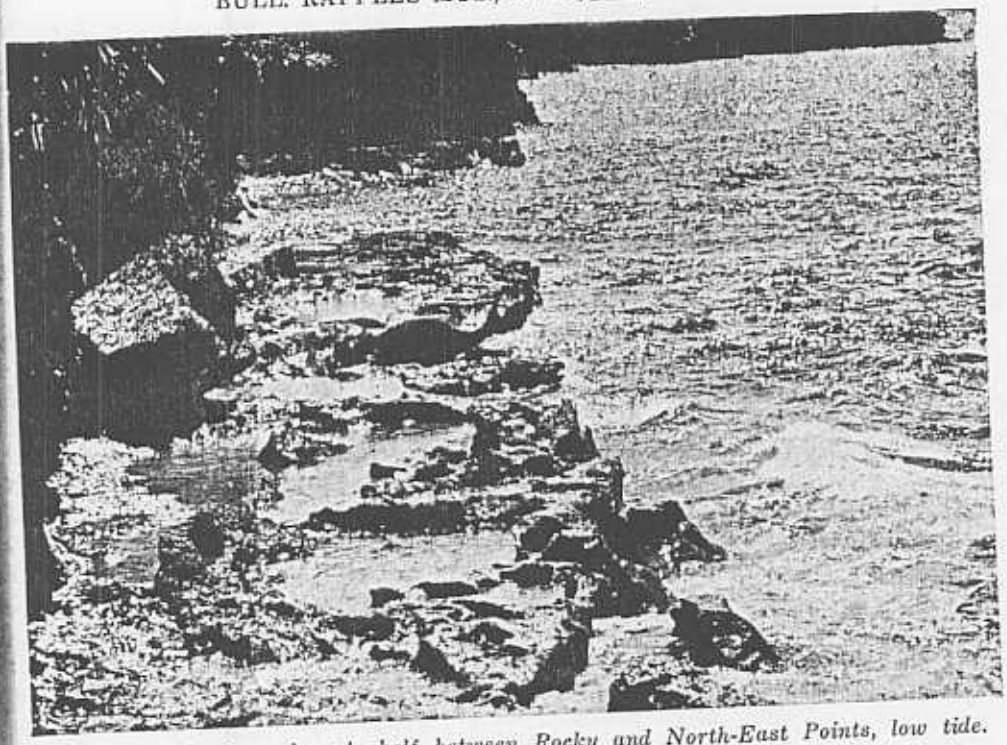
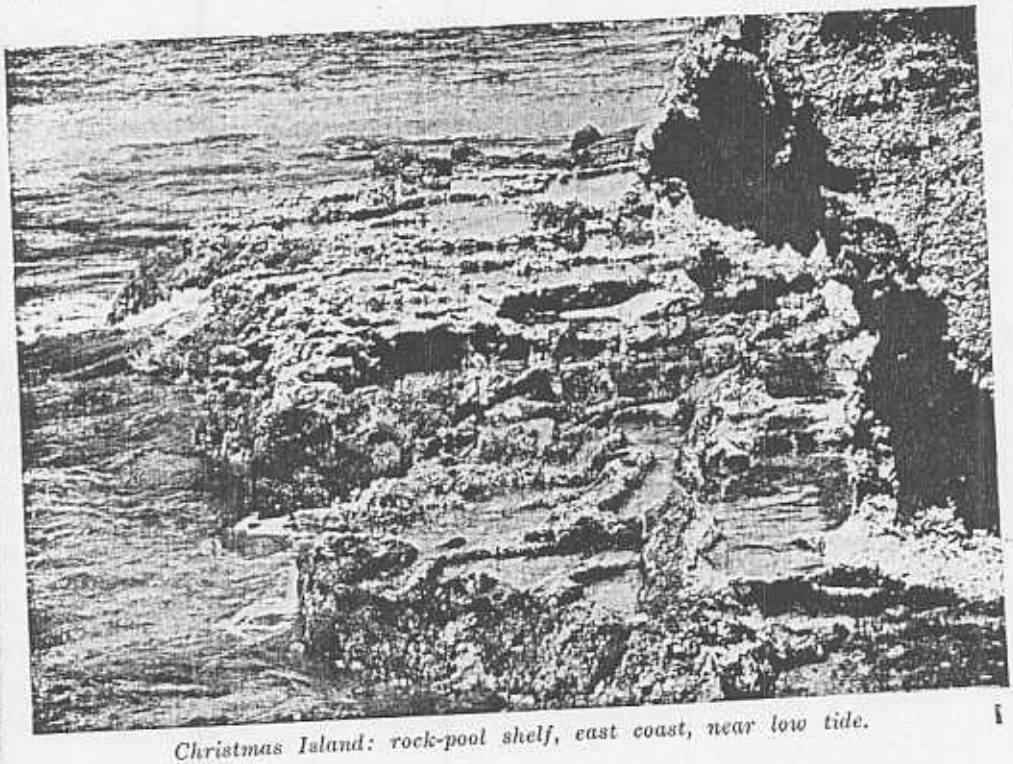


Fig. 1. Sketch-map, based in part on the survey made by Sir John Murray in 1908. The fringing reef is marked by duplication and furring of the coast line. The vertical interval of the contour lines is 300 ft.

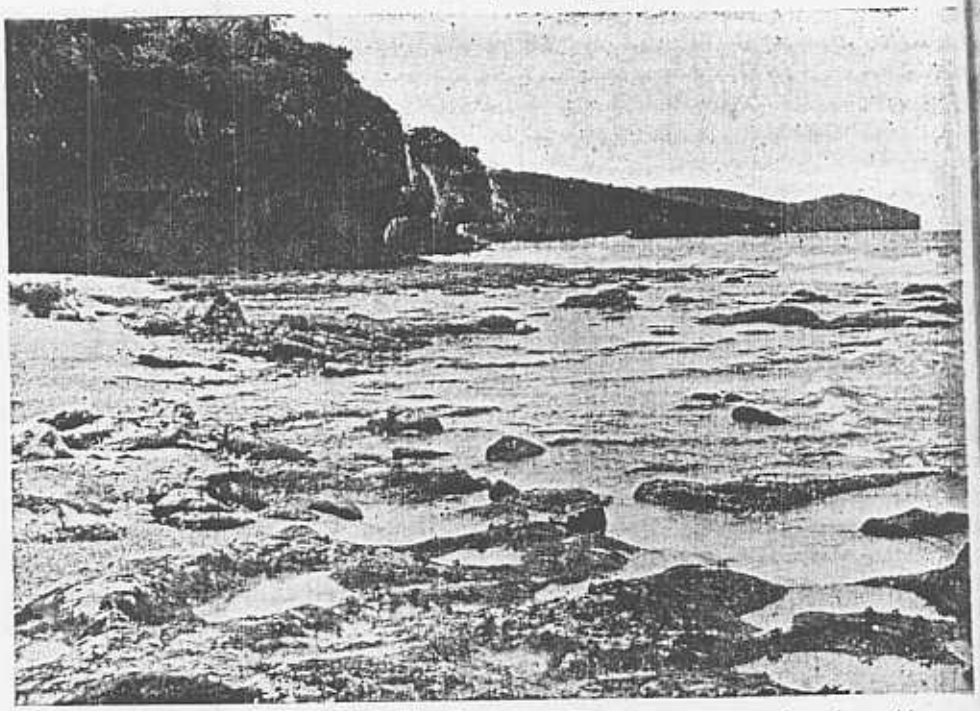
1. At Steep Point, immediately south of Lily Beach, the terrace has dropped away along the line of a fault and the inland cliff, here about a hundred and fifty feet high, falls sheer to the sea for a quarter of a mile. It is also deficient in Flying Fish Cove, where its place is taken by a low platform of talus and coral fragments, which rises some ten to fifteen feet above the normal high tide level.



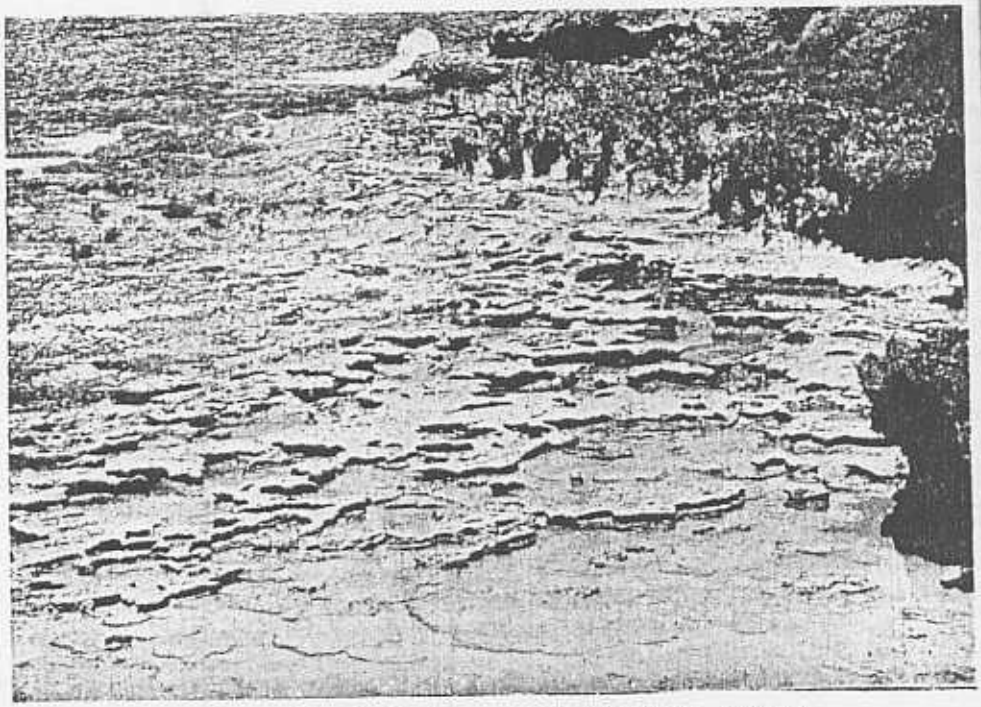
Christmas Island: rock-pool shelf between Rocky and North-East Points, low tide.



Christmas Island: rock-pool shelf, east coast, near low tide.



Christmas Island: fringing reef at Greta Beach two hours after low tide.



Christmas Island: fringing reef at Lily Beach, low tide.

east side of the island there are small, open patches of coarse grass. Any of this area may, in rough weather, be swept by waves of salt mist, and the spider *Cyclosa mulmeinensis* is common. The remainer of the shore terrace, although there are several broad outcrops of irregular, fissured limestone, is fairly well provided with earth and is covered with open jungle and dense belts of *Pandanus*. *Sula sula rubripes* and *Fregata andrewsi* breed almost exclusively in the taller trees in this region. Behind it is a second cliff, the inland cliff, rising, sometimes sheerly, to a height of about five hundred feet. On its slope and crest *Fregata m. minor* and the remaining booby, *Sula abbotti*, nest in the tops of the larger trees, while colonies of the bo'sun, *Phaëthon rubricauda*, inhabit the four steepest portions.

The face of parts of the sea cliff, principally in the north and east, is sheer. In the remainder it has been undercut at the base, often for a considerable distance, by the action of the waves. Along the south coast, where the cliff receives the full force of the heavy south-east swells, which run for the greater part of the year, it has been broken and cut to leave a series of sharp-edged ridges and stack-like projections. Here, mostly between the angle of Smithson Bight and Egeria Point, numerous large caves, like the cavities of dental caries, have been hollowed out at its foot[1]. In many cases the roof of these are split by fissures which communicate with the surface of the shore terrace, so that when there is a strong sea running they throw up great columns of spray, sixty to eighty feet high. This is frequently carried some distance inland by the wind, and there is a broad belt along the cliff-top which is totally devoid of vegetation. Near the outer edge are rock-pools between the limestone pinnacles, (fed mostly by the spray and slightly concentrated by evaporation) a few of which contain small live fish[2]. Further inland are pools of rain-water, tainted by salt-mist and with a salinity ranging up to 1580 parts per 100,000, containing large numbers of mosquito-larvæ, *Aëdes (Stegomyia) aegypti*.

The Noddy, *Anous stolidus pileatus*, nests freely on ledges on the sea cliff all round the coast, although it is a little less common from Smithson Bight to Egeria Point. The crab *Grapsus grapsus tenuicrustatus*, in a variety of shades, also occurs

1. There is a second series of smaller blow-holes, backed by *Pandanus* or coarse grass, along the north-west corner of the island, between North-East Point and Panchoran Bay, and a few round South Point and south of North-West Point.

2. Samples from a number containing fish showed a sodium chloride content varying from 3,220 to 3,630 parts per 100,000. Sea-water, off the north coast of the island, has about 3,110 parts per 100,000. The temperature of these pools also rises, and by early afternoon it frequently reaches between 95° and 96° Fahr., being then as high as the Persian Gulf, the warmest of the world's seas. The maximum which I recorded from the rock-pools was 103·8° at 3 p.m.

everywhere, clambering over the base of the limestone. Empty, moulted, shells can sometimes be found as far as thirty feet above the high tide-level. These crabs are much preyed upon by grey and fawn-grey Moray eels, up to about a metre in length, which dart well out of the water, over the rock, in pursuit of them. Jumping-fish, *Periophthalmus* sp., are abundant in the same area. Where the face of the cliff is soft and very pock-marked, the crab *Pachygrapsus plicatus* is fairly common, hiding in the small holes between, and in the vicinity of, the tide-lines, while *Sesarma obtusifrons* occurs near the top, well out of reach of the sea. The latter species, which is a dull black with the chelæ a dirty off-white, can usually be detected in the shadow of its holes only by the bright, beady yellow of its eyes.

Round the greater part of the coast the ocean floor at the foot of the cliff, which in the shallower areas can be seen to consist of living coral separated by patches of white, coral sand, lies more than five fathoms below the surface of the water. Over the remaining portions, approximately marked on the accompanying map by reduplication and furring of the coast-line, there is a fringing reef, stretching from twenty to two hundred feet seaward. The distribution of this is interesting. The greater part of it occurs along the west and east sides of the island. In the north, except for a long cap round North-West Point and a second between Rocky and North-East Points, it is mostly confined to the neighbourhood of the beaches; while, apart from a few patches on the east, sheltered, flank of Smithson Bight, it is entirely absent from the south coast.

In gross form the fringing reef resembles the existing shore terrace, or, more closely, some of the incomplete terraces between the top of the inland cliff and the plateau. If there were to be a further relative regression of the sea it would come to constitute a second, partial, shelf round the island. At present, in the immediate vicinity of the beaches it is usually dry at low tide,[1] while most of the remainder is covered by a depth of less than one and a half fathoms. The greater part of it is composed of large blocks of coral, cemented together to produce a smooth, hard surface not unlike concrete. Frequently there is a clear channel, varying in width from five to twenty feet, between the inner edge of the reef and the base of the cliff. This is usually absent round the beaches, although, as in Flying Fish Cove, the outer border may here be raised slightly above the level of the remainder. The ocean floor seems to lie from two to four fathoms below the sea edge of the fringing reef, and from the base of

1. This is a general rather than a particular truth. Over the greater part of the year the drop from high to low water is less than four feet. If during this long interval there is a strong sea running (or even only the wind is piling the water on the shore) there is frequently not sufficient recession for the reef to be uncovered.

this submarine cliff it slopes gently to a depth of some twenty fathoms. Beyond this point it descends rapidly for about two and a half miles.

The inner portion of the reef in front of the beaches is much broken by shallow pools and pits, several feet in diameter, containing a number of species of rock-fish. The principal invertebrate inhabitants are holothurians, one of which grows to a length of about fourteen inches, and echinoderms of which *Echinometra mathaei, E. oblonga* and *Echinothrix diadema* are the most prominent. There is little living coral. Towards the shore the pools may contain a number of crustaceans of which *Eriphia sebana, Leptodius gracilis, L. sanguineus, Percnon planissimum, Calcinus herbstii* and *C. elegans,* all occurring abundantly, are the commonest. The sea-border of the fringing reef is much split by deeper channels, at right angles to the line of the coast, through which the water drains off the raised portions at low tide. Here living coral is more plentiful and the commonest crustaceans, apart from pagurids and the smaller forms living in holes in the rock, are two species of large, somewhat highly-coloured, lobsters, which are occasionally taken for food. Moray eels are plentiful all along the reef; and over its edge, among the corals in the slightly stiller waters a few fathoms deeper, are a multitude of fish, including the coffer-fish, *Ostracion,* and Russell's scorpion fish, *Pterois russelli.* The commonest edible fishes in this area are probably a black species of *Balistes,* known to the Malays as "Ikan babi", and several red-coloured members of the genus *Lutianus,* known collectively as "Ikan merah".

Even apart from the neighbourhood of the beaches, most of the cliff behind the fringing reef does not drop straight into the sea. Instead there is a shelf of shallow rock-pools, about five feet wide, level with, or slightly above, the high tide mark, (b on Fig. C). A few scattered stretches of this formation also occur independently of the reef. A number of these pools are cut out of hard, jagged limestone, and are devoid of vegetation. They may contain representatives of some half-dozen species of fish, including the ubiquitous Moray eel; also one or two *Echinometra* forms and a large holothurian. A brittle-star, *Ophiuroidea* sp., is common, but there are very few crustaceans except for *Grapsus grapsus tenuicrustatus,* which is abundant. The remainder of the pools lie in softer, smooth-surfaced masses of cemented coral, similar to those which constitute the greater part of the fringing reef. This is well-tunnelled by marine worms, and much of it is covered with a red-brown or a green alga. A number of crustaceans are common, including *Pachygrapsus minutus* and *Pilodius harmsi,* which are both very plentiful, *Carpilodes bellus, Pachygrapsus plicatus, Eriphia sebana, Calcinus herbstii* and *C. elegans,* and a species of *Pilumnus.* Another

crab, *Eriphia sebana smithii*, occurs fairly frequently in this region, but it is usually found clinging to the cliff-face some two to three feet above the water. Two species of shrimp are common; one, which is small and very agile, appears a dark chocolate colour, with transverse white bars down the dorsal surface, while the other, which may grow to an overall length of about 110 mm. and spends its time hiding in the natural, narrow-necked cavities in the walls of the pool, is a dark, dull green.

This shelf of rock-pools has an interest beyond that of its permanent fauna. Together with certain of the small coves and beaches, it provides the easiest route by which the young forms of the terrestrial crabs can leave the sea, and make their way onto the shore terrace. This is particularly noticeable in the case of *Gecarcoidea humei natalis* whose sub-adults, in a fruitful year, may come up from the water in such concentration that the base of the cliff, and the barer portions of the terrace immediately above, appear to be covered with a red-brown moss. Later, as adults they seem to return to the sea to spawn along approximately the same line as that by which they left it. As a result, although the species is abundant all over the island, when the adults migrate to the coast to reproduce they arrive, almost entirely, at those stretches which are covered by a reef. Certain of the other terrestrial crabs, which generally climb no further than the shore terrace, appear to be influenced by the same factor. The two *Geograpsus* species, *crinipes* and *grayi*, are both commonest on the strip from Smith Point to Dolly Beach, which is protected by rockshelf and reef through most of its length; while the latter, at least, is definitely rare along the flanks of Smithson Bight. *Sesarma jacksoni*, although originally described from a specimen found by Professor Harms in the neighbourhood of Grimes Cave, appears to have a similar distribution. So, on the shore terrace, does *Sesarma obtusifrons*. *Birgus latro*, which I have several times seen laden with spawn descending sheer portions of the cliff between Smith and North-west Points, is probably the only definite exception.

The beaches are all small. The largest is less than four hundred and fifty, and most of them are under two hundred, yards long. Like the fringing reef, they occur principally on the east and north coasts, while they are completely absent from the south side of the island. Thirteen of them have been dignified by names although two, Gladys and Dorothy Beaches, are scarcely recognisable. In addition to these there are several small coves (from fifteen to forty-five feet wide), containing a little sand or coral shingle, on the west coast where the streams from the Dales run into the sea.

Superfically these beaches all appear to be very different from each other but they can, from the littoral aspect, be divided into two main types, with a third, well-defined, midway group. The first of these types, (Fig. B) is represented by three beaches, Margaret, Rhoda and West White, which lie in the sheltered

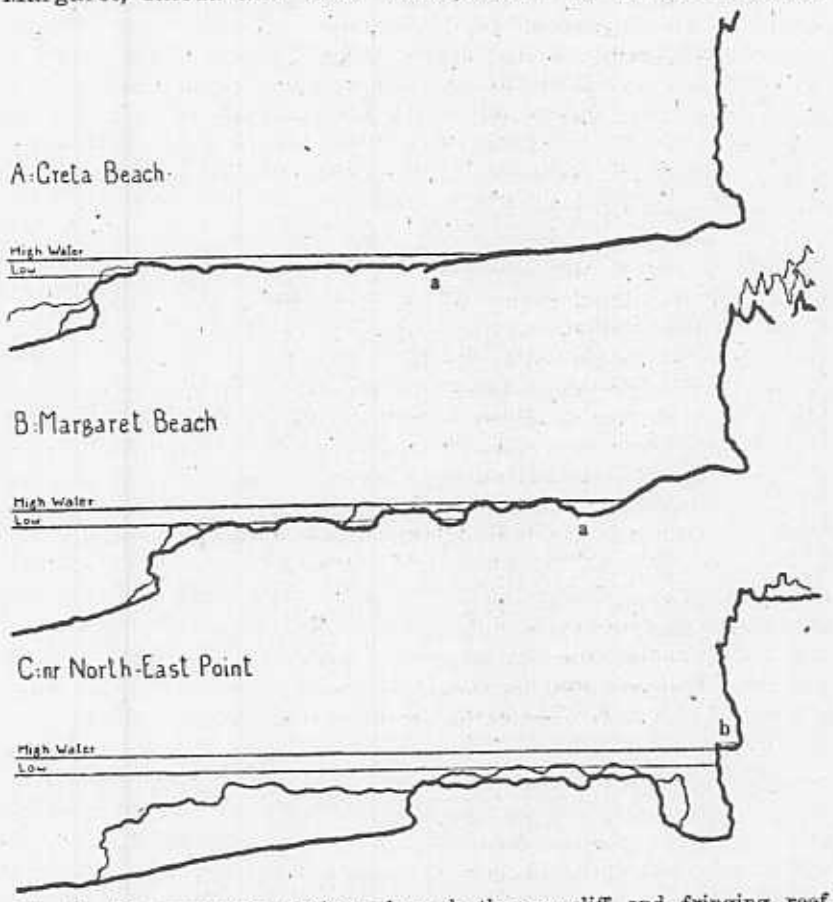


Fig. 2. Diagrammatic sections through the sea-cliff and fringing reef. *A* at Greta Beach, where a beach of fine white sand slopes fairly gently down from the base of the cliff to join, at *a*, a flattened coral reef, most of which is uncovered at low tide. *B* at Margaret Beach, where a narrow beach of coral shingle joining, at *a*, a more broken reef which is partially uncovered at low tide, is banked steeply at the foot of the cliff. *C* on the coast half a mile to the west of North-East Point, where there is only a shelf of rock-pools at the base of the cliff, and the fringing reef, separated from it by a narrow channel, remains covered at all stages of the tide.

trough of the north coast. They are all long for their depth, and their shore consists only of a steepish bank of coarse, coral shingle. There is little or no sand. A small, apparently apterous, cricket and a species of *Gammarus* are common among the pebbles at the top of the bank. The only crustaceans present seem to be *Coenobita perlatus* and *C. rugosus*, which are abundant, together with a few stray specimens of *Sesarma obtusifrons*. No more than a narrow band of the fringing reef, which is here knobbled and irregular in outline, is dry at low water. In parts it is separated from the beach by a shallow ditch. *Grapsus grapsus tenuicrustatus* and the inevitable echinoids are fairly plentiful. At West White Beach the pools contain a number of fine species of coral fish, but crabs are relatively scarce and the reef is not easy to work. At Rhoda and, even more, Margaret Beaches it is rich in crustaceans; especially the small forms which inhabit tunnels in the softer rock. These include several species of *Pilumnus, Pilodius harmsi, Dacryopilumnus eremita* and *D. rathbunae*. Three forms of *Pachygrapsus* (*plicatus, minutus* and *planifrons*) are also plentiful in the pools, together with *Eriphia sebana* and *Micippa platipes*.

The second type of beach (Fig. A) is represented by Dolly and Greta Beaches, lying near the middle of the east coast. In these the shore, which is much deeper, consists of a gentle slope of fine white sand, composed of coral and mollusc-shell fragments. The reef, which is also broader, is flat and fairly level. Most of it is uncovered at low tide, and the majority of the pools are shallow. The two Coenobites occur on the beaches in considerable numbers, but the characteristic crabs are *Ocypoda ceratophthalma, O. kuhli* and *O. cordimana*, of which the last is very common. These spend the day at the bottom of narrow, slanting tunnels which they excavate in the sand. If the weather is dull *cordimana* may emerge up to an hour before sunset, but the other two species only venture out when the evening is well advanced. Even a full moon is sufficient to keep them in, or at least very close to, their burrows. The semi-terrestrial *Geograpsus crinipes* occurs on both these beaches, although it is more plentiful on Dolly Beach. The latter is crossed by two freshwater streams, and backed on its landward side by a steepish slope covered, along its base, with coconut palms. *Metasesarma rousseauxi* is common, together with several earwigs and two millipedes, under the rotting husks which have collected where the springs cross the beginning of the beach. Here, and a little further up, *Ptychognathus pusillus* also occurs, while *Cardisoma hirtipes* is abundant on the mudbanks within the jungle proper. (These last three species of crustacean are absent from Greta Beach, for the latter

has no freshwater and is enclosed by almost sheer cliffs some thirty-five feet high).

Beaches of the type of Margaret or Rhoda (Fig. B) can be derived from certain of the reef-protected sections of the coast such as that between Rocky and North-east Points (Fig. C) by assuming a slight elevation of the reef, and a subsequent filling of the narrow channel between it and the base of the cliff with a steep bank of fragments pounded from the reef. If this process is carried a full stage further a beach of the type of Greta (Fig. A) is formed. Here continued coral growth, together with a stronger wave action pushing back the line of the shore, has produced a broader, flatter reef; while the latter factor has turned the bank of shingle into a sandy beach. The first group is thus an early stage in the development of the second, the members of which have progressed more rapidly because they receive almost the full force of the south-east trades (the prevailing wind for nine months of the year).

The five beaches composing the third, midway, group are all situated round the north-east spur of the island. Three of them are only partially sheltered from the south-east trades. The most southerly of these, Lily Beach, has a fine flat reef, but it lies in a narrow, laterally compressed channel. As a result most of the force of the sea is spent before it reaches the shore, and the latter has remained a steepish slope of rough, coral shingle. The summit of this is so immune from the action of the waves that the fragments have even lost their polish, becoming a dull, pitted grey, while a number of pairs of *Sula leucogaster*, forsaking their usual site on a cliff-edge, nest confidently on the slope. The beach is practically devoid of crustaceans, except for a wood-louse, but the reef contains a number of interesting forms, including *Daira perlata* and *Plagusia depressa tuberculata*. Both of these usually occur just below the low-tide line, the former hiding in the tangled cracks and spaces under the corals, and the latter running freely over the smoother rocks. The most conspicuous molluscs are clams, up to about a foot in length, and cowries. On the right flank of the reef is a raised shelf of rock-pools, which runs out seawards round a bulge of low, jagged limestone. Its principle inhabitants seem to be echinoids and a species of chiton, although some of the pools contain fish and a few lurking crabs.—*Pachygrapsus* sp:, *Eriphia* sp: and *Calcinus* sp:.

A short distance above Lily Beach are two others, Ethel and Panchoran Beaches. These both face north-east to east, and are roughly similar in form. The shores, which are narrowish, are composed of sand and medium coral shingle; while the reefs, which are strengthened in parts by outcrops of basalt, are fairly flat and mostly uncovered at low tide. They are rich in crustaceans, including a Porcellanid, and Moray eels. The commonest

and most typical crabs are those favouring shallow, slightly sandy pools; *Leptodius sanguineus, Thalamita picta, Percnon planissimum* and a *Macrophthalmus* of which unfortunately I collected only immature forms. The lizard, *Lygosoma sinus* occurs frequently on the shore and along the cliff in the immediate neighbourhood. Terrestrial crabs, including especially *Coenobita clypeata*, are very plentiful on the terrace behind the beaches.

Two beaches, Flying Fish Cove and Isabel, remain. These also lie close together, and both face north to north-west. The second, which is very small, has a flat, worn reef of medium width, backed by an abrupt slope of coarse shingle. Unfortunately the loading-piers are situated near to it, and the coral is now dead; the reef-pools contain only sparse representatives of five common crabs, and a few small fish left by the tide. The latter being without cover, and easy to see, attract the reef-herons, *Demigretta sacra*, and a solitary bird can usually be found stalking up and down in search of a meal. At the summit of the shingle bank is a five foot duck-wallow whose muddy border has been colonised by the same species of *Sesarma* as at Dolly Beach. Dermapterids, blattids and millipedes are also abundant there.

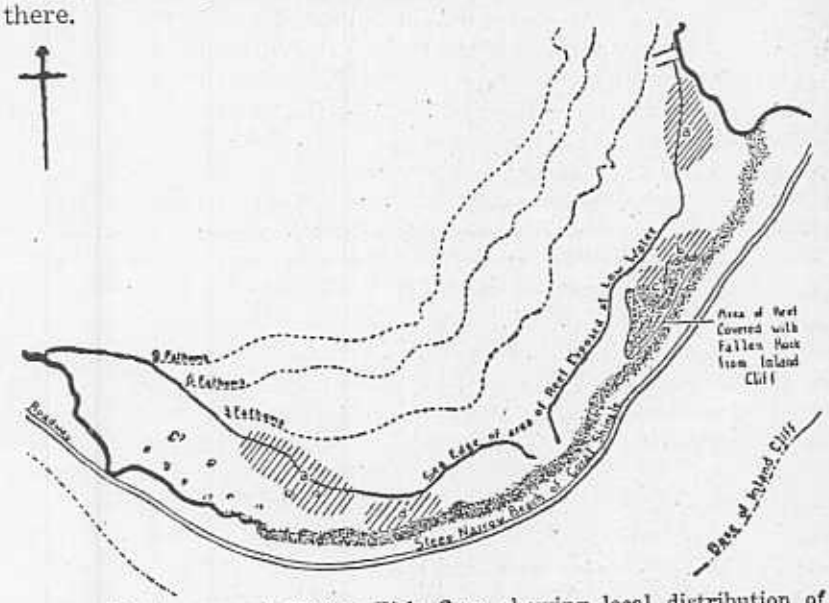


Fig. 3. Sketch map of Flying Fish Cove showing local distribution of marine Pagurids. (*a*) *Calcinus elegans* (which is not plentiful), (*b*) *Clibanarius* sp. 1, (*c*) *Clibanarius corallinus*, (*d*) *Clibanarius* sp. 2.
Calcinus herbstii is common all over the reef, and seems to occur below it almost as far as the three-fathom level.

Flying Fish Cove is a long crescentic beach, with a good, broad, flattened reef whose middle portion is covered at low tide by a foot or two of water, while the outer rim is mostly bare. The shore consists only of a steep, narrow bank of coral shingle, although formerly there was a certain amount of sand which has been removed for building purposes. Along the edge of the shore the reef is strewn with small rounded boulder which have fallen from the inland cliff. At one point there is a great triangular-shaped mass of them, stretching out towards the sea. A number of crabs occur under these rocks, of which the commonest are *Eriphia scbana*, *Leptodius gracilis*, *Pseudozius caystrus* and *Pachygrapsus planifrons*, which are all abundant. Towards the west end of the beach an appreciable amount of sand appears in the shallow pools and *Leptodius sanguineus*, *Pseudograpsus albus* and *Percnon planissimum* become very plentiful. Five Pagurids are found in the cove, and their distribution is interesting. Two are the two species of *Calcinus* which occur abundantly all round the island. One of these, *C. herbstii*, is common all over the reef, and seems to spread below it almost as far as the three-fathom level. The other, *C. elegans*, exists in appreciable numbers only in two areas lying towards the ends of the beach proper. The remaining three Pagurids are species of the genus *Clibanarius* which I have not found elsewhere on the island. The smallest of these is confined to a brief area among the sandy pools at the south side of the cove. The other two (one is *C. corallinus*) occur in distinct, circumscribed patches among, and just to the north of, the large mass of fallen boulders. Here the pools are free of sand. Within their specific limits these crabs are very plentiful, but ten feet outside them it is impossible to find a single specimen.

I am much indebted to Mr. M. W. F. Tweedie for the determination of a number of the species mentioned above, and to Commander W. F. Rhodes and Mr. J. C. Baker for transport by sea, and to Mr. P. Westmacott and Mr. M. G. S. Newton for transport by land, during my investigations.