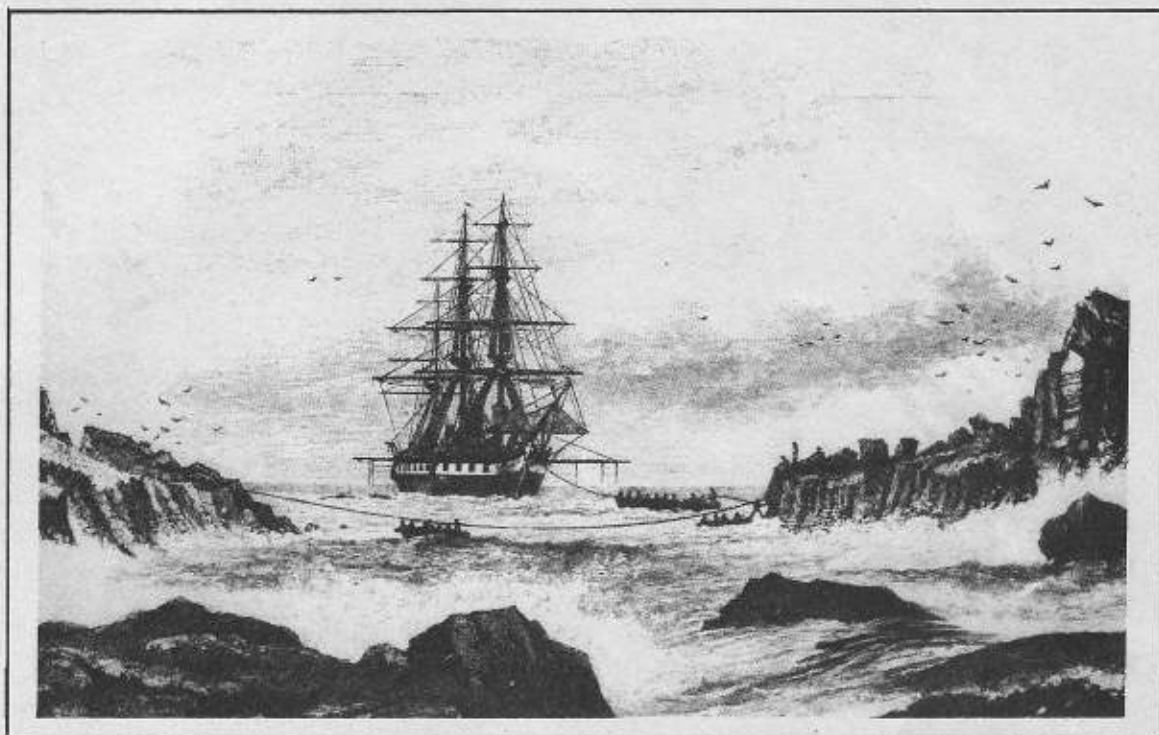


*CAMBRIDGE EXPEDITION to
SAINT PAUL'S ROCKS*



GENERAL REPORT

FRONT COVER

Top: H.M.S. Challenger at Saint Paul's Rocks, August 1873

Bottom: S.V. Andando at Saint Paul's Rocks, September 1979

lots of love,
Al

General Report
of the
Cambridge Expedition to
Saint Paul's Rocks

by

Alasdair Edwards

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CAMBRIDGE EXPEDITION TO SAINT PAUL'S ROCKS

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ill at last moment)

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PREFACE

The Cambridge Expedition to Saint Paul's Rocks was conceived in October 1978 by a group of diving scientists belonging to the Cambridge University Underwater Exploration Group (CUUEG). A team of five finally reached Saint Paul's in September 1979. This team included two postdoctoral zoologists, a doctor and two undergraduate students.

Saint Paul's Rocks are an isolated, uninhabited group of islets in the equatorial Atlantic Ocean ($0^{\circ} 55' 10''\text{N}$ $29^{\circ} 20' 33''\text{W}$), which appeared from the reports of visitors to possess a quite remarkable flora and fauna. Surprisingly, the shallow water ($<60\text{m}$ depth) marine fauna of the Rocks had been almost completely unstudied despite sporadic visits by various scientific research vessels including H.M.S. Challenger.

The aims of the expedition were (1) to make collections of the marine and terrestrial flora and fauna, (2) to establish the biogeographical relationships of the animal and plant species at St Paul's with those from other areas in the tropical Atlantic and (3) to study the large shark population that surrounds the Rocks.

The General Report of the expedition includes a narrative account of the progress of the expedition and a preliminary report of the scientific findings of the expedition.

Alasdair Edwards
December 1979

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Travelogue

Gibraltar

On August 3rd Alasdair Edwards, David Lindsay and Elizabeth Goodburn fly from Gatwick to Gibraltar arriving at about 9 p.m. at night. We eventually find the Brigantine Andando berthed in the Destroyer Pens and join boat. The next few days are spent buying equipment for the expedition, painting the shark cage, unpacking and stowing away all the scientific and diving gear (air-freighted to Gibraltar by the R.A.F.), sorting out all our tinned provisions from Dewhurst, testing out the Namron diver-to-surface communication equipment in the harbour and undertaking a few introductory dives off the Seven Sisters rocks to the south of the Rock. Meanwhile Mr Armstrong (Master of the Andando) and his crew prepare the boat for the Atlantic. Despite all the last minute preparations we find time to visit the top of the Rock, which offers a panoramic view of the Straits of Gibraltar with Morocco to the south and Spain to the north, and walk down the old Moorish walls to the Apes' Den and the Alameda Gardens. Finally at 10.15 p.m. on August 9th Andando slips her moorings and we head out into the Atlantic.

By next morning there is no sign of land and we have a clear sky, little wind and a long Atlantic swell rolling in from the west. We watch the Storm Petrels (Hydrobates pelagicus) following the boat and playing in the wake and gradually gain our sea-legs. Next day the wind freshens and the movement of the boat improves markedly under sail. As we draw abreast of the Ilhas Selvagens (Fig. 1), Manx Shearwaters (Puffinus puffinus puffinus) which breed there become a common sight, effortlessly skimming the water.

Early in the morning of August 14th we see the green, mountainous mist-shrouded island of Tenerife off the star-board bow.

Islas Canarias

We reach Las Palmas on Gran Canaria on the afternoon of the 14th and drop anchor in the bay. Meanwhile Roger Lubbock, Kate Wilson and our cameraman, Gerry Lively, are flying from Heathrow via Bilbao to Las Palmas where they arrive at about 8.30 p.m. On arrival all the filming gear is locked away by zealous customs officials who inform them that it may be collected in two days time (as the next day is a holiday) on production of a letter from the British consul.

The next morning the two halves of the expedition are united and the boat's compliment is complete. Lynne Higginbotham, the sixth expedition member, has unfortunately contracted Salmonella poisoning a few days previously in England, and having been put in quarantine is, sadly, unable to join us. This means that the Andando now has 13 people aboard!

The following day our remaining baggage is extracted from customs after several hours of bureaucratic wranglings. The next few days are spent ensuring that there are adequate supplies on board for the Atlantic crossing and that the somewhat inadequate compressor on the boat will work for the next two months. Luckily one of the crew, Geoff Jackson, is adept at dealing with this mechanical disaster and his expertise will carry us through. We finally bunker on August 18th and leave Las Palmas at 3.45 p.m. with a fresh wind for the Cape Verde Islands.

The trip down to São Vicente is fairly uneventful. Shearwaters and Storm Petrels accompany us, flying-fish are constantly leaping clear of the water in great shoals and a squid is caught by Geoff and eaten. A few sails are torn in squalls but the weather is generally good with rather too little wind to make good speed under sail. Everyone takes to reading to relieve the monotony of the open ocean. Gerry takes to having long conversations with the boat's parrot which answers to the unusual name of Polly. On August 23rd two sharks are seen just behind the boat and

on August 24th we pass a ship going in the opposite direction. Several members of the expedition express a strong desire for terra firma. However, at last on August 26th we sight São Vicente. On a whim of Mr Armstrong we circumnavigate the island before entering Porto Grande, the port of Mindelo.

Arquipélago do Cabo Verde

The island of São Vicente is mainly rugged barren rock and the coast is composed of often spectacular volcanic cliffs interspersed with sandy beaches at the mouths of U-shaped valleys. From Porto Grande the eastern cliffs of the island of Santo Antão may be seen indistinctly through the haze. The day after we land we celebrate Dave Lindsay's 20th birthday and start work underwater. The paucity of corals, the preponderance of seaweeds and the large numbers of relatively few species of fish, gastropod and crustacean are quite unlike anything we have encountered in the tropics before. We discover a new species of damselfish (Pomacentridae) and also a new species of grunt (Pomadasyidae). Surprisingly both species are extremely common. We collect specimens of fish, coral and soft coral and spend several dives photographing underwater animals and plants. Mr Armstrong has to clear up some financial misunderstandings but once these have been sorted out we are able, on September 1st, to depart, albeit rather behind schedule, for Brava (Fig. 1), the most south-westerly of the Cape Verde Islands.

En route we pass the island of Fogo (Portuguese for fire), a cloud girdled volcanic cone of classic shape, thrust almost 10,000 feet out of the ocean. We arrive in Porto de Faja (Brava), a beautiful mountain circled, palm fringed cove, at sunset on the evening of September 2nd. We continue our research in the idyllic surroundings of Porto de Faja, collecting more specimens, building up a checklist of Cape Verde fish and making notes on the ecology of the underwater environment. All members of the expe-

dition get a chance to dive and several go on a night dive. We are particularly struck by the thousands of small black sea-urchins in shallow water which bore into the rock to create individual hollows for themselves, by the forests of black coral (Antipathes sp.) in deep water and by the great overhangs covered with the brilliant orange coral, Tubastrea aurea. We spend one whole day filming both on land and underwater. The underwater cinecamera develops a slight leak but no damage is sustained. Everyone feeds well on spiny lobster, jack and goose barnacles. The latter are a local delicacy, the stalks of the barnacles being the edible part and making an excellent soup. From the islanders we purchase green coconuts, bread fruit and mangoes for the voyage.

It is with some reluctance that, early on September 5th as the sun creeps over the mountains surrounding the cove, we finally leave this island paradise for the inhospitable waters of the mid-Atlantic.

The crossing to St Paul's, almost a thousand nautical miles, is slow, the Andando averaging only about 3.5 knots. On the second day a school of whales appears and soon after an Oceanic Whitetip Shark (Carcharhinus maou) arrives in the company of a few Rainbow Runners. This fearless garbage disposal unit casually devours whatever morsels we can offer for several hours whilst gliding effortlessly around the boat with lazy sweeps of its notched tail. The shark cage is unstowed from the rigging and bolted together in order that we may photograph the shark underwater but unfortunately as noon approaches the Whitetip disappears once more into the blue vastness of the ocean. Rather less exciting but nevertheless interesting is the presence of one of the world's 5 species of oceanic insect, the Water-Strider, Halobates micans, which can be seen skating on the water all around the boat.

The days pass slowly, time being spent reading, checking and preparing equipment for our work at St Paul's Rocks and taking sun sights with a sextant to check how far we

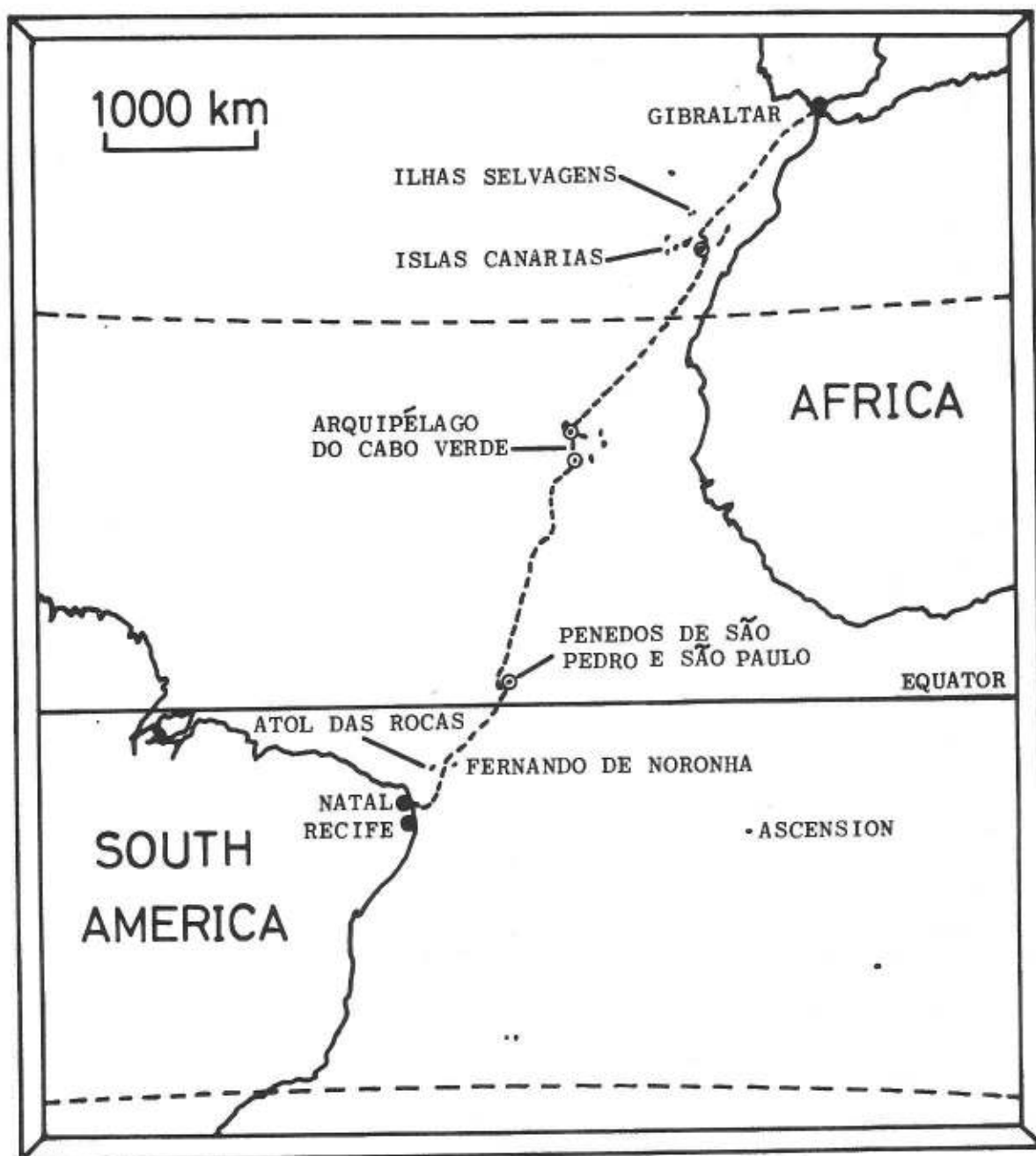


Figure 1. Voyage of the 'Andando'.

are from our destination. The Rocks are gradually erased from the chart as dividers are placed again and again between our position and St Paul's.

For one whole day we are surrounded by a shoal of bonito (Euthynnus alletteratus) and on another we pass through the middle of a school of whales during a refreshing tropical downpour when all hands repair to the deck to take a rainwater shower. On either side of the boat we hear the gasping breaths of whales as small geysers of water shoot into the air. A waterspout is observed off the starboard quarter just before the rainstorm reaches us. Thus some days are full of interest and we forget our impatience to reach St Paul's.

On the night of September 15th we apparently pass within 6 miles of the Rocks and awake on the 16th to find ourselves about 30 miles to the south-west of St Paul's. Mr Armstrong has to use both engines to fight back to the Rocks against a Force 6 wind and the equatorial current. The Rocks are finally sighted at about 3 p.m. At 4 p.m. we see our first Brown Booby (Sula leucogaster) and Brown Noddy (Anous stolidus), the former being a type of gannet and the latter a type of tern. At 5.30 p.m. we suddenly find ourselves in the sheltered quiet water on the lee of the Rocks and can hardly believe that so little land can provide so much shelter. In the setting sun the three guano covered peaks of the Rocks are pink and are gradually filling with birds as Boobies and Noddies come flying in from all points of the compass after a day's fishing. St Paul's surpasses expectations! Whilst we enthuse about the Rocks the crew make Andando fast by means of a series of hawsers following the method used by H.M.S. Challenger on her historic visit in August 1873.

Penedos de São Pedro e São Paulo

We all rise before the sun on our first complete day at St Paul's. Alasdair Edwards and Roger Lubbock prepare to dive. Each carries a powerhead, an explosive shark

stick. We take a dory into the cliff below the disused lighthouse and after a brief inspection of the water for triangular fins roll overboard. The water is a deep blue and wonderfully clear, the cliff which we can see disappearing into the depths 50 metres below is coated in a deep pile carpet of light green seaweed which undulates slowly with the swell. We are not alone. About 20 Galapagos sharks (Carcharhinus galapagensis) and several large barracuda are milling around expressing a disconcerting interest in our arrival. We put our backs to the cliff and submerge. The sharks maintain a policy of observation without aggression and we start to note which fishes are present at St Paul's whilst keeping an eye over our shoulders.

For the first two days at the Rocks the sharks maintain their interest and surround us on every dive. A few fish specimens have to be sacrificed when they get excited and we have one unpleasant moment when several suddenly rush in close and we almost have to powerhead one in self-defence, however, we never actually have to fire a shot in anger. Apart from these large predators the Rocks support a large population of manta rays. Each manta ray carries two remoras on its head and these are observed to occasionally detach themselves, swim around and then reattach. Often 9 rays are seen together at a time. We never tire of diving with these huge, graceful and harmless creatures which allow us to come within inches of them.

Meanwhile on land Kate Wilson and Elizabeth Goodburn are marvelling over the tameness of the Brown Booby and the two species of Noddy (Anous stolidus and A. minutus) that breed on the Rocks. They are censusing the bird populations to discover whether speculation in the scientific literature that the populations at St Paul's are declining is true or not. Also they sift soil and nesting material for insects and arachnids and study the territorial behaviour of the rock pool fish, one species of which jealously guards small farms of algae on which it feeds. Particularly attractive

among the Rocks' inhabitants are the Booby chicks, noisy bundles of white down which, despite their apparent helplessness, wield a beak with deadly effectiveness as the large numbers of scavenging land crabs are fully aware.

A comprehensive collection of algae is built up, a checklist of fishes with specimens of as many species as possible is prepared and molluscs, corals, echinoderms and crustaceans are collected for identification by specialists on our return and for later deposition in Brazilian and European institutions. Everyday is hectic with work from dawn to the small hours of the next morning as we try to make as much use as possible of our short stay at the Rocks.

Gerry Lively films for several hours underwater and for a couple of days on land and we also shoot roll after roll of stills both underwater and on land.

We discover that St Paul's Rocks has the least diverse fish fauna and the least diverse coral fauna of any tropical island in the world. We are startled to find no corals at all until about 15 metres down when we find 2 species living under overhangs. The corals (only 5 species in total) do not really begin until 30 metres below the surface! A few species of fish appear to be unique to the Rocks and new to science and we are surprised to find some albino and weirdly coloured mutant fish, perhaps a product of inbreeding. A new species of butterflyfish is one of our most surprising finds.

The days pass too quickly although some of our work underwater is made much easier when the sharks lose interest in us on about the fourth day at the Rocks. However, this unfortunately means that we cannot now carry out our studies on the response of Galapagos sharks to black and white striped wet suits as we now seldom see a shark during the daytime. On our second to last day at the Rocks Roger decides to dive at night in the shark cage to try to observe and photograph the sharks' nocturnal behaviour. At night the sea around the boat is thick with Galapagos sharks

chasing flying fish. Unfortunately the cage is built to keep out large sharks and a 3-4 foot shark manages, by lowering its pectoral fins, to squeeze through the bars into the cage. Roger is knocked off his feet and the camera is struck violently as the shark struggles frantically to escape. The camera-flash synchronisation is destroyed by this episode so that the remaining photographs are ruined. Even being a spectator of the night dive is not without hazard and several people are struck in the head and body by large flying-fish, some of these missiles leaping a good 5 feet out of the water in efforts to escape pursuing sharks.

On the afternoon of September 24th we reluctantly have to leave the Rocks and head for Atol das Rocas and Fernando de Noronha (Fig. 1) where we hope to study the South American fish fauna so that we can discover how the fish there are related to those at St Paul's. Following custom we deposit a message for future visitors to the Rocks in a bottle in the disused lighthouse.

Two days out from St Paul's we are informed by Mr Armstrong that the only way we can reach Recife in Brazil by our deadline of October 2nd is by missing out our visits to the South American offshore islands. We therefore head straight for Recife.

Extract from the Expedition Log: Tuesday, September 25th. 'The only exciting thing that happened today was watching the water draining down the plug hole. At 11 a.m. it drained clockwise at 12 anti-clockwise. We have crossed the line.'

Apart from this dabbling in experimental physics little of moment occurs in the final, 600 nautical mile, leg of our voyage except for an exciting couple of hours when we are surrounded by a school of porpoises. These swim across the bow with inches to spare, ride the bow wave leap clear of the water and provide a quite enthralling spectacle.

On the morning of September 30th we enter Natal, the boat being unable to reach Recife 130 miles to the south.

We disembark on the evening of October 1st and savour dry land after our voyage, 3,450 miles from Gibraltar and 2,700 miles from Las Palmas.

Brazil

Through the night we drive south to Recife where we buy tickets and arrange the airfreighting of our specimens home. We sample the gastronomic pleasures of Recife, enjoying palm heart soup, excellent seafood and superb ice creams made with fresh fruits such as guava, mango, coconut, passion fruit and papaya. On the evening of October 3rd Kate, Dave and Gerry depart for London. Roger, Alasdair and Elizabeth stay behind to finish our work.

We arrange to visit Fernando de Noronha (Fig. 1), the island off the Brazilian mainland which is nearest to St Paul's. Roger and Alasdair fly to the island on October 16th. The Brazilian Air Force kindly agree to give us accommodation there and the army lend us an inflatable boat to take us to various points along the coast each day. We dive from the shore and collect algae, molluscs and fishes, noting which species we have already seen at St Paul's.

The coast of the island is beautiful and unspoilt because the island is a military governed territory with very limited tourism. However, the depredations of fishermen and spearfishermen are only too apparent underwater where the paucity of fish contrasts strongly with St Paul's. Alasdair returns to Natal by a Brazilian Air Force plane (a Bandeirante) on October 11th and Roger returns by Trans-Brazil on October 13th.

The next day we take a coach to Recife and then go, with a Brazilian friend, on to Maragogi, about 150 km to the south, to study the mainland shore fishes. Here we confirm our suspicion that many of the South American fish

have been mistakenly given the names of Caribbean fishes which they resemble. We also discover that some species we observed at Fernando de Noronha appear to live only at that island and possibly neighbouring Atol das Rocas. We are pleased to have had a fascinating glimpse of the Brazilian marine fauna, enough to sort out most of our biogeographical problems and enough to realise that much work remains to be done on the shore fishes of Brazil.

We fly home on October 18th with many memories of the remarkable islands we have visited and of the Brazilian hospitality and friendship without which we could never have completed our work.

Preliminary Scientific Report

This report summarises the research carried out by the expedition. The research is currently being written up fully elsewhere and will be published both in scientific journals and in reports to Brazilian institutions.

(1) Cape Verde Islands

The objects of the studies in the Cape Verde Islands were (a) to make a representative collection of algae, (b) to collect common corals, Crustacea, echinoderms, polychaetes and molluscs, (c) to prepare a general account of the ecology of the underwater environment, and (d) to inventory the shore fishes as completely as time permitted.

The collections and observations in the Cape Verde Islands were intended primarily to allow reasonably detailed comparisons to be made between the fauna and flora at St Paul's Rocks and that in the Cape Verdes.

Although the Cape Verde Islands lie wholly within the tropics, coral development is poor, the fish fauna is surprisingly non-diverse, and algae and zoanthids are the main organisms which cover the bare rocky substrate.

55 species of shore fish were recorded from the Cape Verde Islands. Large shoals of damselfishes, Chromis cauta (Troschel) and Chromis n.sp., were present at all sites where we dived and accompanying them were large numbers of the trumpetfish, Aulostomus strigosus Wheeler, which hunt them. The butterflyfish, Chaetodon robustus Günther was common as was the parrotfish, Euscarus cretensis (Linnaeus), males of which are coloured a beautiful deep red, silver and yellow. In sandy areas two species of goatfish were very common, Pseudupeneus prayensis (Cuvier), originally described from the Cape Verde Islands, and Mulloidichthys martinicus (Cuvier) which appears to have reached West Africa from the Caribbean. The West African surgeonfish, Acanthurus monroviae Steindachner, was also common and

several species of moray eel (Muraenidae) were frequently observed in rock crevices. The general impression was of an impoverished fish fauna dominated by a few very common species.

The six commonest species of coral were collected; these included a Millepora sp., a Porites sp., a Siderastrea sp., a Favia sp. and Tubastrea aurea (Quoy & Gaimard). None of these corals formed large colonies though Millepora sp. encrusted areas of rock up to half a square metre in diameter. All species were found growing on rock and colonies were seldom more than 10 cm in diameter. On overhangs large numbers of T. aurea colonies often covered substantial areas of rock.

The only commonly observed crustaceans were the arrow crab, Stenorhynchus sp., which was especially common on the breakwaters in Porto Grande, São Vicente, and the spiny lobster, Panulirus guttatus (Latreille), which was common in crevices and caves at Brava. Three species of echinoderm, all of which are also found in the Caribbean, Eucidaris tribuloides (Lamarck), Diadema antillarum Phillipi and Echinometra lucunter (Linnaeus), were common. D. antillarum was especially common in Porto Grande, perhaps as a result of the relatively high amount of suspended matter in the harbour water. E. tribuloides was found in rock crevices at all sites and E. lucunter was extremely common at Porto de Faja, Brava where it bored into the rock in shallow water.

The dominant encrusting invertebrate animals were two species of zoanthid, a Palythoa and a Zoanthus, which commonly encrusted areas of rock up to a metre square at depths of up to 5 m. Below this depth they were less common.

An errant polychaete, the fireworm Hermodice sp., was common everywhere, especially in Porto Grande where we were often stung by their venom-filled setae when we accidentally brushed against them.

At most sites we dived, algae carpetted rocky substrate in between areas covered by invertebrate encrustations,

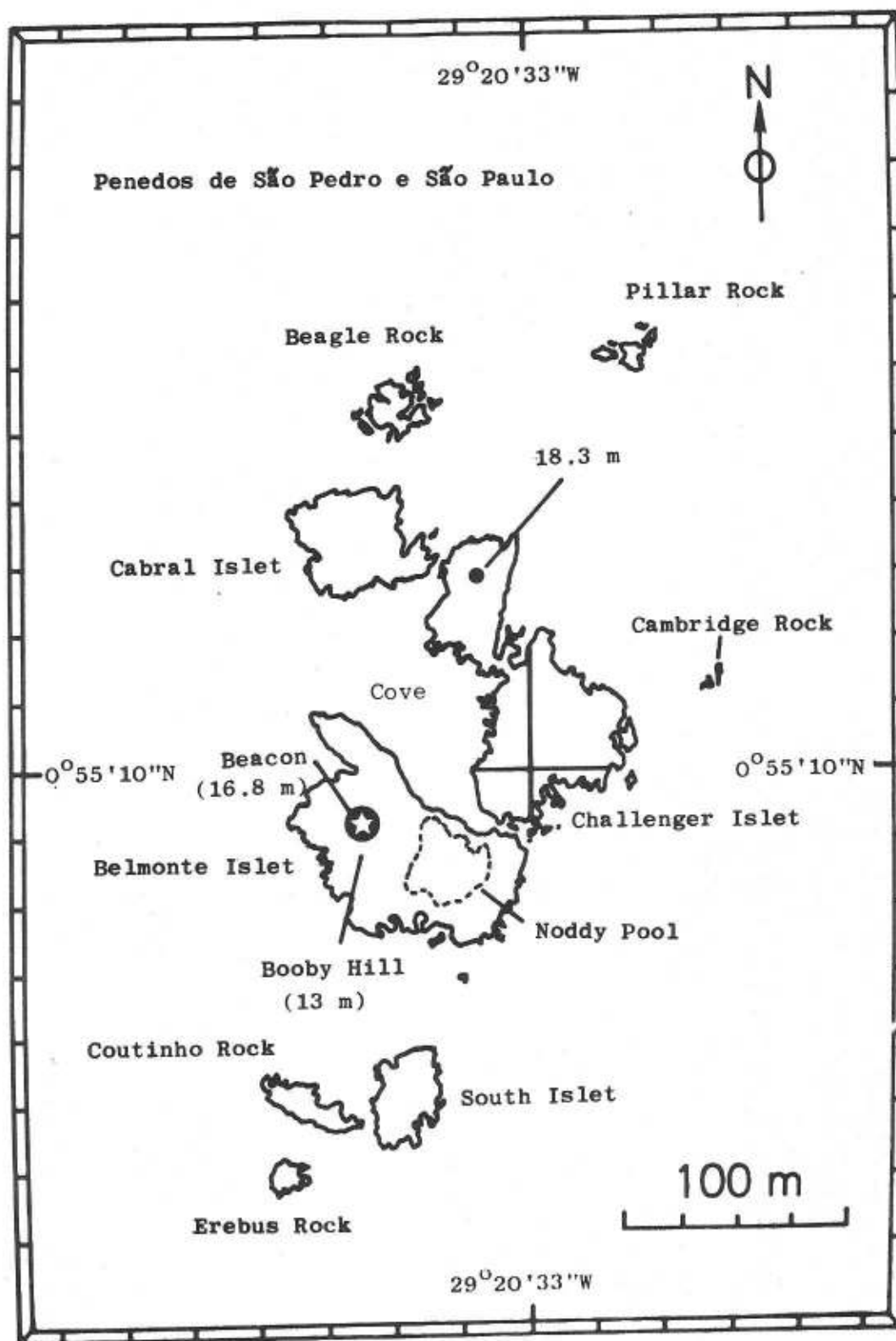


Figure 2. Saint Paul's Rocks (Brazil).

though at Punta Machado on the south coast of São Vicente large areas of almost bare rock were apparent. This contrasted with the dense though thin (approx. 1 cm thick) carpet of algae on the rocks at Porto de Faja, Brava which was present to a depth of 12 m. Below 12 m encrusting red algae were common down to at least 33 m where black coral, Antipathes sp., predominated. Representative collections of algae were made at several sites; algae from the intertidal zone down to 33 m depth were collected.

Our brief stay in the Cape Verde Islands allowed us to gain a reasonable, though basic, knowledge of the marine fauna and flora at the nearest point of land to the east of St Paul's. This was to enable us to gauge the influence of the West African biogeographical region on the biology of St Paul's Rocks.

(2) Saint Paul's Rocks

(a) Mapping and geology

A brief study of the literature on St Paul's Rocks ($0^{\circ}55'10''N$ $29^{\circ}20'33''W$) reveals considerable disagreement about the detailed geography of the Rocks with respect to such matters as the numbers of rocks present and their spatial relationships.

We prepared a map of the Rocks (Fig. 2) from a set of aerial photographs taken from a helicopter from H.M.S. Tiger during her visit to the Rocks in 1964. These were kindly made available for inspection by the Hydrographic Department at Taunton. These photographs were taken during calm weather at about mid-tide; at Spring low tides considerably more the the Rocks are exposed than on the photographs. Previously the rocks to the east and north-east of the Cove have generally been considered as two separate islets, however, on the aerial photographs they appear to be joined by a narrow neck of rock and so must be regarded as one islet (Fig. 2). Observation at the Rocks confirmed this. Indeed on a calm day at Spring low tides it is also possible to walk across from Belmonte Islet to Challenger Islet.

With the exceptions of (a) the splitting of Challenger Islet into two islets and (b) the heights of the islets, the Brazilian naval chart and the U.S.N. map prepared after the visit of U.S.S. Atka in 1955 (Tressler et al., 1956) agree closely with our map. However, earlier maps, made without the use of aerial photography, differ substantially. This is perhaps not surprising considering the difficulties involved in mapping somewhere like St Paul's without modern aids.

The north peak of Challenger Islet is the highest point of the Rocks; our measurements indicate a height of approximately 60 feet (18.3 m) above mean tidal level (MTL). The top of the disused lighthouse on Belmonte Islet is approximately 55 feet (16.8 m) and its base about 42 feet (13 m) above MTL. Our estimates of the maximum height of the Rocks correspond closely with those of Fitzroy (Beagle, 1832 (1839) - 64 ft), Tizard et al. (Challenger, 1873 (1884) - 64 ft) and Wild (Quest, 1821 (1839) - 64 ft).

Tressler et al. (1956) give estimates of 40 feet for the heights of both the top of the lighthouse and the north peak of Challenger Islet (based on observations by U.S.S. Atka in 1955). Delano (1817) estimated that the highest point of the Rocks was 'at least a hundred feet above the sea' in 1799. Tressler et al. (1956) speculate that there has been considerable recent subsidence of the Rocks on the basis of the early 100 feet, later 64 feet and recent 40 feet estimates. However, Delano later describes the Pico at Fernando de Noronha as being 'several thousand feet high' instead of 1060 feet high and our measurements indicate that the recent estimates quoted by Tressler et al. are erroneous (they are apparently subjective visual estimates!). There thus appears to be no evidence for subsidence.

A variety of names have previously been given to the major rocks at St Paul's and some confusion has arisen; for example, Cabral Islet has previously been called

North-east Island (Washington, 1930; Tilley, 1947), North-west Islet (Tressler et al., 1956; Bowen, 1966) and North Rock (Smith et al., 1974). Challenger Islet has previously been listed as two islets, the North-east and South-east Islets of Tressler et al. (1956). To avoid confusion and ambiguity the Rocks have been partly renamed.

Belmonte Islet is named after the Brazilian ship, the 'Belmonte', which carried out the feat of erecting the now disused Aga-type light on this islet in 1930. A cement block with the remains of the inscription 'Belmonte 1930' is still present below the lighthouse. Unfortunately an earthquake badly damaged the lighthouse a few months after it was commissioned and the Brazilians decided that the Rocks were too unstable to justify attempts to keep a light in working order.

Cabral Islet is named after Commander Sacadura Cabral, one of two Portuguese aviators who made the first air crossing of the South Atlantic in 1922, landing by St Paul's Rocks to rendezvous with a ship. Brazil and Portugal were thus joined by air for the first time. Coutinho Rock is named after Rear-Admiral Gago Coutinho who managed the incredible feat of navigating 1000 miles across the open ocean from the Cape Verde Islands to St Paul's in the open cockpit of a slow biplane with Cmdr Cabral. The name, South Islet, follows the map of Tressler et al. (1956) whilst Pillar Rock follows the chart of Wild (1923). Booby Hill was a name coined by Moseley (1879) and Noddy Pool by Mackinnon (1962); both are appropriate. The remaining rocks are named after various scientific expeditions to St Paul's.

Whilst at the Rocks a few geological specimens were collected on Belmonte and Challenger Islets. A representative sample of these specimens was deposited with the Federal University of Rio Grande do Norte at Natal, and a few specimens were brought back to England for deposition in the Museum of Mineralogy and Petrology of the University of Cambridge where Charles Darwin's specimens

from St Paul's are also deposited. The Rocks are geologically of special interest as they are an upper mantle derived ultrabasic intrusion from a depth of at least 45 km, composed of mylonitised peridotites (Melson et al., 1972). With the Seychelles they are the only non-volcanic mid-oceanic islands.

(b) Marine biology and biogeographical relationships

St Paul's Rocks have the least diverse fish and coral fauna of any tropical island in the world. We recorded only 35 species of shore fish (benthic living species) and only 48 fish species in total. Only 5 species of shallow water (<60 m depth) coral were found at the Rocks. Before our visit to St Paul's a total of 9 species of fish had been recorded from the Rocks by scientists (Günther, 1880; Springer, 1972; Smith et al., 1974) and no shallow water corals had been recorded.

Of the 35 species of shore fish about 20 were common and many of these were found at all depths from the surface to at least 55 m. One species of damselfish (a Stegastes) is new to science and is probably the only fish endemic to St Paul's Rocks. At depths greater than 55 m we discovered a new species of butterflyfish (Chaetodon) which although now only recorded from St Paul's is unlikely to be endemic and will probably be found in deep water at Brazilian offshore banks and islands in the future.

About half of the shorefish species recorded at St Paul's are widespread in the tropical Atlantic. Two species are otherwise recorded only from Ascension Island and St Helena and three species from Brazil or from both Brazil and Ascension. Five species are recorded as widespread in the tropical western Atlantic. Thus it would appear that St Paul's is primarily under the influence of the western Atlantic region, has little or no communication with the eastern Atlantic region, and only limited communication with Ascension and St Helena. Surface currents (the South Equatorial Current) generally flow from east to west

by St Paul's so it would appear that migration to the Rocks is predominantly by the easterly flowing deeper current which occurs below 40 m depth and is probably derived from the Brazilian Coastal Current (Bowen, 1966). As the South Equatorial Current carries surface water from the Gulf of Guinea and the Cape Verde and Sierra Leone areas by St Paul's (Bowen, 1966), quite why no species of fish have managed to colonise from the West African province is puzzling.

Preliminary identifications of the corals of St Paul's indicate that three species have colonised from Brazil. Two species of gastropod found at St Paul's were also collected from Fernando de Noronha. Thus preliminary information from other taxonomic groups appears to support the theory that St Paul's is an outpost of the Brazilian faunal sub-province.

A few individuals of both the common Holacanthus species and the common Chromis species at St Paul's were abnormally coloured. Albinotic and semi-albinotic Chromis were observed and totally blue, half blue and bizarre white, black and red-brown variants of the normally predominantly orange Holacanthus were observed. The presence of these abnormal phenotypes in the St Paul's populations may be a result of the very small size of the isolated breeding populations there or a consequence of the founding population which originally colonised the Rocks being extremely small. Inbreeding would allow the expression of abnormal phenotypes.

The underwater ecology of St Paul's is unusual for a tropical island. The Cove gently slopes from about 5 m depth at its head to about 15 m at its mouth and contains large boulders surrounded by sand and pebble. Most of the remaining bottom is composed of very steep rock faces with occasional ledges. Between Belmonte and South Islet there is a steep rocky slope composed of patches of rubble (and occasionally sand) trapped by rocks.

In the intertidal zone rocks are encrusted by pink crustose coralline algae. From 1-5 m depth, depending on exposure, the dominant invertebrate is a zoanthid, probably Palythoa sp., which coats the rocks often in sheets a square metre or more in area. Below this zoanthid dominated zone the rock substrate is covered with green Caulerpa sp. seaweed to depths of 30-40 m where a branching coralline red alga takes over as the dominant alga and corals begin to be found. One of the corals is a deep emerald green Scolymia another the orange Tubastrea aurea which is widespread in the tropical Atlantic. As one descends deeper the algae become sparser and black coral colonies, Antipathes sp., are found.

Few molluscs were observed underwater. Among rubble at all depths one species of gastropod (Buccinidae) was found and in deeper water clam-like and scallop-like bivalves were found attached to the rock. One species of cone shell was observed rarely.

Echinoderms were also poorly represented. The urchins, Diadema antillarum and Echinometra lucunter, which are recorded both from the Caribbean and the Cape Verde Islands were not present at St Paul's. Another species which is widespread in the tropical Atlantic, Eucidaris tribuloides, was present but only two specimens were found and these in rock pools. Small brittle-stars (Ophiuroidea) were common amongst sponge and algae both in rock pools and in deep water. A few sea cucumbers (Holothuroidea) were collected from sandy patches in between rocks in deeper water; these belonged to two species. No starfish (Asteroidea) or feather-stars (Crinoidea) were observed.

The only obvious crustacean underwater was the spiny lobster, Panulirus guttatus, which was common in rock crevices at all depths. However, several species of crabs were collected from amongst rubble, algae and sponges, and alpheid shrimps and stomatopods were also found in rubble.

The most commonly observed polychaete was the fire-worm (Amphinomidae) which carries large numbers of hair-

like, venom filled setae which it protrudes when disturbed.

In summary, surprisingly few species of invertebrates were found; those that were present were generally fairly common. The algal flora was notably less diverse than that at Fernando de Noronha and was dominated by one species (Caulerpa) in a similar manner to the way in which the kelp Laminaria hyperborea dominates the rocky sublittoral of north-west Europe.

(c) Birds and other life on the Rocks

The most obvious feature of life on the Rocks is the large number of birds. These belong to three species; the Brown Noddy, Anous stolidus (Linnaeus), the White-Capped Noddy, Anous minutus (Mathews), and the Brown Booby, Sula leucogaster leucogaster (Boddaert). All three species nest and breed at St Paul's. Both Bowen (1966) and Smith et al. (1974) suggest that the seabird populations at the Rocks may have declined considerably since the visits of H.M.S. Beagle and H.M.S. Challenger (1832 and 1873 respectively). Darwin (1852) describes 'a vast multitude of sea-fowl' whilst Moseley (1879) notes that 'birds were to be seen hovering over the island in thousands'. These early descriptions were not consistent with the observations made by Bowen and Smith et al. However, it should be pointed out that (1) for most of the day about 80% of the birds are away from the Rocks, returning in the evening, and (2) the statements of Darwin and Moseley are descriptive rather than strictly scientific. We estimated that the seabird population was in excess of 1,100 individuals; in the early morning or evening a disturbance might cause several hundred birds to take to the air. Moseley arrived in the evening and Darwin in the early morning when the bird populations at the Rocks are at their peak. Any observations or population estimates made during the middle of the day would necessarily indicate reduced populations since their visits.

Juveniles of both Sula leucogaster and Anous minutus were observed and some S. leucogaster nests contained eggs. No eggs were observed in A. minutus nests and neither eggs nor juveniles of A. stolidus were found. S. leucogaster was present predominantly on Booby Hill, Belmonte Islet but also found on high ground on Challenger and Cabral Islet, and Coutinho and Pillar Rock. A. minutus and A. stolidus were most common on Challenger Islet. Over twice as many A. minutus were observed as A. stolidus. Estimated total populations of each species were as follows: S. leucogaster, 439 individuals; A. minutus, 481 individuals; A. stolidus, 213 individuals.

Both bird ticks and bird lice were common on the birds and in nesting material. Also collected were a beetle, a primitive lepidopteran, 2 species of spider, an earwig, an isopod and some cockroach wings. The cockroach wings were of Periplaneta americana (L.), however, during an overnight stay on Belmonte Islet no cockroaches (nocturnal animals) were observed, so it does not appear that this species has become established at St Paul's. A centipede was seen in the disused lighthouse but could not be captured.

No lichens or terrestrial plants were found, though a visitor to the Rocks in 1976 photographed a patch of vegetation at the foot of Booby Hill.

The most obvious invertebrate on the Rocks is the land crab, Grapsus sp., which is extremely common and was observed eating flying fish which occasionally 'fly' onto the Rocks at night. Two other species of large crab were also collected from rock pools on Belmonte Islet.

The rock pools were rich in life and contained about 9 species of fish, including two species of moray eel. The Stegastes n.sp. which defends a territory containing an algal garden against other herbivores, notably another demselfish, Abudefduf saxatilis, was made the subject of an experimental study. The aggressive interactions between the defending Stegastes on the one hand and A. saxatilis,

other Stegastes and the blennies, Ophioblennius atlanticus and Entomacrodus vomerinus, on the other, were recorded and the effects of removing Stegastes were monitored. The moment a territory was left undefended A. saxatilis entered it en masse and rapidly grazed the algal garden down to the bare rock.

Also found in rock pools were an octopus, zoanthids (Palythoa?), anemones, keyhole limpets (Fissurella sp.), various small crabs and polychaetes, bivalves and sponges. All were collected for later identification.

(d) Shark studies

No sharks were observed underwater by members of the expedition in the Cape Verde Islands during over 30 man dives. One shark, Carcharhinus maou (Lesson), the oceanic whitetip, was observed between the Cape Verde Islands and St Paul's Rocks when the boat was becalmed on 6th September. No sharks were seen during other periods when the boat was drifting or sailing at approx. 1 knot (11th and 15th September) or at any other time on the voyage to St Paul's. On the first day of diving at the Rocks we saw from a minimum of 2-3 sharks (at 11.00 h) to a maximum of 20 sharks (at 15.00 h) together at one time, i.e. in a diver's field of view at one moment. These sharks were all Galapagos sharks. Carcharhinus galapagensis (Snodgrass & Heller), mostly 1.1-1.4 m in length and occasionally up to 1.8 m long. They passed within 1-1.5 m of divers and were not disturbed when prodded with shark billies. The sharks became excited when small fish (7-15 cm long) were speared and came closer, making increasingly frequent and faster passes.

On the second day from a minimum of 3 sharks (11.30 h) to a maximum of 12 sharks (08.30 h) were observed at one time. On the third day a maximum of 5 sharks (08.30 h) were seen at one time whilst on the fourth day no more than 2 sharks (10.30 h) were seen together. Subsequently sharks were only encountered occasionally.

Two C. galapagensis were caught by line in order to check our identification; detailed measurements of these 1.81 and 1.86 m individuals were made and their stomach contents examined. Little except a few scales and an otolith were found in the stomachs. Nicoll (1908) examined the gut contents of at least 30 sharks at St Paul's and in only one shark did he find the remains of food - a half digested fish. Observations at night from the surface and from the shark cage appeared to indicate that the sharks were feeding on flying-fish and jacks (Caranx spp.). Even when no sharks were seen during the daytime, at least 5 or 6, and up to 20 sharks were seen around the boat at night. These were generally 1-2 m long but the largest reached approx. 3-3.5 m in length.

Unfortunately, because of the sudden disappearance of sharks during the daytime we could not carry out our experiments on the response of C. galapagensis to black and white striped wet suits.

About the one thing all visitors to the Rocks have agreed upon is the large numbers of sharks at St Paul's. From Delano's visit in 1799 (1817) to Pettersson's in 1948 (1954) tales of sharks viciously snapping at oars as boats rowed in have been reported. Limbaugh (1963) has reported similar behaviour by C. galapagensis at Clipperton Island, a remote atoll in the eastern Pacific. As late as 1955 there appear to have been enough sharks at St Paul's to make fishing very difficult (Tressler et al., 1956) and one underwater photograph taken in 1976 showed 29 C. galapagensis.

The Galapagos shark populations have undoubtedly declined during the last 25 years. The decline in numbers was noted by Bowen (1966) and Masch (1966) in their reports of visits to St Paul's made in 1963 and 1966 by the R.V. Chain and R.V. Atlantis II respectively.

2 or 3 Brazilian fishing boats have gone to St Paul's each year in recent years and these boats accidentally catch sharks whilst fishing for other species. Also in

1978 a research vessel reported catching 2 tons of sharks at St Paul's Rocks. Even these apparently small catches are adequate to account for the decrease in the shark populations at the Rocks. Sharks grow slowly and produce relatively few offspring. The presumably fairly isolated breeding population at St Paul's is relatively small and thus will recover very slowly from the depredations of man.

Apart from C. galapagensis, two other species of shark were observed at St Paul's, the mako shark, Isurus oxyrinchus Rafinesque, (one specimen 1.5-2 m long) and the whale shark, Rhincodon typus Smith, (one specimen 4.5-6 m long).

(3) Fernando de Noronha

Six sites were studied in the Fernando de Noronha Archipelago. The abundance and diversity of algae was remarkable and at all exposed rocky sites dense masses of detached algae were observed floating above the bottom. A representative collection of algae was made. Fishes, corals, molluscs and polychaetes were also collected and efforts were made to find specimens of the species which we had observed at St Paul's.

The cardinalfish from St Paul's which we had realised was distinct from, though very similar to, the Caribbean Apogon maculatus (Poey), was also present at Fernando de Noronha and turned out to be Apogon americanus Castelnau which was originally described from the mainland coast of Brazil. A Thalassoma sp., one specimen of which (presumably a stray) we had found in a rock pool at St Paul's, was very common in shallow water at Fernando de Noronha and turned out to be Thalassoma noronhana (Boulenger), a poorly known species described from Fernando de Noronha in 1890.

A parrotfish similar to Sparisoma rubripinne (Cuvier & Valenciennes) was observed at St Paul's; the same species was present at Fernando de Noronha. Although similar to the Caribbean S. rubripinne this species appeared to be distinct from it. Further research is needed to ascertain

the correct taxonomic status of the South American parrotfish. The Stegastes at Fernando de Noronha are different from the one at St Paul's and Stegastes rocasensis recently described from Atol das Rocas by Emery (1972) was found to be present at Fernando de Noronha as well. This species is not found on the mainland coast of Brazil. A new species of wrasse (Xyrichtys sp.) was discovered and is currently being described. We prepared a preliminary checklist of the fishes of Fernando de Noronha which includes about 80 species. Boulenger (1890) and Roux (1973) each recorded about 20 species from Noronha, the majority of which were also observed by us.

It became clear from our visit to Fernando de Noronha that the St Paul's fauna is essentially an impoverished South American fauna.

(4) Maragogi

A few dives on reefs at Maragogi on the Brazilian mainland coast indicated that the fish fauna on the coast is more diverse than that on the Brazilian offshore islands, and that several species differ from those found in the Caribbean. In some cases these differences appeared sufficient to classify them as distinct species, in other cases it seemed that they should be classed as subspecies. In all events the Amazon outflow into the Atlantic appears to provide a geographical barrier sufficient to have allowed quite considerable speciation of Caribbean-derived fishes in Brazil.

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Scientific papers in preparation

1. A new butterflyfish (Teleostei:Chaetodontidae) of the genus Chaetodon from Saint Paul's Rocks.
2. A new wrasse (Teleostei:Labridae) of the genus Xyrichtys from the Fernando de Noronha Archipelago.
3. The fishes of Saint Paul's Rocks.
4. The sea-bird population of Saint Paul's Rocks.
5. The ecology and biogeography of Saint Paul's Rocks.
6. The algae of Saint Paul's Rocks.
7. The shark population of Saint Paul's Rocks.
8. A bibliography of Saint Paul's Rocks.

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