Coral Reefs of the Pitcairn Islands

22

Robert Irving and Terry Dawson

Introduction

The Pitcairn Islands (Fig. 22.1) are located approximately equidistant between New Zealand and Peru and are some of the remotest islands on Earth. They lie at the eastern end of the Tuamotu Archipelago in the South Pacific Ocean and are the most south-easterly islands of the Pacific tectonic plate and Indo-Pacific province. Their nearest neighbours are the Gambier Islands group in French Polynesia, which lie 540 km west-northwest. The islands are a British Overseas Territory and comprise Pitcairn Island (the only inhabited island of the group), Henderson Island (the largest), and the two atolls of Ducie and Oeno. There is little reason to group the islands together other than that of geographical proximity (they happen to be neighbouring islands although the outliers, Oeno and Ducie, lie approximately 560 km apart) and political expediency (they were all claimed by Britain during the nineteenth century).

As a result of their isolation, the nearshore environments of the Pitcairn Islands harbour an intriguing array of habitats and species. However, the biodiversity of their reefs in terms of coral, fish and invertebrate species richness is low, which may be attributed to their isolation and low latitude (between 24° and 25°S). Species endemism is also low (at less than 2%).

A Brief History of the Area

It is believed that the islands of Pitcairn and Henderson were first colonized by Polynesians in about AD 900 and their occupation lasted until about 1450 (Weisler 1995). In 1606, the Portuguese explorer Fernández de Quirós was the first European to discover Henderson Island (by now uninhabited) and Ducie Island, though he did not encounter Pitcairn or Oeno. British interest in the islands (and in Pitcairn in particular) began more than a century and a half later in 1767 when HMS *Swallow*, under the command of Captain Philip Carteret, encountered Pitcairn and mistakenly plotted its position 188 nautical miles west of its actual location. This mistake, however, was to be of great benefit to the island's next inhabitants, the mutineers from HMS *Bounty*, who were looking for a safe island hideaway in 1790, remaining undiscovered there for a further 18 years. Pitcairn Island officially became a British dependency on 29 November 1838. The other three uninhabited islands (Henderson, Oeno and Ducie) were annexed by Great Britain in 1902 and were included in the dependency in 1938. The Pitcairn Islands remain the only UK Overseas Territory in the Pacific.

History of Research

It has not always been possible for visiting research expeditions to visit all four islands, even though they might well have done so had time allowed or if the elements were in their favour. Initial collections of biological material were often undertaken on an *ad hoc* basis. The first truly scientific studies (including the collection of various marine shells) in the Pitcairn Islands were under the guidance of Capt. F. W. Beechey on board HMS *Blossom* in 1825. He was also responsible for the first full description of Ducie atoll (Rehder and Randall 1975). Since that time there have been several individual visits and four major expeditions to the four Pitcairn Islands which included marine studies – the 1970–1971 Westward expedition (Rehder and Randall 1975; Randall 1973, 1978, 1999; Rehder 1974); the 1987 Smithsonian Expedition (Paulay and Spencer 1989; Paulay 1989); the 1991/1992 Sir Peter Scott Commemorative Expedition to the Pitcairn Islands (Benton and Spencer 1995a; Irving 1995; Irving et al. 1995); and, most recently, the 2012 National Geographical Society Pristine Seas Expedition to the Pitcairn Islands.

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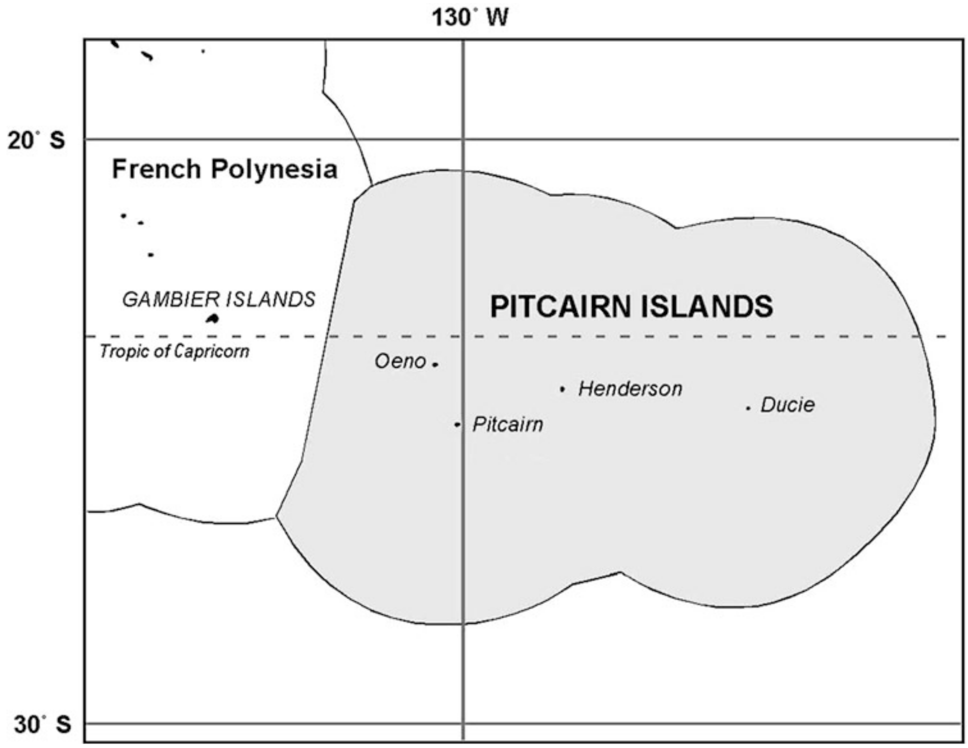

Fig. 22.1 The location of the four islands in the Pitcairn Islands group and their Exclusive Economic Zone (EEZ) which adjoins that of French Polynesia to the west (Illustration adapted from Gillet 2009)

In 2009 a reef monitoring programme off Pitcairn's northwest coast was initiated by the Institut des Récifs Coralliens du Pacifique/Centre de Recherches Insulaires et Observatoire de l'Environnement (Institute for Pacific Coral Reefs/Centre for Island Research and Observatory of the Environment, or IRCP/CRIOBE), based in Moorea, French Polynesia. The programme is part of an ongoing 16-year long-term project monitoring the outer reef slopes of 20 islands spread over the 4 French Polynesian archipelagos (Australs; Marquesas; Society; Tuamotu) and 6 Pacific Island Countries and Territories (PICTs) (Cook Islands; Niue; Kiribati; Tokelau; Kingdom of Tonga; Wallis and Futuna). The project focuses on the effects of natural disturbances on coral reef ecosystems. At Pitcairn, monitoring will be of fish populations (species richness, sizes and abundance), of scleractinian coral populations (photo surveys of species richness and percentage cover) and of a number of physical parameters such as water temperature and swell heights and frequencies (Chancerelle and Lison de Loma 2009).

The Islands Today

Pitcairn remains geographically remote and isolated today, though the installation of a satellite link on the island in 2002 has allowed internet access and the immediacy of e-mail communications. However, getting to and from the island still remains a challenge; there is no airstrip on the island so all visits are by sea. The island supply vessel visits every 3 months but can only carry 12 passengers who can stay for periods of 3 or 10 days. In March 2011, Pitcairn's population stood at 56 resident islanders with 9 non-residents. This compares with a peak in population in the mid-1930s of 250. The island is visited by a number of cruise ships during the austral summer on their way between Easter Island and Tahiti. The three uninhabited islands are rarely visited by the islanders, being largely left to themselves apart from occasional visits by scientific expeditions. Scuba diving is undertaken by a handful of Pitcairners, often linked with catching lobsters and fishes for on-island consumption or for selling on to cruise ships.

Geological Background and Physical Parameters

Much of our knowledge of the deep sea bathymetry of the central South Pacific has come about through interest in tectonics and volcanism during the past 25 years. In December 1989, a number of large volcanic structures were discovered in a virtually uncharted region of the Pacific Ocean some 60–100 km east-southeast of Pitcairn Island (Stoffers et al. 1990). Within an area of about 7,000 km^2, submarine volcanic activity has led to a particularly high density of over 90 volcanic

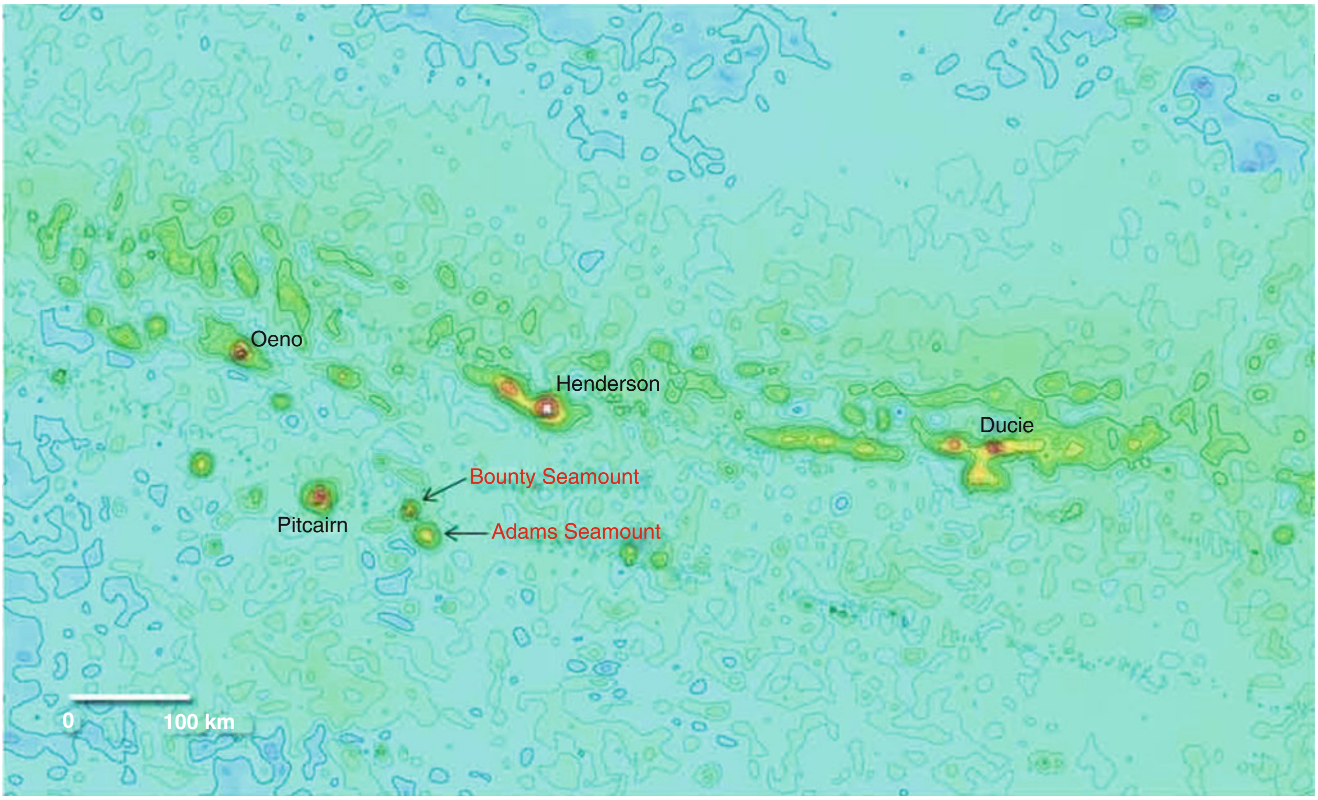

Fig. 22.2 Bathymetric map of the sea floor in the vicinity of the Pitcairn Islands, showing the location of the two seamounts closest to Pitcairn (Adapted from satellite altimetry data [Smith and Sandwell 1997])

cones or seamounts rising from the sea floor at 3,500–3,800 m depth (Fig. 22.2). The largest two edifices, known as Bounty seamount and Adams seamount (lying 90–110 km east-southeast of Pitcairn Island) are still active with steep scarps and fresh lava flows observed on their flanks during submersible diving surveys (Hekinian et al. 2003). The Bounty and Adams seamounts respectively rise to within about 450 and 55 m of the ocean surface. Other smaller edifices in the same locality have been named Christian, Young and McCoy, after some of the original mutineers from HMS *Bounty*.

The seamounts have arisen along two geological 'hotspot' regions, each aligned ESE to WNW. The first, with the youngest features in the south-east, has along it: Ducie (8 Myr); Henderson (13 Myr); and Oeno (16 Myr) [all ages given ± 1 Myr] (Okal and Cazenave 1985). The second active hotspot region has been located in a zone 40–110 km south-east of Pitcairn, and extends through the Gambier Islands to the Duke of Gloucester Islands, running approximately parallel to the first region. This hotspot region was responsible for the creation of Pitcairn Island itself, which is the youngest of the four islands and which was formed as the result of volcanic activity around 0.8–0.9 million years ago (Blake 1995).

When Pitcairn erupted, the weight of the new volcanic island caused the earth's crust beneath it to be depressed, with a consequential uplift approximately 200 km from the load, a see-saw process known as 'lithospheric flexure'. Over thousands of years, this uplift caused Henderson to be raised above sea level and thereby it became an uplifted fossilized reef. The island has been emergent for about 380,000 years. Today, Henderson remains the world's only raised coral atoll with its ecology largely intact.

Annual sea surface temperatures for the area show the monthly mean surface temperature to range from 22.5°C (Aug/Sept) to 26.3°C (Feb/Mar) (Streten and Zillman 1984). This is just above the lower limit for structural coral reef construction which is typically taken as 20°C in the coldest month of the year (Stoddart 1969). At the time of the Oceanic Institute expedition to Ducie in 1970, there was evidence of a relatively recent mass mortality of corals, the cause of which was not identified, although a sudden drop in water temperature was postulated (Rehder and Randall 1975). This may well have come about due to a temporary northwards shift of cooler southern ocean water. All of the islands have regular semi-diurnal tides, with a (measured) spring tidal range of 1.5 m at Henderson (Irving 1995) and 0.4 m at Ducie (Rehder and Randall 1975). The typical water clarity at 20 m depth at Pitcairn is in the region of 50 m, while at Henderson it has been measured at 75 m (R. Irving, pers. obs.). This latter figure probably reflects the fact that there is very little land run-off from Henderson.

Fig. 22.3 Pitcairn Island viewed from the west (Photo: A. MacDonald)

Fig. 22.4 *Left*: View of the landing at Bounty Bay, Pitcairn (Photo: R. A. Irving). *Right*: Tedside, on Pitcairn's NW coast (Photo: R. A. Irving)

Geomorphology and Reef Extent

Each of the four islands which make up the Pitcairn group is different. Not only is this obvious above sea level, but it is also true below sea level. While each of the islands is perched on the tip of its own huge submarine volcano, with steeply sloping sides descending to the abyssal depths, the shallower, nearshore sublittoral environments of each is very different.

Pitcairn

At 25° 04′ S, 130° 06′ W, Pitcairn is just 3.2 km long by 1.6 km wide covering an area of 4.5 km^2 (Fig. 22.3). Its volcanic terrain is rugged and its summit stands 347 m above sea level. Much of its 9.5 km long coastline consists of precipitous cliffs, in places over 120 m high. There are only two landing places – at Bounty Bay and Tedside (Fig. 22.4a, b) and at just a handful of sites where the intertidal zone is accessible from the land. The seabed all the way round the island shelves very gradually from 10 to 30 m in depth for approximately 300–500 m offshore, before plunging to the abyssal depths. In places, a level terrace-like seabed exists, with very little discernable difference in depth for stretches of 150–200 m perpendicular to the shoreline. It is likely that, over tens of thousands of years, the pounding surf affecting the near-shore zone has created a wave-cut platform as the volcanic sand has scoured away the underlying bedrock to a uniform depth.

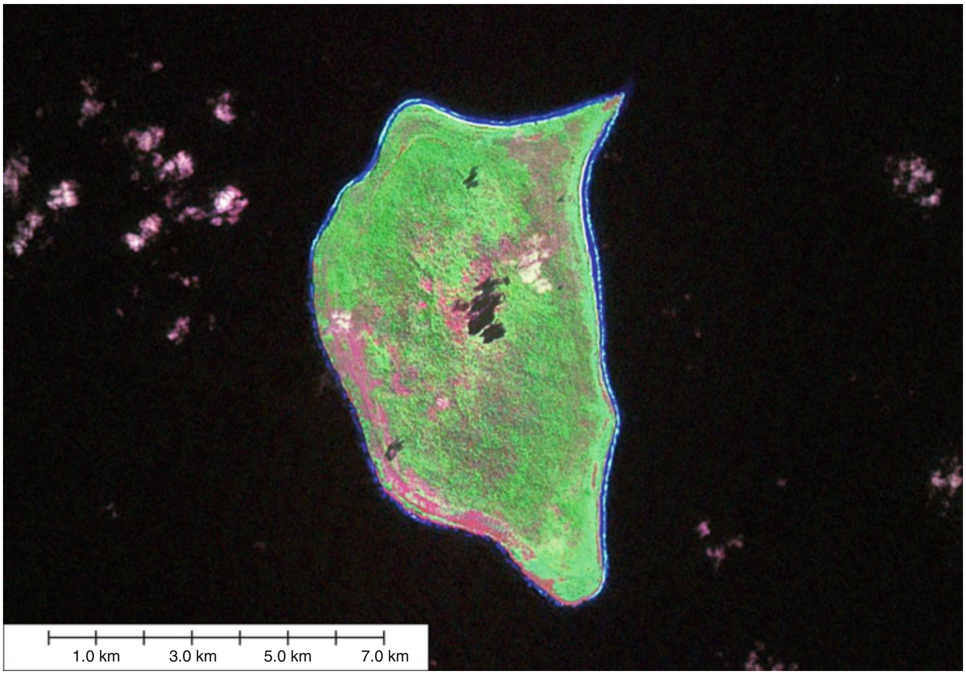

Fig. 22.5 Henderson Island. Colour-enhanced satellite image taken on 20 Sept 2000 (NASA). (Note that the *white patches* are clouds and the *dark areas* are their shadows. *Green areas* indicate dense vegetation/scrub and *pink areas* are unvegetated rock)

Fig. 22.6 Waves pound against the cliffs at the southern end of Henderson Island (Photo: R. A. Irving)

Henderson

Henderson Island, at 24° 21′ S, 128° 19′ W and 200 km east north-east of Pitcairn, is approximately 9.6 km long by 5.1 km wide and covers an area of 43 km^2 (Fig. 22.5). It is a raised coral atoll composed of coralline limestone (makatea) and is surrounded by steep, bare, weathered limestone cliffs (Fig. 22.6), with sandy beaches present off the north, east and north-west coasts (Fig. 22.7). The flat plateau, some 30 m above sea level, is covered by 4–6 m high dense scrub and has a slight depression in the centre where there was once a lagoon.

Fig. 22.7 Henderson's East Beach with its shallow reef platform (Photo: R. A. Irving)

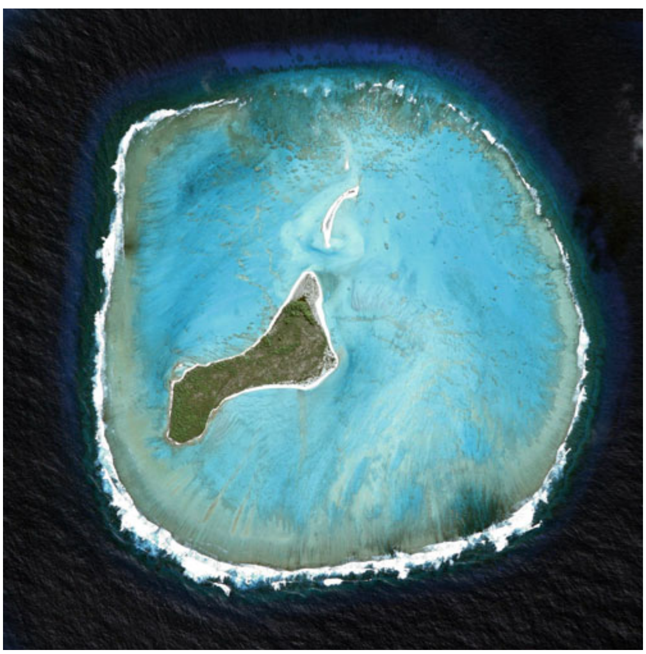

Fig. 22.8 Oeno atoll. Image taken on June 16, 2006 by the Advanced Land Imager on NASA's EO-1 satellite

Henderson has a reef platform adjacent to its North and East Beaches and, to a lesser extent, off the North-West Beach. The near-horizontal platform ranges from 20 to 40 m wide at the North-West beach; 40–75 m wide at the North Beach; and 40–90 m wide at the East Beach (Irving 1995). At low water on spring tides, large areas of smooth horizontal rock are exposed at these beaches. Narrow (<15 cm) channels run perpendicular to the shore every 10–25 m. At the reef front, these channels widen and deepen into larger grooves, allowing water to drain off the flat. The northern end of the East Beach is probably the most biodiverse intertidal area, with small coral heads being exposed at low water on spring tides. There are two narrow channels through the reef on the north and northwest coasts which enable access for small boats, though landing is extremely hazardous. The reef towards the eastern end of the North Beach is formed into a series of spur and groove formations, with live coral dominating the tops and sides of the spurs and extensive areas of coral rubble collecting in the grooves.

Oeno

Oeno atoll lies 120 km to the north-west of Pitcairn at 23° 56′ S, 130° 45′ W (Fig. 22.8). It consists of a central, low-lying island surrounded by a shallow lagoon and a fringing reef (Fig. 22.9). The main island, covered by a mix of trees and other vegetation, is fringed by a narrow beach of sand with bedrock apparent on the north-west side of the island. The lagoon has a shallow entrance/exit connecting with the open sea on its north side. It is about 3 m deep and has an undulating bottom of sand and coral rubble (60%), reef pavement (20%) and patch reefs (20%) (Irving 1995) (Fig. 22.10, left). The patch reefs have near-vertical sides, with some undercut at their bases to form small caves and overhangs. The most striking feature is the large number of 'small' giant clams *Tridacna maxima* embedded within these patch reefs, at an estimated maximum density of 8–10/m^2 (Fig. 22.10,

Fig. 22.9 The north-west shoreline of Oeno and the adjacent lagoon (Photo: R. A. Irving)

Fig. 22.10 *Left*: Assorted corals form a small patch reef within Oeno's lagoon (Photo: R. A. Irving). *Right*: Giant clams *Tridacna maxima* embedded within a patch reef, Oeno lagoon (Photo: R. A. Irving)

right). Beyond the fringing reef, the seabed gradually shelves into deeper water, the angle of steepness increasing beyond 40 m depth.

Ducie

Ducie atoll, at 24° 40′ S, 124° 47′ W, is the easternmost island on the Pacific plate and also the most southerly atoll in the world (UKOTCF 2004) (Fig. 22.11). It comprises a main island (Acadia) and three smaller islets or 'motus' (Edwards, Pandora and Westward) encircling a central lagoon. The islets are composed of coral rubble, echinoid remains and dead shells. Acadia is largely surrounded by reef flats, the reef to the north-west consisting for the most part of an uneven reef pavement flat (Fig. 22.12) and the lagoon contains numerous patch reefs (Fig. 22.13). Most water exchange in to and out of the lagoon takes place via a shallow channel between Westward and Pandora islets.

Biogeographic Background

The Pitcairn Islands are located at the south-eastern extremity of the Indo-West Pacific biogeographic province. This position results in a number of barriers to the establishment of species. Firstly, prevailing winds and currents are dominantly from the east in the central South Pacific, with the

Islands lying upwind and upstream of all Indo-Pacific source areas further to the west. And secondly, the Islands lie just south of the Tropic of Capricorn (23° 26′ S), with relatively cool waters and climates imposing further barriers to the establishment of tropical species.

Studies of groups as diverse as corals, reef fishes, vascular plants and landbirds support the arguments that colonisation of the islands has almost entirely been from the biologically-rich source areas to the west on the margins of South East Asia, taking advantage of the inter-island connectivity of the south west Pacific Ocean (Stoddart 1992). As a consequence of these factors, the diversity of marine species present within the islands' near-shore waters, when compared to island groups further to the west, is impoverished (Benton and Spencer 1995b). It also reflects the lack of some marine and coastal habitats at the four islands, such as mangroves and seagrass beds. Levels of endemism for all four islands are relatively low at around 2% (see also next section). This figure for endemism derives from studies of molluscs (Preece 1995), echinoderms (Paulay 1989) and reef fishes (Randall 1999) in particular. A total of 87 species of sceleractinian corals have been recorded from all four islands (of which 29 are *Acropora* species), together with 19 species of butterflyfish (Family Chaetodontidae) (Irving and Dawson 2012).

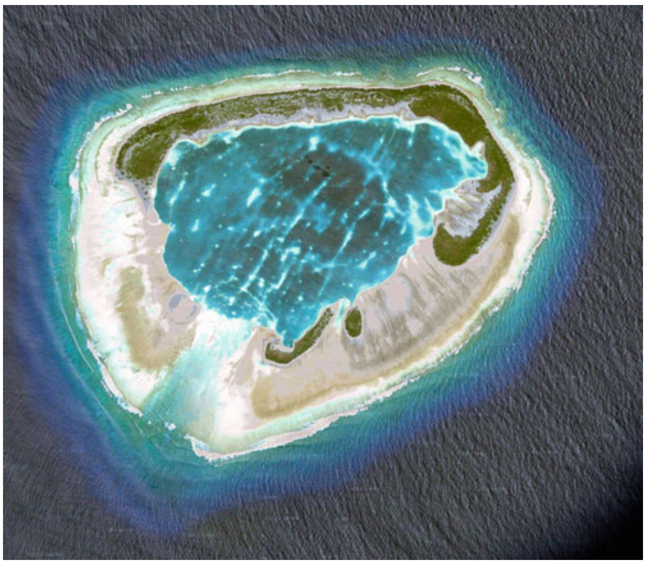

Fig. 22.11 Satellite image of Ducie atoll taken on 30 March 2000 (Photo: © GEOEYE/SCIENCE PHOTO LIBRARY)

Biological Characteristics

As already indicated, the nearshore areas around each of the four islands have their own unique characteristics and they are described separately here. For more detail, the marine environment of the Pitcairn Islands has recently been comprehensively reviewed by Irving and Dawson (2012).

Pitcairn

Much of the near-shore seabed around Pitcairn comprises sand-scoured, low-lying rock outcrops surrounded by sand patches. From about 8–15 m depth, the outcrops are colonised by a small number of foliose brown macroalgae, particularly

Fig. 22.12 View south-westwards across the lagoon from Acadia, Ducie atoll (Photo: R. A. Irving)

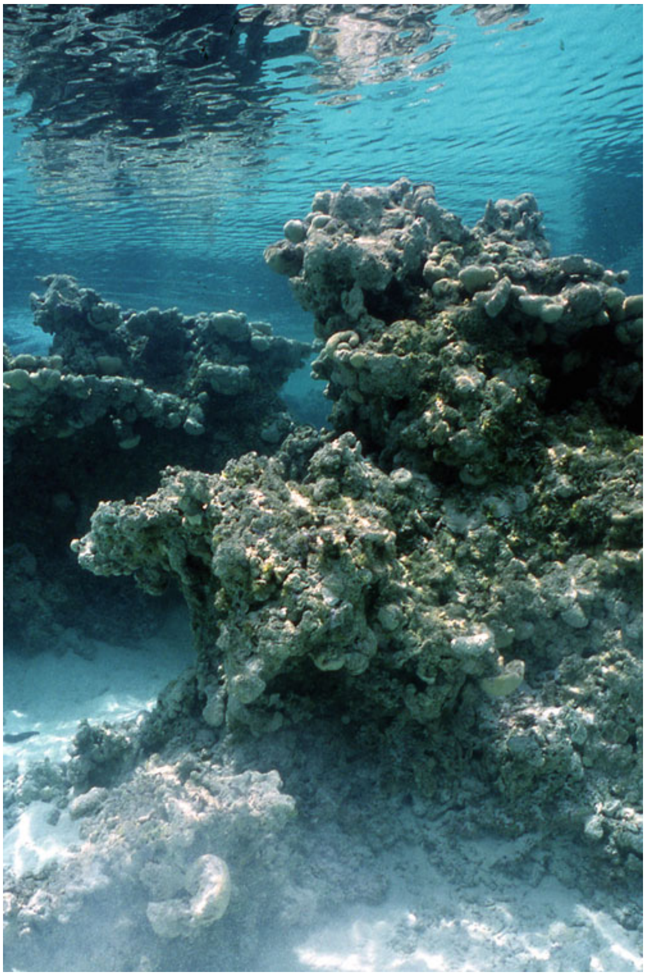

Fig. 22.13 Patch reef within the lagoon at Ducie (Photo: R. A. Irving)

Sargassum odontocarpum and *Lobophora variegata*. Foliose algae appear to do well at Pitcairn (compared to the other islands), which is probably a reflection of the slightly cooler seawater and the higher nutrient levels in the water column linked with rain run-off from the island.

Coral Cover and Reef Structure

Typically, live coral cover can vary from as little as 5% to as much as 80%, depending on the depth and the location around the island. Coral growth seems to be most prolific in the 12–22 m depth range. However, in 1971 Randall (1999) undertook some of his fish collecting dives in deep water. On one such occasion, when diving a feature known as 'The Bear' off the north-east coast, which rises about 9 m above the seabed at 45 m, he recorded the live coral cover as being almost 100%. One of the most extensive areas of live coral growth is present off Adamstown on the north-east coast at a depth of 18–30 m, covering an area estimated to be about 2 km^2.

A total of 15 coral species have been recorded from Pitcairn (probably an underestimate) which include *Pocillopora damicornis*, *Astreopora myriophthalma*, *Porites* aff. *annae*, *Porites lobata*, *Psammocora haimeana*, *Leptoseris hawaiiensis* and *Favia matthaii*. In general, most reef-building corals reach a height of 1–2 m and where sufficiently dense (>80% cover) these are able to provide a three-dimensional structure for other organisms to utilise, most noticeably fishes (Fig. 22.14, left and right). Occasionally, one may encounter large solitary coral structures ('bommies'), often formed by *Porites lobata*, which may be over 5 m tall.

Other Reef-Associated Taxa at Pitcairn

A total of 270 species of reef fishes have been recorded from Pitcairn. This equates to 77% of the total number of reef

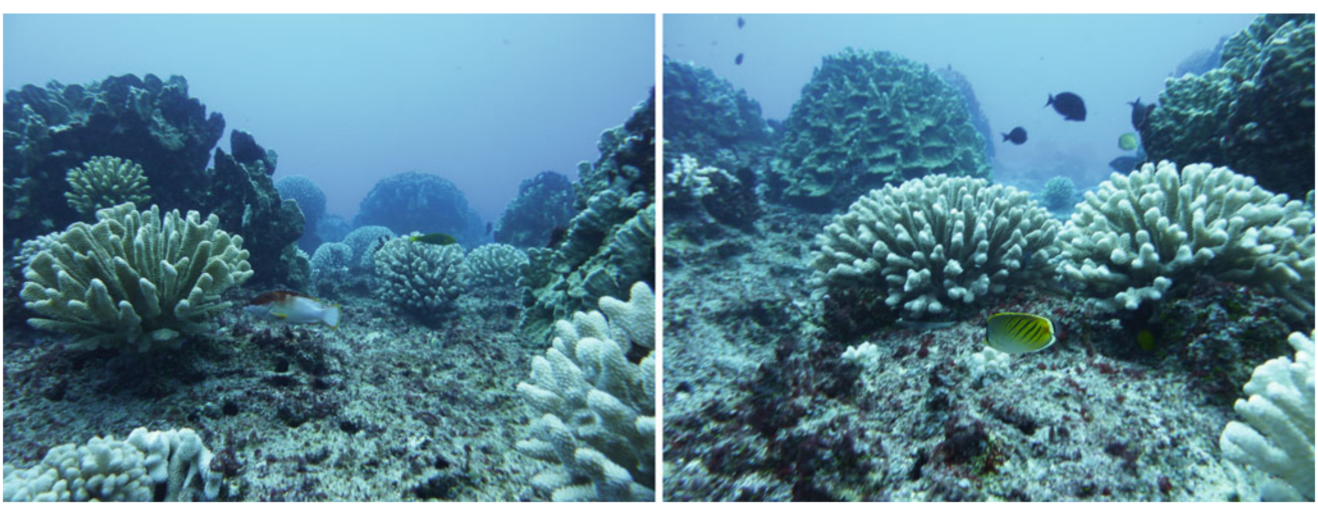

Fig. 22.14 *Left*: Coral formations at 18 m depth off Pitcairn's NE coast. *Right*: Coral formations at 18 m depth off Pitcairn's NE coast. *Pocillopora* sp. in foreground (Photos: R. A. Irving)

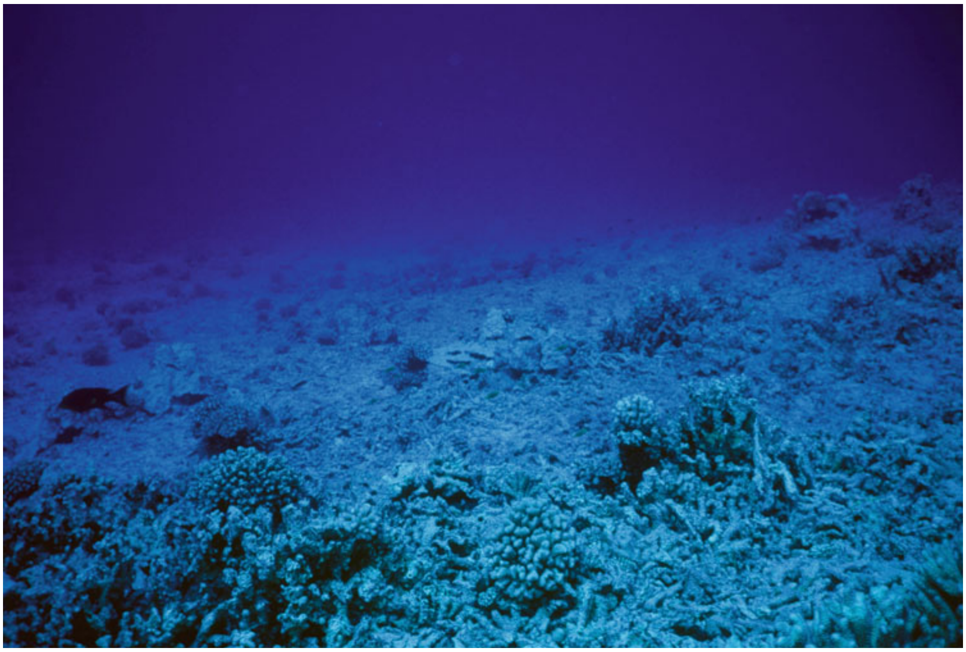

Fig. 22.15 Extensive areas of coral rubble are present at Henderson, particularly off the north coast (Photo: R. A. Irving)

fishes (352 species) recorded from all four islands – a relatively modest figure reflecting the Pitcairn Islands' isolation. Thirty three of these species were new to science when first discovered at Pitcairn in 1971 (Randall 1999). The most common fishes observed at diving depths of about 10–20 m at Pitcairn are the wrasses *Thalasoma lutescens* and *Coris* sp., the surgeonfish *Acanthurus leucopareius*, the damselfishes *Chrysiptera galba* and *Stegastes fasicolatus*, and drummer/nanwi *Kyphosus bigibbus* (Randall 1999; R. A. Irving, *pers. obs*.). The two shark species which may be seen at Pitcairn are the Galapagos shark *Carcharhinus galapagensis* and the whitetip reef shark *Triaenodon obesus*.

Reef-associated invertebrate taxa which have been recorded from Pitcairn include 23 species of echinoderms (although almost half of these are brittlestars which have come from dredge samples, Paulay 1989); over 80 molluscan taxa (although the molluscan fauna remains poorly known, Preece 1995); 29 non-ostracod species of crustacean (likely to be an under-representation) and 47 ostracod species (Irving and Dawson 2012). There are very few sessile, filter-feeding organisms present (such as porifera, sessile polychaetes, bivalve molluscs, ascidians etc.), probably a reflection of the poor nutrient levels in the water column and the low reef biodiversity in general.

Henderson

Coral Cover and Reef Structure

An extensive level terrace at 3–6 m depth is present on the shallow fore-reef beyond the seaward edge of the reef platform off the North-West and East Beaches. The smooth bedrock here is pockmarked by small holes containing the urchin *Echinometra* sp. There is a noticeable absence of coral growth on these terraces. Indeed, generally speaking, the fore-reef as a whole is impoverished in terms of coral diversity, with the percentage of live coral cover typically in the order of 10–30% (Irving 1995). Corals of the genus *Pocillopora* are the commonest corals beyond 10 m depths, though the fire coral *Millepora* sp. is also numerous and widespread. A total of 59 species of scleractinian coral have been recorded from Henderson, together with an unspecified number of soft coral species (Family Alcyonacea) (Irving and Dawson 2012). Of the 18 species of acroporid coral known to occur at Henderson, the majority are found off the East Beach.

At several sites on Henderson's fore-reef, bare bedrock is apparent, typically covered by a thin crust of coralline algae. Elsewhere, and particularly in deeper water (>30 m depth), extensive areas of coral rubble are present (Fig. 22.15). Damage to coral formations is likely to have come about as a result of strong wave action during storm events, with coral debris from shallower waters being moved into deeper waters. The richest area of coral diversity appears to be off the northern end of the east coast (Fig. 22.16). Occasional patch reefs or 'bommies' are present within the 25–35 m depth band around the northern half of the island. These massive structures, which can be 7 m or more in height (Fig. 22.17), are typically formed by just one coral (often *Porites lobata*) and may be over 750 years old (Irving 1995).

Fig. 22.16 While most of Henderson's fore-reef has less than 50% coral cover, areas off the East Beach (such as shown here) boast 100% cover (Photo: R. A. Irving)

Fig. 22.17 A large *Porites lobata* 'bommie' (Photo: R. A. Irving)

Other Reef-Associated Taxa in Henderson

A total of 173 species of reef fishes (belonging to 49 families) has been recorded from Henderson, almost half of the total number of species (352) recorded for all four islands (Randall 1999; Irving et al. 1995). The largest family represented is the Labridae (21 species), followed by the Acanthuridae (16 species), Blenniidae (14 species), and the Chaetodontidae, Serranidae and Pomacentridae (all with 12 species) (Irving et al. 1995). Echinoderms are the most conspicuous invertebrates at Henderson, particularly the echinoids (12 spp.) and the holothurians (10 spp.) (Paulay 1989). *Diadema* cf. *savignyi* appears the most numerous sea urchin on the fore-reef, often present in very large aggregations in areas of coral rubble (Fig. 22.18, left). Other conspicuous echinoid species are *Heterocentrotus trigonarius* (common in the shallows of the reef platforms) and *Heterocentrotus mammillatus* (common in crevices in the fore-reef at depths of 8–15 m) (Irving 1995). Asteroids (starfish) and ophiuroids (brittlestars) are rare. A group of about 150 crown-of-thorns starfish *Acanthaster planci* was reported at 32–38 m depth off the island's west coast in December 1991 (Irving 1995) (Fig. 22.18, right).

Oeno

Coral Cover and Reef Structure

The fore-reef at Oeno slopes gradually into deeper water from the reef margin, steepening beyond the 30 m depth contour (Figs. 22.19 and 22.20). The overall cover of live coral is greater than at Henderson though less than at Ducie, ranging from 5% to 70% (Irving 1995). In contrast to Ducie, large areas of sand are present, with a series of sand channels, up to 3 m wide, running perpendicular to the reef between 5 and 20 depth. There are also extensive areas of coral rubble. A total of 17 species of scleractinian coral have been recorded from Oeno (Irving and Dawson 2012).

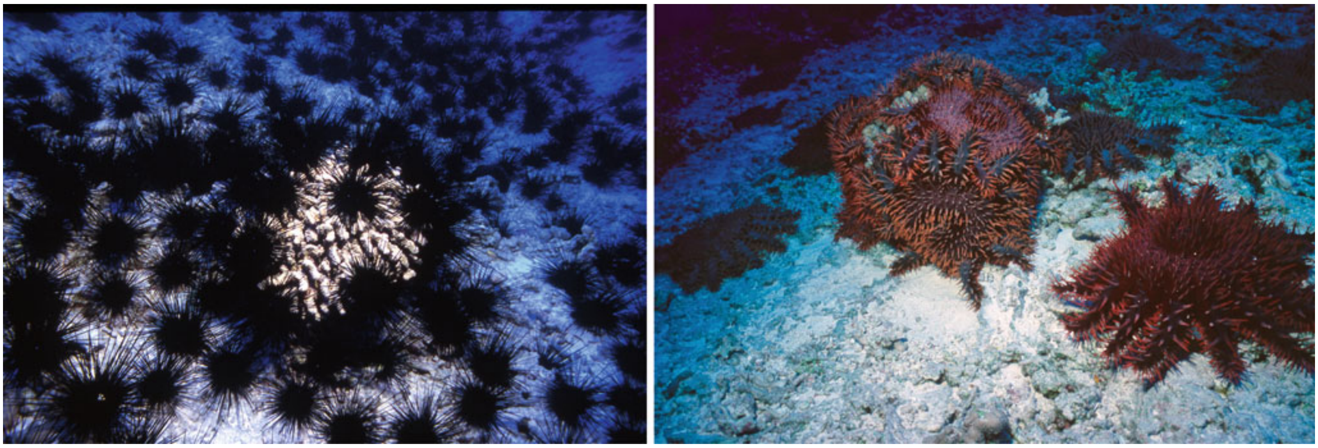

Fig. 22.18 *Left*: Dense aggregations of the long-spined sea urchin *Diadema* cf. *savignyi* occur on the open fore-reef (Photo: J. Jamieson). *Right*: Crown-of-Thorns starfish *Acanthaster planci*, photographed in December 1991 at Henderson (Photo: R. A. Irving)

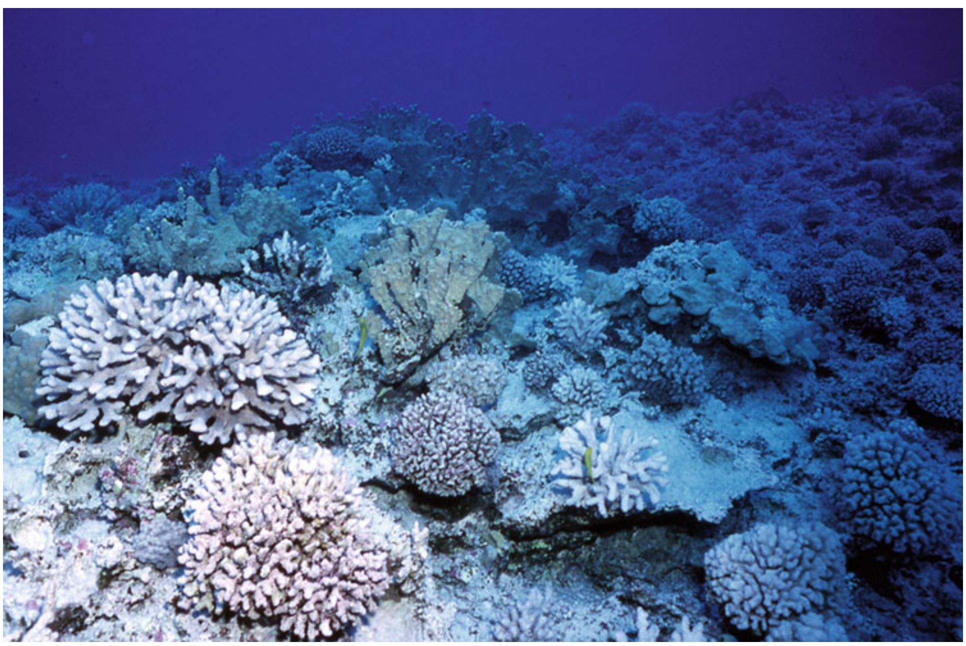

Fig. 22.19 Assorted corals on the fore-reef off the west side of Oeno at about 20 m depth (Photo: R. A. Irving)

Other Reef-Associated Taxa

A total of 255 marine molluscs have been recorded from Oeno, including those found within the lagoon. Preece (1995) found the largest number of bivalve species (45) here when compared to collections made at the other three islands, a fact he put down to the soft sediments within the lagoon. Fifteen species of echinoderm have been recorded from Oeno, together with 165 species of reef fishes.

Ducie

Coral Cover and Reef Structure

The greatest seaward extension of the reef at Ducie is off the south-west of the atoll, where the shelf extends 270 m offshore to a depth of 30 m. Beyond this depth, the seabed steepens noticeably. However, coral growth can be seen extending beyond 40 m in places (Irving and Dawson 2012). Cover of live coral was estimated as being 80–100% in the 11–20 m

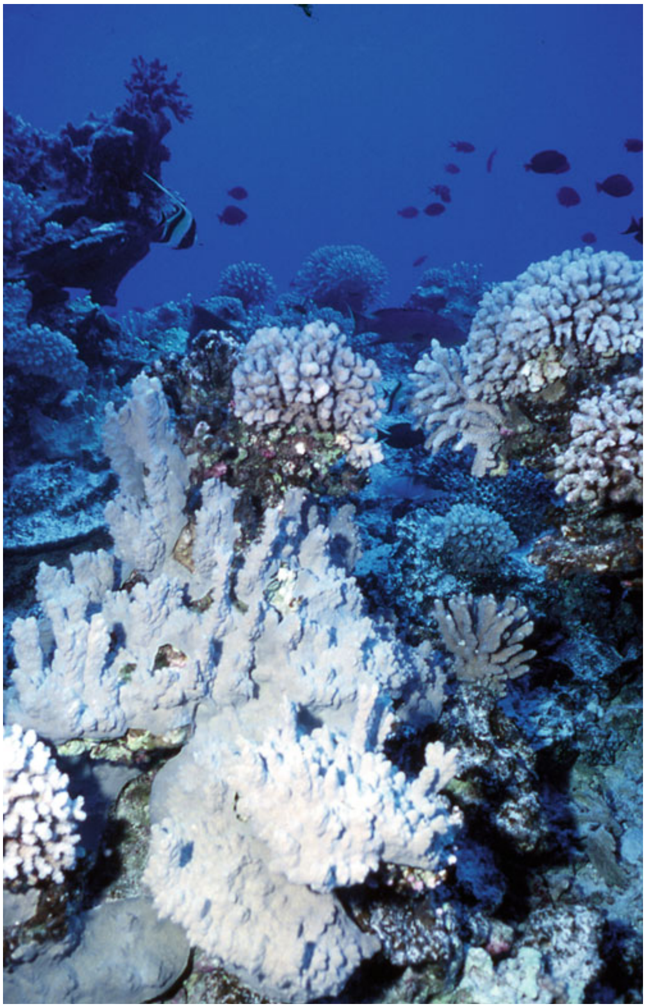

Fig. 22.20 Assorted corals on the fore-reef off the west side of Oeno at about 16 m depth (Photo: J. Jamieson)

depth range (though note here that soft coral species provide 80% of this cover); 25–100% in the 21–30 m depth range; and 10–85% in the 31–40 m depth range (Irving 1995) (Fig. 22.21a, b). Where cover was greatest (particularly off the south-east of the atoll), at between 80% and 100% cover, a large proportion was provided by one species: *Montipora aequituberculata* (Fig. 22.22). A total of 27 scleractinian coral species have been recorded from Ducie (Irving and Dawson 2012).

Other Reef-Associated Taxa

About 80 species of mollusc have been recorded from Ducie (Preece 1995), though the majority of these remain hidden from view. Twelve species of echinoderms have been recorded, including both the purple and red slate pencil urchins *Heterocentrotus trigonarius* and *H. mammillatus*. The long-spined sea urchin *Diadema* cf *savignyi* has also been found to be abundant on the fore-reef (Irving 1995). A total of 127 species of reef fishes have been recorded from Ducie (Randall 1999) which amounts to 28% of the fish fauna for all four islands, including one species of butterflyfish not found at the other three islands (Fig. 22.23). The most common species observed at Ducie were drummer/nanwi *Kyphosus bigibbus*, sunset wrasse *Thalassoma lutescens*, wrasse *Thalassoma heiseri*, steephead parrotfish *Chlorurus microrhinus*, whitebar surgeonfish *Acanthurus leucopareius*, damselfish *Chrysiptera galba*, Emery's Gregory *Stegastes emeryi* and black jack *Caranx lugubris*. Large numbers of grey reef sharks *Carcharhinus amblyrhynchos* were reported as being present at Ducie in 2012 (Enric Sala, pers. comm.), indicating a healthy reef environment.

Fig. 22.21 *Left*: Assorted corals forming 100% cover off Acadia motu, Ducie at 18 m depth (Photo: R. A. Irving). *Right*: Coral formations at 25 m depth off Acadia motu, Ducie (Photo: R. A. Irving)

Fig. 22.22 One of the dominant coral species on the fore-reef at Ducie is *Monitopora aequituberculata*, rarely seen at the other Pitcairn Islands (Photo: R. A. Irving)

Fig. 22.23 A large shoal of Pacific double-saddle butterflyfish *Chaetodon ulietensis*, a species only found at Ducie within the Pitcairn Islands (Photo: R. A. Irving)

Fig. 22.24 The many-spined butterflyfish *Hemitaurichthys multispinosus*, endemic to Pitcairn (Photo: J. E. Randall)

Endemic Species and Species of Particular Nature Conservation Concern

The number of marine endemic species associated with the Pitcairn Islands is relatively small. It is likely more have yet to be discovered, as not all of the major taxa have been studied to any great degree. The gastropod mollusc *Fusinus galatheae bountyi* is a predatory gastropod which is frequently found in the baited pots set around Pitcairn to catch slipper lobsters. It is found in depths of 40–100 m (Rehder and Wilson 1975) and is still understood to be endemic to Pitcairn. The nudibranch *Bornella irvingi* was first discovered at Ducie in 1991 and remains endemic to that island.

Five species of bony fishes are currently believed to be endemic to the Pitcairn Islands (Randall 1999). These are the Pitcairn sandlance *Ammodytoides leptus*, the many-spined butterflyfish *Hemitaurichthys multispinosus* (both only found at Pitcairn) (Fig. 22.24); the Henderson triplefin *Enneapterygius ornatus* and the squirrelfish *Sargocentron megalops* (both found only at Henderson). There is also an undescribed species of combtooth blenny *Alticus* sp. (Randall 1999), found both at Pitcairn and Henderson. Smith's butterflyfish

Fig. 22.25 Smith's butterflyfish *Chaetodon smithi*. Whilst commonly seen at Pitcairn, this species has a very restricted distribution (Photo: R. A. Irving)

Chaetodon smithi (Fig. 22.25), one of the most frequently seen species of butterflyfish at Pitcairn, was a new species to science when discovered at Pitcairn in 1971. Since then its distribution has been found to extend to SE French Polynesia as well.

A summary of the most endangered conservation status (IUCN 2012) of representatives of each taxonomic group of marine organisms which have been recorded to date from within the Pitcairn Islands Exclusive Economic Zone (EEZ) is given in Table 22.1.

Human Uses and Threats (All Four Islands)

Because of their geographical position and isolation, as well as having a small human population (on Pitcairn only), the coral reefs and their habitats of the Pitcairn Islands do not suffer the usual threats associated with human interference. On Pitcairn itself, the community does not practice any major agriculture, mainly growing vegetables in garden plots and harvesting fruit from natural and semi-natural locations around the island. Consequently, there has been no significant land utilisation or conversion or application of fertilisers resulting in no pollution and minimal sedimentation run-off, save during uncommon extreme rainfall events. The islanders use line-caught and trap methods of fishing only. At the current time, with no reliable trading options, overfishing is also controlled to a degree. Even global warming does not seem to present a significant threat to the Pitcairn corals in the medium term due to their low latitude location where temperatures are at the lower end of the corals' thermal tolerance range. There may be problems from fishing and tourism, particularly associated with the dropping of boat anchors on reefs causing localised damage.

Governance of the Area

The islands' 200 nautical mile EEZ was established in 1980 when the Fisheries Zone Ordinance was constituted under Pitcairn laws to establish a fisheries zone contiguous to the territorial seas of Pitcairn, Henderson, Ducie and Oeno Islands and to regulate fishing practices. Although much of the legislation within this ordinance relates to regulation and licensing of foreign fishing vessels within the Pitcairn EEZ, there are also provisions which allow for the Governor of Pitcairn to limit fishing activities to island residents for the purposes of conservation and management of fisheries resources.

Henderson became a UNESCO World Heritage Site in 1988 on account of its 'unique natural history and ecological intactness'. However, it was not until after the Sir Peter Scott Commemorative Expedition to the Pitcairn Islands in 1991/1992 that the composition of that ecology began to be known. A Management Plan for the period 2004–2009 was subsequently drawn up (Brooke et al. 2004), published by the Foreign and Commonwealth Office, London, in conjunction with the Pitcairn Islands Administration and the Royal Society for the Protection of Birds. This consolidated much of the earlier literature and scientific knowledge of Henderson Island as a consequence of UNESCO designation. The Plan was published to provide a framework for the sustainable management of the island with respect to the Pitcairners, visiting scientists and tourists. Following this, a Pitcairn Islands Environment Management Plan, which focused on the other three islands (Pitcairn, Ducie and Oeno), was published in 2008 (Smyth 2008). This develops ten key objectives for managing the environment of the Pitcairn Islands, based upon the Environmental Charter jointly signed by the Mayor of Pitcairn Island and the UK Government in 2001. Although the UK Government ratified the Convention on Biological Diversity (CBD) in 1994, this has not been extended to the Pitcairn Group. A review of the progress on the CBD in UK Overseas Territories, commissioned by the Worldwide Fund for Nature (WWF), highlighted that the main area of CBD legislation with which the Pitcairn Group was not complying, was in connection with the on-going monitoring of biodiversity (Cross and Pienkowski 1998). A UK Overseas Territories Conservation Forum (UKOTCF) review of existing and potential Ramsar sites in UK Overseas Territories and Crown Dependencies, commissioned by the Department of Environment, Food and Rural Affairs (DEFRA), identified the coastal waters of the Pitcairn Group as potential Ramsar Convention sites of International Importance (Pienkowski 2005), but data remain inadequate to determine designations.

Table 22.1 Number of marine species in major taxonomic groups recorded from within the Pitcairn Islands EEZ (After Irving and Dawson 2012)

Group	No. of species recorded to date (May 2012)	No. of endemic species	Most endangered conservation status represented[a]	Species richness	Level of study
Cetaceans	22	0	Endangered **(EN)**	Low/intermediate	Poor/intermediate
Marine birds (breeding)	13	1	Endangered **(EN)**	Intermediate	Good
Marine birds (non-breeding)	20+	0	Endangered **(EN)**	Low/intermediate	Poor
Turtles	2	0	Critical **(CR)**	Low	Poor
Pelagic fishes	13	0	Near-Threatened (NT)	Low	Poor/intermediate
Reef fishes	352	5	Endangered **(EN)**	Low/intermediate	Good
Echinoderms	>64	3	Not Evaluated (NE)	Intermediate	Intermediate
Molluscs	>502	5+	Not Evaluated (NE)	Low	Intermediate
Crustacea	>42	?	Not Evaluated (NE)	Low	Poor
Ostracods	47	?	Not Evaluated (NE)	Intemediate	Intermediate
Stony corals	87	1	Vulnerable **(VU)**	Intermediate	Intermediate
Hydroids	8	0	Not Evaluated (NE)	Low	Intermediate
Sponges	12	0	Not Evaluated (NE)	Low	Poor
Forams	32	?	Not Evaluated (NE)	Low	Intermediate
Algae	29	0	Not Evaluated (NE)	Low	Poor/intermediate
Blue-green algae	4	0	Not Evaluated (NE)	Low	Poor
Totals:	1,249+	15+			

[a]IUCN (2012)Red list of threatened species status categories

Table 22.2 Ramsar information sheets relating to the proposed sites for designation in the Pitcairn Islands (From www.ukotcf.org)

Ramsar code	Site name	Ramsar Criterion[a]
UK62001	Ducie Island: All islands and marine area to 50 m depth contour; or 1.5 km offshore approximately	1, 3, 4, 6, 7
UK62002	Henderson Island: Island and marine area to 50 m depth contour; or 1.5 km offshore approximately	1, 2, 3, 4, 5, 6, 7
UK62003	Oeno Island: Island and marine area to 50 m depth contour; or 1.5 km offshore from atoll approximately	1, 2, 3, 4, 6, 7
UK62004	Brown's Water, Pitcairn Island: Gully surrounding flowing water feature	1, 2, 3
UK62005	Coastal waters, Pitcairn Island: Marine area to 50 m depth contour; or 1.5 km offshore	7

[a]See Annex II of the *Explanatory Notes and Guidelines* for the Criteria for completing the Information Sheet on Ramsar Wetlands and guidelines for their application (Adopted by Resolution VII.11) available at www.ramsar.org

Protected Areas and Management

At the current time, no marine or terrestrial protected areas have been established on any of the four islands, although, due to their isolation and lack of scheduled transportation links, the uninhabited islands of Henderson, Ducie and Oeno are relatively undisturbed by human interference.

The UKOTCF (2004) review of existing and potential Ramsar Convention sites in UK Overseas Territories and Crown Dependencies has resulted in a drafted set of Ramsar Information Sheets for the proposed Pitcairn sites (Table 22.2).

At the current time, however, the evidence base for justifying the designation under each of the Ramsar Criteria supporting the listing of the Pitcairn sites under the Ramsar Convention remains incomplete. Further research is necessary for establishing a baseline, by describing the ecological functions, products and attributes of the sites that sufficiently identify those benefits and values of international importance.

Under its Global Ocean Legacy programme, the Pew Environment Group is aiming to establish a worldwide system of very large, highly protected marine reserves, where commercial fishing and extractive industries are prohibited (see http://www.pewenvironment.org/campaigns/global-ocean-legacy). Because of its isolation, pristine marine conditions and unique ecological status, the Pitcairn Islands' EEZ, covering an area of approximately 836,100 km^2 (322,823 square miles) of ocean, has been identified as a candidate site for the establishment of the world's largest marine reserve. In collaboration with several UK conservation organisations, which together form the Marine Reserves Coalition (MRC), negotiations are currently underway to progress this aim with the Pitcairn Islands Council, the island community and the UK Government.

Fishing

Historically, the number of commercial foreign fishing vessels operating in the open waters of the Pitcairn EEZ has been very low. Targeting mainly tuna (albacore) species, these fishing activities have been limited to longline fishing by distant water fishing nations, principally Japan, Korea, and Taiwan, under licence from the UK Government. Due to the distances involved and the vessels used, the use of purse-seiners is prohibitive, which reduces the problems of over-extraction and bycatch commonly associated with this method. In recent years, however, no commercial fishing has taken place due to the relatively low catch yields compared to neighbouring French Polynesia. A large number of the small island community regularly fish from the shore or from Pitcairn-based boats for subsistence and for sale to the infrequent passing cruise ships. Virtually all near-shore fishing is conducted using hand-lines catching a number of reef fish, dominated by the drummer *Kyphosus bigibbus* (Fig. 22.26a) although a number of other species are targeted, including the highly-prized coral trout *Variola louti*, various grouper species *Epinephelus* spp. and the sunset wrasse *Thalassoma lutescens* (Fig. 22.26b). Other fishing methods used by some of the islanders include trolling using small outboard powered skiffs mainly for wahoo *Acanthocybium solandri* and the occasional yellowfin tuna *Thunnus albacares*, spear fishing using snorkeling and scuba equipment and using trap pots for catching lobsters. The two lobster species caught locally are the pronghorn or red spiny lobster *Panulirus penicillatus* or crayfish as it is locally known (Fig. 22.26c) and the slipper lobster *Scyllarides haanii* (Fig. 22.26d). The former species is caught by hand using SCUBA equipment at rocky inshore locations during calm weather, whereas the latter species are caught using pots, which are deployed at depths of 30–50 m around the island (Dawson & Christian 2010). The visitation of occasional cruise ships and visiting yachts provides the only opportunity for the Pitcairners to sell or trade their marine resources, mainly in the form of fresh fish (caught in the immediately preceding days and refrigerated), or live lobsters. Anecdotal evidence from local fishermen suggests that the artisanal fisheries and lobster fishing activities are relatively healthy and currently sustainable although in recent months there has been increased fishing effort in order to achieve their previous catch weights and a decline in the number of spiny lobsters caught in trying to meet demand from the cruise ships. Because of a contamination

Fig. 22.26 (**a**) Drummer (local name: nanwi) *Kyphosus bigibbus*, an important food fish for Pitcairners (Photo: T. P. Dawson). (**b**) Sunset wrasse (local name: whistling daughter) *Thalassoma lutescens*, another popular food fish for Pitcairners (Photo: R. A. Irving). (**c**) Pronghorn or red spiny lobster *Panulirus penicillatus* (Photo: R. A. Irving). (**d**) Aesop slipper lobster *Scyllarides haanii* (Photo: T. P. Dawson)

of ciguatoxins in the fish caught on the reefs of French Polynesia, the Secretariat of the Pacific Community (SPC) has proposed that the Pitcairn community develop their reef fisheries commercially for export to neighbouring Mangareva. However, no assessment of fish populations has been undertaken as yet and the ecological sustainability and economics of such a venture have yet to be studied in detail.

Other Concerns

Few other human impacts affect the marine environment of the Pitcairn Islands directly. Successfully eradicated from Oeno and Ducie in 1997, the presence of the Polynesian rat *Rattus exulans* on the Islands of Henderson and Pitcairn continues to have a severe negative impact upon the breeding bird populations. A poor swimmer over long distances, the rat is considered to be a significant marker of human migrations across the Pacific, as the Polynesians accidentally or deliberately introduced it to the islands they visited.

The decline of the Henderson Petrel *Pterodroma atrata* populations, which is listed as endangered on the IUCN Red List and which breeds only on Henderson Island, is thought to be mainly caused by chick predation by rats, although land crabs have also been implicated. A major aerial rat eradication programme was carried out by the Royal Society for the Protection of Birds (RSPB) on Henderson in 2011 using helicopters and poison bait drops. However, a positive rat sighting in March 2012 (and subsequently) suggests that the operation was not successful in eradicating the rats. Climate change may also have a negative impact on the Pitcairn Islands in the long term. Sea-level rise may inundate the low lying areas of some parts of both Oeno and Ducie islands and major storms and other extreme climatic events may cause extensive damage to coral reefs as well as the terrestrial habitats. For example, a species of thintail grass *Lepturus* sp. recorded from earlier expeditions had disappeared from Ducie when storm waves deforested the island some time before the 1975 Smithsonian expedition (Rehder and Randall 1975). Rehder and Randall (1975) also commented on a

Fig. 22.27 Heavy coastal and near-shore sedimentation on Pitcairn Island arising from the storm event in February 2012 (Photo: B. Young)

mass mortality of the lagoon corals at Ducie over all the sites they surveyed and hypothesised that they were possibly killed exceptionally by an unusual influx of low temperature water from more southerly latitudes. More recently, a major rainfall event occurred on Pitcairn Island in February 2012 when 600 mm of rain fell over 2 days, the highest since records began, which caused several landslide events across the island resulting in high sedimentation loads entering the near-shore marine environment (Fig. 22.27). Whilst prolonged suspended sediment in the water column is known to have a deleterious effect on coral reef health due to the reduction in the amount of light reaching coral reefs and other shallow benthic systems, the prevailing strong currents surrounding Pitcairn Island are likely to mitigate against these rare events over longer timescales.

Live specimens of Smith's butterflyfish *Chaetodon smithi* (see Fig. 22.25) have become sought after by aquarists on account of their extremely restricted distribution and their bold colouration. However, their export would require a licence and no such licences have been granted to date.

Conclusions

Situated in the central South Pacific at the eastern edge of the Pacific plate, the Pitcairn Islands remain one of the most pristine marine environments in the world. Their nearshore waters have escaped the ravages of modern fishing methods and the degradation often associated with coastal industries. Their extreme isolation and the low human population are the main reasons for this but these factors also create some of their greatest challenges for sustainable management, including the fragile social structure, limited transport access (only accessible by sea) and small economic base. As the sole remaining UK Overseas Territory in the Pacific, the UK's budgetary aid (2012/2013) to meet the territory's reasonable needs for public services, providing transport (shipping) subsidies and maintain the Pitcairn Island Office in New Zealand is £2.9 million, which accounts for 90–95% of the Island's economy (DFID 2012). Since the Island's revenues from postage stamps declined significantly in the 1990s, the UK Government recognises the current prospects for economic self-sufficiency on Pitcairn Island to be very low. The UK Government is currently, alongside other activities, encouraging private sector initiatives to engage the Pitcairn islanders in developing fish exports to Mangareva (DFID 2012), but the authors consider this course of action to be unwise until a full ecological impact assessment of the fisheries and sustainability appraisal has been undertaken. More positively, the UK Department for International Development identifies tourism as a valuable means of significantly increasing the Pitcairn Islands' revenue base through investments in a new alternative harbour facility (accommodating more frequent and year-round island visits to Pitcairn) and through private enterprise in eco-adventure tourism (DFID 2012). Unlike the scheme to expand commercial fisheries for export, this latter development strategy is conducive with the proposed designation of the Pitcairn EEZ as a fully-protected marine reserve. Whilst increasing tourism numbers is not incompatible with maintaining fragile, pristine, and relatively undisturbed natural areas, tourism development must be handled with care and sensitivity to ensure activities are sustainable and environmentally friendly (ecotourism). In many ways the Pitcairn Islands are a microcosm of the ecological and economic changes occurring in the world. With the health of their natural environment vitally important to their economy and wellbeing, the Pitcairners today stand at a crossroads that could change the course of their islands' future. Careful environmental stewardship of the Pitcairn Islands will ensure their unique biodiversity and natural heritage persists for many generations to come.

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