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TERRESTRIAL AND MARINE ECOLOGY OF POIVRE, AMIRANTES, SEYCHELLES

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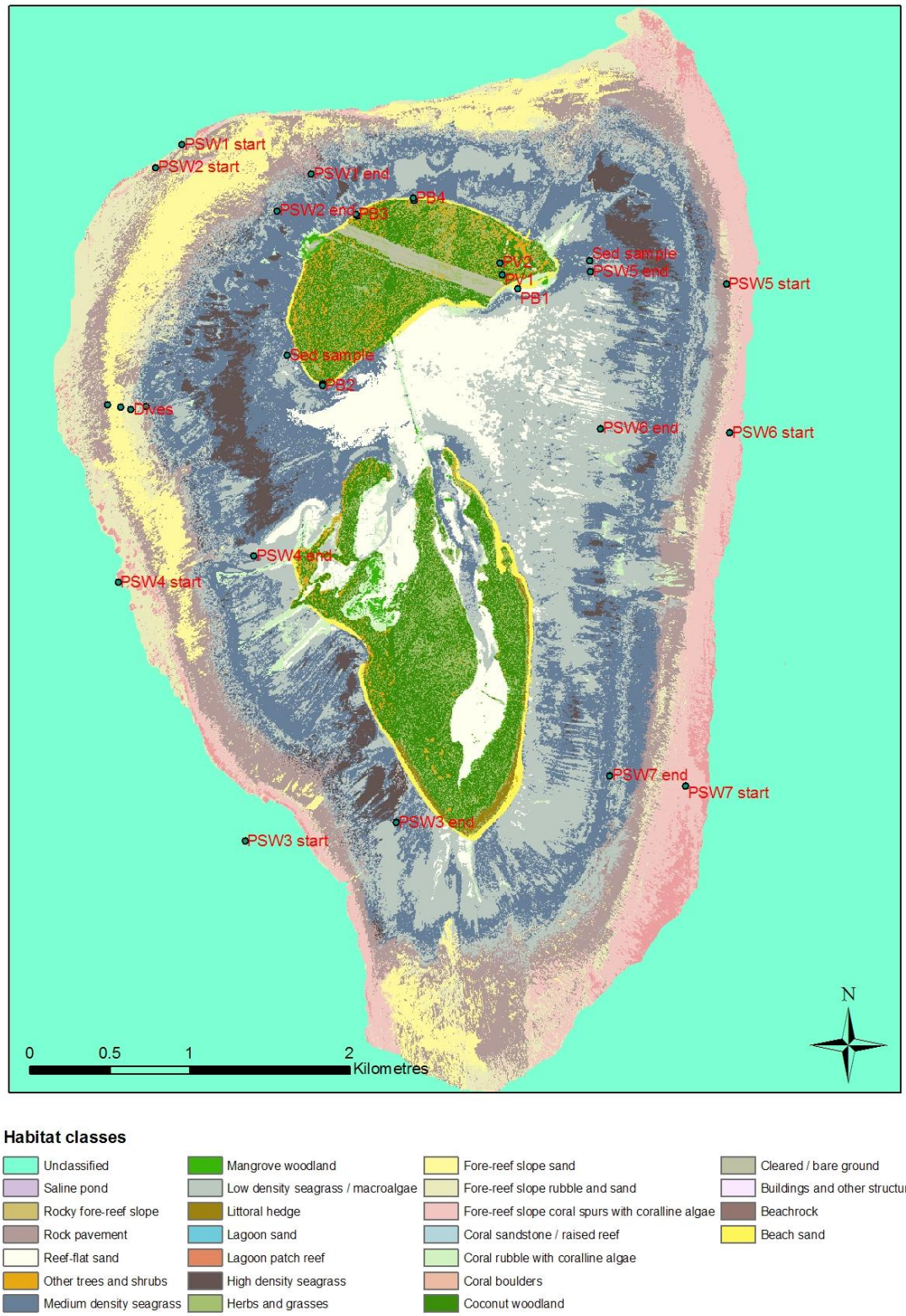

Figure 1. Location of vegetation Line Intercept Transects (PV1 and PV2), beach profiles (PB1, PB2, PB3 and PB4), reef-flat sediment samples (Sed sample), shallow-water transects (PSW1-7) and SCUBA dive surveys at Poivre atoll, 26-27th January 2005. Habitat map from Spencer et al. (2009).

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INTRODUCTION

The Amirantes group, Seychelles, comprises 24 islands and islets lying between 5° and 6° south of the equator on the Amirantes Bank, western Indian Ocean. The islands were discovered by the Portuguese navigator Vasco de Gama on his second voyage to India in 1502, soon after acceding to the rank of Admiral, and the islands were subsequently named Ilhas do Almirante or Admiral's Islands (Lionnet, 1970). The group extends over a distance of 138 km, from African Banks in the north to Desnoeufs in the south. Poivre was visited by the Chevalier du Roslan and named in 1771 by the Chevalier de la Biollière, after Pierre Poivre, former governor of Ile de France (now La Réunion), an agronomist who was instrumental in setting up the spice industry in the Seychelles in the late 1770s. Poivre Atoll lies close to the eastern margin of the Amirantes Bank, in the southern half of the main bank, 15 km southeast of Sand Cay (which is in the centre of the Bank) and 40 km west southwest of the submerged atoll of Desroches. The platform reef consist of two main islands, Poivre island in the north and Ile du Sud in the south, with a large, elongate, shallow lagoon between them and an encircling reef. A third island, Florentin, lies within the western margin of Ile du Sud.

The Percy Sladen Trust Expedition visited Poivre on 9th October 1905. Having crossed the sand-flat from Poivre island to Ile du Sud, expedition members became trapped by the tide and thus had time to fully explore the southern island (Gardiner, 1936). The morphology, soils, ecology and agriculture at Poivre island were documented in the 1960s (Baker, 1963; Piggott, 1969) and a plant list was compiled by S.A. Robertson and F.R. Fosberg following a two day visit to the island by the first author on 26th and 27th October 1976. Robertson found the island in much the same condition as when described by Piggott (1969) but with greater agricultural activity and with cattle and pigs being kept (Robertson and Fosberg, 1983). When Poivre island was visited in 2005, the only agriculture taking place on the island was for subsistence purposes, undertaken by a small number of workers from the Island Development Company (a government parastatal which took over ownership of the island in 1981). A small settlement exists on the eastern tip of Poivre island. In 2005, a hotel development was underway on the island, but progress has been slow. The centre of the island has been

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bisected by an 1,100 m long airstrip and the existing boat channel is being enlarged to facilitate the entry of larger vessels.

The Netherlands Indian Ocean Programme, onboard the R.V. *Tyro*, called at Poivre on 29th and 31st December 1992 and 1st January 1993. SCUBA and snorkel surveys were conducted on the north and west reef-slopes of Poivre (van der Land, 1994). A single seabed trawl at a depth of 57 m was conducted using a 3.5 m Agassiz trawl west of Poivre atoll and three baited fishtraps were deployed at a depth of 43 m northwest of Poivre island (van der Land, 1994).

A collaborative expedition between Khaled bin Sultan Living Oceans Foundation, Cambridge Coastal Research Unit and Seychelles Centre for Marine Research and Technology – Marine Parks Authority to the southern Seychelles was conducted onboard M.Y. *Golden Shadow*, from 10th – 28th January 2005. The primary aim of the expedition was to use a CASI (Compact Airborne Spectrographic Imager) sensor onboard a seaplane to conduct large-scale mapping of the southern Amirantes, Alphonse/St. Francois (Spencer et al., 2009) and Providence Bank. All surveys at Poivre were conducted on 26th and 27th January 2005.

TOPOGRAPHY AND GEOLOGY

Of the seven reef types identified in the Seychelles by Stoddart (1984), three are present in the Amirantes: platform reef, atoll and drowned atoll. The platform reefs vary in their morphology; Spencer et al. (2009) identified three categories of platform reef. Along with the island of D'Arros, they defined Poivre as a Type 3 platform reef, where the infilling of the platform surface has allowed the development of subaerial islands which exceed 2 km^2 in total area. The percentage coverage of the area of the reef platform inside the breaker zone by islands is comparable to the Type 2 reefs but the shallow water habitats seaward of the breaker zone are much less extensive than at the Type 2 sites where the islands sit on extensive, shallow and gently sloping rock platforms. Table 1 provides quantitative information on the Type 3 morphology at Poivre.

Table1. Morphometry of the platform reef at Poivre.

Total reef platform area[1] (km^2)	Peripheral reef area[2] (km^2)	Land area[3] (km^2)	Land area as proportion of total reef platform area (km^2)
20.24	12.01	2.66	13.14

[1] area of terrestrial and shallow marine habitats classified by Spencer et al. (2009) from airborne imagery

[2] area between the breaker zone and island marginal sediments

[3] area of terrestrial habitats and coarse beach materials (including beachrock)

The reef system probably sits on one of a number of topographic highs on the bank margin; local water depths of 15 – 17 m characterize these highs compared to 22 – 39 m on the general bank surface to the west of Poivre. To the east, water depths rapidly increase to in excess of 1,500 m. The reef platform is 5 km in length along a central N – S axis. The eastern margin runs S – N but the western margin is orientated SE – NW in its southerly two-thirds before trending SW – NE. As a result, the atoll is 3.5 km in width towards the north but tapers to less than 2 km in width towards its southern limits. The reef platform supports three reef islands (Fig.1; Plate 1). The most northerly island, Poivre island (110 ha) is a low-lying, oval shaped island measuring approximately 1,700 m from east to west and 750 m north to south (Plate 2). Poivre is connected to the large (135 ha) and topographically complex southern island, Ile du Sud (Plate 3), by a 750 m long causeway (Plates 4 and 5) (wrongly positioned by Baker, 1963). The very small (2.4 ha) third island, Florentin, lies behind and within the western margin of Ile du Sud.

Reef-flat widths, which are modest compared to the widths on other atolls in the Amirantes and the Alphonse Group further south, are greatest on the northwest and northeast coasts, opposite the western and eastern points of Poivre island respectively, where they reach 1 km. Around Ile du Sud reef-flat widths range between 500-750 m (west-facing coasts) and 750 m (east and south-facing coasts) (Plate 6). Thus, notwithstanding some differentiation between windward and leeward coasts, unlike the majority of islands in the Amirantes, reef flats are not best developed on the highest energy coasts facing the southeast trades. Baker (1963) identified shallow breaks in the reef flat at the southern point of the atoll and at several locations along the western margin but the only substantial channel, which gives access to Poivre island, is on the northern reef. There is no central lagoon, the area between Poivre island and Ile du Sud is characterized by reef-flat sands and muds which dry at low tide (Plate 7).

Poivre island is arcuate in form, with a strongly convex northern margin, measuring approximately 1,700 m from east to west and 750 m north to south. Baker (1963) mapped a large area of phosphatic sandstone at its eastern end, with basins, pipes and crevasses filled with guano and mixed to varying degrees with sand and humus. This phosphate outcrops on the inner reef flat immediately offshore from the settlement and along the eastern margin of the boat channel. Gravel sand bars and small spits characterize Pointe Baleine, the eastern point of the island, and Ile Corail, at the northeastern end of the airstrip, where the spits enclose a saline pond. A further discrete patch of phosphatic sandstone lies in the centre of the island with two small outliers further west. The largest land area at Ile du Sud contains a 9 ha area of phosphatic sandstone which presumably represents the old core to the island. This core tapers to the north, to La Pointe; a number of spit structures appear to have developed around it. Firstly, a 2.75 km long eastern arm has probably extended over time northwards, the result of longshore sediment transport driven by waves from the southeast. This arm thins significantly at 1.8 km from the southern tip of Ile du Sud, suggesting a reduction in long-term sediment supply. Recent (2008) satellite imagery suggests continued northward development, in a small arc of mobile sand between the tip of the vegetated island (Pointe Mozambique) and the causeway to Poivre island. Secondly, a complex of islands – named ‘Grande Terre’ by Baker (1963) - extends to the northwest from the central core of Ile

du Sud, formed of a series of closely-spaced low storm-ridges. There are at least three fossil spit units which run SW – NE from the seaward reef-flat margin of this complex. It appears that these spits increase in age to the northwest as the most northwesterly of these units, which has a complex star-like structure with five radiating arms, is clearly currently active, with numerous sand washover deposits and gravel ridges recurving towards the island of Florentin which lies behind this area. This active extension is not shown on Baker's (1963) map and has therefore developed within the last 40 years. It is likely that the island Florentin is now starved of new sediment and is a fixed, fossil feature. In each case, the positioning of the fossilized and vegetated spits represents the landward extension of features analogous to the 'transverse rubble bars' described from the western reef flat at St. Joseph by Stoddart and Coe (1979). These are tongues of storm debris about 1 m above the reef flat which flare seawards to join with extensive coral rubble banks immediately shoreward of the breaker zone and extend across the whole width of the reef flat.

METHODS FOR TERRESTRIAL SURVEYS

Terrestrial Flora and Fauna

Vegetation surveys were conducted using the Line Intercept Transect (LIT) technique over a horizontal distance of 30 m. By summing the intercept lengths for each plant species and dividing this value by the total length of the transect, percentage cover for each plant species was calculated:

$$\text{Percentage cover} = \frac{\text{Total length of plant species}}{\text{Length of transect}} \times 100$$

Two transects were laid at Poivre, both on the east side of the island, close to the settlement (PV1 and PV2; Fig. 1). The short length of these LITs was due to the opportunistic nature in which the work was being undertaken and limited time available. Plants that could be not identified in situ were labelled and photographed with a high resolution (4.1 mega pixels) digital camera for later identification by local botanists Murugaiyan Pugazhendhi and Katherine Beaver. In addition to these vegetation surveys, insects were collected in small plastic jars for identification back on Mahé.

Beach Surveys

Four beach profiles were conducted on Poivre island on the eastern end (PB1; 5°44.932′S, 53°18.664′E - 5°44.932′S, 53°18.671′E), southwestern (PB2; 5°45.202′S, 53°18.043′E - 5°45.208′S, 53°18.042′E), north northwest (PB3; 5°44.671′S, 53°18.123′E - 5°44.661′S, 53°18.117′E) and northern (PB4; 5°44.606'S, 53°18.335′E - 5°44.597′S, 53°18.333′E) sides of the island (Fig. 1). Profiles were measured by Abney level and tape,

in an offshore direction perpendicular to the beach, beginning at the terrestrial vegetation line and continuing to the offshore step (where the waves were breaking, typically marked by a downward step) or as far as safely possible into the water. Eight surface scrape sediment samples of *ca.* 200 – 350 g by weight were collected from Poivre, typically at the start and end points of each beach profile. Positions were recorded for the start and end of each beach profile and for the sites of the sediment samples using a hand-held GPS unit (horizontal resolution = ±10 m). Sediments were dried, disaggregated and sieved using standard techniques at 0.25 phi intervals.

METHODS FOR MARINE SURVEYS

Shallow-water Boat Transects

Two rigid inflatable boats were used to conduct shallow-water transects at seven sites around Poivre atoll. On the west side of the atoll, two transects were run NW-SE (bearings of 120^{o} and 150^{o}) in towards Poivre island and two transects were run W-E in towards Ile du Sud (bearings of 090^{o} and 070^{o}). On the east side of the atoll, transects were run due E-W, one transect was run into Poivre island, one transect was run towards the gap between the two islands and one transect was run in towards Ile du Sud. (All shallow water transects are marked on Fig. 1 as PSW1-7).

Transects were started at a water depth of approximately 20 m, the limit at which the bottom substrate could be accurately determined from the surface. Each time the boat was stopped a GPS position was taken and the water depth and bottom substrate (viewed through a glass-bottomed bucket) recorded. Between 11 and 18 substrate observations were recorded on each transect line.

Benthic Surveys

Quantitative benthic surveys (January 2005) were conducted using SCUBA at 20 m, 15 m, 10 m and 5 m depths on the western fore-reef slope (~5^{o}45.334′S; 53^{o}17.348′E; Dives on Fig. 1). The video transect method was used as this technique enables a large area of reef to be surveyed in a short time period as well as providing a permanent visual record of the reef at a specific time (Carleton and Done, 1995). A Sony digital DCR-SC100 video camera, positioned vertically 30 cm above the substrate, was used to conduct all video transects over a horizontal distance of 20 m following the depth contour of the reef. The video data recorded was a plan view of a rectangular section of benthic reef community measuring 20 m x ~ 0.3 m; by recording both sides of the transect, double the area was covered (or 20 m x ~ 0.6 m).

The video transect footage was analysed using the AIMS 5-dot analysis method by pausing the video at regular intervals and recording the substrate captured by each of the 5 dots (Christie et al., 1996; Osborne and Oxley, 1997). Ten major benthic categories were identified: sand, rubble, bare substrate, dead standing coral, pink calcareous algae on bare substrate, pink calcareous algae on dead standing coral, Scleractinia, non-

Scleractinia, macroalgae and others (e.g. zooanthids, molluscs, bivalves). Scleractinia, non-Scleractinia and macroalgae were identified to genus level. Percentage cover for the 10 benthic categories was calculated as follows:

$$\text{Percentage cover} = \frac{\text{Total number of dot captures for single benthic category}}{\text{Total number of dot captures for entire transect length}} \times 100$$

In addition to the benthic video surveys, fish species observed at Poivre were recorded during the dives. All fish species seen during a 35 minute period at depths of between 20 m and 5 m were recorded. A random search pattern was followed and both pelagic and demersal species noted.

Reef-Flat Surveys

The video transect technique was also used to conduct quantitative surveys on the reef flats at Poivre. The reef-flat transects ran perpendicular to the beach and covered a horizontal distance of 25 m. Only one side of the tape line was videoed, thus giving a rectangular section of reef measuring 20 m x ~ 0.3 m. Five reef-flat video transects were conducted at Poivre – three on the east side of the island and two on the west side. The video was analysed in the same way as the underwater SCUBA video transects, using standard AIMS methods (Christie et al., 1996; Osborne and Oxley, 1997). Surface scrape sediment samples were collected from the reef flats, off the south-west coast and eastern tip of Poivre island.

Seagrass on the reef flats of Poivre was sampled along two 30 m long transects. A pair of 0.5 m x 0.5 m quadrats was placed at each 10 m interval (one either side of the transect), so in total, 8 quadrats were placed along each transect (at 0 m, 10 m, 20 m and 30 m). At each site a visual estimation of percentage cover by different seagrass/ macroalgal species within each quadrat was made. The above ground biomass was then collected, put into labelled plastic bags and frozen. After the expedition, the frozen samples were dried out using a furnace at 225^{o}C. The samples were frequently weighted, until a constant dry weight was obtained.

RESULTS OF TERRESTRIAL SURVEYS

Flora and Fauna Surveys

Poivre island is largely covered in coconut palms and was once an important site of copra production (Plate 8). The first vegetation Line Intercept Transect (PV1; Fig. 1) was conducted approximately 80 m west of the settlement. The area was shady with a high canopy formed by coconut palms (*Cocos nucifera*). The dominant vegetation at this site was the sedge *Cyperus dubius* which occupied 35% of the total cover (Fig. 2). The short grass *Stenotaphrum dimidiatum* was the second most dominant species (24% cover), followed by the creeper *Passiflora suberosa* (12% cover) and *Stachytarpheta*

jamaicensis (12% cover). The herb *Vernonia cinerea*, the roots of which are often used locally for treating abdominal pains occupied 7% of the total cover at this site. Other plant species found along the transect were *Crotalaria* sp. (4% cover), *Cyperus aromaticus* (2% cover), *Turnera ulmifolia* (2% cover), *Euphorbia hirta* (2% cover) and *Alocasia macrorrhiza* (0.6% cover).

The second transect was laid about 200 metres from the settlement perpendicular to the path going to the southeast of the island (PV2; Fig. 1). Once again this was an area shaded by the high canopy of coconut palms. The vegetation was very low, seldom higher than 40 cm. The dominant species at this site was the mat forming grass *Stenotaphrum dimidiatum* which covered 39% of the total transect, followed by 2 creepers; *Passiflora foetida* (27% cover) and *Tridax procumbens* (15% cover) (Fig. 2). *Stachytarpheta jamaicensis* occupied 9% of the total cover. Other plant species found along the transect were *Nephrolepis biserrata* (5% cover), *Passiflora suberosa* (3% cover), *Vernonia cinerea* (1.5% cover), *Synedrella nodiflora* (1.3% cover) and *Crotalaria* sp. (0.2% cover). Areas of other trees and shrubs, Casuarina forest and groves of broadleaf forest are characteristic near the settlement, near the eastern point, immediately to the east of the northeastern end of the airstrip and along the north coast to the west of the airstrip. Ile du Sud and Florentin are also dominated by coconuts, although there are other trees and shrubs in pockets along the western margins of both islands, particularly on Grande Terre. A littoral hedge, dominated by *Scaevola taccada* is particularly prevalent on the eastern tip of Poivre (Plate 9) and characterizes the eastern and southwestern coast of Ile du Sud, being particularly well developed on the southeastern coast (Fig. 1).

Historical records, and collections and sight records from 1976, have established a plant list of 87 species at Poivre (Robertson and Fosberg, 1983). Fifty-four plant species were observed at Poivre during a 3.5 hour period in January 2005; these are listed in Table 2.

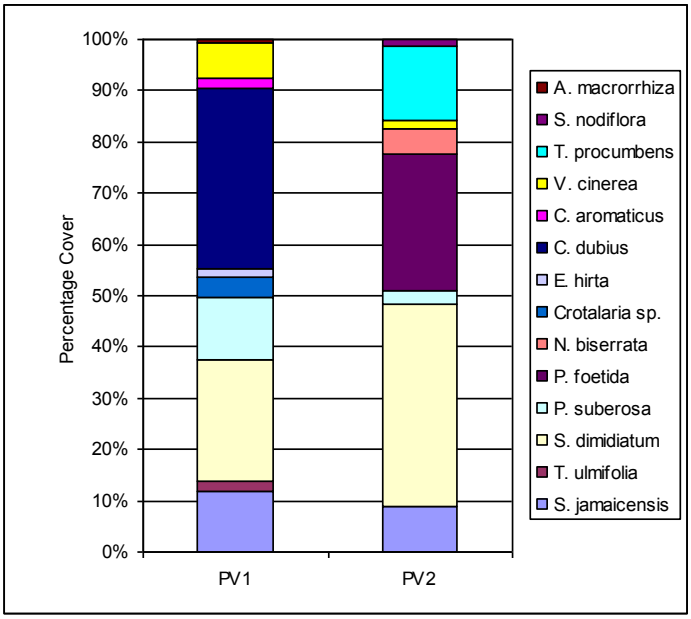

Figure 2. Percentage cover of plant species along two 30 m long LITs at Poivre, January 2005 (see Figure 1 for locations of PV1 and PV2).

Table 2. Scientific and Creole / common names of plants observed at Poivre, January 2005. Total number of plants observed = 54. Number of new records compared to Robertson and Fosberg (1983) = 13 (new records marked with *).

Family and Species	Creole / Common Name
Amaranthaceae	
**Amaranthus viridis*	
Apocynaceae	
Catharanthus roseus	Roz enmer / Madagascar periwinkle
**Ochrosia oppostifolia*	Bois sousouri
Araceae	
Alocasia macrorrhiza	Vya
Arecaceae (Palmae)	
Cocos nucifera	Cocotier / Coconut palm
Asteracea (Compositae)	
Synedrella nodiflora	
Tridax procumbens	
Vernonia cinerea	
Caricaceae	
Carica papaya	Papayer / Papaya
Casuarinaceae	
Casuarina equisetifolia	Cèdre / Pin / Casuarina
Clusiaceae (Guttiferae)	
Calophyllum inophyllum	Takamaka / Indian laurel
Combretaceae	
Terminalia catappa	Badamier / Bodanmyen / Indian almond
Convolvulaceae	
Ipomoea pes-caprae	Batatran / Goats foot creeper / Beach morning-glory
Crassulaceae	
Kalanchoe pinnata	
Cucurbitaceae	
Cucurbita moschata	Pumpkin
Cyperaceae	
**Cyperus aromaticus*	Sedge
**Cyperus compressus*	
Cyperus dubius	Sedge
Euphorbiaceae	
Acalypha indica	Herbe chatte / Lerb sat / Cat grass
Euphorbia hirta	
Euphorbia prostrae	
Phyllanthus amarus	
Fabaceae (Leguminosae)	
* *Crotalaria* sp.	
Desmodium incanum	
**Desmodium triflorun*	

Table 2 (Con'td)

Family and Species	Creole / Common Name
Goodeniaceae	
Scaevola taccada	Scaevola
Hernandiaceae	
Hernandia nmyphaeifolia	Bois Blanc
Lilaceae	
Zephyranthes rosea	
Lomariopsidaceae	
Nephrolepis biserrata	Fern
Lythraceae	
Pemphis acidula	
Malvaceae	
Gossypium hirsutum	Cotton
Sida acuta	
**Thespesia populnea*	Bois de rose / Porcher
Moraceae	
Artocarpus altilis	Friapen / Arbre à pain / Breadfruit
Musaceae	
Musa sp.	Bananier / Banana
Nyctaginaceae	
Boerhavia sp.	Pata covin / Patate cauvin
Bougainvillea spectabilis	Vilea / Bougainvillea
Passifloraceae	
**Passiflora foetida*	
Passiflora suberosa	
Poaceae (Gramineae)	
Dactyloctenium ctenoides	Grass
Eleusine indica	Grass
Stenotaphrum dimidiatum	Grass
* *Stenotaphrum micranthum*	Grass
Unidentified grass sp.	Grass
Rhamnaceae	
**Colubrina asiatica*	
Rhizophoraceae	
Rhizophora mucronata	Mangliye rouge / Rhizophora mangrove
Rubiaceae	
Morinda citrifolia	Bois tortue / Indian mulberry
Scrophulariaceae	
Striga asiatica	Lerb du riz
Solanaceae	
**Solanum nigrum*	
Turneraceae	
**Turnera angustifolia*	Koket / Coquette
Turnera ulmifolia	Koket / Coquette
Urticaceae	
Laportea aestuans	
Verbenaceae	
**Lantana camara*	Ville fille
Stachytarpheta jamaicensis	Épi bleu

Beach Surveys

Narrow sandy beaches surround Poivre island, widening on the central southern shore (Plate 10) and at the eastern point, where they are associated with coral rubble deposits. Sandy beaches also characterize the seaward margin of Ile du Sud, being widest on the southeast coast. Florentin has no sandy beaches. Beach sediments are generally composed of poorly sorted to moderately well sorted coarse to very coarse sands (Table 3, Fig. 3). Textural groups are slightly gravelly sand to sandy gravel.

Beach profile PB1, to the west of the eastern point, Pointe Baleine, of Poivre island, is a narrow (12 m), low angle beach, ending in a 1 m high cliff landward margin (Fig. 4a). At the southwestern point (PB2), the beach is a similar width and characterized by slope angles of 4 - 8^{o} (Fig. 4b). On the northern, seaward side of Poivre island (PB3 and PB4), beach widths are wider (18 – 22 m), with beach angles of 4 – 7^{o} (Figs. 4c and 4d) and some scarping of the upper beach.

RESULTS OF MARINE SURVEYS

Reef-flat Surveys

The reef flat at the eastern end of Poivre island is composed of poorly sorted, very coarse sands in the textural group sandy gravel. In the southwest, the reef flat is composed of poorly sorted, coarse sand in the textural group gravelly sand (Table 3, Fig. 5).

The reef-flat margin on the windward coast is characterized by medium density seagrass, with patches and lineations showing either a WNW – ESE orientation or, near the south point, a NW – SE alignment; away from the seaward margin, medium density seagrass is replaced by a quasi-continuous area of low density seagrass with macroalgae. High density seagrass is rare on the southeastern reef-flat but there is an extensive area at the northeastern corner of the atoll. On leeward coasts west of Ile du Sud there is a mosaic of high, medium and low density seagrass with macroalgae. The reef flat to the west of Poivre island is characterized by more extensive coverage of medium density seagrass and a large band of high density seagrass (Plate 11).

The centre of the atoll, between Poivre island and Ile du Sud, and the interior embayments of Ile du Sud and Florentin, are characterized by bare reef-flat sands and, in places, carbonate muds which dry at low tide. The mangrove *Rhizophora mucronata* is present between the islands of Poivre and Ile du Sud, forming a band along the southern coast of Poivre and near to, and along the causeway (Plates 5 and 12) and infilling areas within the southern embayments of Ile du Sud.

Table 3. Folk and Ward (1957) particle size distribution statistics for sediment samples from beach profiles and reef-flats. Units are given on the phi (ø) scale.

Sample	Environment	D_{50}	M_z	σ	SK	K_G	Description
PB1.1	Upper beach	1.128	1.129	0.683	-0.15	1.531	Medium Sand, Moderately Well Sorted, Coarse Skewed, Very Leptokurtic
PB1.2	Lower beach	0.064	0.106	0.883	0.089	1.436	Coarse Sand, Moderately Sorted, Symmetrical, Leptokurtic
PB2.1	Upper beach	0.925	0.890	0.404	-0.135	1.298	Coarse Sand, Well Sorted, Coarse Skewed, Leptokurtic
PB2.2	Lower beach	-0.286	-0.629	1.225	-0.330	0.917	Very Coarse Sand, Poorly Sorted, Very Coarse Skewed, Mesokurtic
PB3.1	Upper beach	0.425	0.342	1.053	-0.274	1.571	Coarse Sand, Poorly Sorted, Coarse Skewed, Very Leptokurtic
PB3.2	Lower beach	-0.451	-0.681	1.697	-0.139	0.875	Very Coarse Sand, Poorly Sorted, Coarse Skewed, Platykurtic
PB4.1	Upper beach	-0.056	-0.902	1.982	-0.520	0.658	Very Coarse Sand, Poorly Sorted, Very Coarse Skewed, Very Platykurtic
PB4.2	Lower beach	0.256	-0.455	1.744	-0.520	0.773	Very Coarse Sand, Poorly Sorted, Very Coarse Skewed, Platykurtic

Table 3 (Con'td)

Sample	Environment	D50	Mz	σ1	SK1	KG	Description
PRF1	Reef-flat East Poivre	-0.668	-0.537	1.663	-0.018	0.831	Very Coarse Sand, Poorly Sorted, Symmetrical, Platykurtic
PRF2	Reef-flat East Poivre	-0.033	-0.396	1.980	-0.290	0.926	Very Coarse Sand, Poorly Sorted, Coarse Skewed, Platykurtic
PRF3	Reef-flat South-west Poivre	0.450	0.567	1.006	0.123	1.057	Coarse Sand, Poorly Sorted, Fine Skewed, Mesokurtic

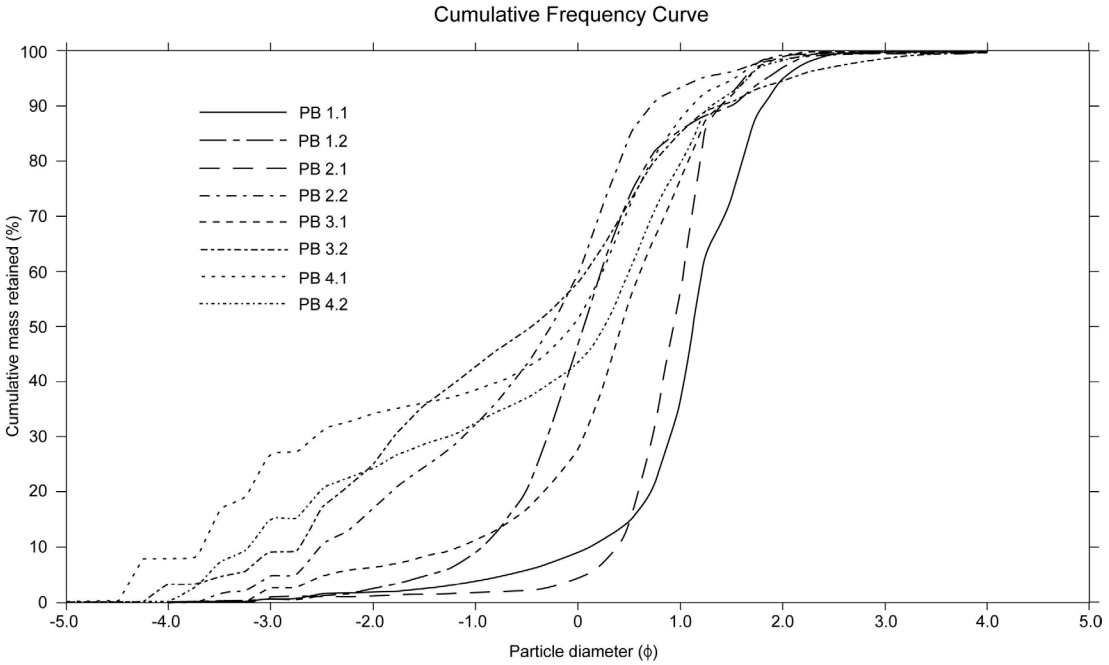

Figure 3. Cumulative frequency curves for sediment samples from upper and lower beaches around Poivre island, Poivre.

Shallow-water Transects: West Side

On the tender transects run NW-SE towards Poivre island substrate observations were made between 19 m (5°44.417′S, 53°17.496′E) and 1.5 m (5°44.508′S, 53°17.951′E) and between 17 m (5°44.484′S, 53°17.421′E) and 1.8 m (5°44.631′S, 53°17.792′E). On the first transect (PSW1), a rubble strewn slope was observed between 18 m and 10 m, which was combined with a bed of *Thalassodendron ciliatum* between 9 m and 8 m. Rubble was present throughout this transect but between 7 m and 2 m, coral on coral rock was also observed. Live coral represented approximately 2 – 10% of the benthic cover and *Halimeda* spp. macroalgae was sparse. At the shallowest depth, 1.5 m, a *Thalassodendron ciliatum* patch was observed, interspersed with rubble. The second transect (PSW2) was dominated by coral on coral rock. Live coral constituted approximately 3 – 10% of the benthos and was mainly *Acropora* spp. A little rubble was observed between 13 m and 10 m and sand patches were observed between 10 m and 5 m. *Thalassodendron ciliatum* was observed at 2 m but not at greater depths.

On the first tender transect on the west side of Ile du Sud (PSW3), substrate observations were made between 24 m (5°46.922′S, 53°17.589’E) and 2.5m (5°46.917′S, 53°18.172′E). At depths greater than 10 m, the substrate was bare sand or dense *Thalassodendron ciliatum* on sand, with no reef being observed at these depths. Between 10 m and 2.5 m branching corals on coral rock interspersed with *Halimeda* spp. and brown filamentous algae was observed.

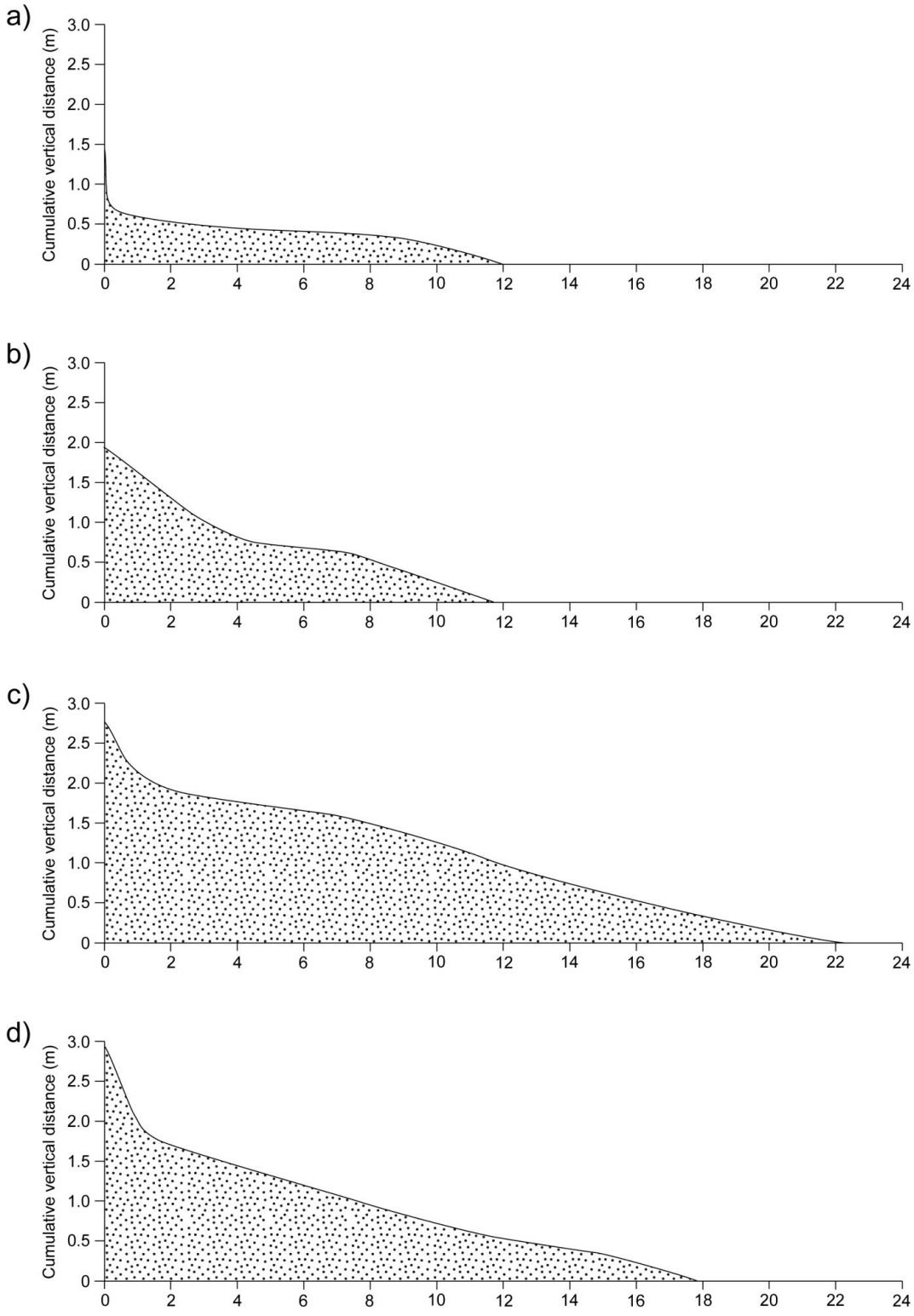

Figure 4. Beach profiles on Poivre island a) on the eastern side of the island at 5°44.932′S, 53°18.664′E - 5°44.932′S, 53°18.671′E; b) at the southestern point of the island at 5°45.202′S, 53°18.043′E - 5°45.208′S, 53°18.042′E; c) on the north north-west side of the island at 5°44.671′S, 53°18.123′E °44.661′S, 53°18.117′E; and d) on the northern side of the island at 5°44.606′S, 53°18.335′E - 5°44.597′S, 53°18.333′E.

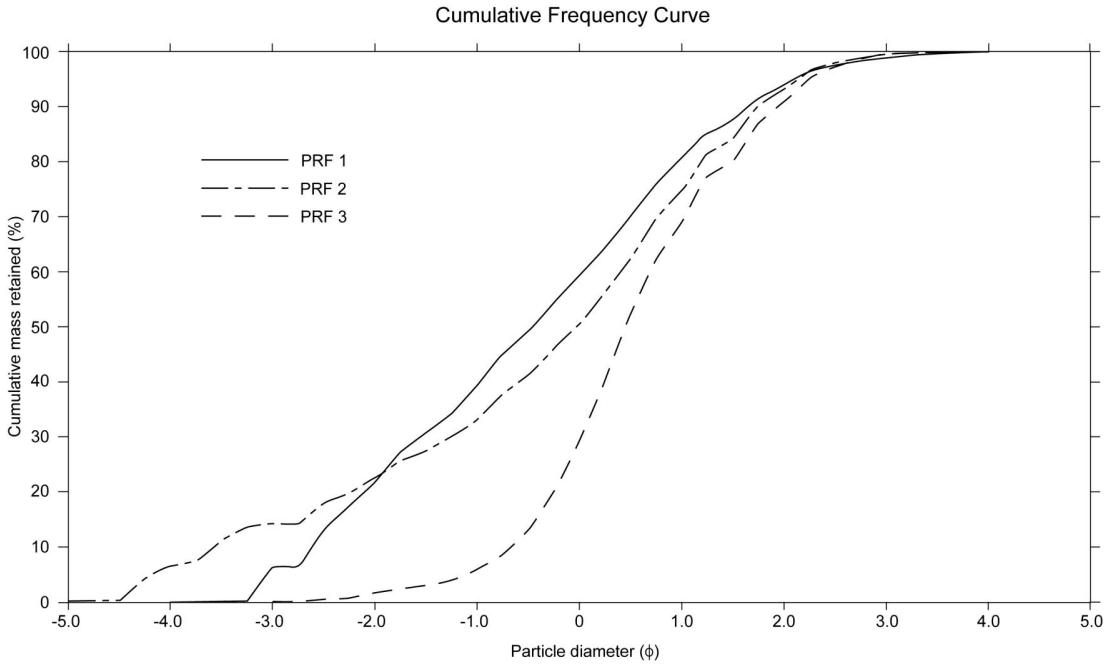

Figure 5. Cumulative frequency curves for sediment samples from reef-flats at Poivre island, Poivre.

The second transect on the west of Ile du Sud (PSW4) observed the substrate between 25 m (5°46.016′S, 53°17.347′E) and 1.9 m water depths (5°45.934′S, 53°17.687′E). Between 25 m and 22 m, the seabed was covered in dense *Thalassodendron ciliatum* on sand and between 21 m and 10 m the substrate was unvegetated sand. Between 10 m and 2.6 m reef was observed, comprising branching corals on coral rock interspersed with *Halimeda* spp. macroalgae. At 1.9 m a large patch of *Thalassodendron ciliatum* was observed.

Shallow-water Transects: East Side

Three shallow-water transects were undertaken on the east side of the islands. The transect that ran due west towards Poivre (PSW5) recorded substrate from 16 m (5°45.091′S, 53°19.431′E) to 5 m (5°45.981′S, 53°19.325′E). Throughout this transect the substrate was observed as coral on coral rock, with sand patches and sand channels shallower than 15 m. The amount of live coral present was estimated to range between 2% and 15% and the dominant genera were *Acropora* and *Pocillopora*. No macroalgae or seagrass was observed along this transect.

The transect on the east side of the atoll which ran in towards the gap between the two islands (PSW6) observed substrate between 21 m (5°45.657′S, 53°19.383′E) and 3.5 m (5°45.571′S, 53°19.225′E). Typically the substrate was composed of coral on coral rock, interspersed with sand and rubble. Live coral cover was estimated to range between 5% and 10% and recognisable genera were *Acropora* and *Turbinaria*. *Halimeda* spp. macroalgae were observed at one sampling site along the transect.

The transect (PSW7) which ran in towards the eastern side of Ile du Sud observed the benthos between 20 m (5°46.637′S, 53°19.259′E) and 3.5 m (5°46.689′S, 53°19.065′E). Between 21 m and 12 m, large amounts of rubble were observed, interspersed with branching corals (*Acropora* spp. and *Pocillopora* spp.), which accounted for approximately 5% of the benthos. At depths shallower than 12 m, coral on coral rock was observed, with live coral cover constituting between 5% and 10% cover.

Benthic Surveys

Benthic surveys (January 2005) were conducted at 20 m, 15 m, 10 m and 5 m depths on the western fore-reef slope (Dives on Fig. 1). Coral rubble accounted for 53% of the benthos at 10 m, and high levels of rubble were recorded at all depths except for at 5 m depth (Table 4). The amount of bare substrate was greatest at the shallowest (5 m) and deepest (20 m) sites and the amount of calcareous algae was also highest at the deepest site. Live scleractinian cover was greatest at 15 m, followed by that at 20 m, where it constituted 25% and 20% cover respectively (Table 4). Live scleractinian cover constituted only half this amount (approximately 10%) at the shallower two sites. Non-Scleractinia were only observed at the shallower two sites and at 10 m depth, contributed to 5% of the benthos. Macroalgal cover was low at all depths, but displayed the highest cover (4%) at the shallowest site.

The coral community was identified to genus level and Table 5 shows the proportions of each coral genus at each of the survey depths.

Table 4. Percentage benthic cover on Poivre fore-reef slope at 20 m, 15 m, 10 m and 5 m water depths, from video data analysis.

Benthic Category	Percentage Cover at 20 m Depth	Percentage Cover at 15 m Depth	Percentage Cover at 10 m Depth	Percentage Cover at 5 m Depth
Sand	3.1	12.9	8.2	33.3
Rubble	23.6	36.9	53.4	8.8
Bare Substrate	21.9	9.9	12.2	33.4
Dead Standing Coral	0.0	0.1	0.2	0.0
Pink Calcareous Algae on Bare Substrate	30.1	15.6	10.1	8.7
Pink Calcareous Algae on Dead Standing Coral	0.0	0.0	0.2	0.1
Scleractinia	19.5	24.6	8.6	11.0
Non-Scleractinia	0.0	0.0	4.8	0.5
Macroalgae	1.8	0.0	2.1	4.0
Others	0.1	0.0	0.2	0.3

Table 5. Coral genera as a proportion of the overall coral community at 20 m, 15 m, 10 m and 5 m water depth, from video transect analysis.

Coral Genus	Percentage of Coral Community at 20m Depth	Percentage of Coral Community at 15m Depth	Percentage of Coral Community at 10m Depth	Percentage of Coral Community at 5m Depth
Scleractinia				
Porites	39.0	47.8	5.7	23.7
Hydnophora	0.0	0.0	1.7	1.4
Favia	0.0	3.8	1.7	0.7
Favites	1.5	2.3	2.3	7.4
Physogyra	0.4	0.0	0.0	0.0
Galaxea	0.0	0.6	0.0	0.7
Goniastrea	3.4	2.6	4.0	15.5
Leptastrea	1.1	1.5	0.0	0.0
Astreopora	0.0	0.0	2.8	8.1
Cyphastrea	0.8	0.0	0.0	0.0
Goniopora	0.0	0.0	0.0	2.7
Pavona	4.2	12.2	4.0	1.4
Platygyra	0.0	0.6	0.0	1.4
Mycedium	0.8	0.0	0.0	0.0
Acanthastrea	0.0	0.6	0.0	0.7
Acropora	5.3	3.8	6.8	9.5
Pocillopora	21.2	19.1	27.8	18.9
Stylophora	0.0	0.0	1.1	4.1
Montipora	13.6	0.0	0.0	0.0
Leptoseris	1.9	0.3	0.0	0.0
Echinopora	0.0	0.0	0.6	0.0
Fungia	6.4	4.9	2.8	0.0
Herpolitha	0.4	0.0	2.8	0.0
Non-Scleractinia				
Sinularia	0.0	0.0	0.6	4.1
Dendrophyllia	0.0	0.0	0.6	0.0
Dendronephthya	0.0	0.0	0.0	0.0
Heliopora	0.0	0.0	34.7	0.0

Figures 6-9 graphically display the proportions of the most prevalent coral genera at each survey depth.

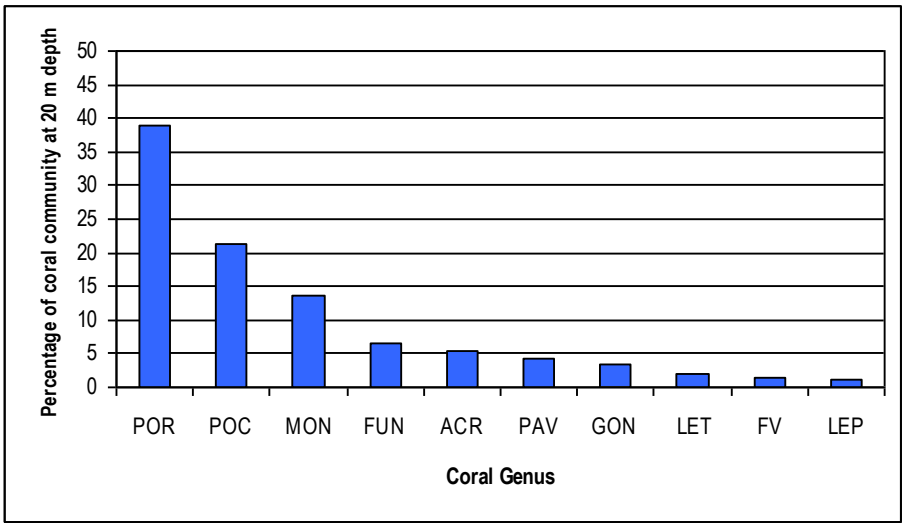

Figure 6. Percentage cover by different coral genera in order of dominance at 20 m depth, from video transect analysis. POR = *Porites*, POC = *Pocillopora*, MON = *Montipora*, FUN = *Fungia*, ACR = *Acropora*, PAV = *Pavona*, GON = *Goniastrea*, LET = *Leptoseris*, FV = *Favites*, LEP = *Leptastrea*.

At 20 m, the dominant coral genus was *Porites*, which represented 39% of the coral community. The second ranking genus, *Pocillopora*, constitution only half this amount (21%). *Montipora* was the third most dominant genus and together these three genera constituted three quarters of the total coral community.

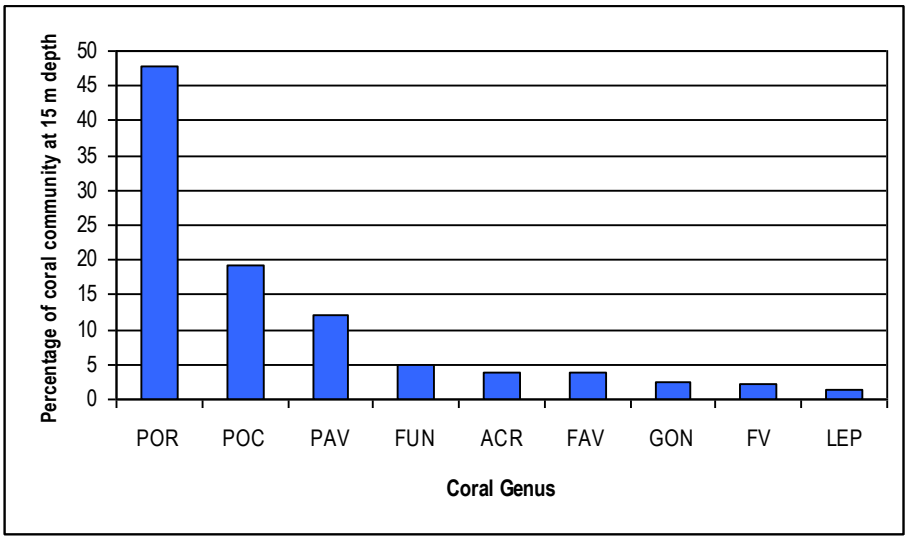

Figure 7. Percentage cover by different coral genera in order of dominance at 15 m depth, from video transect analysis. POR = *Porites*, POC = *Pocillopora*, PAV = *Pavona*, FUN = *Fungia*, ACR = *Acropora*, FAV = *Favia*, GON = *Goniastrea*, FV = *Favites*, LEP = *Leptastrea*.

At 15 m, again the two most dominant genera were *Porites* and *Pocillopora*, but at this shallower depth, the dominance of *Porites* was even greater, representing nearly half of the total coral community. *Pocillopora* represented 19% of the coral community, but at this depth, the third most dominant genus was *Pavona*.

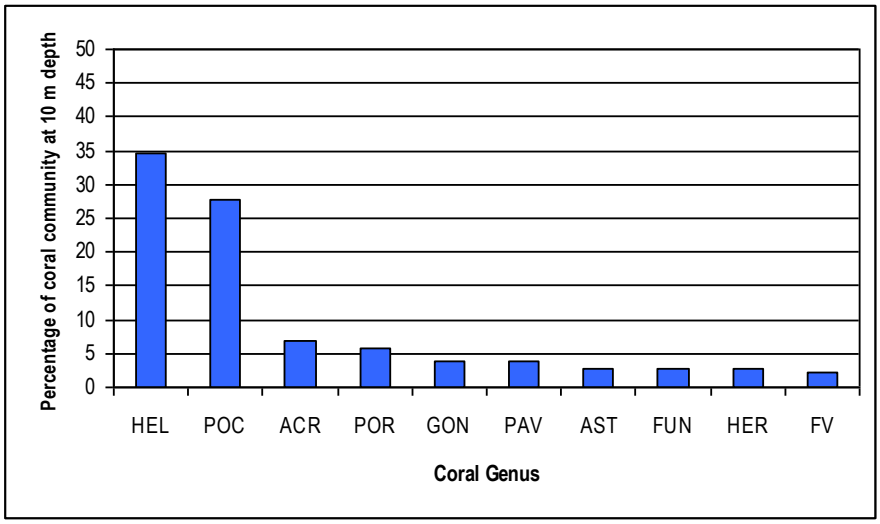

Figure 8. Percentage cover by different coral genera in order of dominance at 10 m depth, from video transect analysis. HEL = *Heliopora*, POC = *Pocillopora*, ACR = *Acropora*, POR = *Porites*, GON = *Goniastrea*, PAV = *Pavona*, AST = *Astreopora*, FUN = *Fungia*, HER = *Herpolitha*, FV = *Favites*.

At 10 m, the blue coral *Heliopora coerulea* was dominant, representing 35% of the coral community, closely followed by *Pocillopora* spp. which represented 28% of the community. Interestingly, *H. coerulea* was not found at any other survey depth. The third and forth most dominant genera were *Acropora* (7% of the community) and *Porites* (6% of the community).

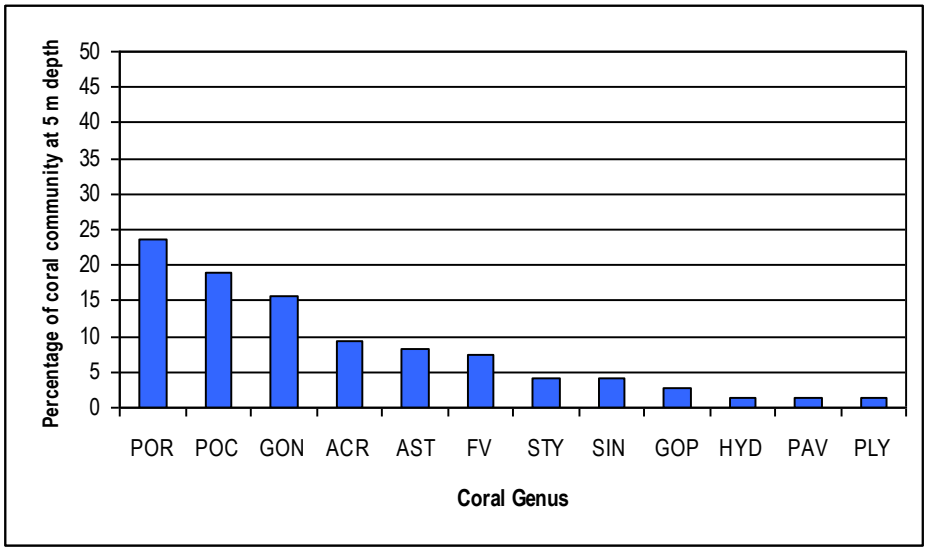

Figure 9. Percentage cover by different coral genera in order of dominance at 5 m depth, from video transect analysis. POC = *Pocillopora*, POR = *Porites*, GON = *Goniastrea*, ACR = *Acropora*, AST = *Astreopora*, FV = *Favites*, STY = *Stylophora*, SIN = *Sinularia*, GOP = *Goniopora*, HYD = *Hydnophora*, PAV = *Pavona*, PLY = *Platygyra*.

At 5 m, coral dominance followed that found at 20 m and 15 m, with *Porites* (24%) being the dominant genus, followed by *Pocillopora* (19%). *Goniopora* and *Acropora* were found to be the next most dominant genera. Non-scleractinian corals were represented by *Sinularia* spp. which represented 4% of the coral community.

Fish Surveys

Seventy-three fish species from 19 families were recorded. These varied in trophic group and size from large lethrinids such as *Lethrinus olivaceus* to small pomacentrids such as *Dascyllus carneus*. Labrids were the most speciose family recorded (18 species) followed by pomacentrids (11 species) and acanthurids (8 species). All fish species observed at Poivre are listed, by family group, below:

Acanthuridae
Acanthurus leucosternon
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus tennenti
Acanthurus triostegus
Ctenochaetus striatus
Ctenochaetus strigosus
Naso lituratus

Balistidae
Balistapus undulates
Melichthys indicus

Caesionidae
Caesio xanthonota

Carangidae
Caranx melampygus

Chaetodontidae
Chaetodon auriga
Chaetodon guttatissimus
Chaetodon lunula
Chaetodon meyeri
Chaetodon trifasciatus

Cirrhitidae
Cirrhitichthys oxycephalus
Paracirrhites forsteri

Gobiidae
Ptereleotris evides

Holocentridae
Myripristis sp.
Neoniphon samara
Sargocentron caudimaculatus
Sargocentron spiniferum

Labridae
Anampses meleagrides
Bodianus anthiodes
Bodianus axillaris
Cheilinus fasciatus
Cheilinus triolobatus
Coris cuvieri
Coris frerei
Epibulus insidiator
Gomphosus caeruleus
Halichoeres scapularis
Hemigymnus fasciatus
Hologymnosus annulatus
Labrichthys unilineatus
Labroides bicolor
Labroides dimidiatus
Macropharyngodon bipartitus
Stethojulis albovittata
Thalassoma hebraicum

Lethrinidae
Lethrinus olivaceous
Lethrinus xanthochilus
Monotaxis grandoculis

Lutjanidae
Aprion virescens
Lutjanus bohar

Monacanthidae
Cantherhines pardalis

Mullidae
Parupeneus barberinus
Parupeneus cyclostomus

Nemipteridae
Scolopsis frenatus

Pomacanthidae
Apolemichthys trimaculatus
Centropyge multispinis
Pomacanthus imperator
Abudefduf sexfasciatus
Abudefduf vagiensis
Chromis dimidiate
Dascyllus carneus
Plectroglyphidodon lacrymatus
Pomacentrus caeruleus
Pomacentrus sulfurous
Pomacentrus weberi

Scaridae
Scarus frenatus
Scarus rubroviolaceus
Scarus sordidus

Serranidae
Aetholoperca rogaa
Cephalopholis argus
Cephalopholis nigripinnis
Nemanthias carberryi
Plectropomus punctatus
Variola louti

Siganidae
Siganus argenteus

Tetraodontidae
Canthigaster valentine

The number of fish species recorded at Poivre was lower than in previous surveys in the Seychelles (Jennings et al., 1995; Spalding and Jarvis, 2002). However the lower sampling effort in this study is presumed to be the major cause of this. Twenty-two species overlapped with the most common and abundant species found by Spalding and Jarvis (2002) in the southern Seychelles and 43 overlapped with Jennings et al.'s (1995) survey of the granitic Seychelles islands.

Reef-Flat Surveys

The reef-flat video transects identified only two species of seagrass; *Cymodocea serrulata* and *Thalassodendron ciliatum*. *C. serrulata* was the more dominant species, with *T. ciliatum* only being recorded at one site on the eastern reef-flat (Table 6). However, the video transect results do not concur with the results of the seagrass surveys (Table 7).

Table 6. Percentage benthic cover on Poivre reef flat from video data analysis.

Benthic Category	Reef-flat T1 (East)	Reef-flat T2 (East)	Reef-flat T3 (East)	Reef-flat T4 (West)	Reef-flat T5 (West)
Sand	11.1	6.3	24.2	62.7	79.4
Cymodocea serrulata	88.9	24.2	75.8	37.3	20.6
Thalassodendron ciliatum	0.0	69.5	0.0	0.0	0.0

Table 7. Percentage composition of seagrass and macroalgae within sample quadrats on Poivre reef flat. * indicates that the species was not recorded within the quadrats but this does not mean that these species were absent at this site.

	Percentage Composition
Seagrass	
Thalassodendron ciliatum	39.3
Cymodocea serrulata	1.8
Halophila ovalis	*
Halophila uninervis	*
Macroalgae	
Halimeda opuntia	35.3
Halimeda discoidea	7.0
Sargasum sp.	*
Other compositions	*
Sand	10.9
Average dry weight (g/m2)	1279.6

The seagrass survey results show that the dominant species sampled on the Poivre reef flat was *Thalassodendron ciliatum*, although this value was equalled by macroalgae of the genus Halimeda. The samples showed a low reef-flat diversity, with just two species (*T. ciliatum* and *H. opuntia*) contributing to three quarters of the total composition. Fauna on the reef-flat included numerous species of sea cucumbers and brittle stars, and between the islands of Poivre and Ile du Sud, mudskippers and barnacles were observed.

Other Observations

A pod of short-finned pilot whales (*Globicephala macrorhynchus*) were sighted on the northeast coast of Poivre (at 5°45.317′S, 53°16.594′E).

DISCUSSION

Terrestrial Surveys

Fifty-four plant species were observed during the short visit (3.5 hours) to Poivre in January 2005. This is approximately two-thirds the number described by Robertson and Fosberg (1983) having spent two days on the island in October 1976 (Robertson and Fosberg (1983) identified 87 species in total). Thirteen of the 54 plants observed in 2005 are new records. Forty-one species were identified by both Robertson and Fosberg (1983) and the 2005 expedition but Robertson and Fosberg (1983) identified a further 46 species that were not observed by the 2005 expedition.

The vegetation at Poivre was seen to closely resemble that at Marie-Louise, but was less similar to that found at Desnoeufs. This could be attributed to the larger sizes of Marie-Louise and Poivre, and the presence of their extensive coconut groves which create microhabitats that enable a more diverse plant community to be maintained. Robertson and Fosberg (1983) did not indicate which were the most dominant species on Poivre, hence direct comparisons cannot be made.

Marine Surveys

The 1997-98 coral bleaching event as a result of increased sea surface temperature had a very severe impact on reefs of the Indian Ocean. As coral rubble is a typical sign of recent coral mortality (Rasser and Riegl, 2002), the high proportion of rubble and bare substrate on the reefs of Poivre suggests that this recent bleaching event may have led to a benthic community with reduced scleractinian cover. However, although the granitic Seychelles islands in the north suffered over 90% coral mortality during the 1997-98 ocean warming (Lindén and Sporrong, 1999), the southern islands were less severely affected, with average mortality of around 60% (Spencer et al., 2000). Although the extent of the 1997-98 coral bleaching in the Amirantes is unknown, due to the relatively shallow nature of the Amirantes Bank (maximum depth ~70 m but typically 11 – 27 m)

it is likely that the bleaching impact was more similar to in the grantics compared to Seychelles reefs further south which are surrounded by much deeper water.

Live coral cover on the western reefs of Poivre was seen to represent between 9% (at 10 m) and 25% (at 15 m) of the benthos in 2005. The two most dominant genera were typically *Porites* followed by *Pocillopora*, except at 10 m where *Heliopora coerulea* dominated. *Pocillopora damicornis* has been described as an opportunistic species, due to its rapid reproductive cycle, widespread larval dispersal and fast growth rate on settling, enabling it to quickly occupy any newly available space (Endean and Cameron, 1990) such as that available following the 1997-98 coral bleaching event in the Amirantes group. However, the presence of *Porites* as the most dominant scleractinian genus at Poivre may suggest that these slow-growing, massive colonies survived the 1997-98 bleaching event.

The Netherlands Indian Ocean Programme expedition conducted three SCUBA surveys at Poivre, two on the northern reef-slope (5°45′S, 53°18′E) on 29th and 31st December 1992 and one on the western reef slope (5°46'S, 53°18'E) on 1st January 1993. On the northern reef-slope, the first survey reported 41% live coral cover, comprising 67% massive *Porites* spp., 40% acroporids and 6% pocilloporids and the second survey reported 50% live coral cover comprising 12% *Porites rus*, 76% acroporids, 10% pocilloporids and 3% *Pavona varians* (van der Land, 1994). The survey on the western reef slope reported only 10% live coral cover, and this comprised 63% massive *Porites* spp., 14% acroporids and 18% pocilloporids (van der Land, 1994). These previous surveys suggest that the 1997-98 bleaching event removed a number of corals, especially branching corals from the community, which may explain the large amounts of coral rubble recorded on the reefs here. *Porites* appears to have always been the dominant coral genus found on the reefs of Poivre.

Shallow water transects at Poivre indicated that *Thalassodendron ciliatum* seagrass beds were abundant on the western side of the atoll but less prevalent on the eastern side. On the reef flats of Poivre, *Thalassodendron ciliatum* was recorded to be the most dominant seagrass species, although it constituted an average of only 39% cover. The sites surveyed at Poivre also exhibited very high coverage by *Halimeda* spp. macroalgae, specifically *Halimeda opuntia* and *Halimeda discoidea*. At Poivre, the substrate on which the seagrass was growing consisted of a greater percentage of mud and silt compared to sand, whereas at other Amirantes islands there was greater percentage of sand and coral rubble in the substrate. This might help explain the greater percentage of *Halimeda* spp. macroalgae compared to at other Amirantes sites.

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PLATES

Plate 1. Aerial view of Poivre Atoll in 1999, showing Poivre island in the north, Ile du Sud in the south and the man-made causeway connecting the two islands (source: Maps Geosystems; reproduced with kind permission of the Government of the Seychelles).

Plate 2. Poivre island looking west, January 2005. Note emergent reef-flat sands, extensive reef flats (with dark areas of high density seagrass), channel to Poivre island and range of fore-reef slope habitats (photograph: Herb Ripley, January 2005).

Plate 3. Ile du Sud and Florentin, looking northwest, January 2005 (photograph: Herb Ripley, January 2005).

Plate 4. Poivre island looking northwest, showing causeway connecting Poivre island to Ile du Sud. Note lineations in reef-flat low density seagrass and macroalgae (photograph: Herb Ripley, January 2005).

Plate 5. View of causeway from Poivre island, looking south to Ile du Sud. Note presence of *Rhizophora mucronata* mangroves on the causeway (photograph: Martin Callow, January 2005).

Plate 6. Southwestern reef flat and Ile du Sud, looking southeast. Note broad embayments in the reef flat and the series of transverse rubble bars on the reef flat which stretch from coral rubble at the reef-flat margin to underpinning the spit structures on northwestern Ile du Sud.

Plate 7. Emergent reef-flat sands and muds between Poivre island and Ile du Sud with single *Rhizophora mucronata* mangrove (photograph: Jen Ashworth, January 2005).

Plate 8. One of the many tracks on Poivre island showing high canopy of *Cocos nucifera* (photograph: Martin Callow, January 2005).

Plate 9. Littoral hedge showing *Scaevola taccada* and *Casuarina equisetifolia* (photograph: Martin Callow, January 2005).

Plate 10. Beach on southern margin of Poivre island (photograph: Jen Ashworth, January 2005).

Plate 11. Medium density seagrass exposed at low tide on the reef flat on the western side of Poivre island (photograph: Martin Callow, January 2005).

Plate 12. *Rhizophora mucronata* mangroves on the southern side of Poivre Island (photograph: Jen Ashworth, January 2005).