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MORPHOLOGY AND MARINE ECOLOGY OF BOUDEUSE, AMIRANTES, SEYCHELLES

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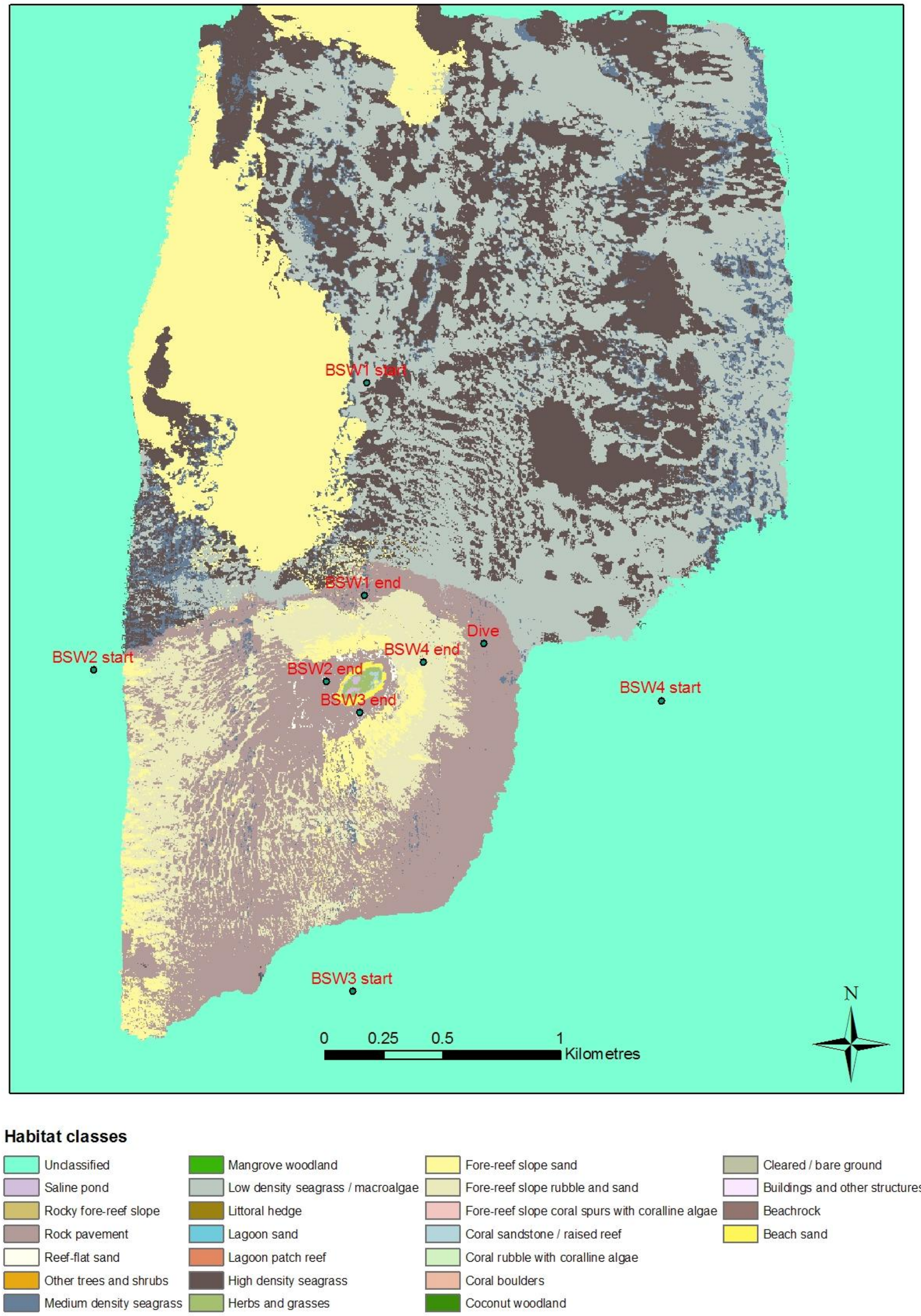

Figure 1. Location of shallow-water transects (BSW1, BSW2, BSW3 and BSW4) and SCUBA dive survey at Boudeuse, 25th January 2005. Habitat map from Spencer et al. (2009).

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INTRODUCTION

The Amirantes group, Seychelles, comprises 24 islands and islets lying between 5º and 6º south of the equator on the Amirantes Bank, western Indian Ocean. The group extends over a distance of 138 km, from African Banks in the north to Desnoeufs in the south. 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. Boudeuse is one of the two sand cays which rise up from the Banc de la Boudeuse, approximately 60 km south-west of Poivre atoll. The other sand cay, Etoile, lies 30 km north-east of Boudeuse. The two islands are believed to have been named after the two ships of Bougainville's circumnavigation (1766 – 1769), being explored by the Chavalier du Roslan in 1771 (Lionnet, 1970). The difficulty of landing in even calm weather, as noted by H.M.S. Alert in 1882 (Coppinger, 1885), and the lack of commercially viable guano deposits, have meant that Boudeuse has never been permanently inhabited.

Boudeuse is small (1 ha) and isolated, being situated at the south-westernmost point of the Amirantes Bank, surrounded by water depths of 11 – 17 m but very close to water depths in excess of 1,000 m. It is approximately 200 m in length and 100 m in width, with a maximum vertical elevation of less than 5 m. The subaerial island of Boudeuse sits upon a rocky platform and displays extensive beach sandstone (Baker, 1963) (Fig. 1). The island is treeless but oblique aerial photographs taken in 2005 show that low growing vegetation is present around the outer edge and in the centre of the island (Plate 1). There are two small saline ponds in the western part of the island. The terrestrial vegetation is interspersed with coral sandstone, which is more extensive in the east of the island. Coral boulders occur on the western beaches and at the southern point.

Boudeuse is thought to be one of the last two strongholds of *Sula dactylatra* (Masked Booby) in the Seychelles, with 3,000 - 5,000 pairs breeding there annually (Stoddart, 1984a). The island is protected under the Wild Birds Protection (Nature Reserve) Regulations of 1966 but law enforcement is extremely difficult as the island has no human presence to report the activities of poachers (BirdLife International, 2008). In July 1955, it was estimated that there were around 5,000 birds present (Ridley and Percy,

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1958). In 1976, 7,000 birds (representing ~3,000 pairs) were estimated on the island at all stages of breeding, but mostly with large chicks. However, Feare noted a pile of corpses left by fishermen and soon after his visit many of the fledglings that he had banded were killed (Feare, 1978).

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 10^{th} – 28^{th} 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. Following an initial reconnaissance, it was deemed unsafe to land on Boudeuse but shallow marine surveys were undertaken on 25^{th} January 2005.

TOPOGRAPHY AND GEOLOGY

Of the seven reef types identified in the Seychelles by Stoddart (1984b), three are present in the Amirantes; platform reefs, atolls and drowned atolls. The platform reefs vary in their morphology; Spencer et al. (2009) identified three categories of platform reef. They defined Boudeuse as a Type 2 platform reef, where the reef island is surrounded by a narrow peripheral reef but where both island and reef sit on an extensive and relatively shallow and gently sloping rock platform, covered in rubble, sand and seagrass beds and often incised by numerous small, sub-parallel and anastomosing channel systems. The total reef platform area, at 9.00 km^2, is very similar to that at Marie-Louise (7.89 km^2) and Desnoeufs (5.93 km^2). Unlike these two islands, however, at Boudeuse both the reefs and the island accounts for a tiny proportion of the total reef platform surface area (Table 1).

Table 1. Morphometry of the platform reef at Boudeuse.

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)
9.00	0.08	0.03	0.29

[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)

There are three major geomorphological units at Boudeuse (Spencer et al., 2009). The sand cay and raised rock platform sit in the north-western quadrant of a more extensive circular reef platform (Plates 1-4). To the west and south of the sand cay, this platform is characterized by a radiating pattern of anastomosing channels filled with sand and rubble (Fig. 1, Plate 1). To the north and east of the island, an extensive area of fore-reef slope sand and rubble covers the rock platform and airborne mapping shows scattered areas of seagrass growing on this platform. 0.5 km north of the island, a sharp convex, E-W trending boundary separates the rock platform from the other two geomorphological units. These are, to the north, an extensive area of bare fore-reef slope sand, 2 km in length and up to 1 km in width, and, to the northeast, extensive seagrass beds of varying densities.

METHODS FOR MARINE SURVEYS

Shallow-water Boat Transects

Two rigid inflatable boats were used to conduct shallow-water transects at four sites around Boudeuse. Transects started in deep water and ran in towards a pre-decided point on the land. Transects ran from N-S (BSW1: 6°04.665′S, 52°49.949′E - 6°05.208′S, 52°49.968′E), W-E (BSW2: 6°05.254′S, 52°49.357′E - 6°05.292′S, 52°49.820′E), S-N (BSW3: 6°06.111′S, 52°49.964′E - 6°05.452′S, 52°49.982′E) and E-W (BSW4: 6°05.405′S, 52°50.684′E - 6°05.309′S, 52°50.134′E) (Fig. 1).

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, the position was fixed using a hand-held GPS unit (horizontal resolution = ±10 m) and the water depth and bottom substrate (viewed through a glass-bottomed bucket) recorded. 27 substrate observations were recorded on the N-S transect, 11 substrate observations were recorded on the W-E transect, 12 substrate observations were recorded on the S-N transect and 21 substrate observations were recorded on the E-W transect.

Benthic Surveys

A single SCUBA dive took place at a single site in the north-east (6°05.271′S, 52°50.273′E; Dive on Fig. 1) at a depth of approximately 10 m. Quantitative surveys were conducted using the video transect method 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 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). Three video transects were conducted at a depth of 10 m.

The video transect footage was analysed using the AIMS 5-dot analysis method, 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 Boudeuse were recorded during the dive. All fish species seen during a 35 minute period at depths of between 12 m and 3 m were recorded. A random search pattern was followed and both pelagic and demersal species noted.

RESULTS OF MARINE SURVEYS

Shallow-water Transects

On the north side of the island (BSW1, Fig. 1), observations were made between 21 m water depth and 3.2 m over a distance of approximately 1 km. At depths greater than 11 m, *Thalassodendron ciliatum* seagrass beds were observed, interspersed with small patches of bare sand at 21 m, 19 m and 14 m water depths. Between depths of 11 m and 7 m, the substrate was typically a mixture of sand and coral rubble, although a small patch of *T. ciliatum* was recorded at 8.7 m depth. Shallower than 7 m, coral on coral rock was observed, interspersed with dense clumps of *Halimeda* spp.

Reefs on the west side of the island (BSW2, Fig. 1) were observed from 19 m to 3.3 m water depth over a distance of approximately 0.75 km. No seagrass was observed on the west side of the island. Rather, at depths greater than 6 m, the substrate was dominated by massive corals, such as Porites spp., and by encrusting corals interspersed with sand. At depths shallower than 6 m, Pocillopora became the dominant coral genus and there was extensive coverage by Halimeda spp. Pink calcareous algal cover was also observed at depths of approximately 3 m.

On the south side of the island (BSW3, Fig. 1), observations were made between water depths of 23 m and 2.6 m, over a distance of approximately 1 km. Seagrass was observed interspersed with corals (*Porites* spp. and *Pocillopora* spp.) at all depths between 23 m and 5.3 m, although at shallower depths, coral rock encrusted with algal turf and/or calcareous algae was the dominant benthic cover type.

Reefs on the eastern side of island (BSW4, Fig. 1) were observed between depths of 12.5 m and 3.8 m, over a distance of 0.9 km. All observations noted the presence of live coral on coral rock, frequently interspersed with *Halimeda* spp. and occasionally interspersed with coral rubble. No seagrass was recorded along this transect.

Benthic Surveys

The quantitative benthic surveys using SCUBA identified bare substrate (coral rock) as the dominant benthic category observed (32% cover) (Table 2). Sand and rubble were the next most dominant benthic categories recorded on the video transects, but neither of these categories featured highly in the shallow-water transects. As was observed on the shallow-water transects, macroalgae, specifically *Halimeda* spp., accounted for a high proportion of cover (15%) and represented twice as much of the benthos as live scleractinian cover (7%).

Table 2. Percentage benthic cover from video data analysis at 10 m water depth.

Benthic Category	Percentage Cover at 10 m Depth
Sand	15.3
Rubble	22.7
Bare Substrate	32.0
Pink Calcareous Algae on Bare Substrate	7.0
Pink Calcareous Algae on Dead Standing Coral	0.0
Scleractinia	7.0
Non-Scleractinia	0.3
Macroalgae	14.8
Others	0.9

The coral community was identified to genus level; Table 3 shows the percentage of each coral genus at the 10 m survey depth and Figure 2 illustrates the proportion of individuals represented by the ten most dominant coral genera.

Table 3. Coral genera as a percentage of the coral community at 10 m water depth, from video transect analysis.

Coral Genus	Percentage of coral community at 10 m depth
Scleractinia	
Porites	32.9
Hydnophora	0.7
Favia	4.6
Favites	16.5
Galaxea	2.6
Goniastrea	2.0
Leptastrea	6.6
Astreopora	2.6
Pavona	0.7
Platygyra	0.7
Acropora	8.6
Pocillopora	7.2
Montipora	9.9
Fungia	0.0
Non-Scleractinia	
Sinularia	1.3
Dendronephthya	3.3

Over a third of the coral community was made up of *Porites*, with the second most dominant genus being *Favites* (17% of the coral community) and the third being *Montipora* (10% of the coral community). The branching corals of *Acropora* and *Pocillopora* were the fourth and fifth most dominant genera, representing 9% and 7% of the coral community respectively. Non-scleractinian coral cover accounted for 0.3% of the total benthos (Table 2) and, within the non-scleractinian coral community, *Dendronephthya* was nearly three times more prevalent than *Sinularia*.

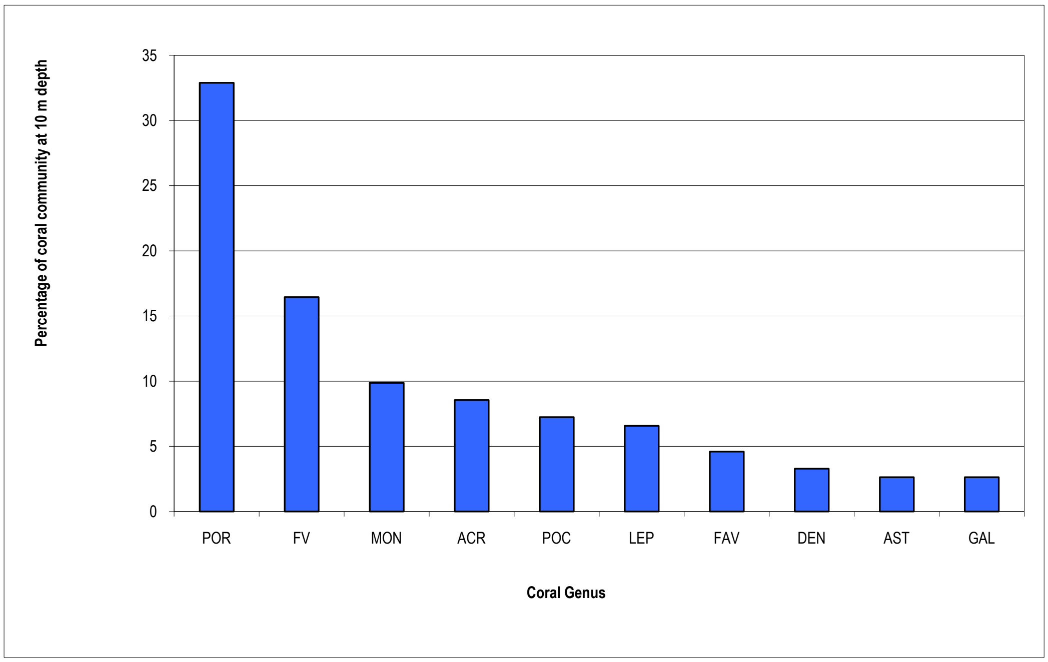

Figure 2. Percentage cover by different coral genera in order of dominance at 10 m depth, from video transect analysis. POR = *Porites*, FV = *Favites*, MON = *Montipora*, ACR = *Acropora*, POC = *Pocillopora*, LEP = *Leptastrea*, FAV = *Favia*, DEN = *Dendronephthya*, AST = *Astreopora*, GAL = *Galaxea*.

Fish Surveys

Fifty-seven fish species from 15 families were recorded at Boudeuse. These varied in trophic group and size from large lethrinids to small gobiids. Labrids were the most speciose family recorded (11 species) followed by acanthurids (9 species). The number of fish species recorded at Boudeuse was lower than documented in previous surveys in the Seychelles (Jennings et al., 1995; Spalding and Jarvis, 2002), most probably due to the lower sampling effort. Fourteen species overlapped with the most common and abundant species found by Spalding and Jarvis (2002) in the southern Seychelles and 32 overlapped with Jennings et al. (1995) survey of the granitic Seychelles islands. All fish species observed at Boudeuse are listed, by family group, below:

<u>Acanthuridae</u>
Acanthurus leucosternon
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus tennenti
Ctenochaetus binotatus
Ctenochaetus striatus
Naso brevirostris
Naso lituratus
Zanclus cornatus

<u>Balistidae</u>
Balistoides viridescens
Melichthys indicus
Sufflamen chrysopterus

<u>Chaetodontidae</u>
Chaetodon guttatissimus
Chaetodon lunula
Chaetodon sp.

<u>Cirrhitidae</u>
Cirrhitichthys oxycephalus
Paracirrhites forsteri

<u>Gobiidae</u>
Valencienna strigata

<u>Holocentridae</u>
Myripristis sp.
Sargocentron diadema
Sargocentron spiniferum

<u>Labridae</u>
Anampses meleagrides
Bodianus axillaris
Bodianus bilunulatus
Cheilinus fasciatus
Coris frerei
Halichoeres hortulanus
Hemigymnus fasciatus
Labroides dimidiatus
Macropharyngodon bipartitus
Thalassoma amblycephalum
Thalassoma hebraicum

<u>Lethrinidae</u>
Gnathodentex aureolineatus
Lethrinus xanthochilus

<u>Lutjanidae</u>
Aprion virescens
Lutjanus bohar
Lutjanus gibbus
Lutjanus monostigma

<u>Mullidae</u>
Parupeneus barberinus
Parupeneus bifasciatus
Parupeneus cyclostomus
Parupeneus macronema

<u>Pomacanthidae</u>
Apolemichthys trimaculatus
Centropyge acanthops
Centropyge multispinis
Pomacanthus imperator
Chromis dimidiata
Chromis vanderbilti
Dascyllus carneus
Dascyllus trimaculatus
Pomacentrus caeruleus

<u>Priacanthidae</u>
Priacanthus sp.

<u>Scaridae</u>
Scarus gibbus
Scarus rubroviolaceus

<u>Serranidae</u>
Cephalopholis nigripinnis
Pseudanthias squamipinis

<u>Synodontidae</u>
Unknown sp.

DISCUSSION

The reefs of Boudeuse displayed a low percentage of live coral cover in 2005 and were dominated by bare rock pavement, coral rubble, sand and macroalgae. The 1997-98 coral bleaching event as a result of increased sea surface temperature had a very severe impact on the reefs of the Indian Ocean (Wilkinson, 2000). The high level of macroalgal cover, bare rock and rubble at Boudeuse suggest that this recent bleaching event may have led to a benthic community with reduced scleractinian cover and increased macroalgal cover, as has been hypothesised elsewhere (e.g. Done, 1999). However, although the granitic Seychelles islands in the north suffered up to 90% coral mortality during the 1997-98 ocean warming (Lindén and Sporrong, 1999), reefs surrounding the southern Seychelles islands, such as the oceanic atolls of Alphonse and Aldabra 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 the grantic islands compared to Seychelles reefs further south which are surrounded by much deeper water.

The biology and reproductive strategy of different coral genera is likely to have influenced how different genera responded to the bleaching event and their subsequent recovery. For example, *Pocillopora damicornis* has been described as an opportunistic species, due to its rapid reproductive cycle and fast growth rate, enabling it to quickly occupy any newly available space (Endean and Cameron, 1990), but *Pocillopora* was only the 5th most dominant genus in the scleractinian community at Boudeuse. Of the small scleractinian community present at Boudeuse, *Porites* dominated the coral cover statistics. *Porites* being the most dominant genus may suggest that these slow-growing, massive colonies survived the 1997-98 bleaching event.

The well-reported difficulty of landing at Boudeuse, also experienced by the 2005 expedition, suggests that the reef here is subjected to consistently high wave energy levels. The constant pounding of waves on the coral rock cliffs surrounding the island may mean that there is generally low coral cover exhibited on the reefs at Boudeuse and/or this may have impeded coral recovery at Boudeuse following the 1997-98 coral bleaching event.

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PLATES

Plate 1. View of Boudeuse looking towards the south-east. Note large sandsheet edged by seagrass in foreground, rocky platform upon which the island sits and rock pavement (breaking waves at margin) to the west of the island (photograph: Herb Ripley, January 2005).

Plate 2. Boudeuse island looking south-east showing vegetated island surface and steep beach with boulder deposits (photograph: Jen Ashworth, January 2005).

Plate 3. Boudeuse island (right) with exposed rock pavement (left). Note shallow submerged rock pavement in foreground (photograph: Martin Callow, January 2005).

Plate 4. Detail of exposed rock pavement to west of island (photograph: Martin Callow, January 2005).