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Cover image: Fisherman pushes his boat along the channels around Inhaca Island, Mozambique (© José Paula)

The benthos and ichthyofauna of Baixo São João, Ponta do Ouro Partial Marine Reserve, southern Mozambique

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Abstract
A reef survey was conducted at Baixo São João, southern Mozambique, in July 2015. This involved point intercept analysis of photo-quadrat transects of the benthos recorded in the northern, central and southern parts of the reef, on the reef top and its inshore and offshore slopes. Visual techniques were used to describe the ichthyofauna. The coral community proved to be uniform within all reef zones and relatively rich compared to other southern Mozambican reefs, but with no unique or fragile species. Hard corals were predominant (mean cover = 32.3%), followed by soft corals (mean cover = 12.8%). Little coral damage was evident. A total of 97 species of reef fish, belonging to 30 families was recorded. Large specimens (>30 cm) were common, including species of commercial importance, as well as top predators. The reef merits protection in view of its good condition, remoteness and depth (>12 m), attributes that may endow it with a measure of resilience to bleaching associated with increased sea temperatures and make it useful as a reference site for baseline and comparative studies.

Keywords: hard coral; soft coral; reef fish; sanctuary; southern Mozambique

Introduction
Coral reefs are declining globally and this is attributed to a variety of human-related disturbances (Wilkinson, 2008). Such reefs are rich in biodiversity making them a focal point for fishing, tourism and scuba diving. This renders them valuable as an economic resource to local communities and recreational stakeholders. This is very much the case in the Western Indian Ocean (WIO) region and Mozambique, where a large proportion of the population lives in the coastal zone and depends heavily on marine and coastal resources (Hicks, 2011).

Reefs in the Ponta do Ouro Partial Marine Reserve in southern Mozambique are a valuable asset: they play a pivotal role in the tourism industry in the area (Daly *et al*., 2015), with social and economical benefits to the local communities (Come, 2014), and constitute a prominent and unique ecological feature, comprising some of the highest-latitude reefs in the world (Celliers and Schleyer, 2008).

Baixo São João lies in the northern section of the Ponta do Ouro Partial Marine Reserve, just south of Inhaca Island. It was surveyed when the development potential of the southern Mozambique coast was assessed in 1996, at which time the mean benthic cover was visually estimated to be 33% (Robertson *et al*., 1996). More recent visits by scientists indicated that this has improved (Pereira *et al*., 2015), resulting in this study.

Methods
Study Area
Baixo São João is a rocky massif lying approximately 4 km off the southern Mozambican coast between ~26.351°S - 26.363°S at ~32.974°E. It appears similar in structure to the reefs known as Baixo Danae north

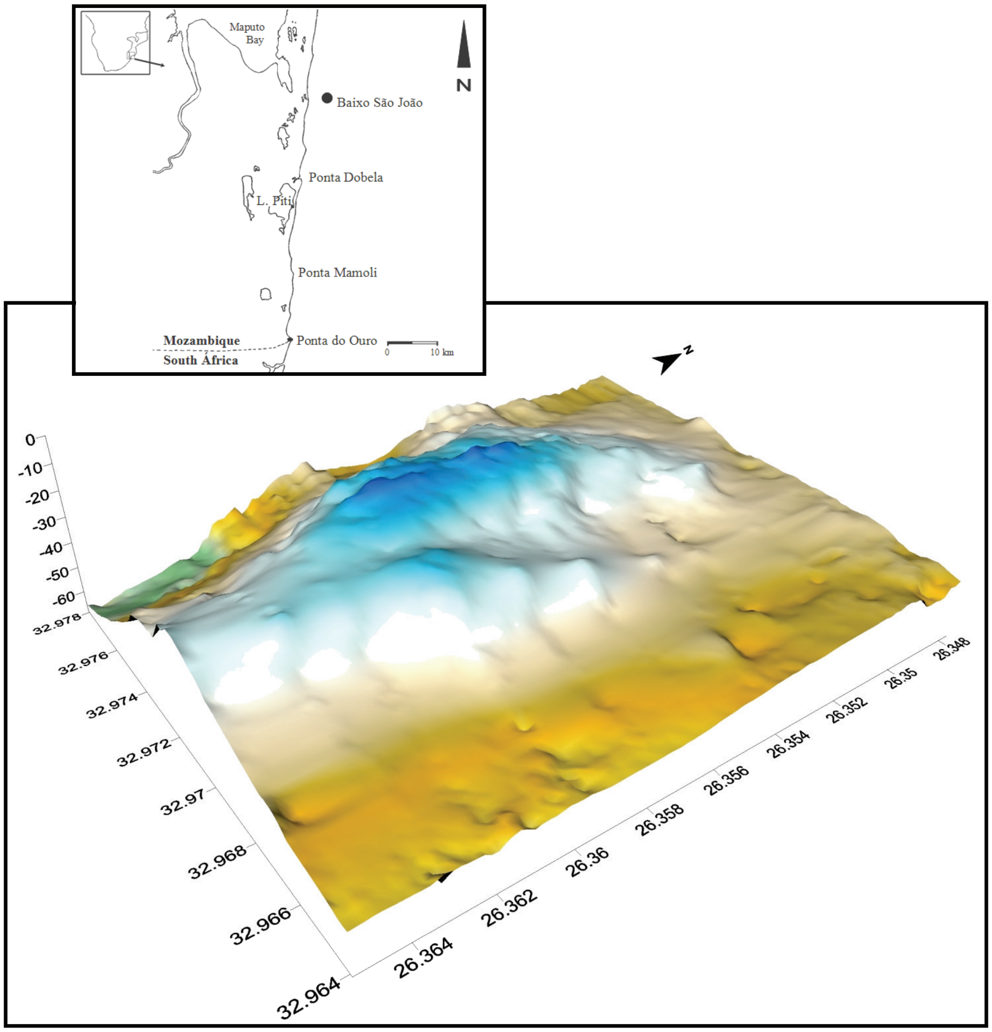

Figure 1. Location, bathymetry and coordinates for Baixo São João, Reserva Marinha Parcial da Ponta do Ouro.

of Inhaca Island, and Aliwal Shoal south of Durban in KwaZulu-Natal. These consist of dune rock known as aeolianite, derived from beach dunes that fossilised prior to the most recent rise in sea levels (Ramsay, 1996). Baixo São João runs parallel to the coast and is a large reef with a smaller side-branch bifurcating from its southern base (Figure 1). It is just over 1 km long, ~400 m wide at the widest point, and rises from a depth of ~30 m at its periphery to 12 m at its narrow crest.

Data Collection

Data were collected between 22 and 25 July 2015. A preliminary bathymetry study was conducted using a combination GPS/fishfinder (Garmin GPSMap 441s) before the reef surveys. A pre-determined grid that was superimposed on existing nautical charts was used, and tracked depth data were collected in transects across the reef. These data were analysed using Surfer 12 software, according to the methodology described by Heyman *et al.* (2007). A representation of the three-dimensional

Table 1. Number of transects undertaken on Baixo São João and the number of photo-quadrats recorded in each. N, C and S denote the north, central and south regions; I, T, and O denote the inner slope, reef top and outer slope respectively.

	Reef zone							
	NI	NT	NO	CT	CO	SI	ST	SO
No.	53	150	80	54	90	88	184	22
Depth (m)	15-23	12-15	15-20	12-18	18-26	14-18	12-14	15-22

reef structure (Figure 1) was then used to determine the location of the benthic surveys.

Reef surveys were conducted using SCUBA and a digital camera in an underwater housing. Eight transects were recorded within bathymetric and physiognomic zones for laboratory analysis, these being in the northern, central and southern (N, C, S) parts of the reef on the reef top and its inshore and offshore slopes (T, I, O). The photographs were taken while swimming with the camera held at right angles to the reef face at a distance of 93 cm, the latter being regulated by a spacer bar attached to the camera housing. The area photographed in each camera frame was thus constant, being 0.32 m^2, and the distance between each photograph was 2-4 m, this being dictated by a pause in the camera

Table 2. List of living biota and non-living substrata recorded in photo-quadrats on Baixo São João with their percentage cover (±SD). Information in bold is referred to in the text.

Categories	% Cover	Sd	Categories	% Cover	Sd
Hard coral			**Soft coral (cont.)**		
Acanthastrea	0.4	2.8	*Lobophytum*	1.1	6.9
Acropora	**3.0**	9.3	*Rumphella*	<0.1	1.5
Alveopora	1.5	10.4	*Sarcophyton*	1.1	6.7
Astreopora	**5.8**	**14.2**	***Sinularia***	**8.8**	**20.0**
Coscinaraea	<0.1	0.6	*Stereonephthya*	<0.1	0.6
Cyphastrea	<0.1	0.4	*Tubipora*	<0.1	1.1
Echinopora	1.1	7.0	**Other Cnidaria**		
Favia	0.4	2.3	Corallomorpharia	<0.1	0.4
Favites	0.7	3.6	**Bivalves**		
Fungia	<0.1	0.4	*Tridacna*	<0.1	0.8
Galaxea	<0.1	0.8	**Macroalgae**		
Goniastrea	0.2	1.9	*Padina*	**<0.1**	**0.4**
Goniopora	<0.1	0.4	Turf	**14.6**	**15.5**
Gyrosmilia	<0.1	0.8	Other macroalgae	0.1	1.1
Hydnophora	<0.1	0.8	**Other live**		
Leptoria	<0.1	0.8	*Diplosoma*	0.2	2.2
Montastrea	<0.1	0.4	*Diadema*	0.1	1.0
Montipora	**13.5**	19.2	Other sea urchins	<0.1	0.8
Mycedium	<0.1	0.4	Sponges	0.4	3.3
Other poritids	<0.1	0.8	**Dead coral (DC)**		
Oulophyllia	0.2	1.9	DC + algae	**0.1**	**1.5**
Platygyra	0.8	4.1	Old DC	**0.8**	**3.0**
Pocillopora	**3.6**	7.8	Recent DC	**0.6**	**2.5**
Porites	1.3	7.3	**Coralline Algae**		
Psammocora	<0.1	0.4	Coralline algae	2.7	0.8
Turbinaria	<0.1	0.8	**Bare reef, sand rubble**		
Other faviids	0.4	2.3	Bare reef	**21.4**	**17.4**
Soft coral			Rubble	**6.9**	**12.3**
Anthelia	0.8	3.4	Sand	**5.3**	**10.1**
Cladiella	0.9	5.0	**Unknown**		
Dendronephthya	<0.1	0.8	Unknown	1.0	2.7

recording system (Nikon Coolpix 4800). The path of the transects was tracked using a floating GPS (Garmin eTrex), their length being determined by the width of the zone in which they were recorded. Fish communities were visually assessed using a semi-quantitative method for species abundance in three categories (Samoilys and Carlos, 2000): present (<5 individuals per dive), common (6-10) and abundant (>10).

Data Analysis

Data were extracted from the reef transects employing a point-intercept technique in which the photographic images, or photo-quadrats, were screened on a computer as JPEG images using Coral Point Count with Excel extensions (CPCe) software (http://www.nova.edu/ocean/cpce; Kohler and Gill, 2006). The biota or substrata underlying ten randomly-placed points were recorded to at least genus level, where possible. The number of intercepts in each category was considered to be directly proportional to the planar area covered by that category (Carleton and Done, 1995); percentage cover could therefore be calculated using the CPCe software. This yielded information on the community structure of the benthos at the sampling sites and the untransformed data were subsequently subjected to similarity analysis using Primer (http://www.primer-e.com).

Results

Coral Communities

A total number of 721 photographs were recorded within the eight transects (Table 1). More were planned but severely inclement weather prevented their execution. Low underwater visibility also made identification of the benthos beyond genus dubious in some cases and data were thus only extracted and analysed to the generic level.

In structure, the reef itself was not rugose and offered little topographic variation to the life it harboured and supported. Results of CPCe analysis of the photo-quadrats (Table 2) revealed that the mean (±SD) algal cover (17.5±16.5%), primarily in the form of algal turf and coralline encrustations, was high on the reef. Hard corals were predominant with a mean cover of 32.3±25.3%; the mean cover of soft corals was 12.8±21.9%. *Montipora* (13.5±19.2%), *Astreopora* (5.7±14.2%), *Pocillopora* (3.6±7.8%) and *Acropora* (3.0±9.3%) were the most abundant hard corals and *Sinularia* (8.8±20.0%) the most abundant soft coral. Substrata devoid of living material (e.g. bare reef, sand, old dead coral) comprised 34.3±21.1% of the reef surface. Indeed, much of the surface of the reef was lightly coated with sand. Little coral damage, disease or mortality was observed on the reef (pers. obs. and DC in Table 2).

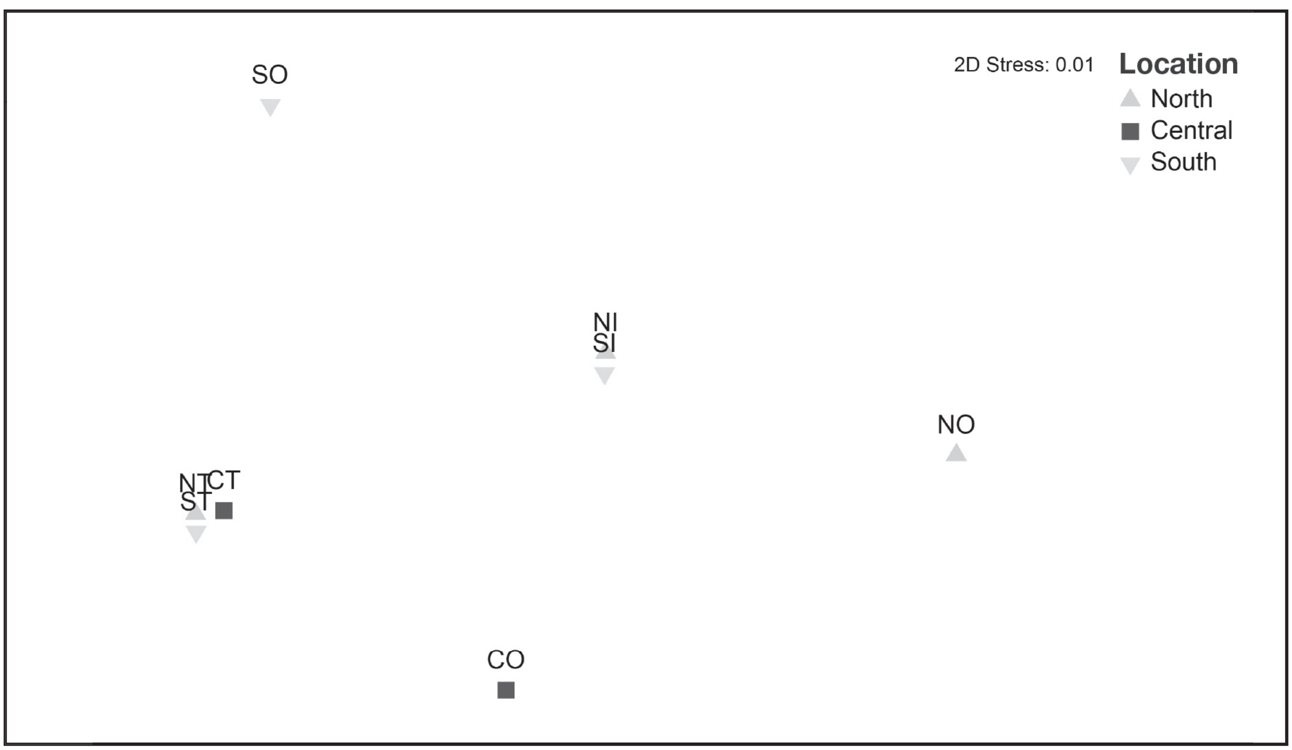

Figure 2. Multi-dimensional analysis of the CPCE results from transects in the different reef zones on Baixo São João. N, C and S denote the north, central and south regions.

Table 3. Results of CPCe analysis of data extracted from the photo-quadrats recorded on Baixo São João; only the highest 15 records are presented. N, C and S denote the north, central and south regions; I, T, and O denote the inner slope, reef top and outer slope respectively; numbers in parentheses after the transect codes are the number of genera recorded in the photo-quadrats.

NO (18)		NT (29)		NI (23)		CO (33)		CT (24)		SI (25)		ST (28)		SO (14)	
Taxon	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**	**Taxon**	**%**
Algae	36	*Montipora*	27	Algae	34	Algae	27	Algae	26	Algae	38	*Sinularia*	23	*Montipora*	36
Alveopora	23	Algae	21	*Astreopora*	20	*Montipora*	18	*Montipora*	24	*Astreopora*	19	*Montipora*	23	Algae	34
Astreopora	16	*Sinularia*	13	*Montipora*	17	*Sinularia*	13	*Sinularia*	13	*Montipora*	18	Algae	23	Sponges	7
Montipora	6	*Acropora*	9	*Acropora*	4	*Astreopora*	11	*Pocillopora*	7	*Sinularia*	6	*Pocillopora*	8	*Acropora*	7
Sinularia	6	*Pocillopora*	6	*Echinopora*	4	*Porites*	7	*Acropora*	6	*Pocillopora*	3	*Acropora*	6	*Pocillopora*	4
Pocillopora	4	*Astreopora*	4	*Porites*	4	*Echinopora*	6	*Astreopora*	4	*Acropora*	2	*Astreopora*	5	*Astreopora*	2
Porites	3	*Sarcophyton*	3	*Sinularia*	3	*Sarcophyton*	3	*Cladiella*	4	*Anthelia*	2	*Lobophytum*	2	*Favia*	2
Sarcophyton	2	*Lobophytum*	3	*Pocillopora*	3	*Lobophytum*	2	*Favites*	2	*Favites*	2	*Anthelia*	1	*Goniastrea*	2
Platygyra	1	*Cladiella*	3	Other faviids	2	*Pocillopora*	2	*Platygyra*	2	*Sarcophyton*	1	*Acanthastrea*	1	*Porites*	2
Favites	1	*Platygyra*	2	*Favites*	1	*Cladiella*	2	*Porites*	2	*Platygyra*	1	*Cladiella*	1	*Sinularia*	2
Echinopora	<1	*Porites*	1	Other	1	*Anthelia*	1	Other faviids	2	*Porites*	1	*Sarcophyton*	<1	*Favites*	<1
Lobophytum	<1	*Anthelia*	1	*Platygyra*	1	*Favites*	1	*Lobophytum*	2	*Echinopora*	<1	*Echinopora*	<1	*Montastrea*	<1
Anthelia	<1	*Echinopora*	1	*Alveopora*	<1	*Oulophyllia*	1	*Echinopora*	1	*Diplosoma*	<1	*Platygyra*	<1	*Platygyra*	<1
Acanthastrea	<1	*Favia*	1	*Goniastrea*	<1	*Favia*	<1	Other	<1	Other faviids	<1	Sponges	<1	*Sarcophyton*	<1

The calculated means yielded high standard deviations; these were indicative of patchiness in the distribution of the benthos as well as relatively low sampling intensity imposed by the inclement weather and logistical constraints.

Further analysis of the CPCe data within the different reef zones revealed fine nuances in the differential abundance of the major biota (Table 3). Multiple dimensional analysis of these data showed that the reef top results were similar, as were those collected on the inner reef slopes; the results for the outer reef slopes were divergent (Figure 2). Differences in the abundance of biota that seemed responsible for this divergence were *Alveopora*, *Montipora*, *Sinularia* and the algae (Table 4). Nevertheless, the level of similarity between all the reef zones was high (Table 5).

Finally, apart from the biota listed in Table 3, a few other organisms were encountered amongst the benthos on Baixo São João. These were the sea cucumber *Holothuria nobilis*, the giant anemone *Heteractis magnifica* and the hard coral *Goniopora*. While sponges were grouped together in the analyses, *Theonella* was notably abundant and *Jaspis* and *Callyspongia* were also encountered.

Fish Communities

A total of 97 reef fish species, belonging to 30 families, were observed on Baixo São João. The great majority (64.9% or 63 species) were present in low abundance (less than five individuals per dive), 14 species were common and 20 species abundant. The relatively low number of species observed reflects the poor sampling coverage which was dictated by the unfavourable weather and logistical constraints. The ichthyofauna of Baixo São João was primarily composed of Indo-Pacific species, where the most speciose families proved to be Labridae, Chaetodontidae and Acanthuridae with 15, 12 and 8 species respectively (Table 6). Large-sized specimens (>30 cm in length) were commonly observed, including species of commercial importance, as well as top predators such as the potato bass (*Epinephelus tukula*) and several species of rays and sharks; these provide a good indication of the health of the fish fauna on Baixo São João.

Table 4. Results of CPCe analysis of the Baixo São João data grouped according to their separation by MDS analysis; only the highest 15 records are presented. N, C and S denote the north, central and south regions. Information in bold is referred to in the text.

Reef top		Inner reef		Outer reef					
				N		C		S	
Taxon	%	Taxon	%	Taxon	%	Taxon	%	Taxon	%
Montipora	25	Algae	36	**Algae**	**36**	**Algae**	**27**	***Montipora***	**36**
Algae	23	*Astreopora*	19	***Alveopora***	**23**	***Montipora***	**18**	**Algae**	**34**
Sinularia	16	*Montipora*	17	*Astreopora*	16	***Sinularia***	**13**	Sponges	7
Pocillopora	7	*Sinularia*	5	***Montipora***	**6**	*Astreopora*	11	*Acropora*	6
Acropora	7	*Acropora*	3	***Sinularia***	**5**	*Porites*	7	*Pocillopora*	4
Astreopora	4	*Pocillopora*	3	*Pocillopora*	4	*Echinopora*	6	*Astreopora*	2
Cladiella	3	*Echinopora*	2	*Porites*	3	*Sarcophyton*	3	*Favia*	2
Lobophytum	2	*Porites*	2	*Sarcophyton*	2	*Lobophytum*	2	*Goniastrea*	2
Platygyra	2	*Favites*	2	*Platygyra*	1	*Pocillopora*	2	*Porites*	2
Sarcophyton	1	*Anthelia*	1	*Favites*	1	*Cladiella*	2	***Sinularia***	**2**
Favites	1	Other faviids	1	*Echinopora*	<1	*Anthelia*	1	*Favites*	<1
Porites	1	*Platygyra*	1	*Lobophytum*	<1	*Favites*	1	*Montastrea*	<1
Echinopora	1	Other	<1	*Anthelia*	<1	*Oulophyllia*	1	*Platygyra*	<1
Anthelia	1	*Sarcophyton*	<1	*Acanthastrea*	<1	*Favia*	<1	*Sarcophyton*	<1

Discussion

While Baixo São João is a massive underwater structure, the reef itself is fairly low in profile and offers relatively little topographical variation to the life it harbours and supports. Two quantitative assessments of the benthos have been undertaken: the present study and a visual survey by Robertson *et al*. (1996). It is apparent that the coral cover has changed between these surveys and is presently higher (45%) than it was in 1996 (33%). Furthermore, the most abundant hard coral genera on the reef (*Acropora*, *Astreopora*, *Montipora* and *Pocillopora*) are known for their rapid growth (e.g. Anderson *et al*., 2012). Thus, it is possible that the coral abundance on Baixo São João varies with fluctuations in the populations of these genera. Since the reef topography is low, such fluctuations may be caused by high turbulence, high turbidity and substantial sand movement. Evidence for this can be found in the strong currents that flow over the reef, the widespread distribution of sediment on its surface, and the absence of fragile coral genera. Examples of these amongst the hard corals would be *Blastomussa*, *Leptoseris*, *Seriatopora*, *Stylophora* and certain fungiids; and amongst the soft corals, *Heteroxenia* and *Xenia*. These are relatively common on more sheltered reefs in the region.

Reefs immediately to the south and closer inshore have higher coral cover and diversity. Cover ≥65% has been recorded at Techobanine (Pereira, 2003) and on South African reefs (Schleyer, 2000); on the latter, 55 genera were recorded compared to the 34 genera on Baixo São João. While a greater diversity of corals would undoubtedly be found on Baixo São João with more extensive study, it must be borne in mind that the variety of habitat on this reef is limited. Furthermore, environmental conditions on the reef would preclude its colonisation by the aforementioned fragile genera.

The fish population on Baixo São João, on the other hand, despite having relatively low diversity, manifested little evidence of fishing pressure and top predators were well represented. The low diversity of the fish community must be attributed at least partially to the lack of variety in the reef habitat, but further study would undoubtedly yield more species.

Table 5. Levels of similarity between the different reef zones on Baixo São João generated by Primer SIMPER analysis. N, C and S denote the north, central and south regions; I, T, and O denote the inner slope, reef top and outer slope respectively.

	NO	NT	NI	CO	CT	SI	ST
NT	48.14						
NI	69.70	60.46					
CO	59.12	73.26	72.99				
CT	51.98	86.43	68.71	74.09			
SI	72.18	64.25	84.57	73.35	67.95		
ST	47.67	83.25	60.90	71.13	83.16	64.01	
SO	51.73	67.49	66.38	56.92	68.94	64.92	63.21

Table 6. Most speciose fish families at Baixo São João, Ponta do Ouro Partial Marine Reserve.

Family	Species
Labridae	15
Chaetodontidae	12
Acanthuridae	8
Pomacentridae	7
Serranidae	7
Balistidae	6
Pomacanthidae	5

Based on these facts, Baixo São João would seem to have little merit for protection within the Ponta do Ouro Partial Marine Reserve. However, other factors must be considered. Baixo Danae, some 50 km to the north, is similar in many respects to Baixo São João, but is more accessible and is heavily dived (unpublished data; pers. obs.) and fished (Pereira and van der Elst, 2014). Aliwal Shoal, in turn, lies 500 km further south and is thus below the latitudinal limits for extensive coral growth. It falls within a marine protected area but is heavily dived and was largely 'fished out' before it received protection (Olbers *et al*., 2009). Baixo São João thus has unique attributes within the region. Its coral communities, although not as rich as those on some inshore reefs, are in good condition, as is its fish community. The reef is remote and showed little damage during the survey: it appears to be naturally protected from human disturbance. It is also located offshore in deeper water, which will protect it to some extent from the coastward drift of warmer water associated with climate change: this should give it a measure of protection from coral bleaching (Graham *et al*., 2015). Corals on deeper reefs of this nature are also known to be more fecund (Holstein *et al*., 2015) and Baixo São João may provide a coral breeding refuge for replenishment of more southern reefs. These attributes potentially make it a useful reference site for baseline and comparative studies. It is often difficult to establish whether changes in environments used by humans are attributable to anthropogenic disturbance or natural events; sites such as Baixo São João could provide decisive evidence in this regard.

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