Reef fishes of praia do Tofo and praia da Barra, Inhambane, Mozambique

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26 Abstract

27 The coral reefs around Praia do Tofo and Praia da Barra, southern Mozambique, are known
 28 for their aggregations of marine megafauna but few studies have examined their reef fish
 29 biodiversity. This study assesses for the first time the ichthyofaunal diversity of the seas
 30 around Praia do Tofo and Praia da Barra. Methods involved underwater observations during
 31 recreational dives between February and September 2016, and the use of photographic
 32 records from 2015. A total of 353 species, representing 79 families, were recorded from 16
 33 patch reefs in the region. The area shows comparable species diversity to others in the
 34 southwestern Indian Ocean, suggesting these reefs are in good condition. But high primary
 35 productivity driven by coastal upwelling may make fish diversity and trophic structure
 36 unreliable measures of the health of these reefs. Future studies investigating the sustainability
 37 of this ecosystem would benefit from utilising a wide range of reef health measures.

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51 Introduction

52 The ecotourism industry of the Inhambane province in southern Mozambique accounts for
 53 approximately 7% of the province's annual income (Mutimucuo & Meyer, 2011). The
 54 primary tourism hotspots are the Bazaruto Archipelago National Park (BANP) and the
 55 southern area around the Inhambane peninsula. In the latter, the seas around Praia do Tofo &
 56 Praia da Barra (hereafter referred to as PTPB) are particularly important due to their resident
 57 populations of manta rays and whale sharks (Pierce *et al.* 2010; Tibirica *et al.* 2011).
 58 Venables *et al.* (2016) estimate that manta ray tourism alone contributes \$34 million USD per
 59 annum to the province's economy. Scientific research in the PTPB area has thus
 60 predominantly focused on these charismatic species (e.g. Rohner *et al.* 2013; 2014); so far,
 61 very little research has been conducted on the biodiversity of resident fish populations. This
 62 aspect of the PTPB's marine ecosystem is expected to gain value in the future, as has
 63 occurred in the BANP (Schleyer & Celliers, 2005), due to the continued decline of local
 64 megafauna populations (Rohner *et al.* 2013). As of 2014, the United Nations & World
 65 Heritage Convention (2014) recommend that the protected area currently represented by the
 66 BANP be extended south to include the seas around PTPB. Knowledge of the fish
 67 biodiversity of this area will help support this recommendation.

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69 Species richness information is currently missing from the PTPB seas but this data is vital for
 70 future ecosystem management. Biodiversity data is necessary to identify key biological
 71 components (as per Pereira, 2000), provide a baseline from which ecosystem stability and
 72 function can be assessed (as per Cleland, 2011), and to predict the effects of biodiversity loss
 73 on ecosystem provision (as per Bellwood & Hughes, 2001; Gillibrand, Harries & Mara, 2007;
 74 Maggs *et al.*, 2010). The PTPB area is bordered by the tropical and sub-tropical latitudes of
 75 the southwestern Indian Ocean and are home to a number of different reef habitats likely to

76 support diverse reef fish assemblages. The most common habitats are deepwater, offshore
 77 patch reefs which are characteristic of southern Mozambique and typically have low levels of
 78 coral cover (e.g. Pereira, 2000; Motta *et al.*, 2002; Schleyer & Celliers, 2005). Other marine
 79 ecosystems in the region include mangrove swamps, estuarine reefs and shallow inshore
 80 fringing reefs. This range of reef and coastal environments provide substantial habitat and
 81 nursery grounds for fish species in the area. The PTPB area has a relatively large associated
 82 human population of over 250,000 people (Instituto Nacional de Estatística, 2007), based
 83 primarily in the cities of Maxixe & Inhambane (Fig. 1). But there is little to no management
 84 in place to safeguard the marine ecosystems and the services they provide. This study
 85 constitutes a baseline assessment of fish diversity of the reefs surrounding Praia do Tofo &
 86 Praia da Barra, and highlights the need for further investigations into the state of these
 87 ecosystems.

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89 Materials & Methods

90 *Study Site*

91 Praia do Tofo (23° 51.205' S 35° 32.882' E) and Praia da Barra (23° 47.541' S 35° 31.142'
 92 E) harbour a number of shallow fringing coral reefs. However, many of the sites frequented
 93 by the local dive industry are in deeper waters to the north and south. In this study, diversity
 94 was recorded on reefs spanning approximately 40 km along the coast of the Inhambane
 95 province (Fig. 1). A total of 16 reef sites between 1 and 32 m (Table 1) were surveyed
 96 between February and September 2016.

97 Sampling

98 The primary method was
 99 underwater observations
 100 during a random swim.
 101 Species were identified
 102 *in situ* if possible and
 103 recorded on an
 104 underwater PVC slate. If
 105 required, a photograph
 106 was taken for subsequent
 107 species identification.
 108 Deep sites (> 8 m) were
 109 surveyed on SCUBA, as
 110 part of a recreational
 111 dive charter operated by
 112 Peri-Peri Divers.
 113 Shallow sites were
 114 assessed by snorkelling.
 115 Fifty-four individual

Figure 1. Map of the study area and its location along the coast of Mozambique (inset). Sampled reefs are indicated by (•); their broad characteristics are described in Table 1.

116 surveys, totalling 2218 minutes of observation time were undertaken (total surveying times
 117 for each site are shown in Table 1). The species richness recorded from underwater
 118 observations was supplemented through the inclusion of species that had been sighted in the
 119 year preceding the survey period, and for which there was photographic evidence available
 120 from local ecotourism and dive operators (e.g. *Mola mola*). The inclusion of solicited data
 121 outside the study period was conducted to represent rare or seasonally restricted species. Data

122 collection was approved by the Maritime Administration of the City of Inhambane and the

Table 1. Names and descriptions of sampled reefs, including the underwater survey method used and the amount of time spent surveying each location

Site Name (Number)	Site Description	Sampling Method	Sampling Time (mins)
Amazon (1)	Offshore, horseshoe reef with an abundance of azooxanthellate soft corals; 23 – 28 metres.	SCUBA	87
Hospital (2)	Offshore, southward sloping reef with occasional short pinnacles; 24 – 26 metres.	SCUBA	80
The Office (3)	Topographically complex offshore reef with an abundance of overhangs and valleys with many encrusting soft corals; 22 – 26 metres.	SCUBA	177
Reggie's (4)	Tall, offshore reef rising between 4 – 8 metres from the seafloor; reef crests are dominated by large colonies of <i>Tubastrea micranthus</i> ; 22 – 30 metres.	SCUBA	231
Buddies (5)	Shallow, inshore reef subject to persistent swell and fishing pressure; 8 – 10 metres.	SCUBA	97
The Wall (6)	Shallow estuarine reef with daily exposure to strong tidal currents; a combination of seagrass, rocky reef and sand patch microhabitats; 0-4 metres.	Snorkel	70
Mike's Cupboard (7)	Submerged sand dune reef, with many potholes and gullies surrounded by sandy reef flats; 12 – 16 metres.	SCUBA	108
Salon (8)	Shallow inshore reef composed of multiple large pinnacles surrounded by sandy bottom; subject to high turbidity from wave action; 10-14 metres.	SCUBA	175
Sherwood Forest (9)	Offshore reef just outside of Tofo bay, made of one large and one smaller pinnacle both supporting large populations of <i>Tubastrea micranthus</i> ; 22 – 26 metres	SCUBA	58
Giants Castle (10)	Straight north-south reef with an extensive reef flat and deep reef wall; known within the local dive industry as having the best sighting rate for marine megafauna; 27 – 32 metres.	SCUBA	214
Marble Arch (11)	Inshore reef exposed to minor wave action; large reef flat with a few large potholes and one large rock arch; 14 – 18 metres.	SCUBA	51
Rob's Bottom (12)	Very patchy eastward sloping reef that is often subject to high current with high algal cover; 23 – 27 metres.	SCUBA	158
Manta Reef (13)	A large offshore reef, with a large central reef flat; peripheries are characterised by short, steep reef slopes with a number of tall pinnacles; 18 – 24 metres	SCUBA	365
Outback (14)	Similar reef shape as Giant's Castle, yet with more small inlets that house a number of deep overhangs and archways; 25 – 30 metres.	SCUBA	76
Coconut Bay (15)	Shallow inshore rocky reef with small patches of encrusting soft coral and larger swathes of seagrass; 4 – 8 metres.	Snorkel	53
Paindane Coral Gardens (16)	Small, shallow reef protected from offshore waves by a barrier rock extending from shore; the most abundant coral community in this area, dominated by <i>Sinularia</i> spp. soft coral and corymbose acroporids; 1 – 6 metres.	Snorkel	182

Ministry of Justice.

Estimated richness and regional comparisons

To determine the number of conspicuous species missed during the visual census, the Coral Fish Diversity Index (CFDI) developed by Allen & Werner (2002) was calculated and compared to the recorded species richness (SR_{obs}). The CFDI examines the diversity of six common and easily observable families as representatives of reef fish species richness. These families are Acanthuridae, Chaetodontidae, Labridae, Pomacanthidae, Pomacentridae & Scaridae. In areas $< 2000 \text{ km}^2$, a theoretical species richness (SR_{theor}) is then generated using the equation $SR_{theor} = 3.39(CFDI) - 20.595$ (Allen & Werner, 2002). SR_{theor} was calculated for other reef systems in the southwestern Indian Ocean, using published literature, to draw loose comparisons between the richness of these areas and that observed in the current study (as per Wickel *et al.* 2014).

Results

A total of 353 species, representing 79 families, were recorded in the current study from visual observations and 25 past photographic records (Table 2). Of the total number of species recorded, 27 were cartilaginous fish and 326 were bony fish. The CFDI-generated

Table 2. Reef fish species checklist from the PTPB area of Mozambique, sighted through surveys (S) and photographic records (P). Where a species' trophic category has been assumed from a congener species, it is labelled with a '*'.
 140 SR_{theor} was 329, lower than the observed species richness (Table 3).

FAMILIES - Species - Authors	Sighting Record	Trophic Category
ACANTHURIDAE		
<i>Acanthurus dussumieri</i> Cuvier & Valenciennes, 1835	S	H
<i>Acanthurus leucosternon</i> Bennett, 1833	S	H
<i>Acanthurus lineatus</i> Linnaeus, 1758	S	H

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Acanthurus nigrofuscus</i> Forsskal, 1775	S	H
<i>Acanthurus tennentii</i> Günther, 1861	S	H
<i>Acanthurus triostegus</i> Linnaeus, 1758	S	H
<i>Acanthurus xanthopterus</i> Valenciennes, 1835	S	H
<i>Ctenochaetus binotatus</i> Randall, 1955	S	H
<i>Ctenochaetus striatus</i> Quoy & Gaimard, 1825	S	H
<i>Ctenochaetus truncatus</i> Randall & Clements, 2001	S	H
<i>Naso brachycentron</i> Valenciennes, 1835	S	H
<i>Naso brevirostris</i> Cuvier, 1829	S	H
<i>Naso elegans</i> Rüppell, 1829	S	H
<i>Paracanthurus hepatus</i> Linné, 1766	S	DPL
<i>Zebrasoma desjardini</i> Bennett, 1836	S	H
<i>Zebrasoma gemmatum</i> Valenciennes, 1835	S	H
<i>Zebrasoma scopas</i> Cuvier, 1829	S	H
AMBASSIDAE		
<i>Ambassis natalensis</i> Gilchrist & Thompson, 1908	S	DC
ANTENNARIIDAE		
<i>Antennarius coccineus</i> Lesson, 1831	S	Pi
<i>Antennarius commerson</i> Lacepède, 1798	S	Pi
<i>Antennarius nummifer</i> Cuvier, 1817	P	Pi
APOGONIDAE		
<i>Cheilodipterus quinquelineatus</i> Cuvier, 1828	S	NC
<i>Ostorhinchus angustatus</i> Smith & Radcliffe, 1911	S	BSI
<i>Ostorhinchus flagelliferus</i> Smith, 1961	S	BSI
<i>Ostorhinchus fleurieu</i> Lacepède, 1802	S	BSI*
<i>Pristiapogon kallopterus</i> Bleeker, 1856	S	NC
<i>Taeniamia mozambiquensis</i> Smith, 1961	S	NA
ATHERINIDAE		
<i>Atherinomorus lacunosus</i> Forster, 1801	S	NPL
AULOSTOMIDAE		
<i>Aulostomus chinensis</i> Linnaeus, 1766	S	Pi
BALISTIDAE		
<i>Balistapus undulatus</i> Park, 1797	S	DC
<i>Balistoides conspicillum</i> Bloch & Schneider, 1801	S	DC
<i>Balistoides viridescens</i> Bloch & Schneider, 1801	S	DC

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Odonus niger</i> Rüppell, 1836	S	DC
<i>Pseudobalistes flavimarginatus</i> Rüppell, 1829	P	DC
<i>Pseudobalistes fuscus</i> Bloch & Schneider, 1801	S	DC
<i>Rhinecanthus aculeatus</i> Linnaeus, 1758	S	DC
<i>Rhinecanthus rectangulus</i> Bloch & Schneider, 1801	S	O
<i>Sufflamen bursa</i> Bloch & Schneider, 1801	S	DC
<i>Sufflamen fraenatum</i> Latreille, 1804	S	DC
<i>Xanthichthys lineopunctatus</i> Hollard, 1854	S	DC*
BLENNIIDAE		
<i>Aspidontus dussumieri</i> Valenciennes, 1836	S	H
<i>Aspidontus taeniatus</i> Quoy & Gaimard, 1834	S	DC
<i>Aspidontus tractus</i> Fowler, 1903	S	DC
<i>Cirripectes stigmaticus</i> Strasburg & Schultz, 1953	S	H
<i>Ecsenius midas</i> Starck, 1969	S	H
<i>Istiblennius edentulous</i> Forster & Schneider, 1801	S	H
<i>Plagiotremus rhinorhynchus</i> Bleeker, 1852	S	NPL
<i>Plagiotremus tapeinosoma</i> Bleeker, 1857	S	O
BOTHIDAE		
<i>Bothus mancus</i> Broussonet, 1782	S	DC
<i>Bothus pantherinus</i> Rüppell, 1830	S	NC
CAESIONIDAE		
<i>Caesio varilineata</i> Carpenter, 1987	S	DPL
<i>Caesio xanthalytos</i> Holleman, Connell & Carpenter, 2013	S	DPL*
<i>Caesio xanthonata</i> Bleeker, 1853	S	DPL
<i>Pterocaesio marri</i> Schultz, Herald, Lachner, Welander & Woods, 1953	S	DPL
<i>Pterocaesio tile</i> Cuvier & Valenciennes, 1830	S	DPL
CALLIONMYIDAE		
<i>Neosynchiropus stellatus</i> Smith, 1963	S	DC
CARANGIDAE		
<i>Alectis ciliaris</i> Bloch, 1787	P	DC
<i>Alectis indica</i> Rüppell, 1830	P	DC
<i>Caranx bucculentus</i> Alleyne & Macleay, 1877	S	DC
<i>Caranx heberi</i> Bennett, 1830	S	DC
<i>Caranx ignobilis</i> Forsskål, 1775	S	DC
<i>Caranx melampygus</i> Cuvier, 1833	S	DC

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Caranx sexfasciatus</i> Quoy & Gaimard, 1825	S	Pi
<i>Elagatis bipinnulata</i> Quoy & Gaimard, 1825	S	DC
<i>Gnathanodon speciosus</i> Forsskål, 1775	S	DC
<i>Seriola lalandi</i> Valenciennes, 1833	S	DC
CARCHARHINIDAE		
<i>Carcharhinus amblyrhynchos</i> Bleeker, 1856	S	Pi
<i>Carcharhinus leucas</i> Müller & Henle, 1839	P	DC
<i>Carcharhinus limbatus</i> Müller & Henle, 1839	S	Pi
<i>Carcharhinus melanopterus</i> Quoy & Gaimard, 1824	S	Pi
<i>Carcharhinus obscurus</i> Lesueur, 1818	S	DC
<i>Triaenodon obesus</i> Rüppell, 1837	S	DC
CENTRISCIDAE		
<i>Aeoliscus strigatus</i> Günther, 1861	P	DC
CHAETODONTIDAE		
<i>Chaetodon auriga</i> Forsskål, 1775	S	BSI
<i>Chaetodon blackburnii</i> Desjardins, 1836	S	BSI
<i>Chaetodon dolosus</i> Ahl, 1923	S	BSI
<i>Chaetodon guttatissimus</i> Bennett, 1833	S	BSI
<i>Chaetodon interruptus</i> Ahl, 1923	S	BSI
<i>Chaetodon kleinii</i> Bloch, 1790	S	BSI
<i>Chaetodon lineolatus</i> Cuvier, 1831	S	BSI
<i>Chaetodon lunula</i> Lacepède, 1802	S	BSI
<i>Chaetodon madagaskariensis</i> Ahl, 1923	S	BSI
<i>Chaetodon melannotus</i> Bloch & Schneider, 1801	S	BSI
<i>Chaetodon meyeri</i> Bloch & Schneider, 1801	S	BSI
<i>Chaetodon trifascialis</i> Quoy & Gaimard, 1825	S	BSI
<i>Chaetodon xanthurus</i> Bleeker, 1857	S	BSI
<i>Forcipiger flavissimus</i> Jordan & McGregor, 1898	S	BSI
<i>Hemitaenichthys zoster</i> Bennett, 1831	S	DPL
<i>Heniochus acuminatus</i> Linnaeus, 1758	S	BSI
<i>Heniochus diphreutes</i> Jordan, 1903	S	DPL
<i>Heniochus monoceros</i> Cuvier, 1831	S	BSI
CIRRHITIDAE		
<i>Cirrhitichthys oxycephalus</i> Bleeker, 1855	S	DC
<i>Cyprinocirrhites polyactis</i> Bleeker, 1874	S	DPL

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Oxycirrhites typus</i> Bleeker, 1857	P	DPL
<i>Paracirrhites arcatus</i> Cuvier, 1829	S	DC
<i>Paracirrhites forsteri</i> Schneider, 1801	S	DC
CLINIDAE		
<i>Clinus venustis</i> Gilchrist & Thompson, 1908	S	NA
<i>Pavoclinus laurentii</i> Gilchrist & Thompson, 1908	S	NA
CLUPEIDAE		
<i>Gilchristella aestuaria</i> Gilchrist, 1913	S	DPL
CONGRIDAE		
<i>Heteroconger hassi</i> Klausewitz & Eibl-Eibesfeldt, 1959	S	NC
DACTYLOPTERIDAE		
<i>Dactyloptena orientalis</i> Cuvier, 1829	S	NC
DASYATIDAE		
<i>Dasyatis microps</i> Annandale, 1908	S	NC*
<i>Himantura jenkinsii</i> Annandale, 1909	S	NC
<i>Himantura uarnak</i> Gmelin, 1789	S	NC
<i>Neotrygon kuhlii</i> Müller & Henle, 1841	S	NC
<i>Taeniura lymma</i> Forsskål, 1775	P	NC
<i>Taeniura meyeri</i> Müller & Henle, 1841	S	NC
DIODONTIDAE		
<i>Diodon holocanthus</i> Linnaeus, 1758	S	NC
<i>Diodon hystrix</i> Linnaeus, 1758	S	NC
<i>Diodon liturosus</i> Shaw, 1804	S	NC
ECHENEIDAE		
<i>Echeneis naucrates</i> Linnaeus, 1758	S	NC
ENGRAULIDAE		
<i>Thryssa vitrirostris</i> Gilchrist & Thompson, 1908	S	DPL
EPHIPPIDAE		
<i>Platax teira</i> Forsskål, 1775	S	O
FISTULARIIDAE		
<i>Fistularia commersonii</i> Rüppell, 1838	S	Pi
GERREIDAE		
<i>Gerres longirostris</i> Lacepède, 1801	S	DC
GINGLYMOSTOMATIDAE		
<i>Nebrius ferrugineus</i> Lesson, 1831	P	NC

FAMILIES - Species - Authors	Sighting Record	Trophic Category
GOBIIDAE		
<i>Amblyeleotris steinitzi</i> Klausewitz, 1974	S	DC
<i>Amblyeleotris wheeleri</i> Polunin & Lubbock, 1977	S	DC*
<i>Caffrogobius saldanha</i> Barnard, 1927	S	NA
<i>Valenciennea strigata</i> Broussonet, 1782	S	DC
HAEMULIDAE		
<i>Diagramma pictum</i> Thunberg, 1792	S	DC
<i>Plectorhinchus flavomaculatus</i> Cuvier, 1830	S	NC
<i>Plectorhinchus gaterinus</i> Forsskål, 1775	S	NC
<i>Plectorhinchus playfairi</i> Pellegrin, 1914	S	DC
<i>Plectorhinchus vittatus</i> Linnaeus, 1758	S	NC
HEMIRAMPHIDAE		
<i>Hyporhamphus affinis</i> Günther, 1866	S	O
HOLOCENTRIDAE		
<i>Myripristis adusta</i> Bleeker, 1853	S	NPL
<i>Myripristis berndti</i> Jordan & Evermann, 1903	S	NC
<i>Myripristis botche</i> Cuvier, 1829	S	NC
<i>Myripristis murdjan</i> Forsskål, 1775	S	NPL
<i>Myripristis vittata</i> Valenciennes, 1831	S	NPL
<i>Neoniphon samara</i> Forsskål, 1775	S	NC
<i>Pagellus natalensis</i> Steindachner, 1903	S	O
<i>Sargocentron caudimaculatum</i> Rüppell, 1838	S	NC
<i>Sargocentron diadema</i> Lacepède, 1802	S	NC
<i>Sargocentron spiniferum</i> Forsskål, 1775	S	NC
ISTIOPHORIDAE		
<i>Istiompax indica</i> Cuvier, 1832	S	Pi
<i>Istiophorus platypterus</i> Shaw, 1792	P	Pi
<i>Makaira nigricans</i> Lacepède, 1802	P	Pi
KYPHOSIDAE		
<i>Kyphosus vaigiensis</i> Quoy & Gaimard, 1825	S	H
LABRIDAE		
<i>Anampses meleagrides</i> Valenciennes, 1840	S	DC
<i>Bodianus anthioides</i> Bennett, 1832	S	DC
<i>Bodianus axillaris</i> Bennett, 1832	S	DC
<i>Bodianus diana</i> Lacepède, 1801	S	DC

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Bodianus trilineatus</i> Fowler, 1934	S	DC*
<i>Anampses twistii</i> Bleeker, 1856	S	DC
<i>Cheilinus trilobatus</i> Lacepède, 1801	S	DC
<i>Cheilinus undulates</i> Rüppell, 1835	S	DC
<i>Cheilio inermis</i> Forsskål, 1775	S	DC
<i>Coris aygula</i> Lacepède, 1801	S	DC
<i>Coris caudimacula</i> Quoy & Gaimard, 1834	S	DC
<i>Coris cuvieri</i> Bennett, 1831	S	DC
<i>Coris formosa</i> Bennett, 1830	S	DC
<i>Gomphosus caeruleus</i> Lacepède, 1801	S	DC
<i>Gomphosus varius</i> Lacepède, 1801	S	DC
<i>Halichoeres cosmetus</i> Randall & Smith, 1982	S	DC
<i>Halichoeres hortulanus</i> Lacepède, 1801	S	DC
<i>Halichoeres iridis</i> Randall & Smith, 1982	S	DC
<i>Halichoeres lapillus</i> Smith, 1947	S	DC
<i>Halichoeres nebulosus</i> Valenciennes, 1839	S	DC
<i>Halichoeres scapularis</i> Bennett, 1832	S	DC
<i>Halichoeres zeylonicus</i> Bennett, 1833	S	DC
<i>Halichoeres zulu</i> Randall & King, 2010	S	DC
<i>Labroides bicolor</i> Fowler & Bean, 1928	S	DC
<i>Labroides dimidiatus</i> Valenciennes, 1839	S	DC
<i>Macropharyngodon bipartitus</i> Smith, 1957	S	DC
<i>Macropharyngodon cyanoguttatus</i> Randall, 1978	S	DC*
<i>Novaculichthys taeniourus</i> Lacepède, 1801	S	DC
<i>Pseudocoris heteroptera</i> Bleeker, 1857	S	DC
<i>Thalassoma amblycephalum</i> Bleeker, 1856	S	DC
<i>Thalassoma hebraicum</i> Lacepède, 1801	S	DC
<i>Thalassoma lunare</i> Linnaeus, 1758	S	DC
LUTJANIDAE		
<i>Aprion virescens</i> Valenciennes, 1830	S	Pi
<i>Lutjanus ehrenbergii</i> Peters, 1869	S	NC
<i>Lutjanus fulviflamma</i> Forsskål, 1775	S	NC
<i>Lutjanus gibbus</i> Forsskål, 1775	S	NC
<i>Lutjanus kasmira</i> Forsskål, 1775	S	NC
<i>Lutjanus lutjanus</i> Bloch, 1790	S	NC

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Lutjanus monostigma</i> Cuvier, 1828	S	NC
<i>Lutjanus notatus</i> Cuvier, 1828	S	NC
<i>Lutjanus rivulatus</i> Cuvier, 1828	S	NC
<i>Lutjanus sebae</i> Cuvier, 1816	S	NC
<i>Macolor niger</i> Forsskål, 1775	S	NC
<i>Paracaesio sordida</i> Abe & Shinohara, 1962	S	DPL
MALACANTHIDAE		
<i>Malacanthus brevirostris</i> Guichenot, 1848	S	DC
MICRODESMIDAE		
<i>Nemateleotris magnifica</i> Fowler, 1938	S	NPL
<i>Ptereleotris evides</i> Jordan & Hubbs, 1925	S	NPL
<i>Ptereleotris heteroptera</i> Bleeker, 1855	S	DPL
MOLIDAE		
<i>Mola mola</i> Linnaeus, 1758	P	DC
MONACANTHIDAE		
<i>Aluterus scriptus</i> Osbeck, 1765	S	O
<i>Acreichthys tomentosus</i> Linnaeus, 1758	S	DC
<i>Cantherhines fronticinctus</i> Günther, 1867	S	BSI
<i>Cantherhines pardalis</i> Rüppell, 1837	S	BSI
<i>Pervagor janthinosoma</i> Bleeker, 1854	S	NA
<i>Stephanolepis auratus</i> Castelnau, 1861	S	NA
MONOCENTRIDAE		
<i>Cleidopus gloriamaris</i> De Vis, 1882	P	NA
MONODACTYLIDAE		
<i>Monodactylus argenteus</i> Linnaeus, 1758	S	DPL
MULLIDAE		
<i>Mulloidichthys ayliffe</i> Uiblein, 2011	S	NC
<i>Mulloidichthys flavolineatus</i> Lacepède, 1801	S	NC
<i>Mulloidichthys vanicolensis</i> Valenciennes, 1831	S	NC
<i>Parupeneus barberinus</i> Lacepède, 1801	S	DC
<i>Parupeneus indicus</i> Shaw, 1803	S	DC
<i>Parupeneus macronemus</i> Lacepède, 1801	S	DC
<i>Parupeneus trifasciatus</i> Lacepède, 1801	S	DC
MURAENIDAE		
<i>Echidna nebulosa</i> Ahl, 1789	S	NC

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Enchelycore pardalis</i> Temminck & Schlegel, 1846	S	Pi
<i>Gymnomuraena zebra</i> Shaw, 1797	S	NC
<i>Gymnothorax breedeni</i> McCosker & Randall, 1977	S	NC
<i>Gymnothorax eurostus</i> Abbott, 1860	S	NC
<i>Gymnothorax favagineus</i> Bloch & Schneider, 1801	S	NC
<i>Gymnothorax flavimarginatus</i> Rüppell, 1830	S	Pi
<i>Gymnothorax griseus</i> Lacepède, 1803	S	NC*
<i>Gymnothorax javanicus</i> Bleeker, 1859	S	NC
<i>Gymnothorax meleagris</i> Shaw, 1795	S	DC
<i>Gymnothorax miliaris</i> Kaup, 1856	S	DC
<i>Gymnothorax nudivomer</i> Günther, 1867	S	NC*
<i>Gymnothorax undulates</i> Lacepède, 1803	S	NC
<i>Rhinomuraena quaesita</i> Garman, 1888	P	Pi
MYLIOBATIDAE		
<i>Aetobatus narinari</i> Euphrasen, 1790	P	DC
<i>Manta alfredi</i> Krefft, 1868	S	DPL
<i>Manta birostris</i> Walbaum, 1792	S	DPL
<i>Mobula japonica</i> Müller & Henle, 1841	S	DPL
ODONTASIPSIDAE		
<i>Carcharias taurus</i> Rafinesque, 1810	S	DC
OPHICHTHIDAE		
<i>Myrichthys colubrinus</i> Boddaert, 1781	S	NC
<i>Myrichthys maculosus</i> Cuvier, 1816	S	NC
<i>Pisodonophis cancrivorus</i> Richardson, 1848	P	NC
OPLEGNATHIDAE		
<i>Oplegnathus robinsoni</i> Regan, 1916	S	O
OSTRACIIDAE		
<i>Lactoria fornasini</i> Bianconi, 1846	S	BSI*
<i>Lactoria cornuta</i> Linnaeus, 1758	S	BSI
<i>Ostracion cubicus</i> Linnaeus, 1758	S	BSI
<i>Ostracion meleagris</i> Shaw, 1796	S	BSI
PEGASIDAE		
<i>Eurypegasus draconis</i> Linnaeus, 1766	S	BSI
PEMPHERIDAE		
<i>Parapriacanthus ransonneti</i> Steindachner, 1870	S	NPL

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Pempheris schwenkii</i> Bleeker, 1855	S	NPL
PINGUIPEDIDAE		
<i>Parapercis schauinslandii</i> Steindachner, 1900	S	DC
PLATYCEPHALIDAE		
<i>Papilloculiceps longiceps</i> Cuvier, 1829	S	DC
PLOTOSIDAE		
<i>Plotosus lineatus</i> Thunberg, 1787	S	NC
POMACANTHIDAE		
<i>Apolemichthys trimaculatus</i> Cuvier, 1831	S	O
<i>Centropyge acanthops</i> Norman, 1922	S	O
<i>Centropyge bispinosa</i> Günther, 1860	S	O
<i>Centropyge multispinis</i> Playfair, 1867	S	O
<i>Pomacanthus chrysurus</i> Cuvier, 1831	S	O
<i>Pomacanthus imperator</i> Bloch, 1787	S	O
<i>Pomacanthus rhomboides</i> Gilchrist & Thompson, 1908	S	O*
<i>Pomacanthus semicirculatus</i> Cuvier, 1831	S	BSI
<i>Pygoplites diacanthus</i> Boddaert, 1772	S	BSI
POMACENTRIDAE		
<i>Abudefduf natalensis</i> Hensley & Randall, 1983	S	O
<i>Abudefduf sexfasciatus</i> Lacepède, 1801	S	O
<i>Abudefduf vaigiensis</i> Quoy & Gaimard, 1825	S	O
<i>Amphiprion allardi</i> Klausewitz, 1970	S	O
<i>Amphiprion perideraion</i> Bleeker, 1855	S	O*
<i>Chromis fieldi</i> Randall & DiBattista, 2013	S	DPL
<i>Chromis nigrura</i> Smith, 1960	S	DPL
<i>Chromis opercularis</i> Günther, 1867	S	DPL
<i>Chromis viridis</i> Cuvier, 1830	S	O
<i>Chromis weberi</i> Fowler & Bean, 1928	S	DPL
<i>Chrysiptera brownriggii</i> Bennett, 1828	S	O
<i>Chrysiptera unimaculata</i> Cuvier, 1830	S	O
<i>Dascyllus aruanus</i> Linnaeus, 1758	S	DPL
<i>Dascyllus carneus</i> Fischer, 1885	S	O
<i>Dascyllus trimaculatus</i> Rüppell, 1829	S	DPL
<i>Neopomacentrus cyanomos</i> Bleeker, 1856	S	NA
<i>Plectroglyphidodon dickii</i> Liénard, 1839	S	O

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Pomacentrus caeruleus</i> Quoy & Gaimard, 1825	S	O
<i>Pomacentrus pavo</i> Bloch, 1787	S	O
<i>Stegastes fasciolatus</i> Ogilby, 1889	S	H
<i>Stegastes pelicier</i> Allen & Emery, 1985	S	H
PRIACANTHIDAE		
<i>Priacanthus hamrur</i> Forsskål, 1775	S	NC
PSEUDOCROMIDAE		
<i>Pseudochromis dutoiti</i> Smith, 1955	S	DC
RACHYCENTRIDAE		
<i>Rachycentron canadum</i> Linnaeus, 1766	S	DC
RHINCODONTIDAE		
<i>Rhincodon typus</i> Smith, 1828	S	DPL
RHINIDAE		
<i>Rhina ancylostoma</i> Bloch & Schneider, 1801	P	NC
RHINOBATIDAE		
<i>Rhinobatus annulatus</i> Müller & Henle, 1841	P	NC
<i>Rhinobatus leucospilus</i> Norman, 1926	S	NC
<i>Rhynchobatus djiddensis</i> Forsskål, 1775	S	NC
SCARIDAE		
<i>Chlorurus cyanescens</i> Valenciennes, 1840	S	H
<i>Chlorurus sordidus</i> Forsskål, 1775	S	H
<i>Scarus ghobban</i> Forsskål, 1775	S	H
<i>Scarus rubroviolaceus</i> Bleeker, 1847	S	H
<i>Scarus scaber</i> Valenciennes, 1840	S	H
<i>Scarus tricolor</i> Bleeker, 1847	S	H
SCOMBRIDAE		
<i>Euthynnus affinis</i> Cantor, 1849	S	DC
<i>Gymnosarda unicolor</i> Rüppell, 1836	S	Pi
<i>Katsuwonus pelamis</i> Linnaeus, 1758	S	DC
<i>Scomberomorus commerson</i> Lacepède, 1801	S	Pi
<i>Scomberomorus plurilineatus</i> Fourmanoir, 1966	P	Pi
<i>Thunnus albacares</i> Bonnaterre, 1788	S	DC
SCORPAENIDAE		
<i>Caracanthus maculatus</i> Gray, 1831	S	NA
<i>Dendrochirus brachypterus</i> Cuvier, 1829	S	NC

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Dendrochirus zebra</i> Cuvier, 1829	S	NC
<i>Parascorpaena mossambica</i> Peters, 1855	S	NA
<i>Pterois antennata</i> Bloch, 1787	S	DC
<i>Pterois miles</i> Bennett, 1828	S	Pi
<i>Rhinopias eschmeyer</i> Condé, 1977	P	Pi*
<i>Rhinopias frondosa</i> Günther, 1892	P	Pi
<i>Scorpaenopsis diabolus</i> Cuvier, 1829	S	Pi
<i>Scorpaenopsis oxycephala</i> Bleeker, 1849	S	Pi
<i>Scorpaenopsis venosa</i> Cuvier, 1829	S	DC
<i>Sebastapistes cyanostigma</i> Bleeker, 1856	S	NA
<i>Taenianotus triacanthus</i> Lacepède, 1802	S	DC
SERRANIDAE		
<i>Cephalopholis argus</i> Schneider, 1801	S	Pi
<i>Cephalopholis miniata</i> Forsskål, 1775	S	NC
<i>Cephalopholis sonnerati</i> Valenciennes, 1828	S	NC
<i>Epinephelus chlorostigma</i> Valenciennes, 1828	S	NC
<i>Epinephelus fasciatus</i> Forsskål, 1775	S	NC
<i>Epinephelus flavocaeruleus</i> Lacepède, 1802	P	Pi
<i>Epinephelus lanceolatus</i> Bloch, 1790	P	NC
<i>Epinephelus macrospilos</i> Bleeker, 1855	S	DC
<i>Epinephelus malabaricus</i> Bloch & Schneider, 1801	S	NC
<i>Epinephelus merra</i> Bloch, 1793	S	Pi
<i>Epinephelus rivulatus</i> Valenciennes, 1830	S	Pi
<i>Epinephelus tauvina</i> Forsskål, 1775	S	Pi
<i>Epinephelus tukula</i> Morgans, 1959	S	NC
<i>Grammistes sexlineatus</i> Thunberg, 1792	S	NC
<i>Nemanthias carberryi</i> Smith, 1954	S	DPL
<i>Plectropomus punctatus</i> Quoy & Gaimard, 1824	S	Pi
<i>Pogonoperca punctata</i> Valenciennes, 1830	S	NC*
<i>Pseudanthias evansi</i> Smith, 1954	S	DPL
<i>Pseudanthias squamipinnus</i> Peters, 1855	S	DPL
SIGANIDAE		
<i>Siganus luridus</i> Rüppell, 1829	S	H
<i>Siganus sutor</i> Valenciennes, 1835	S	H
SOLEIDAE		

FAMILIES - Species - Authors	Sighting Record	Trophic Category
<i>Solea turbynei</i> Gilchrist, 1904	S	NA
SPARIDAE		
<i>Chrysoblephus puniceus</i> Gilchrist & Thompson, 1908	S	DC
<i>Diplodus hottentotus</i> Smith, 1844	S	DC
SPHRYNIDAE		
<i>Sphyrna lewini</i> Griffith & Smith, 1834	S	DC
SPHYRAENIDAE		
<i>Sphyraena putnamae</i> Jordan & Seale, 1905	S	NC
STEGOSTOMATIDAE		
<i>Stegostoma fasciatum</i> Hermann, 1783	S	NC
SYNANCEIIDAE		
<i>Synanceia verrucosa</i> Bloch & Schneider, 1801	S	Pi
SYNGNATHIDAE		
<i>Corythoichthys intestinalis</i> Ramsay, 1881	P	DC
<i>Doryrhamphus dactyliophorus</i> Bleeker, 1853	S	DPL
<i>Hippocampus borboniensis</i> Duméril, 1870	S	DPL*
<i>Hippocampus camelopardalis</i> Bianconi, 1854	P	DPL*
<i>Hippocampus histrix</i> Kaup, 1856	S	DPL
<i>Hippocampus kuda</i> Bleeker, 1852	S	DPL
<i>Solenostomus cyanopterus</i> Bleeker, 1854	S	DC
<i>Trachyrhamphus bicoarctatus</i> Bleeker, 1857	S	NA
SYNODONTIDAE		
<i>Synodus dermatogenys</i> Fowler, 1912	S	Pi
<i>Synodus jaculum</i> Russell & Cressey, 1979	S	Pi
TETRAODONTIDAE		
<i>Arothron hispidus</i> Linnaeus, 1758	S	NC
<i>Arothron meleagris</i> Anonymous, 1798	S	NC
<i>Arothron nigropunctatus</i> Bloch & Schneider, 1801	S	NC
<i>Arothron stellatus</i> Anonymous, 1798	S	NC
<i>Canthigaster amboinensis</i> Bleeker, 1864	S	H
<i>Canthigaster bennetti</i> Bleeker, 1854	S	O
<i>Canthigaster janthinoptera</i> Bleeker, 1855	S	O
<i>Canthigaster smithae</i> Allen & Randall, 1977	S	O*
<i>Canthigaster solandri</i> Richardson, 1845	S	O
<i>Canthigaster valentine</i> Bleeker, 1853	S	O

FAMILIES - Species - Authors	Sighting Record	Trophic Category
TETRAROGIDAE		
<i>Ablabys binotatus</i> Peters, 1855	S	NA
<i>Ablabys macracanthus</i> Bleeker, 1852	S	NA
TORPEDINIDAE		
<i>Torpedo marmorata</i> Risso, 1810	S	Pi
<i>Torpedo spp.</i>	S	Pi
ZANCLIDAE		
<i>Zanclus cornutus</i> Linnaeus, 1758	S	DC
Trophic Categories: Herbivore (H); Omnivore (O); Browser of Sessile Invertebrates (BSI); Diurnal Carnivore (DC); Nocturnal Carnivore (NC); Piscivore (Pi); Diurnal Planktivore (DPL); Nocturnal Planktivore (NPL); Unknown (NA)		

141

142 Twelve families represented over half of the total recorded diversity, these included
143 Acanthuridae (17), Balistidae (11), Carangidae (10), Chaetodontidae (18), Holocentridae
144 (10), Labridae (32), Lutjanidae (12), Muraenidae (14), Pomacentridae (21), Scorpaenidae
145 (13), Serranidae (19), and Tetraodontidae (10). Nearly half the recorded families (48%) were
146 represented by one species only. Five of these families are monospecific including,
147 Rachycentridae, Rhinodontidae, Rhinidae, Stegostomatidae, and Zanclidae. The most
148 species-rich genera were *Chaetodon* (12), *Epinephelus* (10) and *Gymnothorax* (10).

149

150 Discussion

151 This is the first assessment of ichthyofaunal diversity of the seas around Praia do Tofo and
152 Praia da Barra in southern Mozambique. Through the use of underwater observations
153 supplemented by past records, 353 species were recorded from the coral reefs spanning 40
154 km of the southern coastline of the Inhambane province. These results provide a higher
155 estimation of fish species richness than is predicted by the Coral Fish Diversity Index. The
156 diversity of the PTPB area is similar to that recorded in other areas of the southwestern Indian
157 Ocean where visual observations have been the primary data collection method (Table 3)

158 (Maggs *et al.*, 2010; Chabanet & Durville, 2005; Gillibrand, Harries & Mara, 2007; Durville,

Table 3. The diversity of reef fish species and families from other areas in the southwestern Indian Ocean. SR_{obs} = recorded species richness; SR_{theor} = theoretical species richness predicted by the Coral Fish Diversity Index (Allen & Werner, 2002).

Location	Geographical Coordinates	SR _{obs}	SR _{theor}	No. of families	SR _{obs} to no. of families ratio (2 d. p.)	Source
Praia do Tofo & Praia da Barra	23°51'S, 33°54'E	353	329	79	4.47:1	Present study
Bazaruto Archipelago National Park	21°43'S, 35°27'E	249	359	40	6.23:1	Maggs <i>et al.</i> 2010
Maputo Bay	26°S, 32°54'E	327	349	58	5.64:1	Schleyer & Pereira, 2014
Juan de Nova	17°03'S, 42°43'E	299	423	55	5.44:1	Chabanet & Durville, 2005
Andavadoaka	22°05'S, 43°12'E	334	430	58	5.76:1	Gillibrand, Harries & Mara, 2007
Glorieuses Islands	11°33'S, 47°20'E	332	451	57	5.82:1	Durville, Chabanet & Quod, 2003
St. Lucia Marine Reserve	27°44'S, 32°40'E	258	349	48	5.38:1	Floros <i>et al.</i> 2012
Mafia Island	7°52'S, 39°45'E	394	515	56	7.04:1	Garpe & Ohman, 2003
Europa Island	22°21'S, 40°21'E	389	468	62	6.27:1	Fricke <i>et al.</i> 2013
Ponta do Ouro Partial Marine Reserve	26°27'S, 32°56'E	376	318	90	4.18:1	Pereira, Videira & Abrantes, 2004

159 Chabanet & Quod, 2003). In particular, SR_{theor} shows high similarity to areas in southern

160 Mozambique and South Africa that are fully or partially protected (e.g. Floros *et al.* 2012;

161 Maggs *et al.* 2010; Pereira, Videira & Abrantes, 2004).

162 The sub-tropical reefs of the PTPB area have levels of coral cover (Motta *et al.* 2002), which

163 may be assumed to result in a low diversity of fish communities (Komyakova, Munday &

164 Jones, 2013). However, the current study finds a relatively high ichthyofaunal species

165 richness which is comparable to areas with higher coral cover (e.g. Gillibrand, Harries &

166 Mara, 2007; Table 3). This may be partly explained by the extensive visual sampling design

167 used. The high sampling time employed in this study (over 36 hours of underwater

168 observations) allowed for the observation of some cryptic species that would be missed by

shorter visual surveying. For example, four species of gobies and eight species of blennies were recorded on reefs of PTPB (Table 2). Therefore while visual censuses generally do not accurately capture the diversity of cryptobenthic species (Ackerman & Bellwood, 2000) this limitation can be reduced. A high number of families were also recorded in comparison to other areas in the region (Table 3), suggesting a high proportion of uncommon species were observed. The impact of greater sampling effort on species records is evident in the results of Gillibrand, Harries & Mara (2007). These authors examined a smaller area than the current study and recorded 334 species by conducting visual observations across a twelve month period. In contrast, Chabanet and Durville (2005) recorded more than 50 fewer species around Juan de Nova island through 30 hours of visual surveying. This highlights that sampling effort does not solely account for the high fish diversity recorded in the PTPB area.

The present study necessarily examined a large depth range (1-32 m) in order to capture the range of habitats present in the area. As such a higher number of specialist species are expected to have been identified due to the wider variety of physical habitats and biological conditions (Bridge *et al.* 2016; Jankowski, Graham & Jones, 2015). Significant changes in fish assemblages with depth have been observed in previous studies (e.g. Friedlander & Parrish, 1998) and this is likely to be the same in the current study. This may also explain the high number of families observed (Table 3).

Coastal upwelling in these seas drives high levels of primary productivity and in turn supports abundant populations of large charismatic species (Rohner *et al.* 2014). It is also likely to influence the reef fish diversity of the area, potentially boosting species richness in two ways. Firstly, cooler waters allow the area to support species more common in temperate waters (e.g. *Seriola lalandi*, *Oplegnathus robinsoni*). Anderson *et al.* (2015) proposed the

appearance of species characteristic of higher latitudes in their sub-tropical study site to regions of cool water upwelling. In the current study water temperatures were recorded between 18-29°C and the influx of cool water may also influence diversity in the sub-tropical PTPB area. Secondly, upwelling supports high plankton abundance which can reduce competitive exclusion in planktivorous species (Abrams, 1995). This would allow the co-existence of more species on lower trophic levels, an effect which may then propagate up the food chain to produce a higher diversity of secondary and tertiary consumers. The relationship between primary productivity and diversity has been previously acknowledged (Waide *et al.* 1999).

This study demonstrates the PTPB area's biological value beyond its resident megafauna populations, and the future for a broader value of ecotourism to the region. Whilst the relatively large sampling extent precludes comprehensive comparisons with other studies in the southwestern Indian Ocean, the results show that the coral reef ecosystem of PTPB hosts a reef fish community comparable to more isolated or protected areas. As such the current study suggests that the reefs of PTPB are in good condition, despite the large associated human population. Targeted research is needed to examine the current health status of these reefs and to provide a baseline for monitoring impacts of future expansion of tourism and fishing activities in the region.

Acknowledgements

I would like to thank Peri Peri dive centre and the Underwater Africa volunteer program for their support in undertaking both SCUBA and snorkel surveys. Sincere thanks to Dr Tracy Ainsworth, Dr William Leggat, Dr Hudson Pinheiro and an anonymous reviewer for

comments on and improvements to the manuscript. Finally, thank you to all those friends and strangers who provided photographic evidence of rare species.

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