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Distribution and Community Structure of Butterflyfishes (Pisces: Chaetodontidae) in Southern Mozambique

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***Abstract*—**Even though Mozambique has the greatest reported diversity of butterflyfishes (24 species) of the continental states of the Western Indian Ocean region, aspects of the ecology and distribution of this group in Mozambique are poorly documented. The distribution, diversity and community structure of butterflyfishes were studied on nine reefs in southern Mozambique using the point count method. Nineteen species from four genera were identified. Three with generalist feeding habits (i.e. *Chaetodon auriga*, *C. guttatissimus* and *C. interruptus*) were the most abundant with a wide distribution range. The butterflyfish communities of intertidal reefs at Inhaca Island differed from those of the offshore, subtidal reefs, as shown by uni- and multivariate analysis of abundance and diversity data. This is attributed to differences in habitat structure and food availability. However, most species occurred on both reef types. The butterflyfish diversity of the area is considered high and comparable to other high latitude reef areas in the world. These results emphasize the high biodiversity of the region and constitutes a latitudinal biodiversity peak. These findings also highlight the need for effective conservation measures.

INTRODUCTION

Butterflyfishes (Pisces: Chaetodontidae) are conspicuous and important members of the tropical and subtropical fish fauna that live, with few exceptions, in close association with coral reefs (Williams & Hatcher, 1983; Allen *et al.*, 1998). While most butterflyfishes are omnivorous, some species are highly dependant on corals as their main food source (Hiatt & Strasburg, 1960; Hobson, 1974; Harmelin-Vivien & Bouchon-Navaro, 1983). For these reasons, a number of authors have suggested the use of butterflyfishes as bio-indicators of reef health (Reese, 1981; Crosby & Reese, 1996; Öhman *et al.*, 1998). Allen *et al.* (1998) recognized 116 species in ten genera and a diversity peak in the Indo-Pacific (specifically in the central SE Asia region).

While the ecology and biology of butterflyfishes is now well documented for the Indo-Pacific (Hiatt & Strasburg, 1960; Hobson, 1974; Harmelin-Vivien & Bouchon-Navaro, 1983; Adrim & Hutomo, 1989; Fowler, 1990; Öhman *et al.*, 1998), the Red Sea (Bouchon-Navaro & Bouchon, 1989; Roberts *et al.*, 1992; Zekeria *et al.*, 2002) and the Caribbean (Neudecker, 1982; Lasker, 1985; Colin, 1989), very few studies have been conducted in the Western Indian Ocean (WIO) (Righton *et al.*, 1996). The WorldFish Centre database - FishBase (Froese & Pauly, 2004) states that Mozambique has the highest diversity of butterflyfishes [24 species; see also Pereira

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(2000); Pereira *et al*. (2004)] within the continental states of the WIO, ranking second only after the island states. However, ecological and biological aspects of this group have not been subjected to in-depth studies. The existing information is derived from annual coral reef monitoring programmes (e.g. Pereira *et al*., 2003) and other multi-species reef fish assessments (e.g. Loureiro, 1998; Pereira *et al*., 2004). This paper reports on the distribution, community structure and diversity of butterflyfishes in southern Mozambique.

MATERIALS AND METHODS

Study sites

Southern Mozambique comprises 86 km of coastline between Cabo de Santa Maria (26°05' S; 32°58'E) in the north and Ponta do Ouro (26°51'S; 32°58'E) in the south (Figure 1). The coast is straight and exposed, consisting primarily of extensive sandy beaches. The sandy beaches are interspersed with occasional rocky headlands (Hatton, 1995; Robertson *et al*., 1996). The continental shelf narrows in the study area, and extends only few kilometers offshore. The study area is strongly influenced by the warm Agullhas Current, which flows in a southerly direction, reaching mean peak velocities of 1.4 m/s (Lutjeharms & Ruijter, 1996). Inshore, northwards flowing, counter-currents are also common, but normally only reach velocities of less than 0.25 m/s (Schumman, 1988). Swell direction is predominantly from the south, attaining heights in excess of 5 m (Schumman, 1988). The annual mean sea surface temperature for the area is 24°C, the tidal cycle is semi-diurnal and the tidal range is between 1.8 and 2.4 m (Robertson *et al*., 1996).

Nine reefs were surveyed; four at Ponta Malongane (Creche-Cr, Kev's Ledge-KL, Shallow Malongane-SM and Texas-Tx), two sites of the reef at Ponta Techobanine (Techo 1-Te1 and Techo 2-Te2) and three at Inhaca Island (Barreira Vermelha-BV, Ponta Torres-PT and Baixo Danae-BD; Figure 1, Table 1).

The offshore, subtidal reefs at Ponta Malongane are classified as patch reefs. The coral communities grow as a thin veneer on late

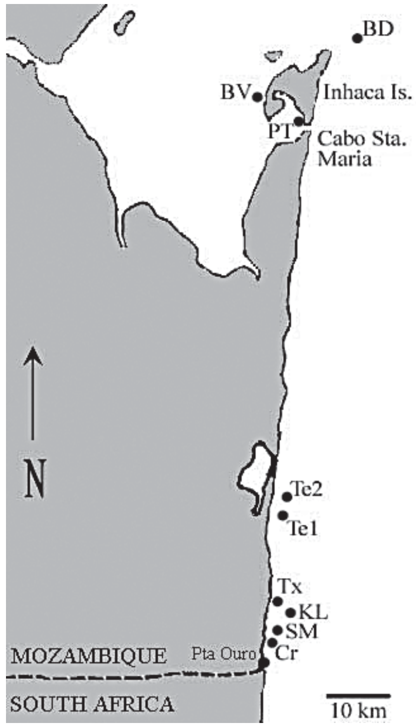

Fig. 1. Schematic map of the location of the study reefs in southern Mozambique. BD = Baixo Danae; BV = Barreira Vermelha; Cr = Creche; KL = Kev's Ledge; PT = Ponta Torres; SM = Shallow Malongane; Te1 = Techo 1; Te2 = Techo 2 and Tx = Texas

Pleistocene sandstone, which originated from submerged coastal sand dunes (Ramsay, 1994) and are not derived from biogenic accretion. Reefs run parallel to the coastline 1 to 2 km offshore and, as in Kwazulu-Natal (Riegl *et al*., 1995), they do not reach the surface while lacking most geomorphological characteristics typical of true coral reefs. None of the usual features of true coral reefs (reef crest, or steep reef slopes) are thus present, resulting in homogenous topographic conditions over most of the reef area. The major topographic features are gullies and associated small drop-offs, usually perpendicular to the dominant SE swells.

Reefs are generally small; the width varies between 10 to 600 m and the length between 50 to 1500 m. Soft corals, predominantly *Lobophytum*, *Sinularia* and *Sarcophyton*, are the most abundant biota on the shallow reefs, while hard corals are

Table 1. Details of the butterflyfish sampling effort, location and other characters of the study reefs in southern Mozambique. Reef codes are as in Figure 1. PC = number of point counts

Reef	PC	Coordinates		Depth range (m)	Remarks
		Latitude	Longitude		
BD	21	25° 54.259' S	33° 03.136' E	16 - 22	Offshore, subtidal
BV	20	26° 01.179' S	32° 54.179' E	1 - 5	Inshore, intertidal
Cr	40	26° 48.371' S	32° 53.622' E	10 - 14	Offshore, subtidal
KL	40	26° 46.673' S	32° 54.268' E	18 - 24	Offshore, subtidal
PT	20	26° 03.853' S	32° 57.523' E	1 - 4	Inshore, intertidal
SM	36	26° 46.784' S	32° 53.993' E	14 - 16	Offshore, subtidal
Te 1	16	26° 37.770' S	32° 54.736' E	16 - 20	Offshore, subtidal
Te 2	13	26° 37.806' S	32° 54.873' E	20 - 27	Offshore, subtidal
Tx	50	26° 46.275' S	32° 54.105' E	12 - 18	Offshore, subtidal

relatively more abundant in deeper areas. Live coral cover varies from 29 to 70% (Pereira, 2003). The reefs have not been studied in detail but initial surveys have identified 376 species of reef fishes (Pereira *et al*., 2004), 19 genera of hard and 10 of soft corals (Robertson *et al*., 1996). Further details of the structure of coral communities of these reefs are provided by Pereira (2003).

The two intertidal fringing reefs at Inhaca Island have been previously studied (Salm, 1976; Nestler *et al*., 1984; Kalk, 1995). Barreira Vermelha is about 2 km long and 50 m wide, while Ponta Torres is smaller, with a maximum length of 1 km and width of 30 m (Salm, 1976). In contrast to other reefs of the study area, these are dominated by hard corals, with *Acropora, Porites, Montipora* and *Pocillopora* being the most abundant genera (Salm, 1976; Kalk, 1995; Perry, 2003).

Field methods and data analysis

Butterflyfish abundance and diversity was estimated using point counts (Bohnsack & Bannerot, 1986) between April 2001 and December 2002. Butterflyfishes encountered within a 7 m radius (154 m^2) and up to 5 m above the substratum were counted over a period of three minutes. A total of 256 point counts were performed (Table 1). Fish counts were made between 0700 and 1700 hours to avoid the diurnal-nocturnal fish community shift (Halford & Thompson, 1994). After diver entry a period of ten minutes was allowed, prior to fish counts, to allow fishes to resume normal behaviour (Carpenter *et al*., 1981).

Fish density data was converted to fish/100m^2 prior to analysis. Data were analysed using Kruskal-Wallis ANOVA (Zar, 1999) in the software package Statistica 6.0. A multivariate clustering technique (hierarchical cluster analysis using a Bray-Curtis matrix) was performed on double square root transformed abundance data.

RESULTS

A total of 19 species representing four genera were observed: *Chaetodon* (15 species), *Forcipiger* (1 species), *Hemitaurichthys* (1 species) and *Heniochus* (2 species). *Chaetodon auriga, C. guttatissimus, C. interruptus* (previously *C. unimaculatus* cf. Allen *et al*., 1998) and *C. meyeri* displayed a wide distribution ranges, occurring on all reefs (Table 2). Other widely distributed species were *C. kleinii*, *C. lunula* and *C. trifascialis*, which occurred on eight of the study reefs. Species with wide distribution ranges were also the most abundant (Table 2). Three species, *C. falcula*, *C. melannotus* and *H. monoceros*, had a restricted distribution and were only found on the northern reefs (i.e. Baixo Danae, Barreira Vermelha and Ponta Torres; Table 2).

Chaetodon auriga, *C. guttatissimus*, *C. interruptus* and *C. kleinii* were the most abundant overall (Table 3) while *C. auriga* was the most commonly observed butterflyfish in both intertidal reefs at Inhaca Island (i.e. Barreira Vermelha = 2.0 individuals/100 m^2 and Ponta Torres = 5.3 individuals/100 m^2). *C. interruptus* dominated Creche (1.2 individuals/100 m^2), Shallow Malongane (2.0 individuals/100 m^2) and Texas (1.9

Table 2. Percentage occurrence of butterflyfish species along the study reefs in southern Mozambique. Reef codes as in Figure 1

Species	BD	BV	Cr	KV	PT	SM	Te1	Te2	Tx
Chaetodon auriga	28.6	85.0	27.5	7.5	100.0	16.7	12.5	30.8	18.0
C. blackburnii	4.8	0.0	57.5	30.0	0.0	22.2	12.5	30.8	34.0
C. falcula	0.0	5.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0
C. guttatissimus	76.2	30.0	77.5	67.5	10.0	80.6	75.0	100.0	62.0
C. interruptus	23.8	15.0	70.0	70.0	5.0	88.9	50.0	53.8	84.0
C. kleinii	95.2	35.0	75.0	85.0	0.0	75.0	81.3	76.9	74.0
C. lineolatus	0.0	10.0	0.0	0.0	10.0	2.8	0.0	0.0	0.0
C. lunula	9.5	35.0	10.0	10.0	20.0	8.3	25.0	0.0	18.0
C. melannotus	0.0	5.0	0.0	0.0	45.0	0.0	0.0	0.0	0.0
C. mertensii	57.1	0.0	42.5	55.0	0.0	58.3	68.8	38.5	56.0
C. meyeri	47.6	5.0	62.5	30.0	5.0	55.6	56.3	46.2	56.0
C. trifascialis	19.0	35.0	2.5	10.0	15.0	22.2	25.0	0.0	8.0
C. trifasciatus	0.0	65.0	0.0	2.5	90.0	0.0	18.8	7.7	2.0
C. vagabundus	9.5	45.0	2.5	0.0	20.0	5.6	6.3	0.0	18.0
C. xanthocephalus	0.0	10.0	0.0	0.0	15.0	2.8	0.0	0.0	0.0
Forcipiger flavissimus	23.8	0.0	82.5	57.5	0.0	27.8	31.3	53.8	40.0
Hemitaurichthys zoster	4.8	0.0	10.0	42.5	0.0	0.0	18.8	0.0	2.0
Heniochus acuminatus	0.0	25.0	0.0	2.5	10.0	0.0	0.0	0.0	0.0
H. monoceros	4.8	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0
Number of species	13	14	12	13	14	13	14	9	13

individuals/100 m^2). At Kev's Ledge and Baixo Danae, *C. kleinii* proved to be the most abundant. Finally, *C. guttatissimus* was the most abundant butterflyfish at both Techo reefs (Table 3).

Barreira Vermelha, Ponta Torres and Techo 1, had the most speciose butterflyfish community, each with a total of 14 species identified. The number of species observed on all the studied reefs was similar, with the exception of Techo 2 where only nine species were identified (Table 2). The differences in butterflyfish community structure of the two intertidal reefs at Inhaca Island (Barreira Vermelha and Ponta Torres) and the other offshore, subtidal reefs was confirmed by hierarchical multivariate cluster analysis (Figure 2), showing a clustering of these two reefs at a dissimilarity level of 22%.

DISCUSSION

This study was carried out in southern Mozambique, a remote area that has received very little attention from marine scientists. While other studies have provided species lists (e.g. Robertson *et al*., 1996; Pereira *et al*., 2004), this constitutes the first quantitative assessment of butterflyfish distribution and diversity in southern Mozambique.

The butterflyfish communities were dominated both in abundance and distribution range by three species: *Chaetodon auriga*, *C. guttatissimus* and *C. interruptus* (Tables 2 and 3). These species have a wide distribution range throughout the Indian Ocean, and occur as far south as Durban, as reported by Fennessy *et al*. (1998). Notably, all species are facultative coral feeders (= generalist feeders) and their diets include hard and soft corals, sponges, polychaetes, crustaceans, anemones and algae (Hiatt & Strasburg, 1960; Hobson, 1974; Harmelin-Vivien & Bouchon-Navaro, 1983; Allen *et al*., 1998). Harmelin-Vivien & Bouchon-Navaro (1983) and Fowler (1990) also reported a dominance of generalist feeders within butterflyfish populations working in Moorea - French Polynesia and One Tree Reef - Great Barrier Reef. The relatively low hard coral cover typical of the offshore, subtidal reefs studied (Pereira, 2003), probably explains the dominance of generalist feeders, suggesting that food availability (Bouchon-Navaro & Bouchon, 1989; Öhman *et al*., 1998; Williams, 1991) might be an important factor in the butterflyfish community

Table 3. Butterflyfish abundance ± SE per 100 m^2, on the study reefs in southern Mozambique. Reef codes as in Figure 1. Results of Kruskal-Wallis ANOVA are shown as * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$. NS = not significant

Species	BD	BV	Cr	KL	PT	SM	Te 1	Te 2	Tx	p
Chaetodon auriga	0.4 ± 0.2	2.0 ± 0.4	0.5 ± 0.2	0.1 ± 0.1	5.3 ± 0.6	0.2 ± 0.1	0.2 ± 0.1	0.3 ± 0.2	0.2 ± 0.1	***
C. blackburnii	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 0.1	0.3 ± 0.1	0.0 ± 0.0	0.2 ± 0.1	0.1 ± 0.1	0.3 ± 0.2	0.3 ± 0.1	***
C. falcula	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ±0.0	0.2 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	***
C. guttatissimus	1.9 ± 0.5	0.4 ± 0.2	1.0 ± 0.1	0.9 ± 0.1	0.1 ± 0.1	1.2 ± 0.2	2.2 ± 0.7	2.6 ± 0.5	0.8 ± 0.1	***
C. interruptus	0.2 ± 0.1	0.2 ± 0.1	1.3 ± 0.2	1.2 ± 0.2	0.0 ± 0.0	2.0 ± 0.2	0.8 ± 0.3	1.1 ± 0.4	1.9 ± 0.2	***
C. kleinii	2.4 ± 0.4	0.3 ± 0.1	0.8 ± 0.1	1.9 ± 0.2	0.0 ± 0.0	1.4 ± 0.2	1.7 ± 0.5	1.8 ± 0.6	1.6 ± 0.2	***
C. lineolatus	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.2	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	*
C. lunula	0.1 ± 0.1	0.6 ± 0.2	0.1 ± 0.0	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.4 ± 0.2	0.0 ± 0.0	0.1 ± 0.0	NS
C. melannotus	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.5 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	***
C. mertensii	0.7 ± 1.2	0.0 ± 0.0	0.7 ± 0.2	0.7 ± 0.1	0.0 ± 0.0	0.7 ± 0.1	1.0 ± 0.3	0.3 ± 0.2	0.7 ± 0.1	***
C. meyeri	0.6 ± 0.1	0.0 ± 0.0	0.6 ± 0.1	0.3 ±0.1	0.0 ± 0.0	0.7 ± 0.1	0.9 ± 0.2	0.4 ± 0.2	0.7 ± 0.1	***
C. trifascialis	0.3 ± 0.2	0.5 ± 0.2	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.0 ± 0.0	0.1 ± 0.0	**
C. trifasciatus	0.0 ± 0.0	1.8 ± 0.4	0.0 ± 0.0	0.0 ± 0.0	3.5 ± 0.7	0.0 ± 0.0	0.3 ± 0.2	0.1 ± 0.1	0.0 ± 0.0	***
C. vagabundus	0.1 ± 0.1	0.4 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	***
C. xanthocephalus	0.0 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	**
Forcipiger flavissimus	0.3 ± 0.1	0.0 ± 0.0	1.1 ± 0.1	1.0 ± 0.2	0.0 ± 0.0	0.3 ± 0.1	0.3 ± 0.1	0.5 ± 0.2	0.5 ± 0.1	***
Hemitaurichthys zoster	0.1 ± 0.1	0.0 ± 0.0	0.2 ± 0.1	0.7 ± 0.2	0.0 ± 0.0	0.0 ± 0.0	0.4 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	***
Heniochus acuminatus	0.0 ± 0.0	0.5 ± 0.2	0.0 ± 0.0	0.2 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	***
H. monoceros	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	NS
Coralivores	0.9 ± 0.3	2.4 ± 0.5	0.7 ± 0.1	0.5 ± 0.1	4.1 ± 0.9	1.0 ± 0.2	1.4 ± 0.4	0.5 ± 1.9	0.7 ± 0.1	NS
Omnivores	6.2 ± 0.8	3.8 ± 0.6	6.3 ± 0.4	6.2 ± 0.4	6.0 ± 0.7	6.2 ± 0.5	6.7 ± 1.0	7.1 ± 0.4	6.4 ± 0.5	***
Planktivores	0.1 ± 0.1	0.5 ± 0.2	0.2 ± 0.1	0.7 ± 0.2	0.2 ± 0.1	0.0 ± 0.0	0.4 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	***
Total	7.2 ± 1.0	6.9 ± 1.1	7.1 ± 0.5	7.4 ± 0.5	10.8 ± 1.2	7.2 ± 0.5	8.5 ± 1.1	7.6 ± 1.0	7.1 ± 0.5	***

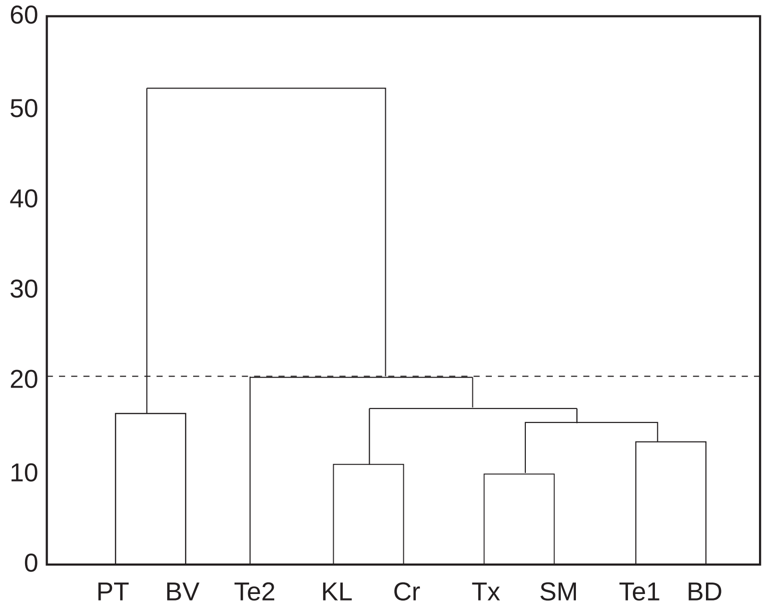

Fig. 2. Clustering (UPGMA) of reefs from southern Mozambique obtained by classification of butterflyfish abundance. The Bray-Curtis dissimilarity index was applied to double square root transformed data. Dotted line shows 22% dissimilarity level. Reef codes as in Figure 1

structure in southern Mozambique. This has been shown to be the case in several studies elsewhere (e.g. Carpenter *et al*., 1981; Harmelin-Vivien & Bouchon-Navaro, 1983; Bouchon-Navaro & Bouchon, 1989; Öhman *et al*., 1998). Furthermore, reefs with relatively higher hard coral cover (e.g. Ponta Torres, Techo 1 and Barreira Vermelha; Pereira, 2003; Perry, 2003) had higher butterflyfish species richness and/or abundance (Tables 2 and 3). Further studies relating to diet, food partitioning and niche breadth of the butterflyfish assemblages in this area should be conducted to clarify the relation with coral community structure.

Nineteen species of butterflyfishes were identified from a total of 24 species recorded in Mozambique (Pereira, 2000; Pereira *et al*., 2004). *Heniochus diphreutes* and *Chaetodon bennetti* were previously recorded in the area (Kalk, 1995; Pereira *et al*., 2004), however, neither species were recorded during our dives. At least three other species (i.e. *Chaetodon dolosus*, *C. marleyi* and *C. zanzibarensis*) also occur in the area and they have been recorded on the Maputaland reefs further south (Chater *et al*., 1993). In general, the diversity of butterflyfishes in southern Mozambique is high and comparable to other high latitude reef areas. For example, Lecchini *et al*. (2003) reported 22 species from the Ryukyu Islands - Japan and Righton *et al*. (1996) reported 17 species for the Red Sea. The findings of this study emphasise the high biodiversity of the southern Mozambique region, which, constitutes a latitudinal biodiversity peak attributable to the admixture of tropical and temperate fauna (Schleyer, 1999). Currently the reefs do not benefit from any formal protection and there is need to implement conservation measures in the area. This makes them vulnerable to anthropogenic activities that include irresponsible tourism, illegal fishing and use of destructive fishing gear.

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