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Newly discovered reefs in the southern Abrolhos Bank, Brazil: Anthropogenic impacts and urgent conservation needs

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A B S T R A C T

The Abrolhos Bank is an area of high ecological, socio-economic importance and harbour the richest and most-extensive coral reefs in the South Atlantic. Here we report the discovery of shallow (12–25 m depth) reef complex with ten large biogenic structures, intermediate between the typical mushroom-shaped pinnacles of the northern Abrolhos Bank (17°–18° S) and the small patch reefs found on the central/southern coast of the Espírito Santo State (19°–20° S). The newly discovered reefs harbour a relatively rich and abundant reef community, with 73 fish and 14 benthic cnidarian species, including endangered and commercially important ones. We discuss on urgent needs of properly mapping and understanding the ecological functioning of this reef system. Information provided here is a baseline for future impact evaluations, particularly considering the recent worst environmental disaster of Brazil from a dam collapse in Doce river that affected the region.

1. Introduction

The Abrolhos Bank is situated between 16°40′–19°40′S and 37°20′–39°10′ W (Fig. 1) on the eastern Brazilian continental shelf and is recognized as the largest and richest coral reef system in the South Atlantic (Dutra et al., 2005; Freitas et al., 2011; Francini-Filho et al., 2013). The reef systems known until now are concentrated in the northern portion of the Abrolhos Bank and are protected by a mosaic of marine protected areas with different conservation levels (Francini-Filho and Moura, 2008). Brazilian reefs have relatively low fish and scleractinian coral species richness in comparison to other regions, but high endemism levels (about 25% for fishes and 30% for scleractinian corals; Moura, 2000; Leão et al., 2003). Most reef structures display a characteristic form of mushroom-shaped pinnacles, which attain 5 to 25 m in height and 20 to 300 m across their tops (Francini-Filho et al., 2013). The Abrolhos Bank also encompasses the world's largest continuous rhodolith bed (Amado-Filho et al., 2012), euphotic (<30 m depth) and mesophotic (30–150 m depth) reefs (Moura et al., 2013), as well as sinkhole-like depressions locally known as “buracas” (Bastos et al., 2013).

It was previously thought that the southern part of the Abrolhos Bank was an area dominated by unconsolidated sediments (sand or terrigenous mud) and devoid of reefs, given its proximity to large river discharges, particularly that of the Doce river (Knoppers et al., 1999; Moura et al., 2013). However, this assumption was recently refuted by sidescan sonar studies, which recorded extensive rhodolith beds with sparse mesophotic reefs in the southern Abrolhos Bank (Moura et al., 2013), as well as the presence of biogenic reefs as far south as the Espírito Santo State (Teixeira et al., 2013). The southern Abrolhos Bank was never recognized as a research priority, preventing bona fide progress in coral reefs studies and leaving these large unexplored reefs virtually unknown by the scientific community. Information provided here is an important baseline for future impact evaluations, particularly

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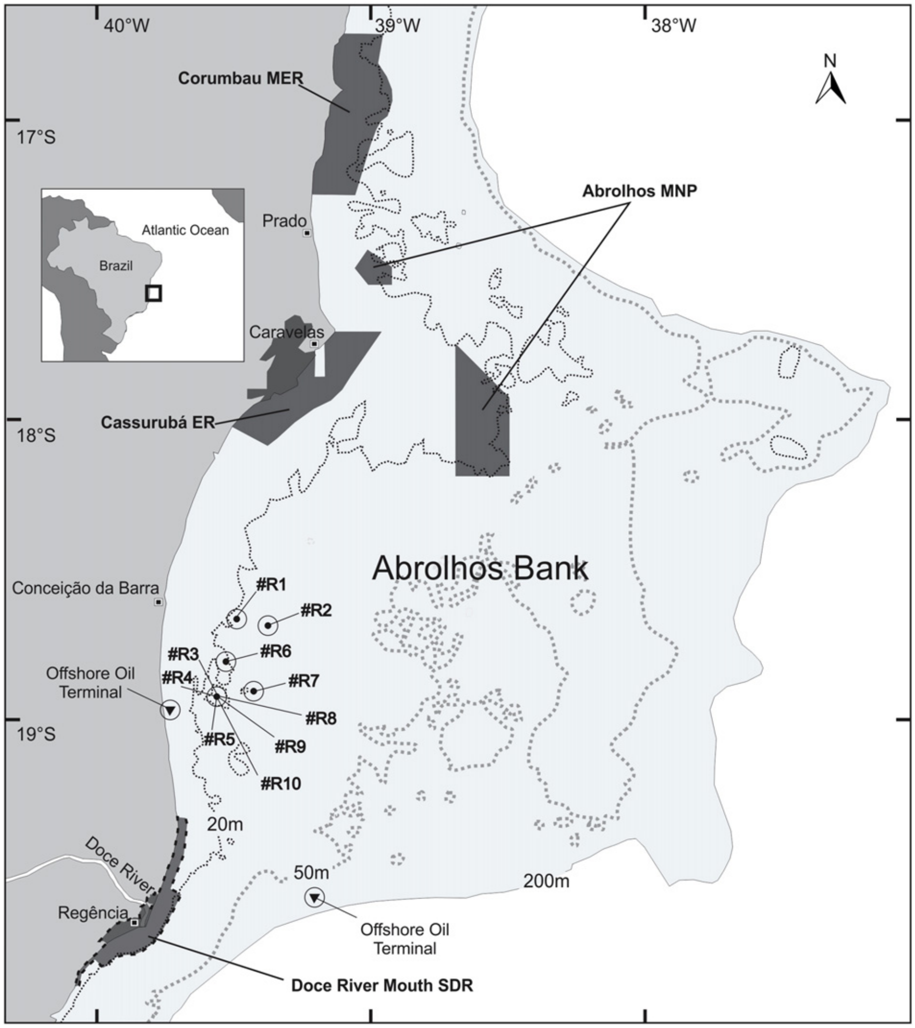

Fig. 1. Newly discovered reef structures in the southern Abrolhos Bank, northern Espírito Santo State. The mosaic of present and proposed marine protected areas (i.e. before the mining dam disaster from the Doce river) with different conservation levels are shown: Abrolhos National Marine Park (MNP), Corumbau Marine Extractive Reserve (MER); Cassurubá Extractive Reserve (ER) and the Doce river Mouth Sustainable Development Reserve (SDR), this latter still a proposal not yet implemented.

considering that the region was recently affected by a huge plume of iron mining waste from a dam collapse in Doce river, now considered the worst environmental disaster in Brazil (Miranda and Marques, 2016).

2. Materials and methods

In order to elaborate a baseline assessment of reef biodiversity in the southern Abrolhos Bank, five expeditions were conducted in November 2013, February and December 2014, as well as March and December 2015 (total of 14 days and 24 h of sampling). During sampling, SCUBA was used to perform rapid visual survey, underwater photography and video, thus generating a checklist of species for each site. Sites ranged between 17 and 28.5 km offshore and 75–102 km from the Rio Doce River mouth.

2.1. Fish sampling

Fishes were identified at the species level, following Craig and Hastings (2007) and Craig et al. (2011) for Epinephelidae, and Westneat and Alfaro (2005) for Labridae. The conservation status of each species was obtained from global (IUCN, 2015), national (MMA, 2014) and regional (IEMA, 2005) red lists (NE: not evaluated; DD: data deficient; LC: least concern; NT: near threatened; VU: vulnerable; EN: endangered; CR: critically endangered). Geographical distribution of reef fish species [Brazilian province (BR); circumtropical (CT); trans-Atlantic (TA); Western Atlantic (WA); Central Atlantic (CA); Eastern Pacific (EP)] was obtained from Froese and Pauly (2016) and trophic categories were assigned following Ferreira et al. (2004) and Francini-Filho and Moura (2008).

2.2. Benthic cnidarians sampling

Coral cover was visually estimated for each reef. Corals were identified at the species level, whenever possible, following SeaLifeBase (Palomares and Pauly, 2016) and their geographical distribution was assigned following FAO Marine Fishing Areas [endemic to the Brazilian province (BR); Western Atlantic (WA); Eastern Central Atlantic (ECA); Western Central Atlantic (WCA), and circumtropical (G)]. The conservation status of each species was obtained from global (IUCN, 2015), national (MMA, 2014) and regional (Espírito Santo State; IEMA, 2005) red lists.

3. Results

Ten biogenic reefs (12–25 m depth, ranging 6–12 m in height and 20–50 m in top diameter) were surveyed in the southern portion of the Abrolhos Bank (Figs. 1 and 2). Scleractinian coral cover was slightly

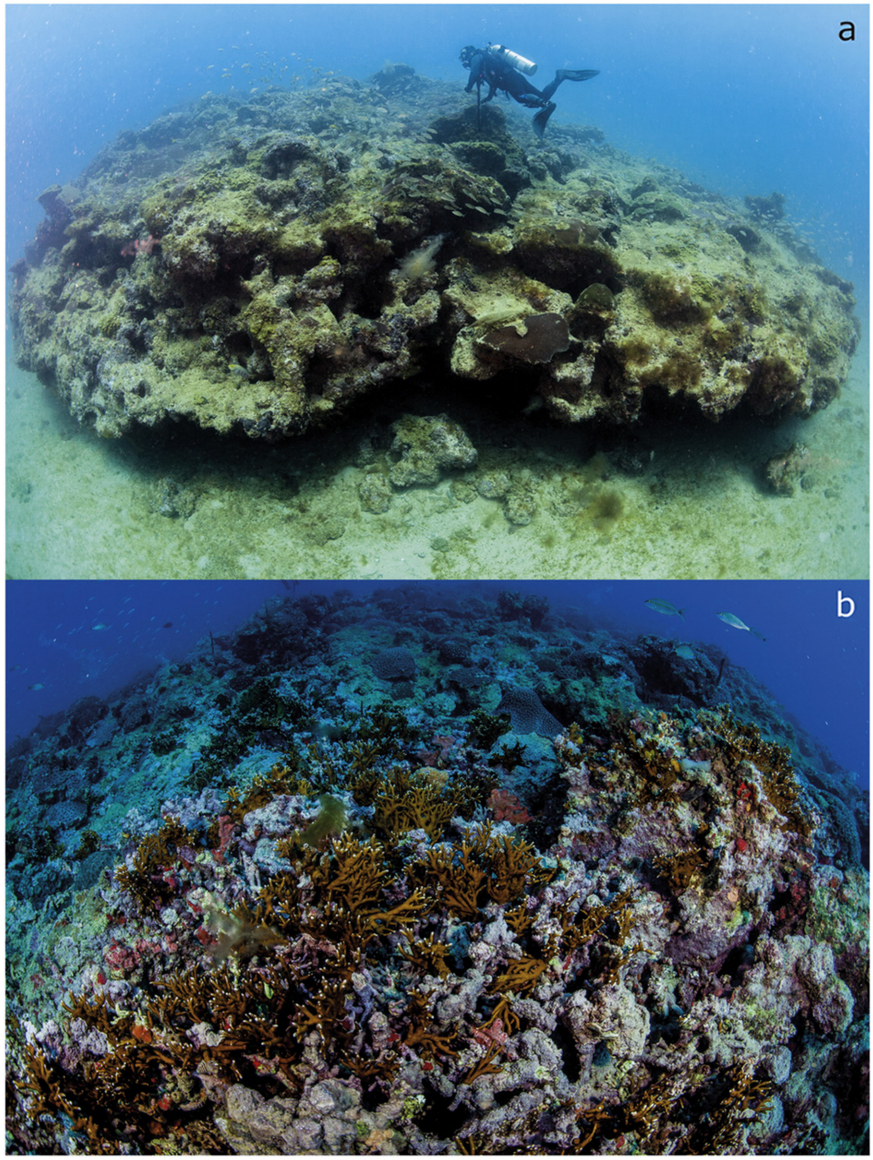

Fig. 2. (a) Landscape view of a reef structure, surrounded by sandy bottoms; (b) reef top with dominance of the hydrocoral *Millepora alcicornis* and the scleractinians *Mussismilia hartii, Mussismilia braziliensis* and *Montastraea cavernosa* (Photos by AAB).

lower (~10–20%) in comparison to reefs in the northern Abrolhos Bank (~5–35%; Francini-Filho et al., 2013). Reef morphology was intermediate between that of typical mushroom-shaped pinnacles ("Chapeirões"; Leão et al., 2003) found in the northern part of the Bank and the small patch reefs found in the central/southern coast of the Espírito Santo State. Information about fish and coral species (geographical range, conservation status and trophic categories) is given in Tables 1 and 2, respectively.

Large healthy colonies (i.e. no visual signs of bleaching and/or disease) of the corals *Montastraea cavernosa*, *Mussismilia harttii*, *Mussismilia braziliensis* and *Millepora alcicornis* were found over the top of the biogenic structures, except for a few bleached colonies of *M. cavernosa* (Fig. 2).

A total of 73 reef fish (Table 1) and 14 benthic cnidarian taxa (Table 2) were recorded. The fish fauna was composed by 34 families and 49 genera. Labridae was the most speciose family (9 species), followed by Haemulidae and Carangidae (5 each), Lutjanidae (4) and Acanthuridae (3). The most speciose genus was *Sparisoma*, with four species, followed by *Acanthurus*, *Haemulon* and *Lutjanus*, with three species each. Sampled reefs sheltered a richer and more abundant fauna than the surrounding rhodolith beds, the former including large, endangered and commercially important reef fishes (Fig. 3). Most families recorded encompassed the carnivorous trophic category (27 families and 54 species representing 74% of the total richness), followed by herbivores (4 families and 11 species, 15%), omnivores (5 families and 7 species, 10%) and planktivores (1 family and 1 species, 1%) (Fig. 4A). The most representative functional groups were mobile invertebrate feeders (13 families, 36% of all species), followed by strict piscivores (3 families, 13%), macrocarnivores (6 families, 11%) and omnivores (5 families, 10%) (Table 1, Fig. 4B).

Most recorded fish species have wide geographical distributions, with 48% ranging across the WA and 25% being TA. About 18% are Brazilian endemics (BR), while 9% have circumtropical (CT) distribution (Fig. 4C). Five fish species are recognized as threatened with extinction by IUCN (2015), while eleven species are listed on the Brazilian red list (MMA, 2014); only two species are listed on the regional red list (IEMA, 2005) (Table 1, Fig. 4). The vast majority of recorded fish species are classified as not-evaluated or data-deficient on global (43 species - 59%) and regional red lists (70 species - 96%) (Fig. 4D and F). One single species (*Epinephelus itajara*) is listed as critically endangered, another

Table 1
Reef fish species recorded in the newly discovered reef system in the southern of Abrolhos Bank, SW Atlantic Ocean. Geographical range, functional group and conservation status according to international (IUCN, 2015), national (MMA, 2014) and state (IEMA, 2005) agencies are indicated. New records from Espírito Santo State (*) and Abrolhos Bank (**) are indicated.

Family	Species	Geographic distribution	Functional group	Conservation status (IUCN/MMA/IEMA)
Albulidae	*Albula vulpes* (Linnaeus, 1758)	G	SAND	NT/NE/—
Muraenidae	*Gymnothorax vicinus* (Castelnau, 1855)	TA	MCAR	NE/DD/—
Synodontidae	*Synodus aff. intermedius* (Spix & Agassiz, 1829)	WA	PISC	NE/LC/—
	Synodus synodus (Linnaeus, 1758)**	TA	PISC	LC/LC/—
Ogcocephalidae	*Ogcocephalus vespertilio* (Linnaeus, 1758)	WA	MINV	NE/NE/—
Holocentridae	*Holocentrus adscensionis* (Osbeck, 1765)	TA	MINV	NE/LC/—
Serranidae	*Serranus baldwini* (Evermann & Marsh, 1899)	WA	MINV	NE/NE/—
	Serranus flaviventris (Cuvier, 1829)	WA	MINV	NE/NE/—
Epinephelidae	*Cephalopholis fulva* (Linnaeus, 1758)	WA	MCAR	LC/LC/—
	Epinephelus itajara (Lichtenstein, 1822)	TA	PISC	CR/CR/EN
	Epinephelus morio (Valenciennes, 1828)*	WA	PISC	NT/VU/—
	Mycteroperca bonaci (Poey, 1860)	WA	PISC	NT/VU/—
Grammatidae	*Gramma brasiliensis* Sazima, Gasparini & Moura, 1998	BR	MINV	NE/NT/VU
Priacanthidae	*Heteropriacanthus cruentatus* (Lacepède, 1801)* **	G	MINV	NE/LC/—
Carangidae	*Alectis ciliaris* (Bloch, 1787)* **	G	MCAR	LC/—/—
	Carangoides bartholomaei (Cuvier, 1833)	TA	PISC	NE/NE/—
	Caranx crysos (Mitchill, 1815)	TA	PISC	LC/NE/NE
	Caranx ruber (Bloch, 1793)	G	PISC	NE/NE/—
	Decapterus macarellus (Cuvier, 1833)*	G	PISC	NE/NE/—
Lutjanidae	*Lutjanus alexandrei* Moura & Lindeman, 2007*	BR	MCAR	NE/LC/—
	Ocyurus chrysurus (Bloch, 1791)	WA	MCAR	NE/NT/—
	Lutjanus jocu (Bloch & Schneider, 1801)	TA	MCAR	NE/NT/—
	Lutjanus synagris (Linnaeus, 1758)	WA	MCAR	NE/NT/—
Haemulidae	*Anisotremus surinamensis* (Bloch, 1791)	WA	MINV	NE/NE/—
	Anisotremus virginicus (Linnaeus, 1758)	WA	MINV	NE/NE/—
	Haemulon aurolineatum Cuvier, 1830	WA	MINV	NE/NE/—
	Haemulon squamipinna Rocha & Rosa, 1999*	BR	MINV	NE/NE/—
	Haemulon plumierii (Lacepède, 1801)	WA	MINV	NE/NE/—
	Haemulon steindachneri (Jordan & Gilbert, 1882)	WA/EP	MINV	LC/NE/—
Sparidae	*Calamus pennatula* Guichenot, 1868*	WA	SAND	LC/NE/—
Mullidae	*Mulloidichthys martinicus* (Cuvier, 1829)**	TA	SAND	NE/NE/—
	Pseudupeneus maculatus (Bloch, 1793)	WA	SAND	NE/NE/—
Kyphosidae	*Kyphosus* sp.	TA	MALG	—/—/—
Chaetodontidae	*Chaetodon striatus* Linnaeus, 1758	WA/CA	SINV	LC/LC/—
Pomacanthidae	*Holacanthus ciliaris* (Linnaeus, 1758)	WA/CA	SPON	NE/DD/—
	Pomacanthus paru (Bloch, 1787)	TA	SPON	LC/DD/—
	Pomacanthus arcuatus (Linnaeus, 1758)	WA	SPON	LC/DD/—
Cirrhitidae	*Amblycirrhitus pinos* (Mowbray, 1927)	WA	MINV	NE/DD/—
Pomacentridae	*Abudefduf saxatilis* (Linnaeus, 1758)	TA	OMNI	NE/LC/—
	Stegastes fuscus (Cuvier, 1830)	BR	THER	LC/LC/—
	Stegastes variabilis (Castelnau, 1855)	WA	THER	NE/LC/—
Labridae	*Bodianus rufus* (Linnaeus, 1758)	WA	MINV	LC/LC/—
	Doratonotus megalepis Günther, 1862	TA	MINV	LC/LC/—
	Halichoeres brasiliensis (Bloch, 1791)	BR	MINV	DD/LC/—
	Halichoeres poeyi (Steindachner, 1867)	WA	MINV	LC/LC/—
	Scarus zelindae Moura, Figueiredo & Sazima, 2001	BR	SCRP	DD/VU
	Sparisoma amplum (Ranzani, 1841)	BR	SCRP	LC/NT/—
	Sparisoma axillare (Steindachner, 1878)	BR	SCRP	DD/VU/—
	Sparisoma frondosum (Agassiz, 1831)	BR	SCRP	DD/VU/—
	Sparisoma tuiupiranga Gasparini, Joyeux & Floeter, 2003	BR	SCRP	LC/LC/—
Blenniidae	*Hypleurochilus pseudoaequipinnis* Bath, 1994	WA	MINV	LC/LC/—
	Hypleurochilus fissicornis (Quoy & Gaimard, 1824)* **	WA	MINV	LC/LC/—
Labrisomidae	*Malacoctenus aff. triangulatus* Springer, 1959	WA	MINV	LC/LC/—
	Malacoctenus delalandii (Valenciennes, 1836)	WA	MINV	NE/LC/—
Chaenopsidae	*Emblemariopsis signifer* (Ginsburg, 1942)	WA	MINV	LC/LC/—
Gobiidae	*Coryphopterus dicrus* Böhlke & Robins, 1960	WA	MINV	NE/LC/—
	Coryphopterus glaucofraenum Gill, 1863	WA	OMNI	NE/LC/—
	Coryphopterus thrix Böhlke & Robins, 1960	WA	OMNI	NE/LC/—
	Elacatinus figaro Sazima, Moura & Rosa, 1997	BR	MINV	NE/VU/VU
Microdesmidae	*Ptereleotris randalli* Gasparini, Rocha & Floeter, 2001	BR	DPLA	NE/LC/—
Ephippidae	*Chaetodipterus faber* (Broussonet, 1782)	WA	OMNI	NE/LC/—
Acanthuridae	*Acanthurus bahianus* Castelnau, 1855	WA	SCRP	LC/LC/—
	Acanthurus chirurgus (Bloch, 1787)	TA	SCRP	LC/LC/—
	Acanthurus coeruleus Bloch & Schneider, 1801	WA/CA	TURF	LC/LC/—
Sphyraenidae	*Sphyraena barracuda* (Edwards, 1771)	G	MCAR	NE/LC/—
Scombridae	*Scomberomorus brasiliensis* Collette, Russo & Zavala-Camin, 1978	WA	MCAR	LC/LC/—
Balistidae	*Balistes capriscus* Gmelin, 1789**	TA	MINV	NE/—/—
	Balistes vetula Linnaeus, 1758	TA	MINV	VU/—/—
Monacanthidae	*Cantherhines pullus* (Ranzani, 1842)	TA	OMNI	NE/LC/—
	Cantherhines macrocerus (Hollard, 1853)	TA	OMNI	NE/LC/—
Ostraciidae	*Acanthostracion quadricornis* (Linnaeus, 1758)	TA	OMNI	NE/LC/—
Tetraodontidae	*Canthigaster figueiredoi* Moura & Castro, 2002	BR	SINV	LC/LC/—
Diodontidae	*Chilomycterus reticulatus* (Linnaeus, 1758)**	G	SINV	NE/LC/—

Table 2
Reef benthic cnidarian species recorded in the newly discovered reef system in the southern of Abrolhos Bank, SW Atlantic Ocean. Geographical range, functional group and conservation status according to international (IUCN, 2015), national (MMA, 2014) and state (IEMA, 2005) agencies are indicated. New records from Espírito Santo State (*) are indicated.

Family	Species	Geographic distribution	Conservation status (IUCN/MMA/IEMA)
Scleractinians			
Agariciidae	*Agaricia fragilis* (Dana, 1848)*	WCA/WA	LC/NE/NE
Astrocoeniidae	*Madracis decactis* (Lyman, 1859)	WA	LC/NE/NE
Faviidae	*Favia gravida* (Verrill, 1868)	BR	NE/NE/NE
	Montastrea cavernosa (Linnaeus, 1766)	G	NE/NE/NE
Mussidae	*Mussismilia braziliensis* (Verrill, 1867)	BR	DD/VU/VU
	Mussismilia harttii (Verrill, 1868)*	BR	DD/EN/NE
	Mussismilia hispida (Verrill, 1902)	BR	DD/NE/NE
	Mussismilia leptophylla (Verrill, 1868)	BR	DD/NE/NE
	Scolymia wellsii (Laborel, 1967)	WA	NE/NE/NE
Poritidae	*Porites astreoides* Lamarck, 1816*	ECA/WCA/WA	LC/NE/NE
Siderastreidae	*Siderastrea stellata* (Verril, 1868)	BR	DD/NE/NE
Hydrocorals			
Milleporidae	*Millepora alcicornis* (Linneaus, 1758)	ECA/WCA/WA	LC/NE/NE
Octocorals			
Clavulariidae	*Carijoa riisei* (Duchassaing & Michelotti, 1860)	G	NE/NE/NE
Zoanthids			
Sphenopidae	*Palythoa caribaeorum* (Duchassaing & Michelotti, 1860)	WCA/WA	NE/NE/NE

(*Balistes vetula*) as vulnerable, three as near threatened, 23 as least concern and four as data deficient according to the IUCN (Table 1, Fig. 4D). According to the Brazilian national red list, six species are classified as vulnerable, five as near threatened, 35 as least concern and five as data deficient (Table 1, Fig. 4E). Thirty-eight species were not evaluated by IUCN and 16 by the Brazilian Ministry of Environment. Considering the regional red list, only two species are classified as vulnerable (Table 1, Fig. 4F). Some incongruences between international and national lists were noted, such as the Queen Triggerfish (*B. vetula*), commonly found at rhodoliths beds surrounding the newly discovered reefs, which is classified as vulnerable according to IUCN (2015), but not evaluated by national lists (IEMA, 2005; MMA, 2014).

The benthic cnidarian fauna was composed by nine families and 14 species (eleven scleractinians, one octocoral, one zoanthid and one hydrocoral) (Table 2). The richest coral (scleractinians plus hydrocorals) families were Mussidae (five species) and Faviidae (two species) (Table 2). The most important reef builders were the Brazilian endemic *Mussismilia braziliensis*, *M. harttii*, and M. *hispida*, along with *Siderastrea stellata*, *Montastrea cavernosa* and the hydrocoral *Millepora alcicornis*. The zoanthid *Palythoa caribaeorum* showed great coverage (up to 10% in some portions of the reefs) and the octocoral *Carijoa riisei* was commonly found on the edges of reef tops. Unidentified species of sponges and sea squirts also made up the benthic reef coverage.

Agaricia fragilis, *M. harttii* and *Porites astreoides* are new records for the Espírito Santo State (Leão et al., 2003). Six (42.9%) of the recorded coral species are endemic to Brazil, the other six (42.9%) of them ranging across the western Atlantic Ocean and two (14.2%) with circumtropical distribution (Fig. 5A). The genus *Mussismilia* is considered a relict from the Tertiary (Laborel, 1970). *Mussismilia braziliensis* is classified as vulnerable and *M. harttii* as endangered (MMA, 2014; Table 2). Four species (38.5%) (*Agaricia fragilis*, *Madracis decactis*, *Millepora alcicornis* and *Porites astreoides*) are considered least concern by the IUCN (2015) (Fig. 5B), while only *M. braziliensis* is listed as vulnerable on the regional list (IEMA, 2005; Fig. 5D). Although still unpublished, in a recent revaluation of the conservation status of Brazilian corals, *M. harttii* category was upgraded to EN under criteria A2c (Debora Pires et al., unpub. data). Five species are classified as data deficient by the IUCN (2015) and twelve by the MMA (2014) (Fig. 5).

4. Discussion

The Abrolhos Bank is recognized as a priority area for biodiversity conservation in the South Atlantic and thus targeted by actions aiming at promoting sustainable use and conservation of natural resources. The Brazilian government considers the area as a high priority for conservation (MMA, 2007), while the World Convention on Biodiversity recognizes it as an Ecologically or Biologically Significant Area (Dutra et al., 2012; CBD, 2014). Finally, the Abrolhos region has been recently included in a proposal of Marine Biosphere Reserve to be submitted to UNESCO (Mazzei et al., 2014).

The Abrolhos Bank and adjacent oceanic environments of the Vitoria-Trindade seamount chain encompass the highest reef-associated biodiversity in the south Atlantic (Leão et al., 2003; Dutra et al., 2005; Lavrado and Ignacio, 2006; Pinheiro et al., 2015a). This region corresponds to an ecological and biogeographic transitional zone between tropical and subtropical marine biotas (Lavrado and Ignacio, 2006; Spalding et al., 2007; Pinheiro et al., 2015b), characterized by the occurrence of range boundaries of multiple species (Andreata and Séret, 1995; Absalão et al., 2006; Paiva, 2006; Serejo et al., 2006). Despite recent mapping surveys across the Abrolhos Bank, the area of the unexplored shallow reefs complex described here was assigned as unconsolidated sediments (see Fig. 8 in Moura et al., 2013). The new reef system of the southern Abrolhos Bank harbours a relatively rich coral community dominated by Brazilian endemics growing over reefs with structural physiography intermediate to that of the mushroom-shaped pinnacles to the north and small patch reefs to the south. The reef system studied here is part of a large mosaic of heterogeneous ecosystems that encompasses mangroves, estuaries, coastal rocky islands and the largest continuous rhodolith beds of the world (Leão et al., 2003; Amado-Filho et al., 2012; Mazzei et al., 2014), and thus is key for understanding and conserving this marine hotspot of biodiversity in the south Atlantic.

The richness of reef-associated species found in this study corresponds approximately to 16.5% of all fishes and 46% of all reef-building corals known for the Brazilian Province (i.e. 21 native scleractinians and five hydrocoral species) (Leão et al., 2003; Neves et al., 2006, 2008; Amaral et al., 2008; Floeter et al., 2008). Nine reef fish species and three corals species were recorded for the first time for the Espírito Santo State (Leão et al., 2003; Floeter et al., 2008; Simon et al., 2013; Pinheiro et al., 2015b; pers. obs. by the authors) (Tables 1 and 2). Six fish species from seven families were recorded for the first time for the Abrolhos Bank (Moura and Francini-Filho, 2005) (Table 1).

The reefs described here might comprise hundreds of patchy structures according to local fishermen (pers. comm.) and they may play an important role in local fisheries. However, while the Espírito Santo State is recognized as a hotspot for conservation due to the

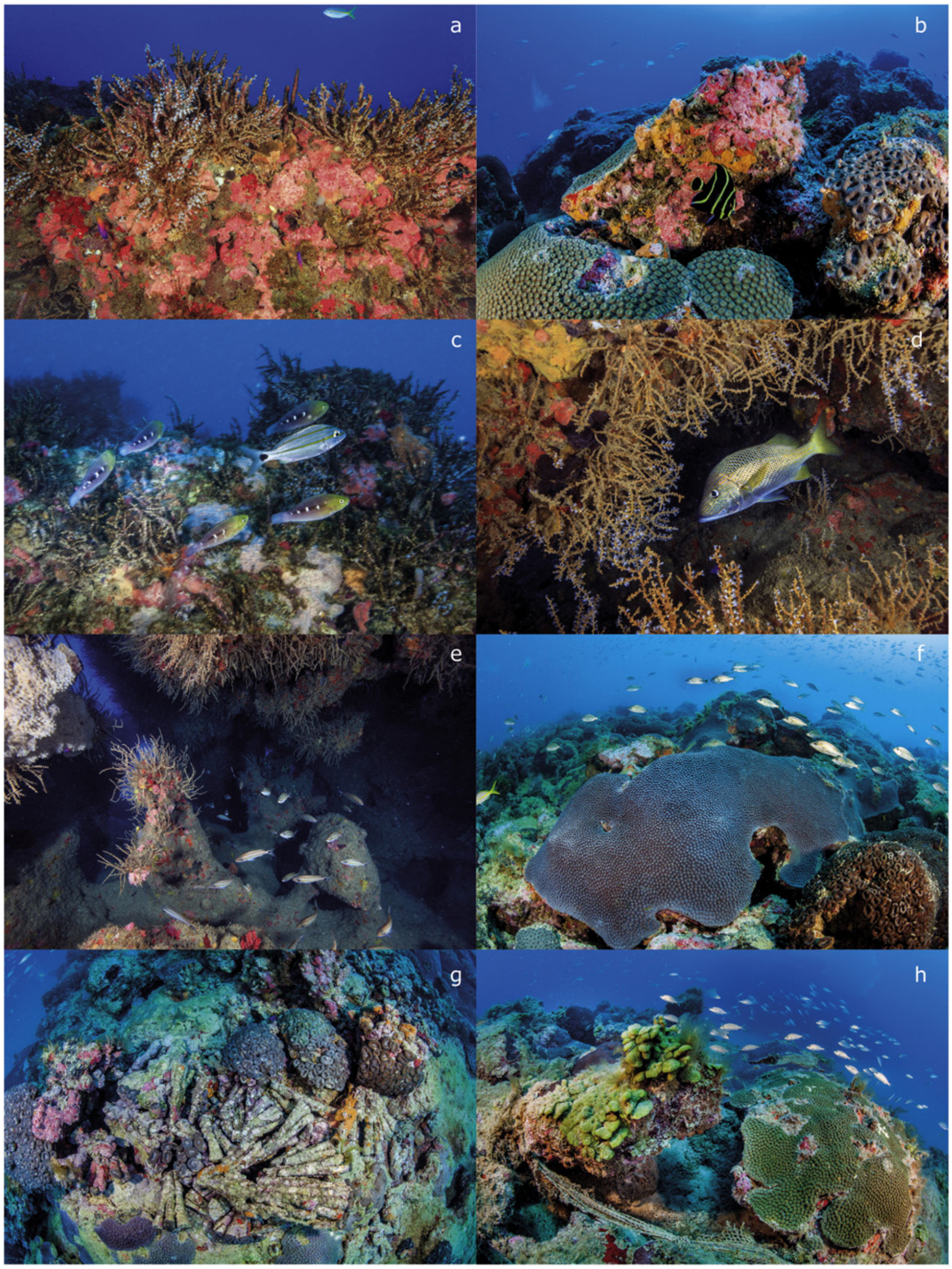

Fig. 3. (a) The octocoral *Carijoa riisei* is abundant on reef edges, as well as the threatened fish *Gramma brasiliensis*; (b) adults and young fish *Pomacanthus paru* are frequent, besides (c) young scarids (*Scarus zelindae*) and (d) commercially important species such as large-bodied *Haemulon plumieri*; (e) high complexity observed inside reef caves and (f) reef cover with schools of *Haemulon aurolineatum* and large colonies of the coral *Montastraea cavernosa*; Observed menaces: (g) signs of anchoring damage over *Mussismilia harttii* and (h) old fishing nets embracing sections of a large colony of *M. cavernosa* (Photos by AAB).

concentration of threatened, endemic and targeted reef fish species it is, awkwardly, the least protected region along the Brazilian coast (Vila-Nova et al., 2014). Signs of anthropogenic impacts are already visible in the newly discovered reefs complex, such as anchoring damage and old fishing nets entangled with reef corals (Fig. 3g, h). In addition, the absence of large predatory fishes as big groupers (Epinephelidae), jacks (Carangidae), sharks and the great dominance of small sized invertivorous reef fishes (i.e. *Haemulon aurolineatum*) suggest overfishing.

The great majority of species recorded here (60% for fishes and 77% for corals) are dada deficient or not evaluated by regional, national and global red lists. This is a worrying pattern considering the plausible increase in anthropogenic impacts in the next decades, such as port expansion, overfishing and mining activities. The recent mining dam collapse in the state of Minas Gerais has produced a flood of ~60 million tons of toxic mud that moved downstream through the Doce river and reached our study area in the southern Abrolhos Bank (Miranda and Marques, 2016; pers. obs; Figs. 6 and 7). This is already being considered as the worse environmental disaster in Brazil to date (Escobar, 2015). The first analyses of the plume indicate high contamination with heavy metals (i.e. cadmium, lead, iron and arsenic) with concentrations far beyond the limits permitted by Brazilian law for fishes (arsenic up to 140 times, cadmium up to 12 times and lead up to 5 times higher than allowed limits), shrimp (arsenic up to 88–115 times, cadmium up to 5 times and lead up to 5 times above safe limits) and zooplankton (Bianchini et al., 2016). However, the newly discovered reefs system, located about half the way between the Doce river (75 km from the mouth) and the Abrolhos Archipelago, are still ignored and no effort

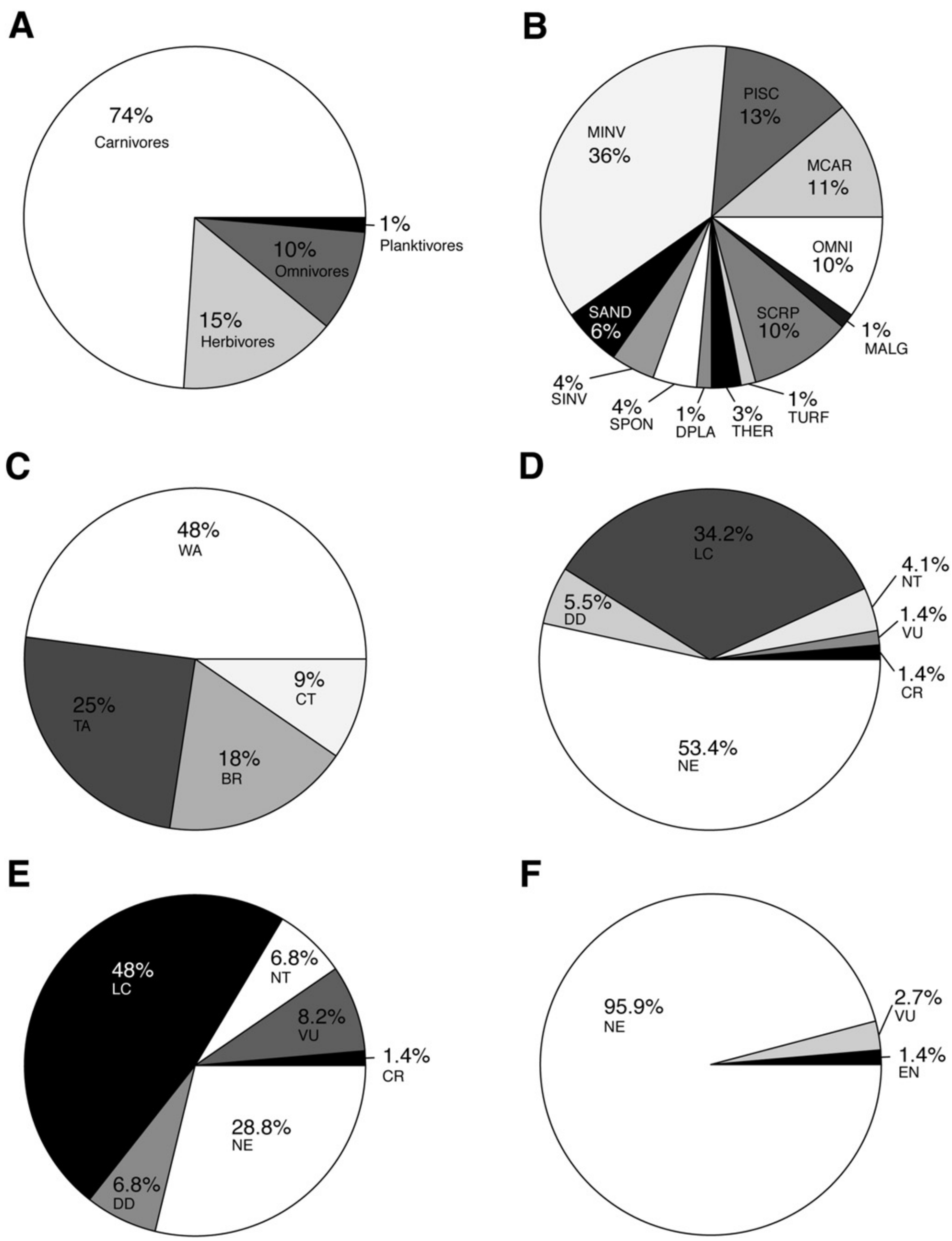

Fig. 4. Relative composition of fish communities from the southern Abrolhos Bankof: A - trophic guilds; B - functional groups; C - geographic distribution; D - global conservation status (IUCN, 2015); E - national conservation status (MMA, 2014) and F - regional conservation status (IEMA, 2005).

has been made to monitor and mitigate the environmental impacts of this disaster (Fig. 7).

Potential impacts from the iron mine waste plume to the newly discovered reefs include: i) bioaccumulation and/or biomagnification through food webs (Luoma and Rainbow, 2008); ii) development of toxic algal blooms due to iron fertilization (Flewelling et al., 2005); iii) latent or delayed effects on fish growth, survival and home-range behaviour (Johnson et al., 2007), and endogenous and exogenous chemical synapses' responses (Lürling and Scheffer, 2007). Different pathways for biotic incorporation of sediment-associated and dissolved metals are possible, including uptake by biofilm, plankton or benthos, transference by benthic-pelagic coupling (Farag et al., 1998, 1999), as well as direct exposure of organisms to pollutants (Luoma and Rainbow, 2008).

Finally, four megaprojects of port enterprises are planned to be implemented in the next few years and are actively encouraged by federal, state and local governments. The establishment of ports and industrial megaprojects would bring severe impacts to marine coastal ecosystems and human populations directly dependent on natural resources (Vianna et al., 2012; Ditty and Rezende, 2014). For example, the oil and gas structures already implemented appear to be, at the very least, a potential threat by acting as vectors of invasive species such as the sun coral (Costa et al., 2014) and, possibly, the mud sleeper *Butis koilomatodon* (Macieira et al., 2012).

5. Conclusions

The southern Abrolhos Bank is part of a proposed mosaic of protected areas that remains on hold in the Brazilian Ministry of Environment. While the marine spatial planning is stranded, the poorly known reefs complex described here are threatened by the intense ore mine spill pollution among other anthropogenic impacts. However, if adequately implemented and enforced, a mosaic of marine protected

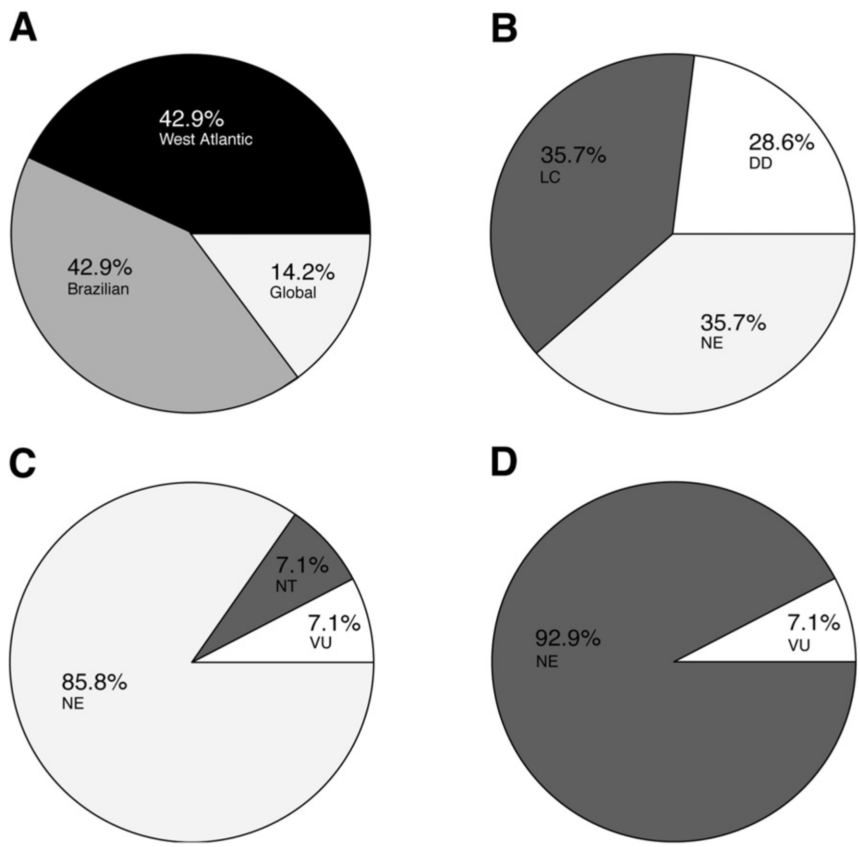

Fig. 5. Relative composition of benthic cnidarian communities from the southern Abrolhos Bank: A - geographic distribution; B - global conservation status (IUCN, 2015); C - national conservation status (MMA, 2014) and D - regional conservation status (IEMA, 2005).

areas (MPAs) would help to maintain the ecological integrity and the biodiversity of the region and create legal paths to mitigate environmental impacts from industrial development.

The fish and coral fauna reported herein are evidence that we still know little about SW Atlantic reef environments. The results provided here are an important baseline on the conditions of reefs before the impacts of the recent mining dam collapse and may also support initiatives for the establishment and planning of marine protected areas over a priority area for biodiversity conservation in the SW Atlantic.

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Fig. 6. Flood of toxic mud moving downstream through the Doce river reaching the Atlantic Ocean and spreading along the coast of the Espirito Santo State. A - photo taken on November 21st, 2015 (looking eastward) and B- February 22nd, 2016 (looking southward) (Photos by Enrico Marcovaldi and EFM, respectively).

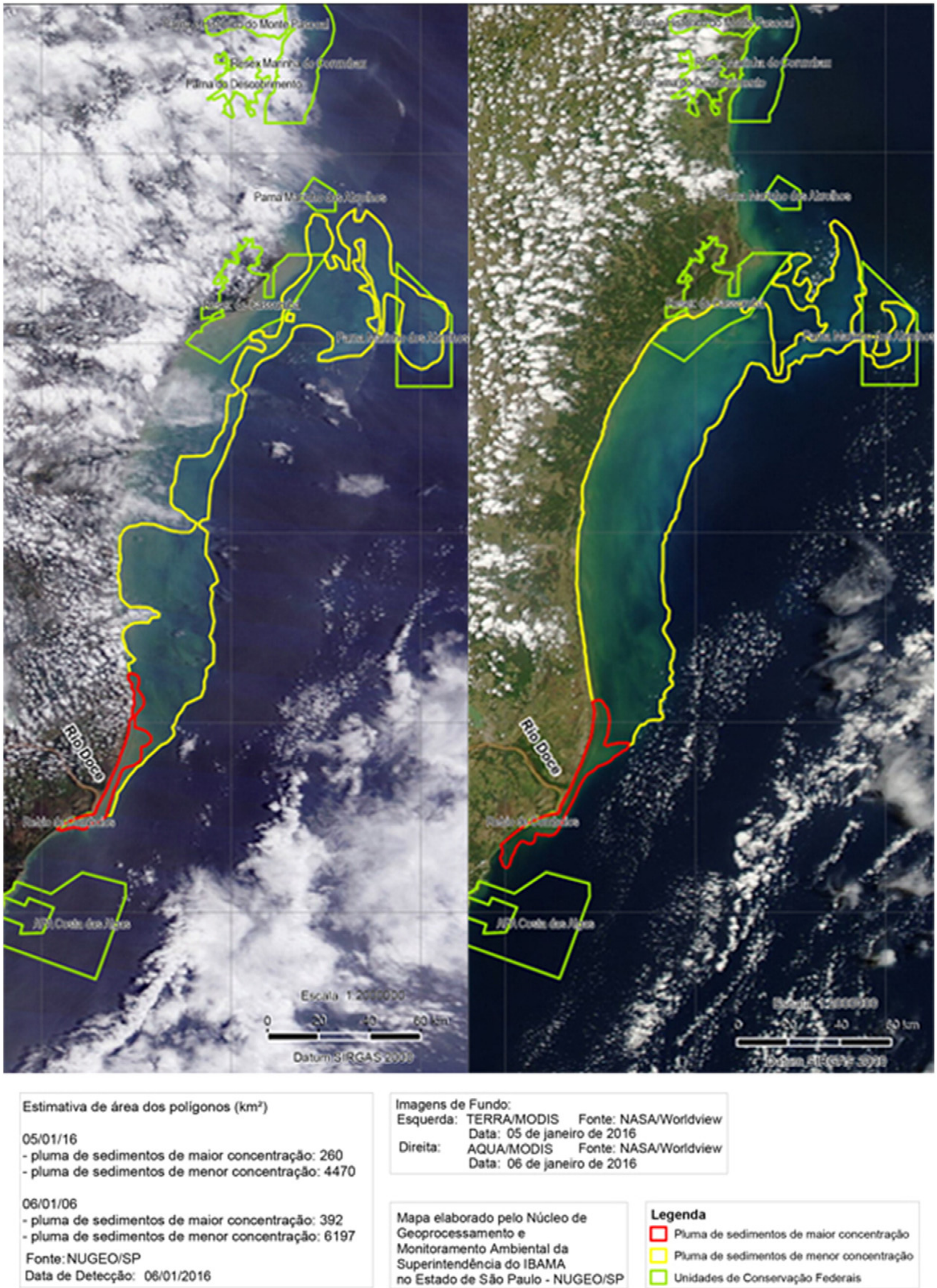

Fig. 7. The mud was transported northward by surface wind-driven currents, reaching the newly discovered reef system in the firsts days of 2016. Satellite images taken from Nasa/Worldview and markings (yellow: mud plume of lower concentration; red: mud plume of higher concentration; green: limits of federally protected areas) made by the Brazilian environmental agencies (IBAMA, ICMBio and IEMA). Available at: http://www.governancapelodoce.com.br/pluma/10-a-14022016/.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.marpolbul.2016.08.059.

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