Title/Name of the area: Atlantic Equatorial Fracture Zone and high productivity system

Presented by

Jose Angel Alvarez Perez, PhD, Centro de Ciências Tecnológicas da Terra e do Mar - Universidade do Vale do Itajaí, Itajaí, SC, Brazil (angel.perez@univali.br)

Rosangela Lessa, Dr., Departamento de Pesca e Aquicultura, Universidade Federal Rural de Pernambuco, Recife, PE, Brazil (rosangela.lessa@pq.cnpq.br)

Paulo Travassos, Dr. Departamento de Pesca e Aquicultura, Universidade Federal Rural de Pernambuco, Recife, PE, Brazil (pautrax@hotmail.com)

Alexandre Novaes Zerbini, PhD. Instituto Aqualie, Projeto Montitoramento de Baleias por Satelite, Rio de Janeiro, RJ, Brazil. (alex.Zerbini@noaa.gov)

Carlos Eduardo Leite Ferreira, Dr. Departamento de Biologia Marinha, Universidade Federal Fluminense. Niterói, RJ (cadu@vm.uff.br)

Francisco Marcante Santana da Silva, Dr., Departamento de Pesca e Aquicultura, Universidade Federal Rural de Pernambuco, Recife, PE, Brazil (framarsan@ig.com.br)

João Carlos Alciati Thomé, B.Oc. Projeto TAMAR. Instituto Chico Mendes de Conservação da Biodiversidade. (joca@tamar.org.br)

Jose Henrique Muelbert, PhD, Instituto de Oceanografia, Universidade Federal do Rio Grande, Rio Grande, RS, Brazil (docjhm@furg.br)

José Eduardo A. R. Marian, Dr. Departamento de Zoologia, Instituto de Biociências, Universidade de São Paulo (jeduardo_marian@yahoo.com.br)

Osmar Luiz Jr, M.Sc. Macquarie University, Sydney, Australia (osmarluizjr@gmail.com)

Eduardo R. Secchi, Dr. Lab. Tartarugas e Mamiferos Marinhos, Instituto de Oceanografia, Universidade Federal do Rio Grande/FURG, Rio Grande - RS, Brasil (edu.secchi@furg.br)

Abstract

The Equatorial Atlantic combines a range of historical, geological and oceanographic features that affect biodiversity patterns of the Atlantic Ocean high seas in both the pelagic and benthic domains. These features include: (a) the Equatorial Fracture Zone, a prominent geological feature that offsets the Mid-Atlantic ridge central axis, affects deep-water circulation patterns and connects deep habitats of the North and South Atlantic, and east-west Atlantic margins; (b) the seasonal East Equatorial Bloom which has an "oases" effect on pelagic biota of the central Atlantic and may be a critical source of energy to the deep habitats of the Equatorial Fracture Zone; (c) the St. Peters and St. Paul's Archipelago, whose coastal fauna and flora have high levels of endemism and a significant role in the fauna dispersal processes in the Atlantic; (d) "hot spots" for life-history stages of different marine organisms, including an array of endangered species; (e) a recently mapped hydrothermal vent field; (f) benthic habitats poorly disturbed by human activities but a historical pelagic fishing pressure with well documented effects on the abundance of commercially important stocks and large nektonic fauna. This area extends mostly beyond the jurisdiction of Atlantic coastal countries and the recognition of its importance seems crucial for eventual conservation initiatives in the high seas.

Introduction

The Atlantic Ocean originated from the break-up of the supercontinent Pangea in the Mesozoic, and has been regarded as the youngest of the major world oceans (Levin and Gooday, 2003). Its configuration and size is the outcome of two independent spreading processes; one that formed the North Atlantic in the early Mesozoic nearly 200 ma, and another that originated the South Atlantic, 100 m years later (Fairhead & Wilson, 2004). As a consequence, northern and southern sectors of the Atlantic not only diverged in age but also in their spreading direction, connectivity with other oceans and oceanographic patterns. Yet they remained connected near the Equator by a relatively narrow area defined as the Equatorial Atlantic and characterized by (a) multiple 1000 – 6000 m deep benthic habitats formed by the Mid-Atlantic ridge and the Equatorial Fracture Zone, (b) the interference of circulation patterns of deep water masses of the Atlantic and

(c) the influence of surface oceanographic processes, including a seasonal phytoplankton bloom, that affect both pelagic and benthic ecosystems. These features combined differentiate the equatorial zone from the adjacent north and south oceanic basins, and particularly from their oligotrophic tropical and subtropical pelagic systems. In that sense the Equatorial Atlantic is unique in the Atlantic Ocean, as also supported by both empirically shown and modeled patterns of biodiversity. It is worth noting that the area also includes a Mid-Atlantic ridge-associated group of islets, the St. Peters and St. Paul's Archipelago, whose coastal fauna and flora has been connected with oceanic dispersal processes among the Atlantic's continental margins and oceanic islands (see reviews in Vianna et al., 2009 and Vaske-Jr. et al., 2010) and a recently mapped hydrothermal vent field (Devey et al., 2005).

Comprehensive descriptions of seafloor features and major oceanographic and productivity patterns are available in the literature and derive from large scale oceanographic programs and satellite imagery analysis (e.g. Ocean Drilling Program, InterRidge, IOC – GOOS, UK Atlantic Meridional Transect - AMT and others). Some of these programs also include general data on diversity, distribution and abundance of zooplankton and pelagic fish and cephalopods that cover the Equatorial as well as adjacent tropical and subtropical areas of the North and South Atlantic (e.g. Gibbons, 1997; Rosa et al., 2008; Kobilianski et al., 2011). Particular data sets also derive from a longstanding research program on the St. Peter and St. Paul's Archipelago (ProArquipelago - Vianna et al., 2009 and Vaske-Jr. et al., 2010) and from pelagic fishing for large predators (tunas, billfishes, sharks) concentrated at the ICCAT organization (www.iccat.org). Other data sets on cetaceans, seabirds and sea turtles distribution and migrations complement our understanding on the biological relevance of the Equatorial Atlantic for nekton communities (e.g. Witt et al., 2011). Finally, data on bathy- and benthopelagic as well as benthic fauna are less comprehensive. Yet recent large-scale surveys derived from the Census of Marine Life program (e.g. MAR-ECO – http://www.mar-eco.no, Chess - http://www.noc.soton.ac.uk/chess/) have produced novel and relevant information on the biota associated to the Equatorial Atlantic deep habitats.

The Equatorial Atlantic combines a wide spectra of historical, geological, oceanographic and biodiversity features, both in the pelagic and benthic domains that justify the definition of an "Ecologically and Biologically Significant Area" of the Atlantic Ocean. This area extends mostly beyond the jurisdiction of Atlantic coastal countries and the recognition of its importance seems crucial for eventual conservation initiatives in the high seas.

Location

The proposed EBSA extends approximately 1.9 m km^2 across the Equatorial Atlantic from the western border of the Guinea Basin (10°W) in the east to the northeast limit of Brazilian continental margin (32°W) in the west. Parallels 2°N and 5°S are proposed as latitudinal limits which enclose three major fracture zones: St Paul's, Romanche and Chain (Figure 1). Seasonal phytoplankton blooms of the Equatorial Atlantic normally occur within these boundaries, concentrating in the eastern side but extending its influence to western areas (Figure 2). The area proposed includes also the St. Peter and St. Paul's Archipelago (Figure 3) (0° 55'01''N, 29° 20' 44''W). After the UNCLOS convention in 1982 and its ratification in 1988, the Brazilian government, through the Interministry Commission for Marine Resources (CIRM), developed an occupation and permanent research program at these islets which consolidated its rights to their 200 miles EEZ.

Feature description of the proposed area

The proposed EBSA combines both benthic and pelagic habitats of the Equatorial Atlantic, as defined by the seafloor topography, surface and deepwater circulation patterns and the equatorial primary productivity regimes. It can also be characterized by particular pelagic and benthic biodiversity patterns. These are explained below.

Seafloor topography.

The connection between the North-South Atlantic spreading centers in the early mid-Cretaceous resulted in a shear zone, which produced the Equatorial Fracture Zone, a large geological feature 60 m yearsold and 4000 m high, that offsets the Mid-Atlantic ridge central axis and largely distorts its linearity (Fairhead and Wilson, 2004). This feature is characterized by parallel ridge crests and trenches that extend in the east-west direction approaching northeast Brazilian and West African continental margins (Figure 1). These crests are normally 1000 – 2000 m deep, except at the eastern extreme where they emerge and form the St. Peter and St. Paul's Archipelago (Figure 3) (Bonnati, 1990). They are generally characterized by a roughed topography but may also include sediment-covered relatively flat areas and gentle slopes. Steep trenches delimit the north-south width of the ridge crests and may reach 4000 – 6000 m abyssal depths. Hydrothermal activity has been described between 4° and 11° S, including some of the world's hottest vents (Devey et al., 2005).

Circulation patterns.

The Equatorial Fracture Zone affects the Atlantic deepwater circulation, chiefly determined by the northward flow of the Antarctic Bottom Water (ABW, >4000 m) and the southward flow of the North Atlantic Deep Water (NADP, 1500 – 4000 m). In the western side these water masses flow through conduits created by the Equatorial Fracture Zone communicating the North and South Atlantic deep environments. Yet in the eastern side, the northward flow of ABW is blocked in the south by the Walvis Ridge mountain chain, and the North-South flow of the NADP predominates filling most of Southeast Atlantic basins (Huang and Jin, 2002; Bickert and Mackensen, 2003). However, at the Equatorial Fracture Zone a branch of ABW deflects to the east and penetrates into the Southeast Atlantic mostly through a particularly deep passage known as the Kane Gap. Such process explains the presence of ABW in the deepest pockets of the east Atlantic basins (> 4000 m) (Stephens and Marshall, 2000). The influence of the Equatorial Fracture zone on the circulation patterns of NADP and ABW have been regarded as a key element to test deepwater fauna dispersal hypothesis (German et al., 2011).

Above 1500 m there is complex wind-driven circulation pattern dominated by the western flow of the South Equatorial Current. From January to July such flow tends to accumulate water on the western side of the Equatorial Atlantic which thickens the South Equatorial Current and provokes a surface and subsurface return flow driven by five currents: the South Equatorial Counter Current (0°- 5°S), North Equatorial Counter Current (~5° N), Subsurface Equatorial Current (1.5° N – 1.5°S, 60 – 100 m deep), South Equatorial Subsurface Current (3° – 5°S, 200 m deep) and North Equatorial Subsurface Current (3°– 5°N, ~200 m deep) (Peterson and Stramma, 1991). The interaction of such currents, some of them established on a seasonal basis, promote an important mechanism for larval dispersion being critical to the distribution patterns of pelagic and benthic diversity, including the coastal habitats of the St.Peter and St. Paul's Archipelago and the deep sea (e.g. Rudorff et al., 2009).

Primary productivity regimes

The Equatorial Atlantic is generally bathed by warm oligotrophic waters. Yet there are important phytoplankton blooms that take place seasonally in the eastern Equator and affect local pelagic and benthic ecology (Longhurst, 1993; Longhurst, 1995). Such blooms originate from the northern displacement of the Intertropical Convergence Zone during the boreal summer, which tends to intensify the southeast trade wind regime. This in turn causes deepening of the thermocline in the western side while shoaling in the eastern size of the Equatorial Atlantic zone where nutrients are entrained above the photic zone and primary production is enhanced (Longhurst, 1993; Pérez et al., 2005). This western productive patch tends to receive allochtonous contributions from the coastal upwelling system off Namibia and the plume produced by the Congo River runoff, and expands its influence westwards, through the flow of the South Equatorial Current, to central Equatorial Atlantic Waters (Figure 2). Bounded by oligotrophic subtropical gyres of the North and South Atlantic, this area characterizes a seasonal "oases" that affects the patterns of pelagic biota in the central Atlantic and may be a critical source of energy to the deep habitats of the Equatorial Fracture Zone. Considerable data has been produced in support of the ecological significance of this primary production enhancement process either by satellite-derived chlorophyll field analysis or *in situ* experiments (Pérez et al., 2005). The area is also continuously monitored by a series of moored oceanographic buoys ("Prediction and

Research Moored Array in the Tropical Atlantic" - PIRATA Project), as part of the Global Ocean Observing System (IOC – GOOS).

Pelagic and Benthic Biodiversity patterns

The fauna and flora of the St. Peter and St. Paul's Archipelago has been extensively described and related to the Atlantic Ocean biogeography, considering its reduced size and intermediate position between South American and West African margins and other oceanic islands (see reviews in Vianna, 2009 and Vaske-Jr. et al., 2010). Reef fish diversity is generally low when compared to the Brazilian and African coasts, but at least five species have been regarded as endemic of the islets rocky shores and slopes: *Stegastes sanctipauli* (Pomacentridae), *Anthias salmopunctatus* (Serranidae), *Prognathodes obliquus* (Chaetodontidae), *Enneanectes smithi* (Tripterigiidae), *Emblemariopsis* sp. (Chaeopsidae) (Lubbock and Edwards 1980 and 1981; Floeter and Gasparini, 2000; Feitoza et al., 2003; Ferreira et al., 2009; Vaske-Jr. et al., 2010). Because these coastal areas are very limited (Figure 3) (e.g. the area above 50 m isobath is less than 0.5 km^2), all endemic species have an extremely restricted distribution area (Luiz et al., 2007) and therefore become highly vulnerable to extinctions. Also oceanic and reef sharks use the archipelago vicinity as feeding and reproductive areas and become vulnerable to the local pelagic fishing pressure. Such pressure seems to have been the main cause of the local extinction of the reef shark *Carcharhinus galapagensis* (Luiz and Edwards, 2011) and threat local populations of other targeted sharks such as *C. falciformes* and *C. longimanus* (Hazin et al., 2007; Cortés et al., 2010). Other large nektonic organisms use the archipelago during key phases of their life-histories, including three tropical seabirds, the brown booby (*Sula leucogaster*), the black noddy (*Anous minutus*) and the brown noddy (*Anous stolidus*), that nest on the islets (Vaske-Jr. et al., 2010), and a resident population of the bottlenose dolphin (*Tursiops truncatus*) (Caon et al., 2009; Moreno et al., 2009).

The Equatorial Atlantic has been characterized by an elevated diversity and abundance of pelagic organisms, when compared to the adjacent northern and southern subtropical gyres of the Atlantic. In essence that has been explained by the effect of complex surface circulation patterns, elevated temperature and productivity regimes. Data in support of these patterns are found in specific plankton and micronekton studies focusing on euphasiids (Gibbons, 1997), myctophids and other mesopelagic fish (Bakus et al., 1970; Bakus et al., 1977; Kobiliansky et al., 2010) and cephalopods (Rosa et al., 2008; Perez and Bolstad, 2011). The area also concentrates important catches of large pelagic fishes including the yellofin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*) and swordfish (*Xiphias gladius*) (www.iccat.org). These are highly migratory species with a wide distribution in the Atlantic but that tend to concentrate in the equatorial areas as part of their feeding and reproductive routes (e.g. *T. albacares*, Figure 4) (Fonteneau and Sobrier, 1996). Similarly the largest known population of leatherback turtle (*Demochelis coriacea*), which nests in the coast of Gabon (West Africa) includes the west Equatorial Atlantic as one of their main feeding grounds (Figure 5). This pattern, also shared by the olive ridley sea turtle (*Lepidochelys olivacea*), allows the access to productive equatorial areas but also exposes these animals to intense tuna-oriented fishing effort (Billes et al., 2006; Fretey et al., 2007; Georges et al., 2007; Witt at al., 2011; Da Silva et al. 2011). These species are critically endangered according to IUCN criteria (www.iucn.org) which highlights the importance of the proposed area as an EBSA.

In terms of benthic and bentho-pelagic fauna much less is known, but models tend to predict a relatively high seafloor biomass, particularly on the western Equatorial area (Wei et al., 2010). Furthermore new data derived from surveys conducted on the southern Mid-Atlantic ridge (MAR-ECO and Chess initiatives, Census of Marine Life) have recently revealed a high benthic diversity (Perez et al., 2010; German et al., 2011), particularly related with the heterogeneity of seafloor habitats (ridges, trenches, flat sediment-covered surfaces, hydrothermal vents). Megabenthos sampling conducted by the first MAR-ECO expedition to the Southern Mid-Atlantic Ridge on flat surfaces of the Romanche Fracture Zone crest, produced abundant and species-rich catches that included both suspension and deposit feeders (Figure 6), as probably the result of habitat diversity and high surface-derived energy input. These samples largely contrasted with those obtained from rocky ridge habitats in tropical latitudes under the influence, at the surface, of the South Atlantic Subtropical gyre (Gebruk, A., unpublished data; Cardoso, 2011).

On March 2005, scientists of the Biogeography of Deep-Water Chemosynthetic Ecosystems project (ChESS - CoML) identified the first hydrothermal vent in the southern Mid-Atlantic Ridge axis 4° – 5°S (Figure 6) (www.coml.org/ discoveries; Devey et al., 2005; German et al., 2008). Since then the area has been defined as part of the "Atlantic Equatorial Belt" chemosynthetic area that congregates hydrothermal vents and cold seeps from Costa Rica to the West African coast (German et al., 2011). These findings have demonstrated that the Equatorial Fracture Zone does not act as a barrier for vent species dispersal, allowing for similarities between North and South Atlantic vent faunas.

Biogeography

Taking into consideration the oceanographic dynamics and productivity patterns described above, Longhurst (1995, 2006) encircled the Equatorial Atlantic into two "biogeochemical provinces", the "East and West Tropical Atlantic". A single "tropical" province was more commonly defined in this area by zooplankton, mesopelagic fish and cephalopods distribution patterns (Bakus et al., 1977; Gibbons, 1997; Rosa et al., 2008). In relation to benthic fauna, the IOC Global Open Ocean and Seabed Biogeographic Classification (GOODS) has distinguished three provinces in the deep Equatorial Atlantic: the "South Atlantic" lower bathyal zone (800 – 3500 m) that includes the mid-Atlantic ridge systems and fracture zones, the "Romanche" hadal depth zone (>6000 m) defined by the Romanche trench, and the "Mid-Atlantic Ridge South" hydrothermal vent province (Vierros et al., 2009).

Feature condition and future outlook of the proposed area

The proposed EBSA is subject to intense pelagic fishing, particularly focused on tunas and billfishes (http://www.iccat.org). In the vicinity of the St. Peter and St. Paul's Archipelago, such pressure has already lead to severe consequences such as the local extinction of the reef shark *C. galapagensis* (Luiz & Edwards 2011) and declines on concentrations of other sharks such as *C. falciformes* and *C. longimanus* (Hazin et al., 2007; Cortés et al., 2010). The endemic reef fish *Anthias salmopunctatus* was thought to be extinct from the islets in 2003 (Feitoza et al., 2003) but rediscovered three years later (Luiz et al., 2007). The archipelago and surrounding pelagic system are regarded as very susceptible to perturbation due to its small area and isolation in the Atlantic Ocean.

In contrast there are no significant records of demersal fishing in the area (Southeast Atlantic Fisheries Organization – SEAFO - http://www.seafo.org), which suggests that deep benthic habitats retain considerable degree of naturality. There are, however, known deposits of cobalt-bearing ferromanganese crusts (Yubko et al., 2004) and polymetallic sulphides associated to hydrothermal vent activity (International Seabed Authority, http:// http://www.isa.org.jm/) both of potential commercial interest for oceanic mining initiatives.

Potential impacts on the seabed, as derived from mining and fishing do not seem as major threats in the near future. However, much research is still needed to access the biodiversity patterns of the deep habitats within the proposed EBSA and fully understand their vulnerability to human perturbation. On the other, hand fishing exerts a significant impact over large pelagic organisms, which suggests that short-term spatial conservation initiatives in this area could help their conservation. Finally it is important to take into consideration the significance of the major geologic and oceanographic features of the Equatorial Atlantic and their role in large scale processes of the Atlantic Ocean, particularly in the light of planetary climate changes. That per se may justify future conservation initiatives in this area.

Several scientific and ocean observation programs currently exist and will continue in the coming years, providing data and more accurate descriptions and models of the geology and oceanography of the Atlantic Ocean. Deep-sea diversity programs, particularly focusing on the Mid-Atlantic Ridge and fracture zones are less common, mostly due to elevated costs and high technological requirements. But it is worth noting the continuity of some field projects born in the umbrella of the Census of Marine Life, that have future plans to coordinate research efforts focused on the South Atlantic Mid-Ocean ridge and related habitats in the near future. These include INDEEP (International network for Scientific Investigation of deep-sea ecosystems - http://www.indeep-project.org/) and the South Atlantic MAR-ECO project (Perez et al., 2010; http://www.mar-eco.no).

Assessment of the area against CBD EBSA Criteria

<table>
<tr><td rowspan="2">CBD EBSA Criteria
(Annex I to decision IX/20)</td><td rowspan="2">Description
(Annex I to decision IX/20)</td><td colspan="4">Ranking of criterion relevance
(please mark one column with an X)</td></tr>
<tr><td>Don't Know</td><td>Low</td><td>Some</td><td>High</td></tr>
<tr><td>Uniqueness or rarity</td><td>Area contains either (i) unique ("the only one of its kind"), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="6">Explanation for ranking

The proposed EBSA is here ranked as "highly unique" chiefly (but not only) because it contains the Equatorial Fracture Zone (Figure 1), a prominent geological feature that offsets the mid-Atlantic ridge central axis and connects the deep habitats of North and South Atlantic, and east-west Atlantic margins (Fairhead and Wilson, 2004). Because it is massive, elevating 4000 km from the seafloor, it affects the circulation patterns of the main deep water masses of the Atlantic influencing dispersal processes of deep fauna (Stephens and Marshall, 2000; German et al., 2011). The Equatorial fracture zone includes an array of benthic habitats formed by ridge crests and trenches. At the western extreme, such crests emerge and form the St. Peter and St. Paul's Archipelago (Figure 3), a group of islets with an important row on the coastal fauna dispersal process in the Atlantic and an elevated level of endemism (Vaske-Jr. et al., 2010). At the southern extreme some of the hottest hydrothermal vents have been found on the southern Mid-Atlantic ridge (Figure 6) and their associated biodiversity compared with those of the North Atlantic vents (German et al., 2011).
A second remarkable feature of this area is associated to the complex South Equatorial Current system and its surface and subsurface counter-currents (Petterson and Stramma, 1991). Influenced by the oscillations of the Inter-tropical Convergence Zone and trade winds regime, this system includes, on the eastern extreme, a seazonal upwelling process that promotes an important equatorial phytoplankton bloom (Longhurst, 1993). This highly productive area in the middle of the vast oligotrophic zones of the northern and southern subtropical gyres has an "oases" effect on both pelagic and deep biota (Figure 2). This is also considered a "unique" feature similar to the one described in the Equatorial Pacific Ocean, which justified the definition of an extensive EBSA in that ocean.
In terms of biodiversity it is important to point out the existence of endemic organisms in the coastal areas of the St. Peter and St. Paul's Archipelago with particular reference to at least five reef fish species (Vaske-Jr. et al., 2010). It is remarkable that these fishes may in fact have the smallest distribution areas known in marine life (see below).</td></tr>
<tr><td>Special importance for life-history stages of species</td><td>Areas that are required for a population to survive and thrive.</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="6">Explanation for ranking

The proposed EBSA encloses a limited area of the vast and highly connected pelagic system of the Atlantic Ocean. Nevertheless, the St. Peter and St. Paul's Archipelago and the seasonal equatorial phytoplankton blooms on the western and eastern extremes, respectively, create "hot spots" for life-history stages of different marine organisms. Important examples are:
• Reef fishes and invertebrates whose populations in the middle of the Atlantic Ocean rest on the existence of the coastal habitats around oceanic islands where these animals can settle, feed, reproduce and recruit. The St. Peter and St. Paul's Archipelago is remarkable in that regard, hosting populations species occurring on the Brazilian and African coasts, other oceanic islands of the South Atlantic, as well as endemic species.
• Pelagic fish and seabirds also use the St. Peter and St. Paul's Archipelago islets and surrounding waters as feeding, nursery and reproductive grounds. Flying fish species (Family Exocoetidae), for example, are</td></tr>
</table>

<table>
<tr><td colspan="6">

widely distributed in the tropical Atlantic but require shallow hard substrates to attach their eggs, which will survive on benthic food sources. The islets provide unique habitats for this process and gather reproductive concentrations of at least one species, Cheilopogon cyanopterus. These in turn attract migratory populations of the yellowfin tuna (Thunnus albacares) that concentrate to feed on this resource and become available to local pelagic fishing activity (Lessa and Vaske Jr., 2009; Hazin et al., 2009). The area is also a spawning ground for wahoo (Acanthocybium solandri) and rainbow runner (Elagatis bipinnulata) (Hazin et al., 2009) and there is a resident and g enetically isolated population of the bottlenose dolphin (Tursiops truncatus) in the area (Caon et al., 2009; Moreno et al., 2009). The islets provide nesting sites for three seabird species: the brown booby (Sula leucogaster) and two noddies (Anous minutus and A. stolidus) (Vaske-Jr. et al., 2010)
Highly migratory tunnids (and swordfish) of the Atlantic tend to concentrate in the equatorial areas for reproduction. That is the case of the commercially important yellofin tuna (Figure 4), which spawns in the western side of Equatorial Atlantic in association with the areas of high productivity (Fonteneau and Sobrier, 1996). The same area attracts important concentrations of the leatherback and the olive ridley turtle (Lepidochelys olivacea), which use the area as important feeding grounds (Figure 5) (Witt at al., 2011; Da Silva et al. 2011).

Similarly to the observed in the pelagic biota, the deep habitats of the Equatorial Atlantic are likely critical for benthic and benthopelagic fish and invertebrate life-histories. Yet much research is still needed assess these patterns.
</td></tr>
<tr><td>Importance for threatened, endangered or declining species and/or habitats</td><td>Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="6">Explanation for ranking

Following the elements presented on the previous criterion, it is important to notice that several organisms, both coastal and pelagic, associated with the St. Peter and St. Paul's Archipelago have been classified as endangered or vulnerable to extinction either by the IUCN or Brazilian local criteria (see examples cited in Vaske-Jr. et al;, 2010). Particular critical is the case of the endemic species whose essential habits are restricted to the small coastal environments of the islets and pelagic sharks whose populations in the Atlantic are declining (e.g. Carcharhinus longimanus, www.iccat.org). The leatherback and the olive ridley turtles are important examples, being classified as critically threatened of extinction by the IUCN redlist (www.iucn.org).</td></tr>
<tr><td>Vulnerability, fragility, sensitivity, or slow recovery</td><td>Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="6">Explanation for ranking

Deep-water ecosystems have usually been characterized as fragile because many of their biotic components have life history traits that result in a slow recovery process after perturbation (long life, slow growth, episodic recruitment etc). Comprehensive descriptions of such habitats in the Equatorial Fracture Zone are still scarce and inconclusive. Yet they have evidenced the presence of reef-forming cold coral forms, sponges and other long-lived invertebrates in the Romanche Fracture Zone (Andrey Gebruk, Shirshov Institute of Oceanology, unpublished data) that suggest the existence of such fragile environments within the proposed area. The hydrothermal vent field identified in the Mid-Atlantic ridge contributes to such a preliminary conclusion (Devey et al., 2005). Yet it is clear that assigning a higher rank to this criterion would involve more sampling and exploring initiatives.
This criterion has often been used to classify large nektonic organisms as fragile and highly vulnerable to extinction. In that sense the concentration and elevated risks of fishing mortality of pelagic sharks, sea</td></tr>
</table>

<table>
<tr><td colspan="6">turtles, seabirds and cetaceans contribute to attribute “some” relevance of the proposed EBSA in this criterion (Cortés et al., 2010).</td></tr>
<tr><td>Biological productivity</td><td>Area containing species, populations or communities with comparatively higher natural biological productivity.</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="6">Primary production in the North and South Atlantic subtropical gyres is characteristically low and uniform during most of the year. In west equatorial regions of the Atlantic and Pacific Oceans, which are governed by trade wind regimes, however, primary production is enhanced during the boreal summer as these winds intensify and thermocline shoals producing an increased nutrient entrainment in the photic zone. In the western Equatorial Atlantic, productivity responds rapidly to this process and an important chlorophyll field, considerably higher than that observed in the adjacent subtropical gyres, is formed (Longhurst, 1995; Pérez et al., 2005) and represents an important energy input for pelagic and benthic biota.
Wei et al., (2010) incorporate this seasonal productivity pattern into models that predict rates of energy transfer to the benthic habitats. As a result they project an elevated benthic biomass over much of the western equatorial seafloor in contrast with poorer deep areas extending underneath the South Atlantic Subtropical gyre, for example. In that sense the proposed EBSA, which includes the geographical amplitude of the equatorial blooms, is ranked high in this criterion.</td></tr>
<tr><td>Biological diversity</td><td>Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.</td><td></td><td></td><td></td><td>X</td></tr>
<tr><td colspan="6">Explanation for ranking

The proposed EBSA was ranked high in this criterion based on a comparative analysis with data available for the adjacent subtropical gyres of the Atlantic and mostly in response to the west Equatorial high productivity area described above. Empirical data produced by historical plankton and micronekton surveys across the South Atlantic have supported a general decline in abundance and richness from the equatorial “belt” to the subtropical gyres (Bakus et al., 1970; Bakus et al., 1977; Gibbons, 1997; Rosa et al., 2008; Perez and Bolstad, 2011; Kobiliansky et al., 2010). In the case of cephalopods, this pattern was attributed to a direct relationship between diversity and resource availability (Rosa et al., 2008). Less can be concluded about deep benthic biodiversity. However, results produced during the South Atlantic MAR-ECO survey support the same pattern shown for pelagic biota (Andrey Gebruk, Shirshov Institute of Oceanology, unpublished data, unpub. data; Cardoso, 2010).
It was also considered, that notwithstanding the St. Peter and St. Paul’s Archipelago is a low-diversity area when compared to the east and west Atlantic coasts and other oceanic islands, it may have a key role in the fauna dispersal processes in the Atlantic.</td></tr>
<tr><td>Naturalness</td><td>Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td colspan="6">Explanation for ranking

A high level of naturalness can be attributed to the benthic habitats of the proposed habitats, since there are no records of significant human activities in these deep areas of the Atlantic Ocean (e.g. demersal fishing, mining etc.) (http://www.seafo.org; http://www.isba.org). Nonetheless, an important pelagic fishing pressure has been established in the area for several decades with well documented effects on the abundance of commercially important stocks as well as large nektonic organisms non-intentionally caught by fishing operations in the Equatorial Atlantic (Cortés et al., 2010; Da Silva et al. 2011; Witt et al, 2011).</td></tr>
</table>

References

Backus, R. H.; Craddock, J. E.; Haedrich, R. L.; Shores, D. L. 1970. The Distribution of Mesopelagic Fishes in the Equatorial and Western North Atlantic Ocean. J. Mar. Res. 28, 179–201.

Backus, R. H.; Craddock, J.E.; Haedrich, R. L.; Robison, B.H. 1977. Atlantic mesopelagic zoogeography. Memoirs of the Sears Foundation for Marine Research 1:266–287.

Bickert, T.; MacKensen, A. 2003. Last glacial holocene changes in South Atlantic deep water circulation. In: Wefer, G.; Mulitza, S.; Ratmeyer, V. The South Atlantic in the late quaternary: reconstruction of material, budgets and current systems, Springer-Verlag, Berlim, pp. 671-695.

Billes, A.; Fretey, J.; Verhage, B.; Huijbregts, B. and others 2006. First evidence of leatherback movement from Africa to South America. Mar Turtle Newsl 111:13–14

Bonati, E. 1990. Subcontinental mantle exposed in the Atlantic ocean on St. Peter-Paul Islets. Nature¸ 345: 800-802. (pdf available at http://www.nature.com/nature/journal/v345/n6278/abs/345800a0.html)

Caon, G.; Moreira, M. B.; Hoffmann, L. S.; Di Tullio, J.; Valdez, F. P.; Fruet, P.; Freitas, T. R. O. 2009. Os mamíferos marinhos. In: Viana, D. L.; Hazin, F. H. V.; Souza, M. A. C. (Orgs). O Arquipélago de São Pedro e São Paulo: 10 anos de Estação Científica. SECIRM, Brasília, pp. 278-285. (pdf available at http://www.mar.mil.br/secirm/publicacao/arquipe.pdf)

Cardoso, I. 2011. Decapods of the South Mid-Atlantic ridge sampled by benthic trawls of MAR-ECO project. The international expert meeting "Understanding deep-water biodiversity in the South Atlantic: options for conservation and sustainable use of resources in the high-seas". April 7th and 8th, IOC – UNESCO, Paris. (pdf available at http://www.ioc-cd.org/index.php)

Cortés, E.; Arocha, F.; Beerkircher, L.; Carvalho, F.; Domingo, A.; Heupel, M.; Holtzhausen, H.; Santos, M. N.; Ribera, M.; Simpfendorfer, C. 2010. Ecological risk assessment of pelagic sharks caught in Atlantic pelagic longline fisheries. Aquat.Living Resour. 23, 25–34. (pdf available at http://journals.cambridge.org/action/)

Da Silva, A. C. C. D.; dos Santos, E. A. P.; Oliveira, F. L. C.; Weber, M. I.; Batista; J. A. F.; Serafini, T. Z.; Castilhos, J. C. 2011. Satellite-tracking highlights multiple foraging strategies and threats for olive ridley turtles in Brazil. Marine Ecology Progress Series 443: 237–247. (pdf available at www.int-res.com/articles/)

Devey, C. W.; Lackschewitz, K. S.; Baker, E. T. 2005. Hydrotermal and volcanic activity found on the southern Mid-Atlantic ridge. EOS, 86: 209-212.

Fairhead, J. D., and Wilson, M. 2004. Sea-floor spreading and deformation processes in the South Atlantic ocean: Are hot spots needed? http://www.mantleplumes.org/SAtlantic.html. Accessed in 18 august 2006.

Feitoza, B. M.; Rocha, L. A.; Luiz-Jr., O. J.; Floeter, S. R.; Gasparini, J. L. 2003. Reef fishes of St. Paul's Rocks: new records and notes on biology and zoogeography. Aqua, Journal of Ichthyology and Aquatic Biology 7(2):61-82. (pdf available at http://www.lbmm.ufsc.br/pdfs)

Ferreira C. E. L.; Luiz Jr., O. J.; Feitoza, B. M.; Ferreira, C. G. W.; Noguchi, R. C.; Gasparini, J. L.; Joyeux, J-C.; Godoy, E. A.; Rangel, C. A.; Rocha, L. A.; Floeter, S.R.; Carvalho-Fo., A. 2009. Peixes recifais: síntese do atualconhecimento. In: Viana, D. L., Hazin, F. H. V.; Souza, M. A. C. (Orgs). O Arquipélago de São Pedro e São Paulo: 10 anos de Estação Científica. SECIRM, Brasília, pp.245-252. (pdf available at http://www.mar.mil.br/secirm/publicacao/arquipe.pdf)

Floeter, S. R.; Gasparini, J. 2000. The southwestern Atlantic reef fish fauna: composition and zoogeographic patterns. Journal of Fish Biology, 56: 1099-1114.

Fonteneau, A.; Soubrier, P. P. 1996. Interactions between tuna fisheries: A global review with specific examples from the Atlantic Ocean. In: Shomura, R. S.; Majkowski, J.; Harman, R. F. (Eds.) Status of Interactions of Pacific Tuna Fisheries in 1995. Proceeding of the Second FAO Expert Consultation on Interactions of Pacific Tuna Fisheries Shimizu, Japan 23 to 31 January 1995. FAO Fisheries Technical Paper. No. 365. Rome, FAO. 1996. 612p. (pdf available at http://www.fao.org/DOCREP)

Fretey, J., Billes, A., Tiwari, M. 2007. Leatherback, *Dermochelys coriacea*, nesting along the Atlantic coast of Africa. Chelonian Conserv Biol 6:126–129

Georges J. Y.; Fossette, S.; Billes, A.; Ferraroli, S. and others 2007. Meta-analysis of movements in Atlantic leatherback turtles during the nesting season: conservation implications. Mar. Ecol. Prog. Ser. 338:225–232

German, C. R.; Bennett, S. A.; Connelly, D. P.; Evans, A. J.; Murton, B. J.; Parson, L. M.; Prien, R. D.; Ramirez-Llodra, E.; Jakuba, M.; Shank, T. M.; Yoerger, D. R.; Baker, S. L.; Nakamura, K. 2008. Hydrothermal Exploration of the Southern Mid-Atlantic Ridge. Earth and Planetary Science Letters, 273: 332-344.

German, C. R.; Ramirez-Llodra, E.; Baker, M. C., Tyler, P. A.; the ChEss Scientific Steering Committee. 2011. Deep-Water Chemosynthetic Ecosystem Research during the Census of Marine Life Decade and Beyond: A Proposed Deep-Ocean Road Map. Plos One, 6(8). (pdf available at http://www.ncbi.nlm.nih.gov/)

Gibbons, M. J. 1997. Pelagic biogeography of the South Atlantic Ocean. Marine Biology 129: 757-768.(pdf available at http://www.springerlink.com/content/kt1j917x1ltj1v2t/fulltext.pdf).

Hazin, F. H.; Oliveira, P. G.; Macena, B. C. L. 2007. Aspects of the reproductive biology of the silky shark, *Carcharhinusfalciformis* (Nardo, 1827), in the vicinity of archipelago of Saint Peter and Saint Paul, in the Equatorial Atlantic Ocean. Col. Vol. Sci. Pap. ICCAT, 60(2): 648-651. (pdf available at http://www.iccat.es/Documents/CVSP/CV060_2007/no_2%5CCV060020648.pdf)

Hazin, F. H.; Vianna, D.; Pinheiro, P.; Fischer, A.; Macena, B.; Véras, D.; Oliveira, P.; Carvalho, F.; Vaske-Jr., T.; Branco, I. 2009. Ecologia de grandes peixes pelágicos. In: Viana, D. L., Hazin, F. H. V.; Souza, M. A. C. (Orgs). O Arquipélago de São Pedro e São Paulo: 10 anos de Estação Científica. SECIRM, Brasília.pp. 227-234. (pdf available at http://www.mar.mil.br/ secirm/ publicacao/ arquipe.pdf)

Huang, R. X.; Jin, X. 2002. Deep circulation in the South Atlantic induced by bottom-intensified mixing over the mid-ocean ridge. Journal of Physical Oceanography, 12: 1150-1164. (pdf available at http://www.whoi.edu/science/po/people/rhuang/publication/2002SAtlantic.pdf)

Kobyliansky, S. G.; Orlov, A. M.; Gordeeva, N. V. 2010. Composition of Deepsea Pelagic Ichthyocenes of the Southern Atlantic, from Waters of the Area of the Mid-Atlantic and Walvis Ridges. Journal of Ichthyology, 50(10):932–949.

Lessa, R.; Vaske-Jr. 2010. A ictiofauna com ênfase aos peixes-voadores (Exocoetidae). In: Viana, D. L., Hazin, F. H. V.; Souza, M. A. C. (Orgs). O Arquipélago de São Pedro e São Paulo: 10 anos de Estação Científica. SECIRM, Brasília, pp. 219-226. (pdf available at http://www.mar.mil.br/ secirm/ publicacao/ arquipe.pdf)

Levin, L. A., and Gooday, A. J. 2003. The deep Atlantic ocean. In: Ecosystems of the deep oceans, ecosystems of the world 28. Tyler, P.A. (Ed.), Elsevier Science, Amsterdam. , pp. 111-178

Longhurst, A. 1993. Seasonal cooling and blooming in the tropical oceans. Deep-sea Research I, 40(11/12): 2145-2165. (pdf available at http://www.sciencedirect.com/science/article/pii/096706379390095K)

Longhurst, A. 1995. Seasonal cycles of pelagic production and consumption. Prog. Oceanog. 36:77-167. (pdf available at http://www.sciencedirect.com/science/article/pii/0079661195000151)

Longhurst, 2006. Ecological geography of the sea. 2nd Ed. Academic Press, London.

Lubbock, R.; Edwards, A. J. 1980. A new butterflyfish (Teleostei: Chaetodontidae) of the genus *Chaetodon* from the Saint Paul's rocks. Rev, Fr, Aquariol. 7(1):13-16,

Lubbock, R.; Edwards, A. J. 1981. The fishes of Saint Paul's rocks. J. Fish. Biol. 18: 135-157.

Luiz, O. J.; Joyeux, J. C.; Gasparini, J. L. 2007. Rediscovery of *Anthias salmopunctatus* Lubbock & Edwards, 1981, with comments on its natural history and conservation. Journal of Fish Biology 70:1283-1286. (pdf available at http://www.doc.ufes.br/ictiolab/publicacoes/2007-rediscovery_of_anthias_salmopuntatus.pdf)

Luiz, O. J.; Edwards, A. J. 2011. Extinction of a shark population in the Archipelago of Saint Paul's Rocks (Equatorial Atlantic) inferred from the historical record. Biological Conservation 144: 2873-2881. (pdf available at http://acropora.bio.mq.edu.au/wp-content/uploads/2011/09/Luiz-Edwards-2011-Extinction-of-a-shark-population-in-the-Archipelago-of-Saint-Paul%E2%80%99s-Rocks-equatorial-Atlantic-inferred-from-the-historical-record.pdf)

Moreno, I. B.; Ott, P. H.; Tavares, M.; Oliveira, L. R.; Danilewicz, D.; Siciliano, S.; Bonnato, S.L. 2009. Os cetáceos com ênfase no golfinho-nariz-de-garrafa, *Tursiops truncatus* (Montagu, 1821). In: Viana, D.L.; Hazin, F. H .V.; Souza, M. A. C. (Orgs). O Arquipélago de São Pedro e São Paulo: 10 anos de Estação Científica. SECIRM, Brasília, pp. 286-292. (pdf available at http://www.mar.mil.br/ secirm/ publicacao/ arquipe.pdf)

Perez, J. A. A.; Bolstad, K. S. R. 2011. Cephalopod diversity in micronekton trawls over the Mid-Atlantic ridge and Walvis ridge, South-Atlantic Ocean. XIV Congresso Latino Americano de Ciências do Mar – COLACMAR. Balneário Camboriu, Brazil, November, 2011.

Perez, J. A. A.; Alves, E.; Barreto, A.; Lima, A.; Gebruk, A.; Kobilianski, S.; Alder, V.; Augustin, J.; Clark, M.; Maciel, P. M.; Pires, D.; Santos, R. S.; Zyl, B. v-; Bergstad, O. A. 2010. Surveying the patterns of life in the understudied depths of the South Atlantic: continuing the legacy of the MAR-ECO project (CoML) into the southern mid-Atlantic ridge. The J. Frederick Grassle Scientific Symposium on the Census of Marine Life. The Royal Society, London, 5-6 October, 2010. (pdf available at http://www.coml.org/pressreleases/census2010/PDF/Census%202010%20Symposium%20Program.pdf)

Pérez, V.; Fernandez, E.; Marañon, E.; Serret, P.; Garcia-Soto, C. 2005. Seasonal and interannual variability of chlorophyll a and primary production in the Equatorial Atlantic: in situ and remote sensing observations. Journal of Plankton Research, 27(2):189-197. (pdf available at http:// plankt.oxfordjournals.org/content/27/2/189.full)

Peterson, R. G.; Stramma, L. 1991. Upper-level circulation in the South Atlantic. Prog. Oceanography, 26:1-73.

Rosa, R; Dierssen, H. M. ; Gonzalez, L.; Seibel, B. A. 2008. Large-scale diversity patterns of cephalopods in the Atlantic open ocean and deep sea. Ecology, 89(12):3449–3461.

Rudorff, C. A. G.; Lorenzzetti, J. A.; Gherardi, D. F. M.; Lins-Oliveira, J. E. 2009. Application of remote sensing to the study of the pelagic spiny lobster larval transport in the tropical Atlantic. Brazilian Journal of Oceanography, 57(1):7-16 (pdf available at http://www.scielo.br/pdf/bjoce/v57n1/02.pdf)

Stephens, J. C.; Marshall, D. P. 2000. Dynamical Pathways of Antarctic Bottom Water in the Atlantic. Journal of Physical Oceanography, 20:622-640. (pdf available at http:// www.ocean.ox.ac.uk/images/c/c1/Sm00.pdf)

Vaske-Jr., T.; Lessa, R. P.; Nobrega, M. F.; Amaral, F. M. D.; O'Brien, S. R. M; Costa, F. A. P. (Organizadores) 2010. Arquipélago de São Pedro e São Paulo- Histórico e Recursos Naturais. Coleção Habitat3. NAVE/LABOMAR. 242 p.

Viana, D.L., Hazin, F.H.V. & Souza, M.A.C. (Orgs). O Arquipélago de São Pedro e São Paulo: 10 anos de Estação Científica. SECIRM, Brasília. (pdf available at http://www.mar.mil.br/ secirm/ publicacao/ arquipe.pdf)

Vierros, M.; Cresswell, I.; Briones, E. E.; Rice, J.; Ardron, J. 2009. Global Open Oceans and Deep Seabed (GOODS) – Biogeographic Classification. Paris, UNESCO-IOC. IOC Technical Series, 84. (pdf available at http://unesdoc.unesco.org/images/0018/001824/182451e.pdf)

Wei, C.; Rowe, G.T.; Escobar-Briones, E.; Boetius, A.; Soltwedel, T.; Caley, M. J.; Soliman, Y.; Huettmann, F.; Qu, F.; Yu, Z.; Pitcher, C. R.; Haedrich, R. L.; Wicksten, M. K.; Rex, M. A.; Baguley, J. G.; Sharma, J.; Danovaro, R.; MacDonald, I. R.; Nunnally, C. C.; Deming, J. W.; Montagna, P.; Lévesque, M.; Weslawski, J. M.; Wlodarska-Kowalczuk, M.; Ingole, B. S.; Bett, B. J.; Billett, D. S. M.; Yool, A.; Bluhm, B. A.; Iken, K.; Narayanaswamy, B. E. 2010. Global Patterns and Predictions of Seafloor Biomass Using Random Forests. PloS ONE, 5(12):1-15. (pdf available at http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0015323)

Witt, M. J.; Bonguno, E. A.; Broderick, A. C.; Coyne, M. S.; Formia, A.; Gibudi, A.; Mounguengui, G. A. M.; Moussounda, C.; Safou, M. N.; Nougessono, S.; Parnell, R. J.; Sounguet, G.; Verhage, S.; Godley, B. J. 2011. Tracking leatherback turtles from the world's largest rookery: assessing threats across the South Atlantic. Proc. R. Soc. B 278, 2338–2347. (pdf available at http://rspb.royalsocietypublishing.org/content/early/2011/01/05/rspb.2010.2467.full)

Yubko, V. M.; Melnikov, M. E.; Kazmin, Y. B.; Glunov, A. I. 2004. Chapter 3. Regional and local variability in the spatial distribution of cobalt-bearing ferromanganese crusts in the world's ocean. In: Minerals other than polymetallic nodules of the International Seabed Area. Proceedings of the Workshop held in Kingston, Jamaica, 26-30 June, 2000. International Seabed Authority. (pdf available at http://www.isa.org.jm/files/documents/EN/Workshops/2004/Proceedings-ae.pdf)