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Research Report

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The evolution and ecology of a poorly known Atlantic biodiversity hotspot

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Abstract

The Island of São Tomé is located about 500 km west of the coast of Africa. Its marine fauna is one of the least known in the world. Here we present preliminary results of our field work carried out from Feb. 04 to 17 2006. The first quantitative descriptions of fish and benthic communities of São Tomé reefs were based on 125 transects of fish visual censuses and a 100 benthic photoquadrats. We also collected tissues and voucher specimens of about 45 species and took more than 500 photos. Among fish, the most important trophic group was the planktivores, followed by mobile invertebrate feeders. Richness per unit area is comparable to sites along the Brazilian coast. We updated the checklist of the coastal fishes, including 59 new records. Hard coral cover varied from 0.5 to 30% with a mean of 8.7%. Some signs of impact of reef fisheries were detected: 1) the observation of few larger sized fish, especially sharks, groupers and snappers; 2) the presence of old nets and nylon lines in the reefs; 3) the presence of small sized fish in the market, including small parrotfishes. This scenario occurs even in the absence of industrial fisheries and with the apparent lack of use of explosives or bottom-trawling activities. It is worrisome that even low profile artisanal fisheries could be impacting the reef system in São Tomé. The need for the establishment of marine protected areas in order to secure the future sustainability of reef fisheries is evident.

Introduction

The Democratic Republic of São Tomé and Príncipe is a group of two islands in the Gulf of Guinea (western Africa), lying between the Equator and 1°42' N. São Tomé, the larger of the two islands (859 km²; see Fig. 1 showing studied sites), is located about 500 km west of the coast of Africa. The tropical marine fauna of the Gulf of Guinea is one of the least known in the world. Since early works by the Portuguese scientist Osório, during the end of the 19th century, very little information about the marine biology of São Tomé has been published (see Gascoigne 1993 and 1996, Afonso et al. 1999). The archipelago is, however, of special interest because the easterly flowing Equatorial currents (the seasonal Equatorial Countercurrents and the subsurface Equatorial Undercurrent) links the western Atlantic and the eastern Atlantic at this latitude and the marine fauna of São Tomé appears to be a mix of the two faunal regions (Scheltema 1971, 1995, Laborel 1974, Wirtz 2001, 2003).

Due to its high levels of endemism, the region is considered a marine biodiversity hotspot (Roberts 2002; Floeter et al. submitted), in spite of its comparatively low species richness. However, even basic species inventories are missing and very little is known about the evolution and ecology of São Tomé's marine fauna. On top of this, recent agreements to conduct oil exploration in São Tomé and Príncipe have been signed and large scale oil exploration (with its inherent ecological impacts) is expected to increase greatly in the coming years (Frynas et al. 2003).



Figure 1. São Tomé Island showing the studied sites.

Results

We carried out field work from Feb. 04 to 17 2006 summing up ~135h of underwater activities. To provide the first quantitative description of fish and benthic communities of São Tomé reefs, we gathered data using non-destructive methods of underwater visual censuses ($n= 125$; Fig. 2a) and photoquadrats ($n= 100$; Fig. 2c). In order to understand more about São Tomé's marine biodiversity and its biogeographical and evolutionary relationships we collected tissues (Fig. 2e) and voucher specimens (Fig. 2d) of about 45 species and took more than 500 photos (Fig. 2b) and 50 short digital films.

Fish density

Mean total fish density among sites varied from 886 to 106 fish per 40m^2 (Fig. 3). The most important trophic group was the planktivores (e.g. *Paranthias furcifer*, *Chromis multilineata*, the two most abundant reef species in the island), followed by mobile invertebrate feeders (e.g. *Holocentrus adscensionis*, *Bodianus pulchellus*) (Fig. 4). Richness per unit area (40m^2) ranged from 10 to 16 species in São Tomé, very comparable to 10 to 18 along the Brazilian coast (Fig. 5).

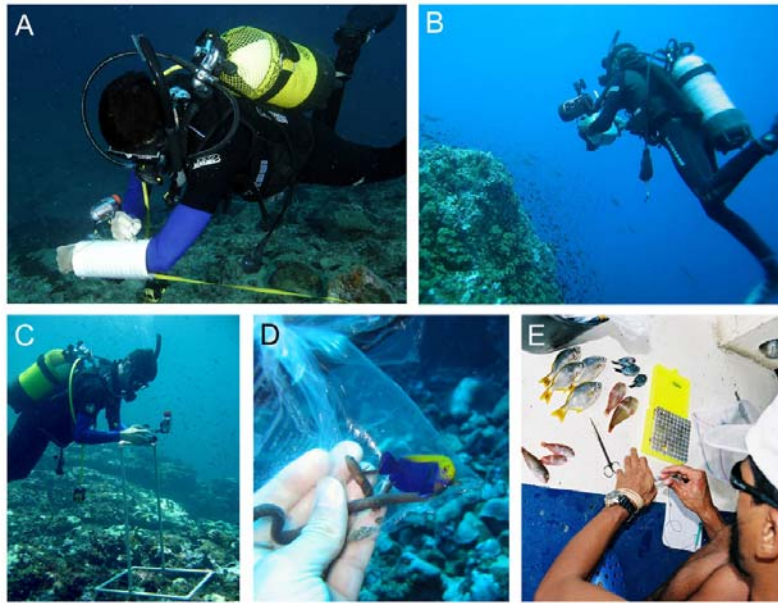


Figure 2. A) underwater visual censuses, 20 x 2m transects were used for counting fish (photo by LA Rocha); B) underwater photography were used to record biodiversity, behavior and habitats (photo by SR Floeter); C) 50 x 50cm photoquadrats (photo by P Wirtz); D) fish collection, first record of *Centropyge aurantonotus* in the eastern Atlantic (photo by SR Floeter); E) tissue collection for DNA analyses (photo by JL Gasparini).

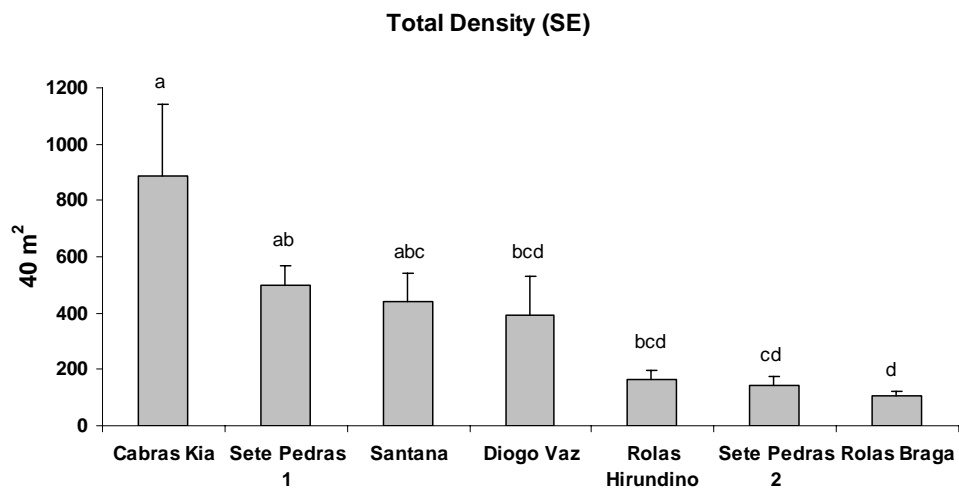


Figure 3. Total fish density in the studied sites in São Tomé Island. ANOVA showed significant differences in fish abundance among sites ($p < 0.05$). Letters above bars indicate homogeneous groups from SNK (post hoc test).

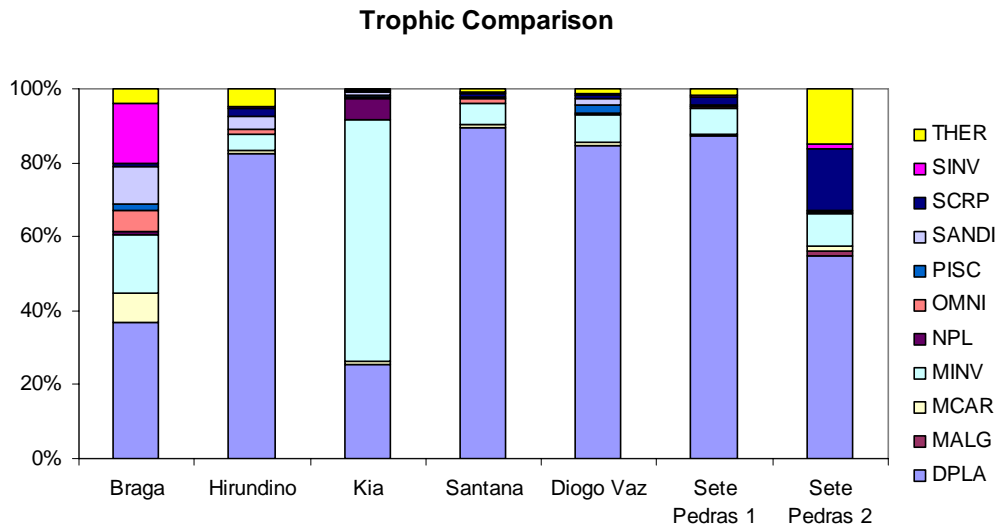


Figure 4. Relative abundance of fish trophic functional groups among the sites. Legend: DPLA = Diurnal planktivores; MALG = Macroalgae browser; MCAR = Macro-carnivores; MINV = Mobile benthic invertivores; NPLA = Nocturnal planktivores; OMNI = General omnivores; PISC = strict Piscivores; SAND = Sand invertivores; SCRIP = Scrapers herbivores; SINV = Coral/colonial sessile invertivores; THER = Territorial algae/detritus herbivores.

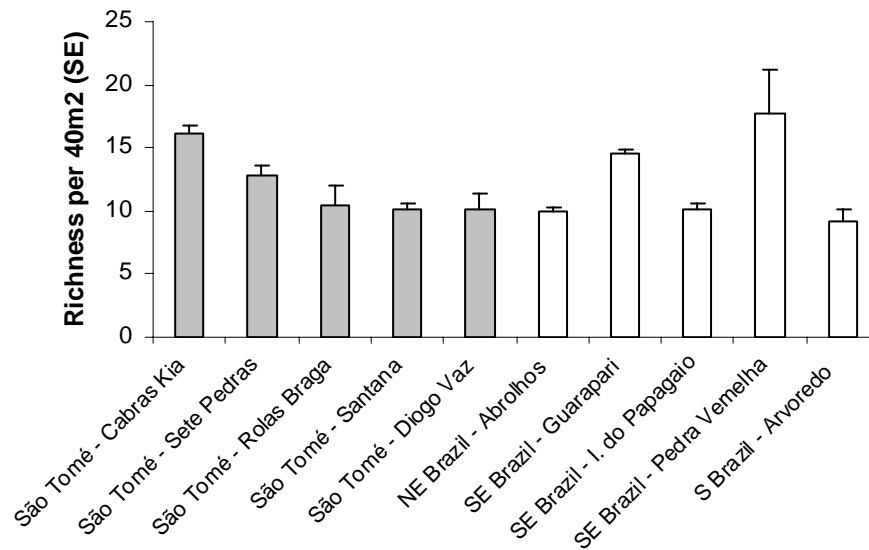


Figure 5. Fish species packing in different sites in São Tomé (grey bars; see Fig. 1) compared to sites along the Brazilian coast (white bars).

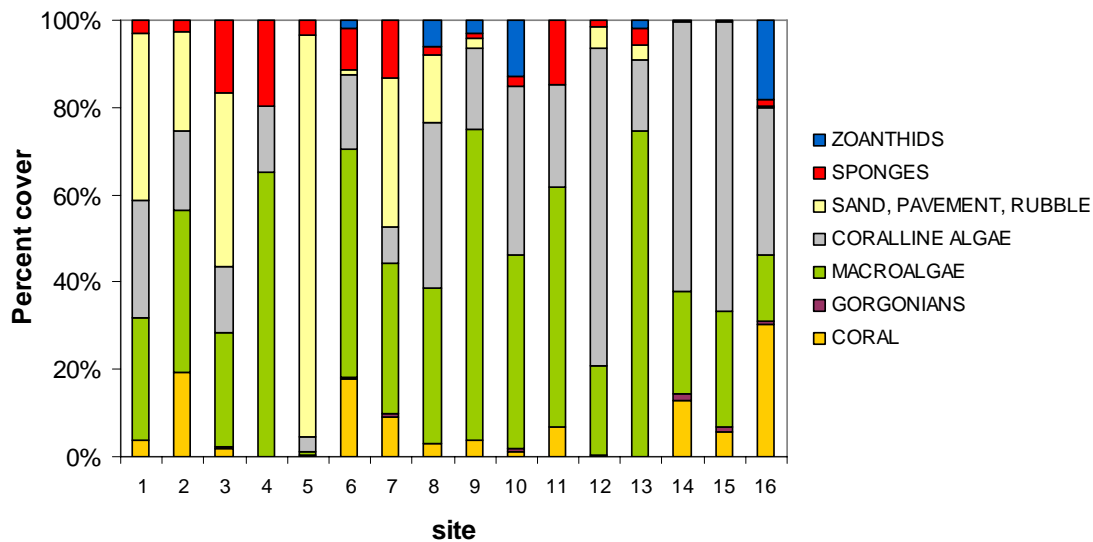


Figure 6. Benthic cover at the different sites and depths in São Tomé. Site legend: 1= Cabras Kia 9m; 2= Cabras Kia 12m; 3= Diogo Vaz 5mA; 4= Diogo Vaz 5mB; 5= = Diogo Vaz 12mA; 6= Diogo Vaz 5mB; 7= = Diogo Vaz 20m; 8= Lagoa Azul 5m; 9= Rolas Braga 20m; 10= Rolas Hirundino 6m; 11= Santana 6m; 12= Santana 19m; 13= Santana 9m interface; 14= Sete Pedras 6m; 15= Sete Pedras 12m; 16= Seter Pedras 19m.

Benthic cover

Benthic cover varied considerably among sites (Fig. 6). Macroalgae percent cover varied from 15 to 75%, coralline algae from 3 to 72%, sponges from 0 to 20%. Hard corals varied from 0.5 to 30%. The most abundant hard coral species was *Montastraea cavernosa*, especially from mid to deeper areas, followed by *Tubastraea aurea*, most abundant in shallow waters of Santana, Rolas and Sete Pedras (Fig. 7).

Mean coral cover in São Tomé was 8.7%, the lowest value recorded in the tropical Atlantic. Although coral cover reached 20-30% in two in São Tomé sites, it was below 10% in 8 other sites. Comparable Brazilian sites range from 12 to 30% coral cover, and the Caribbean mean is 26% (Fig. 8).

Reef fisheries

The collected data will also be important as a baseline for future monitoring, since oil exploration and its potential impacts in the marine environment of São Tomé and Príncipe are expected to increase greatly in the coming years (Frynas et al. 2003). The local artisanal fishery is an important resource for the island's population, with fish providing 60 to 70% of animal protein for human consumption (d'Almeida et al. 1996). Although the most important local fisheries target mobile pelagic species, namely flying-fish, tunas, half-beaks and sailfish, the extent of the reef fisheries is not known. We found some clues that artisanal reef fisheries (Fig. 9), including spearfishing, may be important in terms of its effects in the local trophic web, in fact its impact in the reef fish community could already be detected.

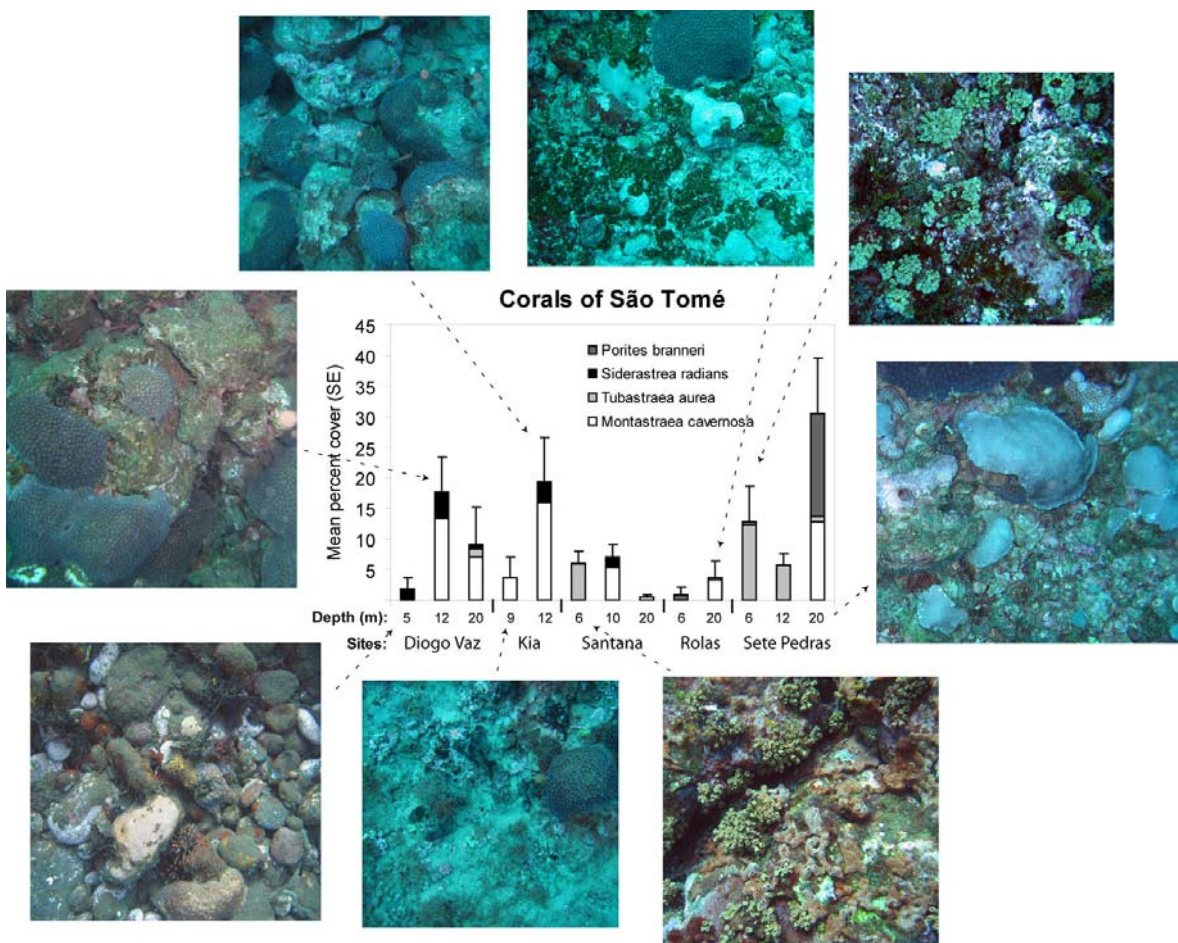


Figure 7. Coral cover at the different sites and depths in São Tomé.

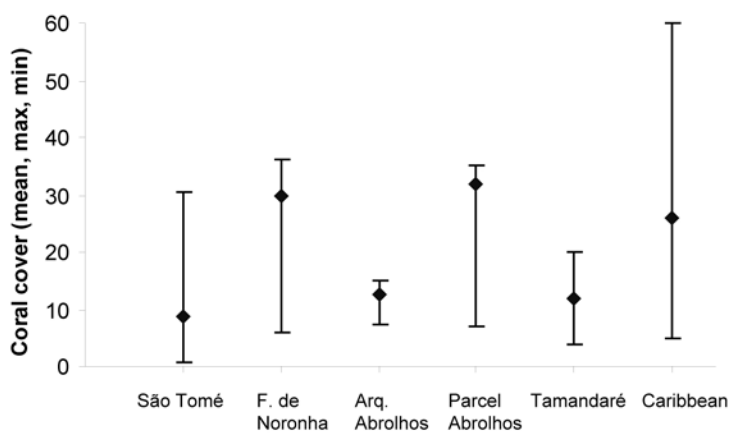


Figure 8. Coral cover at the different sites and depths in São Tomé compared to other areas in the tropical Atlantic. Data sources: Brazilian sites - Ferreira & Maida (2006), Caribbean - Lang (2003).

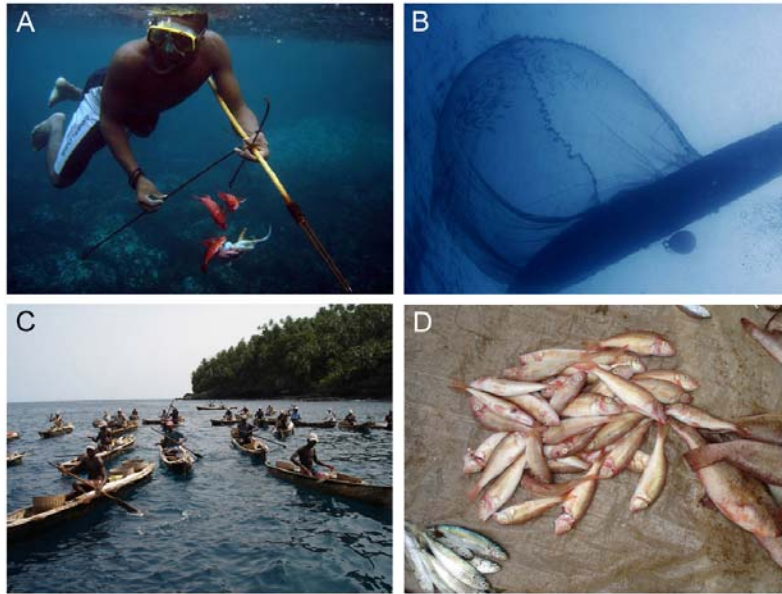


Figure 9. Reef fisheries in São Tomé. A) spearfishing in Diogo Vaz, note the small size of the fish caught (photo by JL Gasparini); B) underwater view of net fishing from canoe (photo by LA Rocha); C) canoes used for hook and line fishing (photo by CL Sampaio); D) fish market in São Tomé, note the small size of the fish and the presence of herbivorous reef fish - family Scaridae (photo by P Wirtz).

Some typical signs of overfishing impact were detected in the studied sites, including: 1) the observation of few larger sized fish, especially the target-species of the families Serranidae (groupers) and Lutjanidae (snappers); 2) the presence of net debris and nylon lines discarded on the reefs; 3) the presence of small sized fish in the market, including small parrotfishes (Scaridae).

This scenario occurs even in the absence of industrial fisheries and with the apparent lack of use of explosives or bottom-trawling activities. It is worrisome that even just artisanal fisheries could drive impacts on the reef system of São Tomé. The need for the establishment of marine protected areas in order to secure the future sustainability of reef fisheries is evident.

Diversity, Biogeography and Evolution

The efforts of this expedition plus other visits to São Tomé & Príncipe islands by co-investigator Peter Wirtz accumulated 59 new records of shore fishes. Ten of these are new species still in process to be described (e.g. Heemstra in prep.; Craig et al. in prep.), including a new genus of a gobiid fish that lives in association with an axiid shrimp (Schliewen & Kovacic in prep.).

The updated checklist of the coastal fishes of São Tomé and Príncipe now contains a total of 234 valid species (including the 59 new records) and an additional 10 doubtful historical records which needs to be verified (Wirtz et al. in press).

Twenty-one of the 59 new records of shore fishes from São Tomé and Príncipe represent fish species that occur on both sides of the Atlantic, i.e. amphi-Atlantic species. A particularly noteworthy example is that of *Centropyge aurantonotus* (Fig. 2d), previously only known from Barbados to southern Brazil in the western Atlantic. Many other fish species present at São Tomé and Príncipe have their sister species in the western Atlantic (e.g. *Clepticus africanus*, *Microspathodon frontatus*, *Myrichthys pardalis*, *Pseudupeneus prayensis*, *Sparisoma* n. sp., *Rypticus* n. sp.).

A large proportion of trans-Atlantic species was already noted for marine invertebrates from São Tomé and Príncipe (Laborel 1974; Wirtz 2001, 2003, 2004; Floeter et al. submitted). At present, amphi-Atlantic species at São Tomé and Príncipe total 64 coastal fish species (representing 27.3% of the valid species; see Table 1). Even though planktonic larvae could cross the Atlantic in as little as 35 to 105 days in the Equatorial Undercurrent (Scheltema 1971), it remains unclear in most cases if the western and eastern Atlantic populations of trans-Atlantic species are still linked genetically today. A genetic study of the fish *Ophioblennius atlanticus* by Muss et al. (2001) suggested that eastern and western Atlantic populations of this species have been genetically separated for several million years and should probably be considered sister species. In contrast, there appears to be ongoing gene flow between American and African populations of the sea-urchin *Eucidaris tribuloides* (Lessios et al. 1999).

Two new results from this expedition add to the latter trend of trans-Atlantic connection. Sequencing of the spotfin hogfish (*Bodianus pulchellus*) from both sides of the Atlantic revealed a difference of just two mutations in 600 base pairs (0.3%) of mtDNA. This implies a genetic connection in the last 50,000 years. The same applies to the cardinalfish *Apogon pseudomaculatus* with only one mutation.

Another cardinalfish, *Apogon imberbis*, was only known by an underwater photograph (Afonso et al. 1999). This expedition collected specimens that allowed identification not only morphologically but also by genetic comparison with specimens from the Azores and from the Canary Islands (Vera Domingues, pers. comm.).

Previous biogeographic hypotheses suggest that exchange of species between regions is largely unidirectional: from the most diverse towards the less diverse region (Briggs 1995; Vermeij 1991; Vermeij & Rosenberg 1993). Thus, a null biogeographic hypothesis is that the tropical eastern Atlantic (Gulf of Guinea) receives most of its species from Brazil and the Caribbean and, indeed, after a phylogeographic analysis of the Atlantic species of four genera, invasion from the New World to the Eastern Atlantic was argued for *Thalassoma* (Bernardi et al. 2004; Costagliola et al. 2004), *Ophioblennius* (Muss et al. 2001), *Holacanthus* (Bellwood et al. 2004 and G. Bernardi & S.R. Floeter, unpubl. data), and *Gnatholepis* (Rocha et al. 2005).

To a much lesser degree, the shore fish fauna of São Tomé and Príncipe also shows some affinity with the Indian Ocean. Genera such as *Coris*, *Lethrinus*, *Prionurus*, and *Plectorhynchus*, not present in the western Atlantic, exemplify such cases (see Floeter et al. submitted).

The following coastal fish species are currently only known from São Tomé and Príncipe and the neighboring (poorly explored) island of Annobón: *Torpedo* sp. 1 and 2, *Clepticus africanus*, *Thalassoma newtoni*, *Scorpaena annobónae*, *Liopropoma* sp.n., *Serranus*

sp.n., Gobiidae gen. & sp. nov., *Gorogobius* n. sp. Time will tell if they are also present on the more distant (and equally poorly explored) shores of the Gulf of Guinea, i.e. the island of Bioko and the African mainland coast.

In terms of invertebrates, new records of many groups were found, such as symbiotic shrimps (Wirtz et al.), Actiniaria, Corallimorpharia, and Pennatularia (Ocaña & Wirtz, in prep.). Moreover, a new species of Mysidacea symbiotic with a sea anemone is being described (Wittmann, in prep.) and a new Caridea crustacean was just published (Udekem d'Acoz C. d' 2007).

Table 1. Distribution types of coastal fishes of São Tomé and Príncipe islands.

Distribution type of São Tomé and Príncipe coastal fishes	Number of species	Percentage of total valid species (n = 234)
Endemic to Gulf of Guinea	28	12.0
Tropical West Africa only	73	31.2
Tropical eastern Atlantic reaching to Brazilian islands	1	0.4
Widespread eastern Atlantic	36	15.4
Widespread western and eastern Atlantic	41	17.5
Western Atlantic reaching to Gulf of Guinea or isolated tropical eastern Atlantic islands	23	9.8
Atlantic and Indo-West Pacific	2	0.9
Circumtropical	30	12.8

Roberts et al. (2002) have rightly called the Gulf of Guinea one of the hotspots of marine biodiversity on earth. A few weeks of diving and collecting has resulted in 59 new records of fishes. Ten of these represent undescribed species. The National Geographic expedition has also collected a large number of marine invertebrates new for the area and new for science. This indicates that the marine fauna of the Gulf of Guinea is seriously underestimated. A broad effort is needed to understand how rich the area really is and how species are distributed within that region.

Ultimately, a better knowledge of the richness and uniqueness of its fauna will hopefully help the government of São Tomé understand the urgent need for conservation efforts through the establishment of marine reserves.

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