Aqua, Journal of Ichthyology and Aquatic Biology

Reef fishes of St. Paul's Rocks: new records and notes on biology and zoogeography

Bertran M. Feitoza[1], Luiz A. Rocha[2], Osmar J. Luiz-Júnior[3], Sergio R. Floeter[4] and João L. Gasparini[5]

1) Universidade Federal da Paraíba, CCEN, Depto. de Sistemática e Ecologia, João Pessoa, PB, 58059-900, Brasil; e-mail: bertranfeitoza@hotmail.com
2) University of Florida, Dept. of Fisheries and Aquatic Sciences,7922 NW, 71st Street, Gainesville, FL 32653, USA;
3) Universidade Metodista de São Paulo, Núcleo e Agência Ambiental, São Bernardo do Campo, SP, 09640-000, Brasil;
4 & 5) Universidade Federal do Espírito Santo, Depto. de Ecologia e Recursos Naturais, Vitória, ES, 29060-900, Brasil.

Accepted: 05.05.2003

Keywords
St. Paul´s Rocks, zoogeography, reef fishes, fish assemblages, dispersal

Abstract

St. Paul's Rocks is a very small group of rocky islands located on the mid-Atlantic Ridge just north of the Equator, about 1000 km from the Brazilian coast. The aim of this work is to add new information on the abundance, biology, zoogeography and taxonomy of its reef fishes. In the course of four expeditions the fish fauna was surveyed in tide pools and over reefs at depths down to 62 m using a number of different methodologies. Seventy-five fish species (25 new records) were found, of which 58 were reef inhabitants and only 17 were pelagic. The most speciose families were Muraenidae (seven species), Carangidae (five), Pomacentridae (five), Labridae (four), Serranidae (three), and Scaridae (three). *Stegastes sanctipauli* (Pomacentridae), *Chromis multilineata* (Pomacentridae), *Melichthys niger* (Balistidae) and *Caranx lugubris* (Carangidae) were the most visually abundant fishes. *Carcharhinus galapagensis* and *Anthias salmopunctatus*) recorded in prior surveys, were not observed by our team. It was found that 60.3% of the reef fish species are carnivores, 15.5% planktivores, 8.6% omnivores, 8.6% territorial herbivores, and 6.9% non-territorial herbivores. Of the 58 reef fishes recorded, four are endemic to St. Paul's Rocks and about 80% also occur off the coast of Brazil. It is thought therefore that St. Paul's Rocks should be regarded as an impoverished outpost of the Brazilian province.

Resumo

O Arquipélago de São Pedro e São Paulo é um conjunto muito pequeno de ilhotas rochosas localizado logo acima do Equador, distante cerca de 1000 km da costa brasileira. O objetivo do presente estudo foi adicionar novas informações acerca da abundância, biologia, zoogeografia e taxonomia dos seus peixes recifais. Durante quatro expedições, a ictiofauna foi levantada em poças de maré e em recifes até 62 m de profundidade através de várias metodologias. Setenta e cinco espécies de peixes (25 novos registros) foram encontradas na área, das quais 58 são habitantes dos recifes e 17 são pelágicos. As famílias mais ricas quanto ao número de espécies foram Muraenidae (sete espécies), Carangidae (cinco), Pomacentridae (cinco), Labridae (quatro), Serranidae (três), and Scaridae (três). *Stegastes sanctipauli, Chromis multilineata, Melichthys niger* e *Caranx lugubris* foram os peixes visualmente mais abundantes. *Carcharhinus galapagensis* e *Anthias salmopunctatus*, registrados em levantamentos anteriores, não foram observadas pela nossa equipe. Foi constatado que 60,3% das espécies de peixes recifais são carnívoras, 15,5% planctívoras, 8,6% onívoras, 8,6% herbívoras territoriais e 6,9% herbívoras não territoriais. Dos 58 peixes recifais registrados, quatro são edêmicos do Arquipélago São Pedro e São Paulo e cerca de 80% ocorrem também na costa do Brasil continental. Acredita-se, portanto, que o Arquipélago de São Pedro e São Paulo deve ser considerado como um ponto externo empobrecido da Província brasileira.

Zusammenfassung

Die St.Paul's Rocks sind eine sehr kleine Gruppe felsinger Inseln, die entlang der mittelatlantischen Kammlinie – nur wenig nördilich des Äquators - , etwa 1000 km vor der brasilianischen Küste, liegen. Der Zweck dieser Untersuchung war die Erfassung neuer

Informationen über Artenreichtum, Biologie, Zoogeografie und Taxonomie ihrer Riffische. Im Verlaufe von vier Expeditioner wurden die entsprechenden Einzelhein der Fischfauna in Tidentümpeln sowie ubre den Rifen, bis hinuter zu Tiefen von 62 m, mit verschiedenartiger Methodik erfasst. Fünfudsiebzig Fischarten (25 davon als Neuaufzeichnungen) wurden verzeichnet. Davon warem 58 Arten Riffbewohner und 17 arten kamen pelasisch vor. Die artenreichsten Familien waren: Muraenidae (7 arten), Carangidae (5 arten), Pomacentridae (5 arten), Labridae (4 arten), Serranidae (3 arten). *Stegastes sanctipauli* (Pomacentridae), *Chromis multilineata* (Pomacentridae) und *Melichthys niger* (Balistidae) waren die am meisten gesehenen Fischarten. Die in früheren Berichten angeführten Arten *Carcharhinus galapagensis* und *Anthias salmopunctatus*, wurden von unserem Team nicht gefunden. Es wurde beobachtet, dass unter den Fischarten dieser Inseln 60.3% Fleischfresser, 15.5% Planktonfresser, 8.5% Allesfresser, 8.6% territoriale Pflanzenflesser und 6.9% nicht-territoriale Pflanzenfresser sind. Von den 58 erfassten Riffischarten waren vier für die St.Paul's Rocks endemisch; etwa 80% kommen ebenfalls entlang der brasilianischen Küste vor. Daher ist es zu vermuten dass man die St.Paul's Rocks als einen fischartenverarmten Vorposten der brasilianischen Provinz betrachten sollte.

Resumé

St Paul's Rocks est un minuscule groupe d'îles rocheuses sises sur la dorsale médiane de l'Atlantique, juste au nord de l'Equateur, à environ 1000 km de la côte brésilienne. L'objectif de ce travail es de fournir des informations nouvelles sur l'abondance, la biologie, la zoogéographie et la taxonomie de ses poissons de récifs. Au long de quatre expéditions, la faune piscicole a été relevée dans les mares tidales et sur les récifs jusqu'à des profoundeurs de 62 m. en utilisant plusieurs méthodologies. Soixante-quinze espèces de poissons ont été collectées (25 sont nouvelles), don't 58 inféodées aux récifs et 17 pélagiques. Les familles comprenant le plus d'espèces étaient les Muraenidae (sept espeses), les Carangidae (cinq), les Pomacentridae (cinq), les Labridae (quatre), les Serranidae (trois) et les Scaridae (trois). *Stegastes sanctipauli* (Pomacentridae), *Chromis multilineata* (Pomacentridae), *Melichthys niger* (Balistidae) et *Caranx lugubris* (Carangidae) étaient lês espèces les plus souvent visibles. Malgré leur présence dans des releves précédents, *Carcharhinus galapagensis* et *Anthias salmopunctatus* n'ont pas été observées par notre equipe. L'analyse a revele que 60,3% des espèces récifales sont carnivores, 15,5% planctonivores, 8,6% omnivores, 8,6% herbivores territoriales et 6,9% herbivores non territoriales. Sur les 58 poissons récifaux collectés, quatre sont endémiques à St.Paul's Rocks et 80% environ figurent aussi au large du Brésil. D'où la conclusion que St Paul's Rocks devrait éter considéré comme un poste avancé plus pauvre en espeses de la province brésilienne.

Sommario

St. Paul's Rocks è un piccolo gruppo di isole rocciose localizzate lungo la dorsale Atlántica, a nord dell'equatore e a 1000 km dalla costa del Brasile. Lo scopo di questo lavoro è quello di fornire nuovi dati sull'abbondanza, la biología, la zoogeografía e la tassonomia dei pesci che abitano le coste di queste isole. Nel corso di quattro spedizioni, utilizando diverse metodologie, è stata censita la fauna ittica marina delle zone costiere dalla fascia delle maree alla barriera fino alla profondità di 62 m. Sono state registrate complessivamente 75 specie (incluse 25 nuove segnalazioni), 58 delle quali sono pesci di barriera, mentre 17 sono pelagici. Le famiglie presenti con il maggior numero di specie sono quelle dei Muraenidae (7 specie), dei Carangidae (5), Pomacentridae (5), Labridae (4), Serranidae (3) e Scaridae (3). *Stegastes sanctipauli* (Pomacentridae), *Chromis multilineata* (Pomacentridae), *Melichthys niger* (Balistidae) e *Caranx lugubris* (Carangidae) erano le specie più abbondanti. Malgrado fossero state Registrate in precedenti spedizioni, le due specie *Carcharhinus galapagensis* e *Anthias salmopunctatus* non sono invece state osservate in questo studio. Dal censimento eseguido risulta Che il 60,3% delle specie di barriera sono carnivore, il 15,5% planctivore, l'8,6% omnivore, l'8,6% erbivore territoriali e il 6,9% erbivore non territoriali. Delle 58 specie di barriera registrate, quattro sono endemiche a St. Paul's Rocks, mentre circa l'80% sono presenti anche lungo le coste del Brasile. Si ritiene pertanto che St. Paul's Rocks debba essere considerato un avamposto impoverito della regione brasiliana.

Introduction

St. Paul's Rocks (Arquipélago de São Pedro e São Paulo) is a very small group of rocky islands located on the mid-Atlantic Ridge, just north of the Equator (00º55'N; 29º21'W), 1000 km from the Brazilian coast, and 1890 km from Senegal, Africa (Fig. 1). It is one of the smallest, most isolated groups of oceanic islands in the world.

The Rocks are particularly interesting from the population biology and biogeographical perspectives because of their very small size and isolation. They are uniquely influenced by both the Equatorial Undercurrent – facilitating eastward dispersal – and the Southern Equatorial Current – directing flow from the central-eastern Atlantic. The area has been visited by scientific expeditions since 1799 (see Lubbock & Edwards, 1981). In the past, the inhospitable nature and inaccessibility of

St. Paul's Rocks had prevented detailed biological studies. However, since the establishment of a scientific station by the Brazilian Navy in July of 1998, ichthyologists have been able to visit the island periodically to reassess the population status of reef fishes (the Rocks, now called 'Arquipelago' are permanently inhabited).

The present study adds to the knowledge of the biology of the reef fishes of St. Paul's Rocks obtained by the 1979 Cambridge Expedition (Lubbock & Edwards, 1981).

Methods

Study area: the Archipelago rises from the 4000 m deep ocean floor close to the mid-Atlantic Ridge, and two putative ages are given to it: 9.5 MYBP (million years before present) if it originated from a nearby ridge, or 35 MYBP if it originated from a farther oceanic ridge (Melson, 1972). It consists of five small rocky islets and four larger islets covering an area of about 16,000 m^2 (Fig. 1). Tide pools are present on most of the islets, which are generally flushed with seawater at high tide (Fig. 2). A small shallow bay (2 to 21 m depth) is formed by the encirclement of three major islets (Fig. 3). Other reef habitats of St. Paul's Rocks consist almost entirely of nearly vertical cliffs extending beyond 60 m depth (Fig. 4). Robertson (2001) noted that this archipelago has one of the most limited areas of shallows habitats (<50 m deep) among oceanic islands, with less than 0.2 km^2. Most of the sublittoral zone is dominated by the soft coral *Palythoa caribeorum* (from 3 to 8 m depth), and the algae *Caulerpa* sp. (from 3 to about 30 m) (Fig. 5). The hermatipic corals *Madracis decatis* (Lyman) and *Scolymia wellsi* Laborel appear where the *Caulerpa* stops at about 30 m, and occur down to at least 45 m

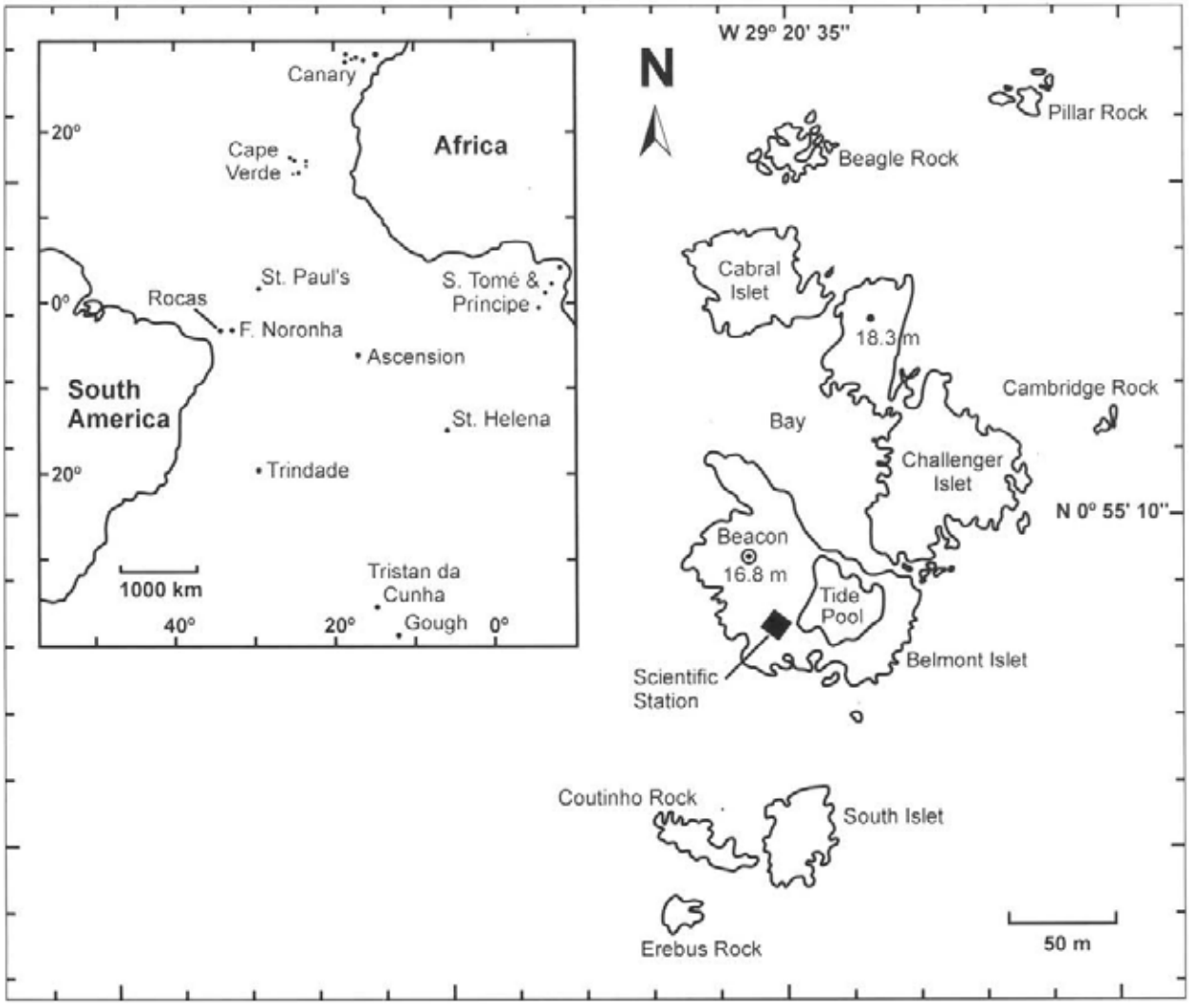

Fig.1. Map of St. Paul's Rocks.

Fig. 2. Tide pool at Belmont Islet, it is flushed with fresh seawater at high tide. Photo by B. M. Feitoza.

Fig. 3. Bay situated between the Belmont, Challenger and Cabral Islets. Photo by B. M. Feitoza.

Fig. 4. Vertical cliff, the typical reef habitat of St. Paul's Rocks. Photo by O. J. Luiz-Junior.

Fig. 5. Underwater view at St. Paul's Rocks, with the green algae *Caulerpa* sp. Dominating most of the sublittoral zone. Photo by O. J. Luiz-Junior.

Where they are quite abundant (Amaral, in press). Two black corals (*Antipathes* spp.) occur from a depth of 45 m to at least 60 m (Edwards & Lubbock, 1983a; Amaral, in press). Edwards & Lubbock (1983a), recorded 14 alga species in their study.

Data collection: four expeditions have been undertaken since 1999 (May and November 1999, September 2000, and August 2001) comprising 47 days of fieldwork and about 124 hours of underwater activity (54 scuba dives to depths of 62 m – including two night dives, and 39 snorkelling dives). The water temperature ranged from 23 to 26.5ºC and visibility from 12 to 30 m. The fish fauna was surveyed in tide pools and over reefs down to a depth of 62 m, through underwater observations, collections and photographs. Three small clove oils stations were conducted aiming to survey cryptic fish not collectable using other methods. Six hours of underwater videos were filmed with a view to investigating fish behaviour. Collected specimens were deposited in the fish col-lections of the following institutions: Universidade Federal da Paraíba, João Pessoa, Paraíba, Brazil (UFPB); and Museu de Biologia Professor Mello Leitão, Santa Tereza, Espírito Santo, Brazil (MBML). Data on voucher specimens is appended.

Species list, populational status and abundance data: The species list is based on the fishes observed, photographed and collected during the four expeditions, as well as on data from the literature (Lubbock & Edwards, 1981) and from fisheries run by comercial fishing boats. Bony fishes are listed in the phylogenetic order of families, following Nelson (1994); elasmobranchs are listed following Compagno (1999). Within the families, species are organized in alphabetical order. We have also included the follow-ing information for each species:

1979 population status – a rough indication of relative abundance in 1979, based on Lubbock & Edwards (1981);

Current population status – an indication of relative abundance in 1999 – 2001 based on a diver's likelyhood of observing a species in its normal habitat and depth range on any given dive (adapted from Humman & DeLoach, 2002), where: AB = abundant (at least several sightings of many individuals – at least 50 – can be expected on nearly every dive), VC = very common (at least several sightings can be expected on nearly every dive, but not necessarily of many individuals), CM = common (sightings are frequent, but not necessarily expected on every dive), OC = occasional (sightings are not unusual, but are not expected on a regular basis), UN = uncommon (sightings are unusual), and RA = rare (sightings are exceptional);

Habitat – where the species has usually been found (adapted from Edwards & Lubbock, 1983a), where:*1* = tide pools (either frequently or infrequently flushed by fresh seawater), *2* = littoral zone (spring-tidal range), *3* = *Palythoa* and *Caulerpa* zone (dominated by *Palythoa caribeorum*, from the bottom of the littoral zone down to 8 m, and by *Caulerpa,* from 3 to about 30 m), *4* = sub-*Caulerpa* zone (from where *Caulerpa* stops, at about 30 m, to at least 60 m), *5* = slope and bay (gently sloping areas with patches of coarse sand, rubble and isolated loose rocks), and *6* = water column (offshore and over reefs, pelagic habitat);

Depth range – range commonly seen in underwater observations;

Geographic range of the species;

Trophic category – determined from direct behavioural observations and available literature (Randall, 1967; 1996), where: TH = territorial herbivores, NT = non-territorial herbivores, C = carnivores, P = planktivores, and O = omnivores.

Record status – how the species was recorded.

We consider 'reef fishes' to be species either associated with hard substrate (*sensu* Thresher, 1991) or epipelagic forms that regularly associate with the reefs (such as carangids, belonids, sharks and pelagic rays). Surveys of the abundance and the occurrence of juveniles and adults of various sizes were used to estimate which members of the fish fauna are residents, i.e. have self-sustaining populations, or vagrants, i.e. exceedingly rare and probably arriving from other sites.

Results and discussion

New records and population reassessment: Lubbock & Edwards (1981) recorded 50 fish species belonging to 29 families, of which 34 are associated with rocky-reef habitats. Our team recorded a total of 75 fish families (25 new records) belonging to 36 families. Fifty eight species were recorded over reef areas (referred to as "reef fishes"), eleven of which are mid-water species that are regularly observed on reefs, and 47 are dependent on rocky-reef habitats (Table I). Seventeen species are pelagic and are not included in Table I (new records are in bold): *Rhincodon typus* Smith, 1829; *Carcharhinus falciformis* (Bibron in Müller & Henle, 1839); ***Prionace glauca*** Linnaeus, 1758; *Isurus oxyrinchus* Rafinesque, 1810; ***Cypselurus cyanopterus*** (Valenciennes, 1847); *Exocetus volitans* Linnaeus, 1758; ***Paraexocoetus* sp.**; ***Remora brachyptera*** (Lowe, 1839); ***R. osteochir*** Cuvier, 1829; *Remorina albescens* (Temminck & Schlegel, 1845); ***Coryphaena hippurus*** Linnaeus, 1758; ***Acanthocybium solandri*** (Cuvier, 1832); *Scomberomorus cavalla* (Cuvier 1829); *Thunnus albacares* (Bonnaterre, 1788); ***T. obesus*** (Lowe, 1839); ***Makaira nigricans*** Lacepède, 1802; and ***Mola* sp**.

Among the 58 reef fishes recorded, the most speciose families were the Muraenidae (seven species), Carangidae (five), Pomacentridae (five), Labridae (four), Serranidae (three), and Scaridae (three). Sixteen species (27.6%) were rare, five (8.6%) uncommon, nine (15.5%) occasional, 13 (22.4%) common, seven (12.1%) very common and six (10.3%) abundant, and (see Table

I). Nine of the 16 rare species (*Cephalopholis fulva, Lutjanus jocu, Stegastes rocasensis, Clepticus brasiliensis, Thalassoma noronhanun, Sparisoma amplum, S. axillare, S. frondosum,* and *Bathygobius soporator*) do not seem to have a self-sustaining population and probably come from other sites where they are commom (e.g. Fernando de Noronha Archipelago).

The population status of most of the species between 1999 and 2001 seems to be nearly the same as that observed by Lubbock & Edwards (1981). Two species previously recorded by Lubbock & Edwards (1981) were not observed by our team: the Galapagos shark *Carcharhinus galapagensis* and the St. Paul's anthias *Anthias salmopunctatus.* The abundance of sharks at St. Paul's Rocks has been noted by most early visitors and partly attributed to the lack of fishing activity (Lubbock & Edwards, 1981). In the past two decades however, fishing pressure has increased greatly, and sharks are now targeted due to the high commercial value of their fins. The pelagic fishes on which sharks feed are also targeted by the fishing industry and this may also have contributed to an apparent population decline of *C. galapagensis. Anthias salmopunctatus* is endemic to St. Paul's Rocks and was listed as vulnerable by IUCN (Hilton-Taylor, 2000). This species was common on rock faces below 30 m, as reported by Lubbock & Edwards (1981), but was not seen by our team.

The St. Paul's Gregory *Stegastes sanctipauli*, the brown chromis *Chromis multilineata,* the black durgon *Melichthys niger* and the black jack *Caranx lugubris* were the most visually abundant fishes in St. Paul's Rocks and certainly account for the most important part of the fish biomass. The latter two species are usually found up to at least 150 m from the Rocks, forming large aggregations from just below the surface down to about 30 m. *Melichthys niger* appears to be common around isolated oceanic islands. There are reports of the same abundance for Ascension Island (Lubbock, 1980), Clipperton Atoll (Robertson & Allen, 1996), Trindade Island (Gasparini & Floeter, 2001), and to a minor degree in the vicinity of Rocas Atoll (Rosa & Moura, 1997) and Fernando de Noronha Archipelago (B. M. Feitoza pers.obs.).

Almost two thirds (60.3%) of the reef fishes species are carnivores, 15.5% planktivores, 8.6% omnivores, 8.6% territorial herbivores and 6.9% non-territorial herbivores. *Stegastes sanctipauli* is primarily considered to be a territorial herbivore, but can also be opportunistic, sometimes preying upon fish eggs and small benthic invertebrates. The same appears to be true for the sergeant major *Abudefduf saxatilis* (primarily treated as a 'planktivore') since it has mostly been seen in mid water, clearly feeding on zooplankton. According to Randall (1967), *A. saxatilis* has one of the most diversified food habits known, and may be observed in aggregations well above reefs, feeding on zooplankton or grazing on benthic algae, or on sessile animal life on the bottom. This feeding flexibility probably enables opportunistic planktivores (e.g. *S. sanctipauli* and *A. saxatilis*) and the classic omnivores (e.g. *M. niger)* to numerically dominate harsh environments around oceanic islands.

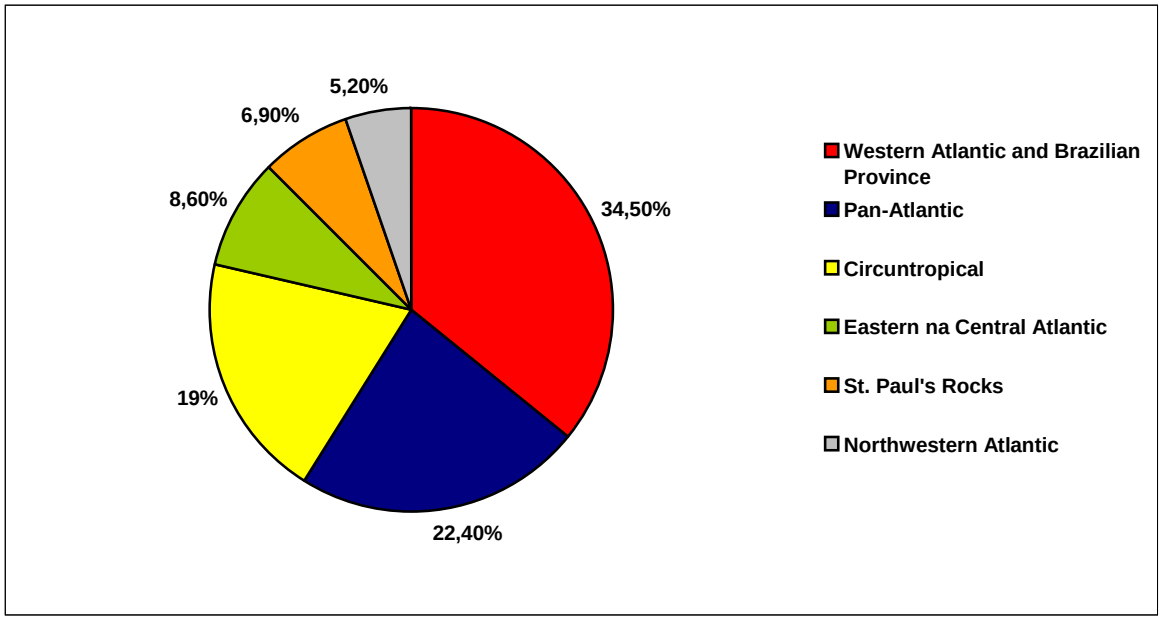

Fig.6. Geographic distribution of St. Paul's Rocks reef fishes.

Table I. Reef fishes from St. Paul's Rocks. Population status, habitat, depth and geographical ranges, trophic categories and record status are shown indicated. New records are in bold.

Family / species	Population Status (1979)	Population Status (2001)	Habitat	Depth Range (m)	Geographic Range	Trophic Category	Record Status
CARCHARINIDAE *Carcharhinus galapagensis* (Snodgrass & Heller, 1905)	CM	--	3,4,5,6	8 – 36	CT	C	L
SPHYRNIDAE *Sphyrna* sp.	UN	UN	6	0 - 40	CT	C	SR,L
MOBULIDAE *Mobula tarapacana* (Phillipi, 1893)	CM	CM	6	0 - 30	CT	P	P,V
MURAENIDAE ***Channomuraena vittata*** (Richardson, 1845)	--	RA	3,4,5	15 – 30	CT	C	P
Enchelycore anatina (Lowe, 1841)	--	OC	3,4,5	3 – 60	EA+CA+FN	C	VS
Enchelycore nigricans (Bonnaterre, 1788)	OC	CM	1,3,4,5	2 – 60	PA	C	VS,L
Gymnothorax funebris Ranzani, 1840	--	RA	3,5	0 – 50	PA	C	V
Gymnothorax miliaris (Kaup, 1859)	UN	CM	3,4,5	2 – 40	PA	C	P,L
Muraena melanotis (Kaup, 1859)	--	OC	3,4,5	3 – 60	EA+CA+FN	C	VS
Muraena pavonina Richardson, 1844	CM	CM	1,3,4,5	2 - 60	CA+BR	C	P,V,L
BELONIDAE ***Ablennes hians*** (Valenciennes 1846)	--	RA	6	0 – 3	CT	C	SR
Strongylura timucu (Walbaum 1792)	--	UN	6	0 - 3	WA	C	P
HOLOCENTRIDAE *Holocentrus ascensionis* (Osbeck, 1765)	OC	OC	1,3,4,5	2 – 60	PA	C	VS,L
Myripristis jacobus Cuvier, 1829	CM	CM	3,4,5	2 - 30	PA	P	P,V,L
AULOSTOMIDAE *Aulostomus* aff. *Strigosus* Wheeler, 1955	CM	VC	3,4,5	2 - 30	PA	C	VS,L
DACTYLOPTERIDAE ***Dactylopterus volitans*** (Linnaeus, 1758)	--	RA	3,5,6	0 - 30	PA	C	P
SCORPAENIDAE ***Scorpaena* sp.**	--	RA	3,4,5	25 – 30	?	C	P
Scorpaenodes insularis Eschmeyer, 1971	UN	UN	3,4,5	5 - 35	CA	C	VS,L
SERRANIDAE *Anthias salmopunctatus* Lubbock & Edwards, 1981	CM	--	4	>30	End	P	L
Cephalopholis fulva (Linnaeus, 1758)	--	RA	3,5	2 – 35	WA	C	SR
Rypticus saponaceus (Bloch & Schneider, 1801)	CM	OC	3,4,5	2 - 62	PA	C	P,L
APOGONIDAE *Apogon americanus* Castelnau, 1855	CM	CM	3,4,5	0 - 40	BR	P	VS,L
CARANGIDAE *Carangoides bartholomaei* (Cuvier, 1833)	UN	UM	3,4,5,6	0 – 40	WA	C	SR,L
Carangoides crysos (Mitchill, 1815)	CM	OC	3,5,6	0 – 40	PA	C	P,L
Caranx latus Agassiz, 1829	OC	OC	3,5,6	1 – 30	WA	C	P,L
Caranx lugubris Poey, 1860	VC	AB	3,4,5,6	0 – 70	CT	C	VS,L
Elegatis bipinnulata (Quoy & Gaimard, 1824)	OC	OC	6	0 - 40	CT	C	P,L
LUTJANIDAE *Lutjanus jocu* (Bloch & Schneider, 1801)	OC	RA	3,4,5	2 - 40	WA+CA	C	P,V,L
CHAETODONTIDAE *Chaetodon obliquus* Lubbock & Edwards, 1980	CM	CM	4	30 – 70	End	C	VS,L
Chaetodon striatus Linnaeus, 1758	CM	CM	3,4,5	2 - 55	WA	C	P,L

Family / species	Population Status (1979)	Population Status (2001)	Habitat	Depth Range (m)	Geographic Range	Trophic Category	Record Status
POMACANTHIDAE							
Holacanthus ciliaris (Linnaeus, 1758)	CM	CM	3,4,5	2 – 60	WA	O	VS,L
Blue morph	UN	OC	3,4,5	2 – 60	End	O	P,V,L
White morph	UN	RA	4	30 – 50	End	O	P,V,L
Other colour morphs	UN	UN	3,4,5	2 - 60	End	O	P,V,L
Pomacanthus paru (Bloch, 1787)	UN	UN	3,4,5	2 - 30	WA+CA	O	P,V,L
KYPHOSIDAE							
Kyphosus sectatrix (Linnaeus, 1766)	CM	vc	3,4,5,6	0 - 25	PA	NH	P,V,L
POMACENTRIDAE							
Abudefduf saxatilis (Linnaeus, 1758)	AB	AB	1,3,4,5,6	0 – 20	PA	P	P,V,L
Chromis aff. *enchrysura* Jordan & Gilbert, 1822	CM	CM	4	40 – 70	WA	P	VS,L
Chromis multilineata (Guichenot, 1855)	AB	AB	3,4,5,6	0 – 60	WA+CA	P	P,V,L
Stegastes rocasensis (Emery, 1972)	--	RA	5	2 – 10	FN	TH	VS
Stegastes sanctipauli Lubbock & Edwards, 1981	AB	AB	1,3,4,5	0 – 60	End	TH	VS,L
LABRIDAE							
Bodianus insularis Gomon & Lubbock, 1980	CM	CM	3,4,5	6 - 60	CA	C	VS,L
Clepticus brasiliensis Heiser,Moura&Robertson,2000	--	RA	3,5,6	5 – 25	BR	P	P,V
Halichoeres radiatus (Linnaeus, 1758)	VC	VC	3,4,5	2 – 30	NWA-FN	C	P,L
Thalassoma noronhanum Boulenger, 1860)	RA	RA	1,3,5	2 - 10	BR	P	P
SCARIDAE							
Sparisoma amplum (Ranzani, 1842)	--	RA	3,4	15 – 30	BR	NH	P
Sparisoma axillare (Steindachner, 1878)	--	RA	3,4,5	10 - 30	BR	NH	SR
Sparisoma frondosum (Agassiz, 1831)	RA	RA	3,4,5	10 - 30	BR	NH	P,L
TRIPTERYGIIDAE							
Enneanectes smithi Lubbock & Edwards, 1981	CM	CM	1,3,5	2 - 25	End	C	VS,L
LABRISOMIDAE							
Malacoctenus aff. *triangulatus* Springer, 1958	CM	VC	1,3,4,5	0 – 40	NWA	C	VS,L
Starksia aff. *sluiteri* (Metzelaar, 1919)	CM	OC	3,4,5	2 - 40	NWA	C	VS,L
CHAENOPSIDAE							
***Emblemariopsis* sp.**	--	VC	3,4,5	2 – 60	End(?)	C	VS
BLENNIDAE							
Entomacrodus vomerines (Valenciennes, 1836)	AB	AB	1,2	0 - 1	BR	TH	VS,L
Ophioblennius trinitatis Miranda-Ribeiro, 1919	VC	VC	1,3,4,5	0 - 50	PA	TH	VS,L
GOBIIDAE							
Bathygobius soporator (Valenciennes, 1837)	--	RA	1	0 - 1	PA	TH	VS
SPHYRAENIDAE							
Sphyraena barracuda (Walbaum, 1752)	CM	CM	3,4,5,6	0 – 60	CT	C	P,V,L
BALISTIDAE							
Canthidermis sufflamen (Mitchill, 1915)	OC	OC	3,4,5,6	5 – 60	WA+CA	C	P,V,L
Melichthys niger (Bloch, 1786)	AB	AB	3,4,5,6	0 - 70	CT	O	VS,L
MONACANTHIDAE							
Aluterus scriptus (Osbeck, 1756)	UN	OC	3,4,5	2 - 40	CT	O	P,L
Cantherhines macrocerus (Hollard, 1854)	UN	CM	3,4,5	2 - 40	WA	O	P,L
DIODONTIDAE							
Diodon hystrix Linnaeus, 1758	RA	RA	3,5	2 - 25	CT	C	VS,L

Population status: AB = Abundant, **VC** = Very common, **CM** = Common, **OC** = Occasional, **UN** = Uncommon, **RA** = Rare or Vagrant. **Habitat**: 1 = tide pools, 2 = littoral zone, 3 = *Palythoa* and *Caulerpa* zone, 4 = sub-*Caulerpa* zone, 5 = slope and bay, and 6 = water column. **Geographic Range**: CT = Circuntropical, PA = Pan-Atlantic, EA = Eastern Atlantic, WA = Western Atlantic, NWA = North-western Atlantic, BR = Brazilian province (including F. Noronha Ridge Islands), CA = Central Atlantic Islands (Ascension, St. Helena and St. Paul's), FN = Fernando de noronha Ridge Islands, End = Endemic to St. Paul's Rocks. **Trophic category**: TH = territorial herbivores, NT = non-territorial herbivores, C = carnivores, P = planctivores, O = omnivores. **Record Status**: VS = Voucher Specimen, SR = Sight Record, P = Photography, V = video record, F = Fishery and L = literature. ? = not known.

Zoogeography and endemism: of the 58 reef fishes recorded at St. Paul's Archipelago, 20 occur in the western Atlantic, seven of which are endemic to the shores of the Brazilian mainland and one to the Fernando de Noronha Ridge Islands. Thirteen are Pan-Atlantic, 11 circuntropical, and five are known primarily from the central Atlantic islands, two of which also occur in the eastern Atlantic coast and one in the Brazilian Province. Three are north-western Atlantic species, one of which also occurs around the Fernando de Noronha Ridge Islands (Fig. 6; see also Table I).

Because of the prevailing currents, St. Paul's reef fish fauna more closely resembles that of the Brazilian Province than of the other mid-Atlantic Ridge islands of Ascencion and St. Helena, with about 80% of its reef fishes occurring in the Brazilian Province.

Thus, we concur with Edwards & Lubbock (1983b), Briggs (1995) and Floeter & Gasparini (2000) that St. Paul's should be regarded as an impoverished outpost of the Brazilain Province.

St Paul's Rocks supports four endemic fish species previously recorded by Lubbock & Edwards (1981) (Fig. 7 a-d). Our survey revealed the presence of a possible fifth endemic species of the genus *Emblemariopsis* from St. Paul's Archipelago (currently being investigated by the senior author) (Fig. 8). This is the first record of a chaenopsid in the area, but a large population of *Emblemariopsis* sp. Has been observed at depths between 3 and 45 m. This species had not been recorded previously, probably because of its cryptic habits.

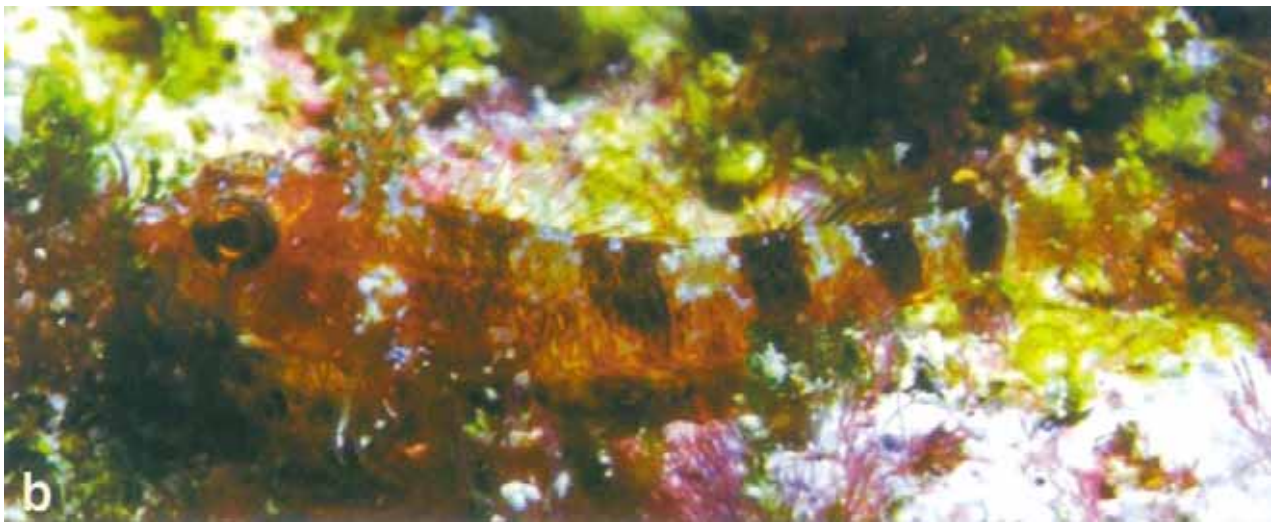

Fig. 7a-f. Endemic fishes from the Central Atlantic Islands: **a-d)** St Paul's; **e-f)** St Paul's, Ascension and St. Helena. **a)***Chaetodon obliquus;* **b)** *Enneanectes smithi; Stegastes sanctipauli,* **c)** juvenile and **d)** adult; **e)** *Bodianus insularis;* and **f)** *Scorpaenodes insularis.* Photos by B.M. Feitoza.

One of the most remarkable features of St Paul's Rocks is the occurrence of different colour morphs of the queen angelfish *Holacanthus ciliaris*. There are three basic colour morphs, yellow, blue and white (Fig. 9 a-c), and several variations and mixtures (Fig. 9 d-h; see also Debelius, 1997: p.143). Moreover, all colour morphs differ from those in all other *H. ciliaris* populations by having shorter dorsal and anal fin filaments (see Figs. 9 and 10 for comparison). The yellow morph was the most abundant pattern observed at the Rocks, accounting for about 95% of all observed morphs. Colour variations occurring in the *H. ciliaris* population of St. Paul's Rocks were attributed to the effects of inbreeding in a small, isolated population (Edwards & Lubbock 1983b). It suggests that no (or very few) recruits are arriving from other sites and the population of *H. ciliaris* at St Paul's is maintaining itself by self-recruitment, a process more common than previously thought (Swearer *et al.* 1999; Jones *et al.*1999; Robertson, 2001). No such colour variation is observed across the remaining range of *H. ciliaris* in the Western Atlantic (Rocha *et al.* 1998; Humann & DeLoach, 2002). Joyeux *et al.* (2001) suggested a posible on going differentiation for *H. ciliaris* at the Rocks. Genetic and morphological comparisons of *H. ciliaris* populations across the Atlantic are needed to better assess the inbreeding and taxonomic status of the queen angelfish population at St Paul's Rocks.

Since Lubbock & Edwards' survey report in 1981, a few presumed albinotic or semi-albinotic *Chromis multilineata* have been recorded from St. Paul's Rocks. The supposed 'albinism' was also related to inbreeding in a small population by Lubbock & Edwards (1981).

However, C. *multilineata* is one of the most abundant fish at the Rocks since 1979. Despite the apparently large population, one presumed 'semi-albinotic' specimen was observed and photographed by our team (Fig. 11).

Our survey revealed the presence at the Rocks of a typical eastern Atlantic species: the honeycomb moray *Muraena melanotis.* This species is very similar to *M. pavonina* with small but consistent differences in colouration (which remain even after preservation) and the size of the posterior nostril (Bohlke et al., 1989). Both species are frequently misidentified (e.g. the M. melanotis photo presented in Debelius (1997: p 75) is actually a photo of the flagged moray *M. pavonina),* and records of *M. melanotis* from the north-eastern Brazilian mainland (Bohike et al., 1989) are probably misidentifications of M. *pavonina.* During a six-year study off the north-eastern Brazilian coast (B. M. Feitoza, unpublished), *M. meianotis* has not been observed, whereas *M. pavonina* was found at several sites. However, the record of *M. melanotis* at Fernando de Noronha Archipelago and Rocas Atoll appears to be correct. Adults of the two species can be readily distinguished by their colour patterns: dark background with a white honeycomb-like pattern (absent or indistinct on the belly), with head spots becoming more closely spaced (even fusing) towards the snout in *M. meianotis* (Fig. 12); and dark background with round white spots randomly placed (including belly), with more widely-spaced head spots, becoming almost absent towards the snout in *M.* pavonina (Fig. 13).

As the zoogeographical analysis implies, the fish fauna at St. Paul's Rocks is derived from that of the Brazilian coast and/or Fernando de Noronha Archipelago. Eventual dispersal of larvae through the equatorial undercurrent (Bowen, 1966; Edwards & Lubbock 1983b) may be presumed by the presence of vagrants of species probably coming from Fernando de Noronha Archipelago, where they are very common (e.g. *Cephalopholis fulva, Lutjanus jocu, Stegastes rocasensis*, *Clepticus brasiliensis, Thalassoma noronhanum, Sparisoma* spp., and *Bathygobius soporator*). A notable case was observed during September 2000, when about ten juveniles of *Stegastes rocasensis* were seen at the bay (Fig. 14a). In the long run, monitoring programs should be implemented in order to provide information on how species turnover occurs, the extent to which vagrants arrive from distant sources, and if they establish resident populations. St. Paul's seems to be the only tropical oceanic island that does not have a resident population of surgeonfishes (Acanthuridae). These fish have a very high dispersal potential and can maintain genetic homogeneity across long distances (Planes & Fauvelot, 2002; Rocha et *al.,* 2002) suggesting that dispersal limitation could not be the main cause of their absence. Surgeonfishes are mainly herbivores and/or detritivores (Randall, 1967, 1996; Dias et ai., 2001), thus ecological limitations such as the relatively low algal diversity (with *Caulerpa* dominating most of the shallow habitats), the lack of sandy and/or fine sediment habitats (i.e. organic detritus) could be reasons for their absence, as well as for the very low densities of scarids. Only two of the 27 algae consumed by the south-western Atlantic surgeonfishes (Acanthurus spp.) off the Paraiba coast, north-eastern Brazil (Dias et *al.,* 2001) are known to occur at the Rocks. In addition, Dias et af. (2001) found that fine sediment, presumably

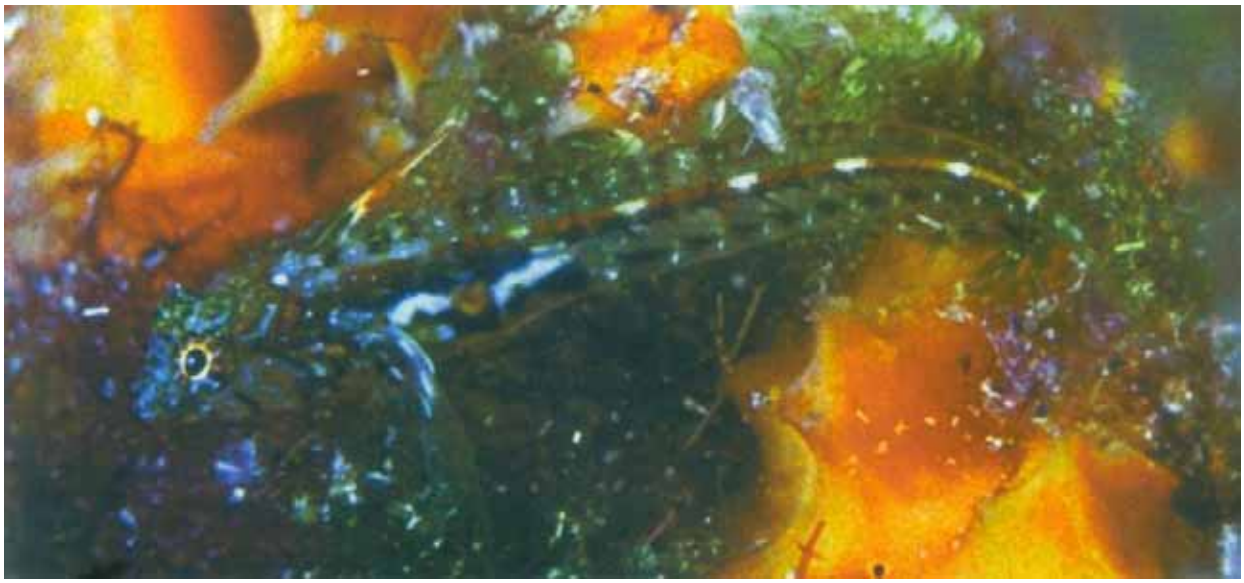

Fig. 8. *Emblemariopsis* sp., a possible fifth endemic species from St. Paul's Archipelago. Photo by B. M. Feitoza.

rich in organic matter (e.g. detritus), is one of the most important food items of the ocean surgeonfish *A. bahianus* and the doctorfish *A. chirurgus.* This food resource is virtually absent from the Rocks. Crossman et al. (2001) showed that detritus is a valuable nutrient source for grazing reef fishes, and that the biomass of algae and detritus decreases from sheltered mid-shelf reefs to highly exposed outer reefs. Goatfishes (Mullldae) and flounders (Bothldae), which are closely associated with unconsolidated substrate, are also missing at the Rocks.

Inter- and intraspecific associations

Reef fishes are known to interact in a complex manner (Sale, 1991; Moyle & Cech, 1996; DeLoach,1999). Common interactions involve interspecific feeding associations, such as cleaning (Sazima el al, 1998; Grutter, 1999: Feitoza et al., 2002), following behaviour (Diamant & Shpigel. 1985; Strand, 1988), camouflage (Aronson. 1983), and intraspecific aggression, such as territorial defence (Snyderman & Wiseman, 1996; Rocha, 2000). These four associations were observed, filmed and photographed at St. Paul's Rocks. Cleaning involves a cleaner species that removes ectoparasites and dead or diseased tissue from the clients (Losey, 1971: DeLoach, 1999). Although no fish were seen acting as cleaners at the Rocks, the Atlantic White-Striped Cleaner Shrimp *Lysmata grabhami* (Gordon 1935), was seen in action. Cleaning stations were located either under rocks or in crevices, at depths of 6 to 60 m, and contained one or two cleaner shrimps, always accompanied by a viper moray *Enchelycore nigricans.* Two client fishes, *Chromis muitilmeata* and *E. nigncans* were seen being cleaned by the shrimps (Fig. 15). Cleaning events usually lasted for five to ten seconds. Following behaviour is an opportunistic strategy that allows small generalised predators (the followers) to capitalise upon displacement or uncovering prey items, when potential predators, grazers or sand-flat feeders (the nuclear species) cause habitat disturbances (Strand, 1988). Following behaviour involving two labrids (the Island hogfish *Bodianus insularis* and the puddingwife *Halichoeres radiafus)* and three follower carangids (the horse-eye jack *Caranx latus,* the black jack *C. lugubris* and the blue runner *Carangoides crysos*), was recorded from St. Paul's (Fig. 16). All three carangid species were seen following both *B. insularis* and *H. radiatus.* Following behaviour involving labrids and carangids in the Western Atlantic has also been recorded: *Haiichoeres radiatus vs. Carangoides ruber* (Bloch, 1793) (see Baird, 1993); and the Spanish hogfish *Bodianus rufus* (Linnaeus, 1758), the spotfin hogfish *B. puichelius* (Poey, 1860) and the blackear wrasse *Haiichoeres poeyi* (Steindachner, 1867) vs. *Caranx latus* (see Sllvano, 2001).Various forms of camouflage are widely used among reef fishes as a means of obtaining food (Moyle & Cech, 1996), The Atlantic cornetfish *Aulostomus strigosus* was seen using one of two forms of camouflage: solitarily, making itself "invisible" both drifting vertically orientated through the water column, andimmobile near *Caulerpa* turfs: or hiding Itself, aligning with other fish. On the former occasion, *A. strigosus* drifted through the water column about 0.6 m or less above the substrate close to rocks or remained still near *Caulerpa* turfs, striking approaching small fishes with a sudden lunge. *A. sirigosus* was observed several times aligning with and swimming close to the whitespotted filefish *Canthe-rhines macrocerus,* but no attack was recorded. It also presented various colour patterns and was seen changing colour according to the background, becoming yellowish, greenish or striped when approaching *Caulerpa* turf, or dark when swimming close to the filefish. Similar behaviour has been described for its congener, the trumpetfish *A. maculatus* Valenciennes, 1837 (Aronson, 1983). Intraspecific aggression appears to be common among labrids and aggressive encounters are frequent (Snyderman & Wiseman, 1996; DeLoach, 2000; Rocha, 2000). Two initial phase coloured *Halichoeres radiatus* were seen and photographed performing agonistic behaviour; they positioned themselves mouth-to-mouth with their dorsal and anal fins erected (Fig. 17), losing interest and separating after about a minute. Most morays are known to live in crevices in reefs, usually hiding alone with only the head protruding during the day, and foraging at night (Böhlke el *al.,* 1989; Randall. 1996; DeLoach, 1999; Humann & DeLoach 2002), Some species, such as *Gymnothorax miliaris* and *Muraena pavonina* forage in the open during the day (Debelius, 1997; Humann and DeLoach, 2002). The Muraenidae are the most speciose family at the Rocks and a large population has been observed mainly at the bay and other gently-sloping areas. Some species (*G. miliaris, Muraena melanotis* and *M. pavonina)* were frequently observed performing both an intra and interspecifc 'friendly' behaviour, staying together in the same hole or even interlacing one with each other (Fig 18 a-c). Similar behaviour has been observed only a few times at the coast of Paraiba State, in north-eastern Brazil, where two specimens of *Gymnothorax vicinus* (Castelnau, 1835) sporadically occupied the same hole (L. A. Rocha, pers. obs,).

Taxonomic comments

The manta ray tentatively identified as *Mobula hypostoma* (Bancroft, 1831) by Lubbock & Edwards (1981), is probably *M. tarapacana* (Philippi, 1893), since the latter was frequently observed in the vicinity of the Rocks, The trumpetfish from St. Paul's was previously identified as *Aulostomus maculatus*

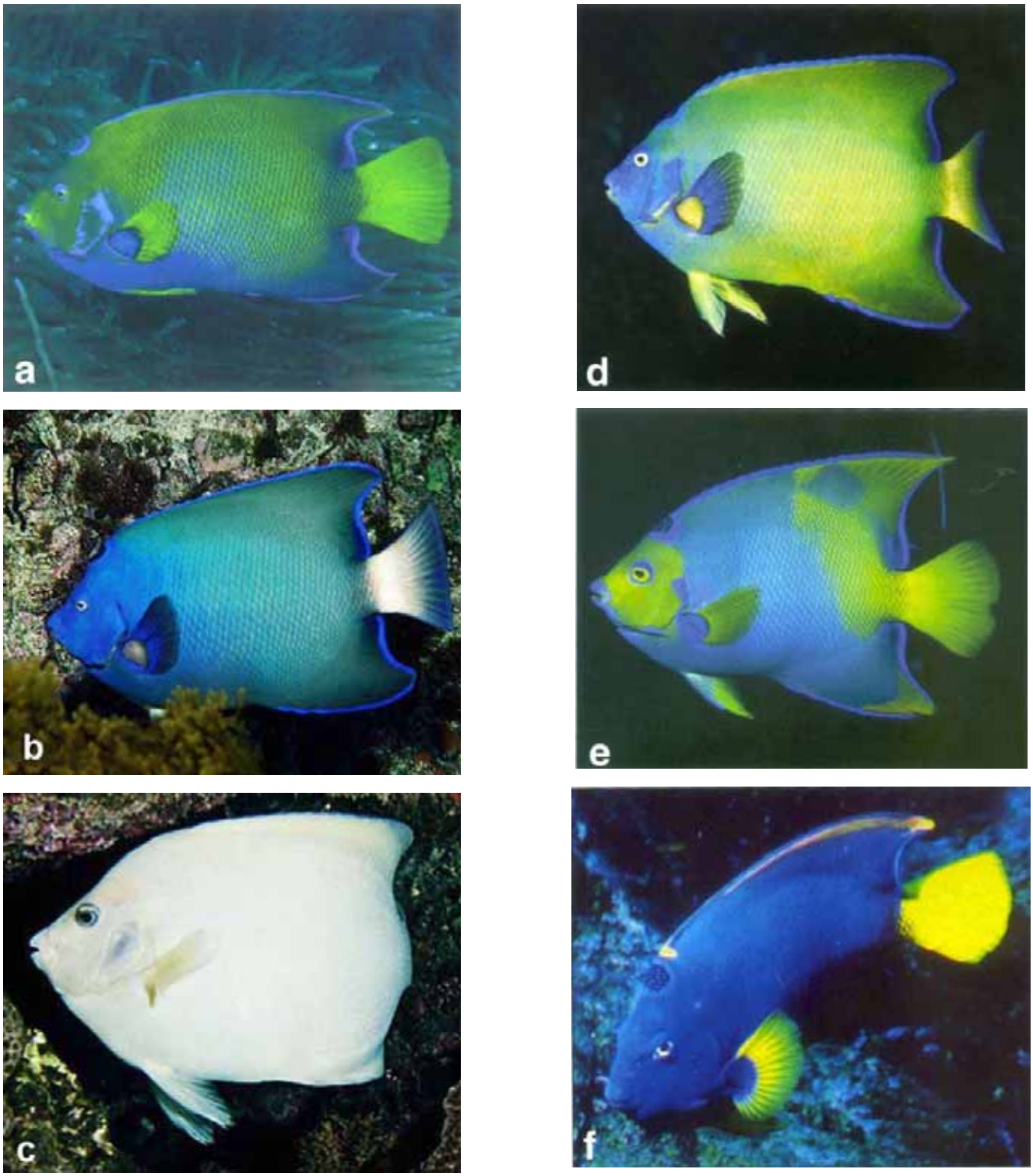

Fig. 9a-h. Colour variations observed in the queen angelfish *Holacanthus ciliaris* at St. Paul's Rocks. **a)** Yellow morph; **b)** blue morph; **c)** white morph; **d-h)** variations and mixtures between blue, yellow, orange and white. Photos **a,d,e** and **h** by B. M. Feitoza; **b,c** and **g** by O.J. Luiz-Júnior; and **f** by E. Fritzche.

Valenciennes, 1842 by Lubbock & Edwards (1981) presumably because of its morphological similarities with that species. Genetically, however, it is more similar to the Eastern Atlantic and coastal Brazilian *A. strigosus* (Bowen *et a*l., 2001).

The blue runner *Caranx fusus* (St Hilaire, 1809) cited by Lubbock & Edwards (1981) is now valid as *Carangoides crysos* (Mitchill, 1815). The Brazilian chromis referred to as *Chromis* sp. by Lubbock & Edwards (1981) is the brown chromis C. *multilineata* (Guichenot, 1853), according to L. A. Rocha (based on an ongoing genetic investigation).The parrotfish referred to as *Sparisoma* sp. By Lubbock & Edwards (1981) is the saddled parrotfish *S. frondosum* (Agassiz, 1831), according to the description provided by these authors and field observations made by our team.

A recent genetic analysis by Muss *et al.* (2001) demonstrated that the *Ophioblennius* species at St. Paul's Rocks is distinct from the Caribbean species and identical to that from the Brazilian coast and Trindade Island. The available name for this species is *Ophioblennius trinitatis* Miranda-Ribeiro, 1919, and it will be used here.

Three species do not have their taxonomic status well defined: *Chromis* aff. *Enchrysura, Starksia* aff. *Sluiteri* and *Malacoctenus* aff. *triangulatus.* The senior author and other Brazilian ichthyologists are currently trying to determine their taxonomic status.

Conservation issues

Despite being sporadically replenished with larvae from elsewhere, St. Paul's Rocks also contains unique, self-sustaining populations and endemic species. It is now clear that marine species are not exempt from the effects of human impact and the risk of extinction (Roberts & Hawkins, 1999; Hawkins *et al.,* 2000). Some characteristics could impose risks to St. Paul's reef fish populations, such as:

a) Restricted geographic range – the only reported case of a reef fish ws an island-endemic species (Robert & Hawkins, 1999), at St. Paul's Rocks, endemic species are at risk due to their limited distribution, and according to Robertson (2001) genetically distinct, isolated populations should be treated as endemic species for conservation purposes; b) Aquarium trade – the isolation of St. Paul's Rocks is not an obstacle for the harvesting of high priced, rare fishes (especially the white and blue colour morphs of *H. ciliaris*) for the aquarium trade. The collection of some specimens was recently observed (B. M. Feitoza pers. obs.); and c) Fisheries – shark fin fisheries could not be sustainable in such a small location as demonstrated by the apparent decrease in shark populations in the past two decades, coinciding with increasing fishing pressure. By-catch in the lobster fishery is also a problem; some fishes (mainly morays, *M. niger* and *H. ciliaris*) were continually found in the lobster traps utilized in commercial fisheries (O. J. Luiz-Júnior and B. M. Feitoza pers. obs.) (Fig. 19, on last cover page).

We thereby recommend the establishment of a marine protected area in the Rocks, due to the vulnerability of its isolated fauna.

Acknowledgements

This study could not have been carried without the essencial logistic support of the Brazilian Navy (Marinha do Brasil) which provided transportation and lodging for B. M. Feitoza and L. A. Rocha at the Rocks. We also thank: B.P. Ferreira, F. Hazin and F.D. Amaral for making our field trips possible; the dive schools Mar Aberto e Águas Claras for supplying SCUBA gear; Captain J.C. Marenga and the crew of the sailboat '*Aussteiger'* for transportation and lodging for O. J. Luiz-Júnior; the crews of the fishing boats '*Transmar I'* and *'Argus'* for making fish available for study; R. Stangorlini for the video records; B. Muniz, C. Buitron, C. Rocha, F.

Fig.10. Normal colour and morphological pattern of *Holacanthus ciliaris* from Rio Grande do Norte coast, north-estern Brazil. Photo by B. M. Feitoza.

Fig.11. A presumed semi-albinotic specimen of *Chromis multilineata* of St. Paul's Rocks. Photo by B. M. Feitoza.

Fig. 12. The honeycomb moray *Muraena melanotis.* Photo by B.M. Feitoza.

Fig. 13. The flagged moray *Muraena pavonina.* Photo by O. J. Luiz-Júnior.

Fig. 14. The Rocas Gregory *Stegastes rocasensis.* **a)** Vagrant juvenile from St. Paul's; **b)** Juvenile from Fernando de Noronha Archipelago; and **c)** adult from Rocas Atoll. Photos **a** and **c** by B.M. Feitoza, and **b** by L.A. Rocha.

Fig. 15. *Lysmata grabhami* cleaning station located at about 60 m depth. Photo by B.M. Feitoza.

Fig. 16. Following behavior between *Halichoeres radiatus* (the nuclear species) and *Caranx latus* (the follower species). Photo by B.M. Feitoza.

Fig. 17. Aggression between two *Halichoeres radiatus* males. Photo by B.M. Feitoza

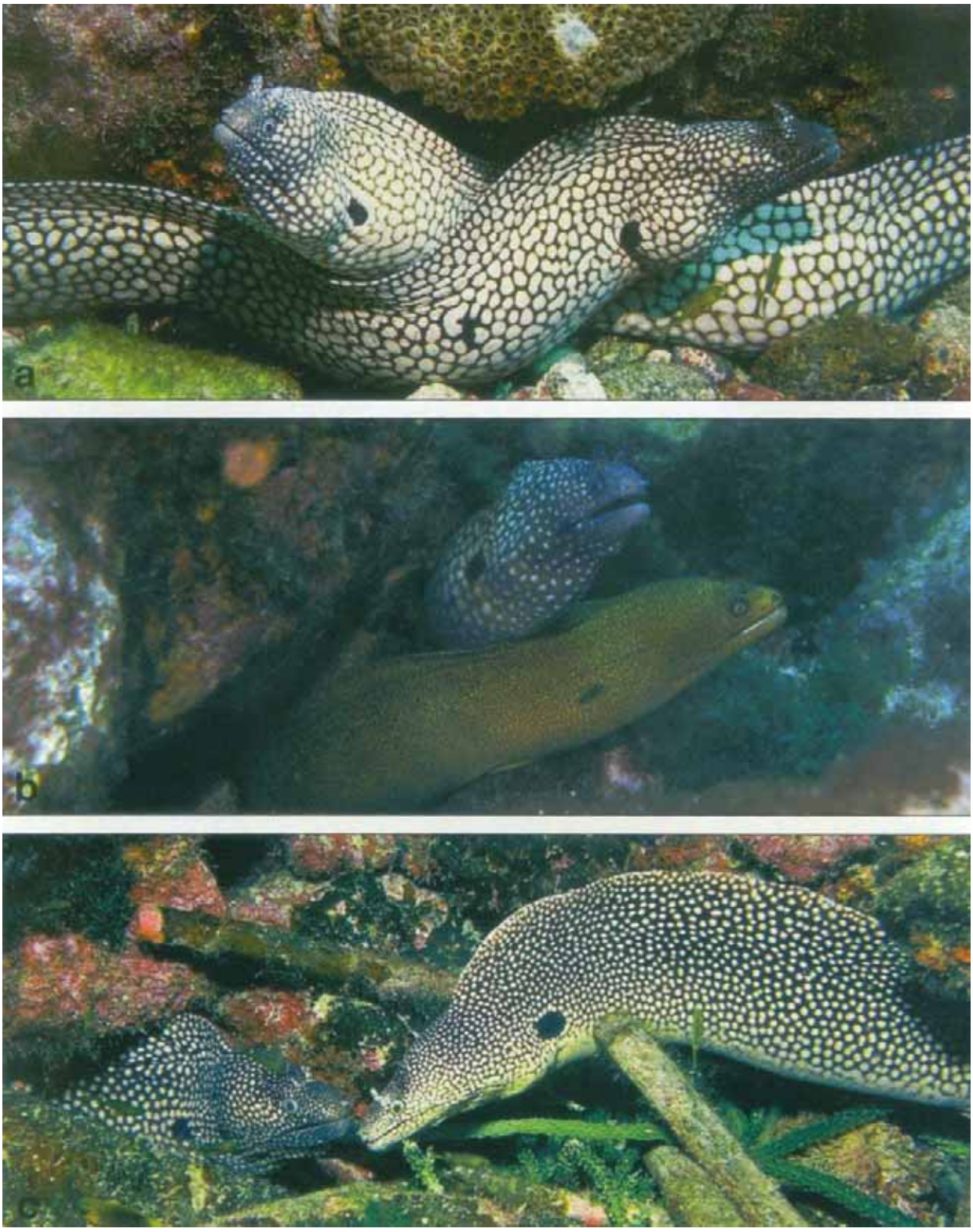

Fig. 18a-c. 'Friendly' behaviour between morays: **a)** *Muraena pavonina* and *M. pavonina;* **b)** *M. pavonina* and *Gymnothorax miliaris;* and **c)** *M. pavonina* and *M. melanotis.* Photos **a** and **c** by O.J. Luiz-Júnior; and **b** by B.M. Feitoza.

C. Moraes, M. M. Hudson and M. Hoffman for helping in field and laboratory work; C.L.S. Sampaio, I.L. Rosa, R.S. Rosa, T.L.P. Dias and W. F. Smith-Vaniz for the loan of literature; E. Fritzche for donating a photograph (Fig. 9-f); and R. Robertson and A. Edwards for critically reading the manuscript. Funding for L.A. Rocha was provided by CAPES, Brazilian Ministry of Education.

Appendix - Voucher specimens from

St. Paul's Rocks arranged in alphabetic order

Apogon amencanus ~ MBML 612. UFPB 5245;
Aulostomus afl. *strigosus* - UFPB 4482;
Bodlanus insularis - UFPB 4481, 4586, 4587, 4588, 4589; *Caranx lugubris* - UFPB 4485;
Chaetodon obliquus - UFPB 5249;
Chromis aff. *enchrysura* - UFPB 5248:
Diodon hystrix - UFPB 4483;
Emblemariopsis sp. - UFPB 5237, 5239;
Enchelycore anatina - UFPB 4480;
Enneanectes smithi - MBML 613 and UFPB 5236, 5240,5242;
Entomacrodus vomerinus-UFPB 5282;
Holacanthus clliaris - UFP8 4585;
Holocentrus ascensionis - UFPB 4484;
Malacoctenus aff. *triangulatus* - MBML 614 and UFPB 5238;
Melichthys niger- UFPB 5246;
Ophioblennius trinitatis- MBML 615 and UFPB 5243:
Remora brachyptera - UFPB 5247;
Remora osteochir- UFPB 5250;
Scorpaenodes insularis - UFPB 5251:
Sparisoma axillare - UFPB 4590;
Sparisoma frondosum - UFPB 4591;
Starksia sluiteri - MBML 616 and UFPB 5241,
Stegastes rocasensis - UFPB 5234;
Stegastes sanctipauli- UFPB 5235, 5244.

References

Amaral, F. D., Hudson, M. M., **Silveira, F. L. & A. E. Migotto.** (in press). Cnidarians of Saint Peter and St. Paul Archipelago. Northeast Brazil. *Proceedings of the Biological Association of Washington.*

Aronson, R. B. 1983. Foraging behavior ot the west Atlantic trumpetfish, *Aulostomus maculatus:* use of large, herbivorous reef fishes as camouflage. *Bulletin of Marine Science,* **33** (1): 166-171.

Böhlke, E.B.,McCosker,J.E.& J.E. Böhlke. 1989 Family Muraenidae. In. *Fishes of the Western North *Atlantic* (Ed, E, B. Bohlke): 104-206. Sears Foundation for Marine Research, Yale University. 665pp.

Bowen, V. T. 1966. St. Paul's on the subway. Oceanus, **12** (4): 2-4.

Bowen, B. W., Bass, A. L., Rocha, L. A. Grant, W. S. & D. R. Robertson. 2001. Phylogeography ot the trumpettish *(Auiostomus):* Ring species complex in a global scale. *Evolution,* 55 (5)- 1029-1039.

Briggs, J. C. 1995. *Global Biogeography, Developments in Paleontology and Stratigraphy, 14.* Elsevier, Amsterdam. 452pp.

Compagno, L. J. V. 1999. Checklist of living elasmobranchs. in. *Sharks, Skates, and Rays. The Biology of Elasmobranch Fishes.* (Ed. W. C. Hamlett): 471-498. The Johns Hopkins University Press, Baltimore and London.

Crossman, D. J., Cheat, J. H., Clements, K.D., Hardy, J. & J. McConochie. 2001 Detritus as food for grazing fishes on coral reefs. *Limnology and Oceanography,* **46:** 1596-1605.

Debelius, H. 1997. *Mediterranean and Atlantic Fish Guide.* IKAN-Unterwasserarchiv, Frankfurt, 305 pp.

DeLoach, N. 1999. *Reef fish behavior: Florida, Caribbean, Bahamas.* New World Publications. Jacksonville, Florida, 359 pp.

Diamant, A. & M. Shpigel. 1985. Interspecific feeding associations of groupers (Teleostei. Serranidae) with octopuses and moray eels in Gulf of Eilat (Aqaba). *Environmental Biology of Fishes*, **13** (2): 153-159.

Dias, T. L. P., Rosa, I. L. & B. M. Feitoza. 2001. Food resource and habitat sharing by the three Western Atlantic Surgeonfishes (Teleostei; Acanthuridae: *Acanthurus*) off Paraiba coast, Northeastern Brazil. *Aqua. Journal of ichthyology and Aquatic Biology,* 5(1): 1-10.

Edwards, A. J. & R. Lubbock. 1983(a). The ecology of Saint Paul's Rocks (Equatorial Atlantic). *Journal of Zoology, London.* **200:** 51-69.

Edwards, A. J. & R. Lubbock. 1983(b). Marine Zoogeography of St. Paul's Rocks. *Journal of Biogeography.* 10:65-72.

Feitoza, B. M., Dias, T. L. P., Rocha, L. A. & J. L. Gasparini. 2002. First record of cleaning activity in the slippery dick *Halichoeres bivittatus* (Perciformes' Labridae), off northeastern Brazil. *Aqua, Journal of Ichthyology and Aquatic Biology.* 5 (2): 73-76,

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

Gasparini, J. L, & S. R. Floeter. 2001. The shore fishes of Trindade Island, western South Atlantic. *Journal of Natural History,* **35:** 1639-1656.

Grutter, A. S. 1999. Cleaner fish really do clean. *Nature,* **398:** 672-673,

Hawkins, J. P., Roberts, C. M. & V. Clark. 2000. The threatened status of restricted-range coral reef fish species. *Animal Conservation.* **3:** 81-88.

Hilton-Taylor, C. (Compiler). 2000. 2000 *IUCN Red List of Threatened Animals.* IUCN, Gland, Switzerland a Cambridge. UK. xviil + 61 pp.

Humann, P. & N. Deloach. 2002. Reef *Fish Identification - Florida. Caribbean, Bahamas.* 3th Edition. New World Publications, Jacksonville, Florida, 481pp.

Jones, G. P., Milicich, M. J., Emslie, M. J & C. Nunow. 1999. Self-recruitment In a coral reef fish population. *Nature,* **402:** 802-804.

Joyeux, J.C., Floeter, S.R., Ferreira, C.E.L. & J.L. Gasparini. 2001. Biogeography of tropical reef fishes: the South Atlantic puzzle. *Journal of Biogeography,* **28:** 831-841.

Lubbock, R. & A. Edwards. 1981. The fishes of Saint Paul's Rocks. *Journal of Fish Biology,* **18:** 135-157.

Lubbock, R. 1980. The shore fishes of Ascension Island. *Journal of Fish Biology,* **17:** 283-303.

Melson, W.G., Hart, S.R. & G. Thompson. 1972. St. Paul's Rocks, equatorial Atlantic; petrogenesis, radiometric ages, and implications on sea floor spreading. *Memoirs of the Geological Society of America,* **132:** 241-272.

Muss, A., **Robertson, D.R., Stepien, C.A., Wirtz, P. & B.W. Bowen.** 2001. Phylogeography of *Ophioblennius*: the role of ocean currents and geography in reef fish evolution. *Evolution,* **55:**(3) 561-572.

Moyle, P.B. & J.J. Cech. 1996. *Fishes: an introduction to ichthyology.* Third edition. Prentice Hall, inc., 590 pp.

Nelson, J.S. 1994. *Fishes of the World.* 3rd edition, John Wiley & Sons, Inc., New York. 600 pp.

Planes¸ S. & C. Fauvelot. 2002. Isolation by distance and vicariance drive genetic structure of a coral reef fish in the Pacific ocean. *Evolution,* **56:** 378-399.

Randall, J.E. 1967. Food habits of reef fishes of the West Indies. *Studies in Tropical Oceanography,* **5:** 665-847.

Randall, J.E. 1996. *Caribbean Reef Fishes.* Third Edition. T.F.H. Publications: Hong Kong, 368 pp.

Roberts, C.M. & Hawkins, J.P. 1999. Extinction risk in the sea. *Trends in Ecol. Evol.* **14:** 241-246.

Robertson, D.R. & G.R. Allen. 1996. Zoogeography of the shorefish fauna of Clipperton Atoll. *Coral Reefs,* **15:** 121-131.

Robertson, D.R. 2001. Population maintenance among tropical reef fishes: inferences from small island endemics. *Proceedings of the National Academy of Sciences.* **98** (10): 5567-5670.

Rocha, L.A. 2000. Interspecific aggression in spanish hogfishes (*Bodianus rufus*) in Northeastern Brazil. *Coral Reefs,* **19:** 184.

Rocha, L. A., Rosa, I. L. & R. S. Rosa. 1998. Peixes Recifais da Costa da Paraiba, Brasil. *Revista Brasileira de Zoologia,* **15** (2): 553-566.

Rocha, L. A., Bass, A. L., Robertson, D. R. & B. W. Bowen. 2002. Adult habitat preferences, larval dispersal, and the comparative phylogeography of three Atlantic surgeonfishes (Teleostei: Acanthuridae). *Molecular Ecolology,* 11: 243-252.

Rosa, R. S. & R. L. Moura. 1997. Visual assessment of reef fish community structure in the Atol das Rocas Biological Reserve, off Northeastern Brazil. *Proceedings of the 8th International Coral Reef Symposium,* 1: 983-986.

Sale, P. F. 1991. *The Ecology of Fishes on Coral Reefs.* Academic Press: San Diego, 754 pp.

Sazima, I.; Moura, R. L. & J. L. Gasparini. 1998. The wrasse *Halichoeres cyanocephalus* (Labridae) as a specialized cleaner fish. *Bulletin of Marine Science,* **63** (3): 605-610.

Silvano, R. A. M. 2001. Feeding habits and interspecific feeding associations of *Caranx latus* (Carangidae) in a subtropical reef. *Environmental Biology of Fishes,* **60:** 465-470.

Snyderman, M. & C. Wiseman. 1996. *Guide to Marine Life: Caribbean, Bahamas, Florida.* Aqua Quest Publications, New York, 284pp.

Strand, S. 1988. Following behavior: interspecific foraging associations among Gulf of California reef fishes. *Copeia,* **1988** (2): 351-357.

Swearer, S. E., Caselle, J. E., Lea, D.W. & R.R. Warner. 1999. Larval retention and recruitment in an island population of coral-reef fish. *Nature,* **402:** 799-802.

Thresher, R. E. 1991. Geographic variability in the ecology of coral reef fishes: evidence, evolution and possible implications. In The *Ecology of Fishes on Coral Reefs* (Sale, P. F. ed.): 401-436. Academic Press, San Diego, 754 pp.