



Fish diversity of a southwestern Atlantic coastal island: aspects of distribution and conservation in a marine zoogeographical boundary

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Abstract: Despite the increase of knowledge about the southwestern Atlantic ichthyofauna, there is still a lack of information along extensive marine areas. The Espírito Santo state (ES) coast, considered a zoogeographic boundary and a transitional zone between tropical and subtropical realms, is still largely unknown. Here is provided a checklist containing 221 fish species at Franceses Island (south coast of ES), which was attained with data from 2000 to 2010 by means of underwater observations, specimen collections and fisheries monitoring. Abundance, habitats and threat risks of each species are shown and discussed. The number of reef fish species found at Franceses Island corresponds approximately to 35% of all fishes present in the Brazilian Province. The conservation of the Franceses Island and surrounding areas would protect a mosaic of environments that can support a high diversity of fish species.

Key words: biogeography, Brazilian Province, Franceses Island, ichthyofauna

INTRODUCTION

Although studies on the Caribbean reef fish fauna began in the 1950s (Hixon 2011), the ichthyofauna of southwestern Atlantic reefs remained largely unknown until the beginning of the 1990s. However, since then, the use of SCUBA for research has contributed for a huge amount of information about Brazilian reef fishes, mainly in respect to taxonomy, community structure, ecology, biogeography and phylogenetics (e.g., Floeter et al. 2001; Joyeux et al. 2001).

Sheltering a large proportion of endemic species

(10 %; Floeter et al. 2008), Brazilian reefs constitute a distinct zoogeographic province (Floeter and Gasparini 2000; Floeter et al. 2008) separated of the others by semi-permeable biogeographic filters (Rocha 2003; Luiz et al. 2012). This singularity, associated with the relatively small area that the Brazilian reef environments represent in the Atlantic, turns it as a priority area for studies and conservation programs (Moura 2000).

During the last decade, the number of studies about reef fishes in Brazilian waters extensively increased. Many studies aimed to understand the relationship of community dynamics for distinct environmental factors (Ferreira et al. 2001; Floeter et al. 2007), fishing effects (Floeter et al. 2006) and management rules (Francini-Filho and Moura 2008a, 2008b). Ecological analysis (Sazima et al. 2000; Bonaldo et al. 2006; Ferreira and Gonçalves 2006; Francini-Filho and Sazima 2008; Francini-Filho et al. 2010) and behavioral patterns (Gibran 2002; Sazima 2002; Sazima et al. 2003; Gibran 2004) were also largely performed in different sites of the Brazilian shore. However, regardless the increase in research, an enormous part of the reef environments of Brazil are still lacking basic knowledge (Mendonça-Neto et al. 2008) and protection (Floeter et al. 2006), suffering impacts from population growth, industrial development, fishing activities and inordinate tourism.

In this context, the Espírito Santo state, a faunal biogeographical marine boundary zone situated in the central Brazilian coast (Floeter et al. 2001; Martins et al. 2007), until recently had received few attention by marine researchers and conservation initiatives. Consequently, most coastal reef environments of the state became highly overfished without a basic preterit

knowledge about its fauna (Pinheiro et al. 2010a). Thus, this study contribute with information about reef fishes of a poorly studied area of the central coast of Brazil, analyzing the composition and distribution of fish species that occur in and surrounding Franceses Island's reefs. Moreover, this is regionally a priority area for a MPA creation and this research raises important data and discussion to contribute for this process.

MATERIAL AND METHODS

The Espírito Santo state ($18^{\circ}22' \text{ S} - 21^{\circ}19' \text{ S}$), central coast of Brazil, is located in a transitional tropical-subtropical area, where tropical oligotrophic waters of Brazilian current coming from the north predominate, but also with the occurrence of a seasonal coastal upwelling from the south (Schmid et al. 1995). Additionally, the state lies in a boundary area between coral reef ecosystems in the north ($00^{\circ}52' \text{ N} - 19^{\circ} \text{ S}$) and rocky reefs ecosystems in the south ($19^{\circ} \text{ S} - 28^{\circ} \text{ S}$) (Floeter et al. 2001). The climate is inter-tropical, with intensive and prolonged rains in summer and dry weather in winter. Predominant winds are from the east and northeast. However, south and southeast winds occur predominantly in the winter (Nimer 1989).

This study was conducted on the rocky shores, reefs and surrounding habitats of Franceses Island (Figure 1;

$20^{\circ}55' \text{ S}, 040^{\circ}45' \text{ W}$), a coastal island located in Espírito Santo southern coast. The island, formed by a crystalline base, is situated 4 km from the coastline. It has an area of 0.135 km^2 and perimeter of 1,700 m, where its largest axis (500 m of length) is disposed parallel to coastline. The rocky shore has a strong difference in declivity and horizontal extension among its sides. In the western side, sheltered from winds and waves, the rocky shore is narrow and highly abrupt, arising 5 m from its deepest part. In this side the interface is composed of sand and mud. The seascape of the area between the isle and the continent is very shallow ($<4 \text{ m}$), and is formed by a mosaic of sand bottoms, macro-algae beds and biogenic reefs and patch-reefs.

In the eastern side, facing the open ocean, the rocky shore is broader and deeper (ca. 120 m and 12 m deep). The interface is constituted by rhodoliths, gravels, bioclastic material and sand. There are also patch reefs few meters from interface of this side. The infralittoral of the island shows an enormous variation of structural complexity due to the presence of big boulders and holes. The isle also has exposed and submersed reefs in northeast face.

The benthic community structure is composed by 31.8% (cover) of zoobenthos, 46.1% of fitobenthos and 22.1% of soft bottom (interface zones) (Costa 2009).

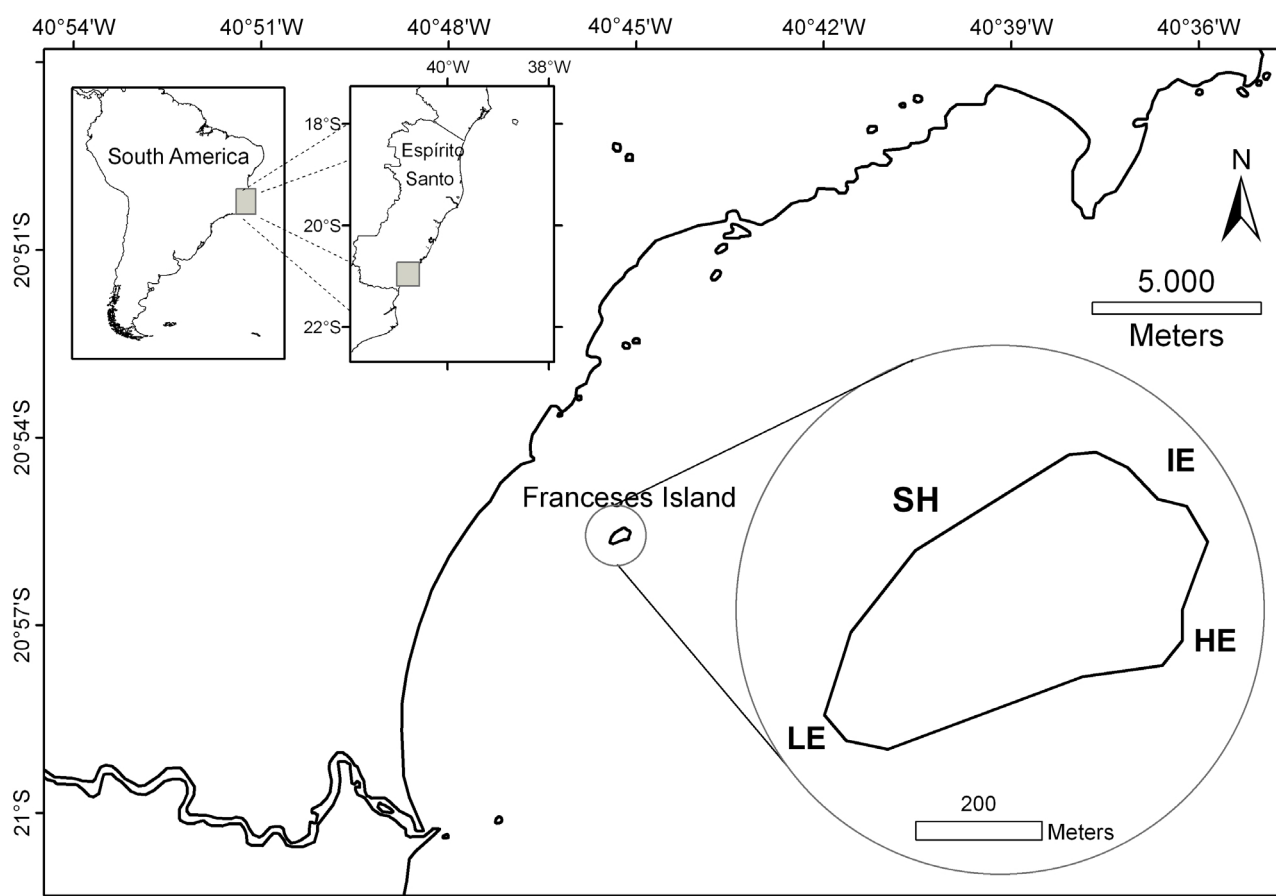


Figure 1. Map of Franceses Island, Espírito Santo state, southeastern Brazil. SH=shelter; LE=Low exposure; IE=intermediate exposure; HE=high exposure to winds and waves.

Turf algae and soft bottom have the highest cover, followed by red algae, brown algae, sponges, briozoans, gorgonians and zoanthids. However, the benthonic cover shows a significant change between sheltered and highly exposed zones. Costa (2009) stated that corals, zoanthids and urchins have the highest cover in sheltered zones, while gorgonians, hydrozoans and macroalgae preferred the higher exposure face.

Additionally, Franceses Island is influenced by two hydrographic basins: Benevente (Anchieta) and Itapemirim rivers (between Maratáizes and Itapemirim). These rivers, in raining periods or strong winter winds, contribute to promote turbidity and suspension of particulate material in the island surrounding waters. In the southwest of the island, in a bottom composed of sand, gravel (rhodolith and bioclastic material) and mud, fishermen practice trawl fishing for shrimps (Pinheiro and Martins 2009). The ichthyofauna of this environment was sampled between 2003 and 2004 (see details in Pinheiro et al. 2009a). In the present work this environment is called the soft bottom adjacent to the island (SBA).

Moreover, Franceses Island is situated in an area proposed for creating a MPA. The Brazilian government considers this region as a biological highly important area with an extremely high priority for action (studies and management) (MMA 2007).

The Franceses Island fish checklist results from underwater observations, photographic records and voucher specimens obtained between 2000 and 2010, where about 70 expeditions and 200 days in the field were conducted. Fishing activities were monitored from 2003 to 2006, when bottom trawls (12 embarkments; 30 hours of trawl), seine trawls (15 trawls) and recreational activities (75 fishermen) were studied, and the species caught identified. Recreational activities constituted angling and spearfishing, and both occur in all surrounding island (for details see Pinheiro et al. 2010a), catching specimens in the rocky reefs (RR), interface (IF) and water column (WC) habitats. The bottom trawl was performed by local boats of the shrimp fishery fleet in a fishing ground located between 500 and 1500 m southwest of the island (for details see Pinheiro et al. 2009a and Pinheiro and Martins 2009) in the habitat denominated SBA. The seine trawls were performed from the island and had as target schools of seasonal fishes. The nets used were nearly 400 m long and 5 m high, seining and catching every fish that occurred in the sheltered zone of the island, involving IF, WC and soft bottom of the island (SBI) habitats. Other professional fishing activities, such as gill nets and trolling, were not evaluated.

Families and genera within families are listed in alphabetical order. Some recent taxonomic revisions were adopted, i.e., Epinephelidae separated from Serranidae

and Scarinae subsumed in Labridae (Westneat and Alfaro 2005; Craig et al. 2011). Thus, the checklist contains the following information of each species (modified from Luiz et al. 2008):

Abundance: an indicator of the relative abundance based in the several observations realized in each distinct habitat described above; where: AB = abundant (several sightings of many individuals – at least 50 – are expected at nearly every dive or fishing catch), VC = very common (several sightings are expected, but not necessarily of many individuals), CO = common (sights are frequent, but not necessarily expected on every dive or fishing activity monitored), OC = occasional (sightings are not unusual, but are not expected on a regular basis), UN = unusual (sights occurs less than occasionally), and RA = rare (sighted on reefs or in the fishing activities only one time).

Habitat: a particular place where a species lives and was sighted. The habitats were defined by physiographic features as substrate type and depth, of which: RR=rocky reefs (shallow and mid-depth areas of the shores and reefs; ranging from 0 to 12 m deep), IF=interface (interface between reef and adjacent soft bottom; 3 to 12 m deep); SBI=soft bottom of the island (consists mainly of sand, mud or bioclastic material near of the isle, although rhodolith patches are also found; < 100 m from the rocky shore or reefs); WC=water column (pelagic environment of the island from 0 to 8 m of depth); SBA=soft bottom adjacent to the island (composed by sand, mud and gravel ground from the surroundings of the isle to 1.5 km away; 4 to 6 m of depth).

Threat: species registered in fishing activities or in red lists of endangered species: PF=species caught by professional fishing activities monitored; RF=species caught by recreational fishing activities monitored; EN=species considered endangered (at risk of extinction, present in the Brazilian list of endangered species; MMA 2014); RO=species considered at risk of over-exploitation (present in the Brazilian list of over-exploited species; IBAMA 2003a, 2003b); IU= species evaluated and considered threatened by the IUCN red list (Critically Endangered, Endangered or Vulnerable); DD=data deficient by IUCN evaluation; NR= species not at risk (those not considered to be threatened by red lists and weren't caught by any fishing activity).

Record type: how the species was registered, where: COL=collected, MUS=museum voucher, LIT=literature, PHO=photograph/video and SIG=sighting. For specimens deposited in museum collections, the institution and voucher number are provided in the Appendix 1.

A cluster analysis of the habitat-types based on a species presence/absence matrix was performed. The Bray-Curtis similarity index was used, and habitats were clustered according to the UPGMA method (Pielou 1984). SIMPROF analysis was performed in order to test

for multivariate structure within the data. Cluster and SIMPROF analysis were made in the software PRIMER v6 (Clarke and Gorley 2006).

RESULTS

A total of 221 species was recorded at Franceses Island and adjacent habitats (Table 1). One hundred sixty-four species (74%) were registered by underwater observations, 77 (35%) being recorded exclusively by this method. On the other hand, 145 species (65%) were registered by fishing activities, 57 (26%) being exclusive by this method.

The richest family was Sciaenidae, with 18 species, followed by Carangidae with 15, Labridae with 13, Haemulidae with nine, Gobiidae with eight and Epinephelidae with seven. Richest genera were *Lutjanus* and *Sparisoma* with five species, followed by *Gymnothorax*, *Caranx*, *Haemulon*, *Cynoscion* and *Sphoeroides* with four each.

Twenty-five species were considered abundant (11%), while 41 were very common (19%), 44 common (20%), 49 occasional (22%), 50 unusual (23%) and only 12 rare (5%) (Table 1). Among all species, 185 (85%) occurred in Franceses Island rocky reefs (RR, IF, WC and SBI habitats), 159 being exclusives. Eighty-six species (39%) occurred in soft bottom habitats (SBI and SBA), 52 being exclusives. Thirty-four species (15%) were found both on soft bottoms (SBI and SBA) and reefs (RR, IF, WC) (Table 1, Figure 2–7).

Habitat dissimilarity analysis shows that the composition of species of each habitat differs strongly from each other (Figure 8; SIMPROF, Global $R=11.8$, $p=0.001$). The WC habitat shows the most different composition, while RR and IF have 41 species in common, and SBI and SBA share 17 in common. The highest richness is found in the RR (95 species), followed by IF (67), SBA (63), WC (46) and SBI (45) (Table 1). The RR habitat also has the

highest exclusive species richness with 49 species, followed by WC (36), SBA (36), SBI (13) and IF (7) (Figure 8).

Eleven species are present in the IUCN red list: *Balistes vetula*, *Epinephelus itajara*, *Gymnura altavela*, *Lutjanus analis*, *Lutjanus cyanopterus*, *Epinephelus marginatus*, *Pagrus pagrus*, *Rhinobatos horkelii*, *Scarus trispinosus*, *Zapteryx brevirostris*. Fifteen species are considered endangered in Brazilian red list: *E. itajara*, *E. marginatus*, *Myceroperca bonaci*, *Ginglymostoma cirratum*, *Elacatinus figaro*, *Gymnura altavela*, *S. trispinosus*, *Sparisoma amplum*, *S. axillare*, *S. frondosum*, *L. cyanopterus*, *Microspathodon chrysurus*, *R. horkelii*, *Z. brevirostris* and *Hippocampus reidi*, and nine are over-exploited: *Sardinella brasiliensis*, *P. pagrus*, *Ocyurus chrysurus*, *Macrodon ancylodon*, *Micropogonias furnieri*, *L. analis*, *Mugil liza*, *Pomatomus saltatrix* and *E. marginatus*. One hundred and eleven species were recorded in the professional activities, and from these four are present in the IUCN red list, five are considered endangered and six at risk of over-exploitation by Brazilian red lists. Sixty-four species were recorded in recreational activities (31 in angling and 48 in spear fishing practices), and from these seven are present in IUCN red list, eight are endangered and four at risk of over-exploitation by Brazilian red lists. Seven species present in Franceses island are considered data deficient by IUCN evaluation (Table 1).

DISCUSSION

Along the Brazilian coast, at least 437 fish species occur in reef environments (Floeter et al. 2008), and the reef fishes found at Franceses Island and adjacent habitats (154 species, *sensu* Floeter et al. 2008) represent about 35% of the Brazilian province reef fish species. Although species diversity is influenced by biogeographic and latitudinal gradients (Floeter et al. 2004, 2008), it also shows a close relation with the local habitat diversity in each area (Cornell and Karlson 2000). Franceses Island,

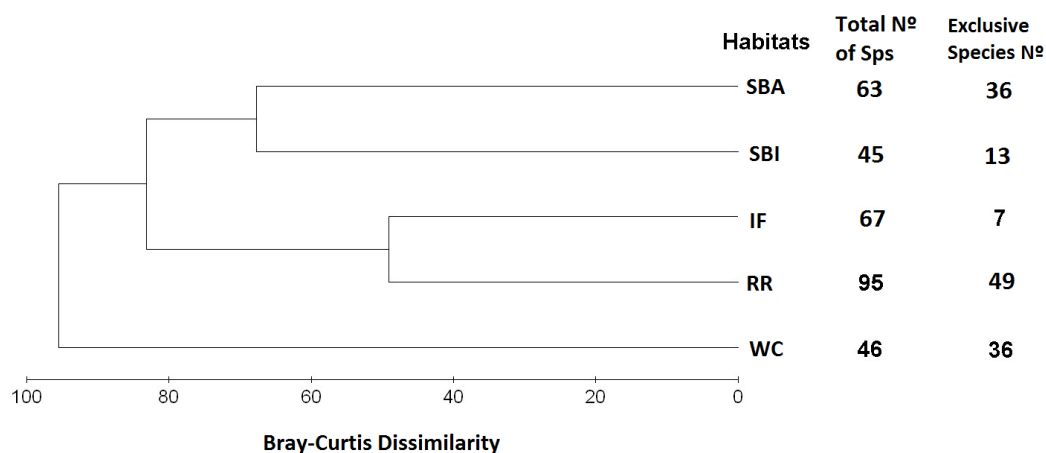


Figure 8. Cluster analysis (Bray Curtis dissimilarity) of habitats found in the Franceses Island and adjacent area. The total number and exclusive number of species are shown for each habitat. RR=rocky reefs; IF=interface; SBI=soft bottom of the island; WC=water column; SBA=soft bottom adjacent to the island.

Table 1. Checklist of fishes from Franceses Island and adjacent environments, southeast Brazil. Abundance (AB = abundant; VC = very common; CO = common; OC = occasional; UN = unusual; RA = rare). Habitat (RR=rocky reefs; IF=interface; SBI=soft bottom of the island; WC=water column; SBA=soft bottom adjacent to the island). Threat (PF=professional fishing; RF=recreational fishing; EN=endangered IBAMA 2014; RO=risk of over-exploitation IBAMA 2003a, b; IU=IUCN red list; DD=data deficient by IUCN evaluation; NR=not at risk). Record type (COL = Collected, MUS = Museum voucher, LIT = Literature, PHO = Photograph/video and SIG = Sighting).

Family	Species	Abundance	Habitat	Threat	Record type
Acanthuridae	<i>Acanthurus bahianus</i> Castelnau, 1855	AB	RR, IF	PF, RF	MUS
	<i>Acanthurus chirurgus</i> (Bloch, 1787)	AB	RR, IF	PF, RF	MUS
	<i>Acanthurus coeruleus</i> Bloch & Schneider, 1801	AB	RR	RF	MUS
Apogonidae	<i>Apogon americanus</i> Castelnau, 1855	CO	RR	NR	MUS
	<i>Phaeoptyx pigmentaria</i> (Poey, 1860)	CO	RR	NR	MUS
Ariidae	<i>Cathorops spixii</i> (Spix & Agassiz, 1829)	UN	SBA	PF	LIT
	<i>Bagre bagre</i> (Linnaeus, 1766)	UN	SBA	PF	COL
	<i>Genidens genidens</i> (Cuvier, 1829)	UN	SBA	PF	COL
	<i>Aspistor luniscutis</i> (Valenciennes, 1840)	UN	SBA	PF	LIT
Atherinidae	<i>Atherinella brasiliensis</i> (Quoy & Gaimard, 1825)	UN	SBI	NR	COL
Aulostomidae	<i>Aulostomus strigosus</i> Wheeler, 1955	OC	RR	RF	SIG
Achiridae	<i>Achirus declivis</i> Chabanaud, 1940	VC	SBA	PF	MUS
	<i>Achirus lineatus</i> (Linnaeus, 1758)	VC	SBA	PF	LIT
Balistidae	<i>Balistes capricus</i> Gmelin, 1789*	UN	WC	RF	SIG
	<i>Balistes vetula</i> Linnaeus, 1758	OC	WC, RR	RF, IU	SIG
Belonidae	<i>Strongylura marina</i> (Walbaum, 1792)	OC	WC	PF, RF	MUS
	<i>Tylosurus acus</i> (Lacepède, 1803)	OC	WC	PF	MUS
Blenniidae	<i>Hypleurochilus pseudoaequipinnis</i> Bath, 1994	OC	RR	NR	MUS
	<i>Hypoblennius invemar</i> Smith-Vaniz & Acero P., 1980	OC	RR	NR	MUS
	<i>Parablennius marmoreus</i> (Poey, 1876)	VC	RR	NR	MUS
	<i>Parablennius pilicornis</i> (Cuvier, 1829)	UN	RR	NR	COL
	<i>Scartella cristata</i> (Linnaeus, 1758)	VC	RR	NR	MUS
Bothidae	<i>Bothus ocellatus</i> (Agassiz, 1831)	UN	SBA	PF	COL
	<i>Bothus robinsi</i> Topp & Hoff, 1972	UN	SBA	PF	COL
Carangidae	<i>Carangoides bartholomaei</i> (Cuvier, 1833)	OC	WC	PF, RF	MUS
	<i>Caranx crysos</i> (Mitchill, 1815) #	CO	WC	PF, RF	MUS
	<i>Caranx hippos</i> (Linnaeus, 1766) #	OC	WC	PF, RF	SIG
	<i>Caranx latus</i> Agassiz, 1831 #	CO	WC	PF, RF	MUS
	<i>Caranx ruber</i> (Bloch, 1793)	OC	WC	PF	SIG
	<i>Chloroscombrus chrysurus</i> (Linnaeus, 1766)	VC	WC, SBA	PF, RF	MUS
	<i>Decapterus punctatus</i> (Cuvier, 1829)	OC	WC	PF	MUS
	<i>Oligoplites saliens</i> (Bloch, 1793)	OC	WC	PF, RF	COL
	<i>Pseudocaranx dentex</i> (Bloch & Schneider, 1801)	UN	WC	NR	PHO
	<i>Selene brownii</i> (Cuvier, 1816)	CO	WC	PF	COL
	<i>Selene setapinnis</i> (Mitchill, 1815)	OC	WC	NR	MUS
	<i>Selene vomer</i> (Linnaeus, 1758)	CO	WC	PF	MUS
	<i>Trachinotus carolinus</i> (Linnaeus, 1766) #	UN	WC	RF	SIG
	<i>Trachinotus goodei</i> Jordan & Evermann, 1896	OC	WC	PF, RF	COL
	<i>Trachinotus marginatus</i> Cuvier, 1832	UN	WC	RF	SIG
Centropomidae	<i>Centropomus parallelus</i> Poey, 1860*	UN	RR	NR	SIG
	<i>Centropomus undecimalis</i> (Bloch, 1792)*	OC	RR	PF, RF	SIG
Chaetodontidae	<i>Chaetodon sedentarius</i> Poey, 1860	UN	RR, IF	NR	SIG
	<i>Chaetodon striatus</i> Linnaeus, 1758	VC	RR, IF	NR	COL
Clupeidae	<i>Chirocentron bleekermanus</i> (Poey, 1867)	AB	SBA	PF	MUS
	<i>Harengula clupeola</i> (Cuvier, 1829)	VC	WC, SBA	PF	MUS
	<i>Odontognathus mucronatus</i> Lacepède, 1800	CO	SBA	PF	MUS
	<i>Opisthonema oglinum</i> (Lesuer, 1818)	CO	WC, SBA	PF	MUS
	<i>Pellona harroweri</i> (Fowler, 1917)	AB	SBA	PF	MUS
	<i>Sardinella brasiliensis</i> (Steindachner, 1879)	OC	WC	RO, PF	MUS
Cynoglossidae	<i>Symphurus plagusia</i> (Bloch & Schneider, 1801)	VC	SBA	PF	LIT
	<i>Symphurus tessellatus</i> (Quoy & Gaimard, 1824)	VC	SBA	PF	MUS
Dactylopteridae	<i>Dactylopterus volitans</i> (Linnaeus, 1758)	CO	SBI, SBA	PF, RF	LIT
Dasytidae	<i>Dasyatis guttata</i> (Bloch & Schneider, 1801)*	OC	IF, SBI, SBA	PF, RF, DD	LIT

Continued

Table 1. Continued.

Family	Species	Abundance	Habitat	Threat	Record type
Diodontidae	<i>Chilomycterus reticulatus</i> (Linnaeus, 1758)	CO	RR	NR	MUS
	<i>Cyclichthys spinosus</i> (Linnaeus, 1758)	AB	IF, SBI, SBA	PF	MUS
	<i>Diodon hystrix</i> Linnaeus, 1758	CO	RR	NR	PHO
Echeneidae	<i>Echeneis naucrates</i> Linnaeus, 1758	UN	WC	PF	SIG
Elopidae	<i>Elops saurus</i> Linnaeus, 1766	OC	WC	PF	MUS
Engraulidae	<i>Anchoa filifera</i> (Fowler, 1915)	CO	WC, SBA	PF	MUS
	<i>Anchoa spinifer</i> (Valenciennes, 1848)	CO	WC, SBA	PF	LIT
	<i>Anchoviella lepidontostole</i> (Fowler, 1911)	UN	WC	PF	COL
	<i>Cetengraulis edentulus</i> (Cuvier, 1829)	UN	WC, SBA	PF	MUS
	<i>Lycengraulis grossidens</i> (Spix & Agassiz, 1829)	UN	WC	PF	COL
Epinephelidae	<i>Alphestes afer</i> (Bloch, 1793)*	RA	RR	RF	PHO
	<i>Epinephelus itajara</i> (Lichtenstein, 1822)	RA	RR	EN, RF, IU	SIG
	<i>Mycteroperca acutirostris</i> (Valenciennes, 1828)*	CO	RR, IF	RF	SIG
	<i>Mycteroperca bonaci</i> (Poey, 1860) #	CO	RR, IF	EN, PF, RF	COL
	<i>Epinephelus marginatus</i> (Lowe, 1834)	RA	RR	EN, RF, IU	SIG
	<i>Rypticus bistrispinus</i> (Mitchill, 1818)	RA	RR	NR	SIG
	<i>Rypticus saponaceus</i> (Bloch & Schneider, 1801)	VC	RR	RF	MUS
Ephippidae	<i>Chaetodipterus faber</i> (Broussonet, 1782)	OC	WC	PF, RF	MUS
Fistulariidae	<i>Fistularia tabacaria</i> Linnaeus, 1758	UN	RR	NR	SIG
Gerreidae	<i>Diapterus auratus</i> Ranzani, 1842	UN	SBI	PF	MUS
	<i>Diapterus olisthostomus</i> (Goode & Bean, 1882)	UN	SBI	NR	COL
	<i>Eucinostomus argenteus</i> Baird & Girard, 1855	CO	SBI	PF	MUS
	<i>Eucinostomus lefroyi</i> (Goode, 1874)	VC	SBI	PF	MUS
	<i>Eugerres brasiliensis</i> (Cuvier, 1830)	OC	RR	RF	PHO
Ginglymostomatidae	<i>Ginglymostoma cirratum</i> (Bonnaterre, 1788)	RA	IF	EN, RF, DD	SIG
Gobiesocidae	<i>Gobiesox barbatulus</i> Starks, 1913	RA	RR	NR	COL
	<i>Tomicodon australis</i> Briggs, 1955	OC	RR	NR	COL
Gobiidae	<i>Bathygobius geminatus</i> Tornabene, Baldwin & Pezold, 2010	CO	RR	NR	MUS
	<i>Bathygobius soporator</i> (Valenciennes, 1837)	OC	RR	NR	SIG
	<i>Coryphopterus dicrus</i> Böhlke & Robins, 1960	VC	IF	NR	MUS
	<i>Coryphopterus glaucofraenum</i> Gill, 1863	VC	IF	NR	MUS
	<i>Ctenogobius saepepallens</i> (Gilbert & Randall, 1968)	CO	IF	NR	MUS
	<i>Elacatinus figaro</i> Sazima, Moura & Rosa, 1997	UN	RR	EN	SIG
	<i>Gnatholepis thompsoni</i> Jordan, 1904	OC	IF	NR	COL
	Gobiidae not identified	UN	SBA	NR	SIG
Grammatidae	<i>Gramma brasiliensis</i> Sazima, Gasparini & Moura, 1998 *	VC	RR	PF	PHO
Gymnuridae	<i>Gymnura altavela</i> (Linnaeus, 1758)	OC	IF, SBI, SBA	EN, PF, IU	LIT
Haemulidae	<i>Anisotremus moricandi</i> (Ranzani, 1842)	VC	RR, IF	RF, IU	MUS
	<i>Anisotremus surinamensis</i> (Bloch, 1791)	AB	RR	RF	MUS
	<i>Anisotremus virginicus</i> (Linnaeus, 1758)	AB	RR, IF	PF, RF	PHO
	<i>Conodon nobilis</i> (Linnaeus, 1758)	VC	SBA	PF	MUS
	<i>Haemulon aurolineatum</i> Cuvier, 1830	AB	RR, IF, SBI	PF	MUS
	<i>Haemulon parra</i> (Desmarest, 1823)	CO	RR, IF	PF, RF	MUS
	<i>Haemulon plumieri</i> (Lacepède, 1801)	VC	RR, IF	PF, RF	MUS
	<i>Haemulon steindachneri</i> (Jordan & Gilbert, 1882)	AB	RR, IF, SBI	PF, RF	MUS
Hemiramphidae	<i>Orthopristis ruber</i> (Cuvier, 1830)	VC	IF, SBI, SBA	PF, RF	PHO, LIT
	<i>Hemiramphus balao</i> Lesueur, 1821	OC	WC	NR	PHO
	<i>Hemiramphus brasiliensis</i> (Linnaeus, 1758)	VC	WC	PF	COL
	<i>Hyporhamphus unifasciatus</i> (Ranzani, 1841)	UN	WC	PF	MUS
Holocentridae	<i>Holocentrus adscensionis</i> (Osbeck, 1765)	AB	RR, IF, SBI	RF	MUS
	<i>Myripristis jacobus</i> Cuvier, 1829	VC	RR	NR	MUS
Kyphosidae	<i>Kyphosus sectatrix</i> (Linnaeus, 1758)	VC	WC	PF, RF	COL
Labridae	<i>Bodianus rufus</i> (Linnaeus, 1758)	AB	RR, IF	RF	PHO
	<i>Cryptotomus roseus</i> Cope, 1871	UN	RR	NR	SIG
	<i>Doratonotus megalepis</i> Günther, 1862	UN	RR	NR	SIG
	<i>Halichoeres brasiliensis</i> (Bloch, 1791)	VC	RR, IF	RF, DD	MUS
	<i>Halichoeres penrosei</i> Starks, 1913	OC	RR	NR	SIG
	<i>Halichoeres poeyi</i> (Steindachner, 1867)	AB	RR, IF	RF	MUS
	<i>Scarus trispinosus</i> Valenciennes, 1840	RA	RR	EN, RF, IU	SIG

Continued

Table 1. Continued.

Family	Species	Abundance	Habitat	Threat	Record type
	<i>Sparisoma amplum</i> (Ranzani, 1841)	RA	RR	EN	SIG
	<i>Sparisoma axillare</i> (Steindachner, 1878) #	AB	RR, IF	EN, PF, RF, DD	PHO
	<i>Sparisoma frondosum</i> (Agassiz, 1831) #	VC	RR	EN, RF, DD	PHO
	<i>Sparisoma radians</i> (Valenciennes, 1840)	OC	RR, IF	NR	SIG
	<i>Sparisoma tuiupiranga</i> Gasparini, Joyeux & Floeter, 2003	UN	RR, IF	NR	SIG
	<i>Thalassoma noronhanum</i> (Boulenger, 1890)	UN	RR	NR	SIG
Labrisomidae	<i>Labrisomus cricota</i> Sazima, Gasparini & Moura, 2002	OC	RR	NR	PHO
	<i>Labrisomus kalisherae</i> (Jordan, 1904)	OC	RR, IF	NR	MUS
	<i>Labrisomus nuchipinnis</i> (Quoy & Gaimard, 1824)	AB	RR, IF	RF	PHO
	<i>Malacoctenus delalandi</i> (Valenciennes, 1836)	AB	RR, IF	NR	MUS
	<i>Malacoctenus</i> aff. <i>triangulatus</i> Springer, 1959	VC	RR, IF	NR	MUS
	<i>Paraclinus arcanus</i> Guimarães & Bacellar, 2002	RA	SBI	NR	MUS
Lutjanidae	<i>Lutjanus analis</i> (Cuvier, 1828)	UN	RR, IF	RO, PF, RF, IU	SIG
	<i>Lutjanus cyanopterus</i> (Cuvier, 1828)	UN	RR	EN, RF, IU	SIG
	<i>Lutjanus jocu</i> (Bloch & Schneider, 1801) #	VC	RR, IF	RF	MUS
	<i>Lutjanus synagris</i> (Linnaeus, 1758) #	CO	IF, SBI	PF, RF	PHO
	<i>Ocyurus chrysurus</i> (Bloch, 1791)	CO	IF, SBI	RO, PF	MUS
Malacanthidae	<i>Malacanthus plumieri</i> (Bloch, 1786)	UN	SBI	NR	SIG
Monacanthidae	<i>Aluterus scriptus</i> (Osbeck, 1765)	OC	RR	NR	SIG
	<i>Cantherhines pullus</i> (Ranzani, 1842)	CO	RR, IF	NR	MUS
	<i>Stephanolepis hispidus</i> (Linnaeus, 1766)	UN	RR, IF, SBI	PF	COL
Mugilidae	<i>Mugil incilis</i> Hancock, 1830	CO	WC	PF, RF	COL
	<i>Mugil liza</i> Valenciennes, 1836	CO	WC	RO, PF, RF	MUS
Mullidae	<i>Pseudupeneus maculatus</i> (Bloch, 1793)	VC	RR, IF, SBI	PF	MUS
Muraenidae	<i>Gymnothorax funebris</i> Ranzani, 1839	CO	RR	RF	PHO
	<i>Gymnothorax moringa</i> (Cuvier, 1829)	VC	RR, IF	RF	PHO
	<i>Gymnothorax ocellatus</i> Agassiz, 1831	CO	SBA	PF	MUS
	<i>Gymnothorax vicinus</i> (Castelnau, 1855)	UN	RR	RF	COL
Myliobatidae	<i>Aetobatus narinari</i> (Euphrasen, 1790)*	OC	WC	PF	PHO
Narcinidae	<i>Narcine brasiliensis</i> (Olfers, 1831)*	UN	IF, SBI, SBA	PF, DD	SIG
Ogcocephalidae	<i>Ogcocephalus vespertilio</i> (Linnaeus, 1758)	OC	SBI, SBA	PF	SIG, LIT
Ophichthidae	<i>Myrichthys breviceps</i> (Richardson, 1848)	UN	SBI, RR	NR	PHO
	<i>Myrichthys ocellatus</i> (Lesueur, 1825)	OC	SBI, RR	NR	SIG
	<i>Ophichthus gomesii</i> (Castelnau, 1855)	UN	SBA	PF	LIT
	<i>Ophichthus ophis</i> (Linnaeus, 1758)	UN	SBI	RF	MUS
	<i>Ahlia egmontis</i> (Jordan, 1884)	UN	IF, SBI	NR	SIG
Ostraciidae	<i>Acanthostracion polygonius</i> Poey, 1876	CO	RR	NR	SIG
	<i>Acanthostracion quadricornis</i> (Linnaeus, 1758)	CO	RR	PF	SIG
Paralichthyidae	<i>Citharichthys macrops</i> Dresel, 1885	CO	SBA	PF	MUS
	<i>Citharichthys spilopterus</i> Günther, 1862	CO	SBA	PF	MUS
	<i>Etropus crossotus</i> Jordan & Gilbert, 1882	OC	IF, SBI	NR	MUS
	<i>Paralichthys brasiliensis</i> (Ranzani, 1842)	UN	IF	RF	COL
	<i>Syacium</i> cf. <i>papillosum</i> (Linnaeus, 1758)	OC	IF, SBI	PF	MUS
	<i>Syacium micrurum</i> Ranzani, 1842	OC	IF, SBI	PF	MUS
Pempheridae	<i>Pempheris schomburgkii</i> (Müller & Troschel, 1848)	CO	RR	NR	COL
Polynemidae	<i>Polydactylus oligodon</i> (Günther, 1860)	UN	SBI, SBA	PF	COL
	<i>Polydactylus virginicus</i> (Linnaeus, 1758)	UN	SBI, SBA	PF	LIT
Pomacanthidae	<i>Holacanthus ciliaris</i> (Linnaeus, 1758)	CO	RR, IF	NR	PHO
	<i>Holacanthus tricolor</i> (Bloch, 1795)	UN	RR, IF	NR	SIG
	<i>Pomacanthus paru</i> (Bloch, 1787)	VC	RR, IF	RF	PHO
	<i>Pomacanthus arcuatus</i> (Linnaeus, 1758)	UN	RR	NR	SIG
Pomacentridae	<i>Abudefduf saxatilis</i> (Linnaeus, 1758)	AB	RR, IF	RF	MUS
	<i>Chromis multilineata</i> (Guichenot, 1853)	VC	RR, WC	NR	SIG
	<i>Microspathodon chrysurus</i> (Cuvier, 1830)	RA	RR	EN	PHO
	<i>Stegastes fuscus</i> (Cuvier, 1830)	AB	RR, IF	NR	COL
	<i>Stegastes variabilis</i> (Castelnau, 1855)	VC	RR, IF	NR	COL
Pomatomidae	<i>Pomatomus saltatrix</i> (Linnaeus, 1766)	UN	WC	RO, PF, RF	PHO

Continued

Table 1. Continued.

Family	Species	Abundance	Habitat	Threat	Record type
Rhinobatidae	<i>Rhinobatos horkelii</i> Müller & Henle, 1841	OC	SBI, SBA	EN, PF, IU	PHO
	<i>Rhinobatos percellens</i> (Walbaum, 1792)*	OC	SBI, SBA	PF	MUS
	<i>Zapteryx brevirostris</i> (Müller & Henle, 1841)	OC	SBI, SBA	EN, PF, IU	MUS
Sciaenidae	<i>Ctenosciaena gracilicirrus</i> (Metzelaar, 1919)	AB	SBA	PF	LIT
	<i>Cynoscion acoupa</i> (Lacepède, 1801)	UN	SBA	PF	MUS
	<i>Cynoscion jamaicensis</i> (Vaillant & Bocourt, 1883)	AB	SBA	PF	LIT
	<i>Cynoscion leiarchus</i> (Cuvier, 1830)	UN	SBA	PF	MUS
	<i>Cynoscion virescens</i> (Cuvier, 1830)*	CO	SBA	PF	LIT
	<i>Isopisthus parvipinnis</i> (Cuvier, 1830)	AB	SBA	PF	LIT
	<i>Larimus breviceps</i> Cuvier, 1830	AB	SBA	PF	MUS
	<i>Macrodon ancylodon</i> (Bloch & Schneider, 1801)	CO	SBA	RO, PF	COL
	<i>Menticirrhus americanus</i> (Linnaeus, 1758)	VC	SBA	PF	MUS
	<i>Micropogonias furnieri</i> (Desmarest, 1823)	VC	SBA	RO, PF	MUS
	<i>Nebris microps</i> Cuvier, 1830	OC	SBA	PF	LIT
	<i>Odontoscion dentex</i> (Cuvier, 1830)	VC	RR, IF	NR	SIG
	<i>Paralanchurus brasiliensis</i> (Steindachner, 1875)	AB	SBA	PF	MUS
	<i>Pareques acuminatus</i> (Bloch & Schneider, 1801)	VC	RR, IF	NR	MUS
	<i>Stellifer brasiliensis</i> (Schultz, 1945)	AB	SBA	PF	MUS
	<i>Stellifer naso</i> (Jordan, 1889)	OC	SBA	PF	MUS
	<i>Stellifer rastrifer</i> (Jordan, 1889)	AB	SBA	PF	MUS
	<i>Umbrina coroides</i> Cuvier, 1830	UN	SBA	PF	LIT
Scombridae	<i>Euthynnus alletteratus</i> (Rafinesque, 1810)	OC	WC	PF	COL
	<i>Scomberomorus cavalla</i> (Cuvier, 1829)	OC	WC	PF	PHO
	<i>Scomberomorus brasiliensis</i> Collette, Russo & Zavala-Camin, 1978	VC	WC	PF, RF	MUS
Scorpaenidae	<i>Scorpaena brasiliensis</i> Cuvier, 1829	OC	RR	NR	COL
	<i>Scorpaena isthmensis</i> Meek & Hildebrand, 1928	OC	RR, SBA	PF	MUS, LIT
	<i>Scorpaena plumieri</i> Bloch, 1789	VC	RR, IF	NR	COL
Serranidae	<i>Diplectrum formosum</i> (Linnaeus, 1766)	VC	IF, SBI, SBA	PF, RF	MUS
	<i>Diplectrum radiale</i> (Quoy & Gaimard, 1824)	VC	IF, SBI	NR	COL
	<i>Serranus baldwini</i> (Evermann & Marsh, 1899)	OC	RR	NR	PHO
	<i>Serranus flaviventris</i> (Cuvier, 1829)	CO	RR, IF	NR	MUS
Sparidae	<i>Archosargus probatocephalus</i> (Walbaum, 1792)*	CO	RR	RF	SIG
	<i>Archosargus rhomboidalis</i> (Linnaeus, 1758)	UN	SBI	PF	MUS
	<i>Calamus penna</i> (Valenciennes, 1830)	OC	IF, SBI	PF	MUS
	<i>Diplodus argenteus</i> (Valenciennes, 1830)	VC	RR	PF, RF	MUS
	<i>Pagrus pagrus</i> (Linnaeus, 1758)	OC	IF, SBI	RO, IU	SIG
Sphyraenidae	<i>Sphyraena guachancho</i> Cuvier, 1829	UN	WC	PF	MUS
	<i>Sphyraena tome</i> Fowler, 1903	CO	WC	PF	MUS
Stromateidae	<i>Peprilus paru</i> (Linnaeus, 1758)	CO	WC, SBA	PF	MUS
Syngnathidae	<i>Microphis brachyurus lineatus</i> (Kaup, 1856)	RA	SBA	NR	LIT
	Syngnathinae not identified	RA	SBI	NR	SIG
	<i>Hippocampus reidi</i> Ginsburg, 1933 #	CO	IF	EN, DD	PHO
Synodontidae	<i>Synodus intermedius</i> (Spix & Agassiz, 1829)	CO	SBI	NR	MUS
	<i>Synodus synodus</i> (Linnaeus, 1758)	CO	SBI	NR	PHO
Tetraodontidae	<i>Canthigaster figueiredoi</i> Moura & Castro, 2002	CO	RR, IF	NR	SIG
	<i>Lagocephalus laevigatus</i> (Linnaeus, 1766)	CO	SNI, SNA	PP	SIG
	<i>Sphoeroides greeleyi</i> Gilbert, 1900	CO	IF, SBI, SBA	NR	LIT
	<i>Sphoeroides pachygaster</i> (Müller & Troschel, 1848)	OC	IF, SBI, SBA	NR	LIT
	<i>Sphoeroides spengleri</i> (Bloch, 1785)	VC	RR, IF	RF	MUS
	<i>Sphoeroides testudineus</i> (Linnaeus, 1758)	OC	IF, SBI, SBA	RF	LIT
Trichiuridae	<i>Trichiurus lepturus</i> Linnaeus, 1758	VC	WC, SBA	PF	MUS
Triglidae	<i>Prionotus punctatus</i> (Bloch, 1793)	OC	IF, SBA	PF	MUS

* Species considered at risk in Espírito Santo state by the authors (see discussion); # Species targeted of a redirection of local fishery activities (due to the collapse of bigger and more valuable species).

even with a small and shallow reef area, displays a large diversity of micro-habitats, such as rocky shores, one beach, emerged and submerged reefs and patch reefs, rhodolith and bioclastic material beds, sand and mud bottoms, and macroalgae beds, distributed in areas sheltered and exposed to winds and waves. This diversity

of habitats can contribute to the high species richness found in the Franceses Islands.

Additionally, some oceanographic features of Espírito Santo State (Schmid et al. 1995) make this region a transitional zone between Brazilian Northeastern (tropical) and Southern (subtropical) coast (Martins et al. 2007),

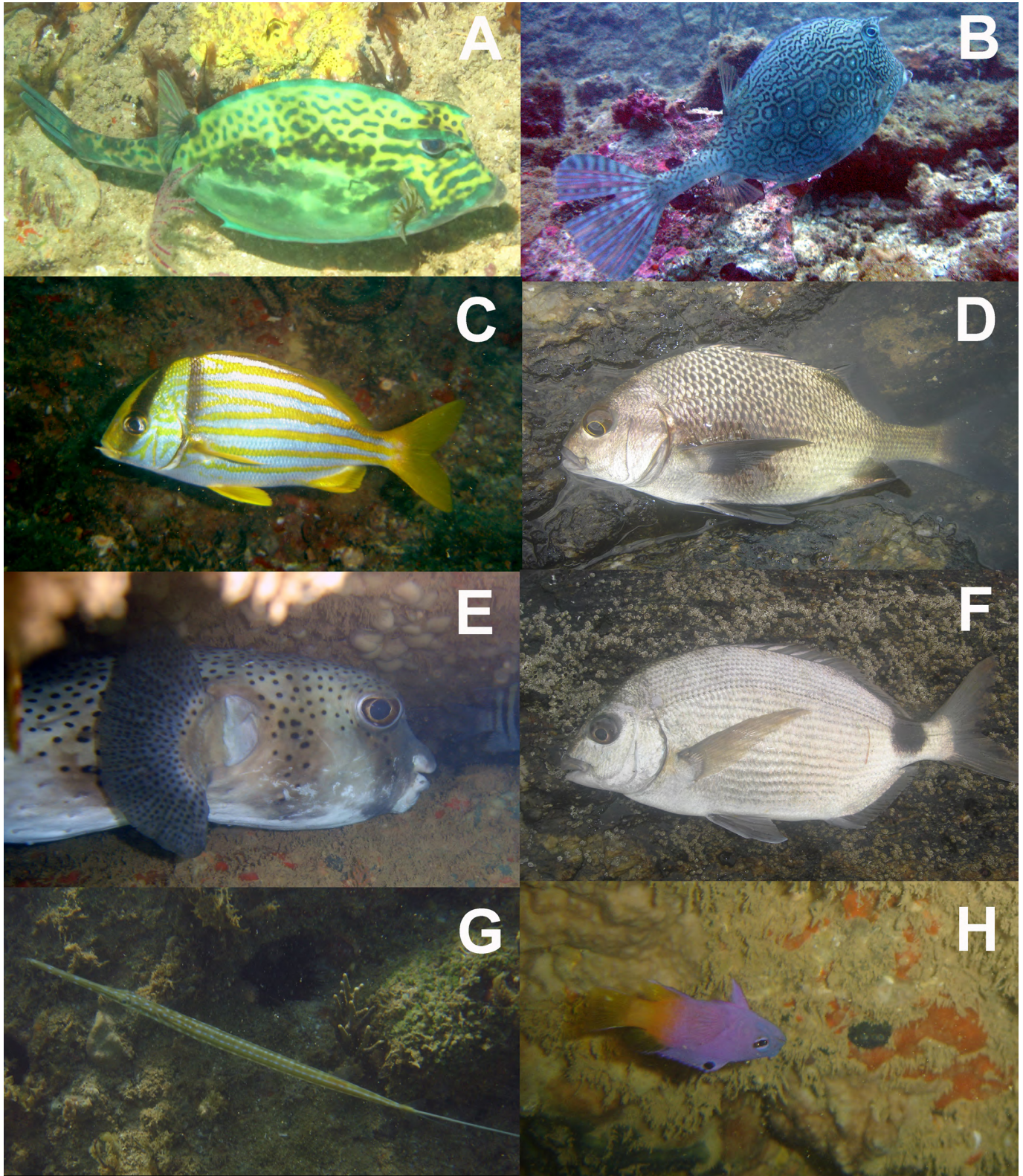


Figure 2. Species recorded on the rocky reefs of Franceses Island, Espírito Santo southern coast, Brazil. A) *Acanthostracion quadricornis*, B) *Acanthostracion polygonius*, C) *Anisotremus virginicus*, D) *Anisotremus surinamensis*, E) *Chilomycterus reticulatus*, F) *Diplodus argenteus*, G) *Fistularia tabacaria*, H) *Gramma brasiliensis*.

what contribute to an increase in local fish diversity. At least four species (*Selene brownii*, *Selene setapinnis*, *Bathygobius mystacium* and *Anisotremus moricandi*) have the Espírito Santo state as their south distribution edge, while other four species (*Epinephelus marginatus*, *Sphyræna tome*, *Rhinobatos horkelii* and *Zapteryx brevirostris*)

have this state as their north distributional edge.

Diversity and dissimilarity analyses among the distinct habitats studied highlight some points. Although RR and IF habitats show the highest richness, the low exclusive species richness of IF and high similarity of both habitats indicate an overlap among species, which

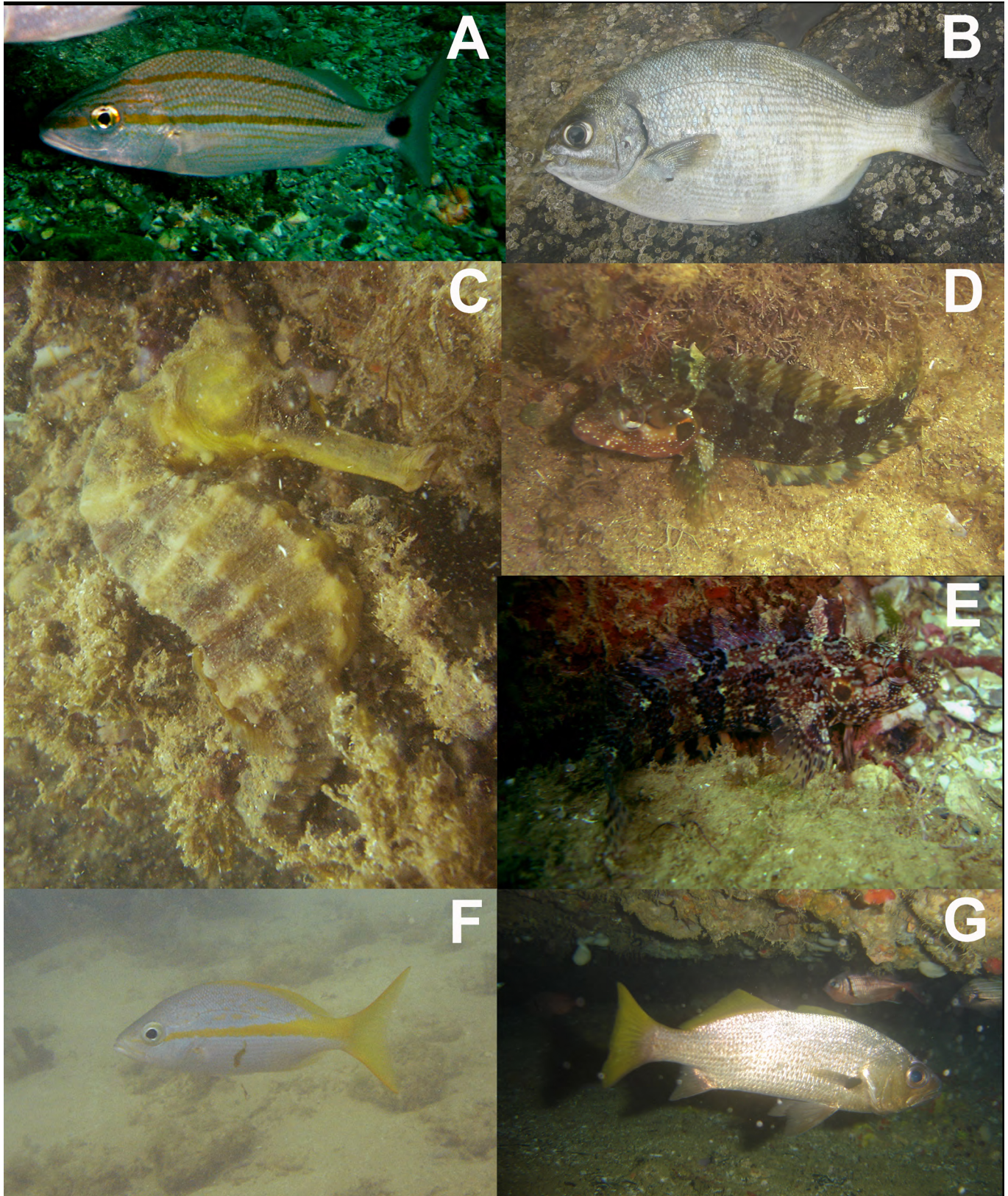


Figure 3. Species recorded on the rocky reefs of Franceses Island, Espírito Santo southern coast, Brazil. A) *Haemulon aurolineatum*, B) *Kyphosus sectatrix*, C) *Hippocampus reidi*, D) *Labrisomus cricota* (male), E) *Labrisomus cricota* (female), F) *Ocyurus chrysurus*, G) *Odontoscion dentex*.

can be related with the geographical proximity and habitat plasticity of species. The similarity of SBI and SBA, even not too high, suggest that many species found in demersal unconsolidated bottoms, even not characterized as reef fishes, can explore and be recorded in island

surroundings habitats, increasing the local richness. Else, WC habitat has the most distinct fauna, showing high exclusive species richness. The majority of species of this habitat used to occur in schools and have a seasonal presence in the area (Froese and Pauly 2014;

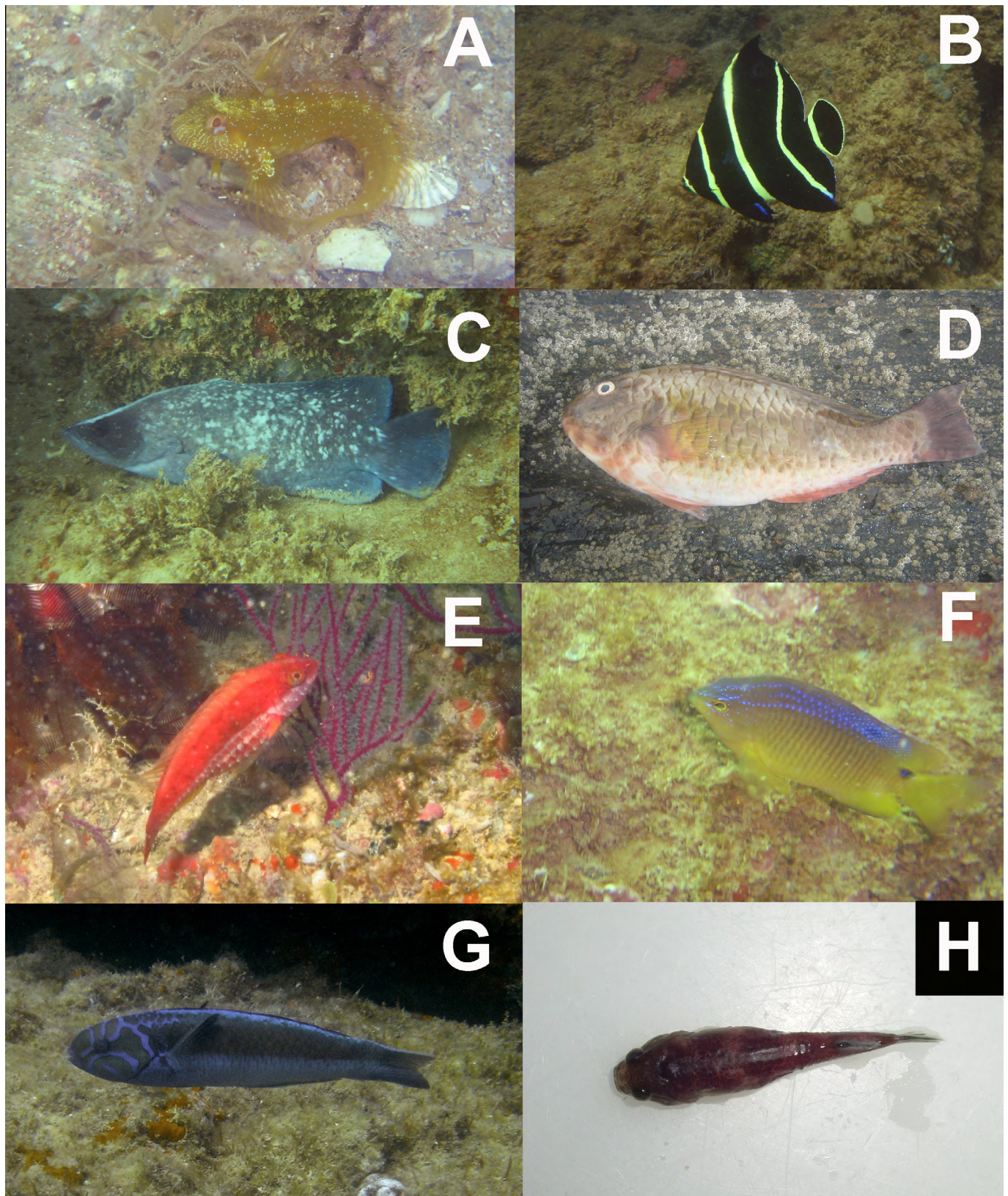


Figure 4. Species recorded on the rocky reefs of Franceses Island, Espírito Santo southern coast, Brazil. A) *Parablennius marmoreus* (yellow morph), B) *Pomacanthus paru*, C) *Rypticus saponaceus*, D) *Sparisoma axillare*, E) *Sparisoma tuiupiranga*, F) *Stegastes variabilis*, G) *Thalassoma noronhanum*, H) *Tomicodon australis*.

personal observation). Thus, the mosaic of seascape, habitat plasticity of many species and seasonal visitant species can also contribute to the high fish diversity found in the studied island.

Moura and Francini-Filho (2005) state that due to the high endemism and large risks Brazilian reefs can be considered a hotspot inside the Atlantic Ocean, so, in need of an immediate attention from scientists and

conservationists. Espírito Santo coast, considered a marine transitional zone and a faunal boundary (Floeter et al. 2001; Martins et al. 2007), should receive a special care. Boundary regions are normally very sensitive to climate and environmental changes (Peters 1994), and depend on the preservation of natural areas for the maintenance of its communities.

Apart of the fact that it contains a representative

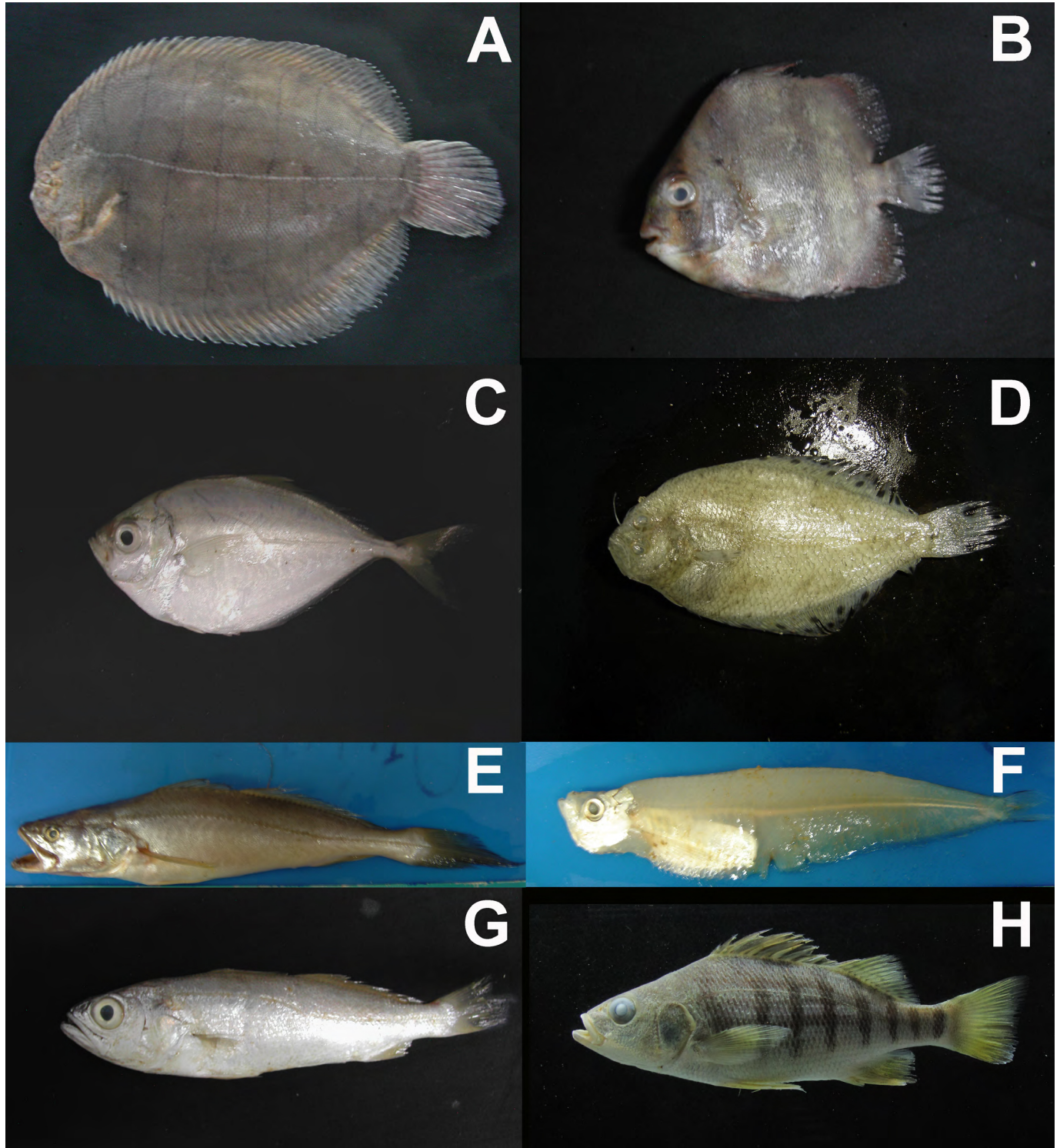


Figure 5. Species recorded on soft bottom habitats around Franceses Island, Espírito Santo southern coast, Brazil. A) *Achirus declivis*, B) *Chaetodipterus faber*, C) *Chloroschombrus chrysurus*, D) *Citharichthys macrops*, E) *Cynoscion virescens*, F) *Chirocentrodon bleekermanus*, G) *Cynoscion jamaicensis*, H) *Conodon nobilis*.

portion of the Brazilian reef fish diversity (35%), Franceses Island also hosts endangered and over-exploited species, as well as several species of commercial and recreational importance. However, the isle has suffered different kinds of impacts, such as increase of sedimentation from two hydrographic basis, uncontrolled tourism and overfishing (Pinheiro et al. 2009b, 2010a, 2010b). These impacts threaten reef areas worldwide and have a high potential to change reef fish community structure. Moreover, some species registered at Franceses Island deserve further attention for an adequate classification of risk. Eight species are considered endangered by Brazilian red list but not by IUCN evaluations. Four species, including a Brazilian endemic, are considered threatened by IUCN but not for Brazilian red lists (Table 1).

Franceses Island reefs seem to be a nursery area for

nine endangered species (*E. marginatus*, *G. cirratum*, *L. analis*, *L. cyanopterus*, *M. bonaci*, *S. trispinosus*, *S. amplum*, *S. axillare*, *S. frondosum*), all targeted by local fishing activities (Table 1). Three endangered elasmobranchs, *G. altavela*, *R. horkelii* and *Z. brevirostris*, have been highly threatened around Franceses Island, as well in other areas of the ES, as by-catch by trawling activities (Pinheiro and Martins 2009; Pinheiro et al. 2009a). Summing to these examples, there are other 12 species (highlighted in Table 1) found at Franceses Island that are not considered threatened neither by IUCN nor by Brazilian lists, but that have populations in risk at Espírito Santo state (pers. obs.), thus deserving a special attention for analysis and classification of risk (six of these are predicted to have a high extinction risk in Brazil; Bender et al. 2012). Other ten species, also pointed

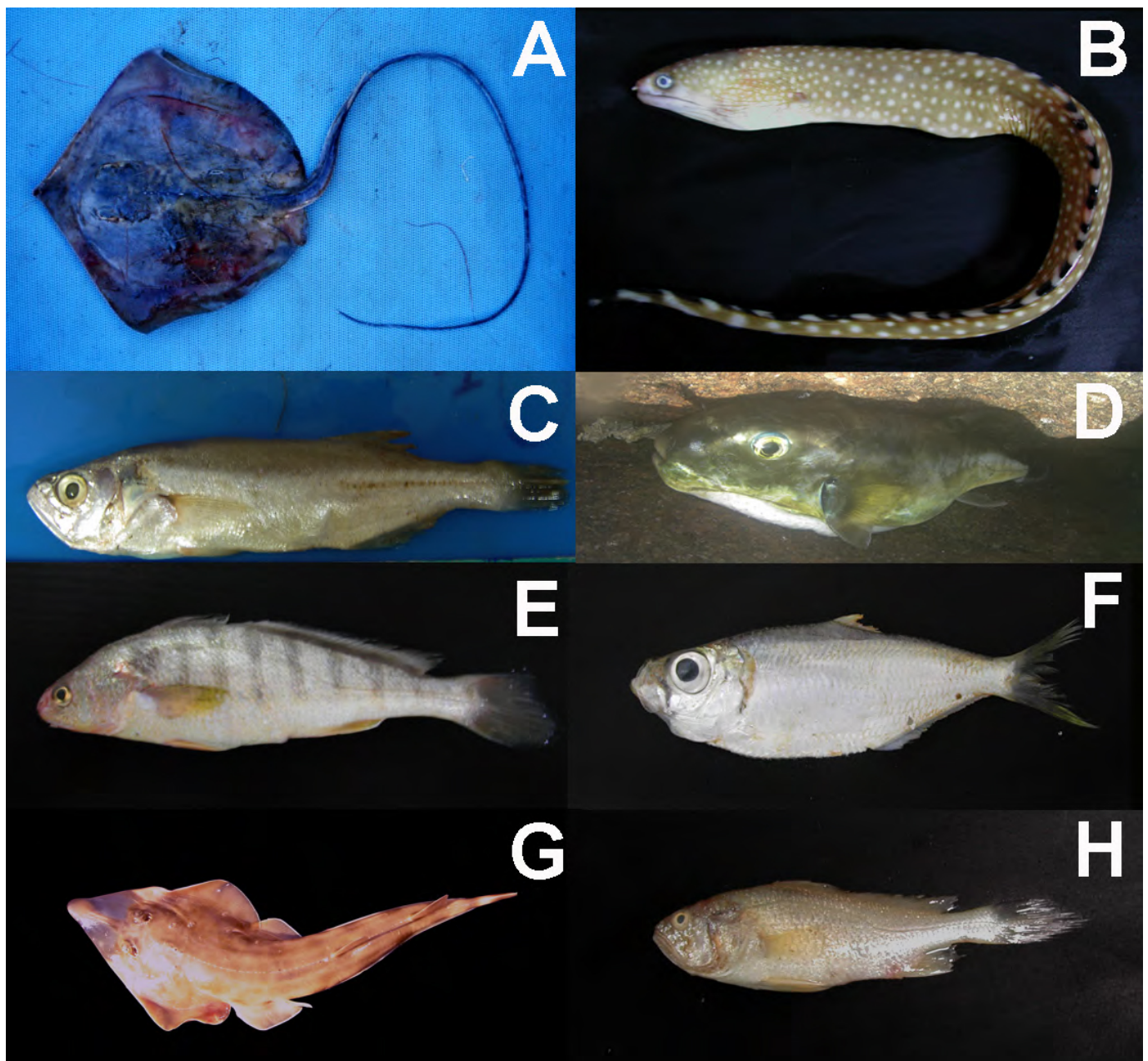


Figure 6. Species recorded on soft bottom habitats around Franceses Island, Espírito Santo southern coast, Brazil. A) *Dasyatis guttata*, B) *Gymnothorax ocellatus*, C) *Isopisthus parvipinnis*, D) *Lagocephalus laevigatus*, E) *Paralichthys brasiliensis*, F) *Pellona harroweri*, G) *Rhinobatos horkelii*, H) *Stellifer rastrifer*.

in Table 1, are common but have been recently target of local fishing since the collapse of bigger and more valuable species, so deserve attention and monitoring by managers in Espírito Santo and Brazil.

Although there is a necessity of improvement of catch regulations, the full protection of habitats has been essential for resource recovery and biodiversity conservation. In this context, Brazilian Environmental Ministry has tried to implement a policy of MPAs creation targeting the goals of the Aichi Convention.

Despite that, Brazil has less than 2% of its marine area effectively protected, and in many cases the establishment of MPAs looks like a political deal or exchange by the aggressive and accelerate industrial growth that is happening and impacting several Brazilian coastal areas (pers. obs.). Presently, management organizations and NGOs are working towards the creation of a MPA in the southern coast of Espírito Santo. The inclusion of Franceses Island and adjacent habitats in a no-take zone can collaborate to the protection of a high biodiversity

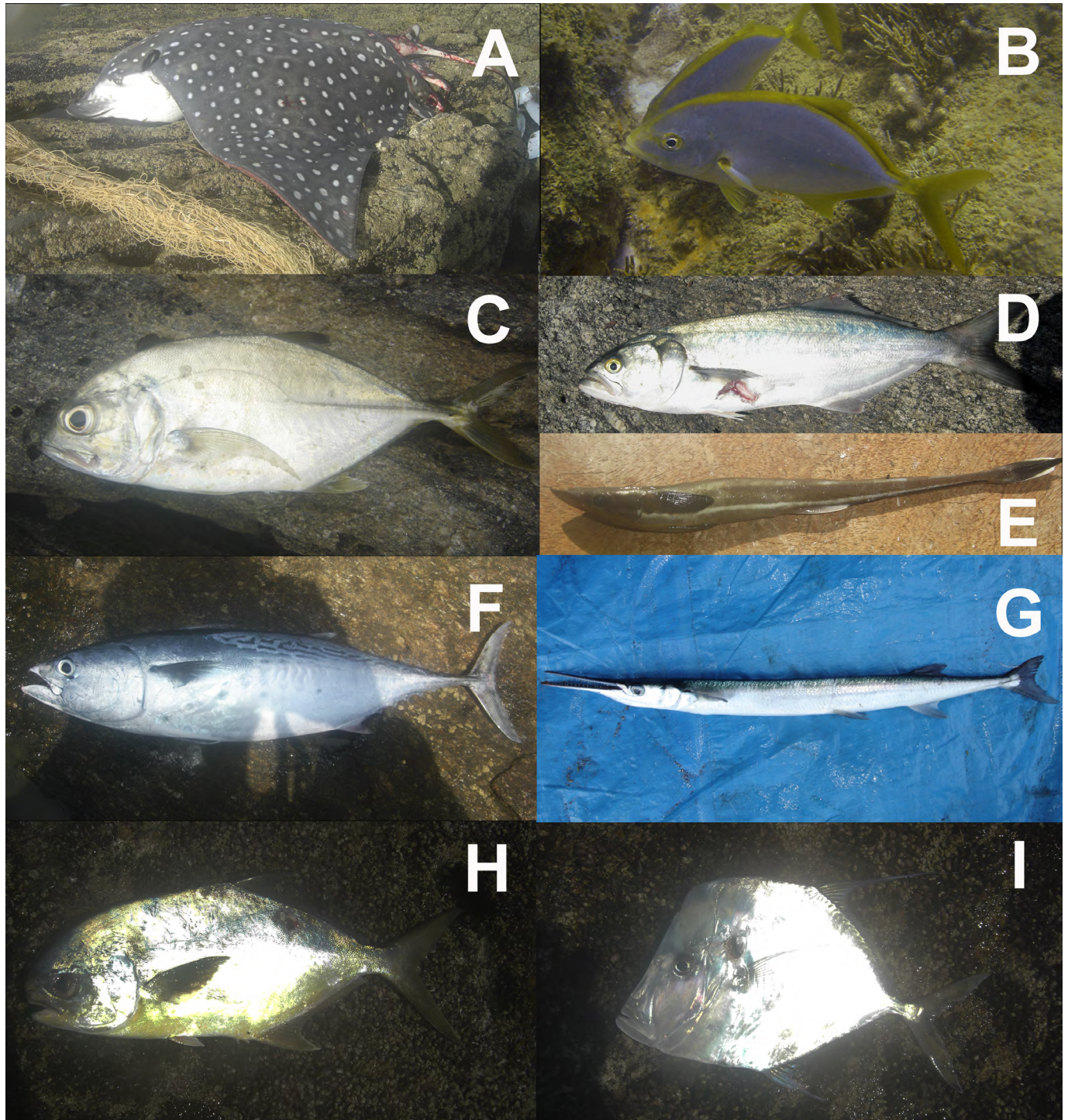


Figure 7. Species recorded in the water column around Franceses Island, Espírito Santo southern coast, Brazil. A) *Aetobatus narinari*, B) *Carangoides bartholomaei*, C) *Caranx latus*, D) *Pomatomus saltatrix*, E) *Echeneis naucrates*, F) *Euthynnus alletteratus*, G) *Tylosurus acus*, H) *Trachinotus carolinus*, I) *Selene vomer*.

area, sustainability of surrounding artisanal fishing and management and valorization of the local tourism.

NOTE

The Brazilian Red List was recently upgraded (IBAMA 2014), with many species added. Regarding reef fishes, four species we considered in the present work to be highly endangered in the Espírito Santo state (*L. cyanopterus*, *S. trispinosus*, *G. altavela* and *Z. brevirostris*) had their endangered status updated to either vulnerable or critically endangered. On the other hand, *Gramma brasiliensis*, highly targeted for the ornamental trade but rare at Franceses Island, dropped out the Red List. The official status of the other species did not change.

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LITERATURE CITED

- Allen, G.R. and M.V. Erdmann. 2009. Reef fishes of the Bird's Head Peninsula, West Papua, Indonesia. Check List 5(3): 587-628. <http://www.checklist.org.br/getpdf?SLO32-09>
- Bellwood, D.R. and P.C. Wainwright. 2002. The history and biogeography of fishes on coral reefs; pp. 5-32, in: P.F. Sale (ed.). Coral reef fishes. Dynamics and diversity in a complex ecosystem. San Diego: Academic Press.
- Bender, M.G., S.R. Floeter, F.P. Mayer, D.A. Vila-Nova, G.O. Longo, N. Hanazaki, A. Carvalho-Filho and C.E.L. Ferreira. 2012. Biological attributes and major threats as predictors of species' vulnerability: a case study with Brazilian reef fishes. Oryx International Journal of Conservation 47(2): 259-265. doi: [10.1017/S003060531100144X](https://doi.org/10.1017/S003060531100144X)
- Bonaldo, R.M., J.P. Krajewski, C. Sazima and I. Sazima. 2006. Foraging activity and resource use by three parrotfish species at Fernando de Noronha Archipelago, tropical West Atlantic. Marine Biology 149: 423-433. doi: [10.1007/s00227-005-0233-9](https://doi.org/10.1007/s00227-005-0233-9)
- Clarke, K.R. and R.N. Gorley. 2006. PRIMER v6: User Manual/tutorial. PRIMER-E, Plymouth.
- Cornell, H.V. and R.H. Karlson. 2000. Coral species richness: ecological versus biogeographic influences. Coral Reefs 19: 37-49. doi: [10.1007/s003380050224](https://doi.org/10.1007/s003380050224)
- Costa, T.J.F. 2009. Estrutura da comunidade bentônica dos recifes rochosos da Ilha dos Franceses, sudeste do Brasil, utilizando a técnica amostral de fotoquadrante digital. Bacharel monography. Vitória (ES): Department of Biology FAESA. 59 pp.
- Craig, M.T., Y.J.M. Sadovy and P.C. Heemstra. 2011. Groupers of the world: a field and market guide. Grahamstown: NISC. 424 pp.
- Ferreira, C.E.L., J.E.A. Gonçalves and R. Coutinho. 2001. Community structure and habitat complexity on a tropical rocky shore. Environmental Biology of Fishes 61: 353-369. doi: [10.1023/A:1011609617330](https://doi.org/10.1023/A:1011609617330)
- Ferreira, C.E.L. and J.E.A. Gonçalves. 2006. Community structure and diet of roving herbivorous reef fishes in the Abrolhos Archipelago, south-western Atlantic. Journal of Fish Biology 69: 1533-1551. doi: [10.1111/j.1095-8649.2006.01220.x](https://doi.org/10.1111/j.1095-8649.2006.01220.x)
- Ferreira, C.E.L., C.G.W. Ferreira, C.A. Rangel, J.P. Mendonça, L.C. Gerhardinger, A. Carvalho Filho, E.A. Godoy, O. Luiz Jr. and J.L. Gasparini. 2007. Peixes recifais; pp. 291-322, in: J.C. Creed, D.O. Pires and M.A.O. Figueiredo (eds.). Biodiversidade Marinha da Baía da Ilha Grande. Brasília: MMA.
- Floeter, S.R. and J.L. Gasparini. 2000. The southwestern Atlantic reef fish fauna: composition and zoogeographic patterns. Journal of Fish Biology 56: 1099-1114. doi: [10.1111/j.1095-8649.2000.tb02126.x](https://doi.org/10.1111/j.1095-8649.2000.tb02126.x)
- Floeter, S.R., R.Z.P. Guimarães, L.A. Rocha, C.E.L. Ferreira, C.A. Rangel and J.L. Gasparini. 2001. Geographic variation in reef fish assemblages along the Brazilian coast. Global Ecology and Biogeography 10: 423-431. doi: [10.1046/j.1466-822X.2001.00245.x](https://doi.org/10.1046/j.1466-822X.2001.00245.x)
- Floeter, S.R., C.E.L. Ferreira, A. Dominici-Arosemena and I.R. Zalmon. 2004. Latitudinal gradients in Atlantic reef fish communities: trophic structure and spatial use patterns. Journal of Fish Biology 64: 1680-1699. doi: [10.1111/j.0022-1112.2004.00428.x](https://doi.org/10.1111/j.0022-1112.2004.00428.x)
- Floeter, S.R., B.S. Halpern and C.E.L. Ferreira. 2006. Effects of fishing and protection on Brazilian reef fishes. Biological Conservation 128: 391-402. doi: [10.1016/j.biocon.2005.10.005](https://doi.org/10.1016/j.biocon.2005.10.005)
- Krohling, W., J.L. Gasparini, C.E.L. Ferreira and I.R. Zalmon. 2007. Reef fish community structure on coastal islands of the southeastern Brazil: the influence of exposure and benthic cover. Environmental Biology of Fishes 78: 147-160. doi: [10.1007/s10641-006-9084-6](https://doi.org/10.1007/s10641-006-9084-6)
- Floeter, S.R., L.A. Rocha, D.R. Robertson, J.C. Joyeux, W.F. Smith-Vaniz, P. Wirtz, A. Edwards, J.P. Barreiros, C.E.L. Ferreira, J.L. Gasparini, A. Brito, J.M. Falcón, B.W. Bowen and G. Bernardi. 2008. Atlantic reef fish biogeography and evolution. Journal of Biogeography 35: 22-47. doi: [10.1111/j.1365-2699.2007.01790.x](https://doi.org/10.1111/j.1365-2699.2007.01790.x)
- Francini-Filho, R.B. and I. Sazima. 2008. A comparative study of cleaning activity of two reef fishes at Fernando de Noronha

- Archipelago, tropical West Atlantic. *Environmental Biology of Fishes* 83(2): 213–220. doi: [10.1007/s10641-007-9322-6](https://doi.org/10.1007/s10641-007-9322-6)
- Francini-Filho, R.B. and R.L. Moura. 2008a. Dynamics of fish assemblages on coral reefs subjected to different management regimes in the Abrolhos Bank, eastern Brazil. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18: 1166–1179. doi: [10.1002/aqc.966](https://doi.org/10.1002/aqc.966)
- Francini-Filho, R.B. and R.L. Moura. 2008b. Evidence for Spillover of reef fishes from a no-take marine reserve: An evaluation using the before-after control impact (BACI) approach. *Fisheries Research* 93: 346–356. doi: [10.1016/j.fishres.2008.06.011](https://doi.org/10.1016/j.fishres.2008.06.011)
- Francini-Filho, R. B., C.M. Ferreira, E.O.C. Coni, R.L. Moura and L. Kaufman. 2010. Foraging activity of roving herbivorous reef fish (Acanthuridae and Scaridae) in eastern Brazil: influence of resource availability and interference competition. *Journal of the Marine Biological Association of United Kingdom* 90 (3): 481–492. doi: [10.1017/S0025315409991147](https://doi.org/10.1017/S0025315409991147)
- Proese, R. and D. Pauly. 2014. Fishbase. Accessed at <http://www.fishbase.org>, 1 February 2014.
- Gibran, F.Z. 2002. The sea basses *Diplletrum formosum* and *D. radiale* (Serranidae) as followers of the sea star *Luidia senegalensis* (Asteroidea) in southeastern Brazil. *Brazilian Journal of Biology* 62(4): 591–594. doi: [10.1590/S1519-69842002000400005](https://doi.org/10.1590/S1519-69842002000400005)
- Gibran, F.Z. 2004. Dying or illness Feigning: an unreported feeding tactic of the comb grouper *Mycteroperca acutirostris* (Serranidae) from the southwest Atlantic. *Copeia* 2004(2): 403–405. doi: <http://www.asihcopeiaonline.org/doi/abs/10.1643/CI-03-200R1>
- Hixon, M.A. 2011. 60 years of coral reef fish ecology: past, present and future. *Bulletin of Marine Science* 87(4): 727–765. doi: [10.5343/bms.2010.1055](https://doi.org/10.5343/bms.2010.1055)
- Hostim-Silva, M., A.B. Andrade, L.F. Machado, L.C. Gerhardinger, F.A. Daros, J.P. Barreiros and E. Godoy. 2005. Peixes de Costão Rochoso de Santa Catarina, I. Arvoredo. Itajaí: UNIVALI Edições. 131 pp.
- IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis). 2003a. Lista Nacional das Espécies da Fauna Brasileira Ameaçadas de Extinção. Anexo à Instrução Normativa nº 3 do Ministério do Meio Ambiente, de 27/05/2003, publicada no D.O.U. nº 101, Seção I, de 28/05/2003.
- IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis). 2003b. Lista Nacional das Espécies de Invertebrados Aquáticos e Peixes Ameaçadas de Extinção e Lista Nacional das Espécies de Invertebrados Aquáticos e Peixes Sobreexploradas ou Ameaçadas de Sobreexploração. Anexos à Instrução Normativa nº 5 do Ministério do Meio Ambiente, de 21/05/2004, publicada no D.O.U. nº 102, Seção I, de 28/05/2004.
- Joyeux, J.C., S.R. Floeter, C.E.L. Ferreira and J.L. Gasparini. 2001. Biogeography of tropical reef fishes: the South Atlantic puzzle. *Journal of Biogeography* 28: 831–841. doi: [10.1046/j.1365-2699.2001.00602.x](https://doi.org/10.1046/j.1365-2699.2001.00602.x)
- Luiz Jr., O.J., A. Carvalho-Filho, C.E.L. Ferreira, S.R. Floeter, J.L. Gasparini and I. Sazima. 2008. The reef fish assemblage of the Laje de Santos Marine State Park, Southwestern Atlantic: annotated checklist with comments on abundance, distribution, trophic structure, symbiotic associations and conservation. *Zootaxa* 1807: 1–25. <http://www.mapress.com/zootaxa/list/2008/zto1807.html>
- Martins, A.S., G.O.M. Silva and P.A.S. Costa. 2007. Padrões de distribuição e estrutura de comunidades de grandes peixes recifais na costa central do Brasil; pp. 45–61, in: P.A.S. Costa, G. Olavo and A.S. Martins (eds.). *Biodiversidade da fauna marinha profunda na costa central brasileira*. Rio de Janeiro: Museu Nacional.
- Mendonça-Neto, J.P., C. Monteiro-Neto and L.E. Moraes. 2008. Reef fish community structure on three islands of Itaipu, Southeast Brazil. *Neotropical Ichthyology* 6(2): 267–274. doi: [10.1590/S1679-62252008000200015](https://doi.org/10.1590/S1679-62252008000200015)
- MMA. 2007. Áreas prioritárias para conservação no Brasil. Accessed at <http://www.mma.gov.br/biodiversidade/projetos-sobre-a-biodiversidade/projeto-de-conservação-e-utilização-sustentável-da-diversidade-biológica-brasileira-probio-i/áreas-prioritárias>, 15 February 2010.
- MMA. 2014. Fauna brasileira ameaçada de extinção. Anexos à Portaria 445 do Ministério do Meio Ambiente, de 17/12/2004, publicada no D.O.U. nº 245, Seção I, pág. 126, de 18/12/2014.
- Moura, R.L. 2000. Brazilian reefs as priority areas for biodiversity conservation in the Atlantic Ocean. *Proceedings of the 9th International Coral Reef Symposium* 2: 917–920.
- Moura, R.L. and R.B. Francini-Filho. 2005. Reef and shore-fishes of the Abrolhos Bank, Brazil; pp. 40–55, in: G.F. Dutra, G.R. Allen, T. Werner and S. McKenna (eds.). *A rapid marine biodiversity assessment of the Abrolhos Bank, Bahia, Brazil*. RAP Bulletin of Biological Assessment 38. Washington: Conservation International.
- Nimer, E. 1989. *Climatologia do Brasil*. 2ª Ed. Rio de Janeiro: IBGE. 422 pp.
- Peters, R.L. 1994. Conserving biological diversity in the face of climate change; pp. 105–132, in: K.C. Kim and R.D. Weaver (eds.). *Biodiversity and landscapes: a paradox of humanity*. Cambridge: Cambridge University Press.
- Pielou, E.C. 1984. *The interpretation of ecological data: a primer on classification and ordination*. New York: John Wiley and Sons. 263 pp.
- Pinheiro, H.T. and A.S. Martins. 2009. Estudo comparativo da captura artesanal do camarão sete-barbas e sua fauna acompanhante em duas áreas de pesca do litoral do estado do Espírito Santo, Brasil. *Boletim do Instituto de Pesca de São Paulo* 35 (2): 215–225. ftp://ftp.sp.gov.br/ftpcesca/35_2_215-225.pdf
- Pinheiro, H.T., A.S. Martins, J.N. Araújo and A.S.S. Pinto. 2009a. Evidence of seasonal changes in community structure for a coastal ecosystem in the central coast of Brazil, south-west Atlantic. *Journal of the Marine Biological Association of United Kingdom* 89(2): 217–224. doi: [10.1017/S0025315408002622](https://doi.org/10.1017/S0025315408002622)
- Pinheiro, H.T., A.L. Ferreira, R.P. Molina, L.M.C. Protti, S.C. Zanardo, J.C. Joyeux and J. Duxsey. 2009b. Profile of social actors as a tool for the definition of marine protected areas: the case of the Ilha dos Franceses, southern coast of Espírito Santo, Brazil. *Natureza & Conservação* 7: 181–194.
- Pinheiro, H.T., J.C. Joyeux and A.S. Martins. 2010a. Reef fisheries and underwater surveys indicate overfishing of a Brazilian coastal island. *Natureza & Conservação* 8: 1–9. doi: [10.4322/natcon.00802008](https://doi.org/10.4322/natcon.00802008)
- Pinheiro, H.T., A.L. Ferreira and J.B. Teixeira (Org.). 2010b. *Diagnóstico Ambiental do litoral sul do estado do Espírito Santo: Estudos complementares para a criação de uma Unidade de Conservação Marinha*. Vitória: Associação Ambiental Voz da Natureza. 228 pp.
- Rocha, L.A., I.L. Rosa and R.S. Rosa. 1998. Peixes recifais da costa da Paraíba, Brasil. *Revista Brasileira de Zoologia* 15(2): 553–566. <http://www.scielo.br/pdf/rbzool/v15n2/v15n2a17>
- Rocha, L.A. 2003. Patterns of distribution and processes of speciation in Brazilian reef fishes. *Journal of Biogeography* 30: 1161–1171. doi: [10.1046/j.1365-2699.2003.00900.x](https://doi.org/10.1046/j.1365-2699.2003.00900.x)
- Sazima, I. 2002. Juvenile snooks (Centropomidae) as mimics of mojarras (Gerreidae), with a review of aggressive mimicry in fishes. *Environmental Biology of Fishes* 65: 37–45. doi: [10.1023/A:1019654721236](https://doi.org/10.1023/A:1019654721236)
- Sazima, I., C. Sazima, R.B. Francini-filho and R.L. Moura. 2000. Daily cleaning activity and diversity of clients of the barber goby, *Elacatinus figaro*, on rocky reefs in southeastern Brazil. *Environmental Biology of Fishes* 59: 69–77. doi: [10.1023/A:1007655819374](https://doi.org/10.1023/A:1007655819374)
- Sazima, I., C. Sazima and J.M. Silva-Jr. 2003. The cetacean offal

- connection: feces and vomits of spinner dolphins as a food source for reef fishes. *Bulletin of Marine Science* 72(1): 151–160. doi: <http://hdl.handle.net/11449/20995>
- Schmid, C., H. Schäfer, G. Podestà and W. Zenk. 1995. The Vitória eddy and its relation to the Brazil current. *Journal of Physical Oceanography* 25: 2532–2546. doi: [10.1175/1520-0485\(1995\)025<2532:TVEAIR>2.0.CO;2](https://doi.org/10.1175/1520-0485(1995)025<2532:TVEAIR>2.0.CO;2)
- Westneat, M.W. and M.E. Alfaro. 2005. Phylogenetic relationships and evolutionary history of the reef fish family Labridae. *Molecular Phylogenetics and Evolution* 36(2): 370–390. doi: [10.1016/j.ympev.2005.02.001](https://doi.org/10.1016/j.ympev.2005.02.001)
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Appendix 1. Species name, institution and voucher number of specimens deposited in museum collections (Table 2).

Table 2. Species name, institution and voucher number of specimens collected in Franceses Island (Espírito Santo state, Brazil) and deposited in museum collections.

Species	Voucher ID	Species	Voucher ID
<i>Abudefduf saxatilis</i>	CIUFES 1034	<i>Hyporhamphus unifasciatus</i>	CIUFES 1914
<i>Acanthurus bahianus</i>	CIUFES 1928	<i>Hypsoblennius invemar</i>	CIUFES 780
<i>Acanthurus chirurgus</i>	CIUFES 1978	<i>Labrisomus kalisherae</i>	CIUFES 806
<i>Acanthurus coeruleus</i>	CIUFES 1979	<i>Larimus breviceps</i>	CIUFES 765
<i>Achirus declivis</i>	CIUFES 1934	<i>Lutjanus jocu</i>	CIUFES 1927
<i>Anchoa filifera</i>	CIUFES 768	<i>Malacoctenus aff. triangulatus</i>	CIUFES 1039
<i>Anisotremus moricandi</i>	CIUFES 1960	<i>Malacoctenus delalandi</i>	CIUFES 801, 1047
<i>Anisotremus surinamensis</i>	CIUFES 1961	<i>Menticirrhus americanus</i>	CIUFES 1897
<i>Apogon americanus</i>	CIUFES 766, 807	<i>Micropogonias furnieri</i>	CIUFES 1940
<i>Archosargus rhomboidalis</i>	CIUFES 1977	<i>Mugil liza</i>	CIUFES 1976
<i>Bathygobius geminatus</i>	CIUFES 1040	<i>Myripristis jacobus</i>	CIUFES 1958
<i>Calamus penna</i>	CIUFES 490, 1908	<i>Ocyurus chrysurus</i>	CIUFES 1953
<i>Cantherhines pullus</i>	CIUFES 1980	<i>Odontognathus mucronatus</i>	CIUFES 1919
<i>Carangoides bartholomaei</i>	CIUFES 1970	<i>Ophichthus ophis</i>	CIUFES 1896
<i>Caranx crysos</i>	CIUFES 1035, 1929	<i>Opisthonema oglinum</i>	CIUFES 1932
<i>Caranx latus</i>	CIUFES 1930	<i>Parablennius marmoratus</i>	CIUFES 781
<i>Cetengraulis edentulus</i>	CIUFES 1943	<i>Paraclinus arcanus</i>	CIUFES 809
<i>Chaetodipterus faber</i>	CIUFES 1899, 1903	<i>Paralichthys brasiliensis</i>	CIUFES 1902
<i>Chilomycterus reticulatus</i>	CIUFES 929	<i>Pareques acuminatus</i>	CIUFES 1964
<i>Chirocentron bleekeri</i>	CIUFES 1922	<i>Pellona harroweri</i>	CIUFES 1926
<i>Chloroscombrus chrysurus</i>	CIUFES 1931	<i>Peprilus paru</i>	CIUFES 1905
<i>Citharichthys macrops</i>	CIUFES 804	<i>Phaeoptyx pigmentaria</i>	CIUFES 767
<i>Citharichthys spilopterus</i>	CIUFES 1935	<i>Prionotus punctatus</i>	CIUFES 1898
<i>Conodon nobilis</i>	CIUFES 1909	<i>Pseudupeneus maculatus</i>	CIUFES 1956
<i>Coryphopterus dicrus</i>	CIUFES 1049	<i>Rhinobatos percellens</i>	CIUFES 1917
<i>Coryphopterus glaucofraenum</i>	CIUFES 1040	<i>Rypticus saponaceus</i>	CIUFES 1952
<i>Ctenogobius saepepallens</i>	CIUFES 1048	<i>Sardinella brasiliensis</i>	CIUFES 1923
<i>Cyclhthys spinosus</i>	CIUFES 1948	<i>Scartella cristata</i>	CIUFES 782, 802
<i>Cynoscion acoupa</i>	CIUFES 764	<i>Scomberomorus brasiliensis</i>	CIUFES 1921, 1975
<i>Cynoscion leiarchus</i>	CIUFES 1911	<i>Scorpaena isthmensis</i>	CIUFES 1036
<i>Decapterus punctatus</i>	CIUFES 1969	<i>Selene setapinnis</i>	CIUFES 1916
<i>Diapterus auratus</i>	CIUFES 489	<i>Selene vomer</i>	CIUFES 1915
<i>Diplacrum formosum</i>	CIUFES 1913	<i>Serranus flaviventris</i>	CIUFES 1037
<i>Diplodus argenteus</i>	CIUFES 1973	<i>Sphoeroides spengleri</i>	CIUFES 1033
<i>Elops saurus</i>	CIUFES 1974	<i>Sphyræna guachancho</i>	CIUFES 1920
<i>Etropus crossotus</i>	CIUFES 1933	<i>Sphyræna tome</i>	CIUFES 1966
<i>Eucinostomus argenteus</i>	CIUFES 492	<i>Stellifer brasiliensis</i>	CIUFES 1904
<i>Eucinostomus lefroyi</i>	CIUFES 491	<i>Stellifer naso</i>	CIUFES 1912
<i>Gymnothorax ocellatus</i>	CIUFES 1947	<i>Stellifer rastrifer</i>	CIUFES 1939
<i>Haemulon aurolineatum</i>	CIUFES 1957	<i>Strongylura marina</i>	CIUFES 904
<i>Haemulon parra</i>	CIUFES 1968	<i>Syacium cf. papillosum</i>	CIUFES 1910
<i>Haemulon plumieri</i>	CIUFES 1959	<i>Syacium micrurum</i>	CIUFES 493
<i>Haemulon steindachneri</i>	CIUFES 560, 1907	<i>Symphurus tessellatus</i>	CIUFES 1936
<i>Halichoeres brasiliensis</i>	CIUFES 1962	<i>Synodus intermedius</i>	CIUFES 1971
<i>Halichoeres poeyi</i>	CIUFES 1955	<i>Trichiurus lepturus</i>	CIUFES 1906
<i>Harengula clupeiola</i>	CIUFES 1963	<i>Tylosurus acus</i>	CIUFES 1895, 1900
<i>Holocentrus ascensionis</i>	CIUFES 1965	<i>Zapteryx brevirostris</i>	CIUFES 882
<i>Hypleurochilus pseudoaequipinnis</i>	CIUFES 783		