

STRUCTURE OF FISH ASSEMBLAGES ON COASTAL ROCKY SHORES OF THE AZORES

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With 4 tables

ABSTRACT. The structure of fish assemblages was investigated from the surface down to 25 m depth on Azorean rocky shores. A total of 57 fish species was recorded by visual censuses, most species (66%) occurring in the whole depth range studied. Fish abundance was dominated by 11 species, mainly sparids, labrids, carangids and pomacentrids, which constituted over 88% of the total number of individuals recorded. The trophic structure of the fish assemblages studied in the Azores was characterized by the dominance of benthic mesocarnivores and high proportions of herbivores and pelagic macrocarnivores.

RESUMO. A estrutura das comunidades ictiológicas dos fundos rochosos dos Açores foi estudada desde a superfície até aos 25 m de profundidade. Um total de 57 espécies de peixes foi identificado com recurso a censos visuais. A maioria das espécies (66%) ocorreu em toda a gama de profundidades estudada. A fauna ictiológica era dominada, em termos de abundância, por 11 espécies, principalmente pertencentes às famílias Sparidae, Labridae, Carangidae e Pomacentridae, os quais constituíram mais de 88% do número total de indivíduos observados. A estrutura trófica das comunidades ictiológicas estudadas nos Açores apresentou-se dominada por meso-carnívoros bentónicos e proporções elevadas de herbívoros e macro-carnívoros pelágicos.

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INTRODUCTION

The archipelago of the Azores, located in the north-eastern Atlantic, represents a “crossroads” where fish species of different geographic origins meet (LLORIS *et al.*, 1991; BRIGGS, 1996). Recently, two checklists of marine fishes of the Azores have been published, indicating that about five hundred fish species occur in that area (ARRUDA, 1997; SANTOS *et al.*, 1997). Intertidal fish assemblages, especially the family Blenniidae, have been well investigated (ARRUDA, 1979; ALMEIDA & HARMELIN-VIVIEN, 1983; SANTOS, 1992; SANTOS *et al.*, 1994, 1995b), but few studies have been published on the distribution of coastal species in deeper waters (PATZNER & SANTOS, 1993; TEMPERA & SANTOS, 1998). During the Bio-Oceanographic survey in the Azores organized in 1979 by the late Professor Luiz Saldanha, the distribution of fishes on coastal rocky shores was studied by visual censuses from the surface down to 40 m, but only preliminary results have been presented in a manuscript of limited circulation (HARMELIN & HARMELIN-VIVIEN, 1979). In the present study, we reanalyse the data obtained in 1979 and present the spatial distribution of fish species according to depth on Azorean coastal rocky shores.

MATERIAL AND METHODS

Sites and visual censuses. The archipelago of the Azores, located between 37°-40° latitude North and 24°-32° longitude West in the north-eastern Atlantic, is composed of nine islands and some small islets. Five islands of the Archipelago were visited during the Bio-Oceanographic Survey in 1979. Visual censuses of fishes were performed by the circular point method (HARMELIN-VIVIEN *et al.*, 1985), mostly between the surface and 25 m depth, with occasional deeper dives (30-42 m). The mean areas sampled by circular points were 350-450 m² during 10 to 15 minutes of observation. During each dive the number of species, number of individuals and size of fishes were recorded on a plastic slate. A total of 27 quantitative censuses were done on five islands, São Miguel (11), Faial (5), Pico (1), São Jorge (2) and Graciosa (8). To specify the ecological distribution of fish species, three depth ranges were distinguished, 0-10 m (n = 9), 11-17 m (n = 10) and 18-25 m (n = 8) for the analysis of data.

List of species. The list of species presented in Table 1 differs slightly from the list in HARMELIN & HARMELIN-VIVIEN (1979) because we verified the identification of several species using underwater photographs taken in the Azores in 1979 and 1991 by J.-G. HARMELIN, and took into account the nomenclature and synonymy of species according to SANTOS *et al.* (1997). Changes due to earlier misidentification are as follows: *Muraena augusti* misidentified as *Gymnothorax maderensis* in 1979, *Chelon labrosus* instead of *Mugil* sp., *Mycteroperca fusca* in

place of *Epinephelus alexandrinus*, *Seriola rivoliana* instead of *Caranx lugubris*, *Tripterygion delaisi delaisi* in place of *Tripterygion* sp., *Labrus bergylta* (green morph) misidentified as *Labrus viridis*, *Sphyaena viridensis* in place of *Sphyaena sphyraena*, *Scorpaena maderensis* for *Scorpaena* sp., and *Sphoeroides marmoratus* for *Sphoeroides spengleri*. Other changes due to synonymy were indicated in SANTOS, *et al.* (1997).

Feeding categories. Seven feeding categories were distinguished according to the main food and feeding behavior of fish species, following the classification of BELL & HARMELIN-VIVIEN (1983) which differs slightly from the classification given by AZEVEDO (1995). Category 1: herbivores (species ingesting over 90% of algae or seagrasses); category 2: omnivores (feeding on both vegetal and animal prey, including detritivores like *Chelon labrosus*); category 3: zooplanktivores or microcarnivores (*Boops boops* was included in this category although it may ingest some floating plant material); category 4: mesocarnivores of the family Labridae (feed mainly on molluscs and small crustaceans); category 5: other mesocarnivores (feed mainly on small crustaceans, polychaetes, molluscs and sessile invertebrates); category 6: nectobenthic macrocarnivores (prey mostly on large crustaceans, cephalopods and fish); category 7: pelagic macrocarnivores (prey on fish, cephalopods, and some crustaceans).

RESULTS

A total of 57 species belonging to 28 families were recorded on the rocky shores of the Azores in 1979 (Table 1). The most diversified families were Labridae (7 spp.), Blenniidae (7 spp.), Carangidae (5 spp.), Sparidae (5 spp.) and Serranidae (4 spp.). Among them, 33 fish species were observed on all the islands surveyed (indicated with an asterisk on Table 1). These species were the most common, as they generally presented high percentages of occurrence at all depth ranges, and also the most numerous, as they formed more than 90% of the total number of individuals recorded.

TABLE 1 - Fish species recorded by visual censuses in the Azores in 1979. Spatial distribution on rocky shores according to depth, with indication of feeding category (diet), mean density (D = mean number of fish per census) and percentage of occurrence (% O = percentage of censuses in which the species was present). (+): species observed between 30 and 42 m deep; - : species not observed in the depth range. The list is organized according to NELSON (1994) and SANTOS *et al.* (1997), and an asterisk indicates the fish species recorded around all the islands surveyed.

| | Diet | D 0-10m | D 11-17m | D 18-25m | >30m | %O 0-10m | %O 11-17m | %O 18-25m |
|---|------|------------|-------------|-------------|------|-------------|--------------|--------------|
| Dasyatidae | | | | | | | | |
| <i>Dasyatis pastinaca</i> (Linnaeus, 1758)* | 6 | 0.11 | 0.20 | 0.50 | | 11 | 20 | 38 |
| Myliobatidae | | | | | | | | |
| <i>Mobula mobular</i> (Bonnaterre, 1788) | 7 | 0.11 | - | - | (+) | 11 | - | - |
| <i>Myliobatis aquila</i> (Linnaeus, 1758)* | 6 | 0.22 | 0.20 | 0.75 | | 22 | 10 | 63 |
| Muraenidae | | | | | | | | |
| <i>Gymnothorax unicolor</i> (Delaroche, 1809)* | 6 | 0.11 | 0.20 | 0.75 | | 11 | 20 | 50 |
| <i>Muraena augusti</i> (Kaup, 1856) | 6 | 0.33 | - | - | | 22 | - | - |
| <i>Muraena helena</i> Linnaeus, 1758 | 6 | 0.22 | - | 0.12 | (+) | 22 | - | 13 |
| Synodontidae | | | | | | | | |
| <i>Synodus saurus</i> (Linnaeus, 1758) | 6 | - | 0.30 | - | | - | 30 | - |
| Phycidae | | | | | | | | |
| <i>Phycis phycis</i> (Linnaeus, 1766)* | 6 | - | 0.20 | 0.50 | | - | 20 | 50 |
| Mugilidae | | | | | | | | |
| <i>Chelon labrosus</i> (Risso, 1826)* | 2 | 22.33 | 1.70 | 0.37 | | 44 | 20 | 25 |
| Belonidae | | | | | | | | |
| <i>Belone belone gracilis</i> (Lowe, 1839) | 7 | - | 3.00 | - | | - | 10 | - |
| Macroramphosidae | | | | | | | | |
| <i>Macroramphosus scolopax</i> (Linnaeus, 1758) | 5 | - | 0.90 | - | | - | 20 | - |
| Scorpaenidae | | | | | | | | |
| <i>Scorpaena maderensis</i> Valenciennes, 1833* | 6 | 1.22 | 2.40 | 1.00 | | 44 | 80 | 25 |
| <i>Scorpaena notata</i> Rafinesque, 1810 | 6 | 0.11 | 20 | 0.37 | | 11 | 10 | 13 |
| <i>Scorpaena scrofa</i> Linnaeus, 1758 | 6 | - | - | - | (+) | - | - | - |
| Serranidae | | | | | | | | |
| <i>Anthias anthias</i> (Linnaeus, 1758) | 3 | - | - | - | (+) | - | - | - |
| <i>Epinephelus marginatus</i> (Lowe, 1834)* | 6 | 0.11 | 0.30 | 1.87 | | 11 | 30 | 88 |
| <i>Mycteroperca fusca</i> (Lowe, 1836) | 6 | 0.22 | 0.10 | 0.25 | | 22 | 10 | 25 |
| <i>Serranus atricauda</i> Günther, 1874* | 6 | 1.33 | 3.10 | 2.75 | (+) | 56 | 90 | 88 |
| Apogonidae | | | | | | | | |
| <i>Apogon (Apogon) imberbis</i> (Linnaeus, 1758)* | 3 | 0.33 | 1.30 | 0.87 | (+) | 22 | 50 | 25 |
| Pomatomidae | | | | | | | | |
| <i>Pomatomus saltator</i> (Linnaeus, 1766) | 7 | - | 0.10 | - | | - | 10 | - |

(Cont. TABLE 1)

| | Diet | D 0-10m | D 11-17m | D 18-25m | >30m | %0 0-10m | %0 11-17m | %0 18-25m |
|---|------|------------|-------------|-------------|------|-------------|--------------|--------------|
| Carangidae | | | | | | | | |
| <i>Pseudocaranx dentex</i> (Bloch & Schneider, 1801) | 7 | 4.00 | 0.20 | 6.00 | | 33 | 10 | 38 |
| <i>Seriola dumerili</i> (Risso, 1810)* | 7 | 1.33 | 0.20 | 0.75 | | 33 | 10 | 25 |
| <i>Seriola rivoliana</i> Cuvier, 1833 | 7 | - | - | 3.75 | | - | - | 13 |
| <i>Trachinotus ovatus</i> (Linnaeus, 1758)* | 7 | 32.67 | 10.50 | 16.87 | | 56 | 20 | 38 |
| <i>Trachurus picturatus</i> (Bowdich, 1825) | 7 | 16.67 | 22.50 | 9.37 | | 22 | 20 | 13 |
| Sparidae | | | | | | | | |
| <i>Boops boops</i> (Linnaeus, 1758)* | 3 | 33.33 | 89.00 | 50.62 | | 78 | 100 | 75 |
| <i>Diplodus sargus cadenati</i> de la Paz, Bauchot & Daget, 1974* | 5 | 51.56 | 40.20 | 46.50 | (+) | 89 | 90 | 88 |
| <i>Pagellus acarne</i> (Risso, 1826)* | 5 | 40.67 | 16.50 | 16.87 | | 67 | 60 | 38 |
| <i>Pagellus bogaraveo</i> (Brünnich, 1768) | 5 | 0.78 | - | - | | 11 | - | - |
| <i>Sarpa salpa</i> (Linnaeus, 1758)* | 1 | 36.56 | 28.70 | 40.25 | | 78 | 80 | 75 |
| Mullidae | | | | | | | | |
| <i>Mullus surmuletus</i> Linnaeus, 1758* | 5 | 5.44 | 2.50 | 0.62 | | 67 | 70 | 38 |
| Kyphosidae | | | | | | | | |
| <i>Kyphosus sectator</i> (Linnaeus, 1766)* | 1 | 0.11 | 0.30 | 0.25 | | 11 | 20 | 13 |
| Pomacentridae | | | | | | | | |
| <i>Abudefduf luridus</i> (Cuvier, 1830)* | 2 | 1.67 | 2.90 | 2.25 | | 67 | 90 | 75 |
| <i>Chromis limbata</i> (Valenciennes, 1833)* | 3 | 13.22 | 26.70 | 8.37 | (+) | 22 | 100 | 88 |
| Labridae | | | | | | | | |
| <i>Centrolabrus trutta</i> (Lowe, 1833)* | 4 | 10.56 | 1.50 | 1.87 | (+) | 78 | 80 | 63 |
| <i>Coris julis</i> (Linnaeus, 1758)* | 4 | 27.56 | 41.90 | 38.37 | | 100 | 90 | 88 |
| <i>Labrus bergylta</i> Ascanius, 1767* | 4 | 0.11 | 0.50 | 1.75 | | 11 | 40 | 50 |
| <i>Labrus bimaculatus</i> Linnaeus, 1758 | 4 | - | - | - | (+) | - | - | - |
| <i>Pseudolepidaplois scrofa</i> (Valenciennes, 1839)* | 4 | 0.78 | 1.10 | 0.87 | | 44 | 70 | 50 |
| <i>Symphodus (Crenilabrus) mediterraneus</i> (Linnaeus, 1758)* | 4 | 0.44 | 0.40 | 0.37 | (+) | 33 | 20 | 25 |
| <i>Thalassoma pavo</i> (Linnaeus, 1758)* | 4 | 7.89 | 1510 | 4.00 | | 100 | 90 | 88 |
| Scaridae | | | | | | | | |
| <i>Sparisoma (Euscarus) cretense</i> (Linnaeus, 1758)* | 1 | 0.78 | 0.50 | 0.50 | | 33 | 40 | 50 |
| Tripterygiidae | | | | | | | | |
| <i>Trypterygion delaisi delaisi</i> Cadenat & Blache, 1971* | 5 | 0.78 | 0.60 | 0.25 | | 33 | 50 | 25 |
| Blenniidae | | | | | | | | |
| <i>Coryphoblennius galerita</i> (Linnaeus, 1758) | 2 | 0.22 | - | - | | 11 | - | - |
| <i>Lipophrys pholis</i> (Linnaeus, 1758) | 2 | 0.22 | - | - | | 11 | - | - |
| <i>Lipophrys trigloides</i> (Valenciennes, 1836) | 2 | 0.67 | - | - | | 33 | - | - |
| <i>Ophioblennius atlanticus atlanticus</i> (Valenciennes, 1836)* | 1 | 3.11 | 0.30 | 0.25 | | 89 | 20 | 25 |
| <i>Parablennius incognitus</i> (Bath, 1968) | 2 | 0.78 | - | - | | 22 | - | - |
| <i>Parablennius parvicornis</i> (Valenciennes, 1836) | 1 | 0.56 | - | - | | 11 | - | - |
| <i>Parablennius ruber</i> (Valenciennes, 1836)* | 2 | 2.56 | 1.00 | 0.87 | | 89 | 40 | 38 |

(Cont. TABLE 1)

| | Diet | D 0-10m | D 11-17m | D 18-25m | >30m | %0 0-10m | %0 11-17m | %0 18-25m |
|---|------|------------|-------------|-------------|------|-------------|--------------|--------------|
| Gobiidae | | | | | | | | |
| <i>Thorogobius ephippiatus</i> (Lowe, 1839) | 5 | - | 0.10 | - | (+) | - | 10 | - |
| Gobiidae sp.* | 5 | 0.33 | 8.20 | - | | 22 | 20 | - |
| Sphyraenidae | | | | | | | | |
| <i>Sphyraena viridensis</i> Cuvier, 1829* | 7 | 5.78 | 0.7 | 62 | | 33 | 50 | 25 |
| Scombridae | | | | | | | | |
| <i>Sarda sarda</i> (Bloch, 1793) | 7 | 1.33 | 0.20 | 16.25 | | 22 | 10 | 38 |
| Bothidae | | | | | | | | |
| <i>Bothus podas maderensis</i> (Lowe, 1834) | 5 | - | 0.40 | - | | - | 30 | - |
| Balistidae | | | | | | | | |
| <i>Balistes carolinensis</i> Gmelin, 1789* | 5 | 1.78 | 1.10 | 1.25 | | 44 | 10 | 13 |
| Tetraodontidae | | | | | | | | |
| <i>Sphoeroides marmoratus</i> (Lowe, 1839)* | 5 | 1.67 | 1.70 | 137 | | 67 | 80 | 75 |

TABLE 2 - Rank and percentage in density (%D) of the most abundant fish species recorded in the Azores and mean total abundance of fish per census in the three depth range surveyed.

| Fish species | 0 - 10 m | | 11 - 17 m | | 18 - 25 | |
|-------------------------------------|----------|------|-----------|------|---------|------|
| | Rank | %D | Rank | %D | Rank | %D |
| <i>Chelon labrosus</i> | 7 | 6.7 | - | 0.5 | - | 0.1 |
| <i>Trachinotus ovatus</i> | 5 | 9.8 | 9 | 3.2 | 5 | 6.0 |
| <i>Trachurus picturatus</i> | 8 | 5.0 | 6 | 6.8 | 8 | 3.3 |
| <i>Boops boops</i> | 4 | 10.0 | 1 | 27.0 | 1 | 18.0 |
| <i>Diplodus sargus cadenati</i> | 1 | 15.5 | 3 | 12.2 | 2 | 16.5 |
| <i>Pagellus acarne</i> | 2 | 12.2 | 7 | 5.0 | 5 | 6.0 |
| <i>Sarpa salpa</i> | 3 | 11.0 | 4 | 8.7 | 3 | 14.3 |
| <i>Chromis limbata</i> | 9 | 4.0 | 5 | 8.1 | 9 | 3.0 |
| <i>Centrolabrus trutta</i> | 10 | 3.2 | - | 0.5 | - | 0.5 |
| <i>Coris julis</i> | 6 | 8.3 | 2 | 12.7 | 4 | 13.6 |
| <i>Thalassoma pavo</i> | 11 | 2.4 | 8 | 4.6 | - | 1.4 |
| <i>Sarda sarda</i> | - | 0.4 | - | 158 | 7 | 5.8 |
| Mean total abundance of fish/census | 332.67 | | 330.00 | | 281.25 | |
| (SD) | 138.21 | | 139.84 | | 223.97 | |

Distribution with depth. The number of fish species recorded decreased slightly with depth, 47 species being observed between the surface and 10 m depth, 44 species between 11 and 17 m, and 41 species between 18 and 25 m. Only 13 species were observed deeper during a few dives between 30 and 42 m depth. The mean overall abundance was about 300 individuals per census and did not vary with depth (Table 2; ANOVA, $F = 0.342$, $p = 0.713$). Most species (38) were observed from the surface

down to 25 m. The bulk of the fish abundance was constituted by only 11 species, *i. e.* by decreasing order of total abundance: *B. boops*, *D. sargus cadenati*, *C. julis*, *S. salpa*, *P. acarne*, *T. ovatus*, *C. limbata*, *T. picturatus*, *T. pavo*, *C. labrosus* and *C. trutta*. These species formed 88.1% of the fish abundance in the 0-10 m depth range, 89.3% at 11-17 m and 88.5% at 17-25 m.

In the shallower waters (0-10 m), the fish assemblage was characterized by the presence of seven species of Blenniidae, the high abundances of the mugilid *C. labrosus* and the wrasse *C. trutta*, the presence of the devil ray *M. mobular* and the abundance of several mid-water species such as *S. dumerili*, *T. ovatus* and *P. acarne*. Only two among the blenniid species, *O. atlanticus* and *P. ruber*, were observed in deeper waters, but their abundance was maximum between the surface and 5 m depth. Between 11 and 17 m, the most abundant species were the sparids *B. boops*, *D. sargus cadenati* and *S. salpa*, the damselfish *C. limbata* and the labrids *C. julis* and *T. pavo* (Tables 1 and 2). The two pomacentrids *A. luridus* and *C. limbata* exhibited their highest abundance in this depth range, as well as the serranid *S. atricauda*, and the labrids *C. julis*, *P. scrofa* and *T. pavo*. Between 18 and 25 m depth, the six dominant species remained the same. In this depth range, serranids were more numerous, especially the dusky grouper *E. marginatus*. The abundance of the labrid *L. bergylta* was maximum in this depth range. Three species were recorded only deeper than 30 m, the scorpaenid *S. scrofa*, the zooplanktophagous serranid *A. anthias* which formed large schools and the labrid *L. bimaculatus*.

TABLE 3 - Trophic structure of fish assemblages on rocky shores of the Azores expressed as percentages of fish abundance (%) in each depth range.

| Feeding category | N of species | 0 - 10 m % | 11 - 17 m % | 18 - 25 m % |
|-------------------------------------|--------------|------------|-------------|-------------|
| 1 - Herbivores | 5 | 12.36 | 9.03 | 14.67 |
| 2 - Omnivores | 7 | 8.55 | 1.69 | 1.24 |
| 3 - Zooplanktivores | 4 | 14.09 | 35.45 | 21.29 |
| 4 - Mesocarnivores (labrids) | 7 | 14.23 | 18.33 | 16.80 |
| 5 - Mesocarnivores (other families) | 11 | 30.96 | 21.88 | 23.78 |
| 6 - Benthic macrocarnivores | 13 | 1.20 | 2.27 | 3.15 |
| 7 - Pelagic macrocarnivores | 10 | 18.60 | 11.33 | 19.06 |

Trophic structure. The trophic structure of the fish assemblage did not vary much with depth (Table 3). The main trophic guild was formed by the mesocarnivores (categories 4 and 5) which represented around 40% of the fish abundance at all depths. The zooplanktivores were the second largest trophic guild and were particularly abundant between 11 and 17 m depth. The third trophic guild, by decreasing order of abundance,

was the pelagic macrocarnivores which represented 11% to 19% of the fish recorded on the rocky shores of the Azores. The herbivores constituted 9 to 15% of the fish abundance, and were dominated by the sparid *S. salpa*. The omnivores were important only in shallow waters (*C. labrosus* and most blenniids), whereas the benthic macrocarnivores were the least abundant trophic guild despite a high species richness. The relative abundance of benthic macrocarnivores increased slightly with depth, but remained at a low level (3%).

DISCUSSION

Despite the particular interest of the archipelago of the Azores in terms of biogeographic relationships, due to its remote position in the mid-Atlantic (LORIS *et al.*, 1991; SALDANHA, 1995; SANTOS *et al.*, 1995a), little attention has been paid to the ecological distribution of fish species along the coasts except for a few studies on intertidal fish assemblages on rocky and sandy areas (ARRUDA, 1979; NASH *et al.*, 1994; SANTOS *et al.*, 1994; AZEVEDO *et al.*, 1995). In the present paper, we described the qualitative, quantitative and trophic structure of the fish assemblage on the rocky shores of the Azores in three depth ranges from the surface down to 25 m depth. The fish assemblages observed appeared to be quite homogeneous (> 66% of species recorded in the three depth ranges) and numerically dominated by a small number of species (11 forming over 88% of the abundance at all depths). The most abundant species belonged to the families Sparidae, Labridae, Carangidae and Pomacentridae. However, the shallower zone differed from the deeper zones by the abundance of blenniids, mugilids and several pelagic species which only occurred there. The most conspicuous inhabitants of the intertidal rock pools are blenniids, the distribution, biology and behavior of which have been thoroughly investigated in the Azores (see references in SANTOS *et al.*, 1997), where they are the most conspicuous inhabitants of the intertidal rock pools. As also noticed by PORTEIRO *et al.* (1996), *Coris julis* and *Thalassoma pavo* were the most abundant wrasses observed during the Bio-Oceanographic Survey in the Azores. They also observed as we did, that *Centrolabrus trutta* was most abundant in shallow waters, whereas *Labrus bergylta* and *L. bimaculatus* were more abundant in deep water. We observed an increasing abundance of large individuals of the dusky grouper *Epinephelus marginatus* with depth, while juveniles colonised very shallow habitats. Similarly, AZEVEDO *et al.* (1995) found a great abundance of juveniles of the dusky grouper in tide pools.

The trophic structure of fish assemblages observed between the surface and 25 m depth on rocky shores of the Azores differed from that described by AZEVEDO (1995), which was based on the number of species in each feeding category and not on numbers of individuals. For instance, benthic macrocarnivores were highly diversified (13 species), but presented very low abundances. Few fish species were herbivorous

(4), but the population of at least one species, *Sarpa salpa*, was large. The trophic structure of the fish assemblages surveyed in the Azores was characterized by higher proportions of pelagic macrocarnivores and herbivores (respectively 11-19% and 9-15% of the fish abundance) than those from visual censuses undertaken in other islands of the Macaronesian archipelagos, Portugal and the Mediterranean Sea in similar habitats and depth range. In Madeira, pelagic macrocarnivores constituted 12% and herbivores 4% of the fishes recorded by ANDRADE *et al.* (1995), whereas in El Hierro, Canary Islands, these two trophic guilds represented respectively only 1% and 5% (BORTONE *et al.*, 1991). On continental Portugal, pelagic macrocarnivores formed 0.5% of the fish abundance observed in the marine reserve of Berlenga, and herbivores 4% (ALMEIDA, 1996). In the marine reserve of Port-Cros, NW Mediterranean, they represented respectively only 0.8% and 2% of the abundance of fishes recorded at 10-15 m by HARMELIN (1987).

The fish assemblage described from the rocky shores of the Azores was highly similar to those described with similar methods (visual censuses) in Madeira by ANDRADE & ALBUQUERQUE (1995) and in El Hierro, Canary islands, by BORTONE *et al.* (1991), with about 2/3 of the species in common (Table 4). The proportions of species in common with fish assemblages from continental Europe were markedly lower: 33% of that recorded on Portugal coasts by ALMEIDA (1996), and only 25-27% of assemblages from north-western Mediterranean (HARMELIN, 1987; GARCIA RUBIES, 1997). These contrasting affinities clearly attested the biogeographic specificity of the fish fauna of the Macaronesian Archipelagos (LLORIS *et al.*, 1991).

TABLE 4 - Number of fish species (N total) recorded by visual census on rocky habitats on different islands of the Macaronesian Archipelagos, continental Portugal and in the Mediterranean Sea, with indication of the number of species in common with the Azores (N common) and the percentage represented (%) by these species in the local fish assemblages.

| Site | N total | N common | % | Reference |
|-----------------------|---------|----------|------|-------------------------------|
| Madeira | 31 | 20 | 64.5 | Andrade and Albuquerque, 1995 |
| El Hierro, Canary Is. | 47 | 30 | 63.8 | Bortone <i>et al.</i> , 1991 |
| Berlenga, Portugal | 51 | 17 | 33.3 | Almeida, 1996 |
| Medas Is., Spain | 65 | 18 | 27.7 | Garcia Rubies, 1997 |
| Port-Cros Is., France | 47 | 12 | 25.5 | Harmelin, 1987 |

ACKNOWLEDGEMENTS

We express our thanks to the Portuguese Navy, the Government of the Azores, the University of the Azores, the Agriculture Services of the Azores, and the local diving Clubs for their efficient help and support during this survey. Special thanks are expressed to João Gomes and Pedro Ré for diving and sampling assistance. This paper is dedicated to the late Professor Luiz Saldanha, our friend and colleague, who organized the Bio-Oceanographic survey in the Azores.

REFERENCES

ALMEIDA, A. J.:

1996. Structure and spatial variability of the rocky fish fauna in the protected marine «Reserva natural da Berlenga» (Portugal). *Arquivos do Museu Bocage*, Nova Série, **2** (35): 633-642.

ALMEIDA, A. J. & M. L. HARMELIN-VIVIEN:

1983. Quelques notes sur des Blenniidae observés et capturés aux Açores en 1979 (Pisces: Blenniidae). *Cybium*, **7**: 39-45.

ANDRADE, C. A. P. & F. M. M. ALBUQUERQUE:

1995. Fish assemblages associated with bottom habitats on the south coast of Madeira. *Boletim do Museu Municipal do Funchal*, Suplemento n.º **4**: 9-20.

ARRUDA, L. M.:

1979. On the study of a sample of fish captured in the tidal range at Azores. *Boletim da Sociedade Portuguesa de Ciências Naturais*, **19**: 5-36.
1997. Checklist of the marine fishes of the Azores. *Arquivos do Museu Bocage*, Nova Série, **3** (2): 13-164.

AZEVEDO, J. M. N.:

1995. Food web of the Azorean shallow water marine ichthyological communities: a guild approach. *Boletim do Museu Municipal do Funchal*, Suplemento n.º **4**: 29-53.

AZEVEDO, J. M. N., J. B. RODRIGUES, M. MENDIZABAL & L. M. ARRUDA:

1995. Study of a sample of dusky groupers, *Epinephelus marginatus* (Lowe, 1834), caught in a tidal pool at Lajes do Pico, Azores. *Boletim do Museu Municipal do Funchal*, Suplemento n.º **4**: 55-64.

BELL, J. D. & M. L. HARMELIN-VIVIEN:

1983. Fish fauna of French Mediterranean *Posidonia oceanica* seagrass meadows. II: Feeding habits. *Téthys*, **11**: 1-14.

BORTONE, S. A., J. Van TASSEL, A. BRITO, J. M. FALCÓN & C. M. BUNDRICK:

1991. A visual assessment of the inshore fishes and fishery resources off El Hierro, Canary Islands: A baseline survey. *Scientia Marina*, **55**: 529-541.

BRIGGS, J. C.:

1996. *Global Biogeography. Development in Paleontology and Stratigraphy*, 14. Elsevier Science, 472 pp.

GARCIA RUBIES, A.:

1997. *Estudi ecològic de les poblacions de peixos litorals sobre substrat rocòs a la Mediterrània occidental: efectes de la fondària, el substrat, l'estacionalitat i la protecció*. PhD Thesis, Department of Ecology, University of Barcelona, 261 pp.

HARMELIN, J.-G.:

1987. Structure et variabilité de l'ichtyofaune d'une zone rocheuse protégée en Méditerranée (Parc National de Port-Cros, France). *P. S. Z. N. I: Marine Ecology*, **8**: 263-284.

HARMELIN, J.-G. & M. L. HARMELIN-VIVIEN:

1979. Mission Bio-Océanographique 1979 aux Açores: Rapport préliminaire. In: Missão Bio-Oceanográfica Açores 79 (Coord.: L. Saldanha), 4 pp. + 4 tables. Faculdade de Ciências de Lisboa.

HARMELIN-VIVIEN, M. L., J.-G. HARMELIN, C. CHAUVET, C. DUVAL, R. GALZIN, P. LEJEUNE, G. BARNABE, F. BLANC, R. CHEVALIER, J. DUCLERC & G. LASSERRE:

1985. Evaluation visuelle des peuplements et populations de poissons: Méthodes et problèmes. *Revue d'Ecologie (Terre Vie)*, **40**: 467-539.

LLORIS, D., J. RUCABADO & H. FIGUEROA:

1991. Biogeography of the Macaronesian ichthyofauna (The Azores, Madeira, the Canary Islands, Cape Verde and the African enclave). *Boletim do Museu Municipal do Funchal*, **43** (234): 191-241.

NASH, R. D. M., R. S. SANTOS & S. J. HAWKINS:

1994. Diel fluctuations of a sandy beach fish assemblage at Porto Pim, Azores. *Arquipélago - Life and Marine Sciences*, **12A**: 75-86.

NELSON, J. S.:

1994. *Fishes of the World* (3rd. Edition). John Wiley & Sons, Inc., New York, 600 pp.

PATZNER, R. A. & R. S. SANTOS:

1993. Ecology of rocky littoral fishes of the Azores. *Courier Forschungsinstitut Senckenberg*, **159**: 423-427.

PORTEIRO, F. M., J. P. BARREIROS & R. S. SANTOS:

1996. Wrasses (Teleostei: Labridae) of the Azores. *Arquipélago - Life and Marine Sciences*, **14A**: 23-40.

SALDANHA, L.:

1995. *Fauna submarina Atlântica - Portugal continental, Açores, Madeira* (2^a Edição). Publicações Europa-América, Lisboa, 364 pp.

SANTOS, R. S.:

1992. *Behavioural ecology, phenology and ethology of an intertidal blenny, Parablennius sanguinolentus parvicornis (Valenciennes in Cuvier & Valenciennes 1836) (Pisces: Blenniidae), from the Azores*. PhD Thesis. Department of Environmental and Evolutionary Biology, University of Liverpool, 293 pp.

SANTOS, R. S., F. M. PORTEIRO & J. P. BARREIROS:

1997. Marine fishes of the Azores. Annotated checklist and bibliography. *Arquipélago - Life and Marine Sciences*, Suplemento **1**: 1-244.

SANTOS, R. S., R. D. M. NASH & S. J. HAWKINS:

1994. Fish assemblages on intertidal shores of the Island of Faial, Azores. *Arquipélago - Life and Marine Sciences*, **12A**: 87-100.

1995b. Age, growth and sex ratio of the Azorean rock-pool blenny, *Parablennius sanguinolentus parvicornis*. *Journal of Marine Biological Association of the United Kingdom*, **75**: 751-754.

SANTOS, R. S., S. J. HAWKINS, L. R. MONTEIRO, M. ALVES & E. J. ISIDRO:

1995a. Marine research, resources and conservation in the Azores. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **5**: 311-354.

TEMPERA, F. & R. S. SANTOS:

1998. Spatial variability of fish assemblages in the Pico-Faial channel (Azores-Portugal). International Symposium on «Behaviour and conservation of littoral fishes», Lisboa, April 1998, Abstract, p. 71.

Date received: 21-04-1998.