

# FISH LARVAE AND ZOOPLANKTON BIOMASS AROUND FAIAL ISLAND (AZORES ARCHIPELAGO). A PRELIMINARY STUDY OF SPECIES OCCURRENCE AND RELATIVE ABUNDANCE

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Plankton hauls were conducted off Faial island (Azores archipelago, NE Atlantic), to a depth of 100 m, between February and June 1998, covering the spawning period of a number of commercially important fish species. Seventy-three fish larvae taxa were identified, of which 51 were quantified, one of them a new record for the region, *Glossanodon leioglossus* (Valenciennes, 1848). The fish larvae community was dominated by mesopelagic and bathypelagic elements (namely Myctophidae and Gonostomatidae), a typical oceanic island environment composition. Total zooplankton showed a biomass peak in May that could correspond to the Spring “bloom”. However, the fish larvae showed an abundance minimum in May and a maximum in June, presenting a general negative relationship with zooplankton biomass and indicating a temporal asynchrony between their annual cycles of production. The comparison of fish larvae abundance with those of other NE Atlantic regions suggests that the zooplankton production in the Azores may be similar to the one found in the Iberian Peninsula continental shelf. Significant spatial density gradients (for fish larvae and zooplankton) were not found with either bathymetry or distance from shore.

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## INTRODUCTION

Studies of fish larvae are important for numerous marine biology areas, particularly for biogeography and fisheries studies. As fish larvae live in a highly dynamic biological environment being a very small part of a system dominated by a great diversity of predators and competitors (MCGOWAN & MILLER 1980), to properly investigate this group's ecology it is important to know the composition, abundance and distribution of the whole zooplanktonic community. Moreover, the reciprocal relations between zooplankton and ichthyoplankton have enormous importance being able to impact stock size regulation for innumerable fish species (RODRÍGUEZ & RUBÍN 1991). However, the study of events in plankton ecology has always been

very difficult due to the highly variable (moving) nature of the system (RÉ 1984a).

In the Azores Region, only two studies involving fish larvae have been published: a study of the *Abudefduf luridus* by RÉ (1980) and a preliminary incomplete ichthyoplankton characterization by CHÍCHARO & TEODÓSIO (1990).

The following main objectives were defined for the present study: characterize the seasonal and spatial distribution (investigating the eventual occurrence of density gradients with the coastal distance and bathymetry) of the zooplankton and fish larvae communities; study the relation between these two groups and to identify the maximum number of larvae species possible in the vicinity of an island in a period of known spawning and larvae development.

## MATERIAL AND METHODS

### Sampling strategy

Plankton sampling was conducted by pelagic tows at night at five fixed stations off the southern coast of Faial island, Azores archipelago (NE Atlantic), on board R/Y ÁGUAS VIVAS (see study area in Fig. 1). The tows were made monthly between February and June 1998 (with the exception of April) with a Bongo net of 60 cm mouth diameter with two different mesh sizes,

335 $\mu$ m and 500 $\mu$ m. Each month, all stations were sampled during one night. The tows were made with a double oblique design until a maximum depth of 100 m using standard methodology (SMITH & RICHARDSON 1977; OMORI & IKEDA 1984), during approximately 30 min., at a velocity between 1.5 and 3 knots. Net monitoring and instant depth control was carried out with the angle method (SMITH & RICHARDSON 1977). Towing depth profiles were verified with a mini datalogger attached to the net (Vemco's TDR). The total volume of filtered water was measured with two flowmeters (G.O. ref. 2030R).

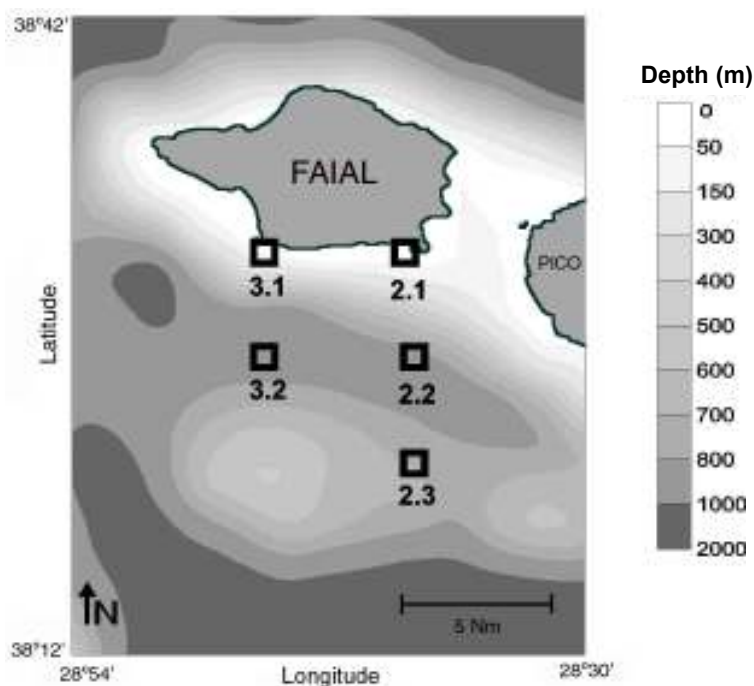


Fig. 1. Sampling stations in the study area – Faial Island, Azores archipelago, NE Atlantic.

### Terminology

Ichthyoplankton is composed by the eggs and larval stages of bony fishes (Osteichthyes). In this study we considered only the larvae (FL), following the terminology adopted by MOSER et al. (1984) and RÉ (1984a) who considered all stages between egg eclosion and transformation (that coincides with the end of the planktonic phase).

For zooplankton we considered two subgroups:

a) Partial zooplankton (PZ), formed by the organisms with individual volumes less than 5 ml that includes the mesozooplankton division (SIEBURTH et al. 1978), mainly composed of crustaceans, chaetognaths, molluscs and siphonophores.

b) Megaloplankton (MZ) formed by organisms with individual volume greater than 5 ml that includes the macrozooplankton and

megazooplankton divisions (SIEBURTH et al. 1978), mainly composed of larger specimens of medusae, tunicates, ctenophores and siphonophores.

These last two groups together were termed total zooplankton (TZ).

#### Sample treatment and data analysis

The zooplankton samples were initially fixed in formalin 5% (salt water) neutralized with borax (PH=8-8.5) and later preserved in ethanol 70% (fresh water) using standard methodology (SMITH & RICHARDSON 1977; OMORI & IKEDA 1984). The biomass of PZ and MZ were estimated by measuring the displaced volume of the filtered samples (AHLSTROM & THRAILKILL 1962 in CIECHOMSKI & SANCHEZ 1983). The fish larvae were sorted without any sub sampling.

The FL abundance is expressed in number of larvae/100m<sup>3</sup> (of filtered water) and zooplankton biomass in ml/100m<sup>3</sup>. As the maximum depth for all the tows was similar (100 m), the results of abundance and biomass can be equally read as per m<sup>2</sup>, which is useful for comparison with results from other studies.

Because the number of samples was low (19) and because the data of FL abundance, PZ and TZ biomass did not follow a Normal distribution – see Appendix 1, the statistical analysis was performed using non-parametric methods.

To compare the samples between the two mesh sizes of the Bongo net we used the Wilcoxon's signed rank test (SIEGEL 1956; CAMPBELL 1974). The Spearman's correlation coefficient (SIEGEL 1956; ZAR 1996) was used to test for the relations between biotic variables (PZ, MZ, FL) and the bathymetry and distance from the coast. The bathymetric values used were the average bottom depth for the area covered by each station.

We did not analyze the FL data through diversity indices because of the high proportions of unidentified larvae.

## RESULTS

### a. Quantitative differences between mesh sizes

Of a total of 3925 ml of partial zooplankton biomass quantified during the sampling period, 2072 ml were collected with the 335 µm mesh size while 1853 ml were collected with the 500 µm; the data relative to the volume of filtered water (ml/100m<sup>3</sup>) reveals a proportion of 1.19:1 between the harvests of the two mesh sizes.

Of a total of 12816 fish larvae counted, 7441 were captured with the 335 µm mesh, while 5375 were collected with the 500 µm; the data relative to the volume of filtered water (number of larvae/100m<sup>3</sup>) reveals a proportion of 1.51:1 between the catches of the two mesh sizes.

Figures 2 and 3 present the biomass of PZ and MZ as well as the FL abundance by station and month and suggest that there are persistent differences in the catchability of the nets. The results of the Wilcoxon's matched pairs test applied to the complete data set are given in Table 1 and confirm these graphical indications. The 335µm net captured greater biomass of PZ and higher numbers of FL, but the harvests of MZ were similar for both mesh sizes. Based on this result and following GRIOCHE & KOUBBI (1997), the data of PZ, TZ and FL will be presented separately (by mesh size) and the MZ presented in average.

Table 1

Wilcoxon's test results for the differences of partial zooplankton biomass, of megaloplankton biomass and of fish larvae community abundance, between the two mesh sizes. The complete set of data was used.

|    |                        |
|----|------------------------|
| PZ | T =29, p =0.008, n =19 |
| MZ | T =6, p =0.093, n =9   |
| FL | T =10, p =0.001, n =19 |

Note: The test for the megaloplankton was only conducted in the months with sufficient captures.

b. Monthly distribution

There was a clear peak of PZ biomass in May and a MZ distribution "window" almost restricted to this month (Fig. 2). A great increase of FL abundance is evident in June (Fig. 3) after some lower fluctuations in the first months. To compare these FL abundance results we refer to other Northeast Atlantic studies (Table 2).

c. Spatial distribution, relation with coastal distance and bathymetry

Usually, the bottom depths increase when the distance from the coast increases, thus are generally used as a single variable (POWLES et al. 1984). However, this is not true in our case

because the bottom depth of station 2.3 is shallower than at stations 2.2 and 3.2 (Fig. 1). In this scenario, we investigated the correlation between each of these two variables and the FL and PZ, for each mesh size data set. The obtained Pearson's correlation coefficients are given in Table 3.

Regarding PZ, the results indicated a trend for weak positive correlations (statistically significant for the 335  $\mu\text{m}$  mesh size, but not significant for the 500  $\mu\text{m}$ ) with both the environmental parameters. The results for FL indicated a trend for a weak positive correlation (though not statistically significant) with depth for the 335  $\mu\text{m}$  mesh. On the other hand, for the 500  $\mu\text{m}$  mesh size, there is significant positive correlation with coastal distance.

Table 2  
Comparison of observed fish larvae maximum abundances with other works in the Northeast Atlantic using very similar methodologies.

| Maximum abundance                | Month     | Sampling period        | Study location                                  | Mesh size         | References             |
|----------------------------------|-----------|------------------------|---|-------------------|------------------------|
| 376.4 larvae/100m <sup>3</sup>   | June      | February to June, 1998 | Faial island, Açores archipelago                | 335 $\mu\text{m}$ | Present study          |
| ⊕ 185.4 larvae/100m <sup>3</sup> | June      | February to June, 1998 | Faial island, Açores archipelago                | 335 $\mu\text{m}$ | Present study          |
| ⊕ 165 larvae/m <sup>2</sup>      | September | 1988                   | Canary archipelago, Spain                       | 335 $\mu\text{m}$ | RODRIGUEZ et al. 1990  |
| 337.3 larvae/m <sup>2</sup>      | April     | April, 1987            | Galicia, Spain                                  | 335 $\mu\text{m}$ | RODRÍGUEZ & RUBÍN 1991 |
| ⊕ 46.8 larvae/100m <sup>3</sup>  | April     | 1979 and 1980          | Peniche, Portugal                               | 505 $\mu\text{m}$ | RÉ 1984a               |
| ⊕ 75 larvae/100m <sup>3</sup>    | May       | 1981 and 1982          | Sines, Portugal                                 | 505 $\mu\text{m}$ | RÉ 1984a               |
| ⊕ 182.8 larvae/100m <sup>3</sup> | April     | 1981                   | Between cape Espichel and cape Sardão, Portugal | 505 $\mu\text{m}$ | AFONSO 1989            |
| ⊕ 320.7 larvae/100m <sup>3</sup> | March     | 1983                   | Between cape Espichel and cape Sardão, Portugal | 505 $\mu\text{m}$ | AFONSO 1989            |

⊕ - Average abundance for a set of sampling stations.

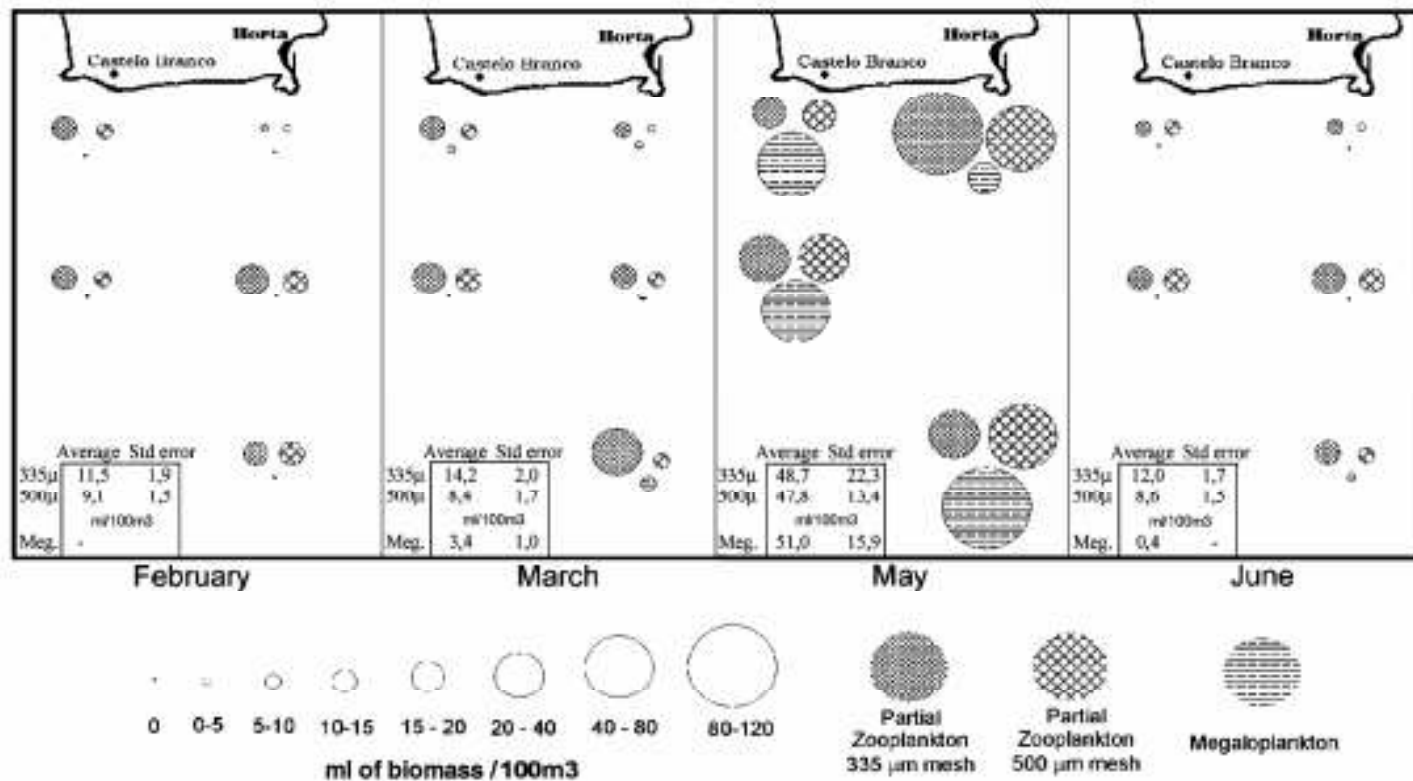


Fig. 2. Spatial distribution of partial zooplankton (PZ) and megaloplankton (MZ) biomass (ml/100m<sup>3</sup>) by month, for both mesh sizes. Note : The 2.2 May sample was lost.

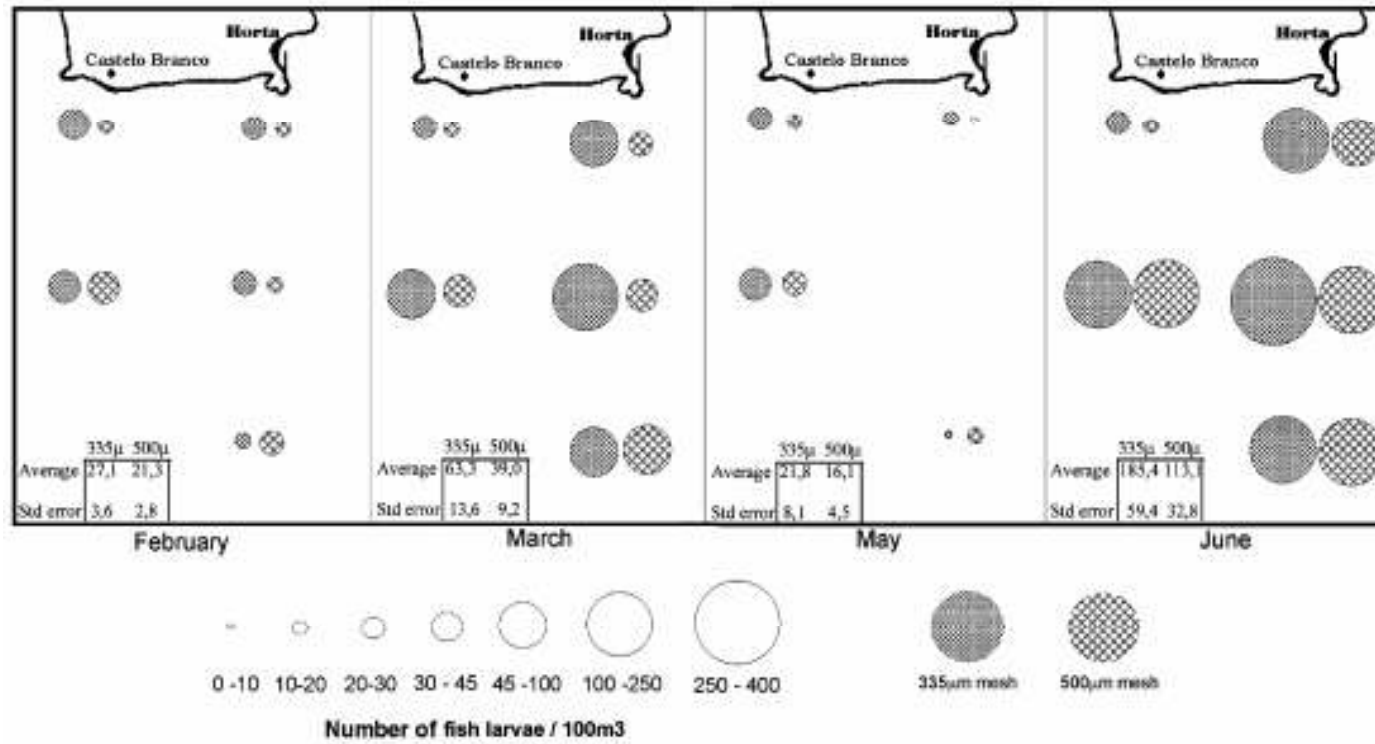


Fig. 3. Spatial distribution of fish larvae (FL) community abundance (n°/100m³) by month, for both mesh sizes. Note : The 2.2 May sample was lost.

Table 3  
Spearman's correlation coefficient (R) between partial zooplankton biomass / fish larvae abundance and coastal distance and water depth, for the complete data set of each mesh size.

|           | 335µm                   |                         | 500µm                   |                         |
|-----------|-------------------------|-------------------------|-------------------------|-------------------------|
|           | Coastal distance        | Water depth             | Coastal distance        | Water depth             |
| <b>PZ</b> | R =0.47, p =0.04, n =19 | R =0.42, p =0.03, n =19 | R =0.25, p =0.31, n =19 | R =0.28, p =0.26, n =19 |
| <b>FL</b> | R =0.14, p =0.55, n =19 | R =0.30, p =0.21, n =19 | R =0.46, p <0.05, n =19 | R =0.72, p =0.17, n =19 |

Note: The megaloplankton data were insufficient to be included in this analysis.

d. Relationship between the fish larvae community and the zooplankton (PZ and TZ)

RODRÍGUEZ & RUBÍN (1991) admitted that the ideal condition to study eventual relations between these two communities is that both follow the same distribution model. This condition was valid in the present work (see Appendix 1). The differences between these two groups were clear between the various months and it was in this context that we analyzed this relationship. The simple observation of Fig. 4 indicates a general trend for a negative association between the FL and both PZ and TZ. The Spearman's correlation analysis also indicates a negative correlation (weak and not statistically significant) between FL and PZ when all the data set is used (R= -0.18, n= 38, p= 0.27). However, it is obvious, comparing Fig. 2 and Fig. 3, that for the May-June sub-set this negative correlation is stronger. The Spearman's correlation coefficients of FL vs PZ and of FL vs TZ applied to these months confirmed it, showing R= -0.44, p= 0.07 and R= -0.55, p=0.01 respectively, for n=18.

e. Fish larvae community characterization

This work resulted in 73 identified taxa belonging to 29 families. Of these taxa, 59 were identified to genus or species. The identified taxa and corresponding abundances are listed in Tables 4 and 5. In Appendix 2 are listed the taxa that were identified but still not quantified because of

substantial doubts about their taxonomical identification.

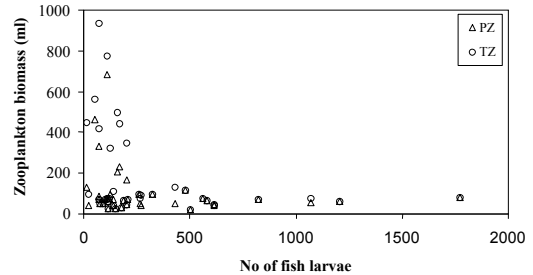


Fig. 4. Abundance of fish larvae (FL) community as a function of partial and total zooplankton (PZ and TZ) biomass.

To characterize the diversity of the fish larvae community we referred only to a specific richness estimation, the number of taxa – see Tables 4 and 5. The most abundant and/or important taxonomical components of the community are summarized in the Table 6 and Fig. 5. The FL samples were dominated, throughout the 5 months period, by only two Families, firstly Myctophids and secondly Gonostomatids. Although in small amounts, we found other ecological groups represented, for example: deep sea - Macrouridae and *Cryptopsaras couesi*; neritic / demersal - *Conger conger* and *Phycis phycis*; shallow waters - *Synodus saurus* and *Bothus podas*; epipelagic - *Sardina pilchardus* and *Trachurus picturatus*; migratory - *Anguilla* sp.

For our data, the dynamics of the two species of the genus *Ceratoscopelus* (mainly *C. madeirensis*) call for attention because of their tremendous abundance and dominance in June following relatively low values in the Winter/Spring months.

f. New record

During the identification of fish larvae a new record for the Azores fish fauna was encountered:

*Glossanodon leioglossus* (Valenciennes, 1848) synonym of *Argentina leioglossa* (Cuvier & Valenciennes, 1848), commonly known as small-toothed argentine (Fig. 6).

Table 4

Identified fish larvae with corresponding abundances (no of larvae/100m<sup>3</sup>) and proportions (%), for February and March and both mesh sizes. This list was organized by Families according to NELSON (1994). The genera and species are in alphabetical order and the scientific names were adopted from WHITEHEAD et al. (1989). Note: The taxa listed as A111, B3 and J5 were species with easily discernable individuals but not yet taxonomically identified.

\* - taxa of commercial interest; \*\* - taxa of shallow waters.

| Taxa                              | February                                |             |   |             | March                                   |             |   |             |
|-----------------------------------|---|-------------|---|-------------|---|-------------|---|-------------|
|                                   | 335µm                                   |             | 500µm                                   |             | 335µm                                   |             | 500µm                                   |             |
|                                   | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample |
| <b>Anguillidae</b>                |   |             |   |             |   |             |   |             |
| * ** <i>Anguilla</i> sp.          |   |             |   |             |   |             |   |             |
| <b>Congridae</b>                  |   |             |   |             |   |             |   |             |
| * <i>Conger conger</i>            | 0.04                                    | 0.13        |   |             | 0.03                                    | 0.06        |   |             |
| <i>Gnathopis</i> sp.              |   |             |   |             |   |             |   |             |
| <b>Nettastomatidae</b>            |   |             |   |             |   |             |   |             |
| <i>Facciolella oxyrhyncha</i>     |   |             |   |             | 0.03                                    | 0.06        |   |             |
| <b>Clupeidae</b>                  |   |             |   |             |   |             |   |             |
| * ** <i>Sardina pilchardus</i>    | 0.03                                    | 0.13        |   |             |   |             |   |             |
| <b>Argentinidae</b>               |   |             |   |             |   |             |   |             |
| <i>Argentina leioglossa</i>       | 0.07                                    | 0.26        |   |             |   |             | 0.03                                    | 0.08        |
| <b>Bathylagidae</b>               |   |             |   |             |   |             |   |             |
| unidentified                      | 0.04                                    | 0.13        | 0.03                                    | 0.15        |   |             | 0.03                                    | 0.08        |
| <b>Gonostomatidae</b>             |   |             |   |             |   |             |   |             |
| <i>Cyclothone</i> spp.            | 1.78                                    | 6.45        | 0.90                                    | 4.26        | 7.40                                    | 11.56       | 4.16                                    | 10.63       |
| <i>Ichthyococcus ovatus</i>       |   |             |   |             | 0.03                                    | 0.06        | 0.06                                    | 0.17        |
| <i>Vinciguerria poweriae</i>      |   |             |   |             | 0.07                                    | 0.11        | 0.06                                    | 0.17        |
| <i>Vinciguerria attenuata</i>     |   |             |   |             | 0.53                                    | 0.85        | 0.48                                    | 1.25        |
| <i>Vinciguerria nimbaria</i>      |   |             | 0.03                                    | 0.15        | 0.28                                    | 0.45        | 0.07                                    | 0.17        |
| <i>Vinciguerria</i> spp.          |   |             |   |             | 0.40                                    | 0.62        | 0.45                                    | 1.16        |
| <b>Sternoptychidae</b>            |   |             |   |             |   |             |   |             |
| <i>Mauroliscus muellerii</i>      | 1.79                                    | 6.58        | 2.12                                    | 10.05       | 4.62                                    | 7.16        | 3.35                                    | 8.47        |
| <i>Sternoptyx</i> sp. ?           | 0.04                                    | 0.13        | 0.03                                    | 0.15        |   |             |   |             |
| <b>Stomiidae</b>                  |   |             |   |             |   |             |   |             |
| <i>Chauliodus</i> spp.            | 0.10                                    | 0.39        | 0.06                                    | 0.30        | 0.53                                    | 0.85        | 0.78                                    | 1.99        |
| <i>Stomias</i> spp.               |   |             |   |             | 0.11                                    | 0.17        | 0.06                                    | 0.17        |
| <b>Synodontidae</b>               |   |             |   |             |   |             |   |             |
| * <i>Synodus saurus</i>           |   |             |   |             |   |             |   |             |
| <b>Paralepididae</b>              |   |             |   |             |   |             |   |             |
| unidentified                      | 0.18                                    | 0.66        | 0.27                                    | 1.22        | 0.10                                    | 0.17        | 0.06                                    | 0.17        |
| <b>Myctophidae</b>                |   |             |   |             |   |             |   |             |
| <i>Ceratoscopelus madeirensis</i> |   |             |   |             | 0.10                                    | 0.17        | 0.03                                    | 0.08        |
| <i>Ceratoscopelus warmingii</i>   |   |             |   |             |   |             |   |             |
| <i>Ceratoscopelus</i> spp.        |   |             |   |             |   |             |   |             |
| <i>Diogenichthys atlanticus</i>   | 0.04                                    | 0.13        | 0.06                                    | 0.30        | 1.57                                    | 2.54        | 0.74                                    | 1.91        |
| <i>Gonichthys coccoi</i>          |   |             |   |             | 0.03                                    | 0.06        | 0.10                                    | 0.25        |
| <i>Lampanyctus pusillus</i>       | 0.08                                    | 0.26        | 0.13                                    | 0.61        | 1.10                                    | 1.75        | 0.88                                    | 2.24        |
| <i>Loweina</i> sp.                |   |             |   |             |   |             |   |             |
| <i>Myctophum punctatum</i>        | 1.91                                    | 7.11        | 1.13                                    | 5.33        | 4.92                                    | 7.84        | 2.90                                    | 7.48        |
| <i>Symbolophorus veranyi</i>      | 0.20                                    | 0.79        | 0.13                                    | 0.61        | 0.11                                    | 0.17        | 0.03                                    | 0.08        |
| unidentified                      | 8.50                                    | 31.18       | 8.77                                    | 40.94       | 24.83                                   | 39.35       | 17.15                                   | 44.02       |
| <b>Macrouridae</b>                |   |             |   |             |   |             |   |             |
| unidentified                      | 0.26                                    | 0.92        | 0.13                                    | 0.61        | 0.85                                    | 1.35        | 0.55                                    | 1.41        |
| <b>Phycidae</b>                   |   |             |   |             |   |             |   |             |
| * <i>Phycis phycis</i>            | 0.35                                    | 1.32        | 0.26                                    | 1.22        | 0.07                                    | 0.11        | 0.13                                    | 0.33        |
| <b>Gadidae</b>                    |   |             |   |             |   |             |   |             |
| * <i>Molva dipterygia</i>         |   |             |   |             | 0.03                                    | 0.06        | 0.03                                    | 0.08        |
| unidentified                      | 0.76                                    | 2.89        | 0.43                                    | 1.98        | 0.07                                    | 0.11        |   |             |
| <b>Ceratiidae</b>                 |   |             |   |             |   |             |   |             |
| <i>Cryptopsaras couesi</i>        | 0.04                                    | 0.13        |   |             |   |             |   |             |
| <b>Macroramphosidae</b>           |   |             |   |             |   |             |   | 4           |
| <i>Macroramphosus scolopax</i>    | 2.61                                    | 9.61        | 1.45                                    | 6.85        | 0.03                                    | 0.06        |   |             |



Table 4 (cont.)

Identified fish larvae with corresponding abundances (no of larvae/100m<sup>3</sup>) and proportions (%), for February and March and both mesh sizes. This list was organized by Families according to NELSON (1994). The genera and species are in alphabetical order and the scientific names were adopted from WHITEHEAD et al. (1989). Note: The taxa listed as A111, B3 and J5 were species with easily discernable individuals but not yet taxonomically identified. \* - taxa of commercial interest; \*\* - taxa of shallow waters.

| Taxa                               | February                                |             |   |             | March                                   |             |   |             |
|------------------------------------|---|-------------|---|-------------|---|-------------|---|-------------|
|                                    | 335µm                                   |             | 500µm                                   |             | 335µm                                   |             | 500µm                                   |             |
|                                    | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample |
| <b>Scorpaenidae</b>                |   |             |   |             |   |             |   |             |
| * <i>Helicolenus dactylopterus</i> | 1.39                                    | 4.87        | 1.06                                    | 5.02        | 2.50                                    | 4.00        | 2.23                                    | 5.73        |
| unidentified                       | 0.45                                    | 1.45        | 0.26                                    | 1.22        | 0.24                                    | 0.39        |   |             |
| <b>Serranidae</b>                  |   |             |   |             |   |             |   |             |
| * <i>Serranus cabrilla</i>         |   |             |   |             |   |             |   |             |
| <b>Callanthiidae</b>               |   |             |   |             |   |             |   |             |
| <i>Callanthias ruber</i> ?         | 0.89                                    | 3.03        | 0.67                                    | 3.04        | 0.57                                    | 0.90        | 0.65                                    | 1.66        |
| <b>Carangidae</b>                  |   |             |   |             |   |             |   |             |
| * ** <i>Trachurus picturatus</i>   |   |             |   |             | 0.25                                    | 0.39        | 0.23                                    | 0.58        |
| * unidentified                     |   |             |   |             | 0.03                                    | 0.06        |   |             |
| <b>Scaridae</b>                    |   |             |   |             |   |             |   |             |
| * ** <i>Sparisoma cretense</i>     |   |             | 0.03                                    | 0.15        |   |             |   |             |
| <b>Callionymidae</b>               |   |             |   |             |   |             |   |             |
| ** <i>Callionymus reticulatus</i>  |   |             |   |             |   |             |   |             |
| <b>Trichiuridae</b>                |   |             |   |             |   |             |   |             |
| * <i>Lepidopus caudatus</i>        | 0.04                                    | 0.13        |   |             | 0.08                                    | 0.11        | 0.03                                    | 0.08        |
| <b>Tetragonuridae</b>              |   |             |   |             |   |             |   |             |
| <i>Tetragonurus cuvieri</i>        |   |             |   |             | 0.04                                    | 0.06        |   |             |
| <i>Tetragonurus</i> spp.           |   |             | 0.03                                    | 0.15        |   |             | 0.03                                    | 0.08        |
| <b>Bothidae</b>                    |   |             |   |             |   |             |   |             |
| ** <i>Bothus podas madeirensis</i> |   |             | 0.06                                    | 0.30        |   |             |   |             |
| <i>Arnoglossus imperialis</i>      |   |             |   |             |   |             |   |             |
| <i>Arnoglossus</i> sp.             |   |             | 0.03                                    | 0.15        |   |             |   |             |
| A111                               | 0.04                                    | 0.13        | 0.03                                    | 0.15        | 1.32                                    | 2.03        | 0.33                                    | 0.83        |
| B3                                 | 0.88                                    | 3.29        | 1.00                                    | 4.72        | 0.10                                    | 0.17        | 0.06                                    | 0.17        |
| J5                                 | 0.04                                    | 0.13        | 0.03                                    | 0.15        | 0.14                                    | 0.23        | 0.03                                    | 0.08        |
| <b>Undetermined</b>                | 4.56                                    | 17.76       | 2.16                                    | 10.20       | 10.16                                   | 16.01       | 3.46                                    | 8.89        |
| <b>Number of taxa</b>              | 26                                      |             | 26                                      |             | 34                                      |             | 30                                      |             |

Table 5

Identified fish larvae with corresponding abundances (no of larvae/100m<sup>3</sup>) and proportions (%), for May and June and both mesh sizes. This list was organized by Families according to NELSON (1994). The genera and species are in alphabetical order and the scientific names were adopted from WHITEHEAD et al. (1989). Note: The *taxa* listed as A111, B3 and J5 were species with easily discernable individuals but not yet taxonomically identified. \* - taxa of commercial interest; \*\* - taxa of shallow waters.

|      | Taxa                              | May                                     |             |   |             | June                                    |             |   |             |
|------|-----------------------------------|---|-------------|---|-------------|---|-------------|---|-------------|
|      |                                   | 335mm                                   |             | 500mm                                   |             | 335mm                                   |             | 500mm                                   |             |
|      |                                   | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample |
| * ** | <b>Anguillidae</b>                |   |             |   |             |   |             |   |             |
|      | <i>Anguilla</i> sp.               |   |             |   |             | 0.04                                    | 0.02        |   |             |
|      | <b>Congridae</b>                  |   |             |   |             |   |             |   |             |
| *    | <i>Conger conger</i>              | 0.05                                    | 0.22        |   |             |   |             |   |             |
|      | <i>Gnathopis</i> sp.              | 0.05                                    | 0.22        |   |             | 0.04                                    | 0.02        |   |             |
|      | <b>Nettastomatidae</b>            |   |             |   |             |   |             |   |             |
|      | <i>Facciolella oxyrhyncha</i>     |   |             |   |             |   |             |   |             |
|      | <b>Clupeidae</b>                  |   |             |   |             |   |             |   |             |
| * ** | <i>Sardina pilchardus</i>         |   |             |   |             |   |             |   |             |
|      | <b>Argentinidae</b>               |   |             |   |             |   |             |   |             |
|      | <i>Argentina leioglossa</i>       |   |             |   |             |   |             |   |             |
|      | <b>Bathylagidae</b>               |   |             |   |             |   |             |   |             |
|      | unidentified                      |   |             |   |             |   |             | 0.04                                    | 0.03        |
|      | <b>Gonostomatidae</b>             |   |             |   |             |   |             |   |             |
|      | <i>Cyclothone</i> spp.            | 2.19                                    | 10.11       | 1.72                                    | 10.58       | 13.59                                   | 7.25        | 7.29                                    | 6.46        |
|      | <i>Ichthyococcus ovatus</i>       | 0.10                                    | 0.44        | 0.09                                    | 0.56        |   |             | 0.11                                    | 0.10        |
|      | <i>Vinciguerria poweriae</i>      | 0.10                                    | 0.44        | 0.09                                    | 0.56        | 0.04                                    | 0.02        | 0.15                                    | 0.13        |
|      | <i>Vinciguerria attenuata</i>     | 1.33                                    | 5.93        | 1.33                                    | 8.08        | 2.61                                    | 1.42        | 2.83                                    | 2.51        |
|      | <i>Vinciguerria nimbaria</i>      | 0.24                                    | 1.10        | 0.23                                    | 1.39        | 0.77                                    | 0.43        | 0.34                                    | 0.30        |
|      | <i>Vinciguerria</i> spp.          | 2.19                                    | 10.33       | 0.32                                    | 1.95        | 3.15                                    | 1.74        | 2.08                                    | 1.84        |
|      | <b>Sternoptychidae</b>            |   |             |   |             |   |             |   |             |
|      | <i>Maurolucus muellerii</i>       | 0.14                                    | 0.66        | 0.26                                    | 1.67        |   |             |   |             |
|      | <i>Sternoptyx</i> sp. ?           |   |             |   |             | 0.05                                    | 0.02        |   |             |
|      | <b>Stomiidae</b>                  |   |             |   |             |   |             |   |             |
|      | <i>Chauliodus</i> spp.            | 0.32                                    | 1.54        | 0.08                                    | 0.56        |   |             | 0.08                                    | 0.07        |
|      | <i>Stomias</i> spp.               |   |             | 0.04                                    | 0.28        |   |             | 0.04                                    | 0.03        |
|      | <b>Synodontidae</b>               |   |             |   |             |   |             |   |             |
| *    | <i>Synodus saurus</i>             |   |             |   |             | 0.78                                    | 0.41        | 0.20                                    | 0.17        |
|      | <b>Paralepididae</b>              |   |             |   |             |   |             |   |             |
|      | unidentified                      | 0.06                                    | 0.22        | 0.05                                    | 0.28        | 0.57                                    | 0.29        | 0.30                                    | 0.27        |
|      | <b>Myctophidae</b>                |   |             |   |             |   |             |   |             |
|      | <i>Ceratoscopelus madeirensis</i> | 1.43                                    | 6.59        | 0.18                                    | 1.11        | 55.41                                   | 29.67       | 42.08                                   | 36.97       |
|      | <i>Ceratoscopelus warmingii</i>   | 0.05                                    | 0.22        |   |             | 6.44                                    | 3.48        | 2.87                                    | 2.55        |
|      | <i>Ceratoscopelus</i> spp.        | 0.49                                    | 2.20        |   |             | 38.59                                   | 20.46       | 15.29                                   | 13.43       |
|      | <i>Diogenichthys atlanticus</i>   | 3.15                                    | 8.35        | 1.12                                    | 6.96        | 1.22                                    | 0.68        | 1.02                                    | 0.94        |
|      | <i>Gonichthys coccoi</i>          | 0.23                                    | 1.10        | 0.23                                    | 1.39        | 0.25                                    | 0.14        | 0.26                                    | 0.23        |
|      | <i>Lampamycus pusillus</i>        | 0.31                                    | 1.32        | 0.50                                    | 3.06        | 0.92                                    | 0.52        | 1.44                                    | 1.31        |
|      | <i>Loweina</i> sp.                | 0.29                                    | 1.32        | 0.04                                    | 0.28        | 0.09                                    | 0.05        | 0.12                                    | 0.10        |
|      | <i>Myctophum punctatum</i>        | 2.15                                    | 9.89        | 1.54                                    | 9.47        | 3.04                                    | 1.74        | 3.18                                    | 2.88        |
|      | <i>Symbolophorus veranyi</i>      | 0.05                                    | 0.22        | 0.22                                    | 1.39        | 0.53                                    | 0.29        | 0.53                                    | 0.47        |
|      | unidentified                      | 2.31                                    | 10.33       | 4.49                                    | 27.86       | 10.58                                   | 5.65        | 11.47                                   | 10.25       |
|      | <b>Macrouridae</b>                |   |             |   |             |   |             |   |             |
|      | unidentified                      |   |             |   |             | 0.04                                    | 0.02        | 0.04                                    | 0.03        |
|      | <b>Phycidae</b>                   |   |             |   |             |   |             |   |             |
| *    | <i>Phycis phycis</i>              |   |             |   |             |   |             |   |             |
|      | <b>Gadidae</b>                    |   |             |   |             |   |             |   |             |
| *    | <i>Molva dipterygia</i>           |   |             |   |             |   |             |   |             |
|      | unidentified                      |   |             |   |             |   |             |   |             |

Table 5 (cont.)

Identified fish larvae with corresponding abundances (no of larvae/100m<sup>3</sup>) and proportions (%), for May and June and both mesh sizes. This list was organized by Families according to NELSON (1994). The genera and species are in alphabetical order and the scientific names were adopted from WHITEHEAD et al. (1989). Note: The *taxa* listed as A111, B3 and J5 were species with easily discernable individuals but not yet taxonomically identified. \* - taxa of commercial interest; \*\* - taxa of shallow waters.

| Taxa                               | May                                     |             |   |             | June                                    |             |   |             |
|------------------------------------|---|-------------|---|-------------|---|-------------|---|-------------|
|                                    | 335mm                                   |             | 500mm                                   |             | 335mm                                   |             | 500mm                                   |             |
|                                    | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample | average no. of larvae/100m <sup>3</sup> | % of sample |
| <b>Ceratiidae</b>                  |   |             |   |             |   |             |   |             |
| <i>Cryptopsaras couesi</i>         |   |             |   |             |   |             |   |             |
| <b>Macroramphosidae</b>            |   |             |   |             |   |             |   |             |
| <i>Macroramphosus scolopax</i>     |   |             |   |             |   |             |   |             |
| <b>Scorpaenidae</b>                |   |             |   |             |   |             |   |             |
| * <i>Helicolenus dactylopterus</i> |   |             | 0.10                                    | 0.56        |   |             |   |             |
| unidentified                       | 0.08                                    | 0.44        | 0.21                                    | 1.39        | 0.30                                    | 0.16        | 0.04                                    | 0.03        |
| <b>Serranidae</b>                  |   |             |   |             |   |             |   |             |
| * <i>Serranus cabrilla</i>         |   |             |   |             | 1.39                                    | 0.72        | 0.84                                    | 0.74        |
| <b>Callanthiidae</b>               |   |             |   |             |   |             |   |             |
| <i>Callanthias ruber ?</i>         | 0.05                                    | 0.22        |   |             |   |             |   |             |
| <b>Carangidae</b>                  |   |             |   |             |   |             |   |             |
| * ** <i>Trachurus picturatus</i>   |   |             |   |             |   |             | 0.04                                    | 0.03        |
| * unidentified                     |   |             |   |             |   |             |   |             |
| <b>Scaridae</b>                    |   |             |   |             |   |             |   |             |
| * ** <i>Sparisoma cretense</i>     |   |             |   |             | 0.04                                    | 0.02        |   |             |
| <b>Callionymidae</b>               |   |             |   |             |   |             |   |             |
| ** <i>Callionymus reticulatus</i>  |   |             |   |             | 0.26                                    | 0.14        | 0.77                                    | 0.67        |
| <b>Trichiuridae</b>                |   |             |   |             |   |             |   |             |
| * <i>Lepidopus caudatus</i>        |   |             |   |             |   |             |   |             |
| <b>Tetragonuridae</b>              |   |             |   |             |   |             |   |             |
| <i>Tetragonurus cuvieri</i>        | 0.05                                    | 0.22        | 0.05                                    | 0.28        |   |             |   |             |
| <i>Tetragonurus</i> spp.           |   |             |   |             | 0.08                                    | 0.05        | 0.07                                    | 0.07        |
| <b>Bothidae</b>                    |   |             |   |             |   |             |   |             |
| ** <i>Bothus podas madeirensis</i> |   |             |   |             |   |             |   |             |
| <i>Arnoglossus imperialis</i>      |   |             |   |             | 0.04                                    | 0.02        |   |             |
| <i>Arnoglossus</i> sp.             |   |             |   |             | 0.35                                    | 0.20        | 0.19                                    | 0.17        |
| A111                               |   |             |   |             |   |             |   |             |
| B3                                 |   |             |   |             |   |             |   |             |
| J5                                 |   |             |   |             |   |             |   |             |
| <b>Undetermined</b>                | 5.68                                    | 26.37       | 3.10                                    | 19.50       | 44.18                                   | 24.37       | 19.39                                   | 17.21       |
| <b>Number of taxa</b>              | 24                                      |             | 21                                      |             | 28                                      |             | 28                                      |             |

Table 6  
Proportion (%) of three groups of interest in the fish larvae community abundance, for both mesh sizes.

|                                | February |       | March |       | May   |       | June  |       |
|--------------------------------|----------|-------|-------|-------|-------|-------|-------|-------|
|                                | 335µm    | 500µm | 335µm | 500µm | 335µm | 500µm | 335µm | 500µm |
| Myctophidae and Gonostomatidae | 68.7     | 76.1  | 78.1  | 86.5  | 72.5  | 77.7  | 73.9  | 80.4  |
| Taxa “island dependant” *      | 10.9     | 11.3  | 6.1   | 8.5   | 1.3   | 2.2   | 1.7   | 1.9   |
| Taxa with commercial interest  | 6.6      | 6.2   | 4.8   | 6.8   | 0.2   | 0.6   | 0.7   | 0.8   |

\* - Neritic, demersal and shallow-water elements.

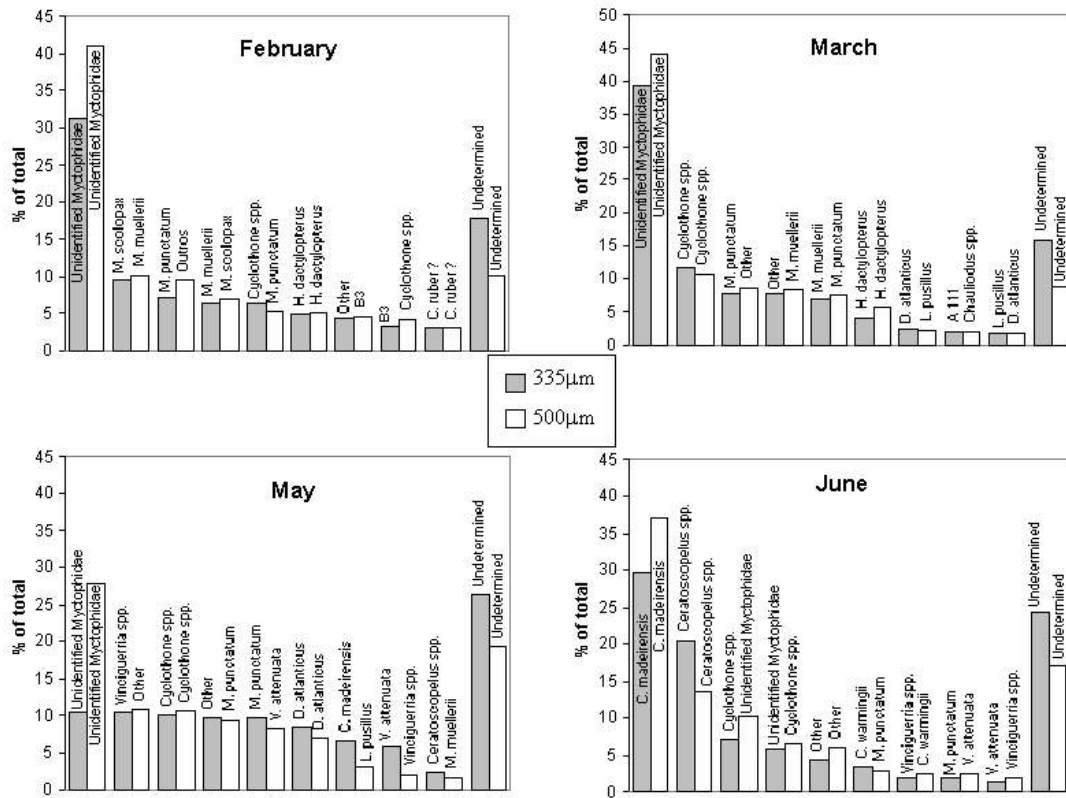


Fig. 5. Average proportion (in descending order) of the most abundant taxa of the fish larvae community, for each month and for both mesh sizes.



Fig. 6. *Glossanodon leioglossus* larva captured in February at station 3.2, 335 $\mu$ m mesh size (photo: Sobrinho-Gonçalves).

## DISCUSSION

The short time data series and the limitations in the spatial scale and number of stations impose a preliminary and indicative character to the obtained results.

### a. Quantitative differences between mesh sizes

The higher harvests obtained with the 335 $\mu$ m mesh size (compared to the 500 $\mu$ m) were naturally associated with its lower rate of small organism extrusion and escapement. The results allow us to state that, for this study area, mesozooplankton and larval fish surveys should preferably use a 335 $\mu$ m mesh (compared with a wider one) as it collects more material with higher diversity without severe net clogging problems.

### b. Monthly distribution

The most striking biomass/abundance variation pattern was clearly the monthly one. From the results it is reasonable to consider that the zooplankton biomass peak found in May corresponded to the spring “bloom” of that year, typical of temperate seas, following the thermal stratification of the water column, which is expected to occur in the Azores in April/May (ISIDRO 1996).

As stated previously, there are no available studies of the FL community of the Azores with

which we could compare our results; therefore we considered studies from other regions. The FL abundances showed in the present study are similar and higher than some values found in the Canary Islands (also a Macaronesian archipelago with ichthyologic affinities to the Azores) (SANTOS et al. 1997) and were not inferior to values found in the Iberian Peninsula continental shelf (European zone, biogeographically close to the Azores) (SANTOS et al. 1995). These results are surprising because, according to the classic biological oceanography concepts, we expected to find much lower FL abundances in the typical oceanic environment of Azores than in a corresponding continental shelf that is theoretically more productive.

### c. Spatial distribution, relation with coastal distance and bathymetry

Coastal distance and bathymetry are considered important factors for the distribution and structure of any zooplanktonic community, being generally accepted as good descriptors of larval fish associations (BOEHLERT & MUNDY 1993; DOYLE et al. 1993). Nevertheless, our results did not reveal the expected clear spatial density gradients with these two factors. The trends observed for both the PZ and FL are difficult to interpret with the amount of data provided by this study. Hydrographical studies of this region are mandatory.

Regarding the PZ, a significant part of the spatial variation of the biomass was associated simultaneously (in a complex way) with the variations of both environmental factors. In general terms, if we disregard the May data, this community showed higher densities at the most distant stations from the coast (5 and 10 nautical miles) with greater depths.

Regarding the FL, the variation of the abundance with the bathymetry seems to be relatively independent of the distance from the coast. In general terms, the results suggest that this community has higher densities at the stations with greater depths (5 nautical miles offshore). This is probably related to the dominance of mesopelagic and bathypelagic taxa in the samples.

d. Relationship between the fish larvae community and the zooplankton (PZ and TZ)

Limited food availability and predation are normally considered as the main factors responsible for ichthyoplanktonic mortality. In this scenario, several authors consider it likely that negative relationships occur between the fish larvae abundance and the zooplankton biomass when the latter community reaches high densities, thus magnifying drastically the pressure of competition and predation (ALVARIÑO 1980; MCGOWAN & MILLER 1980; ALI KHAN & HEMPEL 1974).

In this study, we also found a general trend for a negative relations between the two communities that was, in graphical terms (Fig. 4), very similar to that reported by ALI KHAN & HEMPEL (1974) and AFONSO (1989), in diverse environments. This result cannot be generalized for zooplankton as a whole because our methodology ignored an important component of the community, the microzooplankton, that escaped our nets and which include the majority of the fish larvae prey (e.g. eggs and larval stages of crustaceans). Furthermore, ALVARIÑO (1980) found a general negative relationship between fish larvae abundance and medusae, ctenophores, siphonophores and chondrophores. MILLS (1995) stressed the importance of these same groups as predators in oceanic environments. In this context, we can speculate that the high megaloplankton (MZ) biomass was the main cause for the minimum of FL occurring in our May samples. Regarding the May-June sub-set, we can also speculate about the occurrence, in Azorean waters, of a temporal asynchrony between the maximum abundance/ biomass of the annual cycles of each of these two groups. In order to clarify this last question, it will be necessary to develop this study, especially in terms of the ecologic and specific characterization of the whole macrozooplankton community.

e. Fish larvae community characterization

The higher specific richness (number of taxa) found in the March and May 335 $\mu$ m mesh samples can be explained by the effect of the

larger sample size (when compared with the 500  $\mu$ m samples).

The FL community was clearly dominated by mesopelagic and bathypelagic elements (Myctophiformes and Stomiiformes) throughout all the sampling period. This is not surprising because of a series of factors: 1) the larval reality "reflects", to a certain extent, the features of the adult ichthyologic fauna where the mesopelagic and bathypelagic species currently attains more than 35% of the total of fish species previously cited for Azorean waters (SANTOS et al. 1997); 2) the sampling period did not include the preferred spawning season of the shallow-water species (Summer); 3) relatively deep tows carried out at distances from the coast hardly reached by larval stages of several shallow-water species with larvae-retention strategies. In this context, it is reasonable to conclude that the larval fish community found off Faial island during this study fits the oceanic islands general model proposed by BOEHLERT & MUNDY (1993). In other words, it included some shallow water, neritic and demersal "island-dependant" elements in a clearly oceanic environment.

Larvae of a number of commercially important species were found in the samples but, with the exception of *Helicolenus dactylopterus* (in February and March) their abundance was always relatively low since the majority of these species are neritic and demersal.

Despite of the short time data series, several changes and fluctuations between and within the main groups of FL are visible, indicating a seasonal highly dynamic community. These results also help to define and understand the spawning periods of the identified taxa, indicating the existence of three groups:

1) Winter spawners, including species with larvae occurring mainly in February and March, e.g. *Helicolenus dactylopterus*, *Macroramphosus scolopax*, *Phycis phycis*, *Lepidopus caudatus*.

2) Spring spawners, including species with larvae occurring mainly in May and June, e.g. *Serranus cabrilla*, *Synodus saurus*, *Ceratoscopelus madeirensis*, *Callionymus reticulatus*.

3) Continuous spawners or with a very protracted spawning season, including species

with larvae effective presence in every month of the study, e.g. *Cyclothone* spp., *Diogenichthys atlanticus*, *Lampanyctus pusillus*, *Myctophum punctatum*.

Studies on fish eggs and larval development (age/growth) should be conducted in order to develop this spawning season investigation in the future.

The very high abundances found for *C. madeirensis*, which include a large range of development stages (results not published), make it an interesting key-species for further detailed studies of biology and trophic ecology.

#### f. New record

Three individuals were identified as *Glossanodon leioglossus* (Valenciennes, 1848) following all the major features described by SCHMIDT (1918) and SANZO (in BERTOLINI et al. 1931-1956), mainly the characteristic pigmentation pattern. There is only one species of Argentinidae cited for the Azores (SANTOS et al. 1997), *Argentina sphyraena*, whose larva was described by the same authors. This species cannot be confused with *G. leioglossus*. The known distribution for this species is the Iberian Peninsula, southern Spain to Cape Blanc in Mauritania, West, North of the Mediterranean and the Aegean Sea (PAPACONSTANTINO & TSIMENIDIS 1979; COHEN in WHITEHEAD et al. 1989). With this new record, the distribution becomes wider, with the Azores as the western limit in the Atlantic.

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APPENDIX 1

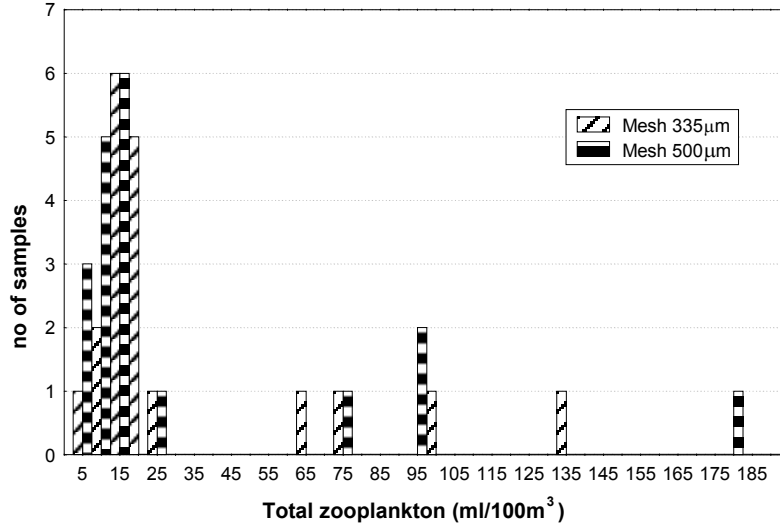


Fig. A. Histogram of the total zooplankton biomass distribution by no of samples (tows).

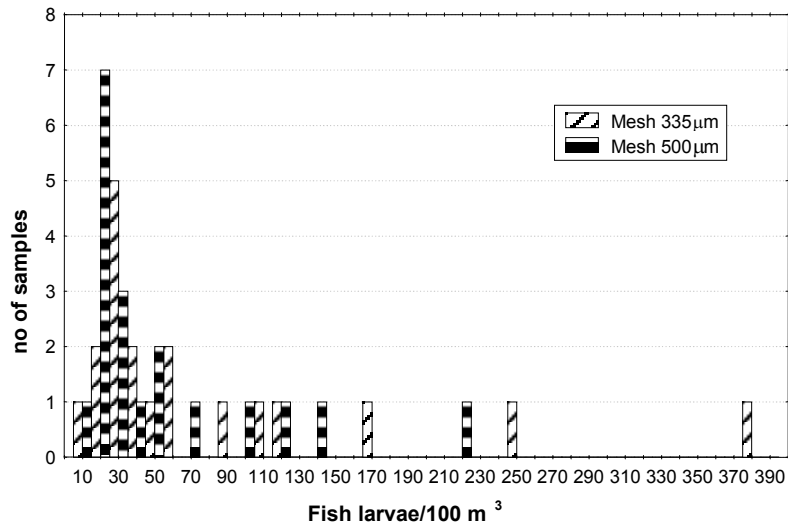


Fig. B. Histogram of the fish larvae community abundance distribution by no of samples (tows).

## APPENDIX 2

Taxa that were identified but not yet quantified.

### **Bathylagidae**

*Bathylagus bericoides* (Borodin, 1929) or *B. longirostris* Maul, 1948 ?

### **Gonostomatidae**

Unidentified Gonostomatidae

### **Stomiidae**

*Aristostomias* sp.?

### **Paralepididae**

*Lestidiops* sp and/or *Macroparalepis* sp. ?

### **Evermannellidae**

*Coccorella atlantica* (Parr, 1928)

### **Myctophidae**

*Diaphus* spp.

*Lampanyctus crocodilus* (Risso, 1810) synonym of *L. gemmifer* (Goode & Bean, 1879)

*Lobianchia dofleini* (Zugmayer, 1911) or *L. gemellarii* (Cocco, 1838) ?

*Hygophum reinhardtii* (Lütken, 1892) ?

*Hygophum hygomii* (Lütken, 1892)

*Hygophum* spp.

*Notoscopelus resplendens* (Richardson, 1845) or

*N. kroyerii* (Malm, 1861) ?

*Notoscopelus bolini* Nafpaktitis, 1975

### **Gadidae**

*Gaidropsarus* spp. ?

### **Scorpaenidae**

*Scorpaena* spp.

### **Serranidae**

*Epinephelus marginatus* (Lowe, 1834)

Unidentified Serranidae

### **Pomatomidae**

*Pomatomus saltator* (Linnaeus, 1758) ?

### **Blenniidae**

*Coryphoblennius galerita* (Linnaeus, 1758)

Unidentified Blenniidae

### **Bothidae**

*Arnoglossus rueppelli* (Cocco, 1844)

? - Uncertain identification