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# The community structure of larval fish populations in an area of the Celtic Sea in 1998

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Ichthyoplankton from an area in the Celtic Sea was studied to provide an insight into the fish larval community structure in March, May and June 1998. Three station groups were defined each month, Neritic, Transition and Oceanic. The Neritic assemblages included larval stages of coastal fish species and the Oceanic assemblages included mesopelagic and high-oceanic fish species which were not recorded from any of the Neritic stations. The Transition stations usually contained species characteristic of both the Neritic and Oceanic assemblages. It is suggested that these broad patterns of larval fish distributions are constant features of the Celtic Sea area, probably related to the spawning location of the adults. The area is, in general, species poor, with the Oceanic stations usually dominated by a single species, indicating the presence of a large spawning school of fish.

## INTRODUCTION

Ichthyplankton surveys are useful for gaining an insight into many aspects of fish biology but may also elucidate the fish larval community structure of an area, and indicate the inter-relationships between various species. Studies of the ichthyoplankton of the Celtic Sea area in recent years have documented the spatial and temporal distribution of larval stages of fish species in general (Horstman & Fives, 1994) and also of certain targeted species (Bartsch & Coombs, 2001; Hillgruber & Kloppmann, 2001; Kloppmann et al., 2001a,b; Fives et al., 2001). Plankton collected during the 1998 Mackerel Egg Survey, co-ordinated by the International Council for the Exploration of the Sea (ICES), was studied as part of the EU-funded project INDICES (Ichthyplankton-based indices of abundance of spring-spawning commercial fish populations in western European waters). The INDICES project had as a primary objective the assessment of the abundance of eggs and larvae of the commercial fish species, mackerel *Scomber scombrus* Linnaeus, 1758, horse mackerel *Trachurus trachurus* (Linnaeus, 1758), hake *Merluccius merluccius* (Linnaeus, 1758), megrim *Lepidorhombus whiffiagonis* (Walbaum, 1792), blue whiting *Micromesistius poutassou* (Risso, 1826), and anchovy *Engraulis encrasicholus* (Linnaeus, 1758). The aim of the present study was to elucidate the position of the species studied in the INDICES project in the overall fish larval populations in the Celtic Sea area.

## MATERIALS AND METHODS

The study area lies south-west of the Great Sole Bank in the Celtic Sea extending from 48° to 52°N and from 8° to 14°W (Figure 1). The plankton samples were collected in 1998, as part of the ICES triennial Mackerel and Horse Mackerel Egg Survey, by the research vessels 'Walther Herwig', 'Scotia', and 'Celtic Voyager'. The samples were collected using encased variants of the Gulf III high speed sampler (Gehringer, 1952), mesh 250-$\mu$m, each sampler fitted with flowmeters to determine the length of the towpath in metres. Samples were taken at the centre of rectangles which were defined by the 0.5° latitudes × 0.5° longitudes. Oblique hauls were taken from surface to required depth and back to surface, sample depth varying with bottom depth, with a maximum depth of 200 m (Milligan & Riches, 1983). Samples were preserved in 4% buffered formaldehyde solution. The number of fish larvae from each sample was standardized to that number found beneath a 10 $m^2$ area of sea surface, using the formula described by Smith & Richardson (1977). Multivariate analyses were undertaken using PRIMER (Plymouth Routines In Multivariate Ecological Research, Clarke & Warwick, 1994 and Carr, 1996). For normal cluster analysis, an agglomerative hierarchical classification technique was used, based on the Bray–Curtis similarity coefficient calculated on logarithmic transformed abundances (numbers 10 $m^{-2}$), employing group-average sorting. Only species >5% at any one station were retained for analysis. Stations where no fish larvae were found were not included. A variable stopping rule (Green, 1979) was used to determine the different station groups. Similarity percentage analyses (SIMPER) were used to assess the contribution of each species to the average Bray–Curtis similarity within the major station groups and also to the average dissimilarity between the major station groups created by the cluster (Clarke, 1993; Clarke & Warwick, 1994). Based on species composition and also on bottom depths, the station groups were designated as Oceanic (stations containing mesopelagic and oceanic species, over depths >200 m), Neritic (stations with species normally associated with coastal waters, over depths <200 m) and Transition (stations containing a mixture of oceanic and neritic species, usually over depths ⩽200 m).

Three measures of diversity were calculated to examine community structure: the Shannon–Wiener diversity index H′ (logarithm to the base 2 was used in the calculation), species richness (SR) (Margalef, 1958) and species evenness index (J) (Pielou, 1975).

Larval specimens that were too damaged to identify to any taxonomic level were listed as unidentified.

## RESULTS

Synoptic results of the distribution of total numbers of fish larvae recorded for March, May and June are illustrated in Figure 1. Table 1 lists the relative percentage abundance of the species, the percentage species composition each month and the species group assignment each month. The mackerel, *Scomber scombrus* was the most numerous species, with 61% of the recorded mackerel occurring in May and 34% in June. The next most abundant species was the horse mackerel *Trachurus trachurus* with 38% of these recorded in May and 61% recorded in June. The pilchard, *Sardina pilchardus* (Walbaum, 1792) was the third most numerous species, with 92% of the larvae recorded in June and the remainder in May. Most of the *Callionymus* sp. Linnaeus, 1758 larvae were recorded in May (68%) and in June (23%). Over 70% of *Benthosema glaciale* (Reinhardt, 1837) larvae occurred in May and 18% in March. The majority (99.2%) of the blue whiting *Micromesistius poutassou* was recorded in March, when it was the most numerous species, forming 40% of total larvae.

The maximum larval abundance in March included large numbers of *M. poutassou* (1501 $m^{-2}$), *Scomber scombrus* (671 $m^{-2}$) and *Lepidorhombus whiffiagonis* (327 $m^{-2}$).

The maximum larval abundance in May included very large numbers of *T. trachurus* (4732 $m^{-2}$) and *S. scombrus* (1291 $m^{-2}$).

The maximum abundance in June, included *T. trachurus* (6451 $m^{-2}$), *Sardina pilchardus* (3376 $m^{-2}$), *Scomber scombrus* (1134 $m^{-2}$) and Clupeidae larvae (1017 $m^{-2}$).

Numerical classification, resulting in station clusters based on fish larval distributions and abundance, indicated three major groups each month.

In March the three groups were identified at an arbitrary similarity level of 26%. The Neritic group of stations, positioned on the eastern edge of the sampled area (Figure 2), had an intra group similarity of 82.7. It was characterized by the coastal species *Crystallogobius linearis* (von Dubën, 1845) which occurred in all stations (Table 2). One of the six stations also contained larvae of *Argentina sphyraena* Linnaeus, 1758 and another station contained *Clupea harengus* Linnaeus, 1758. The SR and J values were calculated for the two stations containing two species and both values ranged from 0.64 to 0.81.

The Transition group of stations, positioned on the continental shelf slope and east of the shelf break had an intra group similarity of 35.9, and was characterized by an assemblage of offshore fish species, including *L. whiffiagonis*, *A. sphyraena*, *Callionymus* sp. and *Buenia jeffreysii* (Günther, 1867) (Table 2). The mesopelagic *M. poutassou* was recorded from only five of the stations, which were situated near the shelf break. Diversity (H′) values, for these Transition stations, ranging from 0.81 to 3.16, SR values of 0.2–1.43, J values of 0.52–0.96 indicated medium diversity, low richness and co-dominance by several species for this assemblage of fish larvae.

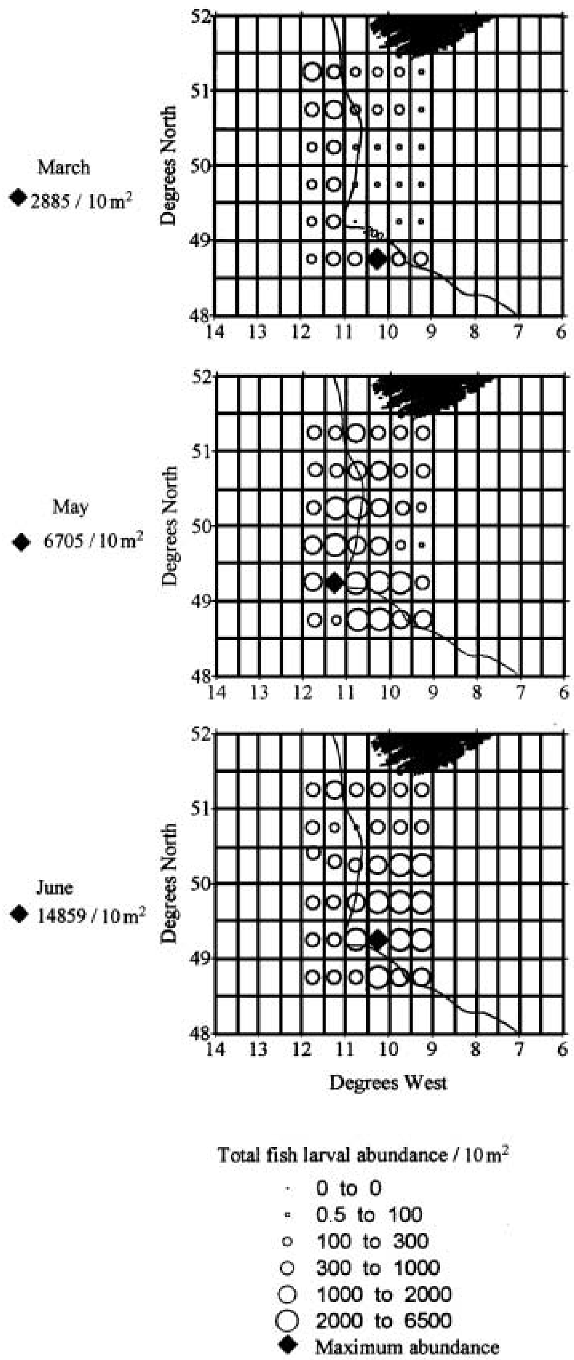


**Figure 1.** Synoptic results for total numbers of fish larvae 10 $m^{-2}$.

The Oceanic group of stations were, with one exception, clustered west of the shelf break. They showed an intra group similarity of 46.7. This group was characterized mainly by mesopelagic, high-oceanic species *M. poutassou*, which was very abundant and occurred in every station and *Benthosema glaciale*, which occurred in all but two of these stations.

H′ values ranged from 0.65 to 2.87, SR values of 0.12–0.86 and J values of 0.34–0.95 and indicated low diversity, low richness and dominance of this assemblage by *M. poutassou*.

Three of the sampled March stations did not form a close part of the above groups. One of these stations did

**Table 1.** *Relative percentage abundance of all species for the study period, the percentage species composition within each month (%) and the group assignments (G.A.: N, Neritic; T, Transition; O, Oceanic).*

| Family | Species | March % | March G.A. | May % | May G.A. | June % | June G.A. | Relative Abundance % |
|---|---|---|---|---|---|---|---|---|
| Clupeidae | *Sprattus sprattus* (Linnaeus, 1758) | | | 1.76 | N T | 0.28 | N | 0.92 |
| | *Sardina pilchardus* (Walbaum, 1792) | | | 1.11 | N T | 15.17 | T | 7.32 |
| | *Clupea harengus* Linnaeus, 1758 | 0.17 | N T | | | | | 0.02 |
| | *Clupeidae* sp. Whitehead | | | | | 9.07 | T | 4.08 |
| Stomiidae | *Stomias boa ferox* Reinhardt, 1843 | 0.65 | O | 0.03 | T | 0.03 | O | 0.01 |
| Sternoptychidae | *Maurolicus muelleri* (Gmelin, 1788) | 0.08 | O | 0.48 | N T O | 1.41 | N T O | 0.86 |
| | *Argyropelecus olfersi* (Cuvier, 1829) | | | | | 0.03 | O | 0.01 |
| Argentinidae | *Argentina sphyraena* Linnaeus, 1758 | 1.76 | N T O | 0.63 | N T | 0.42 | N T | 0.7 |
| | *Nansenia groenlandica* (Reinhardt, 1840) | 0.19 | O | | | | | 0.02 |
| Bathylagidae | *Bathylagus* sp. Günther | 0.09 | O | 0.18 | T O | | | 0.09 |
| Myctophidae | *Benthosema glaciale* (Reinhardt, 1837) | 7.37 | T O | 6.05 | T O | 0.96 | T O | 3.9 |
| | *Ceratoscopelus maderensis* (Lowe, 1839) | | | | | 0.03 | O | 0.01 |
| | *Myctophum punctatum* Rafinesque, 1810 | 1.25 | O | 0.13 | T O | 0.16 | O | 0.25 |
| | *Lampanyctus crocodilus* (Risso, 1810) | | | 0.09 | O | 1.36 | T O | 0.65 |
| | *Protomyctophum (Hierops) arcticum* (Lütken, 1892) | | | 0.16 | T O | 0.18 | T O | 0.15 |
| | *Electrona rissoi* (Cocco, 1829) | 1.05 | T O | 0.03 | T | 0.03 | | 0.13 |
| | *Notoscopelus (Notoscopelus) kroyerii* (Malm, 1861) | 2.26 | T O | 0.05 | O | | | 0.24 |
| | *Myctophidae* sp. Hulley | 0.09 | O | 0.05 | O | 0.18 | O | 0.11 |
| Paralepididae | *Notolepis rissoi* (Bonaparte, 1840) | 1.38 | T O | 0.19 | T O | 0.06 | O | 0.25 |
| | *Paralepis coregonoides* Risso, 1820 | 2.38 | T O | 0.15 | T O | 0.03 | O | 0.31 |
| Merlucciidae | *Merluccius merluccius* (Linnaeus, 1758) | 2.93 | T | 1.06 | N T O | 0.64 | N T | 1.05 |
| Gadidae | *Gadiculus argenteus thori* J. Schmidt | 0.22 | T | 0.31 | N O | | | 0.16 |
| | *Melanogrammus aeglefinus* (Linnaeus, 1758) | 0.43 | T | 0.12 | N T | 0.03 | T | 0.11 |
| | *Merlangius merlangus* (Linnaeus, 1758) | | | 0.41 | N T | | | 0.19 |
| | *Micromesistius poutassou* (Risso, 1826) | 39.63 | T O | 0.07 | T | | | 3.87 |
| | *Pollachius pollachius* (Linnaeus, 1758) | 0.32 | T | 0.12 | T | | | 0.09 |
| | *Pollachius virens* (Linnaeus, 1758) | 0.52 | T | | | | | 0.05 |
| | *Trisopterus* sp. Rafinesque, 1814 | 2.94 | T | 1.56 | N T | 0.08 | N T | 1.03 |
| | *Brosme brosme* (Ascanius, 1772) | | | 0.06 | T | | | 0.03 |
| | Rockling sp. | 1.28 | T O | 0.25 | T | 0.01 | T | 0.24 |
| | *Molva molva* (Linnaeus, 1758) | | | 0.22 | T | | | 0.1 |
| Carangidae | *Trachurus trachurus* (Linnaeus, 1758) | 0.07 | T | 20.78 | N T O | 33.74 | T O | 24.6 |
| Labridae | *Ctenolabrus rupestris* (Linnaeus, 1758) | | | | | 0.21 | N | 0.09 |
| | *Labrus bimaculatus* Linnaeus, 1758 | | | | | 0.04 | N | 0.02 |
| Ammodytidae | *Ammodytidae* sp. Reay | 0.51 | T | 0.18 | N | 0.01 | N | 0.14 |
| Scombridae | *Scomber scombrus* Linnaeus, 1758 | 11.07 | T O | 42.09 | N T O | 23.98 | N T O | 30.95 |
| Gobiidae | *Buenia jeffreysii* (Günther, 1867) | 1.61 | T | 0.61 | N T | 0.63 | N T | 0.72 |
| | *Crystallogobius linearis* (von Dubën, 1845) | 3.36 | N T | 0.13 | N T | 0.2 | N | 0.47 |
| | *Gobius niger* Linnaeus, 1758 | | | | | 0.05 | N | 0.02 |
| | *Gobius paganellus* Linnaeus, 1758 | | | 0.07 | N | 0.22 | N | 0.13 |
| | *Gobiusculus flavescens* (Fabricius, 1779) | | | 0.04 | T | 0.03 | N | 0.03 |
| Callionymidae | *Callionymus* sp. Linnaeus, 1758 | 4.07 | T O | 6.91 | N T O | 2.37 | N T | 4.59 |
| Carapidae | *Echiodon drummondi* Thompson, 1837 | 0.09 | T | 0.06 | T | | | 0.04 |
| Scorpaenidae | *Helicolenus dactylopterus dactylopterus* Delaroche, 1809 | | | 0.07 | T | | | 0.03 |
| Triglidae | *Eutrigla gurnardus* (Linnaeus, 1758) | 0.8 | T | 0.18 | N T O | 0.03 | T | 0.17 |
| Scophthalmidae | *Lepidorhombus boscii* (Risso, 1810) | | | 0.67 | N T O | 0.03 | T | 0.32 |
| | *Lepidorhombus whiffiagonis* (Walbaum, 1792) | 8.05 | T O | 0.38 | N T | | | 0.95 |
| | *Phrynorhombus norvegicus* (Günther, 1862) | | | | | 0.04 | N T | 0.02 |
| Bothidae | *Arnoglossus laterna* (Walbaum, 1792) | | | 0.25 | T | 1.2 | N T | 0.65 |
| | *Arnoglossus thori* Kyle, 1913 | | | | | 1.28 | T O | 0.58 |
| Pleuronectidae | *Glyptocephalus cynoglossus* (Linnaeus, 1758) | 0.15 | T | 0.2 | N T | 0.02 | T | 0.12 |
| | *Microstomus kitt* (Walbaum, 1792) | 0.46 | T O | 0.52 | N T | 0.15 | N | 0.35 |
| Soleidae | *Microchirus variegatus* (Donovan, 1808) | 1.43 | T | 0.83 | N T | 0.35 | N T | 0.67 |
| Lophiidae | *Lophius piscatorius* Linnaeus, 1758 | 0.07 | T | | | 0.06 | T | 0.03 |
| | Unidentified | 1.28 | | 10.77 | N T O | 5.2 | N T O | 7.35 |



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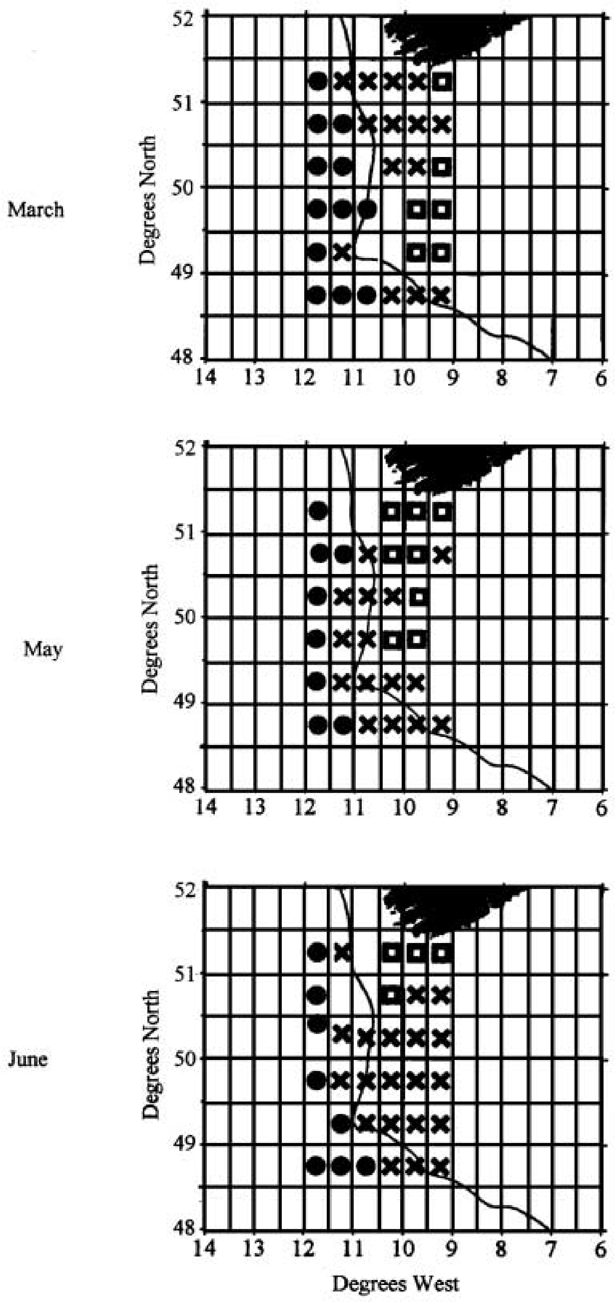


**Figure 2.** Station groupings for March, May and June (●, Oceanic; ×, Transition; □, Neritic).

not contain larvae, the others contained small numbers of a single fish species, *Myctophum punctatum* Rafinesque, 1810, in one station and *Merluccius merluccius* in the other.

The Nertitic assemblage was very dissimilar to both the Transition and Oceanic assemblages. The Transition and Oceanic groups were also very dissimilar (Table 2).

The cluster analysis of the stations sampled in May identified two main groups at an arbitrary similarity level of 29%. Within one of these groups, two assemblages were defined as Neritic and Transition at the 40% similarity level. The Neritic group of stations, positioned north and east within the sampled area (Figure 2), had an intra group similarity of 55.2 (Table 3). This group was characterized by an assemblage of fish larvae dominated by *S. scombrus*, *Callionymus* sp., *Sprattus sprattus* (Linnaeus, 1758) and *Trisopterus* sp. Rafinesque, 1814. The diversity values H′ ranged from 0.88 to 2.48, the SR values from 0.54 to 1.08 and the J values from 0.68 to 0.92 indicating low diversity, low species richness and co-dominance by several species.

The Transition group of stations were positioned on the shelf break and west and east of the break and had an intra group similarity of 62. The group was characterized mainly by very high abundances of *Scomber scombrus*, which occurred in every station and, to a lesser extent, by *Callionymus* sp. and *Trachurus trachurus* which also were recorded from every sample. The hake, *M. merluccius*, known to favour the slope of the shelf break for spawning, occurred in low abundance in all but three of the stations.

The H′ values ranged from 0.88 to 2.48, SR values from 0.43 to 1.18 and J values 0.24 to 0.69 indicating low diversity, low species richness and dominance in most station by one species, *S. scombrus*.

The Oceanic group of stations, positioned west of the shelf break, was characterized by an assemblage of fish species dominated by the mesopelagic, high-oceanic species *B. glaciale*, which was present in all stations in very high abundance. Other oceanic species, for example *Notolepis rissoi* (Bonaparte, 1840) and *Bathylagus* sp. Günther, 1878 and *Maurolicus muelleri* (Gmelin, 1788) were recorded from a few stations and in very low abundances.

The H′ values ranged from 1.14 to 2.55, SR values 0.34 to 1.02 and J values 0.44 to 0.92 indicating low diversity, low species richness and dominance by one species, *Benthosema glaciale*.

Two stations in the north-west of the area did not cluster closely with the Neritic stations but did contain large numbers of *S. scombrus* and *Callionymus* sp. The station closest to the Neritic station also contained *Trisopterus* sp. and other species in common with the Neritic assemblages. The other station had species such as *Notoscopelus* (*Notoscopelus*) *kroyerii* (Malm, 1861) in common with the Oceanic stations. Three stations along the eastern sector did not cluster with the main groups. However, the northernmost station contained *Callionymus* sp., *Trisopterus* sp. and *Crystallogobius linearis* but lacked *S. scombrus*. The other two stations clustered more closely to the Transition group but contained just three and five species in contrast to the Transition stations which contained from six to 13 species each.

The Neritic and Oceanic groups of stations showed a high dissimilarity and the Oceanic and Transition groups were also quite dissimilar but the Neritic and Transition groups were not so dissimilar (Table 3).

The cluster analysis of the June samples identified three main station groups at an arbitrary similarity level of 34%. The Neritic group, positioned south-west of Ireland, had an intra group similarity of 55.2 (Table 4). The group was characterized by the presence in all stations of *Callionymus* sp., *Gobius paganellus* Linnaeus, 1758, *Sprattus sprattus* and *Microstomus kitt* (Walbaum, 1792) and by *Scomber scombrus* and *Crystallogobius linearis* which occurred in three of the four stations. The diversity values H′ ranging from 1.49 to 3.3 indicated medium diversity, the SR values of 0.9–1.53, low species richness and the evenness values J 0.49–0.92 indicated co-dominance by several species.

The Transition group of stations were positioned from the shelf slope eastwards onto the shelf. The group was



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**Table 2.** *Average species abundances (Av. Ab; individuals 10 m$^{-2}$) within each group, percentage species contribution (cont.) to the total average similarity (absolute value) within the group and their percentage contribution to the total average dissimilarity (absolute value) between groups, in March.*

| | Similarity | | | | | | Dissimilarity Contribution (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Neritic | | Transitional | | Oceanic | | | | |
| Species | Av. Ab. | Cont. (%) | Av. Ab. | Cont. (%) | Av. Ab. | Cont. (%) | (N:O) | (N:T) | (O:T) |
| *Crystallogobius linearis* | 47.67 | 100.00 | 8.57 | 4.25 | | | 25.36 | 19.57 | |
| *Micromesistius poutassou* | | | 120.05 | 4.12 | 258.17 | 42.93 | 18.15 | 5.00 | 11.14 |
| *Benthosema glaciale* | | | 5.86 | 1.30 | 67.25 | 25.61 | 12.86 | | 8.70 |
| *Notoscopelus* sp. | | | | | 19.58 | 9.15 | 7.58 | | 5.89 |
| *Paralepis coregonoides* | | | | | 23.00 | 6.23 | 6.32 | | 4.78 |
| *Myctophum punctatum* | | | | | 9.75 | 4.58 | 4.57 | | |
| *Notolepis rissoi* | | | | | 10.75 | 2.69 | 4.14 | | |
| *Lepidorhombus whiffiagonis* | | | 61.41 | 18.68 | 9.11 | 0.50 | 3.94 | 9.35 | 6.93 |
| *Argentina sphyraena* | | | 12.14 | 16.49 | 2.50 | 0.82 | 3.83 | 9.86 | 7.27 |
| *Electrona rissoi* | | | | | 9.50 | 1.48 | 3.51 | | |
| Rockling sp. | | | 6.93 | 1.96 | 4.75 | 1.69 | | | |
| *Callionymus* sp. | | | 31.57 | 14.92 | 4.75 | 1.04 | | 9.12 | 7.33 |
| *Scomber scombrus* | | | 92.61 | 4.52 | 3.28 | 0.12 | | 4.89 | 4.32 |
| *Buenia jeffreysii* | | | 13.86 | 14.67 | | | | 10.33 | 7.85 |
| *Trisopterus* sp. | | | 25.36 | 11.10 | | | | 7.30 | 6.04 |
| *Merluccius merluccius* | | | 24.00 | 4.23 | | | | 3.82 | |
| *Pollachius virens* | | | 4.50 | 1.30 | | | | 2.22 | |
| *Microchirus variegatus* | | | 12.29 | 1.10 | | | | | |
| *Ammodytidae* sp. | | | 4.36 | 0.45 | | | | | |
| *Eutrigla gurnardus* | | | 6.86 | 0.40 | | | | | |
| *Pollachius pollachius* | | | 2.79 | 0.40 | | | | | |
| **Average Similarity** | | **82.67** | | **35.90** | | **46.70** | | | |
| **Average Dissimilarity** | | | | | | | **99.38** | **88.94** | **81.63** |

**Table 3.** *Average species abundances (Av. Ab; individuals 10 m$^{-2}$) within each group, percentage species contribution (cont.) to the total average similarity (absolute value) within the group and their percentage contribution to the total average dissimilarity (absolute value) between groups, in May.*

| | Similarity | | | | | | Dissimilarity Contribution (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Neritic | | Transitional | | Oceanic | | | | |
| Species | Av. Ab. | Cont. (%) | Av. Ab. | Cont. (%) | Av. Ab. | Cont. (%) | (N:T) | (N:O) | (T:O) |
| *Benthosema glaciale* | | | 48.77 | 2.51 | 333.65 | 64.76 | 4.94 | 15.42 | 19.41 |
| *Scomber scombrus* | 234.68 | 26.83 | 1307.00 | 47.47 | 62.49 | 9.45 | 6.04 | 7.99 | 15.27 |
| *Callionymus* sp. | 97.46 | 22.14 | 164.07 | 20.98 | 32.20 | 6.94 | 4.86 | 6.69 | 7.97 |
| *Notolepis rissoi* | | | | | 11.76 | 5.47 | | 4.00 | 5.55 |
| *Bathylagus* sp. | | | | | 8.95 | 4.08 | | 3.89 | 4.12 |
| *Maurolicus muelleri* | | | | | 18.98 | 3.70 | | | 5.11 |
| *Trachurus trachurus* | | | 753.29 | 16.46 | 39.26 | 3.27 | 11.51 | 4.36 | 10.69 |
| *Paralepis coregonoides* | | | | | 8.61 | 0.91 | | | |
| *Protomyctophum arcticum* | | | 2.11 | 0.60 | 7.37 | 0.77 | | | 2.11 |
| *Lepidorhombus boscii* | 14.27 | 0.64 | 15.71 | 1.47 | 4.94 | 0.65 | | | |
| *Merluccius merluccius* | 9.16 | 2.65 | 27.66 | 5.23 | | | | | 4.08 |
| *Buenia jeffreysii* | 9.55 | 0.49 | 16.91 | 3.04 | | | | | 16.91 |
| *Trisopterus* sp. | 60.19 | 13.81 | 15.33 | 1.30 | | | 10.51 | 8.48 | |
| *Argentina sphyraena* | 9.71 | 1.34 | 13.06 | 0.59 | | | 4.84 | | |
| *Merlangius merlangus* | 10.69 | 1.77 | 7.49 | 0.47 | | | | | |
| *Myctophum punctatum* | | | 3.27 | 0.20 | | | | | |
| *Sprattus sprattus* | 103.82 | 20.92 | 14.33 | 0.10 | | | 13.83 | 10.52 | |
| *Molva molva* | | | 2.11 | 0.06 | | | | | |
| *Crystallogobius linearis* | 4.88 | 0.26 | 2.40 | 0.50 | | | | | |
| *Microstomus kitt* | 24.73 | 4.73 | | | | | 5.86 | 4.19 | |
| *Sardina pilchardus* | 59.64 | 2.23 | | | | | 6.10 | 4.38 | |
| *Lepidorhombus whiffiagonis* | 14.91 | 1.94 | | | | | 4.54 | | |
| **Average Similarity** | | **55.15** | | **62.00** | | **47.47** | | | |
| **Average Dissimilarity** | | | | | | | **56.97** | **80.19** | **69.63** |



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**Table 4.** *Average species abundances (Av. Ab; individuals 10 m$^{-2}$) within each group, percentage species contribution (cont.) to the total average similarity (absolute value) within the group and their percentage contribution to the total average dissimilarity (absolute value) between groups, in June.*

| | Similarity | | | | | | Dissimilarity | | |
|---|---|---|---|---|---|---|---|---|---|
| | Neritic | | Transitional | | Oceanic | | Contribution (%) | | |
| Species | Av. Ab. | Cont. (%) | Av. Ab. | Cont. (%) | Av. Ab. | Cont. (%) | (N:T) | (N:O) | (O:T) |
| *Callionymus* sp. | 47.18 | 22.35 | 55.17 | 5.40 | | | 6.72 | 8.95 | 4.76 |
| *Gobius paganellus* | 28.57 | 14.29 | | | | | 8.00 | 6.75 | |
| *Sprattus sprattus* | 27.52 | 13.83 | | | | | 8.10 | 6.87 | |
| *Scomber scombrus* | 182.38 | 12.26 | 616.41 | 34.92 | 40.94 | 15.54 | 7.57 | 7.32 | 7.76 |
| *Microstomus kitt* | 13.63 | 10.29 | | | | | 5.61 | 4.82 | |
| *Crystallogobius linearis* | 10.48 | 7.55 | | | | | 5.11 | 4.43 | |
| *Trachurus trachurus* | | | 928.93 | 33.66 | 29.19 | 12.65 | 12.41 | 5.29 | 8.57 |
| *Sardina pilchardus* | | | 424.29 | 8.45 | | | 7.37 | | 8.41 |
| *Clupeidae* sp. | | | 253.69 | 7.45 | | | 6.32 | | 7.20 |
| *Arnoglossus thori* | | | 33.70 | 6.04 | | | 4.54 | | 6.13 |
| *Merluccius merluccius* | | | 16.44 | 1.62 | | | | 2.81 | |
| *Lampanyctus crocodilus* | | | | | 69.83 | 38.45 | | 11.35 | 15.10 |
| *Maurolicus muelleri* | | | | | 66.73 | 21.01 | | 7.89 | 12.02 |
| *Benthosema glaciale* | | | | | 54.90 | 8.47 | | 5.87 | 8.16 |
| *Protomyctophum arcticum* | | | | | 12.30 | 1.19 | | 2.63 | 3.66 |
| *Buenia jeffreysii* | | | | | | | 6.18 | 5.44 | 2.80 |
| *Ctenolabrus rupestris* | | | | | | | 5.60 | 4.61 | |
| *Myctophum punctatum* | | | | | | | | | 3.35 |
| **Average Similarity** | | **55.18** | | **62.06** | | **53.53** | | | |
| **Average Dissimilarity** | | | | | | | **70.34** | **85.63** | **69.05** |

characterized by very large abundances of *S. scombrus* and *Trachurus trachurus*, which occurred in every sample. Nine of these stations in the south east of the sampled area, grouped at the 73% level of similarity, contained high abundances of *Sardina pilchardus*. Each of these stations also contained very high numbers of damaged *Clupeidae* larvae that could not with certainty be identified to species level but were in all probability *S. pilchardus* larvae. *Arnoglossus thori* Kyle, 1913 was recorded in relatively low abundance in 17 of the 20 stations. The H′ values ranging from 1.01 to 2.57 indicated low diversity, the SR values 0.21–0.97 indicated low richness, the J values 0.5–0.91 indicated co-dominance by *Scomber scombrus*, *T. trachurus* and possibly *Sardina pilchardus* and the *Clupeidae* larvae.

The Oceanic group of stations positioned on the shelf slope and west of the shelf were characterized mainly by the high-oceanic species *Lampanytus crocodilus* (Risso, 1810) present in all stations. *Maurolicus muelleri* was absent only from the one station whose depth (231 m) was less than 1000 m. *Scomber scombrus* and *T. trachurus* occurred in six of the eight stations, being absent from the two most extreme south-west stations. Diversity H′ values of 1.76 to 2.5, SR values 0.42–0.77 and J values of 0.83–0.97 indicated an assemblage of low diversity, very low species richness and dominance by *L. crocodilus* and, to a lesser extent, by *M. muelleri*.

Four of the stations did not cluster with the three main groups. The two stations positioned close to the Neritic group contained *Callionymus* sp. larvae and one also contained *S. scombrus*. The two stations near the Oceanic group contained just two species each, *T. trachurus* in both, plus the oceanic species *Electrona rissoi* (Cocco, 1829) and *Myctophidae* sp.

The Neritic and Transitional groups and the Oceanic and Transitional groups of stations showed high dissimilarity and the Neritic and Oceanic groups very high dissimilarity.

## DISCUSSION

In general, observed larval distributions result from many interacting variables, in particular the spawning location of the adult fish and the timing and intensity of spawning, but also the horizontal transport of the eggs and larvae.

The sampled stations in this study, as in the previous study by Horstman & Fives (1994), clustered into three broad groups each month (Neritic, Transition, Oceanic) based on the type and abundances of larvae in the stations, suggesting that these broad patterns of larval fish distributions are constant features of the Celtic Sea area, probably related to the spawning location of the adults. The presence of large spawning schools of fish was indicated by the dominance of certain species in the Oceanic area in March (*Micromesistius poutassou*), May (*Benthosema glaciale*) and June (*Lampanyctus crocodilus*) and in the Transition area in May (*Scomber scombrus*). The Neritic and Oceanic assemblages identified, showed very high dissimilarity. The Oceanic assemblages included larval stages of mesopelagic and high oceanic fish species such as *Maurolicus poutassou*, *B. glaciale*, *Notoscopelus kroyerii*, *Paralepis coregonoides* Risso, 1820, *Notolepis rissoi*, *Bathylagus* sp., *L. crocodilus*, *Protomyctophum arcticum* (Lütken, 1829), *Stomias boa ferox* Reinhardt, 1843, *Nansenia groenlandica* (Reinhardt, 1843), *Ceratoscopelus maderensis* (Lowe, 1839) and *Myctophidae* sp. None of these species were recorded from the Neritic stations. These fish species spawn over deep water



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(Whitehead et al., 1984) and probably complete their entire life cycle in the oceanic region and the more westerly of the Transition areas.

The Neritic stations were characterized by larval stages of necktonic, coastal species such as *Crystallogobius linearis*, *Gobius paganellus*, *Sprattus sprattus*, *Sardina pilchardus*, which in general spawn in shallow waters close to shore (Whitehead et al., 1984). The *C. linearis* specimens recorded in March were adults but it was evident that, in this study, as in previous studies (Walsh, 1980; Chesney & Noval, 1988; Horstman & Fives, 1994) this species was dominant when there was a paucity of the developmental stages of other fish species.

The Transition stations usually contained species characteristic of both the Oceanic and Neritic assemblages and therefore sometimes did not have a high dissimilarity to the other groups. However, in March the Transition group differed strongly from the other two assemblages because of course at that time the Neritic group of stations was dominated by *C. linearis* and the Oceanic group by *Maurolicus poutassou* and *Benthosema glaciale*. These species occurred in very few of the Transition stations and then in low abundances.

Some Neritic and Transition stations were, on occasions, spatially separated from others of their group. In the north-east of the sampled area in March, one of the Neritic group of stations is surrounded by Transition stations. A quarter of the larvae recorded from this station were *Clupea harengus*, a species not recorded in any other Neritic station, but present in a nearby Transitional station. The three Transition stations to the south-east and a single Transition station in the south, west of the shelf break, are spatially separate from the reminder of the Transition stations. They all yielded *Lepidorhombus whiffiagonis* and *Argentina sphyraena*, two of these stations contained *Callionymus* sp. and three contained *Buenia jeffreysii*, all these species characteristic of the Transition assemblage of fish. However, two stations also contained numbers of *M. poutassou* and *Benthosema glaciale*, species characteristic of the Oceanic group.

In May the Neritic and Transition stations contained many species in common. Indeed, one Transition station in the north-east is spatially separated from the rest of the group. This station yielded *Scomber scombrus*, *Trachurus trachurus* and *Callionymus* sp. which were characterizing species for the Transition group but also contained *A. sphraena* and *Trisopterus* sp. in common with the Neritic group.

Whilst assemblages of larval fish are temporary components of the zooplankton community, they do tend to reflect the general location and intensity of spawning adult populations in a particular period. In this study they indicated the position and relative abundance of the commercial fish species targeted by the INDICES project, in relation to all other fish species which are potential competitors for available food items. These target species, with the exception of *Engraulis encrasicholus* which was not recorded in this study area, did form important components of the various assemblages at different times.

As in the previous study (Horstman & Fives, 1994), *S. scombrus* and *T. trachurus* were the most abundant species overall, but *S. scombrus* did not form as high a percentage of the fish larval population as in these previous years, whilst *T. trachurus* comprised a higher percentage than previously. These differences in dominance and relative abundance may reflect variations in the timing and intensity of spawning. Large spawning shoals of *S. scombrus* travel northwards from the Bay of Biscay area each year (Coombs et al., 1990) and are usually associated with high productivity areas close to the shelf break. Circulation patterns in the study area (Pingree & Le Cann, 1989; Pingree, 1993) would tend to carry the larval stages towards and onto the shelf, where first feeding larvae may find good feeding conditions (Coombs et al., 1990; Kloppmann et al., 2001b). This trend was evidenced by the widespread abundance of these larvae in May and June. *Scomber scombrus* was the most abundant species in the Neritic stations in May and in the Transitions in May and June. In all other areas it was in competition with several more-abundant species.

*Trachurus trachurus* was the second most abundant species in the Transition stations in June but in all other instances was in competition with several more-abundant species.

Larval stages of *M. poutassou*, which spawns west of the British Isles each year (Bailey, 1982; Kloppmann et al., 2001a), was the most abundant species recorded in March when it dominated the Oceanic assemblage, but otherwise was a minor component of the Transition stations in March and May.

*Lepidorhombus whiffiagonis*, a deep-water species, co-dominated the Transition stations in March with several other species, but otherwise formed a very tiny percentage of the March Oceanic and May Neritic assemblages.

*Merluccius merluccius* did not form an important component of any assemblage in any month.

Any of the above species, when not dominant in an area, would obviously be under considerable competition pressure from the more dominant forms.

This study has emphasized the fact that an analysis of the population structure of ichthyoplankton can, in the absence of comprehensive hydrographical data, elucidate one of the factors which has a bearing on survival of the early developmental stages of fish, i.e. competition.

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