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Abundance and distribution of four-spotted megrim (*Lepidorhombus boscii*) in the Aegean Sea

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ABSTRACT. A two-year study of the abundance and distribution of the four-spotted megrim in the North Aegean revealed a pronounced preference of the species for fine sediment (sandy-muddy) bottoms, in a bathymetric range from 200 to 400 m. The depth of maximum predicted megrim density was found to be 339.8 m. The mean size of specimens in areas displaying higher levels of abundance was significantly smaller than that calculated for specimens in shallower and/or deeper waters. A density-dependent bathymetric pattern of distribution appeared to exist in the study area, with larger fish spreading out from habitats of increased fish stock abundance, where stronger competitive interactions might exist. Such interactions may be of great importance, considering that the Aegean Sea is one of the most oligotrophic areas of the world.

INTRODUCTION

The study of the distribution and abundance of a species provides information on the preferred habitats and on possible spatial and temporal shifts of the fish stock. Among the major factors determining the distribution of fish are prey availability and temperature (Rose & Leggett, 1989), which are often correlated with depth (Swain, 1993).

In many aquatic ecosystems, older (larger) demersal fish inhabit deeper and colder water, where they may benefit from lower metabolic costs and greater longevity, than their younger (smaller) conspecifics occupying shallower and warmer waters where food supply and growth rates may be greater (Macpherson & Duarte, 1991). If habitat selection is based on density-dependent resources such as prey abundance, then distribution is also density-dependent (Rosenzweig, 1991). Swain (1993) reported a density-dependent depth distribution for the Atlantic cod in the southern Gulf of St. Lawrence, suggesting a trade-off between the density-dependent benefits of greater prey resources in warmer shallower waters and the density-independent benefits of lower metabolic costs in colder deeper waters.

The four spotted megrim, *Lepidorhombus boscii* (Risso), is a sinistrally oriented flatfish (Scophthalmidae), which constitutes a significant portion of the Aegean groundfish resource (Papaconstantinou et al., 1994). It is of commercial interest, especially when longer than 200 mm. Little information exists on the biology and ecology of the four-spotted megrim. Dwivedi (1964) presented data on morphometric characters, the bathymetrical length-frequency distribution and the length-weight relationship of the species off the Mediterranean coast of France and in the Atlantic. The age and growth of the four-spotted megrim in the Atlantic were studied by Fuertes (1978) and Santos (1994), while in the Mediterranean the limited data that are published come from the Adriatic (Bello & Rizzi, 1987; Ungaro & Marano, 1995). The feeding habits of the species off the Mediterranean Spanish coast were discussed by Macpherson (1979). Santos (1994) analyzed the fecundity of the four-spotted megrim off the Portuguese coast. Its larval development was described by Sabates (1991). Finally, landing statistics of the U.K. megrim fishery, referring to *L. boscii* and *L. whiffiagonis* (Walbaum), were reported by Boon (1984) and trawl selectivity for megrims off the Spanish coast was studied by Astudillo & Sanchez (1989).

This paper analyzes the abundance and distribution pattern of four-spotted megrim collected in the North Aegean Sea, in order to delineate habitat preferences of the species and examine the role that population density plays in the dispersal of specimens.

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MATERIAL AND METHODS

During eight experimental seasonal fishing cruises, from June 1990 till March 1992, 15323 four-spotted megrims were collected in the north Aegean Sea, from a grid of 33 stations designed in order to be representative of all biotopes and depths of the trawlable area (Fig. 1). Bottom substrate at each station was characterized by the material (organisms and sediment type) that was contained in the cod-end of the trawl net, taking into account the classification scheme suggested by Peres & Picard (1964), as well as that of the benthic communities followed by Augier (1982). The vessel used was a commercial trawler equipped with a net having a cod-end mesh size of 14 mm (bar length).

Fig. 1. – Location of sampling stations in the Aegean Sea.

On board, the total length (TL) was measured to the nearest mm and the sex and the state of maturity of the gonads, according to NIKOLSKY's scale (1976), were recorded in most cases. A representative sample from each station was preserved in a deep freeze for further analysis in the laboratory.

Abundance values of the four-spotted megrim at each station, per season were expressed as number of specimens per hour of trawling (N: nh^{-1}) and were subjected to analysis of variance (ANOVA) for investigating the existence of possible differences. The Tukey multiple comparison procedure (ZAR, 1984) was used in order to locate differences among means.

Similarity of the species' spatial distribution was examined by performing complementary clustering (group average) and non-metric multidimensional scaling (MDS) to the seasonal abundance replicates from each site. Abundance values were subjected to square-root transformation before the analysis. The Bray-Curtis similarity coefficient (BRAY & CURTIS, 1957) was computed and then haul data were clustered with a group average fusion strategy (CLIFFORD & STEPHENSON, 1975) using Primer algorithms (CLARKE & WARWICK, 1989). Discontinuities in data from different sites may be accepted as real when the results of cluster analysis and multidimensional scaling agree (CLARKE & GREEN, 1988).

In order to determine which were the characteristics that could distinguish the groups defined by cluster analysis, discriminant analysis was applied to the data using as variables the depth and the substrate type of each station. The distinctiveness of station-groups was measured using a) the Wilk's λ criterion and its correspondent F-statistic to test the significance of the overall difference between group centroids (TASUAOKA, 1971; RAO, 1973) and b) the squared canonical correlation for each discriminant function, which was interpreted as the part of the total variance in the corresponding discriminant function that accounted for the groups (LEBART et al., 1984). Moreover, the percentage of stations correctly assigned to groups by the analysis was computed and considered as an indirect measure of the adequacy of the classification feature.

The regression relating abundance of megrims with depth was of the form: $Ln(N_i+1)=b_0+b_1D_i+b_2D_i^2$, where N is the abundance of megrim (nh^{-1}) in tow i and D is the depth in tow i (SWAIN & MORIN, 1997). The depth of maximum predicted fish density was calculated from the first derivative of the fitted model with respect to depth (i.e. $D_{max}=-b_1/2b_2$) (SWAIN & MORIN, 1997) for males, females and sexes combined.

RESULTS

The abundance of the four-spotted megrim ranged between 0 and 572 nh^{-1} (mean $=60.3$ nh^{-1}, $\pm$S.D.=110.6). In relation to season of sampling, abundance values did not appear to differ significantly (ANOVA: F=1.359, P>0.05), whereas the opposite was true of spatial variations (F=10.897, P<0.001).

For further investigation of site-dependent differences in abundance values, multivariate analysis was performed on abundance replicates from each station. Stations 22, 24, 31, 32, 33 were excluded from the analysis, since they were not exploited during most sampling cruises, due to bad weather conditions. Moreover, stations 16 and 17 were also excluded, because the species was never caught there. Five groups of sites were defined on the basis of the dendrogram and the MDS plot (Fig. 2a & 2b). The major factors responsible for the clustering of the sites seemed to be depth (Fig. 2c) and bottom substrate (Fig. 2d). In sites of group I, where the species presented highest abundance values, depths ranged from 220 to 450 m. Sea bottom in these sites was in all cases covered by mud or by sandy mud. In addition, the synthesis of the macrobenthic fauna encountered was such that we can characterize these sites as the biotopes of the Deep Muds (DM) and Bathyal Gravels (BG) biocoenoses (AUGIER, 1982). Abundance values decreased progressively from sites of group II to sites of group V. Relatively smaller abundance values coincided with sites having depths of 100 to 220 m (e.g. stations 23, 18, 14), and of 450 to 550 m (e.g. site 2). In waters shallower than 100 m and deeper than 550 m the presence of the species was very rare. In cases, however, where bottom type was unfavorable, the influence of

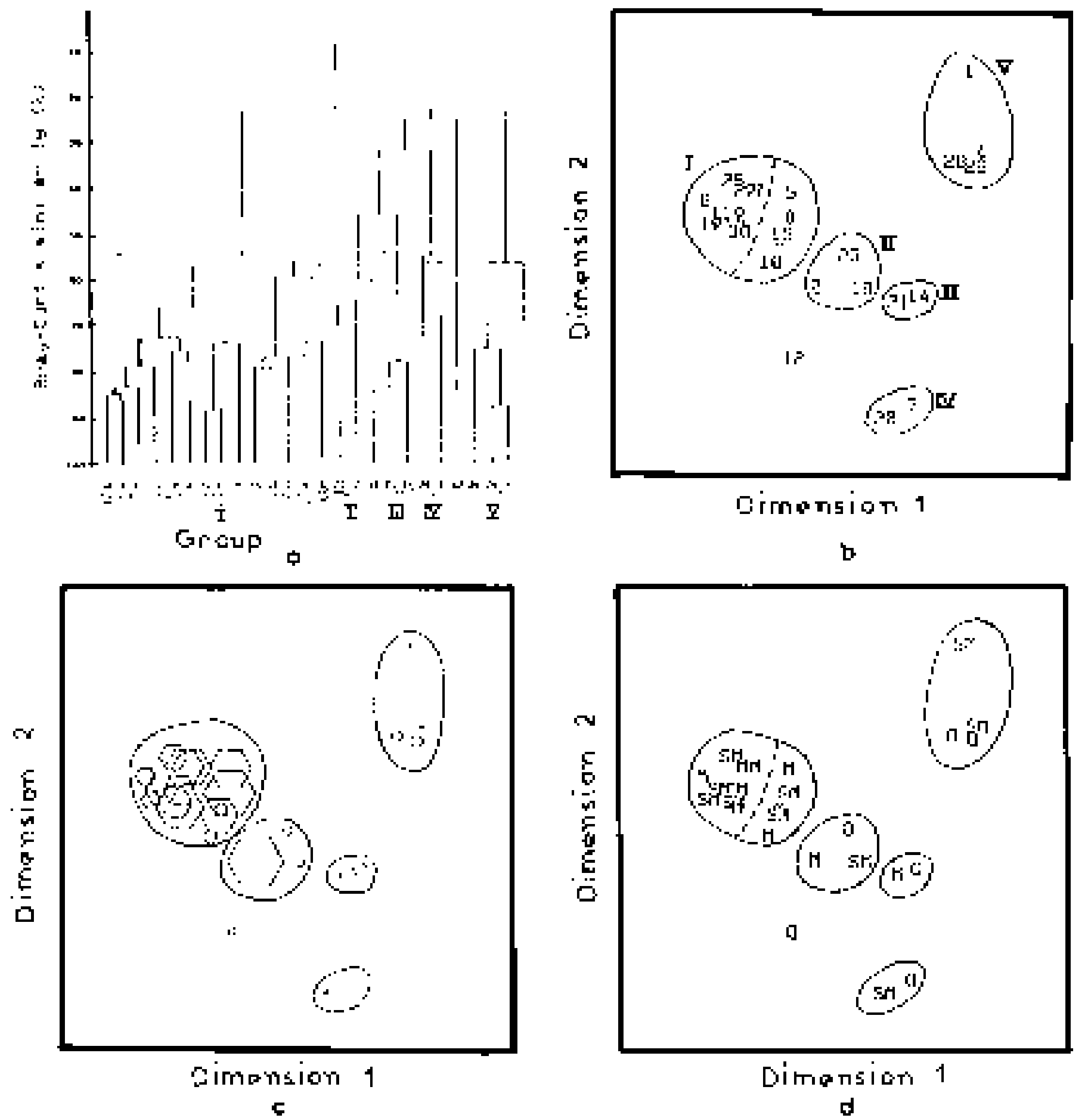


Fig. 2. – Dendrogram (a) and multidimensional scaling plot (b) of stations grouped by similarity in seasonal abundance (Nh^{-1}) of four-spotted megrim. (c) Same as in (b) with superimposed symbols of linear dimensions proportional to the depth at these stations (smallest exagon represents 66 m, largest 545 m). (d) Same as in (b) with superimposed the characterization M, SM for stations having muddy, sandy-muddy substrate, or O for stations with other type of sea bottom.

depth was obscured. This is clear for the sites of group V where the presence of the species was considered occasional. In the latter case, sites were either out of the preferred depth range, or when depth was within range, the limiting factor seemed to be bottom substrate. In particular, stations 1 and 4 had depths less than 100 m. Although stations 26 and 28 were within the preferred depth range, the first one was heavily colonized by echinoderms and the second one was covered by hard substrate. The fact that depth and bottom substrate were factors discriminating the various groups of stations derived from the classification mentioned above was corroborated by the results of discriminant analysis (Table 1).

The second-degree polynomial regressions relating abundance and depth were calculated for males, females and sexes combined (Fig. 3) as follows:

Males: $Ln(N+1)=-2.4874+0.0397D-0.0000592D^2$, $r^2=0.61$, n=17

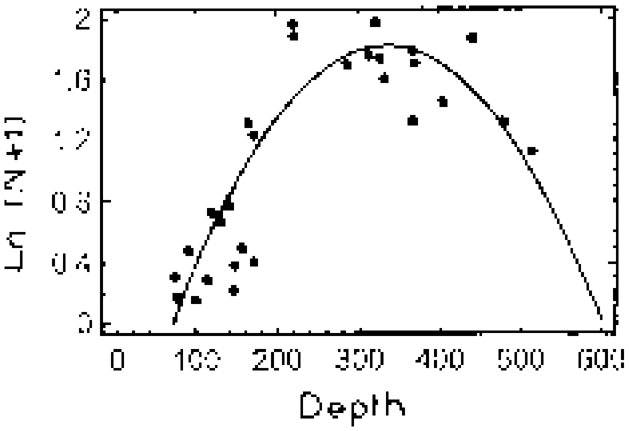
Females: $Ln(N+1)=-3.0652+0.0457D-0.0000681D^2$, $r^2=0.66$, n=17

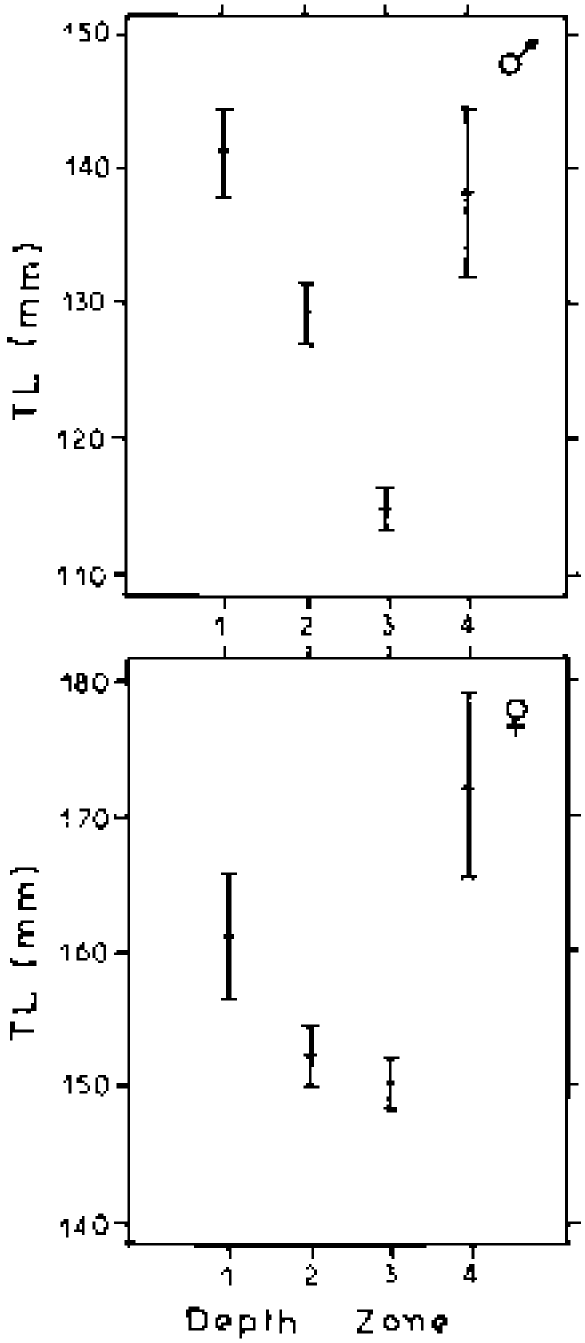
All fish: $Ln(N+1)=-3.1161+0.0401D-0.0000590D^2$, $r^2=0.71$, n=28

TABLE 1

Discriminant analysis on depth and substrate type. SDFC= standardized discriminant function coefficient.

Wilks'λ	Sign. Level	Correct assignments (%)	SDFC	
			Depth	Substrate
0.312	P=0.002	56	-0.621	0.740





The parameters of the above regressions yielded Dmax=335.3 m for males, 335.5 m for females and 339.8 m for sexes combined. ANOVA applied to the four-spotted megrim abundance data at the various depths revealed no significant differences in distribution between the sexes (F=0.32, P>0.05).

The study area was divided into four depth zones (i.e.: <200m, 200-300 m, 300-400 m, >400 m), according to the results of the megrim abundance data, and the mean total length (TL) with 95% confidence interval of males and females collected in each one was calculated (Fig. 4). At intermediate waters of 200-400 m smaller megrims were collected relative to shallower and deeper areas. ANOVA applied to the size data of megrims in the four depth zones displayed significant differences (F=7.81, P<0.001). Tukey's multiple comparison tests indicated that the mean TL of fish caught at depths 200-400 m was significantly smaller than the respective ones of fish caught in shallower and deeper areas. The comparison of the length frequency distributions in the four depth zones showed that at 300-400 m, the majority of specimens had lengths between 70 and 140 mm TL (Fig. 5). Moreover, in this depth zone young-of-the-year (50-80 mm) were recruited to the trawl fishery. At 200-300 m the bulk of the collected specimens had lengths of 100-170 mm TL. In deeper and shallower areas, however, small megrims (TL<120 mm) were rarely found among catches.

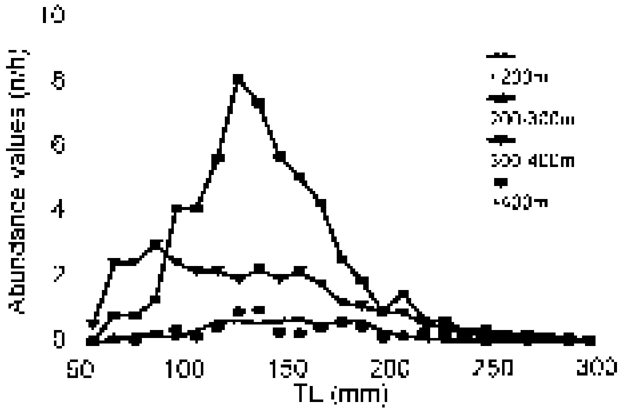
DISCUSSION

Depth and bottom type seemed to be the major factors influencing the four-spotted megrim distribution/abun-

Fig. 3 (upper left). – Relationship between the natural logarithm of the mean abundance (N: n/h), Ln[(N+1], of four-spotted megrim, both sexes combined, collected from 1990 to 1992 and depth (D in m) at the stations of the study area.

Fig. 4 (lower left). – Mean total length (TL, mm) of male and female four-spotted megrim at the four depth zones (1: <200m, 2: 200-300m, 3: 300-400m, 4: >400m) of the Aegean Sea.

Fig. 5 (lower right). – Length frequency distribution of four-spotted megrim collected in the Aegean Sea between 1990-1992.



dance; favorable areas were found to be those with depths of 200 to 450 m, having muddy or sandy-muddy bottom substrate. The species was rare or absent from sites not in the depth range of 100 to 500 m and/or when the sea bed was covered by coarse substrate or presented high concentration of benthic organisms (i.e. echinoderms). DWIVEDI (1964) mentioned that the optimum depth range for the species was between 100 and 250 m in the Mediterranean coast of France and between 300 and 400 m in the Atlantic. BELLO et al. (1988) considered the four-spotted megrim as one of the most abundant teleosts in depths from 100 to 400 m in the Adriatic. FUERTES (1978) reported that off the Spanish coast of Galicia the species preferred areas with depths between 150 and 375 m.

FARGO & TYLER (1991), mention that flatfish off the Canadian coast, with feeding specialized for different benthic organisms, are expected to be distributed according to sediment type, as well as depth. The importance of feeding was very pronounced for the distribution of Dover sole (*Microstomus pacificus* Lockington) (FARGO & TYLER, 1991). The four-spotted megrim diet in the north Aegean Sea comprised mainly decapod crustaceans (unpubl. data, 1996). In fact, the natant *Alpheus glaber* (Olivi), which dominated the stomach contents, is known to dwell exclusively on muddy substrates (VAMVAKAS, 1971). Moreover, the natant *Processa canaliculata* (Leach) and the mysid *Lophogaster typicus* (M. Sars), which were also important components of the species diet, are usually found on muddy substrates (HOLTHUIS, 1987; HATZAKIS, 1982).

Another factor that could play a role on the distribution of the species over fine bottom sediment could be related to the foraging behavior and/or predator avoidance (VASSILOPOULOU, 1998). MARSHALL (1966) suggests that flatfish living on mud or sand, settle into the bottom, flouncing their body and fins so as they cloak themselves with a thin layer of deposit leaving no more to view than a pair of watchful eyes.

The bathymetric pattern that usually appears in demersal fish is associated with larger specimens shifting to deeper waters. This trend is so common that it has been referred to as Heincke's law (CUSHING, 1981). In the case of the Aegean sea four-spotted megrim, however, the results showed strong evidence of a dome-shaped relationship between depth and four-spotted megrim abundance. Fish abundance was maximized at intermediate depths of about 340 m, which appeared to form an "optimal environmental window" either side of the dome apex. A dome-shaped relationship was also found to exist between depth and abundance of the red bandfish (*Cepola macrophthalma* L.) in the Aegean Sea (STERGIOU, 1993). Another important feature that should be also considered regarding the four-spotted megrim bathymetric distribution is that specimens collected in areas of maximum density were usually smaller than those collected at deeper and shallower waters. The above suggest that a density-dependent pattern of depth distribution could possibly exist for the species in the Aegean Sea. In areas where stock abundance is high, a spreading out may occur, with specimens expanding their distribution into marginal habitats. The fact that larger fish are those that appear outside the areas of high concentration may be consistent with the positive effect of fish size in swimming speed and migration or dispersal rates. Bathymetric trends in demersal fish size may be linked to temperature and prey abundance in a manner that optimizes growth and maintenance (MACPHERSON & DUARTE, 1991). Thus larger megrims, with higher bioenergetic needs and increased mobility, could disperse in areas of relatively lower population density, where intraspecific competition for food should be decreased. Moreover, ontogenetic shifts appear in the diet of megrims, with mysids being the main component of the diet of small specimens, replaced by decapods and fish in the diet of larger four-spotted megrims (VASSILOPOULOU, 1998). The existing information on the distribution of these food resources in the Aegean (STERGIOU et al., 1997), does not allow determination of the role of ontogenetic diet differences in the observed bathymetric pattern. Further studies are required in order to elucidate the role of density in the distribution of fish and to clarify specific matters associated with the dispersal of specimens in different habitat types and especially under different conditions of food availability.

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