# Some considerations on the growth performance of Mullus barbatus

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# Some considerations on the growth performance of *Mullus barbatus*

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**SUMMARY -** In this paper, the size structure of *Mullus barbatus* in the area between the Elba Island and the River Magra is analysed. Data come from trawl surveys that made use of two different fishing gears. Surveys were performed from 1985 to 1995. Multivariate analysis allowed to classify and pool together hauls characterized by similar length composition. This procedure gave rise to better knowledge regarding the geographical distribution of the species according to age as well as the changes of size structure in time and space. It was shown that size groups (that correspond to different cohorts) are concentrated in specific areas. The shape of these areas, defined by hauls with similar size structure, changes during the year. The massive presence of the 0+ year class, very close to the coast immediately after the recruitment at the bottom (in summer) is followed by a dispersal towards deeper waters. Monthly samplings not only allowed to make an accurate analysis of the slow displacement towards off-shore but also constituted a very important source of information regarding the species growth performance at the beginning of their demersal phase. The study highlighted the important role of the 0+ age class in the population and in the catch. Given the massive presence of sexually mature individuals at the end of June (almost all the one year-old individuals spawn in June or at the beginning of July), the cohorts were easily aged and this allowed the construction of a sort of age/length key. The age/length couples so obtained were compared with those derived from von Bertalanffy growth curves estimated with a different approach but using the same source of data. It was concluded that none of the curves is able to describe adequately the growth pattern for the whole life of the species. In fact, red mullet is characterized by an extremely fast growth during the first months of life, followed by a slower growth increment with time, hardly explainable with a single set of growth parameters.

**Key words:** Growth performance, spatial distribution, *Mullus barbatus.*

***RESUME -*** *"Quelques considérations sur les performances de croissance de* Mullus barbatus*". Dans cet article, la structure par taille de* Mullus barbatus *à l'intérieur de l'aire définie par l'île d'Elba au sud, le fleuve Magra au nord et la bathymétrie de 700 m vers le large est analysée. Les données proviennent des campagnes scientifiques de chalutage de fond. Deux différentes typologies de métier ont été utilisées. Les campagnes ont été effectuées à partir de 1985 et jusqu'en 1995. Des analyses multivariantes ont permis de classifier et rassembler les stations de pêche caractérisées par une composition de tailles similaires et d'observer ses changements en relation au temps et à l'espace. On a démontré que les groupes de tailles (correspondants aux différentes cohortes) sont concentrés dans des aires spécifiques. La forme et les dimensions de ces aires, définies à partir des stations de pêche caractérisées par une structure semblable par taille, changent durant l'année. La présence massive de la classe d'âge 0+ très proche de la côte immédiatement après le recrutement au fond (à la fin de l'été) est suivie par une dispersion vers les zones plus profondes. Des échantillons mensuels non seulement ont permis de faire une analyse détaillée des lents déplacements vers le large mais ils constituent aussi une très importante source d'information au regard des performances de croissance au départ de la phase démersale. Ils se sont aussi montrés appropriés pour mettre en évidence l'important rôle de la classe d'âge 0+ à l'intérieur soit de la population soit de la capture. En considérant la présence massive des individus sexuellement matures à la fin de juin (presque tous les individus nés une année avant se reproduisent entre juin et juillet) l'âge des cohortes a été très facilement déterminé et ce fait permet la construction d'une sorte de clé taille/âge. Ces couples taille/âge ont été comparés avec les valeurs correspondantes obtenues à travers les équations de croissance de von Bertalanffy estimées avec différentes approches dérivées de la même source d'informations. La principale conclusion est qu'aucune des courbes obtenues n'est capable de décrire d'une manière appropriée le modèle de croissance des individus à travers la vie. En effet, le rouget est caractérisé par un taux de croissance très rapide pendant les premiers mois de vie et par une graduelle diminution de sa vitesse dans les phases suivantes. Ces phénomènes sont difficilement explicables avec un unique ensemble de paramètres de croissance.*

***Mots-clés :*** *Performances de croissance, distribution spatiale,* Mullus barbatus.

## Introduction

Many papers have been produced on red mullet but up to now it is not possible to consider that the species natural history and fisheries are well known. Over the last years, our Institute has performed several studies on partial aspects of the species such as: geographical distribution of juveniles and adults (Voliani *et al.*, 1991), individual growth by sex (Voliani *et al.*, 1995), age-related displacements and their seasonal changes (Abella *et al.*, 1996) and more detailed studies on several biological aspects with direct implicancies on the population dynamics and stock assessment (Voliani *et al.*, in press). In this paper, a direct linkage of some of these aspects was attempted. This was done by utilizing all previous knowledge as well as new dynamical analyses of the collected length frequencies. The study was mainly addressed to a better description of the species growth performance, specially for the first year of life. This was done by means of the analysis of the modes by methods that allow an easier interpretation of their progression with time. Due to the fact that commercial fleet utilizes low selective gears with small-meshed cod end, the knowledge of growth performance in this particular period is very important for the application of assessment models to the Mediterranean groundfish fisheries.

It is generally accepted that models like von Bertalanffy are not suitable for a correct description of the species growth pattern during the whole life-time period.

Almost all the Authors have chosen parameters that are able to describe quite well the growth performance of the individuals but only over a certain size and often very high negative estimates for $t_o$ are given. Length frequency data never allow to estimate $t_o$ (Pauly, 1987); working on "relative age classes", the estimates of "absolute age" produced by the programs ELEFAN (Gayanilo *et al.*, 1996) and MULTIFAN (Fournier *et al.*, 1990) are based on the assumption that the species growth pattern for its whole life is well described by the von Bertalanffy Growth Model and, in consequence, that $t_o = 0$. If in the first part of the curve this assumption does not apply, unreasonable size-at-age values for the younger fish will be obtained and, in consequence, the age of the bigger individuals will be also shifted along the time axis. In this paper, results obtained with different techniques are analysed and some practical solutions are proposed in order to contribute to the choice of a suitable growth model for species exploited with the above described "Mediterranean fishing strategy". This approach does not necessarily imply the use of the von Bertalanffy growth model.

## Materials and methods

Data proceed from trawl-surveys performed with two different fishing techniques. The first one utilized a commercial trawler and a trawl net (tartana) with a stretched mesh size of 38 mm at the cod end. Surveys with this fishing technique covered the area from North of the Elba Island to the Magra River and were done since 1985 up to the current year. Tows were distributed within a depth range 10-700 m and replicated generally 3 times each year. Duration of tows was of one or two hours. Surveys were mainly done in Spring, Summer and Autumn. Only one Winter survey was performed.

Sampling scheme was random stratified by depth. Hauls were distributed in proportion to stratum areas and randomly allocated within strata. During the recruitment period that occurs in Summer, a cover of 20 mm stretched mesh size was placed around the cod end in order to retain almost all the individuals recruited to the ground but not still recruited to the commercial gear.

The second sampling strategy consisted in monthly trawl-surveys utilizing a small trawler and a small meshed net (4 mm stretched mesh size at the cod end). In this case, surveys were performed in a relatively reduced area near Viareggio harbour within a depth range 5-60 m. Sampling design was systematic. 3 transects were positioned perpendicularly to the coast-line and hauls made over each transect at fixed depths (10, 15, 25, 45, 60 m). If we utilize data proceeding from hauls unequally distributed by depth interval areas, the pooled length frequencies so obtained do not represent the real species composition by size for the whole study area, but the size composition of each single haul constitutes an unbiased sample of the population structure in this point.

The size distributions at sea for the month of February, due to the scarcity of Winter data, were reconstructed also by means of the analysis of representative samples proceeding from the commercial landings of Piombino and Livorno harbours.

The program TWINSPAN, a Cornell University Ecology Program (Mohler, 1987), was employed for the analysis of the length frequencies. It is a hierarchical divisive and polythetic classification technique, particularly suitable for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. It is an improvement upon the original "indicator species analysis" in which species are classified as well as samples. The data are first ordinated by reciprocal averaging (RA) along an axis. The species positioned at the axis extremes are emphasized in order to polarize the samples. Then, the samples are divided into two clusters by breaking the ordination axis near its middle. This sample division is refined by a reclassification using the species characterized by a maximum value as indicators of the axis poles. This process is repeated on the two sample subsets to give four clusters and so on. A corresponding and contemporary species classification is produced and the sample and species hierarchical classifications are used together to produce an arranged data matrix. The resultant sample and species hierarchies can be displayed as a dendrogram. The sequences of divisions can be used as integral levels or level values calculated as the average distances between samples in ordination space. For more details see Hill (1979) and Gauch and Whittaker (1981).

The most important part of the output of TWINSPAN is the ordered "two-way table" of samples and species, and their assignment to groups indicated along the margins. Here, the presence of certain size classes within a sample was considered in the same way as the species. Their co-occurrence (and relative abundance) differentiates some samples from others. This is because the classification by TWINSPAN is based on differential "species" (in this case sizes as an alternative) which occur mostly in one group of samples and not in another.

Much of the quantitative information in input can be retained by the method by expressing it on a relatively crude scale. The levels of abundance used in TWINSPAN are termed "pseudospecies cut levels".

In order to eliminate noise due to the observed important differences in growth rates between males and females as well as due to the dispersive movements towards deeper waters that begin as soon as the individuals settle to the ground, the analyses were performed separately by sex and sampling period. This allowed to identify more clearly groups of samples with similar length distributions, to plot them on a geographical chart and to define areas with characteristic demographic compositions. Only one age class was in general massively present in the hauls pooled together by the program of clustering. This was especially true for the 0+ class, but when more age classes (represented by polymodal distributions) were present, the Bhattacharya and NORMSEP techniques, included in the FISAT package (Gayanilo *et al.*, 1996) were utilized for the separation of the "normal" distributions of the different cohorts.

The comparison of the 5 charts separately by sex so obtained (corresponding to the months of July, October, November, May and June) made easier to follow the main deployments of fish, especially those of the "youngs-of-the-year", and to better describe the individual size increments with time during this particular period.

The size frequencies collected immediately after the recruitment (July-December), proceeding from the monthly coastal trawl-surveys performed within the depth range 5-60 m, were analysed without any previous elaboration with TWINSPAN because the area was limited and the catch composed almost exclusively of 0+ age class new recruits. These results were considered complementary to those obtained by means of the analysis made with the program TWINSPAN for the 5 periods described above. The so obtained age-length data sets for males and females were successively compared with other published results.

The analysis of the length composition of the random stratified hauls considering space and time variables, also allowed to quantify which is the proportion of year class 0+ over the whole population and how its contribution to the total number (and biomass) changes with time.

## Results and discussion

The samples analysed with TWINSPAN were pooled in homogeneous groups based on their demographic composition. It is important to remark that separate analyses for males and females gave, for each sampling period, similar geographical distribution pattern suggesting that, concerning to this aspect, noticeable differences by sex do not exist. Five different situations were identified along the year. They can be described as follows:

In July *Mullus* recruits to the ground and the first juvenile individuals are caught. In this month, the program TWINSPAN defined, for both sexes, three different areas (Fig. 1): the inshore area (depths up to 25 m) where there is a net predominance of the new recruits highly concentrated and with only some residual presence of age class 1+ individuals; an intermediate depth interval (up to 80 m) with the almost exclusive presence of the age class 1+, and a third zone that includes the hauls performed up to 200 m (that approximately coincides with the limit of the species depth distribution) where individuals of age 1+ and older are present. It is important to consider that in this period the recruitment is just started and, in consequence, the observed age 0+ mode does not represent the real mode of the individuals of this year class not completely recruited to the bottom; it is composed only by the right hand tail of their size frequency distribution. Fig. 1 and successive only show the geographical distribution by size for females, the males pattern of geographical distribution being very similar.

During October and November (Fig. 2) two different situations were observed: while the shallower waters (up to 100 m depth) are characterized by a massive presence of 0+ age class (already completely recruited), in deeper waters the youngs-of-the-year are still not arrived. It is interesting to remark the noticeable difference in mean size (2-3 cm) between the sexes at only few months from hatching.

In May (Fig. 3) and June three different situations were identified, with a negative trend of abundance of the 0+ individuals (already close to their first birthday) towards offshore.

The modal size progression for both sexes is illustrated in the Figs 4 and 5. The values of the modes, corresponding to the 3 first year classes and estimated by means of the Hasselblad (NORMSEP) and the Batthacharya methods for each sex, are summarized in Table 1 in which mean size for each period of sampling is shown. Assuming a birthday on the 30$^{th}$ of June, twenty couples of length-at-age data for each sex were obtained that accurately describe on average the species growth pattern.

It is now necessary to establish some premises on which the scope of this paper is based. Even if the study of growth has to be considered mainly as the determination of size as a function of age, we can distinguish two qualitatively different approaches to describe growth: the first one is limited to the constitution of a pool of couples of age-length data, the second is a proper model that is constituted by parameters (i.e., the Brody-von Bertalanffy). Both approaches can be very useful depending on the future use of this information. While traditional "analytical" assessment approaches as the well known Yield-per-Recruit model (Beverton and Holt, 1957) need growth parameters as input, new approaches, especially thanks to the development of powerful electronic spreadsheets, can be followed even if growth parameters are not available. When sets of von Bertalanffy growth parameters have been estimated but are unable to explain, correctly and simultaneously, the growth pattern for both, the earlier and the later fraction of their life, the second approach should be more suitable.

The available programs of length frequency analysis for growth parameters estimation like MULTIFAN and ELEFAN assign relative ages at each mode based on a previous estimation of birth simply defined as the point in which the growth curve intercept the age axis. The relative age is then equal to absolute age only if the fish, in the first part of their life, have grown in the same manner predicted by the equation. MULTIFAN output gives also the estimated relative age of the first mode. The results of MULTIFAN for this species (Voliani *et al.*, 1995) assigned arbitrarily to the first mode of the August sample an age of about 0.5 years. This result is not reliable taking in consideration the information derived from this and other studies (De Ranieri, 1979; Gharbi and Ktari, 1981; Orsi Relini and Arnaldi, 1986; Sabates and Palomera, 1987; Vrantzas *et al.*, 1992; Tursi *et al.*, 1994). It is suggested that the growth pattern at the early stages of life (especially during the larval or pelagic phases) follows a different model of growth. Thanks to the available absolute age-length key the estimation of a suitable $t_o$ value was possible and this allowed to shift the curve towards the left in order to assign to the first observed age-length couple (corresponding to the August sample) the real age at this month (about 2 months). The correction was simply made by calculating the difference between the relative age assigned by the program for the first mode and the real age (the time passed from the assumed birth-day fixed on the 30$^{th}$ of June). Without this correction procedure, all the modes would be erroneously shifted towards the right, decisely underestimating the size corresponding to a given age.

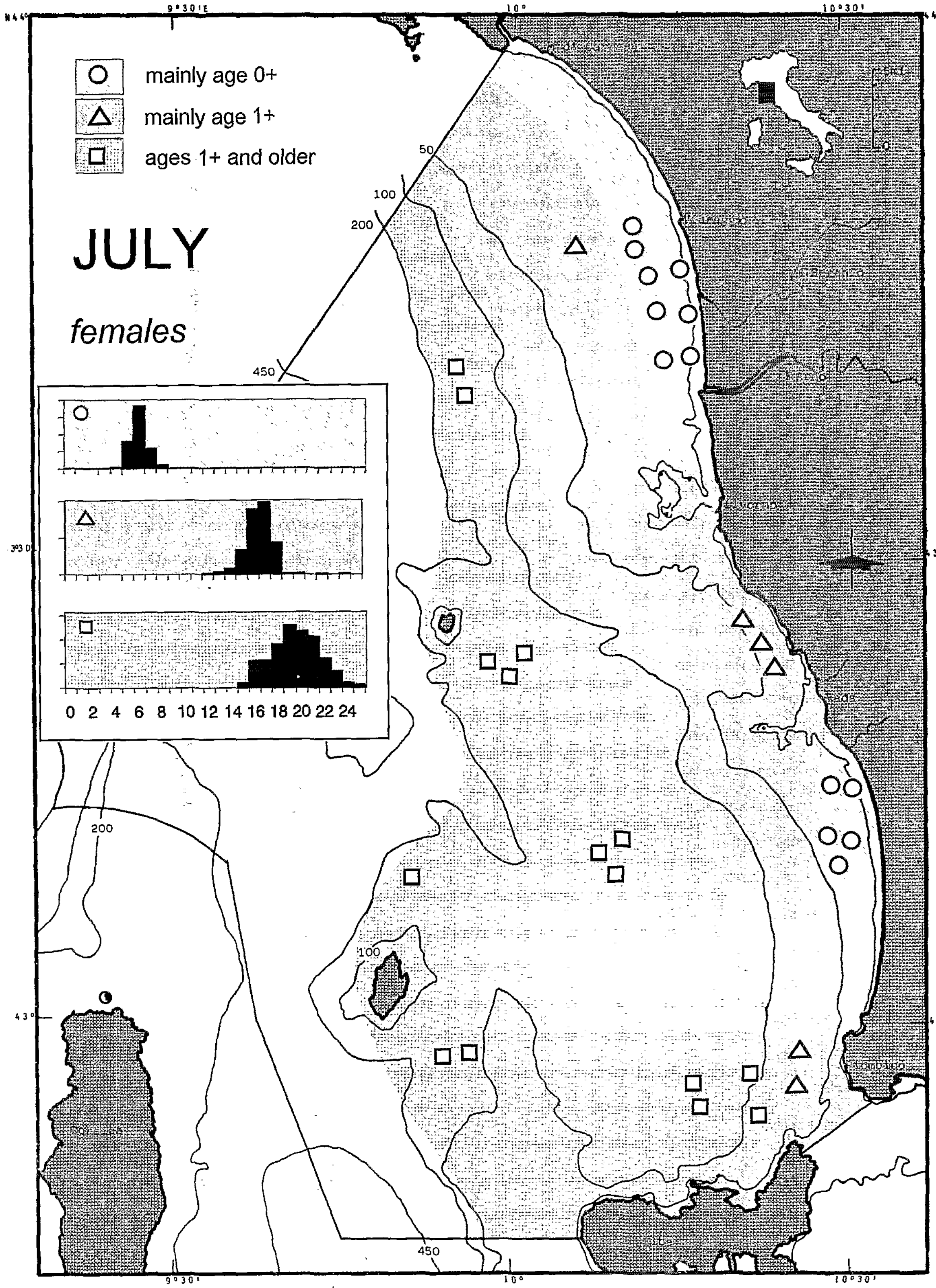


Fig. 1. Geographical distribution of red mullet by size on July and length frequency distributions corresponding to the three defined areas.

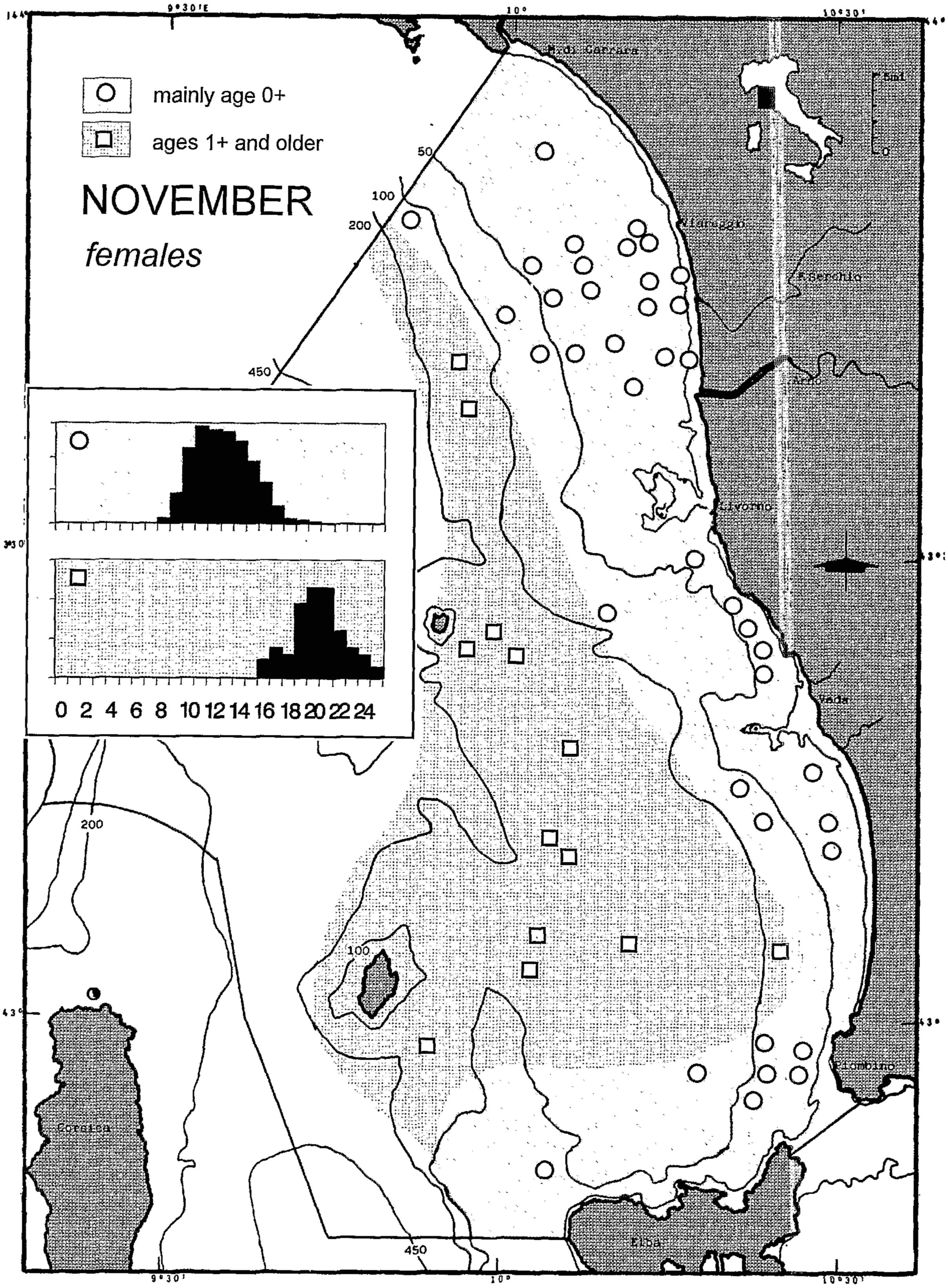


Fig. 2. Geographical distribution of red mullet by size on November and length frequency distributions corresponding to the two defined areas.

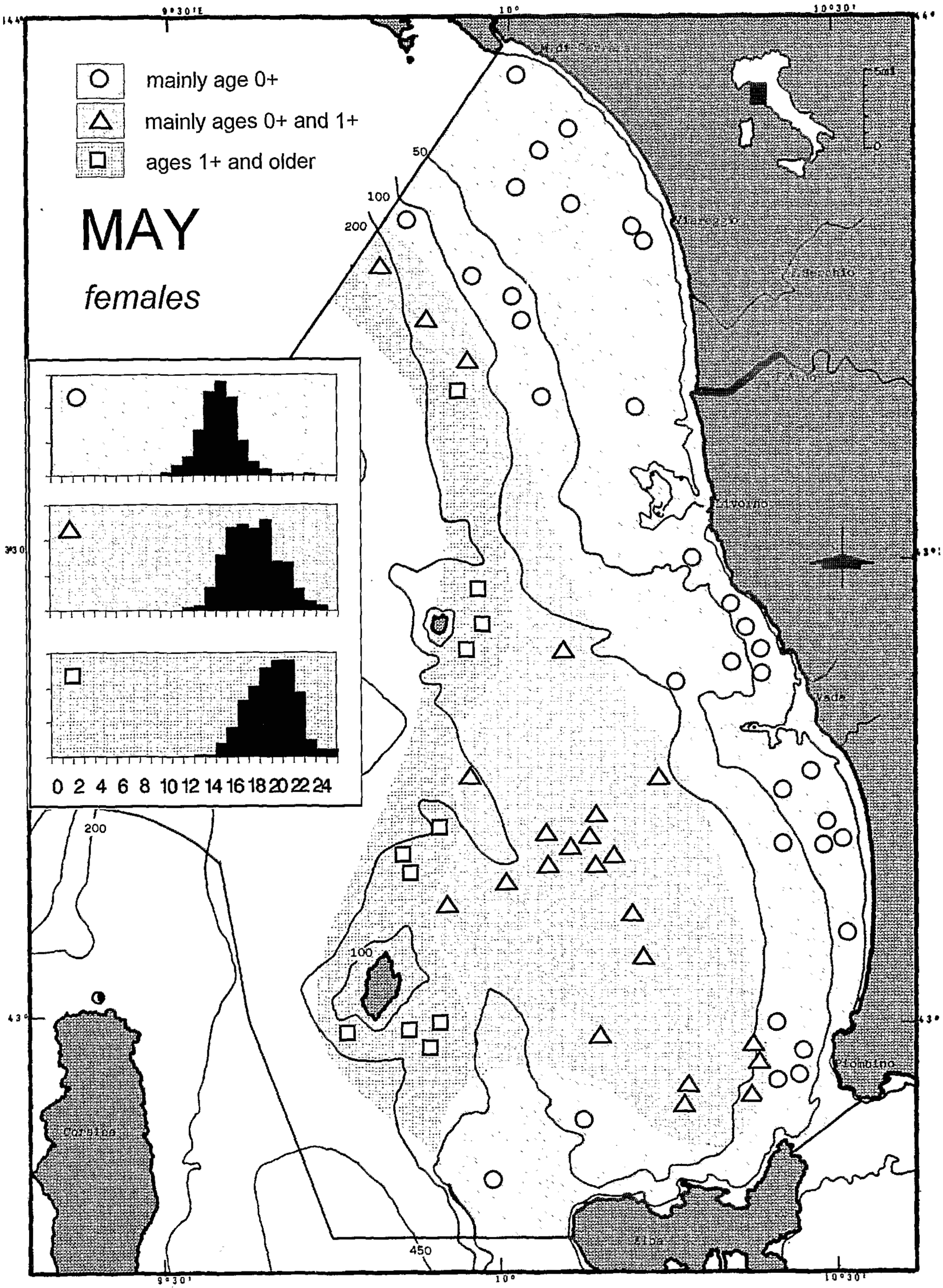


Fig. 3. Geographical distribution of red mullet by size on May and length frequency distributions corresponding to the three defined areas.

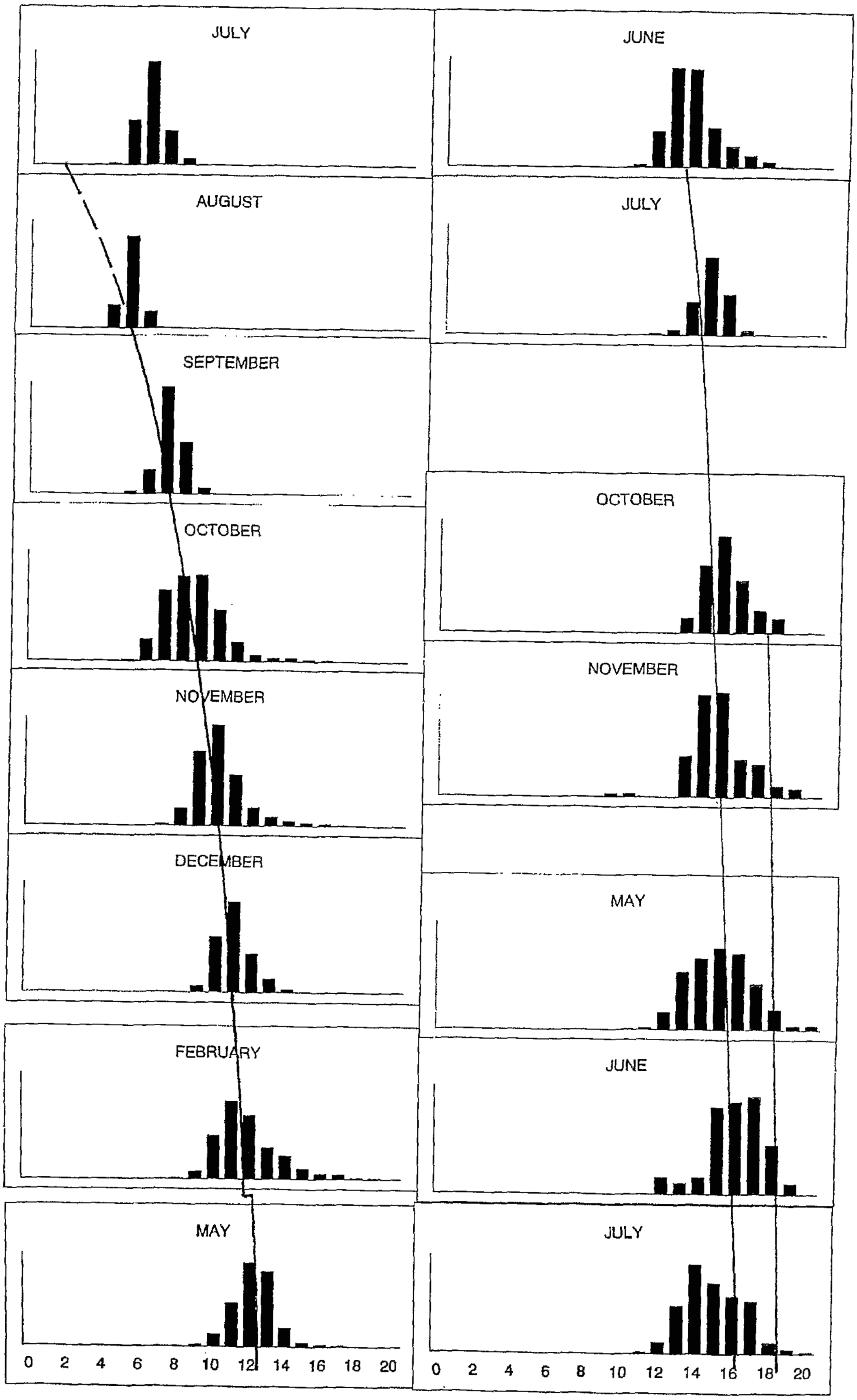


Fig. 4. Interpretation of length frequency data for males of red mullet.

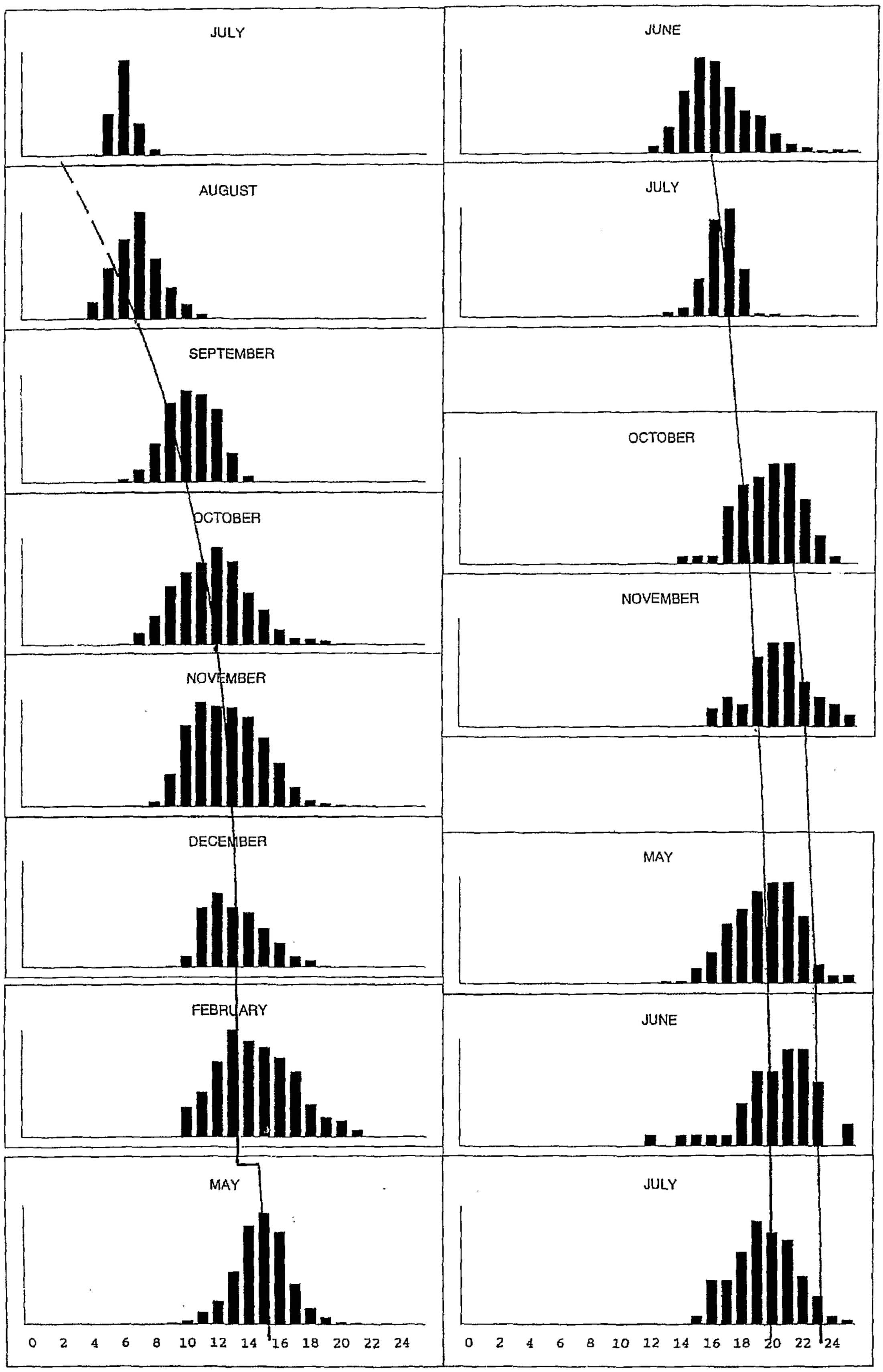


Fig. 5. Interpretation of length frequency data for females of red mullet.

Figures 6 and 7 show the observed age-length data proceeding from Table 1 compared with the von Bertalanffy curve obtained with the MULTIFAN program (males: K = 0.696, $L\infty$ = 20.6, $t_o$ = -0.60; females: K = 0.697, $L\infty$ = 27.0, $t_o$ = -0.39). We can see that a good fitting was obtained after the above described correction procedure.

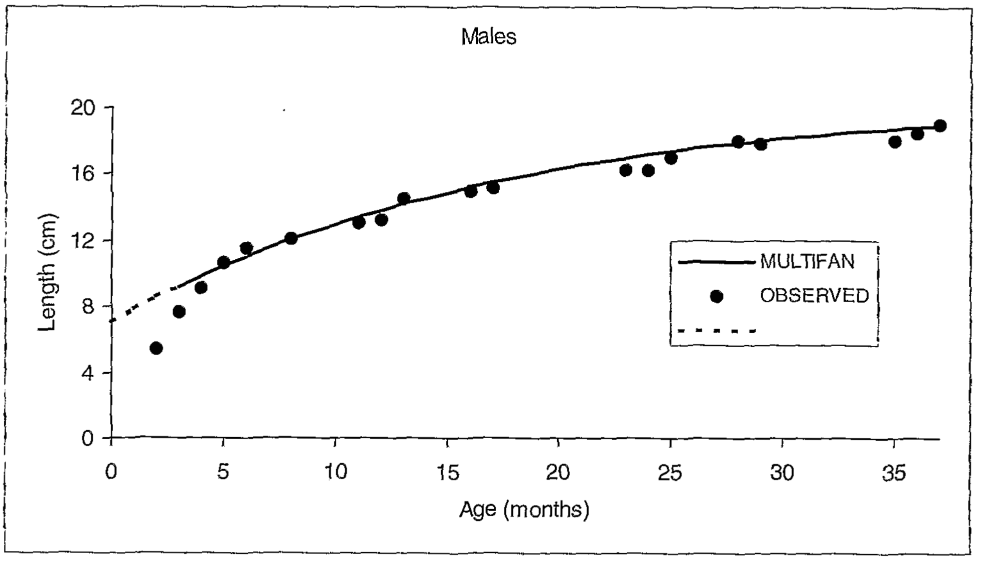


Fig. 6. Comparison between the observed length-at-age data and the theoretical growth curve obtained with the MULTIFAN3 software (males).

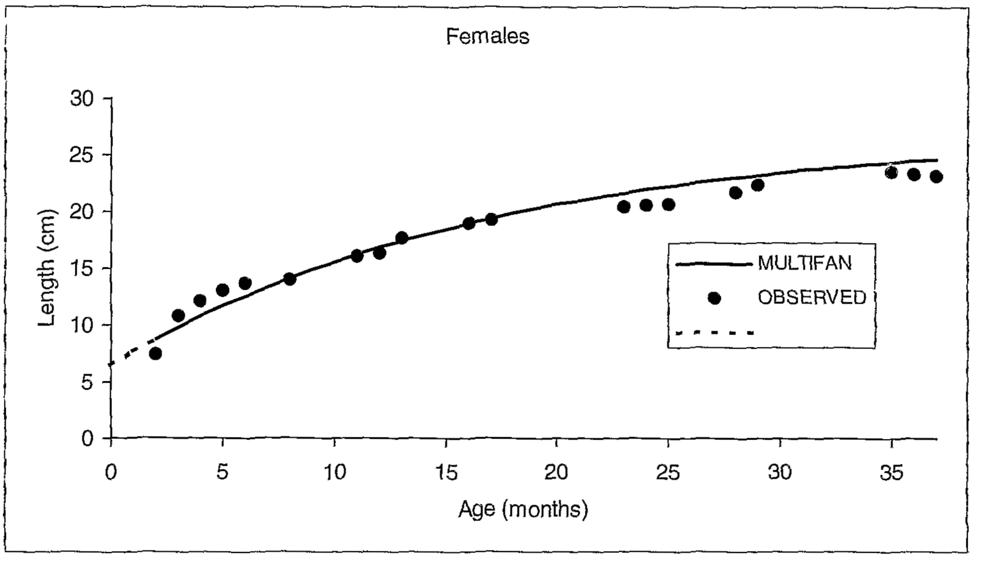


Fig. 7. Comparison between the observed length-at-age data and the theoretical growth curve obtained with the MULTIFAN3 software (females).

The improvements obtained for the year classes discrimination also allowed to estimate the relative importance of year class 0+ over the whole population. The analyses showed that age class 0+ represent 95% of the total population in number during October and November. This proportion is successively reduced to 80% during May and June. In Figs 8 and 9 the described changes in age structure along the year are illustrated. The reduction of the proportion of 0+ class individuals from October-November (just after the recruitment) to May-June suggests that in this period the total mortality for the 0+ class is higher than for the older year classes. This high mortality rate is not only due to natural causes. The geographical referenced information on size structure illustrated here was useful to point out not only that age class 0+ predominates in the population structure but also in the commercial catch. This fact is particularly evident by overlapping the geographical distributions by size presented in this paper onto the charts of distribution of fishing pressure on the groundfish assemblages of the area defined by the different fishing strategies (Abella and Serena, 1995) in which *Mullus* is a main component. Fishing is actually mainly concentrated on the inshore area, where the 0+ class largely prevails, rather than on the more offshore areas, where the older age classes predominate but with modest catch rates. Clearly, then, the higher mortality rate for the 0+ class is also due to a higher fishing pressure.

Table 1. Mean individual size and corresponding sampling period for the former 3 age classes of red mullet along the year

| Age class | Males | Females |
|---|---|---|
| 0+ | | |
| July | 6† | 6† |
| August | 5.4 | 7.4 |
| September | 7.7 | 10.8 |
| October | 9.1 | 12.1 |
| November | 10.6 | 13.0 |
| December | 11.5 | 13.7 |
| February | 12.1 | 14.0 |
| May | 13.1 | 16.0 |
| June | 13.2 | 16.3 |
| 1+ | | |
| July | 14.5 | 17.6 |
| October | 15.0 | 19.0 |
| November | 15.1 | 19.2 |
| May | 16.2 | 20.4 |
| June | 16.2 | 20.5 |
| 2+ | | |
| July | 17.0 | 20.6 |
| October | 18.0 | 21.7 |
| November | 17.8 | 22.4 |
| May | 18.0 | 23.5 |
| June | 18.5 | 23.3 |
| July | 19.0 | 23.2 |

†Not completely recruited

## Conclusions

The analysis of spatial referenced data proceeding from trawl-surveys were demonstrated to be a very important source of information regarding the species growth performance especially at the beginnings of their demersal phase. The very fast growth pattern of the species was confirmed. The comparison between age/length couples obtained by means of multivariate analyses and von Bertalanffy growth curves derived from the same source of data have shown that a single set of von Bertalanffy parameters is not able to adequately describe the growth pattern for the species whole life. In fact, red mullet is characterized by an extremely fast growth rate during the first months of life, followed by a slower growth increment with time.

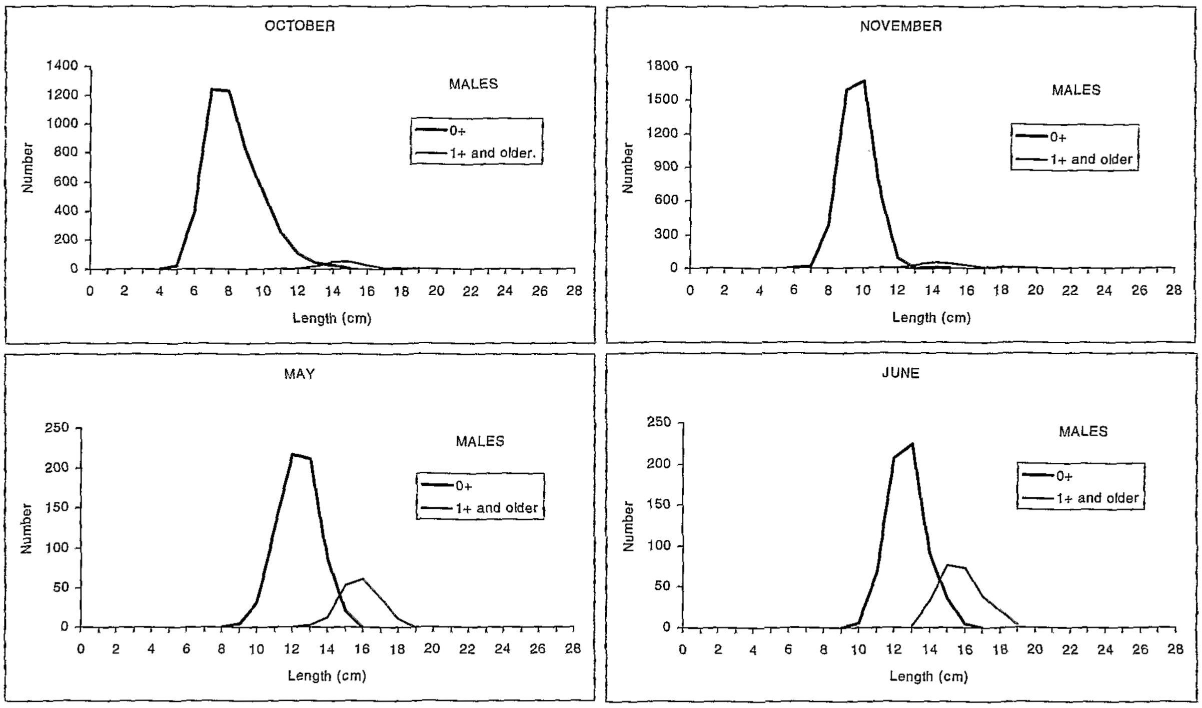


Fig. 8. Changes on the observed relative importance of the age class 0+ along the year (males).

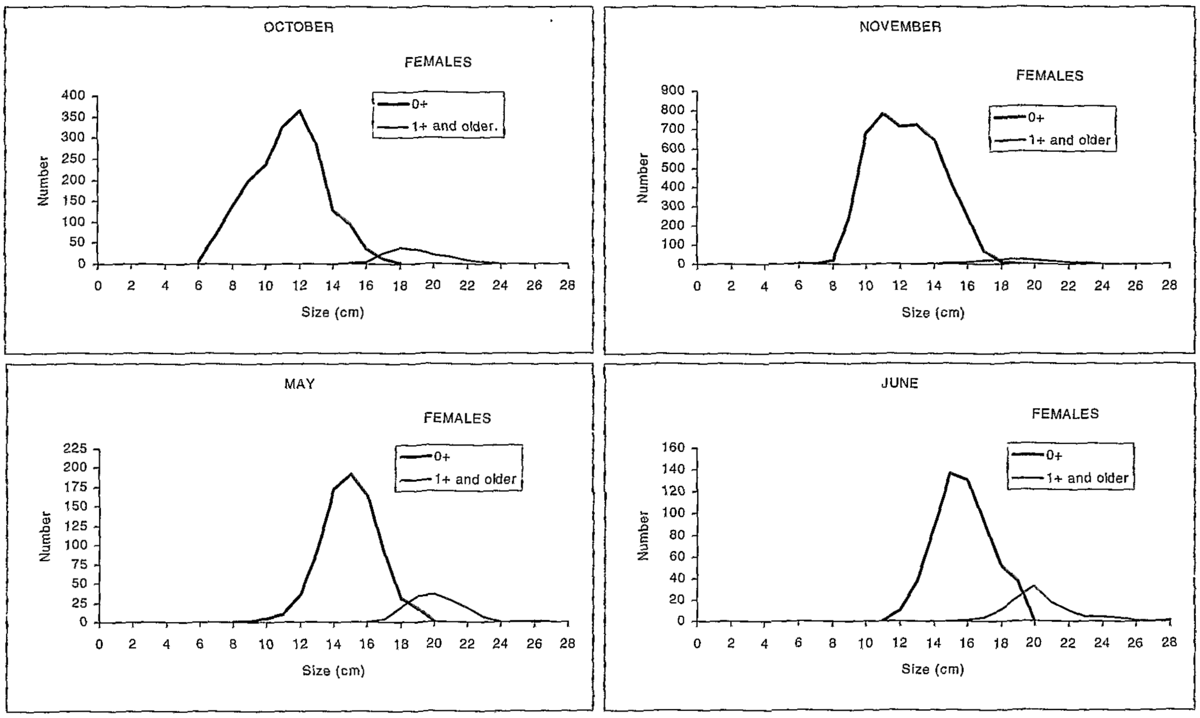


Fig. 9. Changes on the observed relative importance of the age class 0+ along the year (females).

In the Mediterranean Sea, species are traditionally recruited to the fishery when they are very young (often when they are less than one year old) and this fishing strategy may produce a very high mortality among these small individuals. In these cases, for an adequate assessment of the state of the fishery of a stock exploited with such a strategy, there is also a need of a good knowledge of the dynamics of the exploited populations (growth patterns, mortality rates, geographical distribution, fisheries) during their early life histories.

The geographical distribution by size demonstrated its usefulness for the stock assessment and for giving management advice. In fact, the knowledge of the areas in which certain size-classes are concentrated is very important in order to rationalize the commercial exploitation of a given species. In the case of *Mullus barbatus* the employed methodology has demonstrated to be particularly suitable for a best definition of the nursery areas and for the analysis of the distribution changes in time and space addressed to the choice and implementation of adequate management procedures as fishing bans by area or by season. The collected data constituted a piece of ancillary information that contributed to improve the assessment of the real impact of fishing activities on different life phases of the species. The results were also very useful for the evaluation of the contribution of age class 0+ to the population as a whole. Year class 0+ was identified as the only year class that has an important role in the population biomass with a decisive contribution to the total amount of harvesting. *Mullus* constitutes a very important fraction of the total catch obtained by the coastal Tyrrhenian fleet during Summer and Autumn and the success of these fisheries in the mentioned seasons mainly depends on the consistency of recruitment of red mullet. For a species like red mullet characterized by a relatively short lifespan and a relatively high population turnover, the knowledge of the population dynamics, especially during its first year of life, is of particular importance.

The observed different mortality rates by age constitute an important aspect that has to be considered for the assessment of the real impact of fishing activity on the stock. This argument is more deeply discussed in Voliani *et al.* (in press).

Finally, some words can be spent on the suitability of trawl surveys information for stock assessment purposes. Due to their standardized procedures, trawl-surveys provide valuable information on demographic structure of the population at sea for species that are potentially vulnerable to the utilized fishing technique, as demonstrated in this paper. Data from commercial catches should be potentially useful for the same goal but they are more difficult to manage; for instance, the commercial procedures never constitute a random sample of the stock size structure because fishermen look for major concentrations, possibly composed of individuals of high-priced sizes (Sparre *et al.*, 1989).

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