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Spatio-temporal distribution of recruits (0 group) of *Merluccius merluccius* and *Phycis blennoides* (Pisces, Gadiformes) in the Strait of Sicily (Central Mediterranean)

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Abstract

Aspects of the recruitment of hake (*Merluccius merluccius* L., 1758) and greater fork beard (*Phycis blennoides* Brunnich, 1768) in the Strait of Sicily (Central Mediterranean) are presented. Data were collected from 1994 to 1999 during the international bottom trawl survey program MEDITS. In view of the available literature on juvenile growth of these two species in the Mediterranean area, a length-based criterion was adopted to separate fish belonging to the 0 group (recruits). Recruit density indices (R/km^2) by haul were calculated based upon the likely variability of recruit growth among years and used to study abundance variability and spatial pattern of recruitment and to identify the main nursery areas. Although there was inter-annual variability, two stable areas for *M. merluccius* were identified on the eastern side of the Adventure Bank and the Malta Bank at depths ranging between 100 and 200 m. The main nursery areas for *P. blennoides* were deeper (from 200 to 400 m) and two stable nursery areas were identified on the western and eastern side of the Adventure Bank; other nurseries were found in the easternmost part of the Strait in 1998 and 1999. Recruitments of the two species were significantly correlated, with the strongest recruitment occurring in 1998 and 1999 for each species.

Introduction

Description of space and time patterns of different age groups of fish populations is one of the basic elements for understanding stock dynamics. Many authors have identified spawning, nursery and feeding areas, and migratory patterns, as prerequisites for effective stock assessment (Harden-Jones, 1968; Cushing, 1975; Jennings et al., 2001). Research trawl surveys, used to estimate abundance and demography of many demersal stocks, provide useful information of the distribution of fished species. Trawl surveys carried out in many part of the Mediterranean Sea, within national (for example the GRUND program for the Italian Seas in Relini, 2000) and international frameworks (the MEDITS program for the Mediterranean in Bertrand et al., 2002) are allowing increased understanding of the recruitment of hake (*Merluccius merluccius*), the main demersal resource in the Mediterranean (Fiorentini et al., 1997). These studies have focused on timing and depth range of recruitment (Orsi Relini et al., 1989a), juvenile growth (Orsi Relini et al., 1989b; Orsi Relini et al., 1992; Recasens, 1992; Papaconstantinou et al., 1992; Morales-Nin & Aldebert, 1997), diel migration of juveniles from the bottoms into the water column (Orsi Relini et al., 1997), and mapping the nursery grounds (Orsi Relini et al., 1988; Ardizzone & Corsi, 1997; Ardizzone et al., 1999; Lembo et al., 2000; Maynou et al., 2003). Although these studies provide the basic information on the dynamics of the 0-group hake, they have not considered the inter-annual variability of recruitment processes either in terms of year class strength or spatial distribution of recruits.

Despite the importance of the recruitment process in the dynamics of fished species, knowledge on the early life stages and reproductive phases of most of the demersal species living in the Mediterranean is

fragmentary compared with available information on Atlantic stocks (Fogarty, 2000).

According to the literature, *M. merluccius* has a prolonged spawning period in the Mediterranean (Oliver & Massutí, 1995; Papaconstantinou & Stergiou, 1995; Colloca, 1999; Orsi Relini et al., 2002), however, few data are available on the localization of spawning areas. Aggregation of mature adults was reported in the outer shelf-upper slope of the Adriatic Sea (Zupanovic, 1968), and between 100 and 200 m in the Gulf of Tunis (Boulhal, 1973). Eggs were found between 50 and 200 m depth in the Adriatic (Karlovac, 1965) and pelagic larvae in the outer shelf-upper slope along the Catalan coast (Sabatés, 1990). Change from the pelagic to the benthic habitat occurs when young individuals are about 3 cm TL (total length) (D'Ancona, 1956). Orsi Relini et al. (1989a) reported that the distance between spawning areas and nurseries, covered through larval dispersion due to currents, may be considerable, as for other species of genus *Merluccius*, such as *M. productus* (Bailey, 1981; Babcock Hollowed & Bailey, 1989). Settlement is a long process with more than one peak per year (Orsi Relini et al., 2002).

Little is known of the spawning period, eggs and larvae of *P. blennoides* in the Mediterranean region. Reproduction occurs from late summer to early winter (Massutí et al., 1996; Belcari & Biagi, 1999). According to D'Ancona (1933), the change from pelagic to benthic habitat occurs when young fish are between 3 and 4.6 cm TL. In contrast to *M. merluccius*, the Mediterranean populations of *P. blennoides* have a spring discrete recruitment (Belcari & Biagi, 1999; Ragonese et al., 2002); however small fish, between 3 and 8 cm TL, may be caught in winter (Massutí et al., 1996).

The present study aims to provide information on aspects of the recruitment process of two very important commercial gadoids, the hake (*Merluccius merluccius*) and greater fork beard (*Phycis blennoides*), in the Strait of Sicily (Central Mediterranean). This area is one of the most important demersal fishing grounds in the Mediterranean. This work reports recruitment variability and the spatial distribution of the 0 group through a time series, comparing patterns observed in the two species. Patterns are discussed taking into account key biotic and abiotic factors affecting the dynamics of young stages in fish populations.

Study site

The Strait of Sicily has a complex bottom morphology (Fig. 1). Along the southern coasts of Sicily, the shelf is widest in the westernmost (Adventure Bank) and Easternmost sectors (Malta Bank). These large banks are separated by the narrow shelf in the central part. The shape of slope is extremely irregular, incised by many canyons, trenches and steep declives. From an oceanography point of view, the Strait of Sicily is characterised by a two-layer flux model. The upper layer, called "Modified Atlantic Water" (MAW), is identified by water with a relatively low salinity flowing from the western to the eastern basin. The lower layer, called "Levantine Intermediate Water" (LIW), is identified by water with a relatively high salinity flowing in the opposite direction, like an undercurrent (Onken & Sellschopp, 1998). According to Robinson et al. (1991), the MAW motion, called "Atlantic-Ionian Stream" (AIS), shows a rather steady mean path. It enters the Strait from the western boundary along the Adventure Bank, comes close to the southern coast of Sicily, and then moves further from the coast, once it encounters the Malta Bank. The complex bathymetry influences the current features in the region. Measurements have shown that the mesoscale signal prevails in the upper layer, with the presence of eddies, meanders, and filaments.

Materials and methods

Analyses were based on six surveys carried out once a year from 1994 to 1999 within the framework of the MEDITS programme (Bertrand et al., 2002). Sampling was carried out in June, with the exception of 1998 and 1999 when the trawl surveys lasted from late May to early June. Surveys included trawlable areas from a depth of 10 m to 800 m, covering about 44,500 km^2. Each area was sampled with a stratified sampling design, where the number of hauls per stratum was proportional to the stratum surface. A total of 56 hauls were conducted on the same site during each survey (Fig. 1). During each survey, hauls were performed using the MEDITS standardized sampling protocols (MEDITS, 1998). The sampling gear was a bottom trawl with stretched mesh size of 20 mm in the cod-end (GOC 73) and a vertical opening between 2.0 and 2.5 m. The duration of hauls was 30 min over the shelves (up to 200 m), and 60 min along the slopes. The area swept in each tow was calculated