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Recruitment dynamics of eight fishery species in the northwestern Mediterranean Sea*

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SUMMARY: The recruitment dynamics into the fishery of eight species in the northwestern Mediterranean Sea was studied on the basis of a monthly length sampling on commercial landings lasting one year (March 1999-February 2000). The results show that three species or groups of species (*Mullus barbatus* and *M. surmuletus*, *Eledone cirrhosa* and *Loligo vulgaris*) recruited mostly during a well-defined and regular season, while recruitment of the rest of species (*Merluccius merluccius*, *Micromesistius poutassou*, *Phycis blennoides*, *Sepia officinalis* and *Trisopterus minutus capelanus*) took place all year round, though with seasonal peaks. Landings of small *Merluccius merluccius* showed a progressive declining trend from the early 1990s, while the opposite was found for *Mullus barbatus* and *M. surmuletus*.

Key words: recruitment, fishery species, Gulf of Lions, northwestern Mediterranean.

INTRODUCTION

Although in temperate and cold waters almost all fishes reproduce seasonally, there is considerable variation in the length of the breeding season among populations of the same species living at different latitudes (Munro *et al.*, 1990). Northern populations tend to have very discrete breeding and recruitment seasons, whereas southern populations living in warmer waters breed continuously and have long (or continuous) recruitment seasons.

The Mediterranean is generally considered a temperate sea, although subtropical temperatures prevail in eastern and southern areas. Life-history patterns of Mediterranean fishes such as growth and maturation are linked to thermal conditions (Stergiou, 2000). There are some indications that fish species and stocks inhabiting the warm waters of Hellenic Seas are generally small in size, have a low longevity, mature at an early age and size and probably suffer high adult mortality (Stergiou, 2000). Considering the temperate/subtropical characteristics of Mediterranean waters, reproduction and recruitment of some species might not follow a clear seasonal cycle.

This paper aims to study the recruitment dynamics of eight important commercial species in the fishery in the northwestern Mediterranean. The study of seasonality and trend of the recruitment of commercial species is relevant for stock assessment. When seasonality of recruitment is weak or absent, i.e. when fish recruit throughout the year, the determination of key parameters for the population dynamics (e.g. year-class strength, growth and

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maturity ogive) and modelling (e.g. establishment of stock-recruitment relationships and yield per recruit analyses) become difficult if not impossible. The long (or continuous) reproduction and recruitment seasons of some Mediterranean species could therefore constitute an important shortcoming for their assessment.

MATERIALS AND METHODS

A series of monthly catch records was available for eight species or groups of species (henceforth called species) landed for different periods of time (1981-2000) at the port of Roses, one of the most important fishing harbours in the northwestern Mediterranean (Fig. 1). These species were octopus (*Eledone cirrhosa*), squid (*Loligo vulgaris*), hake *(Merluccius merluccius*), blue whiting (*Micromesistius poutassou*), red mullet (*Mullus barbatus* and *M. surmuletus*), greater forkbeard (*Phycis blennoides*), cuttlefish (*Sepia officinalis*) and poor cod (*Trisopterus minutus capelanus*). Catch was recorded in kg and was available by commercial size-classes with the exception of *Loligo vulgaris* and *Sepia officinalis*. Because recruitment estimations do not exist for most commercial species due to the lack of regular stock assessments in the Mediterranean (Lleonart *et al.*, 1998), we used landings of the smallest commercial size-classes as a proxy for recruitment. Landings were mainly from trawlers fishing in the Gulf of Roses and the Gulf of Lions (Fig. 1). Fishing effort (number of trawlers and monthly time at sea) remained nearly stable during the study period. Therefore, catches landed at Roses harbour are raw measures of catches per unit effort. Time series of catches were described by calculating the seasonal component and the trend by means of multiple moving averages using the time series statistical package TESS (Prat *et al*., 2001). This program is based on ARIMA (autoregressive-integrated-moving-average) models (Box and Jenkins, 1976). While the seasonal component shows the spectral peaks at seasonal frequencies (the seasonal value for a given month is the percentage above/below the annual mean), the trend represents the smoothed evolution of the series.

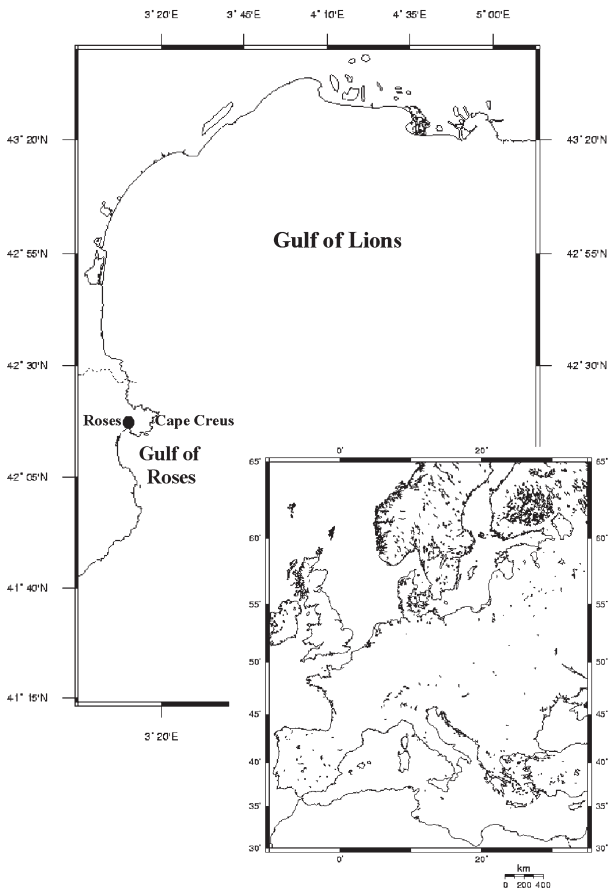

FIG. 1. – Location of the study area (Gulf of Lions and Gulf of Roses; NW Mediterranean) showing the fishing port of Roses where landings are recorded monthly and length sampling was conducted.

Length-frequency samples were obtained from these landings at the Fishmarket of Roses from

TABLE 1. – Number of samples measured monthly for eight species or groups of species (March 1999-February 2000).

Species / month	M	A	M	J	J	A	S	O	N	D	J	F
Eledone cirrhosa	82	10	45	76	66	52	62	20	21	13	77	42
Loligo vulgaris	48	8	0	0	22	70	42	51	160	160	124	78
Merluccius merluccius	143	107	146	106	66	64	30	28	107	93	114	70
Micromesistius poutassou	56	90	120	196	77	145	37	51	70	11	200	106
Mullus barbatus + M. surmuletus	144	93	0	17	0	25	10	63	111	140	196	107
Phycis blennoides	145	75	105	106	83	142	45	40	49	24	120	64
Sepia officinalis	8	0	50	65	0	0	5	27	43	67	47	76
Trisopterus minutus capelanus	197	87	84	101	74	107	62	28	127	113	140	77

March 1999 to February 2000. The sampling programme comprised a different number of monthly length measurements for each of the species considered (see Table 1), from which monthly mean lengths were obtained. Length measurements (total length for fish species and mantle length for cephalopod species) were performed with a precision of one centimetre (cm below).

RESULTS

From March 1999 to February 2000, monthly landings of the smallest size groups of *Merluccius merluccius*, *Micromesistius poutassou*, *Trisopterus minutus capelanus* and *Phycis blennoides* were composed of young fish that were in average between 15 and 20 cm in length (Fig. 2A-2D).

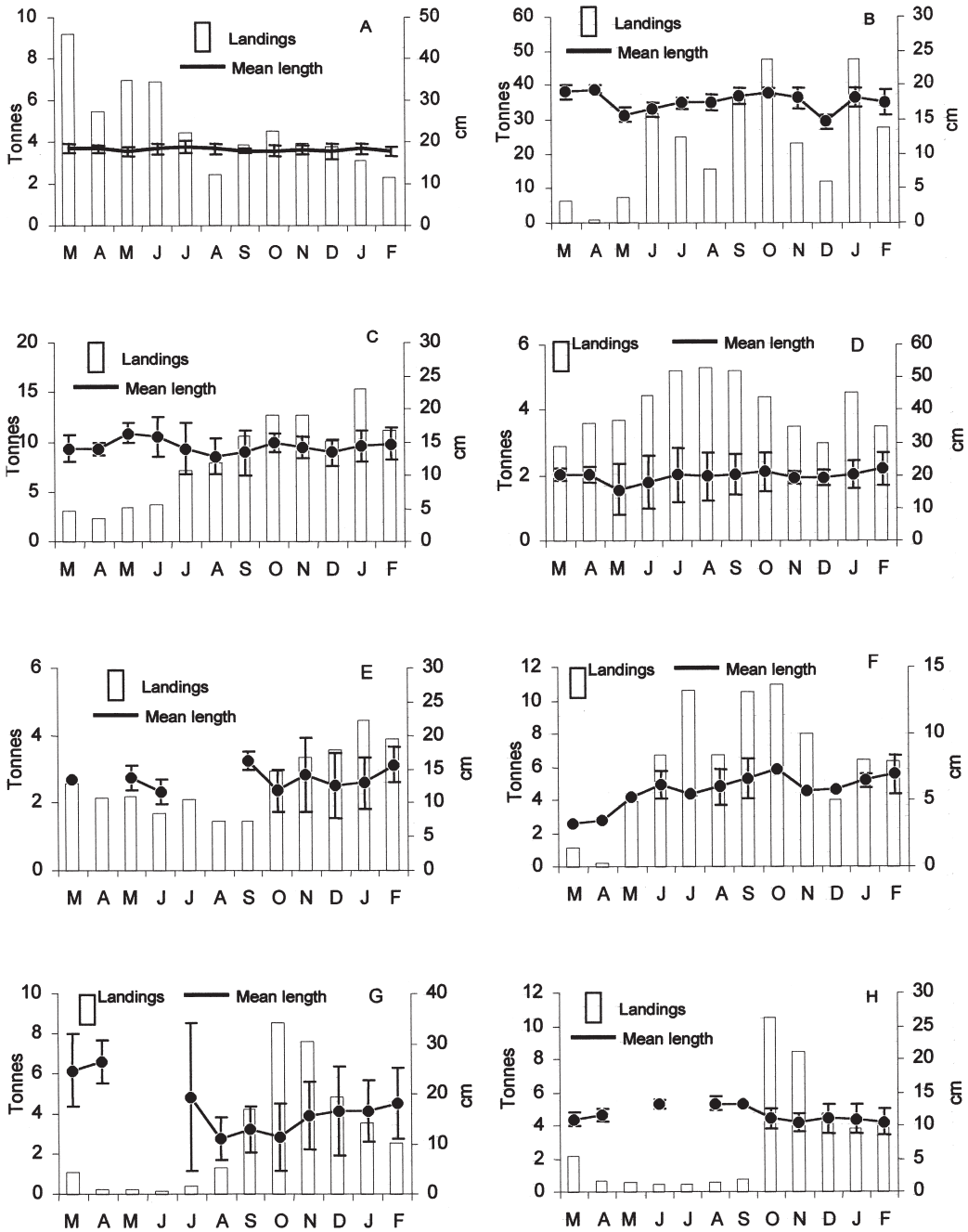

FIG. 2. – Monthly mean lengths +/- 1 standard deviation (in cm) and landings (in tonnes) of the smallest commercial size-classes of (A) *Merluccius merluccius*, (B) *Micromesistius poutassou*, (C) *Trisopterus minutus capelanus*, (D) *Phycis blennoides*, (E) *Sepia officinalis*, (F) *Eledone cirrhosa*, (G) *Loligo vulgaris* and (H) *Mullus barbatus* and *M. surmuletus* for the period March 1999-February 2000. Blank areas in the mean lengths during certain months mean missing data.

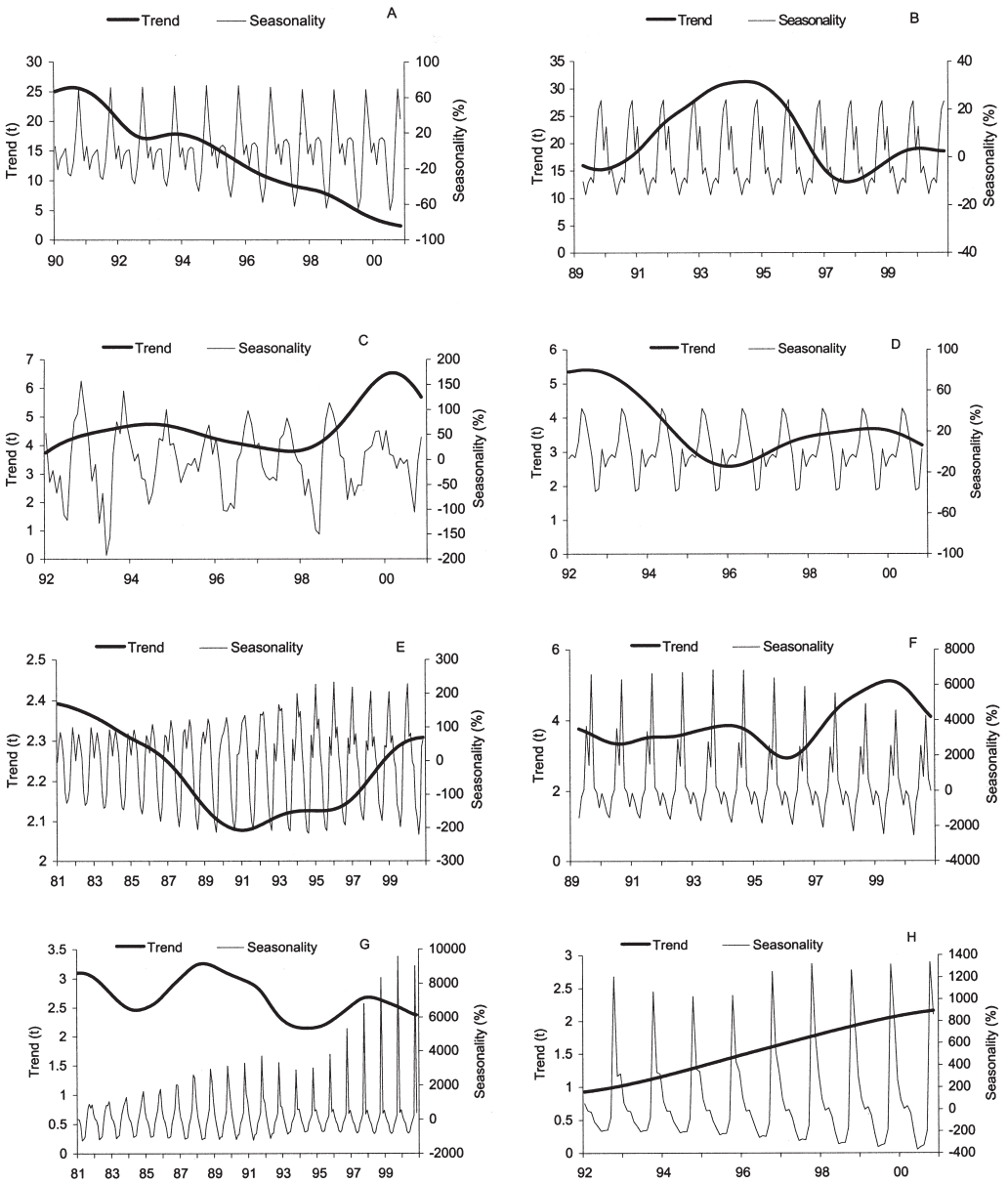

FIG. 3. – Seasonal pattern (% above/below the annual mean landings) and trend (in tonnes) of landings in Roses harbour of the smallest commercial size-classes of (A) *Merluccius merluccius*, (B) *Micromesistius poutassou*, (C) *Trisopterus minutus capelanus*, (D) *Phycis blennoides*, (E) *Sepia officinalis*, (F) *Eledone cirrhosa*, (G) *Loligo vulgaris* and (H) *Mullus barbatus* and *M. surmuletus.*

Recruitment of these species to the fishery took place throughout the year, though it was more intense during spring and autumn for *Merluccius merluccius*, in late summer through early winter for *Micromesistius poutassou* and *Trisopterus minutus capelanus* and in spring and summer for *Phycis blennoides*, when catches peaked (Figs. 2A-2D and 3A-3D). The weak seasonal pattern for these species is shown by low seasonal values (in general below 100% of the annual mean landings; Figs. 3A-3D). Time series of landings of small *Merluccius merluccius* showed a strong declining trend from 1990 to the present (Fig. 3A), whereas small *Micromesistius poutassou*, *Trisopterus minutus capelanus* and *Phycis blennoides* did not show any important long-term trend but did show interannual fluctuations (Figs. 3B-3D).

From March 1999 to February 2000, monthly landings of *Sepia officinalis* consisted of individuals that were in average about 15 cm in mantle length (Fig. 2E). Recruitment of this species into the fishery took place throughout the year, though it was greater in autumn and winter when catches peaked (Figs. 2E and 3E). The weak seasonal pattern is

shown by low values of seasonality (Fig. 3E). In addition to this, there is a medium-term (decade) trend (Fig. 3E).

In contrast to this, *Eledone cirrhosa*, *Loligo vulgaris* and *Mullus barbatus* and *M. surmuletus* recruited mostly during a well-defined and regular season. The strong seasonal pattern in recruitment of these species is reflected by high seasonal values (exceeding 1000%; Figs. 3F-3H). The smallest individuals of *Eledone cirrhosa* (about 3 cm in mean mantle length) and *Loligo vulgaris* (about 12 cm in mean mantle length) were landed in late winter and late summer respectively (Figs. 2F and 2G). Mean size in catches increased progressively thereafter, reaching 7 cm mantle length in *Eledone cirrhosa* (Fig. 2F) and 20 cm mantle length in *Loligo vulgaris* (Fig. 2G). Catches of *Eledone cirrhosa* peaked during summer and fall (Figs. 2F and 3F), while those of *Loligo vulgaris* peaked during late summer, fall and early winter (Figs. 2G and 3G). From 1995 onwards, seasonality of catches of *Loligo vulgaris* intensified (Fig. 3G). None of these two species (*Eledone cirrhosa* and *Loligo vulgaris*) showed any important long-term trend but they did show interannual fluctuations (Figs. 3F and 3G). Landings of *Mullus barbatus* and *M. surmuletus* increased substantially each autumn (when catches exceeded 1000% of the annual mean), and showed a positive trend over years (Fig. 3H). During autumn 1999, landings of red mullets consisted of young fish that were on average 10 cm long, though young fish were landed the whole year (Fig. 2H).

DISCUSSION

According to growth figures available in the literature (FishBase, 1999; Relini *et al.*, 1999), mean lengths in landings for the smallest size-classes studied correspond to individuals that are on average about one year old or less. Thus, these landings represent a proxy for the recruitment. It must be noted that recruitment data do not exist for most species due to the lack of stock assessments in the Mediterranean (Lleonart *et al.*, 1998).

Our findings indicate that recruitment into the fishery of *Merluccius merluccius, Micromesistius poutassou, Phycis blennoides, Sepia officinalis* and *Trisopterus minutus capelanus* can happen throughout the year, even though it is greater during a season depending on the species. The continuous or long duration of recruitment of these species into the fishery constitutes a shortcoming for their assessment because the determination of population parameters (e.g. year-class strength, growth and maturity ogive) and modelling (e.g. establishment of stock-recruitment relationships and yield per recruit analyses) becomes more difficult. Only recruitment of *Eledone cirrhosa, Loligo vulgaris* and *Mullus barbatus* and *M. surmuletus* takes place mostly during a well-defined season, though recruits of the later were observed all year round. Seasonal fluctuations in the landings of these species cannot be attributed to effort, since trawl effort in Roses harbour does not fluctuate seasonally (Lloret *et al*., 2000).

The recruitment dynamics of some of the species considered in this paper has been studied in other areas. It has been demonstrated that the arrival of recruits of *Merluccius merluccius* on the bottom in the Catalan and Ligurian Seas can happen repeatedly throughout the year (Recasens *et al*., 1998; Orsi-Relini *et al*., 1989). In contrast to this, the smallest individuals of *Eledone cirrhosa* have been shown to appear during winter and spring in the Catalan Sea (Sánchez and Martín, 1993), while those of *Mullus barbatus* and *M. surmuletus* appear during fall (Martín, 1989).

The long recruitment period is partly due to the extended spawning seasons of many species inhabiting the Mediterranean, which might reduce larval competition and decrease the impact of adverse environmental conditions on the survival of their eggs and larvae (Politou and Papaconstantinou, 1991). Although a considerable number of species spawn during almost the whole year, there is often a season of higher reproductive activity that varies according to species and geographic areas. The season of high reproductive activity for *Merluccius merluccius* in the western Mediterranean is between late summer and winter (Recasens *et al.*, 1998) and between winter and spring for *Eledone cirrhosa*, *Trisopterus minutus capelanus*, *Micromesistius poutassou* and *Phycis blennoides* (Relini *et al.*, 1999; Lloris and Messeguer, 2000). Reproduction of *Mullus barbatus* and *M. surmuletus, Sepia officinalis* and *Loligo vulgaris* in the western Mediterranean occurs mainly between spring and summer (Relini *et al.*, 1999; Lloris and Messeguer, 2000).

The long duration of the recruitment period of some Mediterranean species might be also due to differences in growth rates between individuals depending on the month when they were born. Differences in growth rates between individuals of the

same year-class do exist, e.g. *Merluccius merluccius* in the Ligurian Sea (Orsi-Relini *et al.*, 1989), and cod (*Gadus morhua*) in the North Atlantic (Frank *et al.*, 1994). One-year-old individuals in both cases show significant differences in mean length depending on the time within the spawning season when the individual was born.

Therefore, it is not possible to determine the factor that has the greatest influence on the recruitment seasonality of the species studied. Both possibilities stated above (i.e. reproductive activity and growth pattern) could explain the seasonal pattern in the recruitment.

Landings of *Micromesistius poutassou, Phycis blennoides, Sepia officinalis, Trisopterus minutus capelanus, Eledone cirrhosa and Loligo vulgaris* showed short and medium term trends (interannual fluctuations). Only landings of *Mullus barbatus* and *M. surmuletus* and of *Merluccius merluccius* display a consistent long-term trend over the study periods. The increase in landings of small *Mullus barbatus* and *M. surmuletus* during the last decade contrasts with sharp declines in catches of small *Merluccius merluccius*. Short and medium term trends of *Micromesistius poutassou, Sepia officinalis, Eledone cirrhosa* and *Loligo vulgaris* are partly due to environmental effects (Lloret *et al.*, 2001). The long-term decreasing trend in landings of small *Merluccius merluccius* is probably due to overfishing (Recasens and Lleonart, 1999), while the long-term increase in landings of small *Mullus barbatus* and *M. surmuletus* could be due partly to long-term environmental changes (e.g. warming). It was recently demonstrated for the population of *M. barbatus* in the Strait of Sicily that, for a given spawning stock biomass, higher than average water temperatures have a positive impact on the recruitment of this species (Levi *et al*., 2000).

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