FLUCTUATIONS IN SPACE AND TIME OF PELAGIC POPULATIONS IN THE NORTH ADRIATIC SEA FROM 1976 TO 1998

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Abstract
The intent of this paper is to discuss some problems that have arisen from the spatial and temporal variability of small pelagic fish in the North Adriatic Sea during the period 1976-1998. This variability can be attributed to variations in physical factors (in this paper surface temperature is considered) acting on these resources in many compound ways, to fishery, and to the internal complexity of the pelagic system.

Keywords: Acoustics, Adriatic Sea, Biomass, Pelagic, Temperature

Introduction
With an acoustic methodology and technology it's possible to examine the trend of the pelagic density through the years and its spatial structure relative to the period of the echo-survey. It may be of extreme importance for fishery to know if biomass fluctuations are periodical and related to its spatial structure. The data of surface temperature can be used together with the biomass' data to see if this physical factor can influence the fish distribution.

Material and methods
The data on the biomass of small pelagic fish and its spatial distribution were collected with acoustic methodologies and technologies. Biological data (fish demography) were acquired from net samplings. Surface temperature data (SST) were obtained from satellite [1]. All data were processed using the GFRDBS (Geographical Fishery Resources Data Base System) SW package designed by the IRPEM acoustic team [2]. GFRDBS processes the data in a geographical context, converting Lat&Lon into X&Y coordinates. The Elementary Sampling Distance Unit (ESDU) of the X, Y map is one nautical mile.

The object of this study is the North Adriatic Sea, which extends from Trieste to S. Benedetto del Tronto, from the Italian coast to the Mid-Line. It has been investigated annually, in summer-autumn, since 1976 [3][4].

Results and discussion
One basic issue is the stability of the pelagic biomass and of its species composition. Figure 1a shows the trend from 1976 to 1998 of the biomass of pelagic populations as a whole.

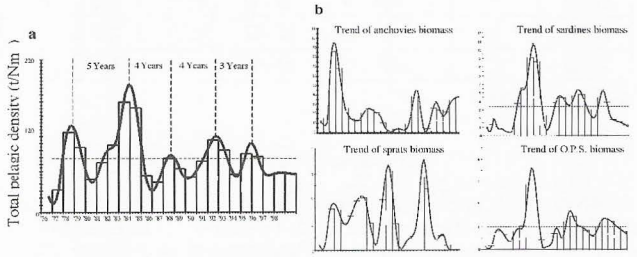


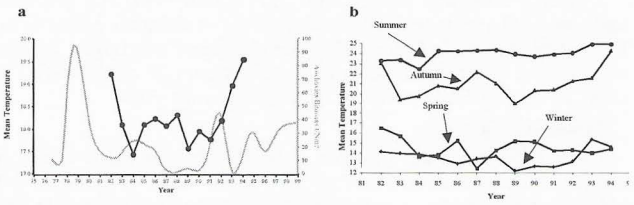
Fig. 1. a. Fluctuation of pelagic biomass as a whole in the North Adriatic Sea. b. Trend of pelagic populations in the North Adriaric Sea

Data indicate that the total pelagic biomass fluctuated in a nearly periodic way. The highest peaks (130 and 190 t/nm^2, observed in 1978 and 1983, respectively) and the longest periods of fluctuation (around 5 years) occurred before 1985. After 1985 the peaks become smaller (85, 110 and 100 t/nm^2) and, accordingly, the fluctuation periods seem to shorten (1987; 1991; 1994). The mean ratio of the maximum level to the minimum one is around 4. Mean biomass density from 1976 to 1998 in the North Adriatic was estimated to be 78 t/nm^2 (i.e. 25%). In Figure 1b the total biomass was divided into four groups: Anchovies, Sardines; Sprats and Other Pelagic Populations (mainly *Scomber scomber, Trachurus trachurus*).

The biomass changes of single populations were not regular. In particular, the anchovy stock reached the maximum peak in 1978-79, it collapsed in 1987-89 and ten years later (1996) began to recover. The ratio between the maximum and minimum level was around 20. Mean density of the anchovy stock was estimated as 23.5 t/Nm^2. By contrast, the sardine stock showed a minimum around 1978, and the highest peak in 1982-83 followed by a period of stability (1985-1996). The ratio between the maximum and minimum level was very similar to that of Anchovy (25). Mean density was calculated as 33.4 t/Nm^2. The other species (sprats, mean density 12.6 t/Nm^2; other pelagic species, mean density 9.8 t/Nm^2) showed very irregular changes. It could therefore be concluded that the pelagic biomass as a whole fluctuates almost regularly, whereas its composition is affected by drastic and unpredictable changes. Moreover, there is evidence of possible interactions between species such as anchovies-sardines and sprats-anchovies.

A second basic question about pelagic resources is their spatial structure and distribution, which for fisheries management may be more important than the simple measurement of total biomass.

Generally, the basic spatial structure of pelagic populations is patchiness, irrespective of the abundance of biomass. However, the surveys indicate a contraction of the patches towards the coast in the period when the anchovy stock collapsed (1986-90) and their expansion towards the open sea when the stock recovered (from 1994). In the period 1992-1994, a movement of the anchovy stock from the North to the South Adriatic was observed. Unusual migrations of sprat from North to Middle Adriatic (1987 and 1993) and as far as to the South Adriatic (1994) were also detected. Figure 2a shows the trend of mean annual surface temperature (SST) over the whole Adriatic Sea and Figure 2b the seasonal trend of the same parameter in the period 1982-1996 [5].



Although there does not appear to be any direct, clear-cut relationship between biomass and climate variations, one observation can be made. The minimum values recorded in spring (1987), summer (1984), autumn and winter (1989) temperatures as well as the fall of annual mean temperature all coincided with the collapse of the anchovy stock (1986-1990). These two phenomena might thus be related in some way.

Conclusion
The central result of this study, relevant also to management, is the temporal and spatial changes of the pelagic biomass as a whole and per species. The fluctuations in time of the pelagic biomass as a whole seem fairly regular and pretty limited; in regard to the single species there is a range of variation much larger and strongly irregular both in time and in space. The fluctuation in space seem to be related, beside to alterations in migration habit, to the biomass abundance. The fluctuations in time have been dramatic for Anchovy (collapse of 1987), and very large for the other species under examination. As an initial simplification the fall of Anchovy stock in the period 1986-1990 have been attributed to the decrease of the surface temperature that could have affected the recruitment. However the appropriate management of these resources requires greater knowledge of how and to what extent the variations in space and time of the single populations can be affected by internal factors (interactions between species), external conditions (climatic variations), predation and fisheries management.

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