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Review

# Analysis of backscatter properties and application of classification procedures for the identification of small pelagic fish species in the Central Mediterranean

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ABSTRACT

The pelagic realm of the Central Mediterranean Sea is populated by four main species of fish: sardine, anchovy, horse mackerel and a mix of other pelagic fish species. In this study we employed a multifrequency acoustics approach to detect and classify fish schools of these groups. Monospecific trawl catches were selected from eight acoustic surveys and examined in relation to the coincident acoustic data. The backscattering properties of the three main species were determined using the decibel difference ($Sv_{120} - Sv_{38}$) and the frequency response ($NASC_{120}/NASC_{38}$). The results indicate that schools of these species cannot be distinguished on the basis of energetic properties alone, because they are very similar in physiology and scattering is dominated by the swimbladder, which is similar in shape and size. However, the use of classification models (classification tree, random forest), using energetic features, as well as bathymetric and morphometric parameters, allowed for some discrimination among the groups. According to the classification tree, school depth was found to play an important role in the identification of these fish groups, especially for anchovy and horse mackerel, for which the contribution to the overall performance of the tree was about 20%. The tree models, with only energetic or morphometric parameters, were able to classify sardine schools reasonably well, but not so well for anchovy and horse mackerel. Using a random forest method, which accounted for the variability in the learning sample, an accuracy of 85% in the overall classification rate was reached with a greater power of discrimination for sardine and anchovy schools.

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## 1. Introduction

Hydroacoustic surveys provide a means to estimate the biomass and map the geographical distribution of many economically important fish stocks (MacLennan and Simmonds, 1992). The essential tool in these surveys is the scientific echosounder, which transmits sound pulses vertically and operates at frequencies in the range from 12 kHz to 200 kHz or more (Misund, 1997). The abundance of fish in an area is determined by means of echo-integration, in which the backscattered echoes are summed over depth and averaged over the sailed distance (Dalen and Nakken, 1983). Biological information from trawl catches and species-specific target strength (TS, in dB) vs. length relationships are required for the estimation process (Simmonds and MacLennan, 2005). A fundamental requirement is the identification, to species, of the fish school echo-traces displayed on the echograms. Typically the identification process is assisted by ground-truthing using the pelagic trawl catch, although experience of the operator plays a major part in the scrutiny of the echogram. This approach is subjective and can affect the accuracy of abundance estimates particularly if the scrutiny is performed by different operators.

Multifrequency echosounder data, combined with an improved knowledge of the backscattering properties of the target species, may be used to characterize acoustic returns and thereby improve the scrutiny process (Korneliussen and Ona, 2002). Such an approach has been used to identify and quantify scattering from zooplankton: Stanton et al. (1998a,b) used acoustic data from 50 kHz to 1 MHz to categorize zooplankton into three groups, based on body shape, size and material properties of the animals; Korneliussen and Ona (2002) used multi-frequency processing techniques to distinguish various different targets including mackerel, swimbladdered fish, and zooplankton; and Madureira et al. (1993) and Miyashita et al. (1997) adopted the same techniques to discriminate planktonic organisms and fish schools. These approaches are possible because echoes from plankton vary according to frequency in a manner well characterized by numerous developed scattering models, whereas fish with swimbladders have a more consistent response at the frequency ranges typically employed. However, the approach is not so easy when trying to distinguish among fish species with similar acoustic properties. For example, the range of frequencies typically employed cannot distinguish Atlantic herring (*Clupea harengus*) from Norway pout (*Trisopterus esmarkii*; Fässler et al., 2007). The acoustic response at different frequencies is in fact mainly due to the morphology of the species (presence or absence of swimbladder, fish shape or body length), so that species with similar characteristics also have similar acoustic properties. This could be the case for the main small pelagic species detected on the Thyrrenean Sea and Sicily Channel, such as anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*) and horse mackerel (*Trachurus trachurus*), which are probably very similar in terms of frequency response. However, to date there have been no studies which have examined this response for these species in the Central Mediterranean Sea. A considerable improvement in the species identification (mainly when fish species have similar acoustic properties) can be derived from acoustic data supplemented by information from non-acoustic sources, as reported in Korneliussen et al. (2009). A more objective species identification from acoustic data could improve the accuracy of biomass estimates, especially for species with aggregative behavior. A better identification of acoustic targets will also allow for more detailed studies of the distribution and behavior of these schooling fish.

The main aim of this study was to develop a multifrequency algorithm to improve the scrutiny process of acoustic survey data. Analyses of the multifrequency scattering properties of three pelagic fish species, detected during acoustic surveys in the study area, were conducted to investigate the acoustic frequency response of these fish. The species are quite similar in terms of morphology and behavior: they all possess swimbladders, occur in schools during daytime and the schools are similar in shape. However, the nature of their swimbladders are essentially different since sardine and anchovy are physostomes while horse mackerel is a physoclist (Van der Kooij et al., 2007). In the physostomes fish the swimbladder is connected to the digestive tract by a pneumatic duct and there is no interior gas gland that allows the fish to inflate the swimbladder once the volume has decreased after the fish has descended (Nero et al., 2004; Fässler et al., 2007). This means that they can not increase the gas contained in the swimbladder without access to the surface. The result is a decrease in swimbladder volume with the depth and therefore a reduction in backscatter from this organ compared with other component, like the body, which can then be potentially important. A idea is that at certain depths the fish body component becomes a relatively stronger scatterer and this effect could help to distinguish these fish from those with to the closed swimbladders. Thereby a distinction between clupeids and horse mackerel may be expected due to the different type of swimbladder.

Finally, discrimination between these species was investigated using a combination of frequency response and other school descriptors (morphometric, bathymetric or other energetic parameters at the various frequencies).

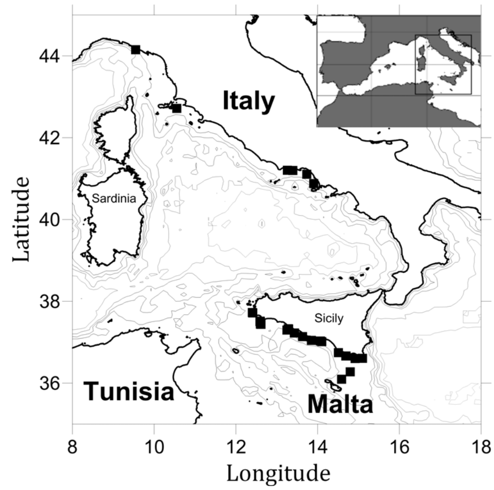


**Fig. 1.** Study area: continental shelf of the Thyrrenean Sea and the Sicily Channel, within the larger Mediterranean Sea (inset). Black squares represent the location of analyzed pelagic trawls.

## 2. Materials and methods

### 2.1. Data collection

Acoustic data were obtained from eight acoustic surveys between 2002 and 2011 performed in the summer in and around the Sicily Channel (Patti et al., 2004). In summer 2009 and 2011 both the Tyrrhenian Sea and Sicily Channel were surveyed (Fig. 1). Data were collected using two different scientific echosounders (SIMRAD EK500 and EK 60) with 3 hull-mounted split-beam transducers operating at 38 kHz, 120 kHz and 200 kHz. In the summer surveys of 2002, 2008, 2009 and 2011, all of the transducers were calibrated according to standard procedures (Foote et al., 1987). The 200 kHz transducer was not calibrated in the summer surveys of 2005, 2006 and 2007, although calibration of the 38 kHz and 120 kHz frequencies was carried out. The EK500 echosounder was configured to ping simultaneously every second with pulse durations of 1.0, 1.0 and 0.6 ms at 38 kHz, 120 kHz and 200 kHz, respectively. A pulse duration of 1.024 ms for all frequencies was set