Fluctuation of sardine and anchovy abundance in the Strait of Sicily investigated by acoustic surveys

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Abstract

This study assembles the main results of the research carried out during the last several years on the application of hydro-acoustic technology to the evaluation of biomass and distribution of small-pelagic-fish species off the southern coast of Sicily. The biomass estimates and the population-density charts presented concern the two main species: sardine (*Sardina pilchardus*) and anchovy (*Engraulis encrasicolus*). Six acoustic surveys were carried out from 1998: in June 1998, October 1999, July and September 2000, October 2001 and July 2002. For biomass-evaluation purposes and for the study of distribution, hydro-acoustic data acquired at 38 kHz were used. Large inter-annual fluctuations were observed both for sardine and anchovy populations: sardine biomass estimates ranged from 6,000 metric tons in July 2002 to over 36,000 metric tons in July 2000; anchovy evaluations ranged from about 7,000 metric tons in June 1998 to 23,000 metric tons in October 2001. Such fluctuations suggest the importance of yearly recruitment success, which is affected by environmental variation. Acoustic estimates are largely consistent with the landings recorded in Sciacca (the main fishing port on the southern coast of Sicily for small-pelagic-fish species) during the year following the evaluation surveys, emphasizing their relevance not only to monitoring but also to managing such resources.

Keywords: Small pelagic fish, sardine, *Sardina pilchardus*, anchovy, *Engraulis encrasicolus*, fish biomass evaluation, population density charts.

1. Introduction

The sustainable exploitation of the marine biological resources should follow an accurate estimation of abundance and distribution of the target species. The acoustic method (Johannesson and Mitson, 1983) is widely acknowledged to be one of the most efficient methods to evaluate the state of certain renewable resources, such as small-pelagic-fish species (sardine, anchovy, etc.). For these species, hydro-acoustic surveys on research vessels are opportunely designed also taking into account information from the biology and ecology of the species.

Anchovy and sardine jointly represent more than 90% of the commercial small-pelagic-fish landings in Sciacca, the main port for this fishery on the southern coast of Sicily (Mazzola *et al*., 2002). There is general agreement that, for this kind of living resource, the main driving factors influencing fluctuations are to be found in the environment.

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The Strait of Sicily has a very complex bottom topography characterized by a quite narrow continental shelf (the preferred habitat for the target populations), with the slope at about 15 nautical miles from the coast from Mazara del Vallo to Marina di Ragusa, though the shelf widens to more than 50 nautical miles over the Adventure Bank and the Malta shelf (Figure 1).

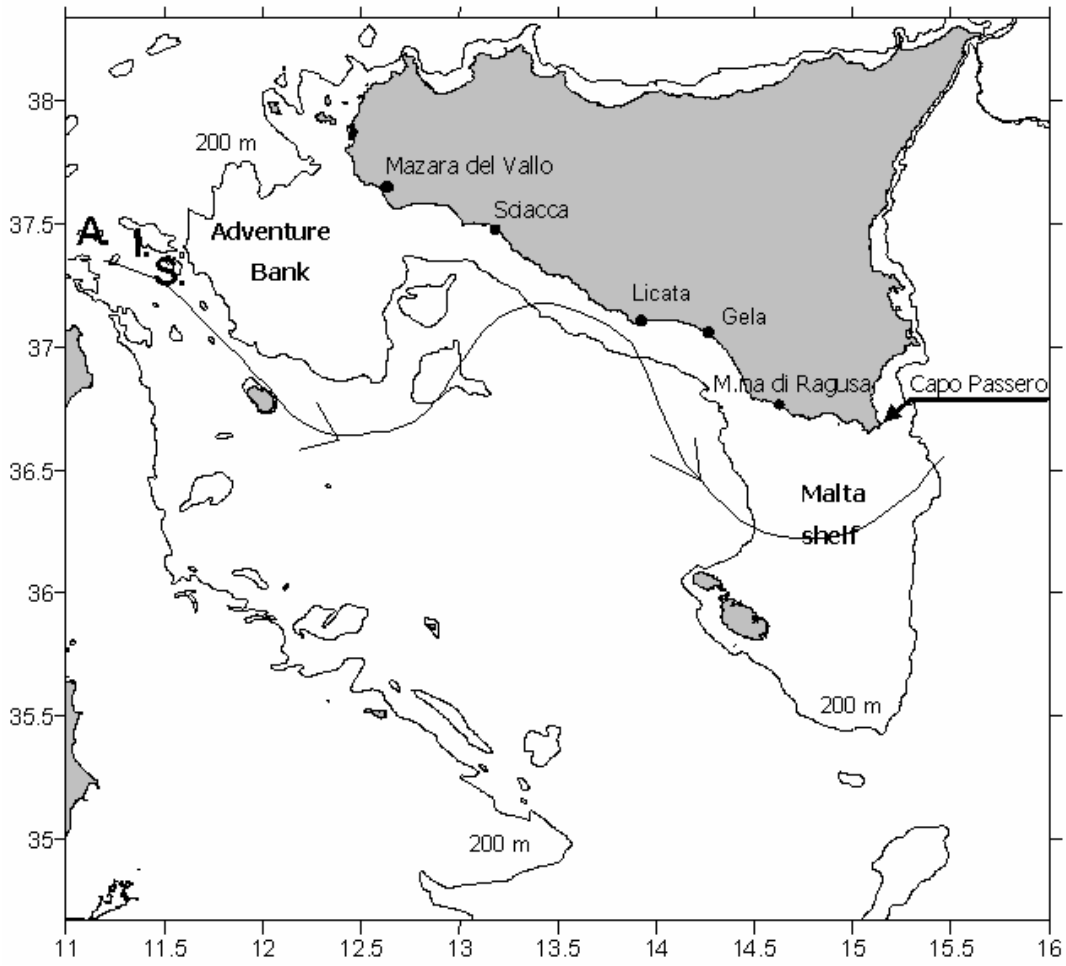

Figure 1. The Strait of Sicily and the mean current of incoming Modified Atlantic Water, the so-called Atlantic–Ionian Stream (AIS).

The Modified Atlantic Water (MAW) current, the so-called Atlantic–Ionian Stream (AIS; Robinson *et al*., 1991) (Figure. 1), controls the surface circulation. During the stratified period, it enters the Strait of Sicily at its western end, meanders, owing to topographic effects, internal baroclinic processes or strong atmospheric forcing, and diverges from the coast when it encounters the Malta shelf. Along this path, the AIS goes around two large cyclonic vortexes; the first one lies over the Adventure Bank and the second, over the Malta shelf, off Cape Passero (see Figure. 1). The circulation favours the establishment of "permanent" upwelling to the left of the Stream at certain places, possibly reinforced by wind-induced upwelling, which may sharpen the density front due to the offshore Ekman transport. The main source of nutrient pumping in the area is associated with coastal upwelling (García Lafuente *et al*., 2002). The AIS path is characterized by significant year-to-year variation, with consequences for other predominant hydrographical phenomena in the region; for example, the extension of upwelling and the formation of fronts. In intermediate and deep layers, the modified Levantine Intermediate Water (LIW) flows from east to west. Additional

intrusions of water from the Ionian Sea, mostly with properties intermediate between those of the MAW and LIW, also occur.

In the present paper, general results of six hydro-acoustic evaluation surveys, carried out from 1998 to 2002, are presented. Data concern both abundance and distribution of the two target species: sardine and anchovy.

2. Materials and methods

The acoustic surveys on the continental shelf off the southern coast of Sicily were carried out in two different periods: June–July in 1998, 2000 and 2002 and September–October in 1999, 2000 and 2001. Sampling periods were chosen taking into account life cycles of target species. In particular, estimates from surveys carried out in the autumn may include the first sign of recruitment for the year, whereas summer surveys provided information on the adult fraction of the anchovy population.

Biomass evaluations were carried out using a standard method and the following equipment:

- SIMRAD EK500 two-frequency (38 and 120 kHz) split-beam echo sounder;
- pelagic trawl net for experimental hauls (horizontal opening 13–15 m, vertical opening 6–8 m, mesh size in the cod-end 10 mm);
- trawl monitoring system based on a SIMRAD ITI sensor.

Before or after each cruise, a calibration procedure was carried out on board using a standard sphere.

During the surveys (1998–2002), 102 control hauls were made, about 75% of which confirmed the presence of sardine and anchovy (Table 1). The vessel speed during surveys was 6–10 knots, whereas during the fishing hauls it was 3–4 knots.

Table 1. Fishing hauls by survey, with the corresponding frequency of occurrence of sardine and anchovy (percentage frequency of occurrence in brackets).

Survey date	Total number of hauls	Number of hauls containing sardine	Number of hauls containing anchovy
19–22 June 1998	12	10	6
14–29 October 1999	11	10	11
6–16 July 2000	18	15	12
11–16 September 2000	18	11	12
4–17 October 2001	22	15	20
4–15 July 2002	21	15	14
Total	102	76 (75%)	75 (74%)

The acoustic sampling design, originally planned with systematic parallel transects, was sometimes discarded in favour of a zigzag scheme which also depended on sea weather conditions.

Only data acquired by the 38-kHz transducer were used to calculate the NASC (Nautical area scattering coefficient, m^2 per square nautical mile) (MacLennan *et al*., 2002) and to estimate the biomass. The echo-integration interval was constant, i.e. 1 nautical mile (1,852 m). For data acquisition and data analysis, the following software was used: EP500 (Simrad), BI500 (Simrad) and EchoView (Sonar Data). Distributions were obtained by interpolating fish surface density (tons per square nautical mile), taking into account the species composition in the control hauls and applying, for each species, the appropriate relationship between Target Strength (TS) and the length of a single specimen. As no TS–length relationship has been definitely established in this area for the two species, in this study we adopted the TS–length relationships proposed by Barange *et al*. (1996). For interpolating surface density, the Kriging geostatistical method (Goovaerts, 1997; Cressie, 1991) was adopted.

The acoustic biomass estimates were compared with small-pelagic-fish landing data collected in Sciacca, the main port for this fishery on the southern coast of Sicily (Mazzola *et al*., 2002).

3. Results and discussion

Sardine biomass appears to be quite uniformly distributed along the southern coast of Sicily, though large differences occurred in both distribution and biomass among surveys (Figure 2).

The anchovy population exhibited a more patchy distribution than that of sardine (Figure. 3). During the peak spawning period for anchovy (echo-surveys in July 1998 and 2000), the main concentrations were observed in the central part of the study area, from Sciacca to Licata, whereas, in the surveys conducted in the autumn, two main concentrations were detected, one north of Sciacca and the other in the Gulf of Gela (south of Licata). During July 2002, sardine and anchovy populations appeared quite segregated, with sardines in the northern region and anchovy in the southern part of the study area.

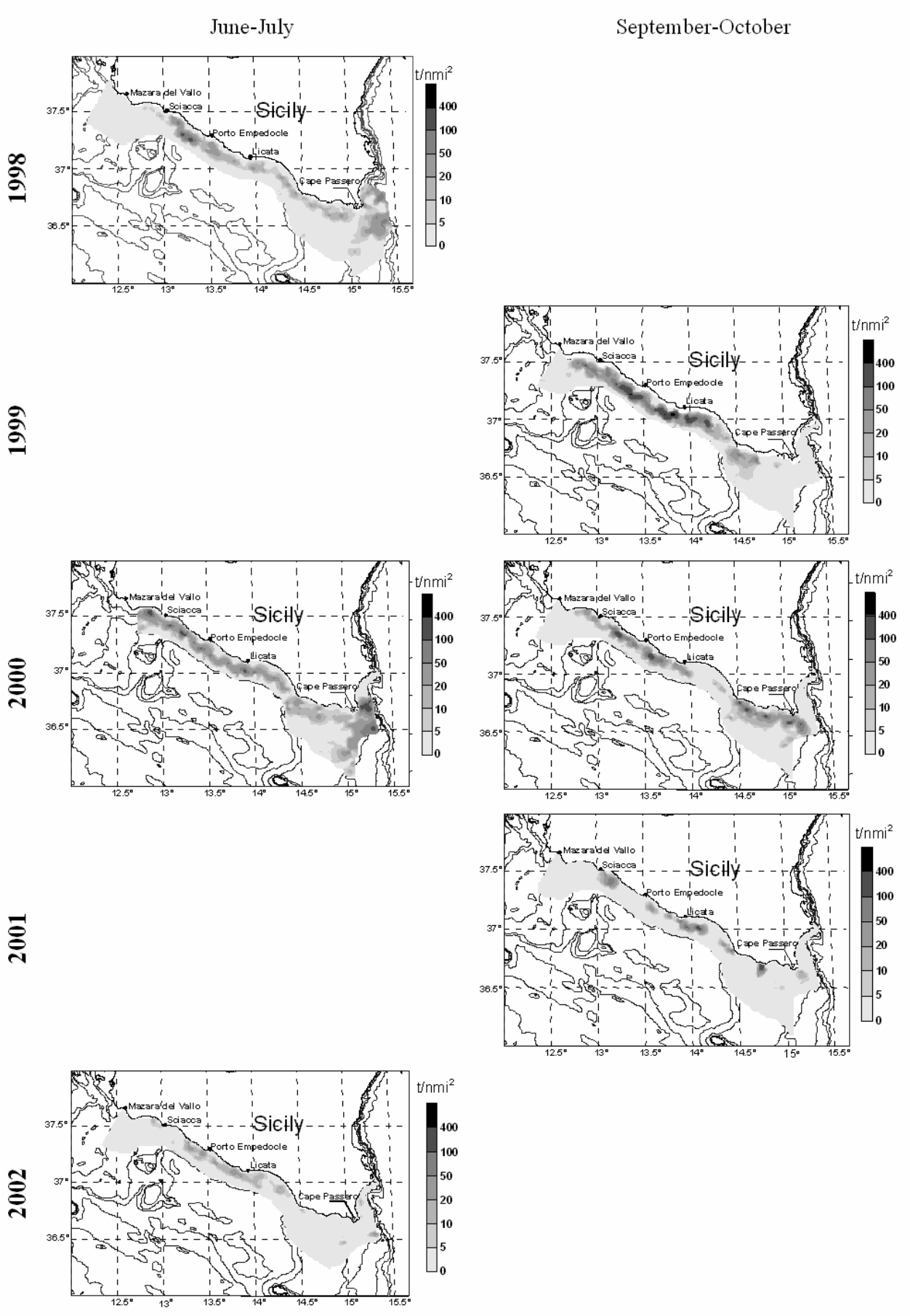

Figure 2. Sardine biomass distributions for the period 1998–2002.

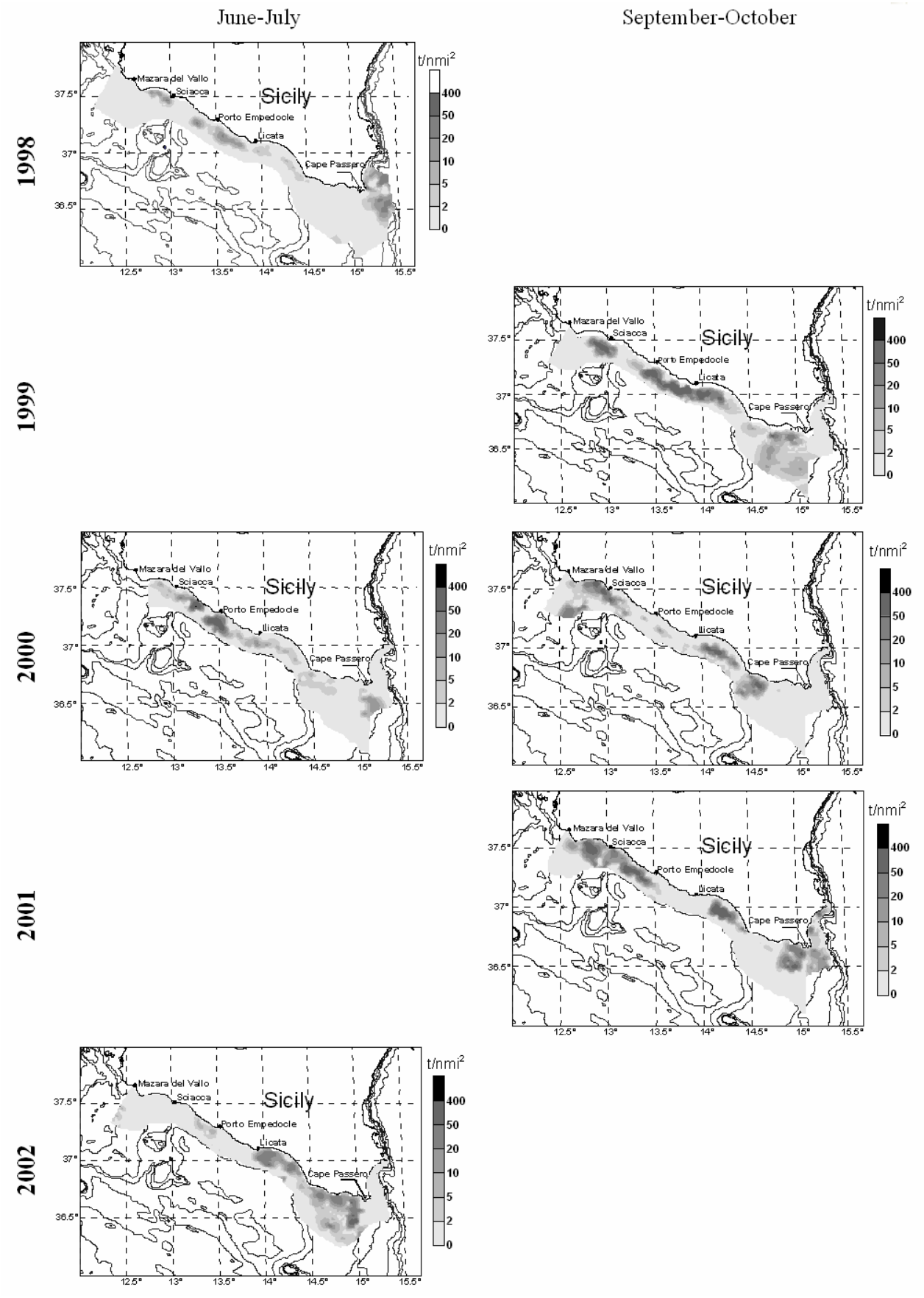

Figure 3. Anchovy biomass distributions for the period 1998–2002.

Estimated biomass, by year and by species, is given in Table 2.

Table 2. Biomass estimates (in metric tons) for sardine and anchovy populations off the southern coast of Sicily, by survey. Investigated area covers approximately 2,400 square nautical miles (8,232 km^2).

Survey	Sardine	Anchovy	Total
June 1998	20,000	7,100	27,100
October 1999	33,700	20,200	53,900
July 2000	36,370	11,000	47,370
September 2000	24,800	11,050	35,850
October 2001	10,054	22,950	33,004
July 2002	6,000	11,500	17,500

Both sardine and anchovy populations experienced quite large inter-annual fluctuations during the period 1998–2002. Sardine biomass estimates ranged from 6,000 metric tons in July 2002 to over 36,000 metric tons in July 2000; anchovy estimations ranged from about 7,100 metric tons in June 1998 to 23,000 metric tons in October 2001.

The sardine population has decreased steadily during the last few years, from 36,000 metric tons in 2000 to just 6,000 metric tons in 2002, so that, from 2001 onwards, the anchovy biomass started to exceed the sardine biomass.

It may be hypothesized that some process of compensation permitted the total biomass to vary moderately, at least up to 2001. For instance, in one year, from September 2000 to October 2001, sardine biomass dropped by 60% and the anchovy biomass increased by 108%, but the total biomass (sardine + anchovy) declined by only 8%.

The weight of the landings in Sciacca are one order of magnitude lower than the biomass estimates; reported landings have varied from 126 metric tons in 1999 to 2,312 metric tons in 2001, for anchovy, and from 1,233 metric tons in 1999 to 2,080 metric tons in 2000, for sardine (Mazzola *et al*., 2002). Although the total catch along the southern coast of Sicily is unknown, the Sciacca fleet accounts for about one-third of the total effort on small-pelagic-fish species in the study area. Consequently, much of the observed fluctuation in the biomass is believed to be related to the effects of the variability of environmental factors on early-life stages of the populations, which would be able to affect yearly recruitment success and ultimately fishing yields during the following year, when recruitment size is reached.

Data on the reproductive biology of the anchovy in the study area (Basilone *et al*., 2003) showed that anchovy caught during summer between Sciacca and Gela are at the peak of spawning. In addition, it is well known that the nursery area is separate from the spawning area close to Cape Passero (García Lafuente *et al*., 2002) where a retention area is formed by the surface circulation (vortex). These considerations suggest that the anchovy finds better environmental conditions for feeding and spawning in the area between Sciacca and Gela, while the AIS transports anchovy larvae to the nursery area.

For sardine it is not possible, at present, to theorize on similar behaviour, since no survey was carried out during the spawning period of this species.

Preliminary results showed that acoustic estimates, when obtained from surveys carried out in time to be significantly affected by the juvenile or recruitment biomass, are largely consistent with the landings recorded in the port of Sciacca during the year following the evaluation surveys (Figure 4). The main exception is the anchovy biomass evaluation from survey carried out in September 2000. From this biomass estimate, a lower level of anchovy landings than that one recorded in 2001 was expected. However, that survey was probably carried out too early to include a significant effect from recruitment success for a population whose peak spawning period occurs in July. Probably, an accurate analysis of the variability of fishing effort and environmental conditions will provide an explanation of the above-reported exception.

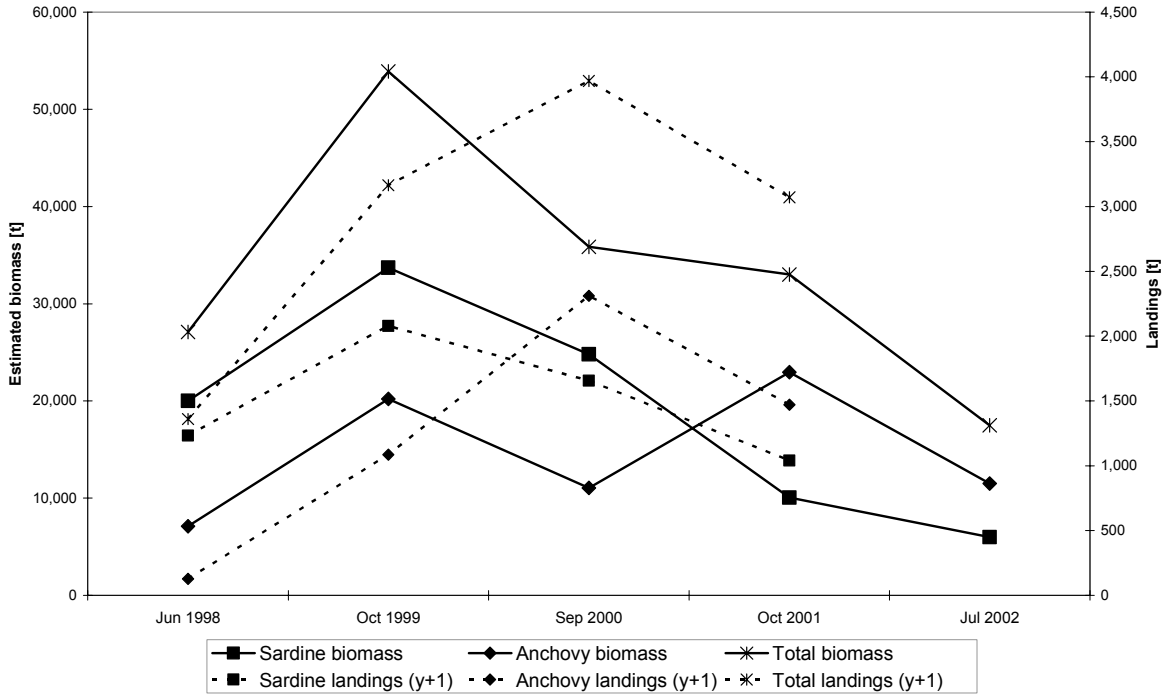

Figure 4. Biomass estimates for sardine and anchovy populations off the southern coast of Sicily and landings in Sciacca during the year following the evaluation surveys (y+1).

4. Conclusions

The study presents the estimates of abundance and distribution of two small-pelagic-fish species (sardine and anchovy), obtained by the hydro-acoustic method in the Strait of Sicily on the Sicilian continental shelf.

The observed fluctuations in the abundance of these species are consistent with the commercial landings in Sciacca. If these preliminary results are confirmed, it would be possible to predict future catch levels from acoustic biomass estimates, thus emphasizing their importance for the management of small-pelagic-fish populations.

5. Acknowledgements

The study was supported by the European Commission under Project MED 96-052 of the DG XIV (Fisheries), by Project 4-A-44 of the Italian Ministero delle Politiche Agricole e Forestali, Direzione Generale della Pesca e dell'Acquacoltura (L. 41/82 - D.M. 9/11/1982) and by Project 1 C10 (ASTAMAR) of the Italian Ministero dell'Istruzione Università e Ricerca – cluster 10 of the Piano Ambiente Marino.

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