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Sardine (*Sardina pilchardus*, Walb.) stock assessment in the Adriatic Sea: 1975-2002

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Sardine (*Sardina pilchardus*, Walb.) stock assessment in the Adriatic Sea: 1975-2002[1]

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Abstract

Sardine (*Sardina pilchardus*, Walb.) is one of the most important commercial species of the Adriatic Sea. Stocks of sardine, living in the Northern and Central Adriatic Sea, is shared between Italy, Slovenia and Croatia. This assessment is relative to the sardine stock of the Northern and Central Adriatic Sea (GFCM GSA 17), pooling together data coming from Italy, Slovenia and Croatia. It has been carried out in the context of the AdriaMed-SP research programme[2]. The annual catch of sardine for the three countries mentioned was obtained for the time interval 1975-2002. These quantities were distributed into fish age classes, so that catch-at-age data were available. That represented the basic input data of Virtual Population Analysis (VPA), employed for this stock assessment. Annual values of mid-year stock biomass at sea, annual values of the unweighted mean fishing mortality rate over the age class range 0-5, annual values of mid-year spawning biomass and corresponding ratios between catch and mid-year spawning biomass were obtained. In addition, annual exploitation rates were calculated and compared with a threshold derived from literature and suggested for small pelagics. Since decline of stock biomass is observed after the peak in the first half of the 1980s, and lowest values of this series only correspond to recent years, it

[1] The preparation of this paper has been promoted by the FAO-AdriaMed Project and it was conceived within the AdriaMed Working Group on Small Pelagics. The opinions, interpretations, conclusions, or recommendations expressed in this document are entirely those of the authors and do not necessarily reflect the view or position of FAO or of the Countries and Institutions participating in the AdriaMed Project.

[2] Within the framework and support of the FAO Regional Project "Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea" (AdriaMed) the research programme titled "Data Collection and Biological Sampling System on Small Pelagics in the Adriatic Sea (AdriaMed-SP)" started in June 2001 with the participation of the following national research institutes: Marine Sciences Institute (ISMAR, formerly IRPEM) – Ancona (Italy); Fisheries Research Institute – Ljubljana (Slovenia); Institute of Oceanography and Fisheries, IOF – Split (Croatia); Fisheries Research Institute, FRI – Durrës (Albania); Marine Biology Laboratory – Bari (Italy). The Population Dynamics Section of ISMAR coordinates this research programme with AdriaMed.

would be unwise for fishing effort to be allowed to rise. An apparent increase in estimated biomass is observed in the last year, 2002: caution has to be taken when considering this, as VPA may have difficulties with incomplete cohorts; in addition, change in discarding phenomenon (particularly for small size sardines) could play a role in an apparent increase such as the one described. Therefore, monitoring of discarded quantities, as well as pattern as a function of sardine size, is also suggested. Concerning the South Adriatic (GFCM GSA 18), not enough catch and effort data and biological data on the sardine is currently available to perform stock assessment. Data collection in the South Adriatic is being carried out in the framework of the AdriaMed-SP research programme; the retrieval of past data is also going on. Therefore, in the near future, a joint stock assessment will also be possible in this area.

Key words: Pelagic fisheries; Shared stocks; Catch/effort; Stock assessment; Population dynamics; *Sardina pilchardus*; MED, Adriatic Sea.

1. Background

The small pelagic species (Anchovy - *Engraulis encrasicolus*, L. and Sardine - *Sardina pilchardus*, Walb.) are of key importance for Adriatic fisheries[3]. They represent about 85% of the Italian small pelagic catches, 85% of the Croatian total catches, and a considerable percentage of the catches of Slovenia. In Albania, small pelagic fishery has been particularly important in the past. Since the 1990s it has drastically regressed as a consequence of the socio-economic changes that took place in the country and of the development of the demersal fishery (Kapedani, 2001). It is believed that small pelagic fishery has the potential to develop again in the future. The small pelagic fishery has developed on both sides of the Adriatic; however, more than 90% of the anchovy catches are landed by the Italian fleet (Figure 1), while the pelagic fleets from Slovenia, Croatia and Albania have concentrated primarily on sardines. In fact the Eastern Adriatic sardine catches are almost equal to the Italian Adriatic catches (Anonymous, 1975 – 1993; Anonymous, 1994). See Figure 2.

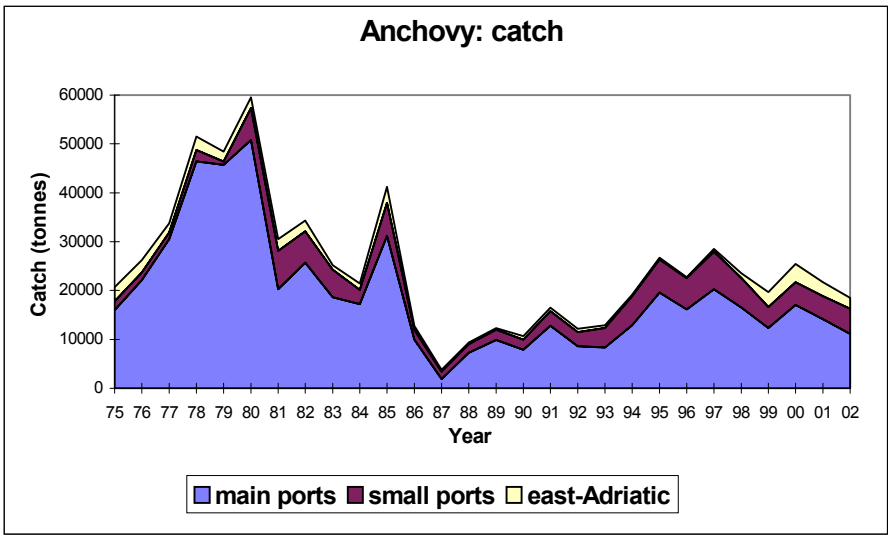

Figure 1. Adriatic (Northern and Central) anchovy landed catches.

[3] Because small pelagic fisheries concern anchovy and sardine, background description is the same for the two papers of the two species, presented at the 2003 SAC-Working Group on Small Pelagics.

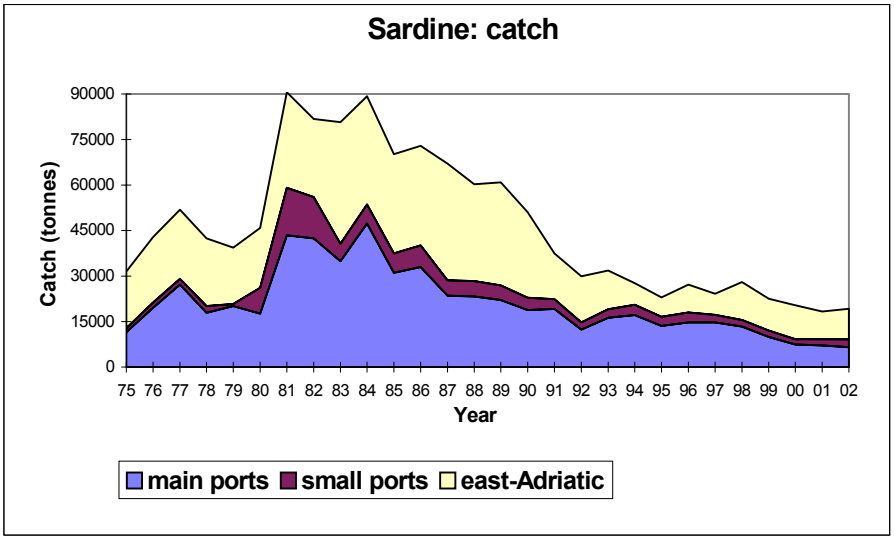

Figure 2. Adriatic (Northern and Central) sardine landed catches.

Anchovy and sardine are the most important species of the shared small pelagics stocks: in Italy and Croatia, sprat and sardinella are almost completely absent from the landed catches, and mackerel represents about 4 - 5% of the total catches of anchovies and sardines. In Slovenia the sardine catches represent more than 90% of the national catches (Marceta, 2001). Sprats are fished in the North Adriatic, while the fishing area of sardinella is in the South. In Italy, in terms of market price, anchovies are considerably more valuable than sardines. The value of the Adriatic catch of anchovy in 1991 was estimated by STCF (STCF, 1991) to be around 14 million US $. A present estimate of the value of the anchovy catch in the Adriatic could be in the order of 32 million US $. In Slovenia and Croatia, sardines are more desirable than anchovies (Marceta, 2001; Sinovcic, 2001).

Northern and Central Italian Adriatic catches of sardines reached a maximum value, (59,000 tonnes), in 1981, decreasing in successive years; current catches total about 9,000 tonnes. Slovenian sardine catches totalled 6,600 tonnes in 1983, while the present catches are about 1,300 tonnes. Croatian sardine catches reached a maximum in 1983 (40,044 tons) and in 1987 (38,439 tons). Significant decreases in catches were noted after 1990. Present Croatian catches are about 10,000 tonnes. Albanian sardines represented about the 90% of catches in the past (before the Nineties).
At present 11 boats are involved in small pelagics fishery in Albania. Present Adriatic sardines catches are about 20,000 tonnes. A high percentage of sardine catches is directed to the fish processing industry. Anchovy catches in Italy reached a maximum value in 1980 (57,328 tonnes) followed by a quick decrease in successive years until the crash of the 1987 (3,375 tonnes). Anchovy catches in Croatia reached a maximum value in 1985 (3,245 tonnes), followed by a period of decrease until 1998. After this year, Croatian anchovy landings increased reaching a new maximum value in 2002 (3,735 tonnes); the present level of Croatian anchovy catches is around 2,500 tonnes.

In the last years, the Adriatic anchovy population showed a recovery. Present catches of anchovies in the Adriatic are about 20,000 tonnes.

Two types of fishing gear are used in Adriatic: midwater pelagic pair trawls (volante) and purse seines with light attraction (lampara). The Italian pelagic fleet is distributed along the Adriatic coastline from Trieste, in the north, to Molfetta in the south and the Croatian fleet from Umag to Dubrovnik. Most small pelagics are caught in the Northern and Central Adriatic: in the Western part from Trieste to Vieste, whereas in the Eastern part they are mainly caught from Istria to the Mid-Dalmatian islands.
Small pelagic fishery is a very important part of the Adriatic fishery (in particular, anchovy and sardine) for economic reasons (total value of catches) and for social reasons (number of fishermen involved). Fish market preferences (anchovies are appreciated on the western coast, while sardines are appreciated on the eastern coast) should help a joint exploitation of small pelagics. It could avoid the discarding of sardines, a common practice in Italy due to their very low price. The shared small pelagic stocks which have greater importance for economic reasons are: anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), mackerel (*Scomber scombrus*), sprat (*Sprattus sprattus*), and sardinella (*Sardinella aurita*).

In the Adriatic Sea two areas could be identified: the North and Central Adriatic characterised by a shallow area and a wide continental shelf and the South Adriatic characterised by deeper water and a narrow continental shelf. This situation is directed related to the fishing productivity, which is higher in the North and Central Adriatic than in the South Adriatic.

The Adriatic area can be best understood when viewed in two Geographical Management Units (MUs) currently referred to as Geographical Sub-Areas (GSA; GFCM, 2001). The MU 37.2.1.a (currently GSA 17) encompasses the North and Central Adriatic and its Southern boundary is the straight line between the mouth of the stream Saccione (Northern limit of the Italian Manfredonia fishery district) and the Croatia-Montenegro border (Cape Ostro on Prevlaka Peninsula. The MU 37.2.2.b (now GSA 18) includes the South Adriatic and its Southern boundary is the straight line between Porto Badisco (Southern limit of Brindisi fishery district) and the Albania-Greece border (Figure 3).

A Geographical Management Unit is an area in which management action could be undertaken. The map in Figure 3 shows the AdriaMed-proposed modification of boundaries of Adriatic Geographical Management Unit 37.2.1.a (GSA 17) and 37.2.2.b (GSA 18; from the solid line to dotted line). The new boundaries are well suited to the physical differences between the North, Central and South Adriatic and the present boundaries of Adriatic countries (AdriaMed, 2001).

2. Methodological notes

Commercial catch data collection on a regional scale in Italy, Slovenia, Croatia and Albania has been carried out by a port sampling network established by AdriaMed as described in Cingolani and Santojanni (2002). The data collection system adopted is coherent with that established in Italy by ISMAR (formerly IRPEM) since 1975 (Cingolani *et al*., 2001).

The sardine stock assessment for the time period 1975-2002 was carried out by means of Virtual Population Analysis (VPA), which is a population dynamics method based on

analysis of the age frequency distributions of total catches (Hilborn and Walters, 1992). Assessments based on VPA for the same stock and using the same core data collected, were also carried out in the past (Cingolani *et al*., 2000; Santojanni *et al*., 2001a,b; Cingolani *et al*., 2002).

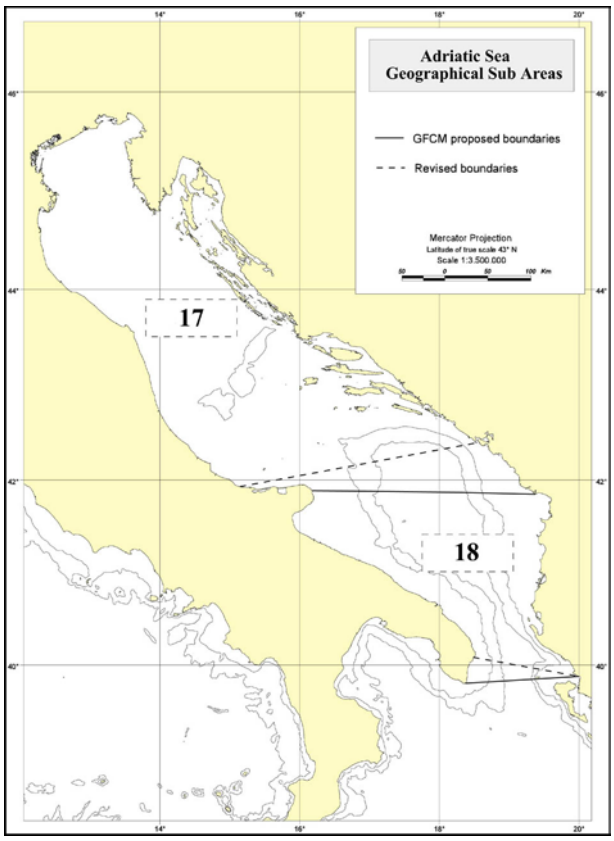

Figure 3. Map showing the boundaries of the Adriatic Sea Geographical Sub-Areas (formerly Geographical Management Units) as originally indicated by the GFCM (solid line) and with the recent revision (dotted line).

The age of fish was estimated by reading otoliths. Age-length keys were applied to the annual catch weighted length frequency distributions of the catch in order to obtain corresponding age distributions, with the age classes ranging from 0 up to the plusgroup 6+ (i.e. including individuals older than 6 years).

The fishing effort was considered as directed to both sardine and anchovy, and annual (as well as monthly) values were calculated for the fleet of the Italian port of Porto Garibaldi, whose sardine and anchovy catches over the period 1976-2002 are respectively around 25% and 20% of the total. Effort was standardised (Santojanni *et al*., 2002) by using Generalised Linear Model (GLM) as suggested by Hilborn and Walters (1992). Combining this effort with corresponding catches, CPUEs were obtained for the same fleet. In particular, the catches were distributed into the age classes so that CPUE-at-age data were obtained.

VPA was performed using the version 3.2 of the software package MAFF-VPA (Ministry of Agriculture, Fishery and Food, UK), developed by Darby and Flatman (1994).

3. Results

VPA was carried out using the Laurec-Shepherd tuning (Laurec and Shepherd, 1983; Pope and Shepherd, 1985), with estimated (i.e. fixed) values of the annual fishing mortality rate, F, for the oldest age class (5 and plusgroup 6+). This method attempts to estimate the fishing mortality rate at age in the final year by fitting to CPUE-at-age data (for Porto Garibaldi) in earlier years, under the assumption that the annual catchability at age, q_a , is constant over time. The catchabilities at age were thought to be quite constant over the very recent years, so that the time interval selected for tuning was 1997-2002. No evident trends over this period were found in the differences between the observed log-catchability at age and the corresponding expected one, yielded by the VPA run. Hence, the assumption of constant catchability at age was respected. On the contrary, when larger time intervals for tuning were used, this assumption was not respected and, furthermore, no significant estimated biomass was obtained for the last year.

In VPA calculations, the annual natural mortality rate, M, is assumed constant over ages and years. In this work, as well as in the previous IRPEM[4] assessments, M was assumed to be equal to 0.5 (yr^{-1}) on the basis of the observed age distributions of the catches. In particular, lower values would imply too many old individuals at sea, which are seldom found in the catches. Too many higher values of M would have implied a not very realistic massive stock biomass at sea over many years, from VPA. Finally, the value M = 0.5 was estimated by Sinovcic (1986) in a past assessment of mid Adriatic sardine stocks.

There is no fully appropriate method for estimating values of the annual fishing mortality rate for the oldest age class. In this work, $F_{5,\ 2002}$ was assumed to be equal to a fishing mortality rate referring to all age groups taken on the whole. In fact, the estimate of this parameter was obtained subtracting M from Z, i.e. the total mortality rate, which was calculated by means of a catch curve analysis (Hilborn and Walters, 1992) using Porto Garibaldi CPUE-at-age data in the most recent years. The value of $F_{5,\ 2002}$ estimated in this way proved to be equal to 0.25 (yr^{-1}).
The values of $F_{5,\ year}$ in all the other years were calculated on the basis of a relationship between $F_{5,\ 2002}$ and Porto Garibaldi effort, as follows:

$$F_{5,\ t} / E_t = F_{5,\ 2002} / E_{2002}$$

where E_t is the effort in the year t (see Table 1). The series of values thus obtained allowed VPA to yield annual exploitation patterns (i.e. F as a function of age in the different years) quite close to what is believed to happen in this fishery (and more in general for small pelagics).

[4] As of the 15th January 2003, IRPEM changed to the Marine Sciences Institute (ISMAR)/Marine Fisheries Department – Ancona (Italy).

Table 1. Series of annual values of sardines unweighted mean fishing mortality rate, F_{0-5} , over the age class range 0-5.

Year	F_{0-5}	Year	F_{0-5}
1975	0.16	1991	0.25
1976	0.22	1992	0.20
1977	0.28	1993	0.23
1978	0.28	1994	0.20
1979	0.25	1995	0.17
1980	0.23	1996	0.20
1981	0.35	1997	0.19
1982	0.35	1998	0.25
1983	0.34	1999	0.28
1984	0.31	2000	0.29
1985	0.22	2001	0.31
1986	0.23	2002	0.33
1987	0.20	1975-02	0.25
1988	0.22	2000-02	0.31
1989	0.25		
1990	0.25		

The average of F_{0-5} for the whole period (1975-2002) and for the last three years (2000-2002) are also reported in Table 1.

Figure 4 shows the results obtained from VPA.

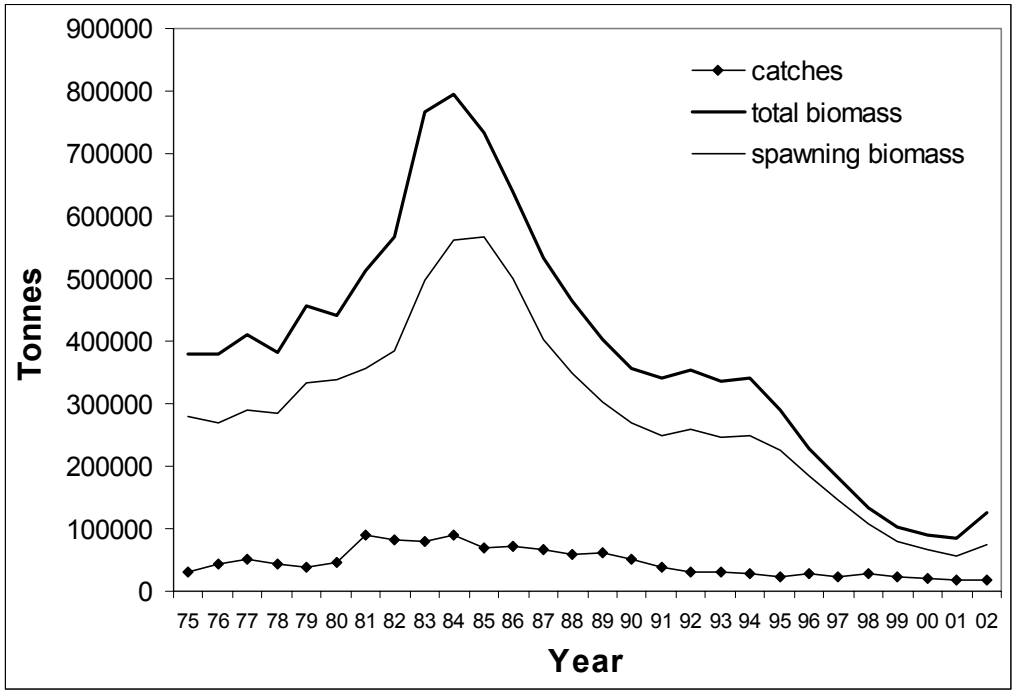

Figure 4. Annual sardine catches, mid-year total (=stock) biomass and mid-year spawning biomass at sea derived from VPA, from 1975 up to 2002.

The average value of catches in the last three years 2000-2002 is equal to 19292 tonnes, while the corresponding average of mid-year total (=stock) biomass is equal to 99410 tonnes.

Since decline of stock biomass is observed after the peak in the first half of 1980s, and lowest values of this series correspond just to recent years, it would be unwise for fishing effort to be allowed to rise. An apparent increase in estimated biomass is observed in the last year, 2002: caution has to be exercised when considering this, as VPA may have difficulties with incomplete cohorts; in addition, change in discarding phenomenon (particularly for small size sardines) could play a role in this kind of apparent increase. Therefore, the monitoring of discarded quantities as well as pattern as a function of sardine size is also suggested.

Finally, on the basis of the VPA results, unweighted mean values of the fishing mortality rate over the age class range 0-5 were calculated for each year from 1975 up to 2002. On the basis of these estimated averages over age and the mentioned value of M, the annual exploitation rates, i.e. the ratios between F and Z = F + M, were obtained. These ratios were compared with the value 0.4, which was suggested by Patterson (1992) to be taken as a reference point for small pelagic stocks, with the values higher than this threshold being associated to high probability of stock decline (see Figure 5).

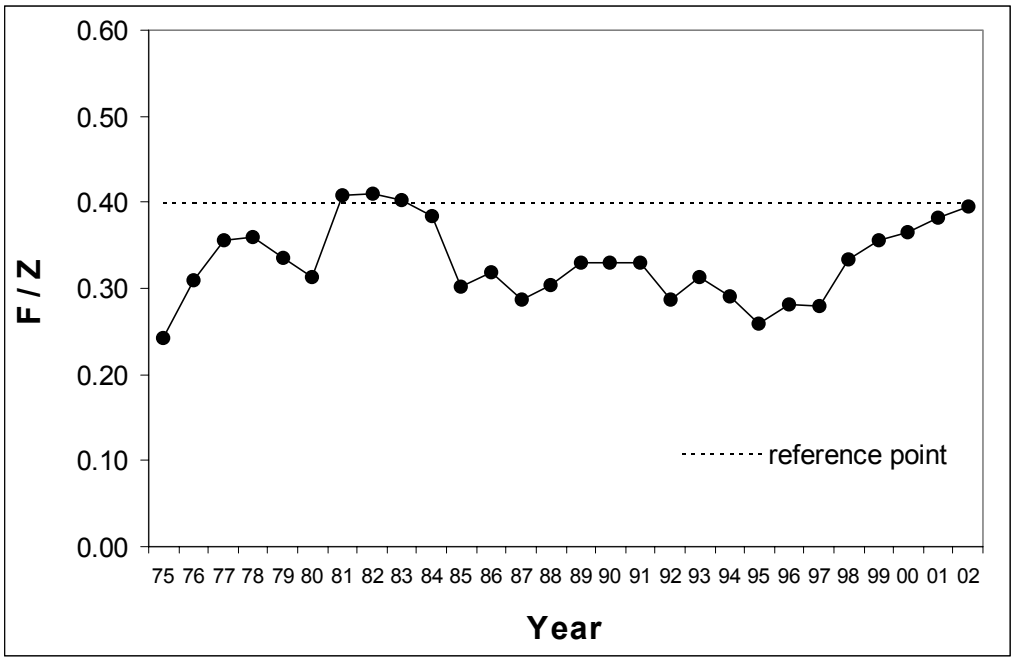

Figure 5. Sardine annual exploitation rate (F / Z) from 1975 up to 2002. The annual value of F is the unweighted mean over the age class range 0-5 obtained from VPA and reported in the Table 1. In this plot, we also reported the threshold 0.4 which should not be exceeded as suggested by Patterson (1992).

Table 2 shows the annual sardine catches and the mid-year spawning biomass derived from VPA. Corresponding ratios between catches and spawning biomass are also reported.

Table 2 - Annual sardine catches (tonnes) and mid-year spawning biomass (tonnes) derived from VPA

1	2	3	4
Year	**Catches**	**SSB mid-year**	**Catches/SSB mid-year**
1975	31455	280005	0.11
1976	42825	269103	0.16
1977	51852	288754	0.18
1978	42417	285006	0.15
1979	39337	334435	0.12
1980	45822	338570	0.14
1981	90563	356593	0.25
1982	81771	385746	0.21
1983	80681	496255	0.16
1984	89213	561464	0.16
1985	70192	566302	0.12
1986	72932	499377	0.15
1987	67017	401393	0.17
1988	60217	347469	0.17
1989	60900	303099	0.20
1990	51056	270354	0.19
1991	37427	248434	0.15
1992	29956	258113	0.12
1993	31804	246930	0.13
1994	27646	249625	0.11
1995	22967	225889	0.10
1996	27223	185545	0.15
1997	24207	146925	0.16
1998	27970	107025	0.26
1999	22547	79700	0.28
2000	20392	65748	0.31
2001	18293	57534	0.32
2002	19189	75384	0.25

4. South Adriatic

The South Adriatic Sea shows different geomorphological characteristics from the other part of the Adriatic Sea, with a continental shelf narrower than the Northern and Central Adriatic. The sea-depth, around the midline, is about 500-700 metres.
Nevertheless, in the upper part, in the Gulf of Manfredonia, there is a very important nursery area for small pelagics, due to the peculiar characteristics of the gulf, with a very large shelf, similar to the shelf of the Northern and Central Adriatic Sea. Research carried out by the Marine Biology Laboratory of Bari using the eggs-larvae methods, showed that the Manfredonian Gulf is one the main nursery areas of the Adriatic Sea for small pelagics

(Marano, 2000).
Lampara is the fishing gear mainly used, but during the fishing season (April-October) the purse seiners of the Western coast migrate into the Northern and Central Adriatic because high catches of anchovies and sardines may be obtained.
Lampara fishing vessels from Albania change fishing gear during the year, due to market constriction.
Before the implementation of the AdriaMed-SP research programme (in June 2001) there was no systematic data collection of catch and effort data and biological sampling of sardine on Western coast of the South Adriatic.
In Albania systematic data collection concerning catch, effort and partial biological sampling of sardine were carried out until 1992. From June 2001 data collection began again under the AdriaMed-SP research programme.
So far, it has not yet been possible to perform stock assessment for the South Adriatic Area and, currently, the retrieval of past data is being carried out.

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