SCIENTIFIC COOPERATION TO SUPPORT RESPONSIBLE FISHERIES IN THE ADRIATIC SEA

MiPAF

Food and Agriculture Organization of the United Nations

Italian Ministry of Agriculture and Forestry Policies

AdriaMed

GCP/RER/010/ITA

Sardine (*Sardina pilchardus*, Walb.) stock assessment in the Adriatic Sea: 1975-2003

Paper presented at the GFCM-SAC Working Group on Small Pelagic Species

(Malaga, 6th-7th May 2004)

GCP/RER/010/ITA/OP-13 Termoli (Italy), September 2004

Sardine (*Sardina pilchardus*, Walb.) stock assessment in the Adriatic Sea: 1975-2003[1,2]

N. Cingolani [*], A. Santojanni [*], E. Arneri [*], A. Berlardinelli [*], S. Colella [*], F. Donato[*], G. Giannetti [*], G. Sinovcic [§], B. Zorica [§]

[*]Marine Sciences Institute (ISMAR)/Marine Fisheries Dept., Ancona (Italy); [§]Institute of Oceanography and Fisheries, Split (Croatia)

This paper should be cited as follows: Cingolani, N., Santojanni, A., Arneri, E., Berlardinelli, A., Colella, S., Donato, F., Giannetti, G., Sinovcic, G., Zorica, B. (2004) Sardine (*Sardina pilchardus*, Walb.) stock assessment in the Adriatic Sea: 1975-2003. Paper presented at the GFCM-SAC Working Group on Small Pelagic Species (Malaga, 6th-7th May 2004). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-13. *AdriaMed Occasional Papers*, 13: 09 pp. Available from the World Wide Web at http://www.faoadriamed.org/pdf/OP-13.zip

Abstract

Sardine (*Sardina pilchardus*, Walb.) is one of the most important commercial species of the Adriatic Sea. Stock 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[3]. The annual catch of sardine for the three countries mentioned was obtained for the time interval 1975-2003. 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 were obtained. In addition, annual exploitation rates were calculated, compared with a threshold derived from literature and suggested for small pelagics. Since a decline in stock biomass was observed after the peak in the first half of the1980s, and the lowest values of this series correspond just to recent years, it would be unwise for fishing effort to be allowed to increase. The exploitation is just higher than the threshold. Furthermore, difficulties in obtaining economically satisfactory catches by fishermen were perceived both in Italy and Croatia.

[1] 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] This work is the outcome of a regional stock assessment workshop to which the following research staff contributed: P. Decolli, R. Kapedani, C.A. Marano, A. Joksimovic, and O. Kasalica.

[3] 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 on the 1st of June 2001 with the participation of the following national research institutes: Marine Sciences Institute (ISMAR) – Ancona (Italy); Fisheries Research Institute – Ljubljana (Slovenia); Institute of Oceanography and Fisheries – Split (Croatia); Fisheries Research Institute – Durrës (Albania); Marine Biology Laboratory – Bari (Italy). The Population Dynamics Section of ISMAR coordinates this research programme with AdriaMed.

Key words: shared stocks, catch statistics, 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[4]. 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. 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 and Croatia have concentrated primarily on sardines. In actual fact the eastern Adriatic sardines catches are almost equal to the Italian Adriatic catches (Anonymous, 1975-1993; Anonymous, 1994). See Figure 2.

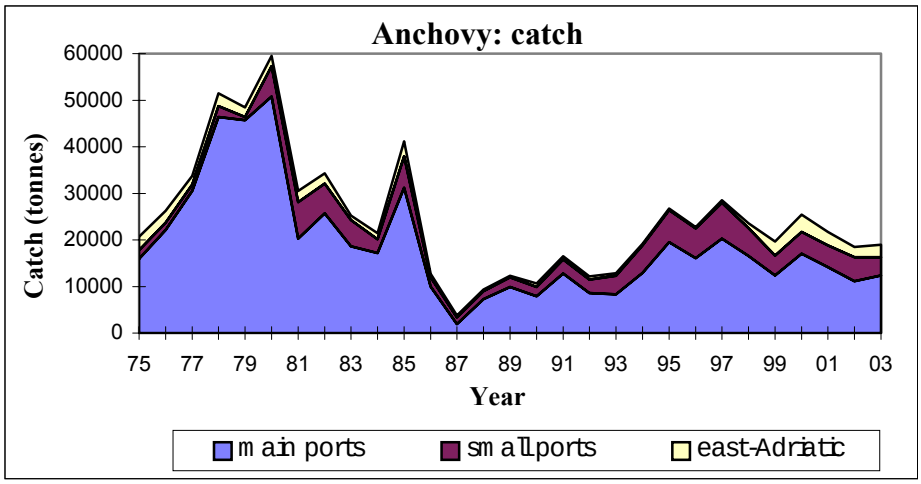

Figure 1. Adriatic (northern and central) anchovy landed catches.

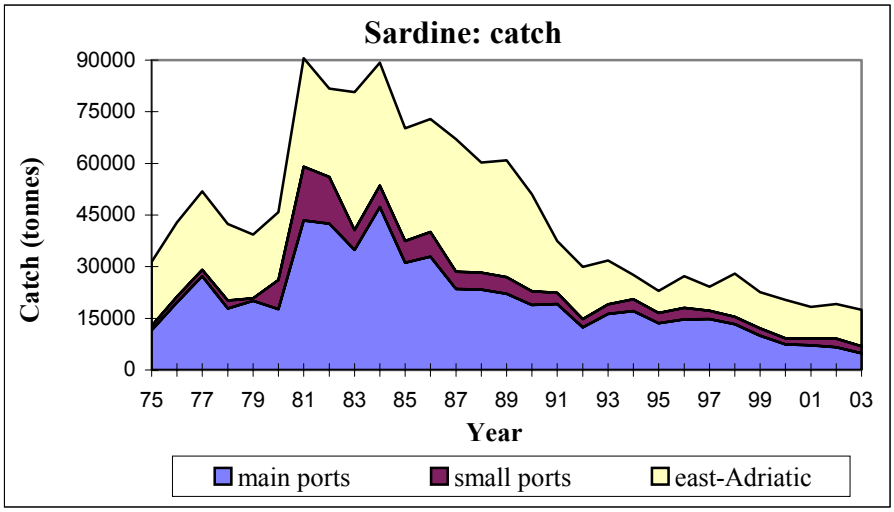

Figure 2. Adriatic (northern and central) sardine landed catches.

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 catches in the total of anchovies and sardines. In Slovenia the sardine catches represent more than 90% of the national catches (Marceta,

[4] Because small pelagic fisheries concern anchovy and sardine, background description is the same for the two papers of the two species, presented at the 2004 SAC-Working Group on Small Pelagics.

2001). Sprats are fished in the north Adriatic, whereas the fishing area of sardinella is in the south. In Italy, in terms of market price, anchovies are considerably more valuable than sardines. Due to a decrease in catches in the last few years, the price of sardine has risen. In some ports and in some periods, market price of sardine is higher than anchovy. In Slovenia and Croatia, sardines are more desirable than anchovies (Marceta, 2001; Sinovcic, 2001).
Italian catches of sardines from the northern and central Adriatic reached a maximum value (59,000 tonnes) in 1981, decreasing in successive years; current catches are about 7,500 tonnes. Slovenian sardine catches were 6,600 tonnes in 1983, while the present catches are about 900 tonnes. Croatian sardine catches reached a maximum in 1983 (40,044 tonnes) and in 1987 (38,439 tonnes). Significant decreases in catches were noted after 1990. Present Croatian catches are about 9,500 tonnes. Present Adriatic sardines catches (GSA 17) are about 18,000 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 1987 (3,375 tonnes). Anchovy catches in Croatia reached a maximum value in 1985 (3,245 tonnes), followed by a period of decline until 1998. After that year, Croatian anchovy catches 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, Adriatic anchovy population showed a recovery; nevertheless biomass seems to be fluctuating once more. Present annual catches of anchovies in the Adriatic (GSA 17) are about 21,000 tonnes.

Two types of fishing gear are used in the 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 to Vieste (GSA 17), 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 the Istria to the mid-Dalmatian islands.
The small pelagic fishery (in particular, anchovy and sardine) is very important in the Adriatic fishery sector 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 the joint management of small pelagic fisheries. It could also avoid the discarding of sardines at sea, a common practice in Italy due to the constantly low price of sardines. Fortunately, this practice in the last years has been negligible because the price of sardines has risen.
The Adriatic area can be best understood when viewed in two Geographical Management Units, MU, 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 Saccione stream (northern limit of the Italian Manfredonia fishery district) and the Croatia-Montenegro border (Cape Ostro on Prevlaka Peninsula.
The map in Figure 3 shows the modification proposed by AdriaMed 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 Adriatic, central Adriatic, south Adriatic and the present boundaries of the Adriatic countries (AdriaMed, 2001).

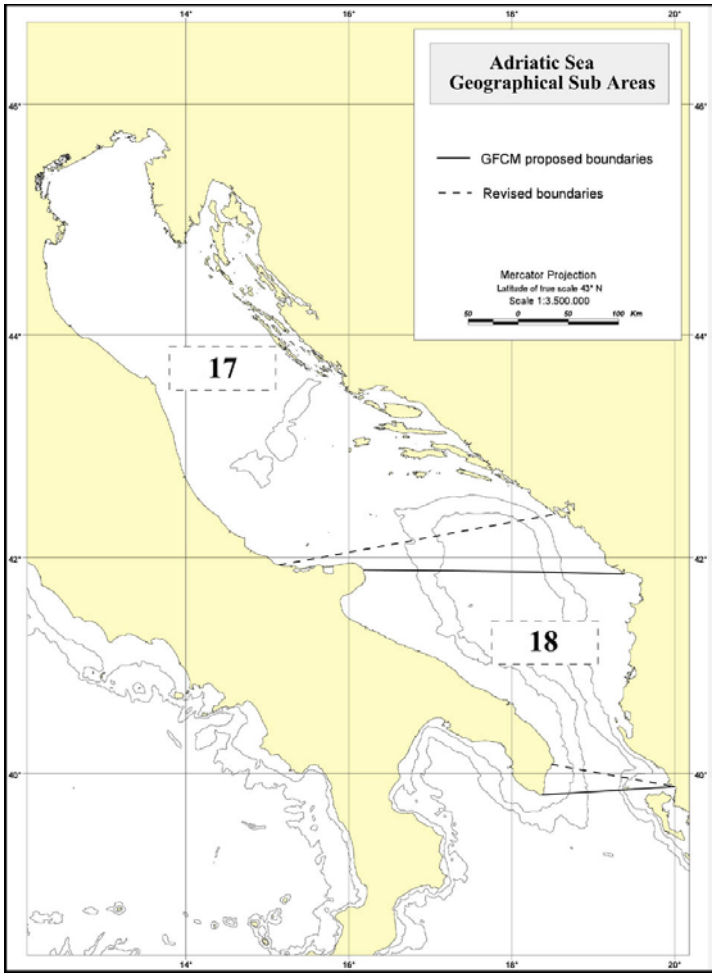

Figure 3. Map showing the boundaries of the Adriatic Sea Geographical Sub-Areas (formerly Geographical Management Units) as originally indicated by the GFCM (solid line) and with the recent revision (dotted line)

2. Methodological notes

Commercial catch data collections on a regional scale in Italy, Slovenia, Croatia and Albania have been carried out by a port sampling network established through 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 with the same core of data collection were also made in the past (Cingolani *et al*., 2000; Santojanni *et al*., 2001; Cingolani *et al*., 2002).

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 thought to be 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 1976-2003 are around 20% (25% in some years) of the total, respectively. The effort was standardized (Santojanni *et al*., 2002) by use of the Generalized 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, i.e. 5 and 6+ (Santojanni *et al*., 2003). The Laurec-Shepherd tuning process attempts to estimate the fishing mortality rate at age in the most recent 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 catchability-at-age were thought to be quite constant over very recent years, so that the time interval selected for tuning was 1997-2003. This is related to the probable reduction in discarding at sea. 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, further, no meaningful estimated biomass was obtained in the most recent year.
There is no fully appropriate method for estimating values of the annual fishing mortality rate for the oldest age class. In this paper, a mean value for the age 3, relative to the period 1997-2003, was assumed to be equal to a fishing mortality rate referred to all age groups taken altogether. 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 total catch-at-age data in the time interval 1998-2003, with total effort being assumed to be constant in this period just to treat catches as CPUE. The value of $F_{3\ 1997\text{-}2003}$, thus estimated, proved to be equal to 0.35 (yr^{-1}). The values of $F_{3\ year}$ in all the other years were calculated on the basis of the following relationship:

$$F_{5,\,t} \;/\; E_t \;=\; F_{5\ 1997\text{-}2003} \;/\; E_{t\ 1997\text{-}2003}$$

where E is the fishing effort of Porto Garibaldi fleet in the year t and period 1997-2003.

In VPA calculations, the annual natural mortality rate, M, is assumed to be constant for all ages and years. In this paper, as well as in the previous IRPEM[5] 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. Higher values of M would have implied an unrealistic massive stock biomass at sea in many years, from VPA estimation. Finally, the value M = 0.5 was estimated by Sinovcic (1986) in a past assessment of mid-Adriatic sardine stock.

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

Table 1 shows the annual values of unweighted mean fishing mortality rate for sardine, $F_{0\text{-}5}$, over the age class range 0-5, yielded by VPA; the averages of these annual rates for the periods 1975-2003 and 2001-2003 are also shown.

Year	$F_{0\text{-}5}$	Year	$F_{0\text{-}5}$
1975	0.16	1991	0.23
1976	0.22	1992	0.21
1977	0.28	1993	0.23
1978	0.28	1994	0.20
1979	0.25	1995	0.17
1980	0.22	1996	0.19
1981	0.34	1997	0.19
1982	0.35	1998	0.25
1983	0.33	1999	0.28
1984	0.31	2000	0.29
1985	0.22	2001	0.33
1986	0.23	2002	0.36
1987	0.20	2003	0.33
1988	0.22	**1975-03**	**0.25**
1989	0.24	**2001-03**	**0.34**

Figure 4 shows the total (=stock) biomass at sea of sardine estimated by VPA, along with the trend of corresponding total catches, from 1975 up to 2003.

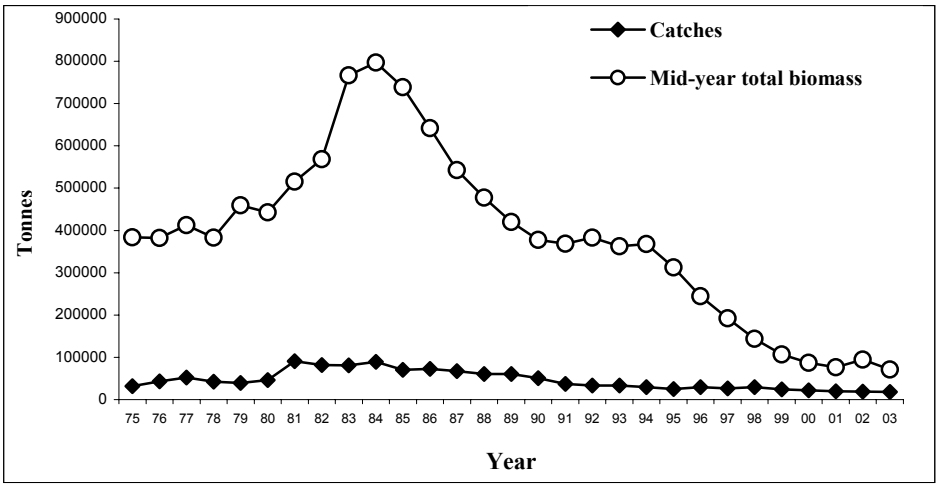

Figure 4. Sardine annual catches and mid-year total (=stock) biomass at sea derived from VPA, since 1975 up to 2003.

Figure 5 shows a comparison between the biomass trend of VPA and the trend of average density (t/nm^2) of sardine obtained by acoustic survey, conducted in the north Adriatic Sea[6] (Azzali et al. 2002). Data from 1987 to 2001 are compared.

[6] Area covered is extended from Trieste (the first port of the north Adriatic) to about the latitude of Pescara, largely coincident with the distribution area of the small pelagic stocks in the GSA 17.

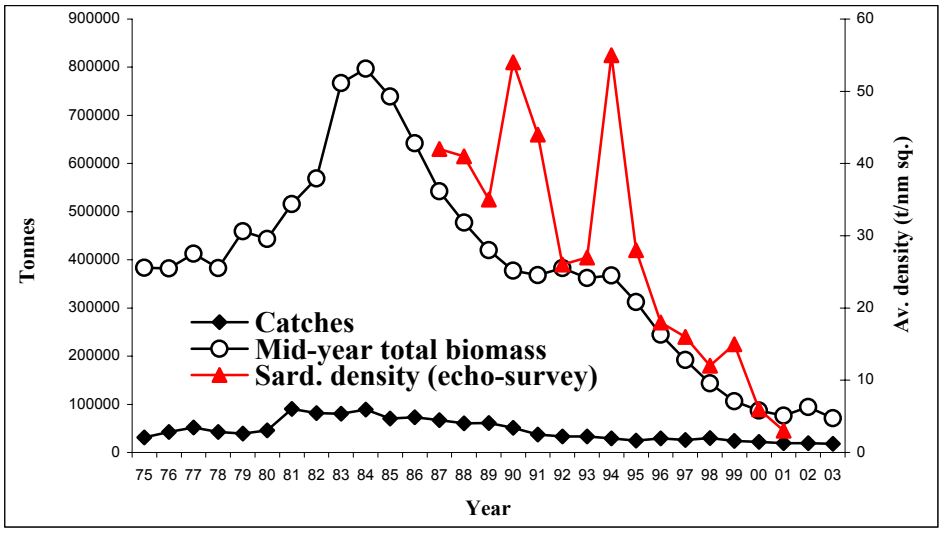

Figure 5. The trend of mid-year total (=stock) biomass at sea derived from the VPA performed using data from 1975 to 2003, is compared with the average density (t/nm^2) of sardine, obtained by acoustic survey in the north Adriatic (1987-2001)

Trends of the two series appear very similar, although echo-survey data show high peaks of sardine density.

The mean value of $F_{0\text{-}5}$ is 0.25 over the whole time series and 0.34 in the last three years. The average value of total catches in the last three years 2001-2003 is equal to 18,904 tonnes, while the corresponding average of mid-year total (=stock) biomass is equal to 80,693 tonnes. The mean ratio between catch and mid-year biomass, in the last three years, is 0.24.

Although a 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. Furthermore, difficulties in obtaining economically satisfactory catches by fishermen were perceived both in Italy and Croatia.

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 to 2003. On the basis of these estimated averages over age and the mentioned value of M = 0.5, 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 6). The values over the threshold in recent years are consistent with the warnings above. The threshold was also slightly exceeded at the beginning of the 1980s, because of high catches and high values of F obtained for older age classes: the exceeded threshold in recent years should be considered a reliable warning because of its occurrence matching with the lowest recorded levels of estimated biomass at sea.

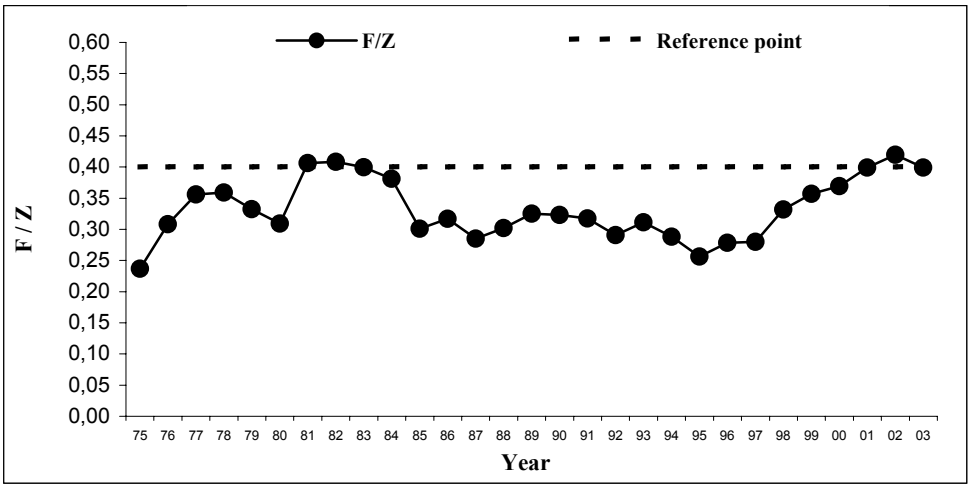

Figure 6. Annual sardine exploitation rate (F / Z) from 1975 to 2003. The annual value of F is the unweighted mean over the age class range 0-5 obtained from VPA and reported in Table 1. In this graph, we also reported the threshold 0.4 which should not be exceeded as suggested by Patterson (1992).

4. References

AdriaMed. (2001) The geographical management units of the Adriatic Sea. Paper presented at the GFCM-SAC Working Group on Management Units (Alicante, 23rd-25th January 2001). FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/OP-02. *AdriaMed Occasional Papers,* 12: 12 pp.

Anonymous. (1975-1993) Morska lovina SFRJ po podrucjima i glavnim vrstama. *Morsko Ribarstvo*, 27-45.

Anonymous. (1994) Morski ulov Republike Hrvatske po podrucjima i glavnim vrstama. Morsko Ribarstvo, 46.

Azzali, M., Cosimi, G., Luna, M., Parmiggiani, F. (2002) Valutazione acustica della biomassa, distribuzione e struttura delle popolazioni pelagiche in Adriatico, in relazione con i dati ambientali ricavati da satellite. Relazione per il MIPAF.

Cingolani, N., Arneri, E., Giannetti, G., Santojanni, A., Belardinelli, A., Colella, S., Donato, F. (2001) The small pelagic fisheries on the Western coast of the Adriatic Sea: monitoring and assessment. In: Mannini, P., F. Massa, N. Milone. (eds), Priority topics related to small pelagic fishery resources of the Adriatic Sea. FAO-MiPAF Scientifc Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-03. *AdriaMed Technical Documents*, 3: 39-52.

Cingolani, N., Arneri, E., Santojanni, A., Belardinelli, A., Giannetti, G., Colella, S., Donato, F. (2002) Stock assessment of sardine (*Sardina pilchardus*, Walb.) in the Adriatic Sea. *Biol. Mar. Medit*., 9(1): 82-88.

Cingolani, N., Kirkwood, G., Arneri, E., Santojanni, A., Belardinelli, A., Giannetti, G., Colella, S., Donato, F., Barry, C. (2000) Discards from the Adriatic small pelagic fishery. Final report on European Community funded project, EU 97/065, IX+439 pp.

Cingolani, N., and Santojanni, A. (2003) Manual of the Recorder - AdriaMed Training Course on Data Collection and Biological Sampling System on Small Pelagics. GCP/RER/010/ITA/OP-06-Rev.1. *AdriaMed Occasional Papers.* No.6 (Rev. 1): 53 pp. (also available at http://www.faoadriamed.org/pdf/OP-06.pdf).

Darby, C.D., Flatman. S. (1994) Virtual Population Analysis: version 3.1 (Windows/Dos)

user guide. Info. Tech. Ser. MAFF Direct. Fish. Res., Lowestoft, 1, 85 pp.
GFCM. (2001) Report of the twenty-sixth session. Lacco Ameno, Ischia, Italy, 10-13 September 2001. *GFCM Report*. No 26. Rome, FAO, 27 pp.
Hilborn, R., C.J. Walters. (1992) Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, 570 pp.
Kapedani, E. (2001) Small pelagic fishery and research in Albania. In: Mannini, P., F. Massa, N. Milone. (eds), Priority topics related to small pelagic fishery resources of the Adriatic Sea. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-03. *AdriaMed Technical Documents*, 3: 30-38.
Laurec, A., J.G. Shepherd. (1983) On the analysis of catch and effort data. *J. Cons. Int. Explor. Mer*., 41: 81-84.
Marano G. (2000) Piccoli pelagici: valutazione della biomassa (1984-1996). *Biol. Mar. Med*. 7 (4):59-70.
Marceta, B. (2001) Status of Slovene research and fishery on small pelagics. In: Mannini, P., F. Massa, N. Milone. (eds), Priority topics related to small pelagic fishery resources of the Adriatic Sea. FAO-MiPAF Scientifc Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-03. *AdriaMed Technical Documents*, 3: 24-29.
Patterson, K. (1992) Fisheries for small pelagic species: an empirical approach to management targets. *Rev. Fish Biol. Fish*., 2: 321-338.
Pope, J., J.G. Shepherd. (1985) A comparison of the performance of various methods for tuning VPA's using effort data. *J. Cons. Int. Explor. Mer*., 42: 129-151.
Santojanni, A., Arneri, E., Belardinelli, A., Cingolani, N., Giannetti, G. (2001) Fishery and stock assessment of sardine (*Sardina pilchardus*, Walb.) in the Adriatic Sea. *Acta Adriat*., 42(1): 151-168.
Santojanni, A., Cingolani, N., Arneri, E., Giannetti, G., Belardinelli, A., Donato, F., Colella, S. (2002) Calculation of small pelagic catch per unit of fishing effort in the Adriatic Sea. *Biol. Mar. Medit*., 9(1): 89-95.
Santojanni, A., Arneri, E., Barry, C., Belardinelli, A., Cingolani, N., Giannetti, G., Kirkwood, G. (2003) Trends of anchovy (*Engraulis encrasicolus*, L.) biomass in the northern and central Adriatic Sea. *Scientia Marina*, 67(3): 327-340.
Sinovcic, G. (1986) Estimation of growth, mortality, production and stock size of sardine, *Sardina pilchardus* (Walb.), from the middle Adriatic. *Acta Adriat*., 27(1-2): 67-74.
Sinovcic, G. (2001) Small pelagic fish from the Croatian fishing grounds. In: Mannini, P., F. Massa, N. Milone. (eds), Priority topics related to small pelagic fishery resources of the Adriatic Sea. FAO-MiPAF Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea. GCP/RER/010/ITA/TD-03. *AdriaMed Technical Documents*, 3: 53-58.
STCF. (1991) Commission of the European Communities, 19th Report of the Scientific and Technical Committee for Fisheries. *SEC* (91) 1651, 103pp.