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Anchovy (*Engraulis encrasicolus*, L.) stock assessment in the Adriatic Sea: 1975-2002[1]

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Abstract

Anchovy (*Engraulis encrasicolus*, L.) is one of the most important commercial species of the Adriatic Sea. The stock of anchovy living in the northern and central Adriatic Sea is shared between Italy, Slovenia and Croatia. This assessment is relative to the anchovy stock of the northern and central Adriatic Sea (GFCM GSA 17), pooling together data from Italy, Slovenia and Croatia. It has been carried out in the context of the AdriaMed-SP research programme[2]. The annual catch of anchovy 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 the stock assessment described herein. Annual values of mid-year stock biomass at sea, annual values of the unweighted mean fishing mortality rate over the age class range 0-3, 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. The minimum value of both catch and biomass at sea were

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[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.

estimated in 1987, when a substantial drop in the catch and crisis of the anchovy fishery occurred. Even if high values of both fishing effort and fishing mortality rate were obtained for some years before 1987, very low levels of recruitment in 1986 and 1987 seem to be mainly responsible for the collapse of the stock. Since current biomass seems not have risen to the values observed before collapse, it would be unwise for fishing effort to be allowed to rise. With regard to the south Adriatic (GFCM GSA 18), not enough catch and effort data and biological data are currently available for the anchovy to allow stock assessment to be performed. Data collection in the south Adriatic is being carried out in the context of AdriaMed-SP research programme together with the retrieval of past data. Therefore, in the near future, a joint stock assessment will be possible in this area too.

Key words: Pelagic fisheries; Shared stocks; Catch/effort; Stock assessment; Population dynamics; *Engraulis encrasicolus*; 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 which 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 the Slovenia, Croatia and Albania have concentrated primarily on sardines. In fact the eastern Adriatic sardines catches are almost equal to the Italian Adriatic catches (Anonymous, 1975 – 1993; Anonymous, 1994). See Figure 2.

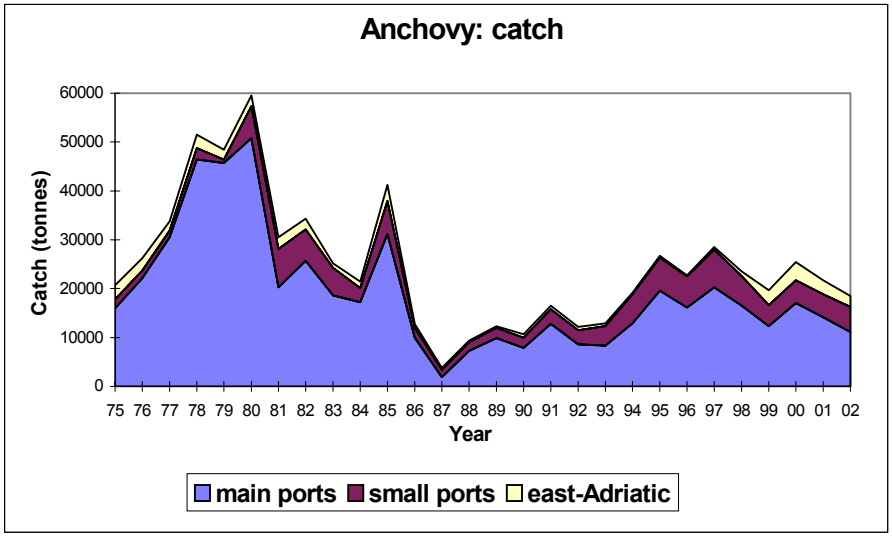

Figure 1 – Adriatic (northern and central) anchovy landed catches.

[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.

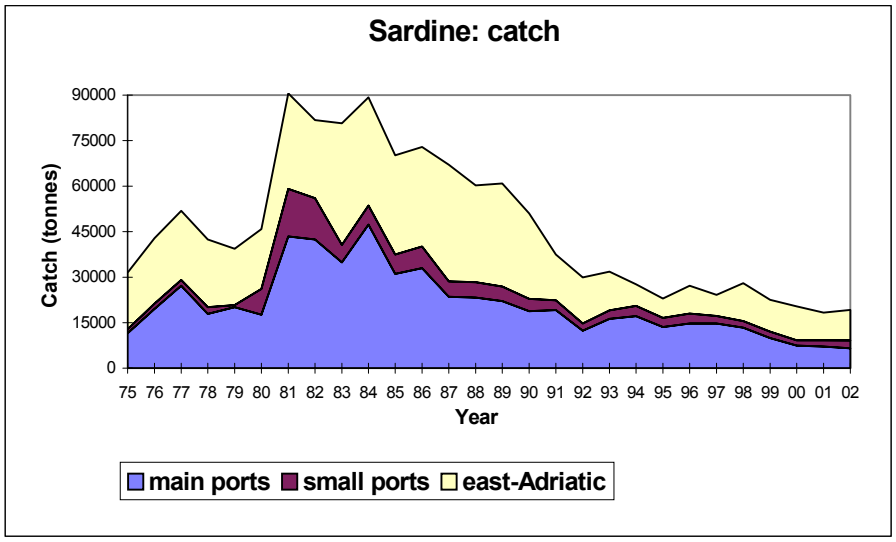

Figure 2 – Adriatic (northern and central) sardine landed catches

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 catches in the total 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).

Italian northern and central Adriatic catches of sardines reached a maximum value, (59,000 tonnes), in 1981, decreasing in successive years; current catches are about 9,000 tonnes. Slovenian sardines catches were 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 pelagic fishery. Present Adriatic sardine 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 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 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, 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 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, 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 the Istria to the Mid-Dalmatian islands. The small pelagic fishery is very important in the Adriatic fishery sector (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 the very low price. The economically most important small pelagic shared stocks listed 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, MU, 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 Adriatic, Central Adriatic, 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 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 anchovy 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 of data collection,

were also carried in the past (Cingolani *et al*., 1996; 1998; Santojanni *et al*., 2001; in press). Since the reproduction of the Adriatic anchovy is particularly relevant in spring-summer and a conventional birthday on the first of June is more coherent with the biology of the species, assessment was carried out taking this birthday date into account. The birthday effect is expected to be significant, especially in the assessments based on catch at age data, such as VPA. Consequently, all data originally recorded according to calendar year were modified in order to calculate split year data, using the first day of June as the birthday, so that data relative to one year x were referred to the time interval ranging from the first of June of the year before up to the 31st day of May of that year x. Hence, on split year basis, the time series analysed was from 1976 up to 2002.

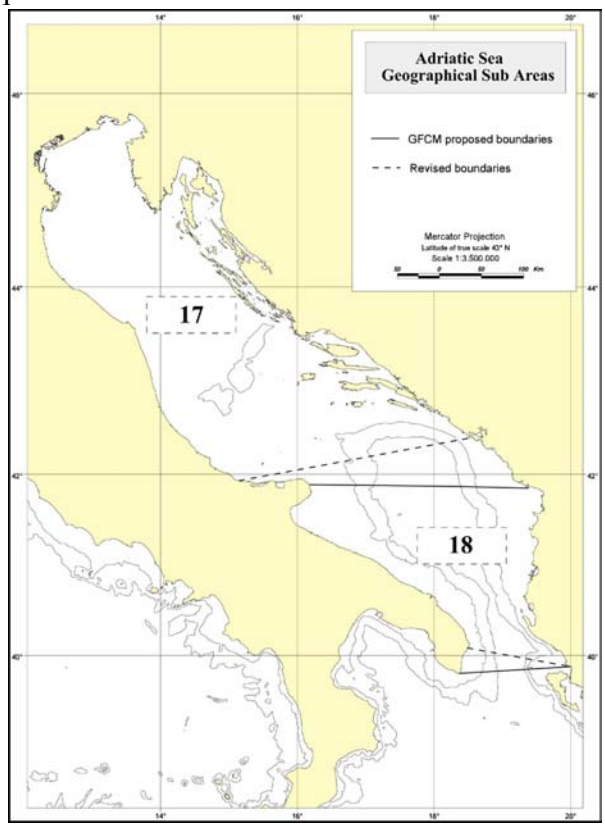

Figure 3. Map showing the boundaries of the Adriatic Sea Geographical Sub-Areas (formerly Geographical Management Units) as originally indicated by the GFCM (solid line) and with the recent revision (dotted line).

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 group 4+ (i.e. including individuals older than 4 years).

The fishing effort was considered for both anchovy and sardine, and annual (as well as monthly) values were calculated for the fleet of the Italian port of Porto Garibaldi, whose anchovy and sardine 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 (3 and plusgroup 4+). 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 catchability at age was thought to be quite constant over the whole time interval of the data analysed, so that the time interval selected for tuning was just 1976-2002. 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.

In VPA calculations, the annual natural mortality rate, M, is assumed constant over ages and years. In the present work, M was assumed equal to 0.6 (yr^{-1}) on the basis of the observed age distributions of the catches. In particular, lower values would imply too much old individuals at sea, which are not or are seldom met in the catches. The value used in this (as well as previous) assessment, 0.6, is towards the low end of the range of estimates of M reported in the literature for anchovies (Sinovčić, 2000), according thus to a precautionary approach.

There is no fully appropriate method for estimating values of the annual fishing mortality rate for the oldest age class. In the present work, $F_{3,\ 2002}$ was assumed to be equal to a fishing mortality rate referred 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 $F_{3,\ 2002}$ so estimated resulted to be equal to 0.36 (yr^{-1}).
The values of $F_{3,\ year}$ in all the other years were calculated on the basis of a relationship between $F_{3,\ 2002}$ and Porto Garibaldi effort, as follows:

$$F_{3,\ t} / E_t = F_{3,\ 2002} / E_{2002}$$

where E_t is the effort in the year t (see Table 1, column 2). A second series (b in the text, see Table 1, column 3) of values of $F_{3,\ year}$ was obtained replacing E_{2002} in proportion by the mean value of Porto Garibaldi effort over the whole split year period 1976-2002.

Table 1 - Two series of annual values of unweighted mean fishing mortality rate for anchovy, F_{0-3}, over the age class range 0-3

1	2	3
Year	**F_{0-3}**	**F_{0-3}**
1976	0.21	0.14
1977	0.25	0.17
1978	0.32	0.23
1979	0.37	0.26
1980	0.39	0.28
1981	0.42	0.31
1982	0.52	0.39
1983	0.51	0.37
1984	0.44	0.31
1985	0.47	0.36
1986	0.72	0.56
1987	0.36	0.25
1988	0.28	0.19
1989	0.32	0.22
1990	0.28	0.19
1991	0.27	0.19
1992	0.32	0.22
1993	0.26	0.18
1994	0.28	0.19
1995	0.33	0.23
1996	0.32	0.21
1997	0.30	0.20
1998	0.34	0.24
1999	0.34	0.25
2000	0.40	0.32
2001	0.34	0.28
2002	0.26	0.22
1976-02	0.36	0.26
2000-02	0.33	0.27

The two series showed in Table 1 were derived from VPA carried out under the hypothesis of a (column 2) and b (3) about the annual fishing mortality rate for the oldest age class. The average of F_{0-3} for the whole period (1976-2002) and for the last three years (2000-2002) are also reported in Table 1.

The values of series (b) were lower - and thus less conservative - than the values of series (a). In particular, even if obtained by using a mathematically inappropriate procedure, series (b) allowed VPA to yield annual exploitation patterns (i.e. F as a function of age in the different years) closer to what is believed to happen in this fishery (and more in general for small

pelagics), than series (a) did.

Figure 4 shows the results obtained from VPA under hypothesis (a) and hypothesis (b) of the annual fishing mortality at the oldest age class.

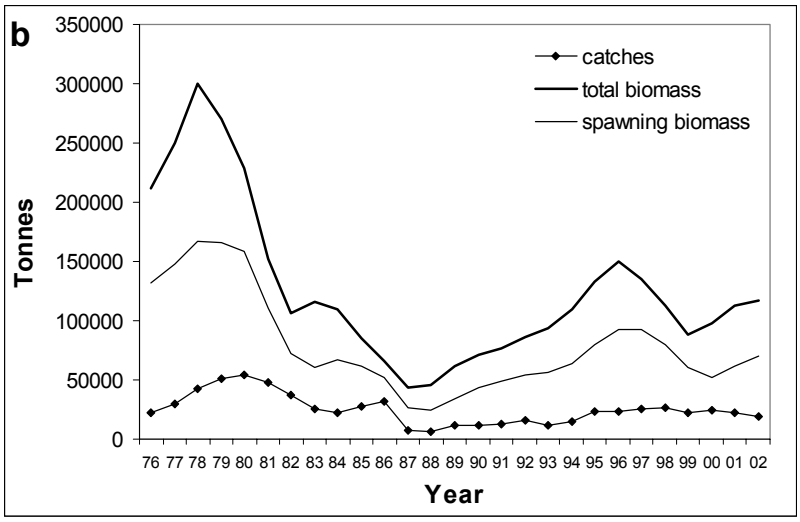

Figure 4. Annual anchovy catches, mid-year total (=stock) biomass and mid-year spawning biomass at sea derived from VPA, from 1976 up to 2002.

Figure 5 shows the results obtained from VPA comparing only the biomass estimated under the two hypotheses (a) and (b) concerning the annual fishing mortality rate for the oldest age class.

The average value of catches in the last three years 2000-2002 is equal to 22150 tonnes, while the corresponding average of mid-year total (=stock) biomass is equal to 88764 and 109377 tonnes, under the hypothesis (a) and (b), respectively.

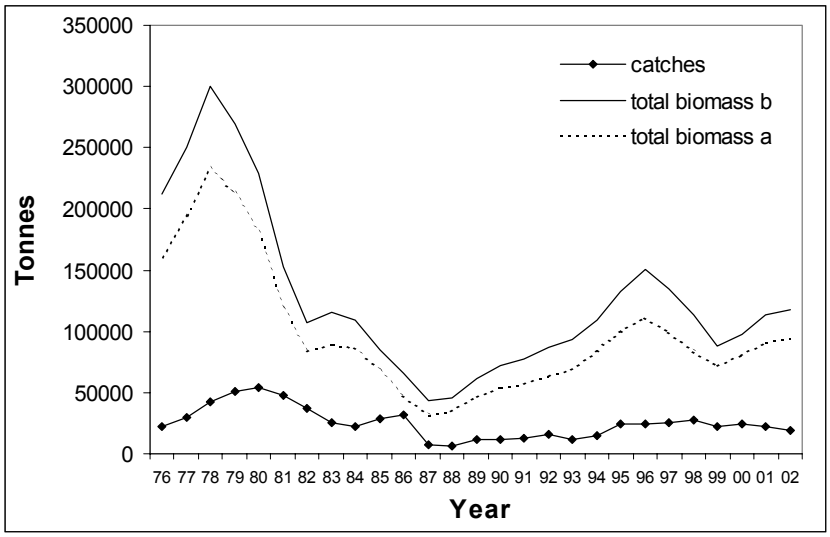

Figure 5. Anchovy annual catches and mid-year total (=stock) biomass at sea derived from VPA, from 1976 up to 2002.

The minimum value of both catch and biomass at sea were estimated in 1987, when a strong

drop in the catch and a crisis of the anchovy fishery took place. Even if high values of both fishing effort and fishing mortality rates were obtained for some years before 1987, very low levels of recruitment in 1986 and 1987 seems to be mainly responsible for the collapse of the stock. Since current biomass seems not to have risen to the values observed before collapse, it would be unwise for fishing effort to be allowed to rise.
Finally, on the basis of the VPA results, unweighted mean values of the fishing mortality rate over the age class range 0-3 were calculated for each split year from 1976 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 6).

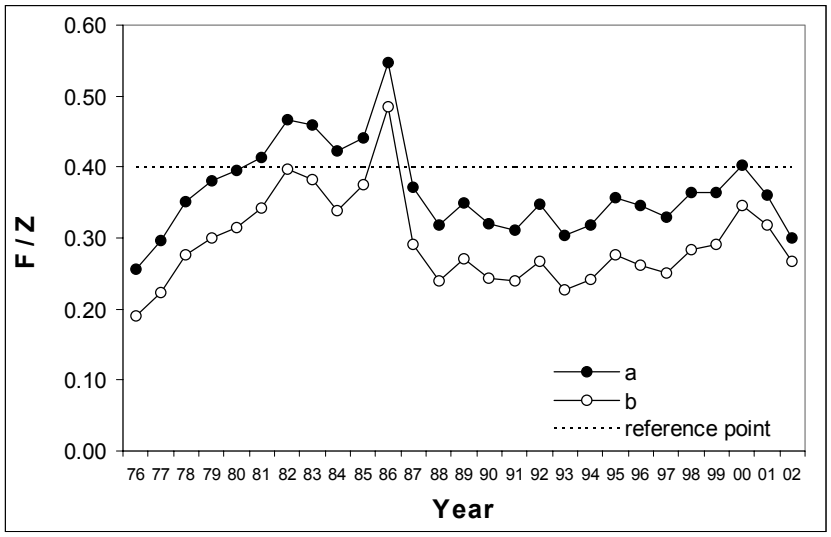

Figure 6. Anchovy annual exploitation rate (F / Z) from 1976 up to 2002. The annual value of F is the unweighted mean over the age class range 0-3 obtained from VPA and reported in the Table 1; VPA was carried out under the two hypothesis (a) and (b) for the annual fishing mortality rate for the oldest age class. In this plot it is also reported the threshold 0.4 which should not be exceeded as suggested by Patterson (1992).

Table 2 shows the annual anchovy catches and the mid-year spawning biomass derived from VPA. This was carried out under hypotheses (a) (columns 3, 4) and (b) (5, 6) for the annual fishing mortality rate for the oldest age class. Corresponding ratios between catches and spawning biomass are also reported.

Table 2 - Anchovy annual catches (tonnes) and mid-year spawning biomass (tonnes) derived from VPA.

1	2	3	4	5	6
Year	**Catches**	**SSB mid-year**	**Catches/ SSB mid-year**	**SSB mid-year**	**Catches/ SSB mid-year**
1976	22215	95646	0.23	131753	0.17
1977	29400	109626	0.27	147768	0.20
1978	42422	126520	0.34	167412	0.25
1979	50633	126846	0.40	166018	0.30
1980	54279	119649	0.45	158461	0.34
1981	47346	82472	0.57	111080	0.43
1982	37525	54446	0.69	72321	0.52
1983	25418	45743	0.56	60419	0.42
1984	21930	50985	0.43	67042	0.33
1985	28113	47397	0.59	61808	0.45
1986	32110	36074	0.89	51666	0.62
1987	7558	18370	0.41	26283	0.29
1988	5875	18149	0.32	24686	0.24
1989	11390	25119	0.45	34149	0.33
1990	11287	31697	0.36	43438	0.26
1991	12654	35530	0.36	48928	0.26
1992	15753	38553	0.41	54212	0.29
1993	11641	40076	0.29	55873	0.21
1994	14676	47182	0.31	64008	0.23
1995	23895	58670	0.41	80007	0.30
1996	23877	66465	0.36	92449	0.26
1997	25332	66100	0.38	92965	0.27
1998	27073	56852	0.48	80105	0.34
1999	21817	45056	0.48	60166	0.36
2000	24503	42537	0.58	52337	0.47
2001	22528	49665	0.45	61623	0.37
2002	19418	55517	0.35	70251	0.28

4. South Adriatic

The South Adriatic Sea shows different geomorphological characteristics to 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 singular characteristics of the gulf, with 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 predominantly used fishing gear, but during the fishing season (April-October) the purse seiners of the western coast migrate to 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 AdriaMed-SP research programme (in June 2001), on the western coast of the south Adriatic there was no systematic data collection of catch and effort data or biological sampling of anchovy.
In Albania systematic data collection concerning anchovy catch, effort and partial biological sampling were carried out until 1992. Since June 2001, data collection has started 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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