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Abstract

Anchovy (*Engraulis encrasicolus*, L.) is one of the most important commercial species of the Adriatic Sea. Stock of anchovy, living in the northern and central Adriatic Sea and 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), with pooled data coming from Italy, Slovenia and Croatia. It has been carried out in the context of the AdriaMed-SP research programme. The annual catch of anchovy 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 the present stock assessment. Annual values of mid-year stock biomass at sea and annual values of the unweighted mean fishing mortality rate over the age class range 0-3 were obtained. In addition, on the basis of the fishing mortality rates and natural mortality rate mentioned, 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 was estimated in 1987, when a strong drop in the catch and crisis of the anchovy fishery took place. 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

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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.

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1986 and 1987 seem to be mainly responsible for the collapse of the stock. Since current biomass seems not to have risen to the values observed before the collapse, it would be unwise for fishing effort to be allowed to increase.

**Key words:** shared stocks, catch statistics, 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\(^4\). 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 fact the eastern Adriatic sardines catches are almost equal to the Italian Adriatic catches (Anonymous, 1975 - 1993; Anonymous, 1994). See Figure 2.

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\(^4\) 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.
Anchovy and sardine are the most important species of the shared small pelagic 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, 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 decrease until 1998. After that year, Croatian anchovy 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 few years, the Adriatic anchovy population showed a recovery; nevertheless, biomass seems to be fluctuating once more. Present 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 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 discarding at sea of sardines, a common practice in Italy due to a 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).

![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).](image)

2. Methodological notes

Commercial catch data collection on a regional scale in Italy, Slovenia and Croatia has been carried out by a port sampling network, established through AdriaMed as described in Cingolani and Santojanni (2003). The data collection system adopted is coherent with that used in Italy by ISMAR (formerly IRPEM) since 1975 (Cingolani et al., 2001).

The anchovy stock assessment for the time period 1975-2003 was carried out by means of Virtual Population Analysis (VPA), which is a population dynamics method based on analyses 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 out in the past (Cingolani et al., 1996; 1998; 2001; Santojanni et al., 2001; 2003).
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, therefore an assessment was made, taking into account a birthday date. The birthday effect is not expected to be negligible; more likely, in the assessments based on catch at age data, just like VPA. Consequently, all data originally recorded on a calendar year basis were modified in order to calculate split year ones, 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 a split year basis, the time series analyzed was from 1976 to 2003.

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 since 0 up to the plus group 4+ (i.e. including individuals older than 4 years).

The fishing effort was focused on both anchovy and sardines, 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 1976-2003 are around 20% (25% in some years) of the total, respectively. 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. 3 and 4+ (Santojanni et al., 2003). The Laurec-Shepherd tuning procedure 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 was thought to be quite constant over the whole time interval of the data analyzed, so that the time interval selected for tuning was 1976-2003, but higher weights were set on the last six years (Darby and Flatman, 1994). No evident trends 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, without any weighting being used, some trends - even if not particularly strong - appeared after 1987 for the age class 0 and 1. The biomass discussed here are those obtained by the use of weights.

There is no fully appropriate method for estimating values of the annual fishing mortality rate for the oldest age class. In this work, a mean value for the age 3, relative to the period 1998-2003, 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 by 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 1999-2003, with total effort being assumed to be constant in this period just to treat catches as CPUE. The value of \( F_{3,1998-2003} \), estimated thus, proved to be equal to 0.53 (yr\(^{-1}\)). The values of \( F_{3,\text{year}} \) in all the other years were calculated on the basis of the following relationship:

\[
F_{3,t} / E_t = F_{3,1998-2003} / E_{1998-2003}
\]

where \( E \) is the fishing effort of Porto Garibaldi fleet in the year \( t \) and period 1998-2003.

In VPA calculations, the annual natural mortality rate, \( M \), is assumed constant over ages and years. In this work, \( M \) was assumed to be equal to 0.6 (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 not or are seldom met in the catches. The value used in this assessment (as well as previous ones) 0.6, is towards the low end of the range of estimates of \( M \) reported in the literature for anchovies, according to a precautionary approach.

Table 1 shows, for anchovy, the annual values of unweighted mean fishing mortality rate, \( F_{0-3} \), over the age class range 0-3, yielded by VPA; the averages of these annual rates for the periods 1976-2003 and 2001-2003 are also shown.

<table>
<thead>
<tr>
<th>Year</th>
<th>( F_{0-3} )</th>
<th>Year</th>
<th>( F_{0-3} )</th>
</tr>
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<tbody>
<tr>
<td>1976</td>
<td>0.25</td>
<td>1990</td>
<td>0.34</td>
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<tr>
<td>1977</td>
<td>0.31</td>
<td>1991</td>
<td>0.32</td>
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<tr>
<td>1978</td>
<td>0.39</td>
<td>1992</td>
<td>0.38</td>
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<tr>
<td>1979</td>
<td>0.44</td>
<td>1993</td>
<td>0.32</td>
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<tr>
<td>1980</td>
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<td>1994</td>
<td>0.34</td>
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<tr>
<td>1981</td>
<td>0.49</td>
<td>1995</td>
<td>0.40</td>
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<tr>
<td>1982</td>
<td>0.60</td>
<td>1996</td>
<td>0.38</td>
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<tr>
<td>1983</td>
<td>0.60</td>
<td>1997</td>
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<tr>
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<td>1985</td>
<td>0.54</td>
<td>1999</td>
<td>0.41</td>
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<tr>
<td>1986</td>
<td>0.82</td>
<td>2000</td>
<td>0.48</td>
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<tr>
<td>1987</td>
<td>0.42</td>
<td>2001</td>
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<tr>
<td>1988</td>
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<td><strong>1976-03</strong></td>
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<td></td>
<td><strong>2001-03</strong></td>
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<td><strong>0.34</strong></td>
</tr>
</tbody>
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Figure 4 shows the total (= stock) biomass at sea of anchovy estimated by VPA, along with the trend of corresponding total catches, from 1976 up to 2003.

Figure 5, on the contrary, allows us to compare this biomass trend with the previous ones discussed in the meeting of the GFCM-SAC Working Group on Small Pelagic in 2003 (Tangier, 12th-14th March 2003), with data updated to 2002. In these past assessments no weighting was used for tuning, while Porto Garibaldi CPUE-at-age data were employed to estimate the value of \( F \) in the most recent year (i.e. no “mean period” was used for \( F \), and
two different hypothesis (a) and (b) about the effort to associate it in a relationship analogous to that reported above.

Figure 4. Anchovy annual catches, mid-year total (=stock) biomass at sea derived from VPA, from 1976 up to 2003

Figure 5. The trend of mid-year total (=stock) biomass at sea derived from the VPA performed using data from 1976 to 2003, is compared with the two series discussed in the previous Small Pelagic Working Group meeting (Tangeri, 2003), thus based on data updated to 2002

Figure 6 shows a comparison between the biomass trend of VPA and the trend of average density (t/nm²) of anchovy coming from an acoustic survey, carried out in north Adriatic Sea⁵ (Azzali et al. 2002). Data from 1987 to 2001 are compared.

⁵ The area covered is extended from Trieste (the beginning 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 6. The trend of mid-year total (=stock) biomass at sea derived from the VPA performed using data from 1976 to 2003, is compared with the average density (t/nm$^2$) of anchovy, obtained by acoustic survey in north Adriatic (1987-2001).

Trends of the two series appear quite similar from 1987 to 1997. Both series show an increase in the last year (2001).

The mean value of $F_{0-3}$ is 0.42 during 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 20,518 tonnes, while the corresponding average of mid-year total (= stock) biomass is equal to 94,092 tonnes. The mean ratio between catch and mid-year biomass, in the last three years, is 0.23.

The minimum value of both catch and biomass at sea was 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 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 (Cingolani et al., 1996; Santojanni et al., 2003). Although as current biomass seems not have risen to the values observed before collapse, it would be unwise for fishing effort to be allowed to increase. In addition, it should be noted that, after a continuous increase over more than ten years after the collapse, biomass seems to be fluctuating again.

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 year since 1976 up to 2003. On the basis of these estimated averages over age and the mentioned value of $M = 0.6$, 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 7). Values above the threshold and close to it were obtained before the collapse, and in some subsequent years, the last of them in 2001 (except for the year 2000).
Figure 7. Annual anchovy exploitation rate (F / Z) from 1976 up to 2003. The annual value of F is the unweighted mean over the age class range 0-3 obtained from VPA and reported in Table 1. In this plot, we also reported the threshold 0.4 which should not be exceeded as suggested by Patterson (1992).

4. References


